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OVERSIGHT OF THE U.S. GEOLOGICAL SURVEY

HEARING

BEFORE THE

COMMITTEE ON ENERGY AND NATURAL RESOURCES UNITED STATES SENATE

ONE HUNDRED FOURTEENTH CONGRESS

SECOND SESSION

APRIL 7, 2016

Printed for the use of the
Committee on Energy and Natural Resources

Available via the World Wide Web: http://www.govinfo.gov

U.S. GOVERNMENT PUBLISHING OFFICE

21–972 WASHINGTON : 2018

For sale by the Superintendent of Documents, U.S. Government Publishing Office
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OVERSIGHT OF THE U.S. GEOLOGICAL SURVEY

THURSDAY, APRIL 7, 2016

U.S. SENATE,
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, DC.

The Committee met, pursuant to notice, at 10:06 a.m. in Room SD–366, Dirksen Senate Office Building, Hon. Lisa Murkowski, Chairman of the Committee, presiding.

OPENING STATEMENT OF HON. LISA MURKOWSKI, U.S. SENATOR FROM ALASKA

The CHAIRMAN. Good morning. The Committee will come to order.

We are here this morning to conduct oversight of the U.S. Geological Survey (USGS). It has been a long time since our Committee has conducted direct oversight of this agency outside of the nominations process. I think that there is clearly a level of interest. There are a number of important and relevant issues for us to explore today.

Director Kimball, I appreciate you being here. I understand you are a little bit under the weather, but you are clearly a trooper, ready to rally. We appreciate it, and hopefully this hearing will be quick and you can get some rest.

I am among those who appreciate both the work of the USGS and the spirit in which it is typically undertaken. The agency is known for being non-partisan and for seeking out concrete, scientific evidence. I, for one, appreciate that.

I think it is good. I think it is refreshing in an agency that comes before our Committee that perhaps does not have a significant regulatory agenda that is plowing straight ahead. It has been really greatly appreciated, the cooperative working relationship that we have, and I appreciate your leadership on that.

It is also comforting to know that the Survey is collecting and monitoring data that is vital to the safety and the well-being of the American people. Alaskans, in particular, are grateful for the work that USGS does to help us cope with the daily threat of volcanic eruptions, earthquakes and other natural hazards. People might say, "Daily threat, Lisa, relax a little bit." But during my week back home, I was grounded by a volcano because the airplanes could not fly. And it was just a few days after that that we had a magnitude 6.2 earthquake. No damage, but 6.2 gets your attention, although not quite as much as the 7.1 that we had a couple

months prior to that. But yes, we have a lot of stuff going on there, and we appreciate the vigilance of USGS.

I do recognize, again, that we have parts of our country here that are active in different ways and the need for real time volcano monitoring, the recognition that we have very tectonically active areas, certainly in Alaska, as I mentioned. So knowing what you do there at the Agency is important.

Another success story can be found with the Alaska Mapping Executive Committee. The AMEC, composed of representatives from 15 federal and state agencies was formed in 2012 to prioritize the collection of high resolution elevation data. This initiative has expanded to collect other map layers, providing vital data to ensure the safety of our pilots and those wanting to explore the Alaska wilderness.

Director, you were up in Alaska last year when we were celebrating the 50 percent mark where we had mapped over 50 percent of the state. Actually, in fairness, I think we were up to 57 percent. But it says something when we have a celebration when we hit 50 percent. I noted that at the time we have got a ways to go, but hey, we are halfway there and we appreciate that. We look forward to working it further.

While I support many efforts and activities within USGS, I also believe that some of its core areas lack attention and resources. That is another reason why we are here today, to review the agency's priorities.

Our mineral security is one of them. This will come as no surprise to anyone who has followed our Committee, but I remain seriously concerned about our growing foreign mineral dependence. Last year we imported more than 50 percent of our supply of 47 minerals, including 100 percent of 19 of them.

Even though minerals are more important to our modern society than ever before, we are paying less and less attention to them. That shows, I think, in the USGS budget where not even 10 percent goes to the energy and minerals program.

It shows elsewhere as well. After the USGS reports our foreign dependence, it is very difficult to find anyone anywhere in the Federal Government who is responsible for doing anything to meaningfully reduce it.

Now going back to mapping, the USGS has used hyperspectral imagery to map more than 96 percent of the country of Afghanistan. While hyperspectral imagery is used for mineral exploration, very little of the U.S. has been mapped with this same technology. There is some frustration to hear that USGS has conducted surveys on the other side of the world while the assessments are still much needed here in this country. I do recognize the importance of the Survey's other mission areas, but those cannot come at the expense of the Congressionally-authorized and Congressionally-mandated responsibilities that USGS holds.

So I am glad we are having this hearing. We will have an opportunity to highlight areas of success for the Survey, but also identify the gaps within the agency that prevent it from meeting its original and primary directives.

Again, Director Kimball, I appreciate you being with us before the Committee today and for your leadership there at USGS.

Let's turn to Senator Cantwell for your opening remarks.

STATEMENT OF HON. MARIA CANTWELL, U.S. SENATOR FROM WASHINGTON

Senator CANTWELL. Thank you, Madam Chair, and thank you for scheduling this important hearing. Like Alaska, Washington has a lot of related issues, so this is a hearing of great importance to our state as well.

I would like to extend a warm welcome to all the witnesses today and thank you for being here, Ms. Kimball.

I also want to say hello to Dr. John Vidale, who is here from Washington State. He is the Washington State Seismologist, Director of the Pacific Northwest Seismic Network, and Professor at the University of Washington. These are people we count on all of the time, and we so appreciate them being here.

It is a great opportunity this morning to talk about the importance of the USGS—the premier Earth Science agency—and its most respected roles that are so important to us: producing the nation's maps, monitoring our rivers, guiding our energy and mineral development, supporting the management of public lands, and helping us respond to natural disasters such as floods, earthquakes, volcanoes and landslides. As the primary science agency for the Department of the Interior, they play an incredible role in informing decision-making for the Department in many of its areas. They also provide technical assistance to states, tribes and communities across the country.

So these partnerships are particularly important in informing our decisions at the local level. In many states, the USGS is a critical partner, as it is in our state, and I would like to take a few minutes just to highlight what that partnership means.

The first area of partnership is to protect the public from natural disasters. The USGS is the federal agency responsible for monitoring these natural hazards such as volcanoes, earthquakes and landslides. Washington, like Alaska, has its share of these, and we are so glad that they are an absolutely critical partner in monitoring and responding to these hazards.

As many people know, Mount St. Helens erupted in 1980 and was the largest volcanic eruption in U.S. history. In fact, Washington State has six high risk volcanoes, including Mount Rainier, which is considered one of the nation's most dangerous. Since the 1990s the U.S. has partnered with Pierce County to operate a lahar warning system to protect the lives and property that could be affected in that eruption—and there are probably 80,000 people in the path of that potential eruption and lahar—so not that Mount St. Helens wasn't significant, but the population density around Mount Rainier is a total other story. However, new monitoring, science and warning systems are needed throughout the West Coast. That is why Chairman Murkowski and I are co-sponsoring the National Volcano Early Warning and Monitoring System Act to protect communities that are in these high risk areas.

Another significant hazard in Washington State is earthquakes, just like the Chair said. And Dr. Vidale, who is here, is the State Seismologist, who has been working with USGS and other states along the West Coast to develop an earthquake early warning sys-

tem. USGS studies show that a major earthquake could occur in the next 50 years. It has been estimated that this earthquake could approach the intensity of the quake and tsunami that struck Japan in 2011 and particularly could affect major cities like Seattle. In fact, we are having a large-scale tsunami drill two months from now, in the next 60 days, in the Northwest. There are going to be thousands of people participating and learning how to respond to that type of event.

That is why we continue to advocate for the Earthquake Early Warning System—because it would save lives and billions of dollars. That is also why we introduced the Tsunami Warning, Education, and Research Act which passed the Senate last year and would require USGS to work with NOAA on a tsunami program.

Madam Chair—because I know you care so much about this—from our work on the Commerce Committee in looking at this, it is clear there is so much that needs to be done with the mapping and then working with the local community that needs to be knitted together. People need to see the maps, what could potentially happen, and then the community has to knit together a response. And all the agencies that are responsible for that need to work together.

Finally, I want to mention the terrible tragedy of Oso that occurred in March 2014, which caused 43 deaths. That mudslide was such a devastation, and we still feel the loss of life and thank so many of our first responders who responded to that. The USGS provided critical assistance in the search and rescue operation, including real-time monitoring to keep our first responders safe. A horrible tragedy and yet we couldn't even, without USGS, send the first responders into the area without their information and data about whether it was safe to go into the area. So we were counting on them.

Landslides cause over two dozen fatalities and $1–$2 billion a year in damages across the country, so this is a significant issue. So, I think better understanding these hazards and their impact and potential for helping save life and property is very important. I am pleased to hear that USGS is proposing to increase its work in this area. We need a national landslide mitigation strategy, more science, more monitoring, to prevent these tragedies from occurring.

Another area I just want to highlight is partnerships with the USGS to protect and restore watersheds. Washington is home to some of the greatest rivers and estuaries—the Puget Sound and Columbia River are the economic and cultural lifeblood of our region, so their work there is very important.

The USGS has faced a number of institutional challenges in carrying out its mission. With a budget of only $1.06 billion, the organization leverages its resources many times over; however, many areas, such as hazard and water monitoring, are severely underfunded. This is where, I think, good science really can help all of us move forward.

Strategic investments are needed to advance new science and tools. A number of programs and business practices need to be modernized and streamlined, and it is important that we have and strengthen these programs.

Again, I know other of our Committees are talking a lot about drones and drone systems. These can provide some very critical tools and information. We want to see that move forward so that these agencies can use these effectively.

I am so glad that we are having both panels today, and again, thank you for being here.

The CHAIRMAN. Thank you, Senator Cantwell.

Senator Cantwell just mentioned we do have two panels today. We are pleased to have the Director of USGS, Director Suzette Kimball. Welcome to the Committee. After you have presented your oral comments this morning, we will have a series of questions and then we will move to our second panel and look forward to their input this morning as well.

So, welcome.

STATEMENT OF HON. SUZETTE KIMBALL, DIRECTOR, U.S. GEOLOGICAL SURVEY

Dr. KIMBALL. Well, thank you very much, Senator Murkowski and Senator Cantwell and members of the Committee. I very much appreciate the opportunity to testify before you today. I'm very excited to share the views of the USGS on the state of our organization and its mission.

And I'd very much like to start the conversation at the point in which Senator Murkowski, you started the discussion that Congress established the USGS in 1879. And our mission then was not only to map the West and locate resources, but also to push the boundaries of science. Our scientists have pursued that mission with uncommon dedication, and I'm very honored to be their 16th Director.

Since we were established, technology and Earth science have evolved and we have evolved as well. As you noted, two years ago, Madam Chairman, on the anniversary of the 1964 Good Friday Earthquake in Alaska, USGS Science in response to that event helped confirm the theory of plate tectonics, fundamentally changing how we approach earthquake science.

In 1995 Congress merged the National Biological Survey with the USGS making us an integrated Earth science agency, one of the only agencies of this type worldwide. Since then the value of bringing Earth science disciplines together has become more apparent.

I want to stress that we rely on partnerships to pursue our mission. State geological surveys, universities, municipal governments, other federal agencies and foreign governments are all critical partners for the USGS. Our budget is leveraged resulting in approximately an additional half billion dollars contributed by our partners. These partnerships, for example, have made it possible to publish such reports that offer industry and regulators guidance on how to site, develop and close mines with resource and environmental implications taken into account.

The USGS also works closely with other Interior bureaus and other federal agencies such as the EPA, NASA, NOAA and the Army Corps of Engineers. Rather than duplicate these agencies' missions, we complement their research and contribute sound science to their decisions.

While I'm proud of the Bureau's integrated approach to problem solving, innovation is a characteristic that I hope to nurture during my tenure in this office. For example, we continue to pursue 21st century mapping. In Alaska we're harnessing our partnerships with the state and university and using IFSAR to produce modern geospatial information for the state, and we closed last year, by the way, at 63 percent completion for Alaska.

Meanwhile, in the lower 48, LiDAR collected by a coalition of federal, state and private industry partners, can enable mapping and even forecasting of landslides. The tragedy at Oso, Washington in 2014, like the Good Friday Earthquake, pushes us to complete scientific achievements worthy of the investment and trust placed in us by the American people.

Speaking of hazards, the USGS has long led federal research into geologic hazards and we're pushing innovative approaches in this area too. Along the West Coast, we're establishing an earthquake early warning system that could readily be expanded to Alaska and other high risk regions of the country. We're also applying advanced telemetry and remote sensing tools to make volcano early warning a reality.

The unknown unknowns of Earth science motivate us to advance our understanding of the world. Looking to the future I see challenges where we are positioned to lead, water security and availability, the tools for addressing natural hazards, the assessment of critical minerals, the forecasting and preventing of biological threats and, of course, developing the next generation of mapping technology.

The mission of the USGS in the 21st century will be to locate natural resources for the benefit of the nation and to find ways to sustainably exploit those resources so that our prosperity endures. Indeed, research suggests that we may someday even harness the energy of coal using microbes that will avoid many of the associated environmental costs. It's the job of the USGS, working with our partners, to help bring that future to fruition.

So on behalf of the more than 8,000 employees of the USGS, thank you again for inviting me here today and for the opportunity to testify. I will be very happy to answer any questions you may have. Thank you.

[The prepared statement of Dr. Kimball follows:]

Statement of
Dr. Suzette S. Kimball
Director
U.S. Geological Survey
before the
Senate Committee on Energy and Natural Resources
regarding
Oversight of the U.S. Geological Survey

April 7, 2016
Washington, DC

Chairman Murkowski and Ranking Member Cantwell, members of the committee, thank you very much for inviting me to testify today. I am excited for this opportunity to share some of my views on the state of the USGS and its mission. I would like to start this conversation with some history.

In 1879, Congress passed legislation that merged several Federal scientific and mapping surveys. We call this statute our Organic Act[1] because it inaugurated the U.S. Geological Survey (USGS). From the beginning, the mission of this combined endeavor was not only to map the West and locate resources, but also to push the boundaries of science. USGS scientists, for almost 140 years now, have pursued that mission with an uncommon dedication. I am honored to be their 16th Director and cognizant of the responsibility that the President, the Congress, and this committee have entrusted to me.

Not only is the USGS older than 12 of the States, it is also the forbearer of several important government agencies, including the Bureau of Ocean Energy Management and the Bureau of Reclamation. In the time since we were established, technology and Earth science have evolved and we have evolved along with it, to meet the scientific needs of the Nation. For example, with the increase in global demand for critical mineral commodities, USGS has focused on conducting research to understand geologic processes that have concentrated known mineral resources at specific localities in the Earth's crust and to estimate or assess quantities, qualities and areas of undiscovered mineral resources, or potential future supply. We have increased resources toward the National Geospatial program, earthquake early warning, volcano monitoring and the national streamgage network. USGS has also focused our activities on fulfilling statutory authorities, most recently by addressing national water availability and use through the SECURE Water Act.

[1] 43 USC 31 et seq.

Our evolution is evident, as you noted two years ago, Madame Chairman, in a resolution recognizing the anniversary of the massive earthquake that occurred in the Prince William Sound region of Alaska on March 27, 1964 (the Good Friday Earthquake). USGS science in response to that event helped confirm the theory of plate tectonics, fundamentally changing earthquake science. Shortly thereafter, in 1966, Bill Pecora, our 8th Director, advocated for the use of satellites to study natural resources. This innovation led to Landsat and opened the age of Earth observation from space.

In 1995, Congress merged biologists from the National Biological Survey with the USGS, helping us to become an integrated Earth science agency. As scientific and technological advances have revealed the complexity of the issues we face, the value of bringing Earth science disciplines together has become ever more apparent. Today's challenges demand the innovation made possible by integrating the full breadth of USGS capabilities.

One example that illustrates the value of USGS's diverse scientific capabilities is our leadership in understanding methylation processes of mercury. Mercury is a toxin that can build up in the food chain, becoming deadly to humans. It is most dangerous after undergoing a specific chemical change, methylation. Our geological expertise allows us to understand how and where methylation occurs, and our biological expertise allows us to understand how it affects plants, animals, and humans. Combining the talents, tools, and methods from these two disciplines is necessary to correctly assess methylmercury and its potential impacts.

I want to stress that we rely on numerous partnerships to pursue our scientific mission. The state geological surveys, universities, municipal governments, other Federal agencies, and foreign governments all count as critical partners of the USGS. As you may know, our budget is leveraged resulting in, approximately, an additional half a billion dollars contributed by our partners, especially State governments and other Federal agencies. We see this as an indication of their confidence in and support for our work. Such partnerships also have made it possible, for example, to create and publish a whole-lifecycle mining report, that offers industry and regulators guidance on how to site, develop, and close a mine with resource and environmental implications taken into account. In the future, we plan to do similar work for energy resources.

The USGS works closely with other Interior bureaus such as the Fish and Wildlife Service, the National Park Service, and the Bureau of Land Management, as well as other Federal agencies such as the Environmental Protection Agency, the National Aeronautics and Space Administration, the U.S. Army Corps of Engineers, and the National Oceanic and Atmospheric Administration. Rather than duplicate those agencies' missions, the USGS complements their research activities and contributes sound science for their decisionmaking. We are pleased to know that Congress looks to us, too, because researchers from the USGS are here hundreds of times a year meeting with you and your offices.

While I am proud of our integrated approach to problem solving, drawing on geological and biological science, remote sensing, epidemiology, ecology, or any of the myriad disciplines that constitute Earth science, innovation is the characteristic I most hope to nurture during my tenure in this office. While the Bureau has often been at the forefront of innovative research and science, we must take advantage of technological change and respond to emerging scientific directions to meet our full potential.

Today USGS labs are spearheading novel technologies. For example we are using eDNA to monitor the spread of Asian carp. We also work on other invasive species such as zebra mussels, brown tree snakes, and cheatgrass. Through our groundbreaking work on white-nosed syndrome, avian influenza and other wildlife diseases, the Bureau has become known as "the CDC of wildlife," and is on the front lines of possible future epidemics.

One of our ongoing pursuits is 21st century mapping. In Alaska, we are harnessing our partnerships with the State and the University of Alaska, along with the technology of interferometric synthetic aperture radar, or ifsar, to produce modern geospatial information for the State. Back in the lower 48, high resolution elevation data are being collected using lidar technology by a coalition of Federal, State and private industry partners, to inform decisionmaking and enable newfound abilities like mapping and even forecasting landslides. The landslide tragedy at Oso, Washington, in 2014, not unlike the Good Friday Earthquake, pushes us to look farther, aim higher, and complete a scientific achievement worthy of the investment and trust placed in us by the American people.

Speaking of hazards, the USGS has long led Federal research into various geologic hazards and we are pressing forward on innovative approaches in this area, too. Along the West Coast, we are establishing, in cooperation with states, universities, and philanthropic partners, a state-of-the-art earthquake early warning system. This system could readily be expanded to Alaska and other high-risk regions of the country. We are also applying advanced telemetry and remote sensing technologies, making a volcano early warning system a reality. For many of your constituents, these are hazards they live with every day and they are also threats to the Nation as a whole.

The unknown unknowns of Earth science motivate us to advance our understanding of the natural world. As we look toward the future I see challenges where we are positioned to lead, all of which I have touched on: water security and availability, tools for protection from and response to natural hazards, assessment of critical minerals, forecasting and preventing biological threats, and creating the next generation of mapping tools and technology.

I have every confidence that the USGS will continue to meet these challenges, and I am heartened by a recent survey of marine and coastal scientists and managers which found the

USGS to be the most credible Federal science agency.[2] This is not a reason to boast, but a calling to meet such high expectations.

The mission of the USGS in the 21st century will not only be to locate natural resources for the benefit of the Nation, but to find ways of exploiting those resources sustainably so that our prosperity is not fleeting or fragile. For example, we are researching microbial production of natural gas, which may someday make it possible harness the energy of coal resources while avoiding many of the environmental costs traditionally associated with it. It is the job of the USGS, working with our partners, to help bring that future to fruition.

On behalf of the approximately 8,000 employees of the USGS, thank you again for inviting me here today. I would be happy to answer any questions you have.

[2] March 2016 issue of *Ocean & Coastal Management*. Survey of scientists, interest groups, and industry associated with marine and coastal policy issues.

The CHAIRMAN. Thank you, Director Kimball.

Let's begin. We have got good participation by the Committee this morning and hopefully more will drop by as well.

I appreciate you acknowledging not only the core mission of the USGS but also some of the challenges that we have going forward. I have noted, particularly, your comment about water security. I do not think that we spend near enough time understanding our water resources. We all know that, at least from the West, water is the thing that we fight over all the time. So understanding that as a resource is key.

I want to ask you about the importance of minerals within the USGS mission. In my December 18 letter to you regarding the concerns that I had outlined about the budget priorities, I indicated that USGS has reduced its traditional core function of assessing this country's mineral resources. You responded by noting that the Minerals and Energy Resources Program has not been demoted but rather has been elevated. What I am wondering this morning is how it has been elevated from a budget perspective because that is really where we are placing priorities, and we need to know to what extent then, as we have done an assessment for our mineral commodity's summaries, how we are working to expand our knowledge and understanding within this database here? If you can just speak to the priorities within the agency focused on our minerals and understanding our inventories?

Dr. KIMBALL. Well thank you very much for that question. And I want to assure you that the USGS has taken very seriously the comments that we've received from this Committee in previous hearings, as well as the questions for the record that we've received.

As you point out, we have taken concrete steps to address new strategic directions for our minerals work to enhance our ability to do life cycle analysis which we think is going to be essential as we move into new technologies that will require different types of minerals being applied to activities.

As you pointed out, we have identified and submitted a reprogramming request last fall to Congress to have created, which we've done, an Associate Director specifically for our Energy and Mineral Resources. That individual's responsibility will be to pursue those kinds of activities that will help enhance the budget through our various partnerships. And those partnerships are very important. We have strong partnerships with industry. We have strong partnerships with other federal agencies. And that's going to be essential to having an understanding of the global scale and scope of mineral resources.

The CHAIRMAN. Can I interrupt and ask a question on that?

You have noted that, for instance, with Alaska mapping now we are at 63 percent which is making some progress.

Do we know to what extent we have surveyed our lands to determine the extent of our own domestic mineral base? Can you say we have surveyed and analyzed 50 percent, that we are halfway there? To what extent do we know our own mineral base here in this country in terms of an inventory?

Dr. KIMBALL. I don't have the answer for that today but our scientists and our program coordinators know that number and we'll be happy to provide that for the record.

The CHAIRMAN. I would be interested.

Along those same lines, the geologic mapping in terms of the extent to which we have surveyed and understand and have accurate mapping of our geologic resources. Is that information that you can also make available to us?

Dr. KIMBALL. Yes, we can.

The CHAIRMAN. Great.

Dr. KIMBALL. We have that information.

The CHAIRMAN. Great, I appreciate that.

And then my last question, the White House, you mentioned the Earthquake Resilience Summit that they held on February 2nd.

Was USGS consulted by the White House on that summit? We were very surprised that Alaska did not have any role or participation. Our state seismologist was not brought into the loop. Now we had the Secretary of the Interior here not too long ago and she indicated the same thing, that this might be readily expandable to Alaska. It is all a function of money. But we did find that it was somewhat unusual that the most seismically active state was not brought into this process. Do you know what happened there?

Dr. KIMBALL. I do not know all of the details. This, of course, was an event that was coordinated through the White House.

I know that——

The CHAIRMAN. Were you all involved at USGS?

Dr. KIMBALL. We were involved and for that matter, we did have conversations with the state seismologist about participation but it was late in the game and my understanding was at that point they were not able to travel.

However, that being said, I need to assure you that the USGS agrees that Alaska is very much in our minds in terms of the next place where we need to begin working on earthquake early warning. We have opportunities within Anchorage, but we also recognize that Alaska has priorities in being able to establish a statewide seismic network and that that is one of the higher priorities within the state. We have been having discussions with your Commissioner of Natural Resources and the State Geologist about how to accomplish that and move forward with that.

The CHAIRMAN. We will have further conversation on that but recognizing that it is the most seismically active state and then also that it is not part of the contiguous United States and that if we did have a major earthquake along the lines that we had in 1964, you are cut off effectively from the rest of the country and, really, from an asset. So it is part of a bigger plan, but I look forward to talking with you about that as well.

Senator Cantwell.

Senator CANTWELL. Thank you, Madam Chair.

Dr. Kimball, the New Yorker article that came out about the Cascadia subduction zone, I think it was a year ago. "The Really Big One," I think was the title of the article, about an earthquake that will destroy a sizable portion of the Pacific Northwest Coast. The question is when?

[The information referred to follows:]

The New Yorker – July 20, 2015

The Really Big One

An earthquake will destroy a sizable portion of the coastal Northwest. The question is when.

By Kathryn Schulz

The next full-margin rupture of the Cascadia subduction zone will spell the worst natural disaster in the history of the continent. (Credit Illustration by Christoph Niemann; Map by Ziggymaj / Getty)

When the 2011 earthquake and tsunami struck Tohoku, Japan, Chris Goldfinger was two hundred miles away, in the city of Kashiwa, at an international meeting on seismology. As the shaking started, everyone in the room began to laugh. Earthquakes are common in Japan—that one was the third of the week—and the participants were, after all, at a seismology conference. Then everyone in the room checked the time.

Seismologists know that how long an earthquake lasts is a decent proxy for its magnitude. The 1989 earthquake in Loma Prieta, California, which killed sixty-three people and caused six billion dollars' worth of damage, lasted about fifteen seconds and had a magnitude of 6.9. A thirty-second earthquake generally has a magnitude in the mid-sevens. A minute-long quake is in the high sevens, a two-minute quake has entered the eights, and a three-minute quake is in the high eights. By four minutes, an earthquake has hit magnitude 9.0.

When Goldfinger looked at his watch, it was quarter to three. The conference was wrapping up for the day. He was thinking about sushi. The speaker at the lectern was wondering if he should carry on with his talk. The earthquake was not particularly strong. Then it ticked past the sixty-second mark, making it longer than the others that week. The shaking intensified. The seats in the conference room were small plastic desks with wheels. Goldfinger, who is tall and solidly built, thought, No way am I crouching under one of those for cover. At a minute and a half, everyone in the room got up and went outside.

It was March. There was a chill in the air, and snow flurries, but no snow on the ground. Nor, from the feel of it, was there ground on the ground. The earth snapped and popped and rippled. It was, Goldfinger thought, like driving through rocky terrain in a vehicle with no shocks, if both the vehicle and the terrain were also on a raft in high seas. The quake passed the two-minute mark. The trees, still hung with the previous autumn's dead leaves, were making a strange rattling sound. The flagpole atop the building he and his colleagues had just vacated was whipping through an arc of forty degrees. The building itself was base-isolated, a seismic-safety technology in which the body of a structure rests on movable bearings rather than directly on its foundation. Goldfinger lurched over to take a look. The base was lurching, too, back and forth a foot at a time, digging a trench in the yard. He thought better of it, and lurched away. His watch swept past the three-minute mark and kept going.

Oh, shit, Goldfinger thought, although not in dread, at first: in amazement. For decades, seismologists had believed that Japan could not experience an earthquake stronger than magnitude 8.4. In 2005, however, at a conference in Hokudan, a Japanese geologist named Yasutaka Ikeda had argued that the nation should expect a magnitude 9.0 in the near future—with catastrophic consequences, because Japan's famous earthquake-and-tsunami preparedness, including the height of its sea walls, was based on incorrect science. The presentation was met with polite applause and thereafter largely ignored. Now, Goldfinger realized as the shaking hit the four-minute mark, the planet was proving the Japanese Cassandra right.

For a moment, that was pretty cool: a real-time revolution in earthquake science. Almost immediately, though, it became extremely uncool, because Goldfinger and every other seismologist standing outside in Kashiwa knew what was coming. One of them pulled out a cell phone and started streaming videos from the Japanese broadcasting station NHK, shot by helicopters that had flown out to sea soon after the shaking started. Thirty minutes after

Goldfinger first stepped outside, he watched the tsunami roll in, in real time, on a two-inch screen.

In the end, the magnitude-9.0 Tohoku earthquake and subsequent tsunami killed more than eighteen thousand people, devastated northeast Japan, triggered the meltdown at the Fukushima power plant, and cost an estimated two hundred and twenty billion dollars. The shaking earlier in the week turned out to be the foreshocks of the largest earthquake in the nation's recorded history. But for Chris Goldfinger, a paleoseismologist at Oregon State University and one of the world's leading experts on a little-known fault line, the main quake was itself a kind of foreshock: a preview of another earthquake still to come.

Most people in the United States know just one fault line by name: the San Andreas, which runs nearly the length of California and is perpetually rumored to be on the verge of unleashing "the big one." That rumor is misleading, no matter what the San Andreas ever does. Every fault line has an upper limit to its potency, determined by its length and width, and by how far it can slip. For the San Andreas, one of the most extensively studied and best understood fault lines in the world, that upper limit is roughly an 8.2—a powerful earthquake, but, because the Richter scale is logarithmic, only six per cent as strong as the 2011 event in Japan.

"Perhaps I've said too much."

Just north of the San Andreas, however, lies another fault line. Known as the Cascadia subduction zone, it runs for seven hundred miles off the coast of the Pacific Northwest, beginning near Cape Mendocino, California, continuing along Oregon and Washington, and terminating around Vancouver Island, Canada. The "Cascadia" part of its name comes from the Cascade Range, a chain of volcanic mountains that follow the same course a hundred or so miles inland. The "subduction zone" part refers to a region of the planet where one tectonic plate is sliding underneath (subducting) another. Tectonic plates are those slabs of mantle and crust that, in their epochs-long drift, rearrange the earth's continents and oceans. Most of the time, their movement is slow, harmless, and all but undetectable. Occasionally, at the borders where they meet, it is not.

Take your hands and hold them palms down, middle fingertips touching. Your right hand represents the North American tectonic plate, which bears on its back, among other things, our entire continent, from One World Trade Center to the Space Needle, in Seattle. Your left hand represents an oceanic plate called Juan de Fuca, ninety thousand square miles in size. The place

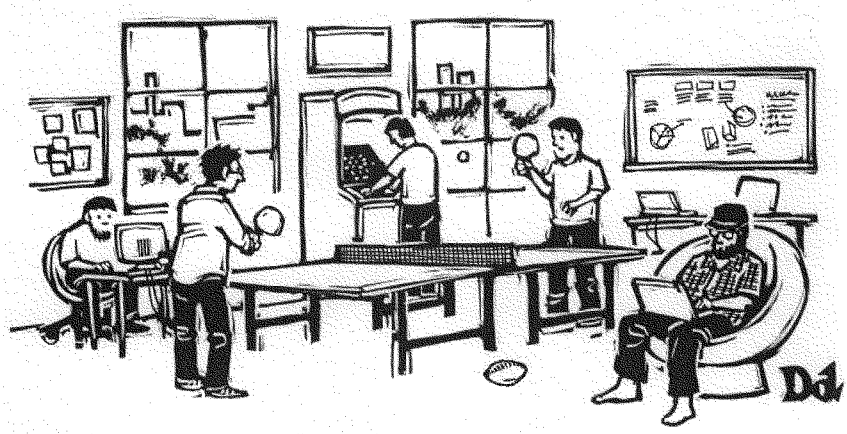
where they meet is the Cascadia subduction zone. Now slide your left hand under your right one. That is what the Juan de Fuca plate is doing: slipping steadily beneath North America. When you try it, your right hand will slide up your left arm, as if you were pushing up your sleeve. That is what North America is not doing. It is stuck, wedged tight against the surface of the other plate.

Without moving your hands, curl your right knuckles up, so that they point toward the ceiling. Under pressure from Juan de Fuca, the stuck edge of North America is bulging upward and compressing eastward, at the rate of, respectively, three to four millimetres and thirty to forty millimetres a year. It can do so for quite some time, because, as continent stuff goes, it is young, made of rock that is still relatively elastic. (Rocks, like us, get stiffer as they age.) But it cannot do so indefinitely. There is a backstop—the craton, that ancient unbudgeable mass at the center of the continent—and, sooner or later, North America will rebound like a spring. If, on that occasion, only the southern part of the Cascadia subduction zone gives way—your first two fingers, say—the magnitude of the resulting quake will be somewhere between 8.0 and 8.6. *That's* the big one. If the entire zone gives way at once, an event that seismologists call a full-margin rupture, the magnitude will be somewhere between 8.7 and 9.2. That's the very big one.

Flick your right fingers outward, forcefully, so that your hand flattens back down again. When the next very big earthquake hits, the northwest edge of the continent, from California to Canada and the continental shelf to the Cascades, will drop by as much as six feet and rebound thirty to a hundred feet to the west—losing, within minutes, all the elevation and compression it has gained over centuries. Some of that shift will take place beneath the ocean, displacing a colossal quantity of seawater. (Watch what your fingertips do when you flatten your hand.) The water will surge upward into a huge hill, then promptly collapse. One side will rush west, toward Japan. The other side will rush east, in a seven-hundred-mile liquid wall that will reach the Northwest coast, on average, fifteen minutes after the earthquake begins. By the time the shaking has ceased and the tsunami has receded, the region will be unrecognizable. Kenneth Murphy, who directs FEMA's Region X, the division responsible for Oregon, Washington, Idaho, and Alaska, says, "Our operating assumption is that everything west of Interstate 5 will be toast."

In the Pacific Northwest, the area of impact will cover* some hundred and forty thousand square miles, including Seattle, Tacoma, Portland, Eugene, Salem (the capital city of Oregon), Olympia (the capital of Washington), and some seven million people. When the next full-margin rupture happens, that region will suffer the worst natural disaster in the history of North America. Roughly three thousand people died in San Francisco's 1906 earthquake. Almost two thousand died in Hurricane Katrina. Almost three hundred died in Hurricane Sandy. FEMA projects that nearly thirteen thousand people will die in the Cascadia earthquake and tsunami. Another twenty-seven thousand will be injured, and the agency expects that it will need to provide shelter for a million displaced people, and food and water for another two and a half million. "This is one time that I'm hoping all the science is wrong, and it won't happen for another thousand years," Murphy says.

In fact, the science is robust, and one of the chief scientists behind it is Chris Goldfinger. Thanks to work done by him and his colleagues, we now know that the odds of the big Cascadia earthquake happening in the next fifty years are roughly one in three. The odds of the very big one are roughly one in ten. Even those numbers do not fully reflect the danger—or, more to the point, how unprepared the Pacific Northwest is to face it. The truly worrisome figures in this story are these: Thirty years ago, no one knew that the Cascadia subduction zone had ever produced a major earthquake. Forty-five years ago, no one even knew it existed.



"I'll do what everybody does—sell this startup just before we have to hire a female employee."

In May of 1804, Meriwether Lewis and William Clark, together with their Corps of Discovery, set off from St. Louis on America's first official cross-country expedition. Eighteen months later, they reached the Pacific Ocean and made camp near the present-day town of Astoria, Oregon. The United States was, at the time, twenty-nine years old. Canada was not yet a country. The continent's far expanses were so unknown to its white explorers that Thomas Jefferson, who commissioned the journey, thought that the men would come across woolly mammoths. Native Americans had lived in the Northwest for millennia, but they had no written language, and the many things to which the arriving Europeans subjected them did not include seismological inquiries. The newcomers took the land they encountered at face value, and at face value it was a find: vast, cheap, temperate, fertile, and, to all appearances, remarkably benign.

A century and a half elapsed before anyone had any inkling that the Pacific Northwest was not a quiet place but a place in a long period of quiet. It took another fifty years to uncover and interpret the region's seismic history. Geology, as even geologists will tell you, is not normally the sexiest of disciplines; it hunkers down with earthly stuff while the glory accrues to the human

and the cosmic—to genetics, neuroscience, physics. But, sooner or later, every field has its field day, and the discovery of the Cascadia subduction zone stands as one of the greatest scientific detective stories of our time.

The first clue came from geography. Almost all of the world's most powerful earthquakes occur in the Ring of Fire, the volcanically and seismically volatile swath of the Pacific that runs from New Zealand up through Indonesia and Japan, across the ocean to Alaska, and down the west coast of the Americas to Chile. Japan, 2011, magnitude 9.0; Indonesia, 2004, magnitude 9.1; Alaska, 1964, magnitude 9.2; Chile, 1960, magnitude 9.5—not until the late nineteen-sixties, with the rise of the theory of plate tectonics, could geologists explain this pattern. The Ring of Fire, it turns out, is really a ring of subduction zones. Nearly all the earthquakes in the region are caused by continental plates getting stuck on oceanic plates—as North America is stuck on Juan de Fuca—and then getting abruptly unstuck. And nearly all the volcanoes are caused by the oceanic plates sliding deep beneath the continental ones, eventually reaching temperatures and pressures so extreme that they melt the rock above them.

The Pacific Northwest sits squarely within the Ring of Fire. Off its coast, an oceanic plate is slipping beneath a continental one. Inland, the Cascade volcanoes mark the line where, far below, the Juan de Fuca plate is heating up and melting everything above it. In other words, the Cascadia subduction zone has, as Goldfinger put it, "all the right anatomical parts." Yet not once in recorded history has it caused a major earthquake—or, for that matter, any quake to speak of. By contrast, other subduction zones produce major earthquakes occasionally and minor ones all the time: magnitude 5.0, magnitude 4.0, magnitude why are the neighbors moving their sofa at midnight. You can scarcely spend a week in Japan without feeling this sort of earthquake. You can spend a lifetime in many parts of the Northwest—several, in fact, if you had them to spend—and not feel so much as a quiver. The question facing geologists in the nineteen-seventies was whether the Cascadia subduction zone had ever broken its eerie silence.

In the late nineteen-eighties, Brian Atwater, a geologist with the United States Geological Survey, and a graduate student named David Yamaguchi found the answer, and another major clue in the Cascadia puzzle. Their discovery is best illustrated in a place called the ghost forest, a grove of western red cedars on the banks of the Copalis River, near the Washington coast. When I paddled out to it last summer, with Atwater and Yamaguchi, it was easy to see how it got its name. The cedars are spread out across a low salt marsh on a wide northern bend in the river, long dead but still standing. Leafless, branchless, barkless, they are reduced to their trunks and worn to a smooth silver-gray, as if they had always carried their own tombstones inside them.

What killed the trees in the ghost forest was saltwater. It had long been assumed that they died slowly, as the sea level around them gradually rose and submerged their roots. But, by 1987, Atwater, who had found in soil layers evidence of sudden land subsidence along the Washington coast, suspected that that was backward—that the trees had died quickly when the ground beneath them plummeted. To find out, he teamed up with Yamaguchi, a specialist in

dendrochronology, the study of growth-ring patterns in trees. Yamaguchi took samples of the cedars and found that they had died simultaneously: in tree after tree, the final rings dated to the summer of 1699. Since trees do not grow in the winter, he and Atwater concluded that sometime between August of 1699 and May of 1700 an earthquake had caused the land to drop and killed the cedars. That time frame predated by more than a hundred years the written history of the Pacific Northwest—and so, by rights, the detective story should have ended there.

But it did not. If you travel five thousand miles due west from the ghost forest, you reach the northeast coast of Japan. As the events of 2011 made clear, that coast is vulnerable to tsunamis, and the Japanese have kept track of them since at least 599 A.D. In that fourteen-hundred-year history, one incident has long stood out for its strangeness. On the eighth day of the twelfth

month of the twelfth year of the Genroku era, a six-hundred-mile-long wave struck the coast, levelling homes, breaching a castle moat, and causing an accident at sea. The Japanese understood that tsunamis were the result of earthquakes, yet no one felt the ground shake before the Genroku event. The wave had no discernible origin. When scientists began studying it, they called it an orphan tsunami.

Finally, in a 1996 article in *Nature*, a seismologist named Kenji Satake and three colleagues, drawing on the work of Atwater and Yamaguchi, matched that orphan to its parent—and thereby filled in the blanks in the Cascadia story with uncanny specificity. At approximately nine o' clock at night on January 26, 1700, a magnitude-9.0 earthquake struck the Pacific Northwest, causing sudden land subsidence, drowning coastal forests, and, out in the ocean, lifting up a wave half the length of a continent. It took roughly fifteen minutes for the Eastern half of that wave to strike the Northwest coast. It took ten hours for the other half to cross the ocean. It reached Japan on January 27, 1700: by the local calendar, the eighth day of the twelfth month of the twelfth year of Genroku.

Once scientists had reconstructed the 1700 earthquake, certain previously overlooked accounts also came to seem like clues. In 1964, Chief Louis Nookmis, of the Huu-ay-aht First Nation, in British Columbia, told a story, passed down through seven generations, about the eradication of Vancouver Island's Pachena Bay people. "I think it was at nighttime that the land shook," Nookmis recalled. According to another tribal history, "They sank at once, were all drowned; not one survived." A hundred years earlier, Billy Balch, a leader of the Makah tribe, recounted a similar story. Before his own time, he said, all the water had receded from Washington State's Neah Bay, then suddenly poured back in, inundating the entire region. Those who survived later found canoes hanging from the trees. In a 2005 study, Ruth Ludwin, then a seismologist at the University of Washington, together with nine colleagues, collected and analyzed Native American reports of earthquakes and saltwater floods. Some of those reports contained enough information to estimate a date range for the events they described. On average, the midpoint of that range was 1701.

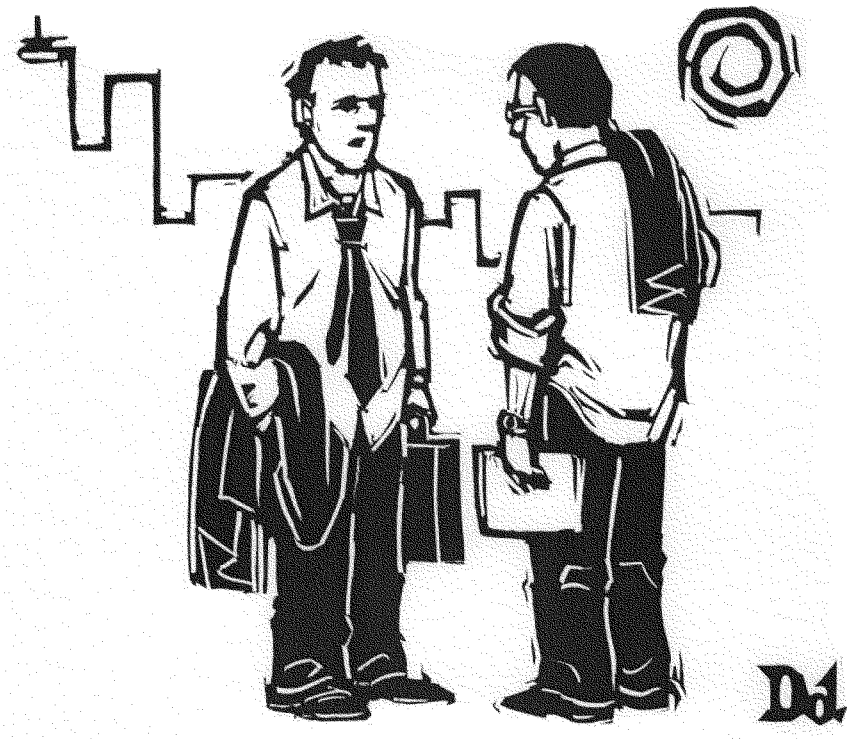
It does not speak well of European-Americans that such stories counted as evidence for a proposition only after that proposition had been proved. Still, the reconstruction of the Cascadia earthquake of 1700 is one of those rare natural puzzles whose pieces fit together as tectonic plates do not: perfectly. It is wonderful science. It was wonderful *for* science. And it was terrible news for the millions of inhabitants of the Pacific Northwest. As Goldfinger put it, "In the late eighties and early nineties, the paradigm shifted to 'uh-oh.' "

Goldfinger told me this in his lab at Oregon State, a low prefab building that a passing English major might reasonably mistake for the maintenance department. Inside the lab is a walk-in freezer. Inside the freezer are floor-to-ceiling racks filled with cryptically labelled tubes, four inches in diameter and five feet long. Each tube contains a core sample of the seafloor. Each sample contains the history, written in seafloorese, of the past ten thousand years. During

subduction-zone earthquakes, torrents of land rush off the continental slope, leaving a permanent deposit on the bottom of the ocean. By counting the number and the size of deposits in each sample, then comparing their extent and consistency along the length of the Cascadia subduction zone, Goldfinger and his colleagues were able to determine how much of the zone has ruptured, how often, and how drastically.

Thanks to that work, we now know that the Pacific Northwest has experienced forty-one subduction-zone earthquakes in the past ten thousand years. If you divide ten thousand by forty-one, you get two hundred and forty-three, which is Cascadia's recurrence interval: the average amount of time that elapses between earthquakes. That timespan is dangerous both because it is too long—long enough for us to unwittingly build an entire civilization on top of our continent's worst fault line—and because it is not long enough. Counting from the earthquake of 1700, we are now three hundred and fifteen years into a two-hundred-and-forty-three-year cycle.

It is possible to quibble with that number. Recurrence intervals are averages, and averages are tricky: ten is the average of nine and eleven, but also of eighteen and two. It is not possible, however, to dispute the scale of the problem. The devastation in Japan in 2011 was the result of a discrepancy between what the best science predicted and what the region was prepared to withstand. The same will hold true in the Pacific Northwest—but here the discrepancy is enormous. "The science part is fun," Goldfinger says. "And I love doing it. But the gap between what we know and what we should do about it is getting bigger and bigger, and the action really needs to turn to responding. Otherwise, we're going to be hammered. I've been through one of these massive earthquakes in the most seismically prepared nation on earth. If that was Portland"—Goldfinger finished the sentence with a shake of his head before he finished it with words. "Let's just say I would rather not be here."



"This heat is killing me. Let's get a drink in Little Antarctica." July 20, 2009

The first sign that the Cascadia earthquake has begun will be a compressional wave, radiating outward from the fault line. Compressional waves are fast-moving, high-frequency waves, audible to dogs and certain other animals but experienced by humans only as a sudden jolt. They are not very harmful, but they are potentially very useful, since they travel fast enough to be detected by sensors thirty to ninety seconds ahead of other seismic waves. That is enough time for earthquake early-warning systems, such as those in use throughout Japan, to automatically perform a variety of lifesaving functions: shutting down railways and power plants, opening elevators and firehouse doors, alerting hospitals to halt surgeries, and triggering alarms so that the general public can take cover. The Pacific Northwest has no early-warning system. When the Cascadia earthquake begins, there will be, instead, a cacophony of barking dogs and a long,

suspended, what-was-that moment before the surface waves arrive. Surface waves are slower, lower-frequency waves that move the ground both up and down and side to side: the shaking, starting in earnest.

Soon after that shaking begins, the electrical grid will fail, likely everywhere west of the Cascades and possibly well beyond. If it happens at night, the ensuing catastrophe will unfold in darkness. In theory, those who are at home when it hits should be safest; it is easy and relatively inexpensive to seismically safeguard a private dwelling. But, lulled into nonchalance by their seemingly benign environment, most people in the Pacific Northwest have not done so. That nonchalance will shatter instantly. So will everything made of glass. Anything indoors and unsecured will lurch across the floor or come crashing down: bookshelves, lamps, computers, cannisters of flour in the pantry. Refrigerators will walk out of kitchens, unplugging themselves and toppling over. Water heaters will fall and smash interior gas lines. Houses that are not bolted to their foundations will slide off—or, rather, they will stay put, obeying inertia, while the foundations, together with the rest of the Northwest, jolt westward. Unmoored on the undulating ground, the homes will begin to collapse.

Across the region, other, larger structures will also start to fail. Until 1974, the state of Oregon had no seismic code, and few places in the Pacific Northwest had one appropriate to a magnitude-9.0 earthquake until 1994. The vast majority of buildings in the region were constructed before then. Ian Madin, who directs the Oregon Department of Geology and Mineral Industries (DOGAMI), estimates that seventy-five per cent of all structures in the state are not designed to withstand a major Cascadia quake. FEMA calculates that, across the region, something on the order of a million buildings—more than three thousand of them schools—will collapse or be compromised in the earthquake. So will half of all highway bridges, fifteen of the seventeen bridges spanning Portland's two rivers, and two-thirds of railways and airports; also, one-third of all fire stations, half of all police stations, and two-thirds of all hospitals.

Certain disasters stem from many small problems conspiring to cause one very large problem. For want of a nail, the war was lost; for fifteen independently insignificant errors, the jetliner was lost. Subduction-zone earthquakes operate on the opposite principle: one enormous problem causes many other enormous problems. The shaking from the Cascadia quake will set off landslides throughout the region—up to thirty thousand of them in Seattle alone, the city's emergency-management office estimates. It will also induce a process called liquefaction, whereby seemingly solid ground starts behaving like a liquid, to the detriment of anything on top of it. Fifteen per cent of Seattle is built on liquefiable land, including seventeen day-care centers and the homes of some thirty-four thousand five hundred people. So is Oregon's critical energy-infrastructure hub, a six-mile stretch of Portland through which flows ninety per cent of the state's liquid fuel and which houses everything from electrical substations to natural-gas terminals. Together, the sloshing, sliding, and shaking will trigger fires, flooding, pipe failures, dam breaches, and hazardous-material spills. Any one of these second-order disasters could swamp the original earthquake in terms of cost, damage, or casualties—and one of them

definitely will. Four to six minutes after the dogs start barking, the shaking will subside. For another few minutes, the region, upended, will continue to fall apart on its own. Then the wave will arrive, and the real destruction will begin.

Among natural disasters, tsunamis may be the closest to being completely unsurvivable. The only likely way to outlive one is not to be there when it happens: to steer clear of the vulnerable area in the first place, or get yourself to high ground as fast as possible. For the seventy-one thousand people who live in Cascadia's inundation zone, that will mean evacuating in the narrow window after one disaster ends and before another begins. They will be notified to do so only by the earthquake itself—"a vibrate-alert system," Kevin Cupples, the city planner for the town of Seaside, Oregon, jokes—and they are urged to leave on foot, since the earthquake will render roads impassable. Depending on location, they will have between ten and thirty minutes to get out. That time line does not allow for finding a flashlight, tending to an earthquake injury, hesitating amid the ruins of a home, searching for loved ones, or being a Good Samaritan. "When that tsunami is coming, you run," Jay Wilson, the chair of the Oregon Seismic Safety Policy Advisory Commission (OSSPAC), says. "You protect yourself, you don't turn around, you don't go back to save anybody. You run for your life."

The time to save people from a tsunami is before it happens, but the region has not yet taken serious steps toward doing so. Hotels and businesses are not required to post evacuation routes or to provide employees with evacuation training. In Oregon, it has been illegal since 1995 to build hospitals, schools, firehouses, and police stations in the inundation zone, but those which are already in it can stay, and any other new construction is permissible: energy facilities, hotels, retirement homes. In those cases, builders are required only to consult with DOGAMI about evacuation plans. "So you come in and sit down," Ian Madin says. "And I say, 'That's a stupid idea.' And you say, 'Thanks. Now we've consulted.' "

These lax safety policies guarantee that many people inside the inundation zone will not get out. Twenty-two per cent of Oregon's coastal population is sixty-five or older. Twenty-nine per cent of the state's population is disabled, and that figure rises in many coastal counties. "We can't save them," Kevin Cupples says. "I'm not going to sugarcoat it and say, 'Oh, yeah, we'll go around and check on the elderly.' No. We won't." Nor will anyone save the tourists. Washington State Park properties within the inundation zone see an average of seventeen thousand and twenty-nine guests a day. Madin estimates that up to a hundred and fifty thousand people visit Oregon's beaches on summer weekends. "Most of them won't have a clue as to how to evacuate," he says. "And the beaches are the hardest place to evacuate from."

Those who cannot get out of the inundation zone under their own power will quickly be overtaken by a greater one. A grown man is knocked over by ankle-deep water moving at 6.7 miles an hour. The tsunami will be moving more than twice that fast when it arrives. Its height will vary with the contours of the coast, from twenty feet to more than a hundred feet. It will not look like a Hokusai-style wave, rising up from the surface of the sea and breaking from above. It

will look like the whole ocean, elevated, overtaking land. Nor will it be made only of water—not once it reaches the shore. It will be a five-story deluge of pickup trucks and doorframes and cinder blocks and fishing boats and utility poles and everything else that once constituted the coastal towns of the Pacific Northwest.

To see the full scale of the devastation when that tsunami recedes, you would need to be in the international space station. The inundation zone will be scoured of structures from California to Canada. The earthquake will have wrought its worst havoc west of the Cascades but caused damage as far away as Sacramento, California—as distant from the worst-hit areas as Fort Wayne, Indiana, is from New York. FEMA expects to coördinate search-and-rescue operations across a hundred thousand square miles and in the waters off four hundred and fifty-three miles of coastline. As for casualties: the figures I cited earlier—twenty-seven thousand injured, almost thirteen thousand dead—are based on the agency's official planning scenario, which has the earthquake striking at 9:41 A.M. on February 6th. If, instead, it strikes in the summer, when the beaches are full, those numbers could be off by a horrifying margin.

Wineglasses, antique vases, Humpty Dumpty, hip bones, hearts: what breaks quickly generally mends slowly, if at all. OSSPAC estimates that in the I-5 corridor it will take between one and three months after the earthquake to restore electricity, a month to a year to restore drinking water and sewer service, six months to a year to restore major highways, and eighteen months to restore health-care facilities. On the coast, those numbers go up. Whoever chooses or has no choice but to stay there will spend three to six months without electricity, one to three years without drinking water and sewage systems, and three or more years without hospitals. Those estimates do not apply to the tsunami-inundation zone, which will remain all but uninhabitable for years.

How much all this will cost is anyone's guess; FEMA puts every number on its relief-and-recovery plan except a price. But whatever the ultimate figure—and even though U.S. taxpayers will cover seventy-five to a hundred per cent of the damage, as happens in declared disasters—the economy of the Pacific Northwest will collapse. Crippled by a lack of basic services, businesses will fail or move away. Many residents will flee as well. OSSPAC predicts a mass-displacement event and a long-term population downturn. Chris Goldfinger didn't want to be there when it happened. But, by many metrics, it will be as bad or worse to be there afterward.

On the face of it, earthquakes seem to present us with problems of space: the way we live along fault lines, in brick buildings, in homes made valuable by their proximity to the sea. But, covertly, they also present us with problems of time. The earth is 4.5 billion years old, but we are a young species, relatively speaking, with an average individual allotment of three score years and ten. The brevity of our lives breeds a kind of temporal parochialism—an ignorance of or an indifference to those planetary gears which turn more slowly than our own.

This problem is bidirectional. The Cascadia subduction zone remained hidden from us for so long because we could not see deep enough into the past. It poses a danger to us today because we have not thought deeply enough about the future. That is no longer a problem of information; we now understand very well what the Cascadia fault line will someday do. Nor is it a problem of imagination. If you are so inclined, you can watch an earthquake destroy much of the West Coast this summer in Brad Peyton's "San Andreas," while, in neighboring theatres, the world threatens to succumb to Armageddon by other means: viruses, robots, resource scarcity, zombies, aliens, plague. As those movies attest, we excel at imagining future scenarios, including awful ones. But such apocalyptic visions are a form of escapism, not a moral summons, and still less a plan of action. Where we stumble is in conjuring up grim futures in a way that helps to avert them.

That problem is not specific to earthquakes, of course. The Cascadia situation, a calamity in its own right, is also a parable for this age of ecological reckoning, and the questions it raises are ones that we all now face. How should a society respond to a looming crisis of uncertain timing but of catastrophic proportions? How can it begin to right itself when its entire infrastructure and culture developed in a way that leaves it profoundly vulnerable to natural disaster?

The last person I met with in the Pacific Northwest was Doug Dougherty, the superintendent of schools for Seaside, which lies almost entirely within the tsunami-inundation zone. Of the four schools that Dougherty oversees, with a total student population of sixteen hundred, one is relatively safe. The others sit five to fifteen feet above sea level. When the tsunami comes, they will be as much as forty-five feet below it.

In 2009, Dougherty told me, he found some land for sale outside the inundation zone, and proposed building a new K-12 campus there. Four years later, to foot the hundred-and-twenty-eight-million-dollar bill, the district put up a bond measure. The tax increase for residents amounted to two dollars and sixteen cents per thousand dollars of property value. The measure failed by sixty-two per cent. Dougherty tried seeking help from Oregon's congressional delegation but came up empty. The state makes money available for seismic upgrades, but buildings within the inundation zone cannot apply. At present, all Dougherty can do is make sure that his students know how to evacuate.

Some of them, however, will not be able to do so. At an elementary school in the community of Gearhart, the children will be trapped. "They can't make it out from that school," Dougherty said. "They have no place to go." On one side lies the ocean; on the other, a wide, roadless bog. When the tsunami comes, the only place to go in Gearhart is a small ridge just behind the school. At its tallest, it is forty-five feet high—lower than the expected wave in a full-margin earthquake. For now, the route to the ridge is marked by signs that say "Temporary Tsunami Assembly Area." I asked Dougherty about the state's long-range plan. "There is no long-range plan," he said.

Dougherty's office is deep inside the inundation zone, a few blocks from the beach. All day long, just out of sight, the ocean rises up and collapses, spilling foamy overlapping ovals onto the shore. Eighty miles farther out, ten thousand feet below the surface of the sea, the hand of a geological clock is somewhere in its slow sweep. All across the region, seismologists are looking at their watches, wondering how long we have, and what we will do, before geological time catches up to our own. ♦

*An earlier version of this article misstated the location of the area of impact.

Senator CANTWELL. I think, probably, that is the most I have heard from my constituents, from people across the country, people I grew up with, people in Europe, everybody saying, "Have you read this?"

So the question is, I don't even know if people here in our nation's capital have their mind wrapped around this. It was very frustrating. I think the FEMA Region 10 Director was quoted in the article as saying, "Everything West of I–5 will be toast."

This is something we need to prepare for. I guess my question is, do we have all the tools necessary now to accurately depict the understanding of the Cascadia subduction zone? And what leadership role do you think that we need to push forward with other agencies so that we have the information and resources to move forward on a concrete plan?

Dr. KIMBALL. Well thank you for the question. And yes, I think we've all read the New Yorker article.

Within USGS we do have a priority activity to begin looking at the Cascadia subduction zone. It is the kind of system that could generate the same sorts of magnitude activities that we saw with the Tohoku earthquake in Japan and the Fukushima issues there. So we agree that it is important to look at that.

There is more to be done to understand the mechanics. I think, perhaps, a more important aspect now, and you're taking the first steps with the tsunami activity that's coming up later this year, is to make sure that individuals understand the potential, understand the true probability of an event and what to do should that kind of event occur.

That's one of the premises behind the various activities like the Earthquake ShakeOut events and the ARkStorm events to have those kinds of events take place in cities up and down the West Coast and especially in the Pacific Northwest. So I think that will be an important activity.

Senator CANTWELL. I just want to make sure that we are knitting this together. I guess that is the best word.

Just having been in Pacific County a week or so ago and having people from the University of Washington there and the local community which is, basically, a very rural part of our state. So you have a scientist on one hand saying this is the devastation and I will help you plan, and you have a local community that is a very small, rural community, and county commissioners, Madam Chair, and mayors, who are trying to do their best job. They are trying to get a plan for their community. I don't know that I would call that knitting it together. I think the exercise we are going to do will probably be a better knitting together, but I guess what I am saying is I feel like we have to keep doing work to make this plan a reality at the federal level because I think it is going to—this size that people are talking about, the map that they show is all the way from—I am sure it will have an impact on Alaska, but everything from Washington all the way through California. Basically one of the largest economies in the world, the West Coast economy, will be greatly impacted by this, so I think we want to keep knitting it together.

And on that point, you have signed an MOU, I think, with Pierce County, as it relates to a warning system. What can we do to make

sure that that funding is there? And how do we make sure that we get the amount of funding that we need for the LiDAR data since this also, from just a mudslide perspective, is critical?

Dr. KIMBALL. Right.

Well having the LiDAR database is absolutely foundational to being able to understand the potential risk associated with these efforts.

At the moment——

Senator CANTWELL. You are saying not just on landslides, but for the Cascadia subduction zone, having the LiDAR mapping system is going to be——

Dr. KIMBALL. Is not just for landslides, but for understanding flood potential, for instance. Having the information about the topographic expression is going to be very, very important.

Of course, working with the state geologist's office and developing the geologic maps is also going to be essential if you want to best understand the Cascadia subduction zone as well.

So all of these need to come together in a coordinated fashion.

As you point out that the knitting together is important, I'd like to point out that we have an office that is called Science Applications for Risk Reduction that is specifically dedicated to doing that. We've worked very closely with the seismic community and with SAFRR, the acronym, to help knit together both information, technology and infrastructure needs and public awareness. I think using the kinds of tools and technologies for communication and for pulling communities together will help with an understanding both of landslide potential and of the potentials associated with tsunami in the Northwest.

Senator CANTWELL. Thank you, Madam Chair.

The CHAIRMAN. Thank you.

Senator Franken.

Senator FRANKEN. Thank you, Madam Chair, and thank you, Dr. Kimball.

We talked a little at the beginning about the Asian Carp, and it sounds like you have done some trials and are about to go in the field with the experiment on, sort of, this magic bullet that will target the carp's ability to reproduce. Is that right?

Dr. KIMBALL. Yes, sir.

The bio bullet has gone through the laboratory trials. We are finished with that. We'll be doing field trials this spring and summer, and at that point we have information to put it into the system that actually registers the drugs for application. And so, we are well on our way to demonstrating the utility and viability of that particular method for carp control.

Senator FRANKEN. That is very good news and thank you for that work.

Dr. Kimball, according to your mission statement, the USGS serves the nation by providing reliable scientific information to describe and understand the Earth, minimize loss of life and property from natural disasters, manage water, biological energy and mineral resources and enhance and protect our quality of life. You have a big job.

Climate change is one of the biggest threats that we face. Climate change has and will continue to impact critical areas within the USGS mission.

Dr. Kimball, I am struck by the overlap between the core mission of the USGS and the potential impacts of climate change, and I am pleased that you have made climate change a priority at USGS including strong funding for climate-related activities in the Administration's FY2017 budget request.

I am interested in the USGS' work in satellite imagery and the monitoring of the Earth's system. Can you describe the importance of this work in understanding climate change and its impact on our society?

Dr. KIMBALL. Well satellite imagery is a tool of the future in any number of ways.

Within USGS we operate the Landsat satellite system which provides eight-day repeat imagery of the globe at 30-meter resolution. This is the perfect mid-range resolution for understanding aspects associated with water supply, with agriculture, with forestry, with changes in land use. And in the 44 history, or 44-year history, of Landsat we've been able to do that.

It has amazing commercial applications. We've been part of an analysis that has indicated that the provision of the Landsat data set and free and open access has resulted in over $2 billion return for commercial applications in terms of things like better management of irrigation systems.

Senator FRANKEN. Sure.

Dr. KIMBALL. Better management of forestry.

So having the ability to use satellite-based global observations gives us that global perspective that allows us to identify change and change through time. Coupled with geologic change, the understanding of the long-term cycles within the Earth is we are able then to put together a very good picture of how change might occur affecting various aspects of Earth resources.

Senator FRANKEN. Thank you. Thank you.

I want to talk about One Health. Over three quarters of the emerging diseases we faced in the last century have come from an animal source. Our ability to stop outbreaks relies on fast detection and response, and this means that wildlife experts and public health officials must work together in a One Health approach.

My One Health bill will direct the Administration to create a framework that will strengthen coordination between the agencies and support initiatives that foster more disease surveillance in animal populations at the state and local levels. The USGS plays an important role in this framework.

Dr. Kimball, in your testimony you describe USGS as the CDC of wildlife. Can you tell us more about how the work done by USGS helps prevent the spread of zoonotic diseases and what ways does the USGS coordinate with other public health agencies to prevent and respond to disease outbreaks?

Dr. KIMBALL. Well thank you very much for that question, Senator Franken.

The National Wildlife Health Center is a unique facility that has responsibilities for not only responding to particular disease events, die offs, for instance, but also for providing worldwide monitoring

that's associated with the vectors that disease spread for things like, for instance, Avian influenza, West Nile virus.

We are privileged to be part of the White House Fast Track Action Committees for diseases that are typically considered human health diseases such as Ebola and Zika, but those diseases actually have a genetic connection to wildlife disease. And so being able to connect our understanding of the spread of wildlife disease, the spread of vectors such as mosquitoes and changes in mosquito reservoirs based on understanding of say, climate change variables, is an important connection to the public health arena.

I'd also like to point out that our minerals work is also very closely connected to the public health sector. Understanding things like the risk associated with asbestos-formed minerals and the risk associated with various air quality conditions and water quality conditions is another aspect of environmental health that is important and a key mission priority for us.

Senator FRANKEN. Well thank you for the great work that you guys do.

Thank you, Madam Chair.

The CHAIRMAN. Thank you, Senator Franken.

Senator Hirono is next, but I understand that she is going to defer to Senator Manchin. Thank you.

Senator MANCHIN. First of all let me thank Senator Hirono, my friend, and I appreciate it.

But very quickly the USGS has the Leetown Science Center headquarters in Leetown, West Virginia, and it does a tremendous amount of ecological work. I think it has six other states that are involved with this one center.

The only thing I am asking is would you come and visit the center with me, if I can extend that invitation to you?

Dr. KIMBALL. Thank you, I would be delighted to have the opportunity.

Senator MANCHIN. Would you, if we could go? Okay.

Dr. KIMBALL. To visit the center.

Senator MANCHIN. We will arrange it then with your office.

Dr. KIMBALL. Absolutely, thank you.

Senator MANCHIN. Okay.

The other thing I want to talk to you about is seismic operations and deep well injections. I know you have come out with a report.

I have been speaking to the NETL, National Energy Technology Labs. We are all concerned because I know that the Marcellus shale in West Virginia was not mentioned in that. But I would assume that any type of injections, if it is not done and done properly, can be contributed toward the seismic activity that we are seeing.

Dr. KIMBALL. Our work on induced seismicity leads us to believe that it is most often associated with deep waste water injection wells. And again, depending on how those wells are constructed and how the operations take place can affect it.

Senator MANCHIN. So you know there is a proper way and an improper way. I am just asking if we have come to the conclusion that we can do it and do it safely, and I will give you a perfect example. I know that we are concerned about well water impregnation as far as our drinking water aquifers and all that. In West Virginia we

require basically double wall casing with cement in between all the way to formation which prevents that from happening, if it is done and done properly.

Also with the deep well injection we know if it is done properly with NETL's research that they are doing. I think working maybe with you all too, we are looking for that, that we can minimize, almost minimize, any risk that we have for seismic operations from deep well.

My concern is this. The energy this country needs and energy this country is using in so many different areas, whether you like it or not, there is a proper way to do things rather than just saying we are going stop it all together. That is what I am concerned about, because people will just shut it down for the sake of shutting something down. We need this energy, and we are looking for the proper ways.

Have you all seen, basically, with the proper injections, the proper deep well type of formations? And have you come out with recommendations, rules and recommendations of how this should be injected?

Dr. KIMBALL. No, we do—have not come out with——

Senator MANCHIN. That's not your——

Dr. KIMBALL. The rules and recommendations. That's not within our mission purview.

However, I can commit to you that our scientists would be happy to have discussions about the observations of what actually may trigger these kinds of events.

Senator MANCHIN. I would just say if I can work with your scientists and work with basically NETLs, our National Energy Technology Labs, making sure that we are all concurring on how we can do it and do it right and start forming the rules and regulations, working with EPA to make sure before they start overreaching and shutting things down, making sure they can comply and do it safely and do it properly. Because I think every state is a little bit different here on this, and before you know it it is going to have a snowball effect and we are going to have an energy shortage and be back to where we were before.

Dr. KIMBALL. Well, we'd be very happy to enter into that discussion with you.

Senator MANCHIN. Okay.

That is all I needed to say. We will contact you on that too, if you can get your people.

Dr. KIMBALL. Absolutely.

Senator MANCHIN. Get your people with our people, how about that?

Dr. KIMBALL. That sounds good. Yes, sir.

Senator MANCHIN. Thank you.

Dr. KIMBALL. Thank you.

The CHAIRMAN. Senator Hirono.

Senator HIRONO. Thank you, Madam Chair.

Dr. Kimball, the Ohia tree is a native species that is an anchor to Hawaii's rain forests and is currently being threatened by rapid Ohia death, or ROD.

As of early 2016 ROD, which has a 100 percent mortality rate for infected trees, has impacted 34,000 acres of native forest on Ha-

waii island. Of course, that impacts our watershed, et cetera. So as you can imagine this crisis situation requires a coordinated effort on the part of the county, state, federal agencies including, of course, yours.

Can you provide an update on the models that USGS scientists have been constructing to predict the spread of the fungus that causes ROD and when will these models be ready to be implemented? And how has the recent prediction by scientists that burrowing beetles are spreading ROD impacted model development?

Dr. KIMBALL. Well thank you for that question.

Our Center Director at the Pacific Islands Ecological Research Center has, in fact, informed me about the importance of this issue and the potential devastating impacts that this could have to the ecosystems in Hawaii.

I do not have the answer with me and to specifically answer your question about the model development, but I will be happy to provide that for the record.

Senator HIRONO. Thank you so much.

Then turning to Albizia. USGS, in collaboration with the University of Hawaii Hilo, worked to collect satellite imagery of the forest canopy in Puna on Hawaii Island following Tropical Storm Iselle in the fall of 2014. This imagery was gathered to assess the most heavily impacted areas and develop a model of tree canopy conditions that were impacted during the storm.

Frankly, a lot of the damage that arose out of the Tropical Storm Iselle was the fact that these Albizia trees would just fall over and create a lot of the property damage was due to that.

Can this model be used to identify the highly invasive Albizia trees which grow like weeds, practically, in areas with canopy conditions similar to those impacted in order to locate and remove Albizia trees to mitigate impact from future storms? And what other steps can be taken to identify Albizia trees in potential hazard locations for the future? This may be another one where you need to check and get back to me.

Dr. KIMBALL. I will have to check for the specifics.

I can tell you that there are a number of techniques that allow us to identify through global Earth observations, either from space or from airborne technologies, that allow us to identify particular species, canopy species, and their distribution from their reflectance in the—as the imagery is collected. So there are a number of different ways. The ways that could be most effective for modeling those tree distributions within Hawaii is beyond my knowledge base right this instant, but we will be more than happy to provide that information for you.

Senator HIRONO. Thank you so much.

Your organization's Hawaii Volcanoes Observatory plays a crucial role in monitoring Hawaii's active volcanoes, and as you know, Kilauea has been active for decades.

Scientists communicated closely with the state Civil Defense and the county during the lava flows at Kilauea last year. Given the increased seismic activity at Mauna Loa on the Big Island, can you discuss any ways that Congress can continue to provide support to this critical work to ensure public safety due to active volcanoes?

I realize we have over 100 active volcanoes in our country, so do we provide enough support for what you are doing?

Dr. KIMBALL. Well——

Senator HIRONO. —volcanoes?

Dr. KIMBALL. This particular Committee, in providing bipartisan proposed legislation to establish volcano early warning and volcano monitoring systems, is going a long way toward elevating the need and the kinds of activities that need to take place in order to maintain that monitoring system.

As always, new technologies evolve that are very helpful. And as those technologies evolve for looking at things such as gas emissions, that help us understand when volcanoes are getting ready to erupt and the ability to pursue those new innovations, is going to be essential for maintaining those long-term monitoring systems.

We are absolutely committed to that effort. We're absolutely committed to enhancing and providing additional assistance for volcano monitoring.

The President's proposed budget for 2017 actually puts into our proposed base funding those funding levels that Congress has put in as one-time increases over the past two years. So we are working to increase our base funding to address volcano monitoring issues.

Senator HIRONO. Thank you.

Just very briefly, I know that you are focusing on the next generation of young people to scientific inquiry, and I commend you for those efforts and especially the focus on Native American young people.

Dr. KIMBALL. Thank you.

Senator HIRONO. Thank you, Madam Chair.

The CHAIRMAN. Senator Stabenow.

Senator STABENOW. Well thank you very much, Madam Chair.

Dr. Kimball, thank you so much for your work and the work of your agency. We appreciate it very much. With my Great Lakes hat on, and we have a number of members of our Committee that surround the Great Lakes, we thank you for your ongoing efforts. That is really what I want to talk about and that is the whole effort around trying to stop the Asian Carp from getting into the Great Lakes which has been of such concern to all of us on a bipartisan basis, who represent the area. I appreciate the role that U.S. Geological Survey is playing as part of the Asian Carp Regional Coordinating Committee.

I first wanted to just ask you your thoughts. As you know, we have seven federal agencies, departments, natural resource officials from all of the Great Lakes states as well as regional bodies that came together through the President's initiative just set up, the Asian Carp Regional Coordinating Committee. I have been thinking it might be good to actually authorize that officially in law. I wonder if you have any thoughts about that?

Dr. KIMBALL. Thank you, Senator.

As I've had the opportunity to talk to colleagues in the Great Lake states, they feel that that particular committee has been very, very effective. It's been a keystone in the way we're able to coordinate science needs, science priorities with the actual operational activities that need to take place. So I can tell you that our sci-

entists feel that that Committee is very effective and should remain in operation, however we do that.

Senator STABENOW. Great. Well thanks very much.

I appreciate your working with the Great Lakes Fisheries Commission, the Council of Lake Committees. I mean, all the effort and research that is going on.

This is what I wanted to zero in on in terms of research right now as we look how we stop these fish that grow up to 100 pounds and have no functioning stomach and basically will destroy the other fish habitat and fish in the Great Lakes as well as the boating industry and so on and so on. This is actually a very serious economic and ecological issue for us, trying to stop these fish.

When we look at the best strategy right now, as you know, about 40 miles south of Chicago is the Brandon Road Lock and Dam which is a place where the rivers come together and where we have been focused. The Army Corps of Engineers is looking at the best technologies to deploy there in addition to the electric fences that are there down in the water and so on.

I wonder if you could talk about the technologies and deterrents you are reviewing for deployment at this particular spot and whether carbon dioxide barriers are at a point soon to be deployed? We have heard a lot about that as a possible deterrent for the fish and wondered if you might speak about the technologies, but also about the carbon dioxide barriers that they are testing?

Dr. KIMBALL. Well we've been working very closely with the Corps of Engineers on these particular technologies.

One of the challenges that we face is how do you maintain the consistent pressure through the water column that will have the desired effect on the Asian Carp and not impact other species? And so, that is a challenge now. And it's one that the Corps of Engineers from a technology development perspective and the USGS from an understanding of fish physiology are working closely together to try and address.

I don't have an answer for you in terms of how far we are from an actual implementation of that kind of technology, but I'd be happy to go back and ask our scientists to provide that answer for you.

[The information requested has not been provided as of the date of printing.]

Senator STABENOW. We are very concerned. We have a bipartisan Great Lakes Task Force, as you know, in the Senate as well as the House, which not long ago held a meeting where we were urging the Army Corps, USGS and everyone, to not wait until everything has been analyzed, that if there is one technology that looks like it will work to begin to deploy that. So we are interested in the carbon dioxide research that has been done. And the other one is, I am wondering if you know how far along the approval process, under FIFRA, that the micro particles that everyone talked about that would put toxins into micro particles to target the carp? Are you are aware at all where that technology stands?

Dr. KIMBALL. We've completed the laboratory trials for that technology, and we'll be going to field trials this spring. And I do not know how long it will take in the drug registration process to move it through, but I do know that we are going to field trials now.

Senator STABENOW. Well if you feel that this is something that is credible and will work, we certainly want to know and work with you and do everything we can to be able to make sure that this is expedited in the right way to be able to get it out the door because the fish are not waiting for us, as you know. We debate and hold hearings and discuss things and they keep finding a way to get closer and closer to the Great Lakes.

So I am anxious to continue to work with you, and I appreciate your agency's work.

Thank you.

Dr. KIMBALL. Well thank you. And we're happy to work with you, and we'll continue to provide you updates as we move forward with this.

Senator STABENOW. Thank you.

The CHAIRMAN. Director Kimball, thank you.

I have a whole series of questions, many related to unconventional oil and gas, some questions about land patenting issues and then the work that USGS is doing in better understanding the migration and winter habitat of the black brant, but I will be submitting those to you for followup. Senator Cantwell.

Senator CANTWELL. I have a couple to submit too.

The CHAIRMAN. Other members of the Committee may have some followup as well. But because we do have a second panel and I know we have votes that are coming up, I think we will excuse you. Again, thank you for appearing before the Committee today.

Dr. KIMBALL. Again, thank you very much for the opportunity, and I'll look forward to the questions for the record.

Thanks.

The CHAIRMAN. Great. Thank you very much.

Let's call up the second panel at this time.

We are joined this morning by some very esteemed scientists and folks with an understanding of so many of these issues in good and deep detail.

We have Mr. Ed Fogels. Ed is the Deputy Commissioner for the Alaska Department of Natural Resources. He has had an opportunity to appear before the Committee in other areas. Not only do we appreciate your insight, Ed, but we also appreciate the fact that you have traveled a long way to be here with us this morning and we greatly appreciate that.

Next we have Dr. P. Patrick Leahy, not to be confused with a Patrick Leahy that——

Senator CANTWELL. We all know.

The CHAIRMAN. We all know and work with on a daily basis. Dr. Leahy is the Executive Director for the American Geosciences Institute.

We also have another Alaskan and fellow Fairbanksan, Dr. Robert McCoy, who is the Director of the Geophysical Institute at the University of Alaska Fairbanks. He is another individual we rely on a great deal for his expertise, so welcome and thank you for traveling all this way.

And as Senator Cantwell mentioned earlier, Dr. John Vidale, who is the Washington State Seismologist and Director at the Pacific Northwest Seismic Network at the University of Washington.

Again, a very esteemed panel and a panel that has come from long distances to be with us.

We will go ahead and begin with your opening comments. We would ask you to keep your comments to about five minutes. Your full statements will be incorporated as part of the record, and then we will have an opportunity for questioning.

I will also offer my apologies. I am trying to be in two places at once. I have an Appropriations hearing that is going on downstairs, so I will be bouncing in and out. That does not mean that I am not interested, it means that I need to be in two places at once.

Let's start with you, Mr. Fogels. Again, welcome back to the Committee.

STATEMENT OF EDMUND FOGELS, DEPUTY COMMISSIONER, ALASKA DEPARTMENT OF NATURAL RESOURCES

Mr. FOGELS. Thank you, Chairwoman Murkowski, Ranking Member Cantwell and honorable members of the Committee. My name is Ed Fogels. I'm the Deputy Commissioner of the Alaska Department of Natural Resources. And on behalf of Governor Bill Walker, thank you for this opportunity to testify in strong support of Alaska's mapping and the critical role that the U.S. Geological Survey plays in this effort.

Alaska is a huge place. It is one-fifth the size of the entire United States, and it is the least geographically and geologically understood of all states. It has twice the land area of Texas and covers 32 ecoregions. In many respects, the planet Mars has been mapped better than Alaska.

The USGS is Alaska's primary partner in improving our knowledge base of our vast state, whether it be mapping our topography, our geology, our geologic hazards or our energy and mineral resources. The good news is that we, largely because of our strong partnership with the USGS, have made a great deal of progress mapping Alaska.

In 2006 the State of Alaska established the Statewide Digital Mapping Initiative to create an accurate base map of Alaska consisting of satellite imagery and elevation data. To date, the State of Alaska has appropriated $19.5 million in this effort and our federal partners have contributed $35.1 million, and we are well on our way to finishing our base map.

These efforts gave rise to the Alaska Mapping Executive Committee, chaired by the Department of the Interior and having representatives from 19 federal agencies and the State of Alaska, and the USGS has been instrumental in this effort. Our mapping collaboration with the USGS involves creating a number of data layers that together form our digital base map.

First, the elevation layer is the most foundational. This layer is a digital model of our terrain. In Alaska, many areas are only mapped at 60 meter resolution. This results in enormous errors and inaccuracies. We are now collecting improved elevation data at a five meter resolution using the IFSAR technology. We are approximately 63 percent complete and hope to be over 70 percent after this summer, a testament to the highly effective collaborative efforts through AMEC, the Alaska Mapping Executive Committee,

between the State of Alaska and federal agencies such as the USGS.

The next layer is imagery. From imagery, additional information such as roads, railways, pipelines and trails can be derived. We now have a two and a half-meter resolution satellite image available for almost all of Alaska.

Our third layer is hydrography. Hydrography is a map of all the water features in Alaska such as lakes, streams, ice fields and coastlines. We have completed 11 percent of Alaska, soon to be at 28 percent, with the help of many partners including the USGS, and we are making great strides in improving this important data set.

The other critical layer that I need to mention is geodetic control. Geodetic control provides the framework to accurately position all our mapping activities. Key to good geodetic control are what we call continuously operating reference stations which are fixed ground stations that help GPS devices give more accurate positioning. The more of these stations we have, the more accurate our GPS positioning is.

Alaska already has one of the lowest densities of any state, and over half of our existing stations are in danger of decommissioning when the Earthscope project loses its funding in two years. We are also looking at ways to utilize existing infrastructure such as the Earthscope transportable array stations to collocate this equipment.

I'd like to give the Committee an example of a real world product that is being produced using all of this new data, a product that is helping everyone from hikers enjoying Alaska's great parks to geologists mapping our mineral resources, to agency land managers, new topographic maps. Alaska's topographic maps are compiled from antiquated surveys dating from the '40s and '50s. Much to our delight the USGS National Geospatial Program is now creating the new U.S. topo map in Alaska providing far more accurate maps.

Now let me move from our foundational mapping data to something much more specific, mapping Alaska's geology. In Alaska, good geologic mapping has been completed for about 17 percent of our state. The remaining area to be mapped is roughly equal to the combined area of California, Oregon, Washington and Idaho, and at our current rate of mapping this would take about 400 years to complete.

USGS' National Cooperative Geologic Mapping Program, STATEMAP, is an excellent example of the cooperative funding and leveraging of state and federal dollars to conduct the geologic mapping.

We need help with mapping our geologic hazards. Alaska is an exciting place with 52 active volcanoes and lots of earthquakes and permafrost hazards. Some key areas in need of additional mapping are coastal erosion, flooding, tsunami inundation mapping and avalanche and landslides susceptibility mapping.

Alaska's earthquake monitoring system lags behind those in the rest of the nation. The National Science Foundation's Earthscope project will deploy 261 seismic stations and those are not, at this

point, programmed to be kept after that time period and integrated into Alaska's seismic array.

As you can see, Alaska has a wonderful and necessary collaborative relationship with the USGS. It is critical for us and the rest of the nation that this relationship continue on and be strengthened. The USGS needs more resources to help finish mapping our great state.

Thank you very much for the opportunity to provide my testimony today.

[The prepared statement of Mr. Fogels follows:]

Testimony before the U.S. Senate Committee on Energy and Natural Resources

Hearing to conduct Oversight of the U.S. Geological Survey

April 7, 2016

Submitted by:
Mr. Edmund Fogels, Deputy Commissioner
Alaska Department of Natural Resources
Chair Alaska Geospatial Council

Testimony on behalf of:
The State of Alaska

I. Introduction

Chairwoman Murkowski, Ranking Member Cantwell, and honorable members of the Senate Committee on Energy and Natural Resources – My name is Ed Fogels and I am Deputy Commissioner of the Alaska Department of Natural Resources (AK DNR). On behalf of Governor Bill Walker, thank you for this opportunity to testify in strong support of Alaska mapping and the critical role the U.S. Geological Survey (USGS) plays in this effort. I have personally been active in the mapping initiative since 2006.

Before testifying, I want to recognize USGS Director Suzette Kimball. The State of Alaska would like to thank Director Kimball for the recent efforts on behalf of the USGS to map the state of Alaska. We have certainly made progress to date and the State applauds this progress — but, as is abundantly clear, there is much yet to be done. I also want to recognize Mr. Kevin Gallagher, Associate Director of USGS in charge of Core Sciences, and thank him for his work in this area.

II. Background on Alaska and its Mapping Needs

Alaska is one fifth the size of the entire United States, is the only state with lands north of the Arctic Circle, and is the least geographically and geologically understood of all the states. It has twice the land area of Texas and covers 32 ecoregions, from temperate rainforest to tundra. Its easternmost point to its westernmost is roughly the same distance as Savanah, Georgia, is from Santa Barbara, California. From Barrow to Juneau is the equivalent distance of New York to Orlando (See Figure 1). The federal government is the largest landowner in Alaska with 60% of lands, or roughly 222 million acres under federal management, which makes cooperation and joint funding for mapping efforts critical.

Alaska is also under-explored and very incompletely mapped. The USGS is Alaska's primary partner in improving our knowledge base of our vast state, whether it be mapping our topography, our geology, our geologic hazards, or out energy and mineral resources.

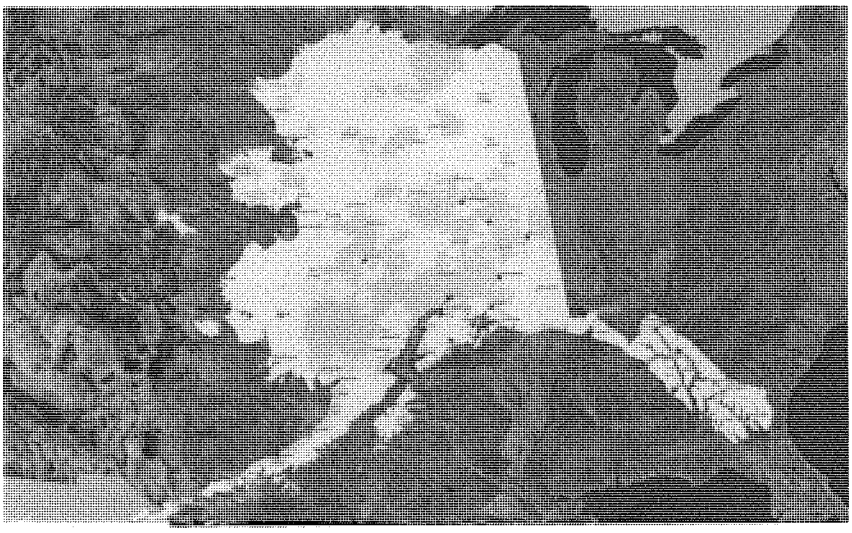


Figure 1.

Alaska's topographical maps, which a myriad of disciplines rely on for public and private business, are in excess of a half-century old and compiled from antiquated surveys dating from 1948 to 1955. They are notoriously inaccurate and have never met National Map Accuracy Standards. In fact, the current effort to modernize Alaska's maps has found evidence of mountains horizontally displaced by over one quarter mile with ridgelines that are off by 1,000 meters or more vertically on these maps. Regarding scale, Alaska's maps are 1:63,000 in scale while a typical map for the remainder of the United States is 1:24,000 or better. These facts alone show how dramatically Alaska lags behind the nation in mapping and how the numerous public interests involved with understanding Alaska have been underserved.

Alaska was the last state in the United States to procure a modern statewide digital base map of uniform resolution and accuracy providing contiguous statewide coverage. *In many respects, the planet Mars is more accurately mapped and more extensively mapped than Alaska*.

These shortcomings have impacts to Alaska and the Nation as a whole. The map of Alaska is widely regarded as being incapable of supporting modern electronic information management practices and analyses, which are mission critical in the digital era across many different applications. Accurate geospatial data is essential to economic and infrastructure development as well as responsible resource development – cornerstones of Alaska's economy. It is also essential to the responsible management and preservation of Alaska's public lands, wildlife habitat and water resources – some of the most pristine in the Nation. Finally, accurate geospatial data is foundational to the preservation of human life and public safety, search and rescue, as well as the advancement of scientific discovery, physical science and the understanding of climate change, its impacts and adaptation. As the last frontier, Alaska's needs in all of these areas are significant.

III. Progress to Date

Despite the shortcomings in Alaska's maps, the USGS and the State have made a great deal of progress on these issues recently. In 2006, the State of Alaska appropriated $2 million dollars in capital funds to address these needs. These funds were appropriated as seed money for the planning and creation of an accurate base map of Alaska consisting of satellite imagery and elevation data, and the Statewide Digital Mapping Initiative (SDMI) was established. The SDMI executed a broadly supported stakeholder survey and conducted two public workshops producing two enlightening white papers regarding satellite imagery and elevation data. Broad stakeholder consensus on a path forward was achieved in 2009 and data collection commenced in 2010 under a State and Federal cost sharing collaborations. To date the State of Alaska has appropriated $19.5 million dollars (including $13.5 million alone for interferometric synthetic aperture radar or IfSAR data) and our federal partners have contributed $35.1 million in good faith efforts to collaborate and jointly benefit from acquiring accurate map data. (See Table 1).

Governmental Unit (000)	2005	2010	2011	2012	2013	2014	2015	2016 *TBD*	TOTAL (000)
BLM	$2,755	$ 216	$ 20	$1,000	$ 141	$ 50	$2,062	$ 50	$ 6,474
FWS				550			250		800
NGA		2,400							2,400
NPS		100	150	182	30		450		912
USDA/NRCS		100	232	100	630	450	200	300	2,012
USDA/USFS				354	50	447	233	250	1,334
USGS	2,755	1,016	870	3,066	3,701	2,581	3,526	3,700	21.215
Federal Total	5,509	3,832	1,272	4,253	4,552	3,628	6,151	4,300	35,147
State of Alaska		1,875		5,050	2,550	2,800		1,300	13,575
TOTAL	**$5,509**	**$5,707**	**$1,271**	**$9,302**	**$7,103**	**$6,428**	**$6,151**	**$5,600**	**$48,722**
FUNDING NEEDED TO COMPLETE IFSAR (Elevation):									***$19,700***

Table 1.

Using a federal grant, the SDMI authored two intergovernmental and stakeholder-driven plans: *the Geospatial Strategic Plan & the Geospatial Business Plan*. These plans served to identify and document the most responsible and efficient path forward for these mapping efforts. They address data acquisitions, data stewardship, and intergovernmental governance/oversight, and were finalized in 2011 and 2012 respectively.

The above efforts paved the way to the 2012 Alaska/Federal Mapping Roundtable here in Washington DC[1], which was robustly attended by 29 high-level agency and administration officials. The resulting unanimous conclusion was that every federal agency has a stake in mapping Alaska and would be a direct beneficiary of the mapping efforts, and that there was no time to waste. The roundtable gave rise to the Alaska Mapping Executive Committee (AMEC),[2] chaired by the Department of Interior and having 29 active members representing 19 federal

[1] http://agc.dnr.alaska.gov/?content=federal_coordination

[2] http://nationalmap.gov/alaska/ak_excomm.html

agencies/departments and the State of Alaska. The USGS has been instrumental in this effort, and the State is very appreciative for all of their work in the area.

In 2014, the SDMI graduated to become the Alaska Geospatial Council (AGC)[3] as prescribed in the Alaska Geospatial Strategic Plan and endorsed by Governor Sean Parnell and subsequently Governor Bill Walker. As a council, the AGC enjoys executive representation from interests including state, federal, and local government as well as tribal and university stakeholders. Additionally, several technical working groups comprised of an all-voluntary intergovernmental cadre of subject matter experts are now established and functional. The AGC is now addressing all mapping and geospatial concerns within Alaska whereas the SDMI addressed only imagery and elevation.

The USGS has been an integral partner in this effort, establishing the Alaska Mapping Initiative[4] in 2012 and providing the largest portion of funding for elevation data to date. As of 2015, elevation acquisitions for Alaska exceeded 63% and, in 2016, expectations are they will exceed 70%. This accomplishment is largely achieved through end-of-year unbudgeted funding, which has been coordinated by AMEC. The incoming elevation data is being used to produce modernized USGS topographic maps of Alaska. The data is also being used to dramatically update hydrological features such as surface water. The Federal Aviation Administration (FAA) is also eagerly awaiting the completed dataset to revise and modernize Alaska's aeronautical maps.

Elevation data is the most critical and expensive part of a map to acquire, but is useful for a very long time once acquired. The USGS manages the 3D Elevation Program (3DEP) in response to the increasing need for high-quality elevation data. In Alaska, the data collected is moderate resolution IfSAR while the remainder of the United States will utilize high resolution Light Detection And Ranging (LiDAR). In preparation for 3DEP, the USGS contracted with Dewberry Consulting (2011) to perform the National Enhanced Elevation Assessment (NEEA). A total of 602 mission-critical activities were identified that need significantly more accurate data than are currently available. The results of the assessment indicate enhanced elevation data have the potential to generate $13 billion in new benefits annually.[5]

IV. The Seven Framework Layers of Data

The National States Geographic Information Council has defined seven framework layers that form a foundation for a robust geospatial framework. These are elevation, imagery, hydrography, transportation, geodetic control, parcel boundaries and administrative boundaries. These layers provide information necessary to identify and predict spatial trends and patterns used to plan strategically for improved public health and safety, responsible and sustainable economic development and protection of the environment, and are considered essential to business in the rest of the US. However, accurate, detailed geospatial information is lacking for much of Alaska, inhibiting responsible development and resource conservation, delaying or preventing adequate

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[3] http://agc.dnr.alaska.gov/

[4] http://nationalmap.gov/alaska/index.html

[5] http://pubs.usgs.gov/fs/2012/3088/pdf/fs2012-3088.pdf

response to natural disasters and emergencies, and preventing effective measurement and monitoring of ecological processes. For Alaska, these foundational datasets need to be fully acquired and receive the maintenance, updates and stewardship required to ensure their continued relevance over time.

Modernized geospatial information acquired to date in Alaska supports the development of updated USGS topographic maps at a scale of 1:25,000, improving from previous 1:63,360 scale maps produced in the 1950's. These new digital maps are an essential tool for many, such as first responders such as wildland firefighters. Their situational awareness is enhanced with detailed, accurate and current elevation, imagery, hydrography and infrastructure understandings. Operational safety is improved for these responders through conducting indivisibility, view shed and line of sight analysis for the placement of communications repeaters to improve overall communication. Slope and aspect analysis are used for determining and mitigating the associated risk of wildfire for Hot Shot crews. Understanding slope and topographic effects allows prediction and mitigation of wildfire behavior and progression. Slope and aspect are also important for predetermination of helicopter landing and wildland fire personnel safe zones, and have an impact in assessing burned areas for recovery and potential stabilization needs. The best tools for situational awareness and spatial understanding are good, accurate, and updated geospatial layers available for use in Geographic Information System (GIS) and the derivative mapping products in a mobile, field-ready format for both operations and planning.

Elevation

Elevation is the most foundational spatial dataset. Other layers, such as imagery, are draped over elevation to provide three-dimensional models of the earth's surface. Elsewhere in the United States, elevation is being acquired at 1-meter or better resolution, often repeatedly to show changes over time. In Alaska many areas are only mapped to 60-meter resolution elevation data. This results in enormous errors and inaccuracies, which has proven fatal to pilots relying on accurate information to safely navigate in low visibility conditions. IfSAR technology is now being used to collect improved elevation data in Alaska at a 5-meter resolution.

Alaska's IfSAR elevation dataset is now approximately 63% complete (Anticipated to be over 70% after this summer field season), a testament to the highly effective collaborative efforts between the state of Alaska and partnering Federal agencies, especially USGS. This dataset allows for detailed 3-dimensional modeling of mountain ranges, drainage basins, and even glaciers. For IfSAR data, radar pulses are used to measure surface (tree tops) and bare earth elevations. Another product of IfSAR are images of the radar returns called orthorectified radar images, or ORIs, which are used for mapping soils and geology. The State is making this elevation data publically available for download or as a web service through the Division of Geological & Geophysical Surveys web site.

Imagery

Imagery is the second most basic dataset after elevation. From imagery, additional information such as hydrography, infrastructure including roads, structures, railways, pipelines and trails can be derived. For other states in the U.S., the National Agriculture Imagery Program provides high-resolution imagery every one to three years. In 2010 a joint state-federal imagery

project was launched in Alaska which resulted in 2.5-meter resolution imagery being available statewide in 2015, with the exception of 14,000 km^2 in the Aleutian Islands where nearly perpetual cloud cover prevented acquisition of cloud free images. Prior to this effort, 30-meter resolution digital images were the best available for many areas of the state. Details such as buildings, trails and other infrastructure such as drilling pads are now discernible, and coastlines, vegetation, and other natural features can be clearly and accurately mapped. A program for imagery refresh is needed for Alaska which provides up-to-date imagery throughout the state on a three to five year cycle.

Hydrography

The National Hydrography Dataset (NHD) is the standard national surface water mapping dataset. It is a comprehensive set of digital, geographic information systems (GIS) surface water data including common features such as lakes, streams, ice fields, coastlines, stream gages, dams and flow networks. The NHD is critical for meeting both short and long-term science, regulatory, cartographic, natural resource management and planning requirements. However, like other data sets, the NHD in Alaska needs to be updated.

While consistently mapped at 1:24,000 scale or better in the contiguous U.S., the NHD in Alaska was taken from 1950s-era USGS Historical Topographic Maps at a broad scale of 1:63,360. These historic data need extensive updates and improvements to meet modern mapping standards and applications. The dataset contains many errors including streams outside their channels, misrepresentations of flowlines, irregular stream density, disconnected streams and broken hydrologic networks, omission of existing streams and waterbodies, poor lake and waterbody perimeter mapping, and lack of stream/lake connectivity.

Updated hydrography is an essential dataset necessary to identify, monitor, and conserve key aquatic resources. It supports research and management; guides community, infrastructure, and industrial development; and aides in design and permitting for many other resource management decisions. Successful completion of hydrography updates requires coordination between local, state, federal and NGO partners, which is accomplished through the Alaska Hydrography Technical Working Group (AHTWG). In recent years, efforts by AHTWG and partners have updated the NHD to modern mapping standards in approximately 11% of Alaska with additional partial updates across more than 28% of the state. Although much work remains to complete hydrography updates statewide, many partners are making great strides in improving this important dataset. An estimated $10 million is needed to complete the NHD update for Alaska.

Geodetic Control

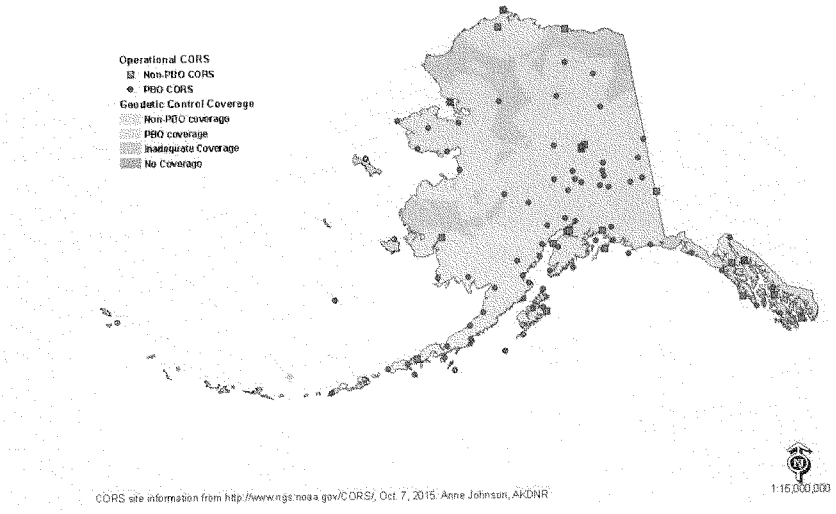
Geodetic control allows accurate horizontal and vertical positioning of overlaying datasets, including elevation. Geodetic control provides the framework for all positioning and mapping activities in Alaska, including the accurate horizontal and vertical positioning of geospatial datasets. The foundational elements of geodetic control are latitude, longitude, elevation, and their changes over time. Geodetic positions may be accessed via passive control (benchmarks) or via active GNSS/GPS-based control (in the form of Continuously Operating Reference Stations, or CORS) combined with an accurate model of the earth's gravity potential (provided by the GRAV-D project). Sound geodetic control contributes to informed decision-making and impacts a wide range of

important activities including mapping and charting, navigation, flood risk determination, transportation, land use and ecosystem management.

NOAA's National Geodetic Survey (NGS) launched the GRAV-D project (Gravity for the Redefinition of the American Vertical Datum) to correct problems in positioning across the nation, and most especially in Alaska. In Alaska, elevations can be incorrect on average 2 meters or 6.5 feet, and probably worse than that in mountainous regions. The GRAV-D project enables NGS to correct the elevations within the state by creating a new vertical reference surface, called a vertical datum. This new datum will be released in 2022. GRAV-D has performed an airborne gravity survey over nearly 60% of mainland Alaska since 2008, and surveys are about to commence now in Juneau and then later in western Alaska, out of Nome.

We expect Alaska to reap the benefits of more accurate heights in a variety of ways. More accurate elevations allow us to better measure and monitor coastal erosion, it provides the correct surface with which to refer IfSAR, LiDAR and photogrammetry products (instead of to GPS heights which do not relate to sea level). Better heights allow improved prediction of possible inundation from storm surges or tsunamis, which are a real risk along the western coast. Better heights along with better horizontal positions and digital elevation models from the Statewide Digital Mapping Initiative, will improve aviation safety.

The density of CORS used as control for GPS in Alaska is 1 for every 6,000 square miles of land, making Alaska 46th in the nation with regards to the density of our active geodetic control network. In addition, overlapping coverage from CORS in adjoining states is not available in Alaska as it is for other states. More than half of Alaska's CORS are run by the Plate Boundary Observatory Program, a part of the UNAVCO Earthscope project established through a 2013 National Science Foundation award. Funding to support these plate boundary observatory stations will run out in two years. Only 70% of the state currently has adequate CORS coverage, broadly defined here for the purpose of illustration as being within 250 km of three active CORS stations. If no funding is provided to maintain the UNAVCO CORS, adequate geodetic control coverage will not be available for 75% of the state's area. Alaska's Geospatial Framework Data Status is available at http://arcg.is/1Ua2N40.



V. Improved U.S. Topographical Maps

Prior to the start of the "U.S. Topo" map program in Alaska, statewide USGS topographic maps were 15-minute 1:63,360-scale printed maps produced nearly 50 years ago. Starting in 2013, the USGS National Geospatial Program began creating US Topo maps in Alaska, providing a new map series for the state. The new 7.5-minute digital maps are created at 1:25,000 map scale, and show greatly increased topographic detail when compared to the older maps. The term "US Topo" refers specifically to quadrangle topographic maps published in 2009 and later, reflecting the 2009 start of the National US Topo project. Up-to-date digital map data for US Topo maps is fed from The National Map, and includes data that is refreshed such as imagery, transportation, geographic names, topographic contours, boundaries, hydrography, and structures, plus additional layers such as the Public Land Survey System (PLSS) and United States National Grid (USNG).

When completed, over 11,000 US Topo maps will be created to cover all of Alaska at a 1:25,000 map scale. Maps can only be created where satellite imagery and highly detailed elevation data exist. The USGS is coordinating with the State of Alaska and multiple Federal agencies to acquire required data through partnerships such as the Alaska Statewide Digital Mapping Initiative and the Alaska Mapping Executive Committee. This multi-year mapping initiative vastly improves the base topographic maps for the state, and the underlying digital map data benefits high priority applications in safety, planning, research and resource management.

VI. Geologic and Geophysical Surveys

Alaska is the nation's largest producer of silver and zinc, and second largest producer of lead and gold. Alaska is blessed with vast mineral potential. Based on USGS estimates, if Alaska was a country, it would be in the top 10 for:

- Coal (17% of the world's coal; 2nd most in the world)
- Copper (3% of the world's copper; 5th most in the world)
- Lead (3% of the world's lead; 8th most in the world)
- Gold: (7% of the world's gold; 5th most in the world)
- Zinc: (4% of the world's zinc; 6th most in the world)
- Silver (1% of the world's silver; 9th most in the world)

In addition, Alaska has more than 70 known occurrences of rare earth elements (REEs) and multiple occurrences of other strategic and critical minerals. For example, Alaska has two exciting projects that this Committee should be aware of. The Graphite-1 deposit is the largest graphite deposit in the US, and is currently in the pre-permitting phase. There has not been any graphite mined in the US since 1991. The Bokan Mountain project is also in the pre-permitting phase, and, contains significant amounts of heavy rare earth elements. We expect that continued exploration will lead to additional discoveries, and welcome federal initiatives to stimulate this exploration.

Industry experts routinely rank Alaska in the top three jurisdictions globally in terms of pure mineral potential. The state is known for its world-class mines such as Red Dog, Greens Creek and Pogo, as well as many huge undeveloped mineral deposits. The state is underexplored, and explorers recognize the great potential present in a region that is underexplored and is so richly endowed in mineral resources. However, Alaska does not rate so highly in the same surveys in terms of the quality and quantity of geologic data available on the states mineral resources. Alaska routinely ranks in the middle tiers in terms of geologic, geophysical and geochemical data availability. This reflects the size of the state, and the scale of efforts to date.

Alaska is a young state, having entered the union on January 3, 1959. Alaska is also the largest state in the union, equal in area to about one fifth of the contiguous states. Alaska's geological survey has a staff of 39 dedicated geoscientists compared to a combined staff of 2,000 in the contiguous states. Based on area alone, Alaska's geological survey should have a staff of roughly 400, or ten times its current staff. In today's budget climate it seems unlikely that our geological survey will grow to have a staff of 400, but this illustrates that the various tasks will take a considerable length of time to accomplish with current staffing and funding levels. This inevitably leads to slow progress being made on the many fronts calling for additional information.

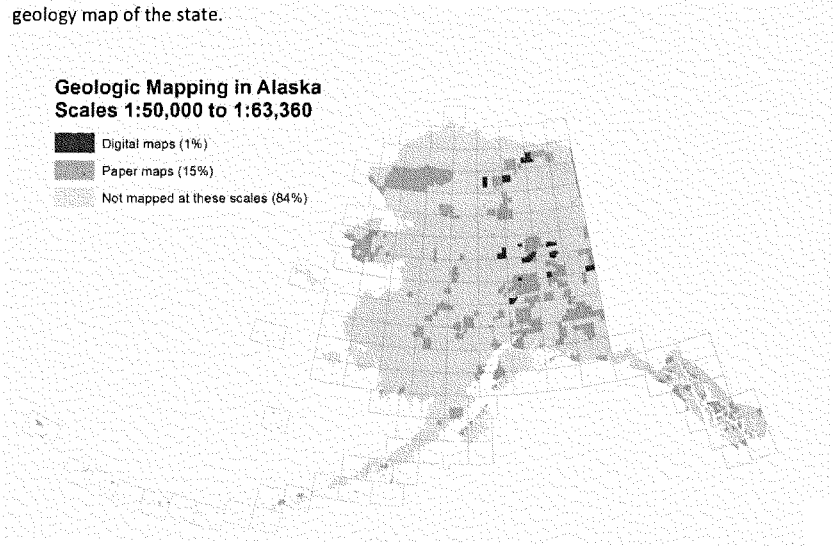
There are three key areas of basic information that, if improved, would greatly enhance the Alaska's attractiveness to mineral exploration companies. This involves completing geologic mapping, airborne geophysical, and modern geochemical surveys in areas that are both prospective for and open to mineral development. In addition, Alaskan communities urgently need additional geologic hazard mapping efforts to adequately prepare Alaskan for the many existing hazards and the changes that will results from a warming climate, shrinking sea ice and permafrost degradation.

Geologic Mapping

Geologic mapping is a foundational informational layer, upon which many additional layers of information are built. These secondary layers include soil, landslide, mineral occurrence, geochemistry, landslide, fault location and groundwater maps. Quality geologic maps are necessary before these additional layers can be constructed, and for any activity that involves working in or on the earth.

The National Cooperative Geologic Mapping Program (STATEMAP) is an excellent example of the cooperative funding and leveraging of state and federal dollars to conduct geologic mapping. This national program has been a cornerstone of cooperation between State Geologic Surveys and the USGS and has been supported by Alaska. Since inception in 1992, this program has produced approximately 4,000 geologic maps across the nation, and mapped over 500,000 square miles. STATEMAP leverages federal funding by requiring states to match federal grant dollars 1:1. This year $5.5 million, or roughly 20% of this programs funding was made available to the states. However, this year, as in most years, the states left a roughly equal amount of funding on the table. The State supports expanded funding to the authorized level for the STATEMAP portion of this program, to further the production of geologic maps and to fully leverage the available state funding.

Statewide geologic mapping at a scale suitable for mineral or energy exploration activities has been completed over 17% of the state. While not sounding very substantial, this is equal in area to the state of Arizona, but the remaining area to be mapped is roughly equal to the combined area of California, Oregon, Washington and Idaho. Unfortunately, at the current rate of geologic mapping, this will take over 400 years (and possibly over 1000 years) to complete. Completing a geologic map of Alaska is not an insurmountable task, as the remaining area is roughly equal to the combined area mapped under the STATEMAP portion of the National Cooperative Geological Mapping Program over the last 23 years. The State of Alaska has a long-standing productive relationship with various program areas within the USGS, and staff from both organizations readily participate in ongoing joint mapping activities. We hope these relationships continue to strengthen going forward. Geologists in Alaska were thrilled by the 2016 USGS publication of a statewide digital geology map, and the State supports continued mapping to ultimately complete a more detailed geology map of the state.

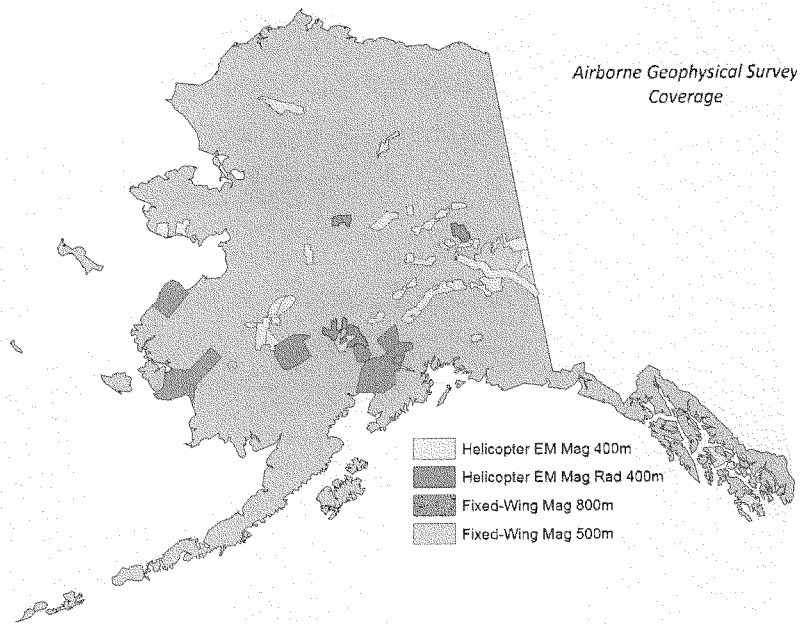


In light of a major recent oil discovery on Alaska's North Slope, geologic mapping and additional geologic data is required to allow the USGS to update the resource estimates for technically recoverable undiscovered conventional oil resources on Alaska's North Slope. In addition, tight sand plays associated with this recent discovery may also contain significant oil resources and should be included in resource estimates. The state supports funding the proposed three year collaborative State-USGS program at the requested $1.6 million per year.

Another key federal program that helps to archive samples and other forms of legacy geologic and geophysical data is the National Geological and Geophysical Data Preservation Program. A tremendous amount of valuable new information was acquired at a very low cost in Alaska by sampling archived materials from both the State and USGS collections. It is imperative that this cost-effective program is maintained and sufficiently funded to protect at-risk geologic data and samples.

Airborne Geophysical Surveys

Airborne geophysical surveys collect data on the magnetic, electromagnetic and radiometric properties of the various rock units on the earth's surface. These surveys are of great use in support of geologic mapping, and resource development, as they can help map the rock units beneath soil layers. Data is usually collected by either helicopter or fixed-wing aircraft at low altitudes, with variable additions of electromagnetic and radiometric surveys. Airborne geophysical surveys have been completed over only about 4% of the state. These have been principally funded by the State of Alaska, the Bureau of Land Management and the USGS, with support from industry and Alaska



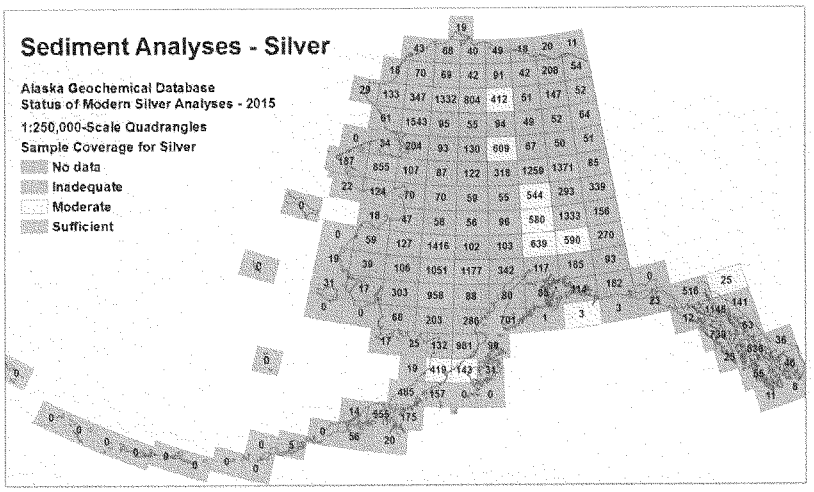
Native Claims Settlement Act (ANCSA) corporations.

All of these data are made available through the State of Alaska Division of Geological & Geophysical Surveys web site. It is widely recognized that these surveys provide incredibly valuable information in support of geologic mapping and mineral resource discovery. State and federally funded airborne geophysical surveys in combination with geologic mapping have assisted in numerous mineral discoveries in Alaska, and will continue in the future. Completing an airborne fixed-wing geophysical survey over areas of high mineral potential would quite possibly pay huge dividends in terms of mineral discoveries and improved geologic understanding.

The State's geological survey has a close collaborative relationship with the USGS and anticipates flying an airborne magnetic survey for the USGS in Eastern Alaska near the Canadian border in 2016. Continuing to collect data over areas of high mineral potential, is a priority for the state and we look forward to continuing collaborations with the USGS. To complete moderately detailed, fixed-wing airborne magnetic surveys over mineral-rich portions of the state is achievable in a reasonable time-frame (20 years) with expenditures of roughly $1.5 million per year. The State supports continued funding for these programs within the USGS.

Hyperspectral surveys collect data on light reflecting from vegetation or soil surfaces. These data provide information on minerals present in the soil and exposed rock, as well as vegetation types. This data helps geologic mapping and mineral development, and has numerous applications in the areas of agriculture, forestry and ecology. These surveys have barely begun in Alaska, with far less than 1% surveyed, yet they would offer many benefits to help geologic mapping, mineral exploration, as well as forestry, land cover and ecological applications from determination of mineral content, vegetation type and changing patterns of vegetation with a changing climate. The University of Alaska has equipment and personnel in place to conduct such surveys in cooperation with the USGS, and the state geological survey. Due to the multiple benefits from such surveys the State strongly supports a statewide data collection, and construction of a web-based portal for data distribution.

Geochemical Surveys



The third area of critical need for mineral exploration is sufficient regional modern stream sediment and soil geochemical information. Data such as these provide direct chemical evidence to explorers of their target elements being present in a particular area. The information is also of great use for environmental and land use planning.

Sufficient, modern stream sediment analyses are only available in 15% of the state at a regional scale of 1:250,000 and about 1% of the state is covered at a detailed scale of 1:63,360. In many areas the samples from the original collections remain in sample archives and only funding for modern analyses and data compilation is required. It is estimated that to complete analyses on existing samples to bring the entire state to an adequate regional data density and would costs $3.4 million.

Soil geochemical maps of the continuous states were recently produced by the USGS. These are extremely useful products. An Alaska set would be similarly beneficial, and form a portion of a geochemical atlas for the state along with upgraded stream sediment analyses. The State supports funding for collection and analyses of soils for the generation of a series of soil geochemistry maps for Alaska.

Geologic Hazards

Alaska has all of the kinds of geologic hazards present in the rest of the nation, with additional hazards from 52 active volcanoes. Alaska is the most seismically active state with a subduction zone over 2,000 miles long that has spawned 3 of the 10 largest earthquakes ever recorded, and contains geologic hazards associated with permafrost and sea-ice.

Much of the central, northern and western parts of the state have landforms, ground and surface water patters and ecological systems controlled by the distribution of permafrost, and in

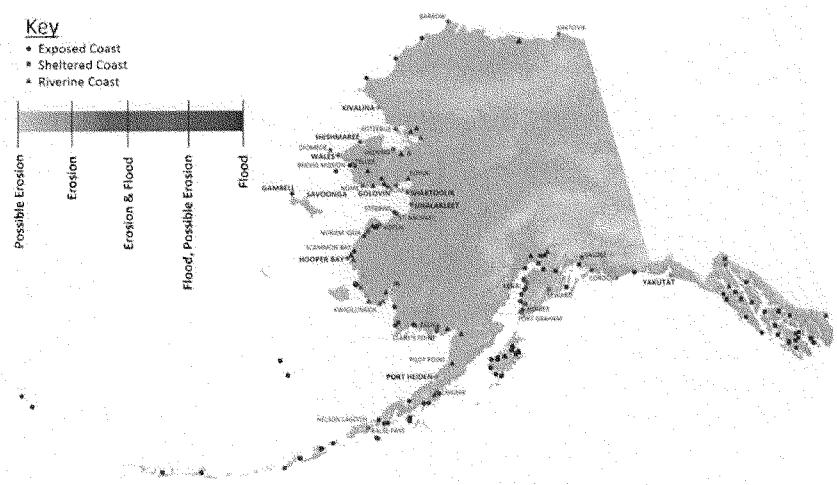
many cases the land is only stable because it is frozen. Thaw out the permafrost and all aspects of the system influenced by the presence of permafrost change to reflect this new environment. Surface and groundwater patterns change, lakes either drain, or reform elsewhere, hydrologic patterns change causing vegetation and ecological changes that affect bird and mammal populations. All of these affect the human population. Understanding changes to the permafrost is crucial to understand potential impacts of climate change on all aspects of life in Alaska.

The USGS Alaska Climate Science Center works closely with many organizations researching these issues, and Alaska strongly supports expanding funding for the Climate Science Center research. Alaska supports expanding these research efforts so we can be ahead of these changes and adapt to them proactively.

The level of completion of geologic hazard mapping in Alaska is, for the majority of hazards, far behind that of geologic mapping. Some key areas in need of addition mapping are coastal erosion, coastal flooding, avalanche and landslide susceptibility mapping. All of these have regional or statewide significance and the lack of basic information claims lives with unfortunate frequency.

The USGS has mapped coastlines along Alaska's northern shore and a portion of its western shore. The State of Alaska's Division of Geological and Geophysical Surveys has also mapped shoreline positions along sections of coast and near communities. In order to conduct shoreline position change, additional iterations need mapping along much of the north and west coast. This will allow estimates of erosion rates around communities, with the benefit of determining which communities are stable, and which will need relocation, and provide estimates of when. The cost to complete this program is estimated at $0.75 million.

Shrinking sea ice, and ice that either forms later, or breaks up earlier, leaves coastal communities vulnerable to fall and spring storms, with associated erosion, sea ice inundation, and flooding. Most of Alaskan coastal communities do not have sufficient information on tides, water level, community elevation data and wave run up to accurately predict what will happen during any particular storm. The State of Alaska is working collaboratively with the USGS Climate Science



Center, the Land Conservation Cooperatives, the National Oceanic and Atmospheric Administration (NOAA), the Alaska Ocean Observing System and the University of Alaska to conduct the research necessary to generate upgraded storm surge models and community inundation maps. Much additional work remains before we can predict with reasonable accuracy the effects of a storm at the community level, and the State of Alaska strongly supports increased funding for these activities.

Landslides claimed the lives of three Alaskans last year. The warming climate and changing precipitation patterns indicate this may unfortunately become a more common event. As permafrost melts, slopes will become unstable. Alaska does not have either a statewide, or community level series of maps depicting areas with known landslides, or areas at risk for future landslide. This is a crucial dataset that would save lives by improving community planning through landslide avoidance. Completion of a first-pass landslide mapping assessment for communities and infrastructure corridors is estimated to cost $5 million. The recently introduced legislation entitled a National Landslide Loss Reduction Act would greatly help with these efforts. Alaska strongly supports passage and full funding of this vital piece of legislation.

Changing precipitation patters, and climate change models suggest avalanches patterns will change across the state. Alaska has no statewide avalanche susceptibility maps, and annually avalanches claim lives, and threaten homes and communities. A statewide assessment could be quickly conducted using the new IFSAR data being collected, and would provide communities and transportation planners with a rapid first look at areas susceptible to avalanches. This would be a huge first-step in saving lives and provide groundwork for more rigorous analyses of higher-risk areas, and is estimated to cost $0.5 million.

Potentially destructive earthquakes occur in Alaska on average every two months (greater than magnitude 6), the most recent being the 2015 Iniskin (magnitude 7.1) that ruptured gas lines, burned several homes and damaged roads. Alaska is the most seismically active state, with all of the earthquakes greater than magnitude 8 in the last 300 years, and 71% of the earthquakes greater than magnitude 7 in the United States. Yet Alaska's earthquake monitoring system lags those in the rest of the nation. The Alaska monitoring network falls far short of the Advanced National Seismic Standards (ANSS). Under the USArray portion of the National Science Foundation's Earthscope project, 261 seismic stations will be deployed in Alaska through 2018. Currently there are no plans to adopt a portion of the USArray into Alaska's seismic monitoring network. There is a limited window of opportunity to develop and implement a strategy to retain a subset of these stations before they are removed in 2018/2019. If integrated into the Alaska seismic monitoring network, these could form the backbone for an earthquake early warning system, and bring Alaska far closer to meeting ANSS. The USGS has formulated a working group to define the cost-benefit of such an adoption and the State is highly supportive of this effort, and steps that lead to improved seismic monitoring, and development of an earthquake early warning system. Initial estimates are that adoption of 80 of these stations would cost $2.5 to $3 million a year to maintain.

Along with earthquake monitoring, the State of Alaska Division of Geological & Geophysical Surveys, in collaboration with the USGS, NOAA and the University of Alaska, Fairbanks has a well-established and ongoing tsunami inundation mapping program that is sequentially mapping a prioritized list of coastal communities. To date thirteen communities have been mapped, leaving 10 communities in process, and as many as another 27 to be evaluated. This is a high-value impactful

program of great value to Alaska communities. Additional local detailed topographic and bathymetric information would help these analyses. Completion of each community tsunami evaluation costs roughly $250,000.

VII. Conclusion

The above cost-sharing table (Table 1) illustrates past performance for the funding and acquisition of the IfSAR elevation dataset, which is foundational to all map layers related to topographic mapping. Other framework datasets are also needed. This table clearly demonstrates USGS as a leader in funding and speaks to current USGS commitment to an accurate map of Alaska.

The State of Alaska greatly appreciates the leadership role of DOI and especially USGS in the AMEC. We will continue to work diligently with AMEC to leverage our diminishing state funding with funding from our other federal partners. We believe that other federal agencies will have a definite benefit from a more accurate map: the Federal Aviation Administration is a primary beneficiary and user of elevation data, which will improve aviation safety. The Federal Emergency Management Agency and the U.S. Army Corps of Engineers both have an interest in better mapping to address coastal and inland flooding and erosion.

The State of Alaska is currently in a severe budgetary crisis and it is unlikely Alaska will be able to contribute additional funding beyond 2016's contribution but having said that I believe Alaska has demonstrated a good faith effort to advance our shared mapping initiative. Federal agencies need to proactively program their budgets to meet this mapping need. This need will not be met simply because the elevation data has been finalized. Geodetic control, orthoimagery, transportation, hydrography, cadastral and administrative boundaries are all fundamental framework layers. Soils mapping and vegetation also needs to be addressed as does geology, hazards and etc. In short the State of Alaska is deeply appreciative of the on-going efforts to modernize the Alaska map. The State welcomes AMEC's and USGS' efforts to incentivize a more proactive budgeting process across all affected departments and beneficiaries.

Thank you very much for the opportunity to provide my testimony here today. The USGS has been an excellent partner for the State of Alaska in our efforts to better map and understand the natural resources of our great state.

The CHAIRMAN. Mr. Fogels, thank you very much. It is always a little bit astonishing to learn how far we have to go; 400 years, I don't know if we can wait.

Let's go to Dr. Leahy, welcome.

STATEMENT OF DR. P. PATRICK LEAHY, EXECUTIVE DIRECTOR, AMERICAN GEOSCIENCES INSTITUTE

Dr. LEAHY. Thank you very much, Chairman Murkowski and Ranking Member Cantwell. It really is a pleasure to be here and to have this opportunity to provide remarks on behalf of the American Geosciences Institute on the role and the importance of the U.S. Geological Survey to the geoscience community and to the nation.

As you know, my name is Pat Leahy, and I'm the Executive Director of the American Geosciences Institute.

Let me tell you a little bit about AGI, which is the acronym for the American Geosciences Institute. It's sort of a unique organization in that we're a non-profit federation of 51 geoscientific associations that represent approximately a quarter of a million U.S. Earth scientists. Our member societies represent the full breadth of the geosciences, everything from petroleum geologists to geophysicists, medical geologists, geographers, you name it.

AGI provides information services to geoscientists, serves as the voice of shared interest in our profession, plays a major role in strengthening geoscience education and strives to increase public awareness of the vital role the geosciences play in society's use of resources, resilience to natural hazards and health of the environment.

This year we published a document that was distributed earlier called, "Geoscience for America's Critical Needs: An Invitation to a National Policy Dialogue." This is a collaborative document between AGI and its 51 member societies which outlines the major geoscience issues facing the nation. The document attempts to begin a national dialogue between decision-makers and geoscientists on topics ranging from ensuring sufficient supplies of clean water to developing energy to power the nation, and it provides a high level overview of all geoscience topics including water, energy, natural hazards, soils, mineral resources, oceans and coasts, climate change, waste disposal and workforce and education.

In the mineral resources arena, the priorities that were identified include assessing the nature and distribution of domestic mineral resources; quantifying domestic and global supply of, demand for and the flow of minerals; supporting socially, economically and environmentally responsible domestic mineral production; fostering innovative solutions to lessen the environmental impact of production; and, use of minerals.

In the natural hazards arena, geoscientists help communities identify, mitigate, prepare for, respond to and recover from natural disasters. Some of the priorities include encouraging basic and applied research to strengthen community resilience, prioritizing natural hazard monitoring, support communication of risk and vulnerabilities associated with hazards to the public and mitigate the hazard impacts on people, buildings and infrastructure.

Clearly, USGS science and research contributes to the advancement of all of these community-wide priorities. Now much has been said about the importance of the USGS. I don't intend to go over that again. It's a critical agency in terms of the Earth sciences. I do want to point out a couple things.

First of all, assessing the nature and distribution of our domestic supplies of mineral resources is a critical component. Just this year, highlighting the importance of monitoring data collection, USGS released on April 1st, a report announced that it will be carrying out an airborne geophysical survey as part of mapping the upper peninsula in Michigan. This investment is providing publicly available information that can be used for decision-making by a wide array of individuals from industry to the public.

The other thing I want to mention now is that the organization, as someone mentioned, was founded in 1879. During that period of time it has developed a repository of irreplaceable geoscientific information that does not go out of date and cannot be replicated. Its store of more than a century of geoscience records including field notes, maps, samples, drill cores, publications, data sets, satellite and topographic data is used constantly by other researchers and by businesses large and small. Clearly, the USGS is a very, very important organization.

I'll close by saying, on behalf of the geoscience community, I urge you to support the critical work of the USGS and to strengthen its capability to carry out its geoscience research, monitoring, data collection, analysis and to expand the distribution of its information. And those are topics we discussed earlier at the opening remarks.

Thank you for the opportunity to testify today, and I would be pleased to answer any questions you may have.

[The prepared statement of Dr. Leahy follows:]

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Prepared Testimony of
Dr. P. Patrick Leahy
Executive Director
American Geosciences Institute

Oversight Hearing of the U.S. Geological Survey
Senate Committee on Energy and Natural Resources
April 7, 2016

Chairman Murkowski, Ranking Member Cantwell, and Members of the Committee:

Thank you for the opportunity to provide remarks on behalf of the American Geosciences Institute (AGI) on the role and importance of the U.S. Geological Survey (USGS) to the geoscience community and to the nation. My name is Pat Leahy and I am the Executive Director of the American Geosciences Institute.

AGI is a nonprofit federation of 51 geoscientific and professional associations that represent approximately 250,000 geologists, geophysicists, and other Earth scientists. Our member societies represent the full breadth of the geosciences. Geoscientists study all aspects of the Earth system, including resource exploration and development, environmental geology, and natural hazards, and they work at all levels in industry, academia, government, and K-12 education. Founded in 1948, AGI provides information services to geoscientists, serves as a voice of shared interests in our profession, plays a major role in strengthening geoscience education, and strives to increase public awareness of the vital role the geosciences play in society's use of resources, resilience to natural hazards, and the health of the environment.

The USGS is the premier federal geoscience agency and it is recognized across the world as a leader in geoscience research and data collection. It has unique responsibility within the federal system for understanding the planet on which we live. It is impossible to overstate the importance of understanding the nature and behavior of the Earth, which provides the mineral, water, and energy resources on which life and the economy depend. The Earth also determines the substrate on which all living things exist, and it can threaten lives and infrastructure through natural hazards.

Since its inception in 1879, USGS has provided reliable, impartial, timely, and consistent geoscience information in service to the nation. Federal agencies fill a unique role in collecting, preserving, analyzing, and providing access to information of national importance and extent. USGS has fulfilled this role for the geosciences in the face of severe budget constraints. The data that USGS collects is used not only by governments at the federal, state, and local levels, but also by industry and business, non-governmental organizations, academia, and perhaps most importantly, the general public. USGS data and information underpin decision making and investment in both the public and private sectors.

USGS information is notable for its spatial extent – it covers the nation; for its temporal extent – in long-term collection of such things as stream flow, water quality, and mineral production

information; its high standards of quality control that ensure accurate and reliable information; and its continuity of effort – trends in the Earth system can only be identified through constant and stable monitoring and analysis, and must be based on long-term, consistent, accurate datasets.

USGS strives to be aware of how its information can best serve the nation, whether that be in the arena of national security, economic prosperity, environmental quality, or health and safety, and to ensure that its products meet the greatest needs. Taking water as an example, USGS monitors and critically assesses the quantity, distribution, and quality of the nation's surface water and groundwater resources. To ensure that the information is relevant to end users, USGS must critically assess this information in the context of agriculture, energy, environment, ecosystem, and other uses for water. In a similar way, USGS is the world's leading source of information on earthquake activity. The agency collects fundamental data on earthquakes, but to ensure that these data are useful, accessible, and understandable to the communities that most need the information, USGS has developed products and programs that put earthquake information in a broader context and thus the information is likely to provide much greater societal benefit and return on investment.

USGS is a repository of irreplaceable geoscience information that does not go out of date and cannot be replicated. Its store of more than a century of geoscience records, including field notes and maps, geological samples, drillcore, publications, geochemical and geophysical datasets, topographic and satellite data, is used constantly by academics and businesses large and small. These records are an important part of the geoscience infrastructure and are often of particular interest to the environmental and exploration sectors. Preserving these records and making them publically accessible saves needless expense in duplicating studies and makes historical information available for reinterpretation. The USGS Library serves as the foundational library for the geosciences in the country. Its extensive collections, which are shared through inter-library loans, make the global wealth of geoscience research available to a much wider audience than just USGS personnel. Maintaining the USGS Library and other USGS data repositories is an extremely valuable service to the geoscience community.

USGS's functions have evolved as the needs of the nation have changed and in response to our improved understanding of the complex and interconnected elements of the Earth system. The initial charge to the USGS, as listed in the Organic Act, relates to "classification of the public lands, and examination of the geological structure, mineral resources, and products of the national domain." USGS has primary responsibility for understanding the geological structure of the nation, which includes all facets of the subsurface and the geoscientific aspects of interactions between the Earth and human systems. These discipline-specific tasks are, and should be, at the core of the USGS's geoscience activities. Nevertheless, the solid earth, oceans, and atmosphere are all intimately linked to each other and to human existence and human activities. A firm understanding of each element in this complex system, plus a clear understanding of the interactions between each element, is the cornerstone of informed decision making. USGS must be prepared to address the key issues in its jurisdiction, both from the perspective of the geosciences and also from the perspective of the role of the geosciences in Earth-human interactions.

In 2015, AGI in collaboration with its 51 member societies, published *"Geoscience for America's Critical Needs: Invitation to a National Policy Dialogue,"* which outlines the major geoscience issues facing the nation. This document reflects, to the extent possible, a consensus community view on priorities for the geosciences. I will highlight the important contribution that USGS makes to addressing national priorities identified for just two of the nine major headings in the booklet, Mineral Resources and Natural Hazards, both of which are under the jurisdiction of this Committee.

For Mineral Resources, the main goal is to support a secure supply of minerals and the community identified these priorities (shown in bold):

1. **Assess the nature and distribution of domestic mineral resources.** This is one of USGS's longest established functions, going back to its establishment in 1879, and the Survey continues to study our mineral resources. Just last week, on April 1, USGS announced that it will be carrying out an airborne geophysical survey of part of the Upper Peninsula of Michigan. This investment in providing publicly available information will support informed decision making by industry, regulators, and the public.
2. **Quantify domestic and global supply of, demand for, and flow of minerals.** The USGS National Minerals Information Center is the sole source of this information, which is used widely, including by the Central Intelligence Agency, the U.S. Treasury, the Departments of State, Defense, and Commerce, and the financial, insurance, and investment sectors, in addition to manufacturers and the minerals industry.
3. **Support socially, economically, and environmentally responsible domestic mineral production.** Extensive geochemical, geophysical, and geological studies by USGS provide information that helps to identify prospective areas and the environmental challenges and solutions that may be associated with developing mineral resources.
4. **Foster innovative solutions to lessen the environmental impact of mining and mineral use.** USGS brings unique expertise to full life-cycle studies of mineral products, from exploration to extraction to disposal of the final products, enabling industry and regulators to minimize the impacts of development and disposal.

Under the heading of Natural Hazards, the community identified four priorities:

1. **Encourage basic and applied research to strengthen community resilience.** USGS carries out topographic and geologic mapping and monitoring, undertakes fundamental research, and develops methodologies for assessing a wide range of natural hazards. This research and data collection provides the essential information needed to identify hazards and risk to communities and infrastructure, and to formulate plans to strengthen community resilience. USGS works closely with state agencies, particularly state geological surveys, to compile geological information under the National Cooperative Geologic Mapping Act, and to share specialized expertise with those working closest to the sites of natural hazards.
2. **Prioritize natural hazard monitoring.** Earthquake monitoring is one of USGS's best-known monitoring programs. The National Earthquake Information Center determines the location and size of all significant earthquakes worldwide and immediately shares this information with national and international agencies, scientists, critical facilities, and the public. USGS has many other monitoring programs related to flooding, landslides, volcanic eruptions, and other hazards. First responders, planners, and the public all rely on this information and on USGS analysis and research on natural hazards.

3. **Support communication of the risks and vulnerabilities associated with natural hazards to the public.** The SAFRR (Science Applications for Risk Reductions) Project in the Natural Hazards Mission Area is one example of how USGS is addressing the need to communicate risk. SAFRR focuses on building partnerships to improve the use of USGS natural hazards information and on developing products that meet the needs of users. USGS supports Great ShakeOut Drills throughout the country, which are an effective and popular way to teach people how to react in case of a major earthquake.
4. **Mitigate hazard impacts on people, buildings, and infrastructure.** USGS works with other agencies including the Federal Emergency Management Agency, the National Institute of Standards and Technology, and state and local emergency managers to link scientific understanding of hazards to actions that reduce the potential impact of those hazards.

USGS's critical mass of geoscience expertise, skills, and technical infrastructure makes it the most important geoscience institution in the country. It has a long and well deserved reputation for scientific excellence and the highest standards of data collection and preservation. It is the one federal agency charged with the study of the Earth, its resources, and its complex system. Unfortunately, funding for geoscience activities in USGS has not kept pace with the costs of maintaining its skilled workforce and the laboratory, information technology, and data curation facilities that are essential parts of the nation's research infrastructure.

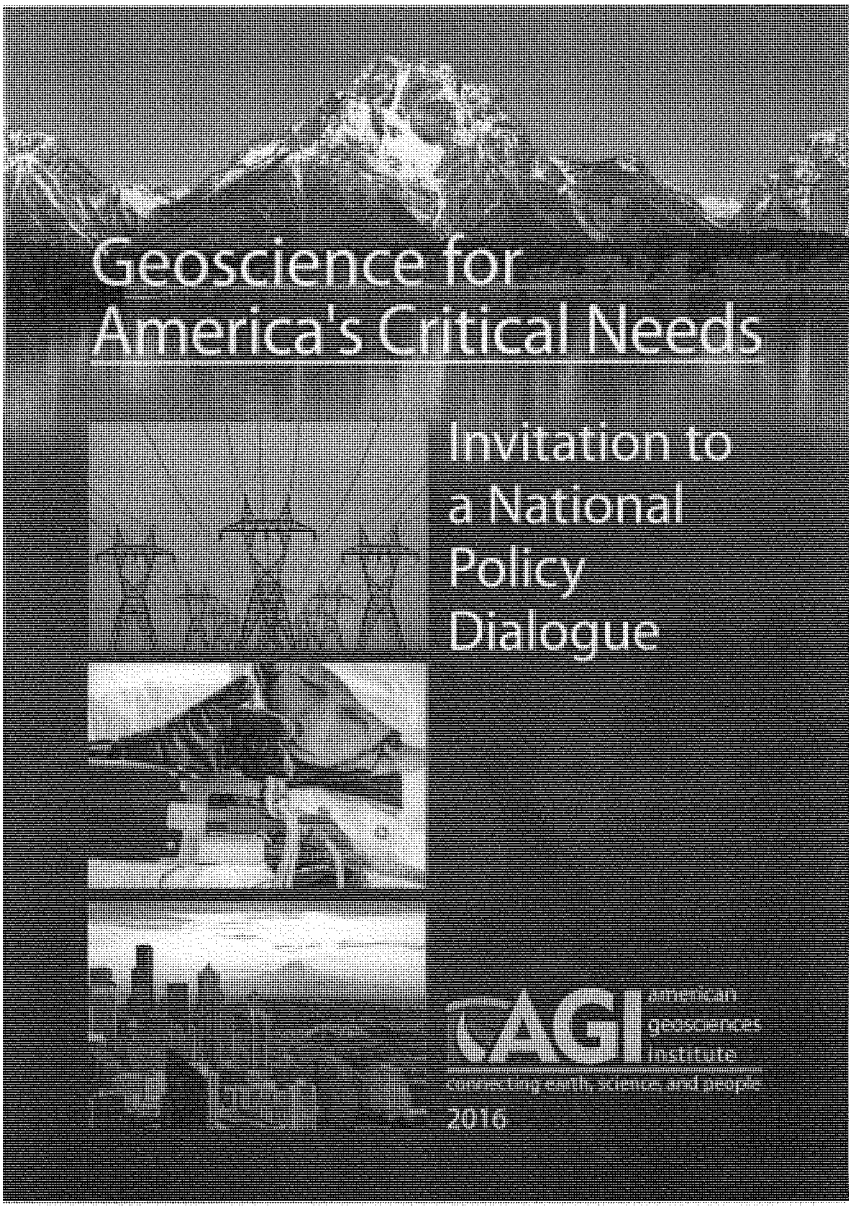
We are at a point where it is more important than ever to understand the interactions between Earth's natural system and human activities, where land-use decision should be based on sound information, and where the availability and flow of domestic and global mineral, energy, and water resources can have significant effects on national security and prosperity. USGS is a key agency that provides geoscience information that is not duplicated in any other part of the federal government.

On behalf of the geoscience community, I urge you to support the critical work of the USGS and to strengthen its capability to carry out geoscience research, monitoring, data collection, and analysis, and to expand the distribution of its information in formats that meet the needs of the users of USGS information.

Thank you for the opportunity to testify today and I would be pleased to answer any questions you may have.

Please visit the AGI website at www.americangeosciences.org, or contact Maeve Boland, Director of Geoscience Policy, at 703-379-2480, mboland@agiweb.org, if you would like further information.

Geoscience for America's Critical Needs: Invitation to a National Policy Dialogue can be accessed at www.americangeosciences.org/policy/critical-needs.


Geoscience for
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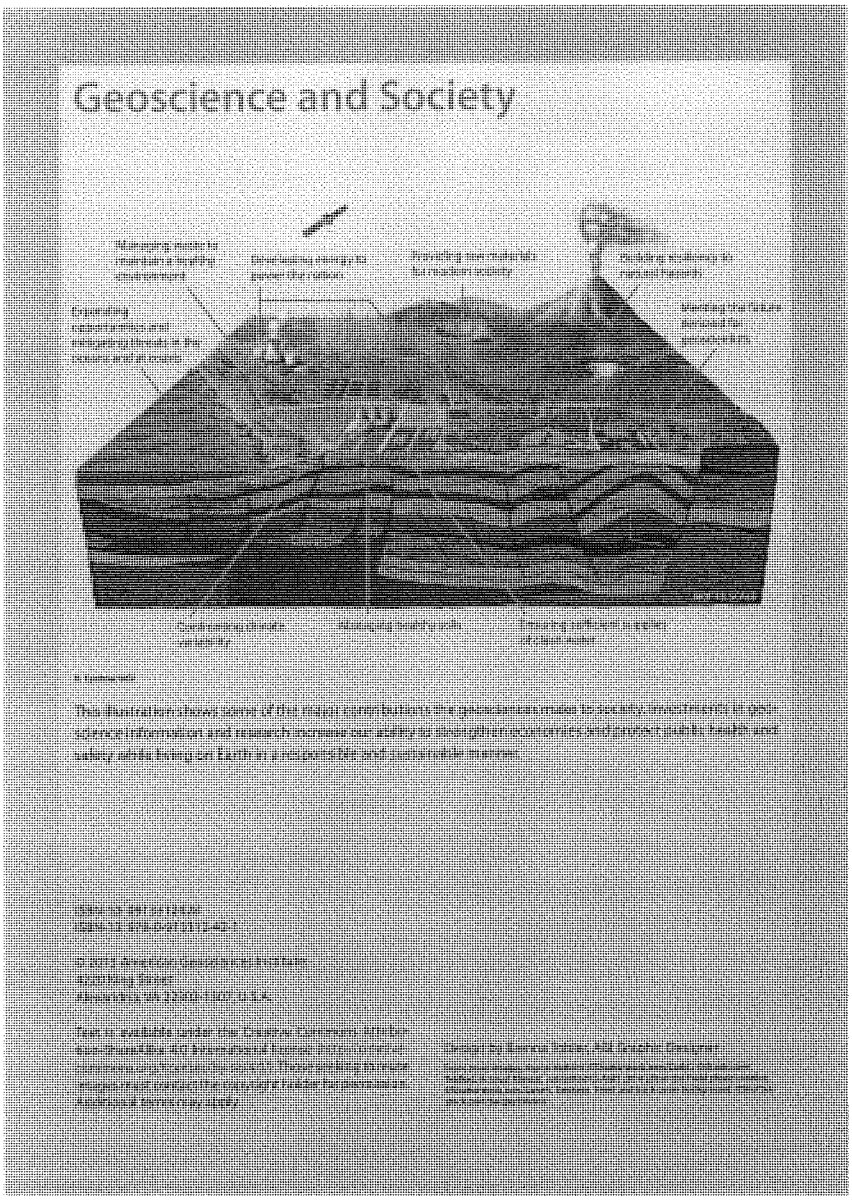
Geoscience and Society

Invitation to a Dialogue

The geoscience community has the knowledge, experience, and ingenuity to address a wide range of societal needs. We study Earth's systems, the complex geologic, marine, atmospheric, and hydrologic processes that sustain life and the economy. Geoscience expertise allows us to better understand and predict the interactions between people and Earth's systems; such expertise is essential to developing solutions to critical economic, environmental, health, and safety challenges.

As you develop policy, we in the geoscience community offer to share our scientific expertise and perspectives on topics such as:

- Ensuring sufficient supplies of clean water
- Developing energy to power the nation
- Building resiliency to natural hazards
- Managing healthy soils
- Providing raw materials for modern society
- Expanding opportunities and mitigating threats in the ocean and at sea
- Confronting climate variability
- Managing waste to maintain a healthy environment
- Meeting the future demand for geoscientists

The American Geosciences Institute (AGI) connects Earth, science, and people by serving as a unifying voice for the geoscience community. On behalf of the geoscientists represented by the 51 member societies of AGI, we invite you to join us in a dialogue on how to achieve our shared research in meeting American critical needs.

This document outlines high-level actions to address major policy issues where the geosciences play a significant role. We urge you to draw on the expertise of the geoscience community when crafting your solutions. Together, we can achieve our national goals: a strong economy, thriving and resilient communities, and a healthy environment.

Sincerely,

Dr. Richard C. Aster
Chair, Geoscience & Critical Needs Working Group
Department of Geosciences
Warner College of Natural Resources
Colorado State University

Dr. F. Patrick Leahy
AGI Executive Director

Geoscience & Critical Needs Working Group members: Richard Aster (Chair), Edith Allison, Jennifer Bauer, Kathleen Eden, George Hornberger, Leonard Konikow, Jonathan C. Price, Jeff Rubin, Michael Young

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american geosciences institute

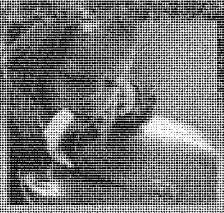
connecting earth, science, and people

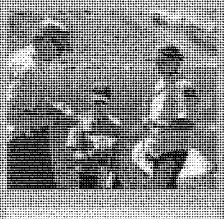
Water

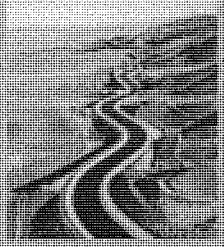
Ensuring Sufficient Supplies of Clean Water

Clean water is fundamental to life and is essential for economic prosperity. However, the long-term security of water supplies is threatened by overuse, pollution, and climatic variability. Long-term planning and water management are critical for agriculture, electricity generation, fisheries, industry, transportation, recreation, municipal supplies, and healthy ecosystems.

Geoscientists provide the expertise necessary for effective water resource planning and management, and they conduct research to better understand and predict changes in the amount, quality, and location of water resources.







To optimize availability of clean water:

Increase monitoring of both the quantity and quality of surface water and groundwater. Knowledge of the state of water resources and how they are changing is critical for protecting, maintaining, and restoring the nation's water resources. It is important to collect and manage this information effectively and share it widely.

Improve understanding of connections within the hydrologic cycle and between water resources and other critical issues. We need to better understand the interaction between surface water and groundwater and integrate that knowledge into water and land management practices. Understanding links between water and other critical issues, including energy, agriculture, natural hazards, and waste disposal, will facilitate integrated planning and informed decision making.

Balance water use with ecosystem needs. Healthy ecosystems purify water and, in many cases, reduce erosion and degradation, maintain and enhance fish and wildlife, and provide recreation. Sustaining healthy ecosystems depends on a sufficient water supply.

Develop and maintain infrastructure to collect, treat, store, and deliver safe water and ensure sufficient capacity to meet changing needs. The high costs of infrastructure development, maintenance, and replacement present challenges. Decisions about infrastructure require long-term planning based on sound understanding and innovative engineering.

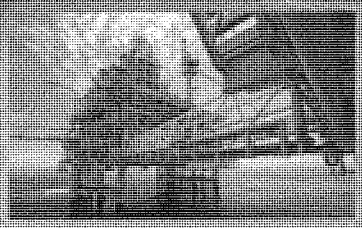
Address persistent sources of contamination and identify threats to water quality as a whole. Water quality is compromised by many sources and contaminants, such as trace elements, nutrients, pathogens, and organic compounds. Contaminants can be introduced by point sources, such as industrial or municipal wastewater discharges, and by nonpoint sources, such as runoff from agricultural fields, urban areas, and mining operations. Contaminants can also be introduced by pesticides, pharmaceuticals, and other synthetic chemicals.

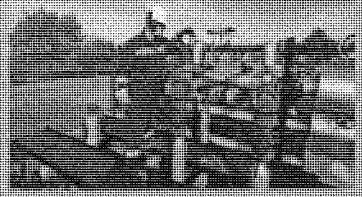
Energy

Developing Energy to Power the Nation

Energy supports economic growth, national security, and all the elements of daily life — food, water, transportation, communication, and entertainment. The United States' historically robust and secure energy systems have contributed to our high quality of life.

Geoscientists find and develop earth- and ocean-sourced energy, such as oil, natural gas, coal, uranium, and geothermal. They also find and develop the raw materials needed for renewable energy sources, such as cement and metals for dams, and rare earth elements for wind turbines and solar installations. In addition, geoscientists help determine suitable locations for energy infrastructure, including refineries, transmission lines, dams, and wind farms.





For an energy-secure nation:

Assess the quantity and location of energy resources. Geoscientists improve understanding of energy resources, helping decision makers to create robust energy policies and allowing energy producers to develop resources more efficiently.

Develop the nation's diverse energy sources. The United States relies on a variety of energy sources, including petroleum, natural gas, coal, nuclear, hydroelectric, geothermal, and other renewables, like wind and solar. The continued responsible development of these resources and the advancement of emerging energy sources will ensure reliable supplies for the future.

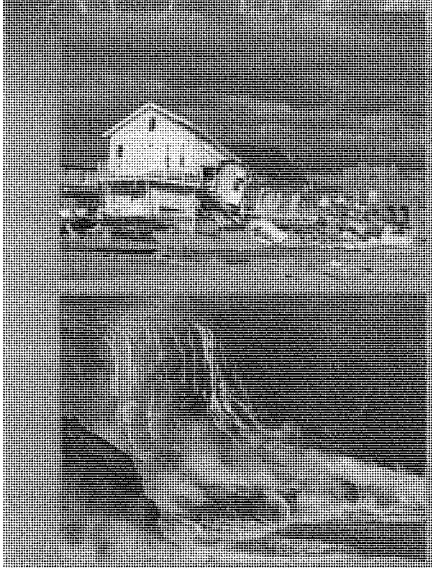
Study and develop solutions that reduce the environmental impacts of energy extraction and generation. Geoscientists contribute to understanding the short- and long-term impacts of energy development, use, and waste disposal that help inform energy policy decisions.

Natural Hazards

Building Resiliency to Natural Hazards

Natural hazards affect every state in the nation. Earthquakes, volcanoes, landslides, sinkholes, wildfires, tornadoes, hurricanes, floods, extreme heat and cold, and drought, among others, result in billions of dollars in annual losses to the United States. These hazards threaten lives and property, disrupt services, damage infrastructure, and weaken economies. A thriving nation requires resilient communities that help protect citizens from economic and social disruptions related to natural hazards.

Geoscientists help communities identify, mitigate, prepare for, respond to, and recover from natural disasters. In coordination with engineers, social scientists, public safety professionals, and emergency managers, geoscientists conduct natural hazards research, monitoring, training, education, and public outreach to create an integrated approach to developing resilient communities.



To minimize the potential impact of natural hazards:

Encourage basic and applied research to strengthen community resilience. Geoscientists study the links between natural hazards and Earth processes and the ways natural hazards impact society. They identify hazard-prone areas through geologic mapping, remote sensing, and other investigations.

Prioritize natural hazard monitoring. Geophysical tools such as satellites, tilt meters, networks, and stream gauges help geoscientists collect data vital to disaster assessment and response and develop better models, forecasts, and warnings.

Support communication of the risks and vulnerabilities associated with natural hazards to the public. Geoscientists [illegible] information regarding hazards and risks to the public, emergency managers, and decision makers.

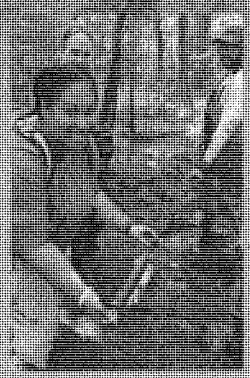
Promote sound research on people, buildings, and infrastructure. [illegible] to develop [illegible] and building codes, [illegible] and other [illegible]

Soils

Managing Healthy Soils

The ability of soil to support plant life is vital to the food we eat and the air we breathe. Soils are primarily made of a complex and variable combination of minerals from rocks, organic matter from plants and animals, air, and water.

Geoscientists study the characteristics, history, and efficient management of soils to improve agricultural yields, purify water, treat waste, supply industrial and pharmaceutical goods, evaluate foundation stability for infrastructure, and reduce impacts from natural disasters.



To manage the nation's soils efficiently:

Encourage monitoring of soil quality and moisture for optimal agricultural production. Soil fertility and its ability to produce crops depend on the nutrients it contains. Better monitoring and management can improve crop yields and potentially reduce offsite contamination.

Incorporate knowledge of soil characteristics and properties into the planning, design, construction, and modification of critical infrastructure. Soil and rock serve as the foundation for our national buildings, roads, bridges, water systems, and pipelines. Understanding soil properties and how they react to the underlying geology can lead to more resilient infrastructure.

Expand the use of soil as a filter to remove pollutants from water. Environmental geoscientists use soil filtration as a natural and relatively inexpensive method to mitigate pollution and improve water quality, particularly the fertilizer enrichment in agricultural runoff.

Characterize soil biodiversity and its relation to essential ecosystem functions. Healthy soil supports a wealth of biotic diversity. Geoscientists study underground food webs and microbial communities that function in ways that provide for support plant growth, remediate contaminants, and contribute to a healthy and food-rich biosphere.

Improve soil characterization and geologic mapping to identify underlying hazards. Earthquakes, landslides, sinkholes, floods, and other natural hazards can be better anticipated and mitigated by identifying and mapping potential vulnerabilities in the subsurface environment, including the likelihood and impact of disasters.

Mineral Resources

Providing Raw Materials for Modern Society

Daily activities, national security, and the greater economy all depend on an abundant supply of minerals — from gold for cell phones, to potassium for crop fertilizers, to rare earth elements for missile guidance and clean energy technology, to crushed stone in concrete for buildings and roads.

Despite the pervasiveness of minerals in everyday life, the full extent and accessibility of the nation's mineral resources is not known; supplies of some critical minerals are vulnerable to disruption; and mineral extraction, use, and disposal have environmental impacts that should be better understood and mitigated.

Geoscientists locate and characterize mineral deposits and provide essential information for efficient resource extraction and effective environmental stewardship.

To support a secure supply of minerals:

Assess the nature and distribution of domestic mineral resources. This basic information on the nation's natural wealth is essential for government, industry, environmental, investment, and community decision-making.

Quantify domestic and global supply of, demand for, and flow of minerals. Industry relies on a stable supply of raw material. Understanding and predicting the market forces that impact mineral supply is essential to anticipate and avoid supply disruptions and to make well-informed financial and policy decisions.

Support socially, economically, and environmentally responsible domestic mineral production. The United States relies on imports for more than one-half of its apparent consumption[1] of 45 mineral commodities, including several that are considered critical to the national interest, such as rare earth elements.

Pursue innovative solutions to lessen the environmental impact of mining and mineral use. Recycling and substitution are increasing, but mining is and will continue to be the primary source for most materials. New approaches in mining, mineral use, and product design can mitigate the impacts of mineral production and consumption.

[1] Apparent consumption is defined as domestic production + imports − exports.

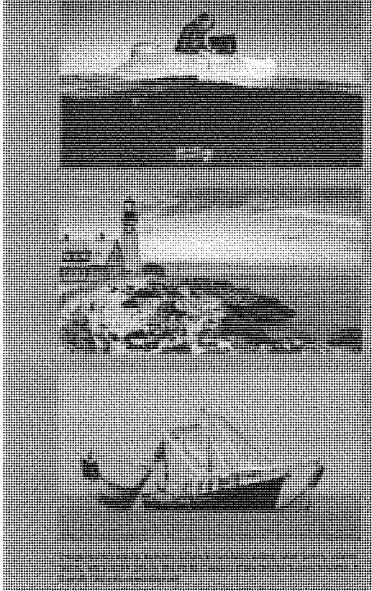
Ocean & Coasts

Expanding Opportunities and Mitigating Threats

The United States depends on the ocean and the Great Lakes for food, national security, energy resources, transportation, recreation, and myriad other critical needs. More than half of the United States population lives in coastal watershed counties that generate 58 percent of the nation's gross domestic product.[1] The United States has jurisdiction over 3.4 million square miles of oceans, more than the land area of all 50 states combined. This vast marine area offers environmental resources and economic opportunities. However, coastal communities are also threatened by tsunamis, hurricanes, industrial accidents, and water-borne pathogens. A better understanding of our ocean and coastal areas will strengthen our economy and protect our people.

Geoscientists provide information about how our planet's coasts, ocean, and seafloor operate now and how they have functioned in the past. They conduct research on marine energy and mineral resources, natural hazards, rising sea, and ocean acidification.

[1] National Oceans Economics Report. Population trends from 1970 to 2020 indicate oceans and Great Lakes states will continue to grow and contribute to economic growth and prosperity.



To ensure the long-term sustainable use of our ocean and coastal resources:

Support basic and applied research on ocean and coastal issues. Better knowledge of the ocean and its role in global processes now and in the past allows scientists to forecast for the future, the improved understanding of ocean and coastal processes will reduce damage and promote economic growth of coastal communities.

Enhance ocean observations. The ocean does not stop at the water and weather occurring on shorelines. Hurricanes and tsunamis are products of the Earth's hot, wet, and dynamic interior. Ocean observations from space, from the ocean surface, and at depth.

Develop research and expertise to anticipate the impacts of climate change and ocean acidification. [illegible] coastal communities, commerce, and [illegible] and from [illegible] high seas.

Assess marine energy and mineral resources, and their environmental consequences. [illegible] of the nation's coastal waters, [illegible] and [illegible] energy [illegible].

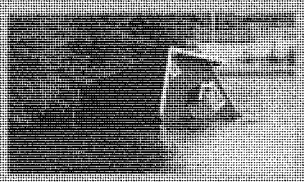
Climate Change

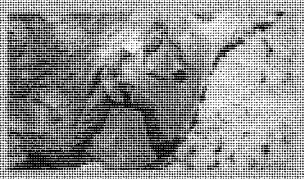
Confronting Climate Variability

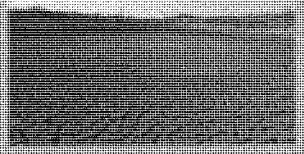
Decades of scientific research show that Earth's climate, the long-term seasonal averages of weather on a regional or global scale, changes as a result of both natural and human causes. Over the past century, global average temperatures have increased significantly.[1] These changes drive sea level rise and exacerbate ocean acidification. Climate change will likely lead to greater storm surges, droughts, heat waves, flooding, and other events that could cost the nation billions of dollars and affect domestic and global security.

Scientists use rock and ice cores to study records of past climate, satellites and weather stations to monitor current climate, and sophisticated computer models to project future conditions. This information supports decisions about agriculture, human health, and critical infrastructure.

[1] Temperature Anomalies Time Series, June 2015. National Oceanic and Atmospheric Administration. climate.noaa.gov/cmb/global/2015/06/







To better equip society for a changing climate:

Encourage research and improve models to understand the connection between Earth's systems, human activity, and climate change. For more than four billion years, land, water, ice, and the ocean have helped shape, and have been shaped by, a changing climate. Understanding past climates through evidence preserved in the geologic record increases the accuracy of today's climate models and the ability to forecast how ecosystems will respond to climate change.

Plan for the diverse and complex societal impacts of climate change. Humans plans consider not just single weather events but extended effects, such as drought, crop failures, changing diseases, and damage to infrastructure, which carry the potential for long-term social and economic impact. Information from organizations, who are familiar with the interrelated processes that impact climate, can inform effective change adaptation plans.

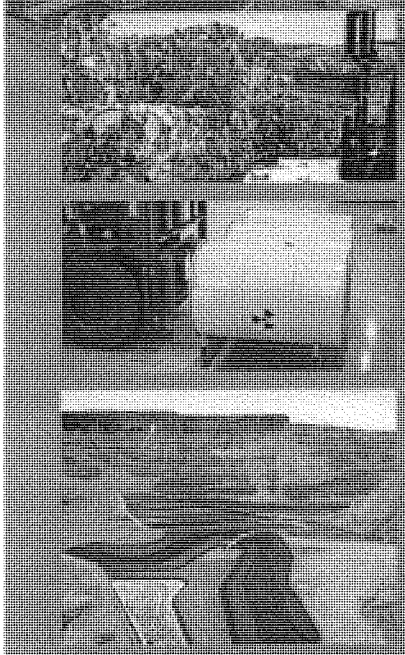
Evaluate strategies for limiting carbon in the atmosphere. Soil and forest carbon sequestration reduces carbon in the atmosphere and helps mitigate global temperature increases. Replacing carbon-generating and polluting fossil fuels with cleaner, zero-carbon or carbon-neutral energy and storage sources are effective means to limit atmospheric CO2.

Waste Disposal

Managing Waste to Maintain a Healthy Environment

Waste is an inevitable byproduct of society. Waste types are as varied as human activities themselves, and many waste products are toxic. Protection of human health and the environment often relies on geoscience knowledge to isolate waste materials from people and ecosystems.

Geoscientists translate their understanding of complex Earth systems into practical approaches for locating waste streams and remediating waste sites.



To optimize the balance between resource use and a healthy society,

Assess the safety of disposing of liquid waste in deep wells. This method of disposal is commonly used today to dispose of treated wastewater, chemicals, and oil field brines, but it has potentially serious ramifications for contaminating groundwater. Geoscientists investigate and help make decisions about

Understand and minimize impacts of energy production and storage. Energy harvesting methods, such as hydro, thermal, and solar, produce waste. Fossil fuels, such as coal, oil, and natural gas, are a significant source of waste from power plant cooling, transportation, and combustion such as CO2.

Mitigate the risk posed by nuclear waste. Nuclear power plants produce high-level radioactive waste that must be isolated from the biosphere for thousands of years. Nuclear weapons also produce waste, and a variety of other radioactive materials are used in medicine and industry. Nuclear waste is a very complex problem, and it is important for the public and policymakers to understand the risks and benefits associated with nuclear power and weapons. Nuclear waste is a very complex problem, and it is important for the public and policymakers to understand the risks and benefits associated with nuclear power and weapons.

Recognize the role of other toxic waste, including lead, and other heavy metals. Lead is particularly dangerous because it is a neurotoxin that affects the brain and nervous system. Lead poisoning is a major public health concern, especially for children. Lead poisoning is a major public health concern, especially for children.

Workforce & Education

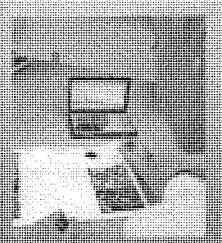
Meeting the Future Demand for Geoscientists

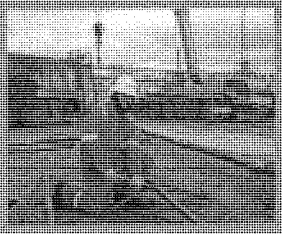
The 300,000 geoscientists currently working in the U.S. private and public sectors help the nation ensure a clean and sustainable water supply, explore, access, and manage its energy and mineral resources both on land and under the sea, monitor, forecast, and mitigate terrestrial and marine natural hazards, support agricultural soil productivity, research land-sea-atmosphere interactions to understand the changing climate, and safely clean up environmental contamination and disposal of waste. By sharing their knowledge with students and the public, geoscientists help to create a society that understands Earth processes and recognizes resource, hazard, and environmental issues.

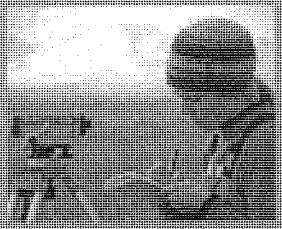
The economic demand for geoscientists will continue to grow within the United States and worldwide, yet increasing numbers of U.S. geoscientists are reaching retirement age. AGI estimates a shortage of 135,000 geoscientists within the U.S. economy by 2022.[1] The nation's schools, colleges, and universities must be ready to educate and train this next generation of geoscientists.

[1] Wilson, S.E., The Status of the Geoscience Workforce 2014, Alexandria: American Geosciences Institute, 2014. www.shortage.geoinstitute.org/workforce-survey-observation-2014/

[2] Ibid.







To develop a knowledgeable, experienced, and innovative geoscience workforce:

Sustain and grow programs to educate a diverse group of students in science, technology, engineering, and math (STEM). Collaborate with agencies ensure that students across the U.S. at all levels have opportunities to learn about the Earth. Take recruit, train, and retain talented students and encourage them to pursue careers in geoscience and related STEM disciplines.

Support federal investments in basic and applied geoscience research. [illegible]

Encourage partnerships between industry, government, and universities and colleges. [illegible]

What do the Geosciences Include?

Water research to **ensure water quality and quantity**

Petroleum geology to **identify and recover energy resources**

Natural hazard science to **help ensure safer, more resilient communities**

Soil science to **monitor soil quality and health for agriculture and construction**

Environmental geology to **protect and provide a healthy environment**

Engineering geology to **build stable infrastructure**

Economic geology to **locate and extract mineral resources**

Coastal geology to **support sustainable use of coastlines**

Oceanography to **protect maritime productivity and ocean commerce**

Atmospheric research for **weather forecasting and climate modeling**

Planetary science to **better understand Earth and other planets**

Geoscience education to **cultivate a society that understands the Earth**

[illegible]

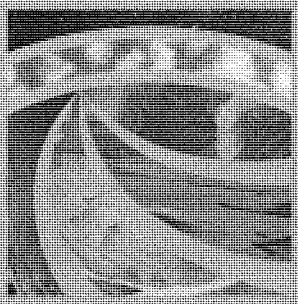
american geoscientific institute

connecting earth, science, and people

About AGI

AGI connects Earth, science, and people by serving as a unifying force for the geoscience community. With a network of 51 member societies, AGI represents more than a quarter-million geoscientists with specialized knowledge of the Earth and its interactions.

AGI was founded in 1948, under a directive of the National Academy of Sciences, as a network of associations representing geoscientists with a diverse array of skills and knowledge of our planet. The Institute provides information services to geoscientists, serves as a voice of shared interests in our profession, plays a major role in strengthening geoscience education, and strives to increase public awareness of the vital role the geoscientist play in society's use of resources, resilience to natural hazards, and the health of the environment.



AGI Programs

EARTH magazine: The monthly publication explores the science behind the headlines. EARTH magazine gives readers definitive coverage on topics from natural resources, energy, natural disasters and the environment to space exploration and paleontology and much more.

Education and Outreach: AGI Education offers products and services for K-12 educators, including NSF-funded curricula, high definition videos, classroom activities, teacher professional development, and online resources.

GeoRef: GeoRef is a comprehensive, bibliographic database containing over 3.6 million references to geoscience journal articles, books, maps, conference papers, reports, and theses.

Policy and Critical Issues: Geoscience Policy works with AGI member societies and policy makers to provide a focused voice for the shared interests of the geoscience profession in the federal policy process. Critical Issues provides a portal to comprehensive, impartial geoscience information for decision makers.

Workforce: AGI Workforce studies the human resources of the geoscience community, produces the Directory of Geoscience Departments, collects data on the supply of and demand for geoscientists, and works to ensure that the health of the profession is understood and improved.

Earth Science Week: Reaching over 50 million people, Earth Science Week promotes awareness of Earth science and appreciation of the geoscientist's role in society. This international public awareness campaign, organized each October by AGI, provides educational resources, educational materials, and a variety of events and activities for students, teachers, and others. Everyone participating in government, industry, and the nonprofit sector utilizes ESW to focus their efforts and continue the unbroken tradition of success of this nearly two-decade old initiative across the world.

Center for Geoscience and Society: The Center links geoscience information to diverse constituencies worldwide, with a particular emphasis on communicating with the news media, all levels of government, and the educational community.

AGI Foundation: The Foundation is the principal source of AGI's tax-deductible development and programmatic contributions to the American Geoscience Institute from individuals, corporations, foundations, and societies.

AGI Member Societies

AASP-The Palynological Society (AASP)

American Association of Petroleum Geologists (AAPG)

American Geophysical Union (AGU)

American Institute of Hydrology (AIH)

American Institute of Professional Geologists (AIPG)

American Rock Mechanics Association (ARMA)

Association for the Sciences of Limnology and Oceanography (ASLO)

Association for Women Geoscientists (AWG)

Association of American Geographers (AAG)

Association of American State Geologists (AASG)

Association of Earth Science Editors (AESE)

Association of Environmental & Engineering Geologists (AEG)

Clay Minerals Society (CMS)

Council on Undergraduate Research, Geosciences Division (CUR)

Environmental and Engineering Geophysical Society (EEGS)

Friends of Mineralogy (FOM)

The Geochemical Society (GS)

Geo-Institute of the American Society of Civil Engineers (GI)

Geological Association of Canada (GAC)

Geological Society of America (GSA)

The Geological Society of London (GSL)

Geoscience Information Society (GIS)

History of Earth Sciences Society (HESS)

International Association of Hydrogeologists U.S. National Chapter (IAH)

International Medical Geology Association (IMGA)

Karst Waters Institute (KWI)

Mineralogical Society of America (MSA)

Mineralogical Society of Great Britain and Ireland (MSGBI)

National Association of Black Geoscientists (NABG)

National Association of Geoscience Teachers (NAGT)

National Association of State Boards of Geology (ASBOG)

National Cave and Karst Research Institute (NCKRI)

National Earth Science Teachers Association (NESTA)

National Ground Water Association (NGWA)

National Speleological Society (NSS)

North American Commission on Stratigraphic Nomenclature (NACSN)

Paleobotanical Section of the Botanical Society of America (PSBSA)

Paleontological Research Institution (PRI)

Paleontological Society (PS)

Petroleum History Institute (PHI)

Seismological Society of America (SSA)

SEPM (Society for Sedimentary Geology) (SEPM)

Society for Mining, Metallurgy, and Exploration, Inc. (SME)

The Society for Organic Petrology (TSOP)

Society of Economic Geologists (SEG)

Society of Exploration Geophysicists (SEG)

Society of Independent Professional Earth Scientists (SIPES)

Society of Vertebrate Paleontology (SVP)

Soil Science Society of America (SSSA)

United States Pharmacopeial Convention (USPC)

International Associate Societies

Canadian Federation of Earth Sciences (CFES)

Geological Society of Africa (GSAF)

International Association for Promoting Geoethics (IAPG)

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AGI american geosciences institute

connecting earth, science, and people

Senator CANTWELL [presiding]. Thank you, Dr. Leahy. Thank you for being here and for your advocacy.

Dr. McCoy.

STATEMENT OF DR. ROBERT McCOY, DIRECTOR, GEOPHYSICAL INSTITUTE, UNIVERSITY OF ALASKA FAIRBANKS

Dr. MCCOY. Thank you, Senator, for inviting me today.

I'm the Director of the Geophysical Institute at the University of Alaska Fairbanks. We were created by your organization, by Congress, back in 1946 at the end of World War II, to establish a permanent institute for the study of geophysics in the Arctic and maintenance of geophysical research for Arctic regions. It was focused on all the diverse geophysical hazards in Alaska but also primarily focused on space weather hazards and impacts to HF communications.

You've already heard there are 52 active volcanoes in Alaska. There's an eruption about every three months. And like Senator Murkowski and several others in the room, I was delayed here last week when Pavlof popped ash up to 37,000 feet.

The Alaska Earthquake Center is part of my institute, and last year they counted 40,000 earthquakes in Alaska—about one every 13 minutes. The magnitude 7.1 earthquake in the Cook Inlet back in January that Senator Murkowski mentioned shook Anchorage well but also caused breaks in gas lines and fires, and four homes were destroyed. So we live in a very exciting and hazardous region.

Tsunamis—there have been a number of tsunamis. If you fly around Alaska, you can still see some of the high water marks from the '64 earthquake, the Good Friday Earthquake, and the resulting tsunami.

We haven't mentioned much space weather, but space weather is also a major hazard. We see the aurora almost every day in the winter when it's clear, and that there's big implications for a major space weather event.

My institute does research and educates students, but we also do a lot of operational things. In partnership with the USGS and the state DGGS, the Department of Geological and Geophysics Survey, we man the Alaska Volcano Observatory, the Alaska Earthquake Center and the College International Geophysical Observatory, to monitor volcanoes, earthquakes and geomagnetism from space weather events.

We have other operational programs. We downlink satellite data, we map the state, we fly unmanned aircraft, we launch rockets into the aurora and we do active ionospheric experiments using an HF heater.

We've been a—we've had a very strong partnership with the USGS and DGGS over the years. We're especially enthused about the efforts by the USGS to establish the National Volcano Early Warning System and to reauthorize the National Earthquake Hazards Reduction Program and the Tsunami Warning Education and Research Act.

You've heard mention of the Earthscope Program with the Boundary Observatory Subprogram and the U.S. Array Program. This is a major enhancement we'll have. This will be a major aug-

mentation to the seismic network in Alaska, and it's already providing new insight into what's going on in Alaska.

A lot of us are working hard to figure out a way to keep some of those sites there when the NSF Program completes in a couple years and starts moving those out again. This could be a major opportunity.

And just finally I want to mention space weather. The National Space Weather, the Administration of National Space Weather Program, the USGS and that program will be enhancing their geomagnetic, geomagnetism program that will provide increased monitoring for geomagnetic hazards from space weather events, and we're pretty excited about that.

So thanks for the invitation, and I enjoyed talking about the diverse hazards and wonderful things going on in Alaska.

[The prepared statement of Dr. McCoy follows:]

I am Dr. Robert McCoy, Director of the Geophysical Institute (GI) at the University of Alaska Fairbanks. The GI was established by an act of Congress in 1946 at the end of WWII which called for the:

"*establishment of a geophysical institute at the University of Alaska... dedicated to the maintenance of geophysical research concerning the arctic regions*"

The primary motivation for the creating the GI was to mitigate impacts to high frequency communication caused by the space weather effects on the ionosphere but also because of the diverse and abundant natural hazards in the Arctic. The people of Alaska are reminded about these hazards regularly. Ash from the ongoing eruption of the Pavlof volcano caused the cancellation of more than 70 flights, and delayed my own trip here to DC by two days. In January, shaking from a magnitude 7.1 earthquake under Cook Inlet was so strong that it ruptured gas lines and caused fires that destroyed 4 homes in the town of Kenai.

Important hazards in Alaska that fall under the purview of the USGS include:

- Volcanoes - we have 52 historically active volcanoes, with a new eruption on the average about every three months. About 85% of air traffic from Asia passes over these volcanoes including 50,000 passengers per day. Alaska Volcano Observatory (AVO) is charged with monitoring these volcanoes, as a partnership between the USGS, the GI, and the state of Alaska.

- Earthquakes – Alaska is by far the most seismically active state. Last year the Alaska Earthquake Center (AEC) recorded and located 40,000 earthquakes in Alaska (about one every 13 min). The second largest earthquake ever recorded was in Alaska and 90% of US earthquakes above magnitude 6 are in Alaska.

- Tsunamis – Alaska has been battered over time by numerous tsunamis and the shoreline of Alaska still bears the marks of the residue from the tsunami generated by the 1964 "Good Friday Earthquake". Tsunamis from this and several other Alaska earthquakes have crossed the Pacific to cause severe damage and casualties in Hawaii and the west coast.

- Snow, ice, permafrost and glaciers: We have a coastline larger than the rest of the US with extensive sea ice, more permafrost than an area twice the size of Texas and more than 100,000 glaciers. Most of those glaciers are losing mass rapidly.

- Space weather: Throughout the winter months (weather permitting) residents of Alaska are treated to glorious displays of auroral activity. While unforgettably beautiful, this space weather effect plays havoc with a wide range of communication and navigation systems including HF, satellite communications and GPS navigation. Large magnetic storms can drive geomagnetically induced currents threatening power grids and potentially causing large area power outages.

For 70 years the GI has performed research and educated students in a wide range of geophysical phenomena in Alaska and around the world but our mission extends beyond research to operations. The GI is Alaska's largest in-state source of natural hazards research and monitoring. We install, maintain, and operate sensor networks and analyze data to provide hazard warnings and assessment to the State of Alaska and the nation. In Alaska we partner with the Alaska Division of Geological & Geophysical Surveys (ADGGS) and the USGS to operate the Alaska Volcano Observatory (AVO), the Alaska Earthquake Center (AEC) and the College International Geophysical Observatory (CIGO). Additionally, we operate seven other research facilities for satellite downlink, mapping, infrasound monitoring, unmanned aircraft, sounding rockets and active ionospheric heating.

The partnership between the USGS and the GI has been mutually beneficial to both organizations for decades. The USGS providing federal standards, resources, and authority, while the GI provides in-state expertise, coordination with state government, and a tight connection to Alaska's research university.

The AVO, established in 1988, leverages the resources and unique capabilities of the GI, DGGS and USGS and is physically distributed across all three organizations. Because the vast majority of explosive domestic volcanic eruptions occur in Alaska, AVO is not only at the forefront of monitoring, it is also the source of much of our understanding about how eruptions unfold. AVO is the model for how a volcano observatory can be operated as a joint partnership between the USGS and state entities.

The AEC was established in 1989 specifically to unite the separate earthquake monitoring efforts being carried out at the time by the USGS and the GI. Uniting earthquake monitoring under one organization, housed at the GI, has been highly efficient, and is an ideal way to promote close consultation and joint messaging during earthquake crises. Today the AEC is the Alaska partner to the Advanced National Seismic System[1]. Because of Alaska's size and dynamic geology, the vast majority of large earthquakes in the United States are assessed and reported under the auspices of the AEC. The successful partnerships between the GI and the USGS is an excellent example of cooperation called for by the President in 2013 to help respond to natural and man-made disasters in the Arctic[2].

The GI supports the USGS efforts to establish and maintain congressional authorizations for the nation's hazards including the establishment of the National Volcano Early Warning System (NVEWS), the re-authorization of the National Earthquake Hazards Reduction Program (NEHRP), and the re-authorization of the Tsunami Warning, Education, and Research Act (TWERA). Living in a state with so many real natural hazards the GI is highly motivated to promote and support the adoption of these landmark congressional authorizations.

An initiative of the National Science Foundation, EarthScope, the final stage of which has recently come to Alaska provides a great potential to enhance hazards monitoring in the state. The EarchScope project has the Plate Boundary Observatory (PBO) and

USArray subprograms and will support the temporary deployment of diverse geophysical instrumentation across Alaska which will used monitoring and research for earthquakes, volcanoes, and tsunamis. The geodetic GPS data provided by the PBO has provided unprecedented resolution of deformation across Alaska, and enables diverse studies including volcanoes, glacier changes, hydrology, and snow depth. These data are currently informing the next generation of the USGS earthquake hazard maps. Earthquake activity in areas of Alaska that have long remained beyond of the reach of the ANSS will finally be revealed as the USArray seismic array continues be deployed. The USArray has the potential to harden real-time geophysical data collection to ensure continuity of operations and to lay a foundation for earthquake early warning. The PBO brought much-needed geodetic monitoring to several Aleutian volcanoes, and the infrasound component of USArray has now measured the atmospheric disturbance of eruptions hundreds of miles away. Together, USArray and the PBO have the potential to transform tsunami-warning capabilities by offering very rapid assessment of the largest earthquakes—a historically challenging task.

Transforming EarthScope assets deployed temporarily into a long-term facility requires coordinated effort and resources. The numerous vested parties in the state and at the federal level must be engaged so that the facility benefits as many stakeholders as possible. The financial support for this facility should come from a broad spectrum of agencies. All large collaborative efforts need leadership, however, and the long-standing partnership between the GI and the USGS can provide exactly that. The two organizations working together can harness the many resources and assets both in and out of state.

In 2017, under the Administration's new National Space Weather Strategy, the USGS Geomagnetism Program will be enhanced to provide improved geomagnetic monitoring with expanded international cooperation and data exchange to help address geomagnetic storm risk to the national power grid and electronic systems.

There is nothing new about all these natural hazards in Alaska, they have been occurring for millions of years. What is new is that as the globe warms and polar ice recedes, the nation is becoming aware of the importance of the Arctic and that because of Alaska, the US is an Arctic nation. Those coming to Alaska for research, investment, or operations should be aware of the diversity and magnitude of the natural hazards in Alaska. The GI is prepared to continue to partner with ADGGS and the USGS to monitor and help mitigate natural hazards in Alaska.

[1]Assessment of Seismic Monitoring in the United States: Requirement for an Advanced National Seismic System, http://pubs.usgs.gov/circ/1999/c1188/circular.pdf

[2]National Strategy for the Arctic Region, https://www.whitehouse.gov/sites/default/files/docs/nat_arctic_strategy.pdf

Senator CANTWELL. Thank you, Dr. McCoy. We are glad you were able to make it this week.

Doctor, my staff tells me it is Vidale. Is that correct?

Dr. VIDALE. Vidale.

Senator CANTWELL. Vidale, okay, thank you. Thank you so much for being here and for your work at the University of Washington.

STATEMENT OF DR. JOHN VIDALE, WASHINGTON STATE SEISMOLOGIST, AND DIRECTOR, PACIFIC NORTHWEST SEISMIC NETWORK, UNIVERSITY OF WASHINGTON

Dr. VIDALE. They usually mispronounce, so that's the norm.

[Laughter.]

Dr. VIDALE. Good morning, Chair Murkowski, Ranking Member Cantwell and members of the Committee. Thank you for the opportunity to testify about the FY'17 budget and ongoing efforts of the USGS. I'm John Vidale, Director of the Pacific Northwest Seismic Network at the University of Washington. I'm privileged to have worked closely with USGS for the last decade to protect the public from earthquake hazards, so that's what I'll mainly talk about.

In my oral remarks I'll focus on new methods to reduce the risk from large earthquakes. USGS also has important initiatives to seismically monitor the Central and Eastern U.S. and to maintain the global seismic network, and I don't mean to argue for prioritization among these projects.

A recent article in the New Yorker captured public attention with the nightmare scenario of an impending magnitude nine earthquake on the Pacific Northwest Coast which has worried people across the entire nation. It last struck in the year 1700 in the Cascadia fault and is now locked and loaded again. When it comes, the strongly shaken region will extend from Northern California, up the coast to Canada including the entire coastlines of Oregon and Washington. Coastal Alaska faces a similar threat.

We know what earthquakes of this size can do. In 2011 the M9 Tohoku earthquake in Japan shook communities for four minutes and triggered a devastating tsunami. Through this example we've seen the level of destruction that could happen along the Pacific Northwest coast. Fortunately, we can act to protect lives and property now.

I'll highlight two opportunities at the USGS that can reduce devastation from quakes of all sizes, earthquake early warning and seafloor monitoring, and discuss why subduction zone earthquakes, the gravest type, need a special focus.

The newest advance in USGS earthquake risk mitigation development of shake alert earthquake early warning, we use seismometers and GPS to recognize an earthquake within seconds of its occurrence and then broadcast a warning of seconds to minutes to vulnerable communities telling people how strong shaking will be and when it will come.

Earthquake early warning reduces earthquake risks and public fears in several ways. In terms of life safety, simply giving people such as schoolchildren a few extra seconds to drop, cover and hold has great benefit. ShakeAlert can also stop trains, call off airplane takeoffs and landings, halt surgeries and much more. In the private sector companies can reduce losses by battening down fac-

tories, racing computer operators and shutting off pipelines. Emergency responders can jump-start emergency operations while communications still work.

The implementation plan for earthquake early warning for Washington, Oregon and California costs $16 million per year for equipment and operations. This state-of-the-art system is entering the public testing phase. We're halfway there. The USGS funding level for earthquake early warning from Congress was $8 million for Fiscal Year '16 and the Administration has requested the same in Fiscal Year '17 budget thanks to strong public and private support for universities, coordination from the USGS, major commitments from the Moore Foundation and corporations, as well as strong support from Congress. We're very grateful for leadership in supporting ShakeAlert from West Coast Congressional delegations. Extension to other states simply requires careful study followed by judicious expansion of ShakeAlert operations.

The second opportunity I'll discuss is the placement of earthquake-sensing instruments on the seafloor exactly as Japan has already done to protect their coastal communities. Seafloor sensors would yield more accurate and rapid warnings of shaking and tsunamis, providing more critical time for people to take life-protecting action. Even more critically, offshore instruments would watch for subtle tectonic unrest which preceded several recent subduction zone earthquakes and would accelerate scientific understanding of the associated risks. There's a high level of interest in exploring subduction zone science, both within the academic community and the USGS which goes beyond offshore instrumentation.

In summary, the great earthquakes in the last decade in Japan and Sumatra, which cost hundreds of thousands of lives and hundreds of billions of dollars, are forerunners of the inevitable devastating earthquakes in the U.S. To prepare, we should complete both an Earthquake Early Warning System and emplace seafloor monitoring. The ShakeAlert Warning System is well on its way to help protect lives and property, and I urge that it be completed quickly and fully for Washington, Oregon and California and evaluated for other vulnerable regions.

Thank you again for allowing me to testify, and I look forward to your questions.

[The prepared statement of Dr. Vidale follows:]

Testimony of John Vidale, Ph.D.
Professor, Dept of Earth and Space Sciences, Univ of Washington
Director, Pacific Northwest Seismic Network
Washington State Seismologist

Hearing on:
United States Geological Survey Oversight

Before the US Senate Committee on Energy and Natural Resources

April 7th, 2016

Good morning Chair Murkowski, Ranking Member Cantwell and members of the committee. Thank you for the opportunity to testify about the FY 2017 budget and ongoing efforts of the U.S. Geological Survey (USGS). I'm John Vidale, a Professor at the University of Washington. As director of the Pacific Northwest Seismic Network and the Washington State seismologist, I'm privileged to work closely with the USGS to protect the public from earthquake and volcano hazards.

The USGS performs yeoman service assessing and mitigating hazards from earthquakes, landslides and volcanic activity. The combination of universities and the USGS working together, exemplified by the seismic networks covering much of the country, which blend bleeding-edge research, operations, and deep outreach, have been supremely successful. For another example, in my home state of Washington, scientists use airborne laser mapping (also known as LiDAR) to find the locations of previously unknown active faults, slopes prone to destructive landslides, and downstream deposits of past eruptions of Cascade volcanoes. LiDAR mapping is critical to our understanding of natural hazards in the Pacific Northwest and across the Nation.

I'll focus here on new methods to reduce the risk from large earthquakes. A recent article in *The New Yorker* captured public attention with a nightmare scenario of an impending magnitude-9 earthquake on the Pacific Northwest coast, which has worried people across the entire Nation. This M9 in the Pacific Northwest might not come for centuries or it might come tomorrow. It last struck in the year 1700, and the Cascadia fault is now locked and loaded again. When it comes, the strongly shaken region will extend from northern California up the coast to Canada, including the entire coastlines of Oregon and Washington. Coastal Alaska faces a similar threat.

We know what earthquakes of this size can do. In 2011, the M9 Tohoku earthquake in Japan shook communities for four minutes and triggered a devastating tsunami. Damage from the quake and tsunami have cost Japan more than $300 billion, and claimed over 15,000 lives. Through this example, we have seen the level of

destruction that could happen along our Pacific Northwest coast. Fortunately, we can act to protect lives and property now.

I will highlight two opportunities at the USGS that can reduce devastation from quakes of all sizes - earthquake early warning and seafloor monitoring, and discuss why subduction zone earthquakes – the gravest type – need a special focus.

The newest advance in USGS earthquake risk mitigation is the development of ShakeAlert Earthquake Early Warning. We use seismometers and GPS monitors to recognize an earthquake within seconds of its occurrence, and then broadcast a warning to vulnerable communities telling people how strong shaking will be and when it will come.

Early Warning reduces earthquake risks and public fears in several ways. In terms of life safety, ShakeAlert can stop trains, call off airplane take-offs and landings, halt surgeries, clear bridges, stop elevators, open critical doors, and allow for faster tsunami warnings. Simply giving people, such as school children, a few extra seconds to drop, cover, and hold on has great benefit.

Early warnings can kick-start actions that reduce damage for a range of industries. In the private sector, companies can reduce losses by battening down factories, bracing computer operations, and shutting off pipelines. Emergency responders can jump-start emergency operations while communications still work.

ShakeAlert is a powerful tool, built to protect public safety during future earthquakes, and operated in collaboration with universities, state agencies and private companies. USGS-coordinated open collaboration means our methods are transparent. This is necessary because providing serious help in devastating earthquakes may only be needed once every few years and has to work the first time. Open also means that the early warning system is flexible and can be adapted to other earthquake-vulnerable regions across the US. Presently, we are beta testing this system on the West Coast, but the system can be deployed across the US to monitor and give warning to Alaska, Hawaii, Utah, Oklahoma, and Tennessee. In fact, although the system is designed in the US, elements have already been published, discussed and tested in many places across the globe. For example, ElarmS, an essential element in the system, has been tested on four continents, facing a variety of challenging cases.

Several earthquake early warning situations arise from the diverse geology across the United States. The long faults such as the San Andreas in California and the Cascadia and Aleutian subduction faults in the Pacific Northwest and Alaska can allow up to minutes of warning. In contrast, for the faults running through our cities, sometimes only a few seconds of warning are physically possible. So it's imperative that we have a system that can instantly recognize and characterize an earthquake and notify communities about the impending shaking.

The implementation plan for Earthquake Early Warning for Washington, Oregon, and California costs 16 million dollars per year for equipment and operations. This state-of-the-art system is entering the public testing phase. But fully turning on the system for the West Coast requires complete funding to employ the workers needed to deploy the full network of sensors and provide speedy and reliable data transmission.

We are halfway there. The USGS funding level for earthquake early warning from Congress was $8 million in FY 2016 and the Administration has requested the same in the FY 2017 budget, thanks to strong public and private support for four universities — Berkeley, Caltech, the University of Oregon and the University of Washington, coordination from the USGS, and major commitments from the Moore Foundation and corporations, as well as strong support from Congress. We are very grateful for leadership in supporting ShakeAlert from West Coast Congressional delegations. Extension to other states simply requires careful study followed by judicious expansion of ShakeAlert operations.

The second opportunity I'll discuss is the placement of earthquake-sensing equipment on the seafloor, exactly as Japan has already done to protect their coastal communities. There, seafloor sensors sit directly on top of the faults that host great earthquakes. This instrumentation is especially critical for places like the Pacific Northwest, where the Cascadia Subduction Zone runs just offshore and underwater. Just a couple of spots now have realtime instruments, but vast tectonically-active and dangerous areas will be uncovered for the foreseeable future. Seafloor sensors would yield information that provides communities with more accurate warnings that arrive sooner, providing more crucial time for people to take life-protecting action.

Even more critically, offshore instruments would watch for subtle tectonic unrest, which preceded several recent great subduction zone earthquakes, and would accelerate scientific understanding of the associated risks. There is a high level of interest in exploring subduction zone science, both within the academic community and USGS, which goes beyond offshore instrumentation. This type of scientific undertaking is essential to the health and balance of the USGS hazards research aimed at getting to the heart of these dangerous problems.

Earthquake early warning is driven by the need to provide advanced warning of shaking, which dominates the $5 billion per year FEMA estimate of long-term earthquake losses in the US. For example, one of our corporate partners, Intel, has determined it will cost the company $15 million for each hour they are off-line. Furthermore, losses from tsunamis have also been horrific in the past decade, and Earthquake Early Warning, particularly in concert with near-shore seafloor sensors, can speed up tsunami warnings by seconds to minutes and refine the accuracy of inundation forecasts.

In summary, the great earthquakes in the last decade in Japan and Sumatra, which cost hundreds of thousands of lives and hundreds of billions of dollars, are forerunners of the inevitable devastating earthquakes in the US. To prepare, we should complete both an earthquake early warning system and emplace seafloor monitoring. The ShakeAlert warning system is well on its way to help protect lives and property, and I urge it be completed quickly and fully for Washington, Oregon, and California, and evaluated for other vulnerable regions.

Thank you again for allowing me to testify and I look forward to your questions.

Senator CANTWELL. Thank you to all the witnesses for your testimony.

Thank you, Dr. Vidale. And as I said, thank you for your advocacy for the State of Washington's perspective. I cannot tell you how vital we think this science is and how much it is going to help in saving lives and property. So thank you for what you do.

Dr. Vidale, I would like to drill down on what you are saying about the early warning system, particularly as it relates to seafloor monitoring and the development of the system. Where are we exactly? And where are we as it relates to the budget and the shortfall that we need to cover these activities?

Dr. VIDALE. Right. The early warning system we've designed, the implementation plan from the Survey covers the system on land, and it should perform quite well.

We have half the funding in hand. With the $16 million a year, we could build it out over the next few years so it's operational according to that implementation plan. With extra funds up front, and the figure $38 million has been mentioned, we could build it a few years faster. California is looking to raise $20 million this year to jump-start that capability.

The offshore aspect is something that's longer-term. We're still studying the different ways it could be done with a cable or with gliders or with OBSs for things that aren't so real time, but that's a long-term goal. It's not something we'll build in the next year or two.

Senator CANTWELL. But should we think about that seafloor-based monitoring as an extension of the land-based system in giving us more time? My understanding is that Tokyo residents had about 80 seconds of warning. We're talking about something more than that, is that right?

Dr. VIDALE. Well it's complicated because it will depend on exactly where the earthquake starts. And you know, they can start right under the cities for earthquakes in the crust or they could start on the far edge of the zone that's going to rupture. So in the Pacific Northwest the best case is if, for us, the earthquake starts in California and then we can see it coming for three or four minutes. If it starts right next to us, then we'd have less warning time.

If we have instruments offshore we gain some warning time, but the more important monitoring would be to see the kind of anomalous activity that sometimes means the risk is elevated. For example, before that disastrous Japanese earthquake there were several days of slow slip, you know, a technical term, that could have alerted people that the risk was higher. It wouldn't have said there was an earthquake coming, but they would have been watching more closely. So there are a number of things we don't understand that we're just blind to now without instruments on the seafloor reporting back in real time.

Senator CANTWELL. My understanding is, just because we visited the NOAA center, that you could take a device like this today and the network information is available. I could download an app, and I could get this information. So this part of the delivery system is here.

Dr. VIDALE. Oh yeah, the system——

Senator CANTWELL. So what is not——

Dr. VIDALE. The system is complete. I mean I have an app on my phone too, which, when they update it next week, will give me the warning that we're trying to produce but it will be slower than it should produce at the full system. It won't be as reliable or as accurate. So, you know, we could take halfway measures now.

Senator CANTWELL. Right.

My point is what we are getting out of the next development is the fact that we are pushing out our systems to get the information sooner.

You are indicating that the seafloor indications are—how much more time is that giving us, I guess, is the question?

Dr. VIDALE. Yeah and that's a great question.

Now it only brings a few tens of seconds so it's the waves that are generated offshore coming to the shore fairly quickly. So the gain in the early warning is fairly modest. I think that the bigger reason for the seafloor is to understand the risk better and to see the signs of unrest that indicate changing levels of danger. And so this is something, it's a long-term goal and something we'll need to study to figure out the best approach.

Senator CANTWELL. Well I just want to bring up our two former colleagues, the Senator from Alaska and the Senator from Hawaii.

The CHAIRMAN [presiding]. Stevens and Inouye?

Senator CANTWELL. Yes, Senators Stevens and Inouye.

They were very involved in the development of this system. I remember one incident in Hawaii when people got the warning and then it turned out the tsunami risk was not as great.

My point is that what you are saying today is that what you would be getting from the seafloor monitoring is a better understanding of how big the risk might be. So to better prepare, is that what you are saying?

Dr. VIDALE. That's right. And also the early warning systems are just now emerging with the tsunami warning systems because they give a faster warning of the earthquakes than the tsunami warning system currently does. And if we were to put offshore instruments we'd be directly measuring the waves, not just the ground shift which is a much less accurate way to predict the waves. So there are a number of benefits we'd have from seafloor instruments for tsunami warnings as well as a warning of the shaking.

Senator CANTWELL. So you are requesting an extra $1.7 million for warning capabilities on earthquakes on the West Coast.

Dr. VIDALE. 1.7. We're talking about, I guess, $16 million a year for the West Coast early warning system of which we currently have eight. So we're, kind of, short $8 million a year to be building the system on the West Coast.

Senator CANTWELL. Thank you.

Dr. VIDALE. Yeah.

Senator CANTWELL. Thank you, Dr. Vidale.

The CHAIRMAN. Thank you.

Gentlemen, I apologize that I was not able to hear the testimony from the other three of you before I had to scoot out, but I am glad that we are back and able to ask some questions. I have read your testimonies.

I want to continue the discussion about the geologic hazards. It is one thing to have the early warning, but we are also better armed if we have done the mapping.

Deputy Commissioner Fogels, you mentioned that we have mapped 17 percent of the geologic hazards in the State of Alaska. Senator Cantwell has mentioned the need to knit together all of this information so that within our communities we are better prepared, better able to respond.

If we have not been able to do an adequate job in mapping, whether it is the hazards around our communities, our infrastructure corridors, how do we get to what Senator Cantwell is saying, that level of preparedness and what our communities can do?

So the question, and I'll direct this to you, to start, Mr. Fogels. We need to step it up in order to be able to be more prepared, but you have to start with some basic mapping that is accurate. Am I thinking that somehow or other we can jump over this step?

Mr. FOGELS. Senator, you're absolutely right. We do need to step it up as far as our mapping, and I touched on that in my testimony. I think it's worth emphasizing that a couple times in my testimony I mentioned the Earthscope project.

The CHAIRMAN. Right.

Mr. FOGELS. In Alaska, through a National Science Foundation (NSF) grant, we're in the process of installing about 261 sensors throughout the state. I mean, those are going to be fantastic for our state and for the rest of the nation to provide real time data.

And so, our concern is to make sure that once those things are in, at some point, some select few of those get to be maintained and integrated with our own earthquake systems. I think that's critical not only for the geologic hazards, but as I mentioned, those can provide a real boost to our geodetic control which lets us actually make sure that our data is positioned properly on the planet surface and that's——

The CHAIRMAN. Well, let me ask further to that and I will ask you, Dr. McCoy, to weigh in as well because when we had the Secretary, I think it was when Secretary Ventura was in front of us and we were asking this question about, is there some discussion going on about how the State of Alaska can continue what Earthscope has put in place?

I mean our state is not doing well financially right now. You certainly know it at the University level. But what happens if we get to that situation where we do not have the federal funding to pay for the operation and maintenance of the network, and we have not been able to work out an agreement? Does that just move us backward in terms of our ability to have any kind of an early warning system, to have the level of preparedness that we would hope for around the state?

I do not want to talk about worst case scenario, but I need to understand what that does to us as a state if we are not able to continue the benefits that we have seen from this Earthscope project.

Dr. McCoy?

Dr. MCCOY. Yes, the Alaska Volcano Observatory and Alaska's Earthquake Center have deployed sensors all along the Aleutians and over a big chunk of Alaska. Of the 52 active volcanoes I men-

tioned, we can only monitor, directly, 26 of them. We monitor the others using satellite data or infrasound remotely.

The seismicity has been changing in Alaska. We've had earthquakes near Kotzebue that weren't there before, so we've had to deploy temporary sensors.

The Earthscope Array, these 260 something sensors, is extraordinary. This is going to really improve—it's a diverse set of instruments, seismic, GPS. It's a $70 million effort that's a fantastic enhancement to our capabilities.

The State Seismologist who is in the Geophysical Institute, he's already working to integrate that data as well as he already integrates Department of Defense (DoD) seismic data into this overall——

The CHAIRMAN. Does DoD maintain different instrumentation around the state separate from——

Dr. MCCOY. There's a few seismic sites that are used for nuclear treaty verification. And we partner closely, so does USGS, and we work closely with those, with the DoD on that.

So all of a sudden, for a short time, a couple years, two or three years, we're going to have an extraordinary map of seismicity in Alaska. But the bad news is if we don't do anything at the end of that two years, NSF will go back and take all this back out again.

So we're in active discussions as to how to keep, as Mr. Fogels said, just a subset, just a few of those at key locations that are hard to get to and we're looking for funding to operate them and maintain them. Maintaining them is important. We spend most of our summer flying around Alaska with USGS help to maintain, replace batteries, and upgrade systems and maintain.

So we'll degrade back to where we were in the past, but for a short time it'll be really amazing. If we can keep some of those then we've made a definite improvement for the State of Alaska.

The CHAIRMAN. So after two years where do these go? Where is USGS going to take these geodetic stations?

Dr. MCCOY. Well they're required to go back. Dig them out of the ground and return them.

The CHAIRMAN. Return them to where?

Dr. MCCOY. Storage.

The CHAIRMAN. Return them to storage.

Dr. MCCOY. Or——

The CHAIRMAN. Are they going to be used elsewhere?

Dr. MCCOY. I doubt it.

The CHAIRMAN. What a horrible waste when you could be advancing the research, science and the data and allowing us to be so much smarter. We are required to take them out of the ground, and then I was thinking somebody else was going to be able to gain benefit.

Dr. MCCOY. Well I'm sure somebody else might, someplace else but Alaska——

The CHAIRMAN. The person who has the storage unit that gets the rental from them. I don't know.

Dr. MCCOY. So I'm not sure exactly what they have planned, but we're working hard with our partners and the state and with USGS to figure out a way to keep a select subset of those.

The CHAIRMAN. Okay, know that we want to be working with you.

Dr. MCCOY. Terrific.

The CHAIRMAN. It just seems to me that if NSF has made this investment, this is an investment in data and if the state can figure out a way to do the operation and maintenance end of it, NSF is going to continue to gain benefit. Obviously the state will as well. So this appears to me to be one of those no-brainers that we need to ensure we don't allow a lapsing.

Dr. MCCOY. Absolutely. In the lower 48 this program has already been completed. This is the final stage in Alaska. And in most states, especially in the states that are seismically active, there were some ways found to keep many of those sensors in place. So now we're working on trying to find ways to keep a subset in place in Alaska.

The CHAIRMAN. Okay. Well we are going to work with you.

I will turn to Senator Cantwell for additional questions.

Senator CANTWELL. Thank you.

I want to go back to you, Dr. Vidale.

We were talking with Director Kimball about Mount Rainier and installing lahar equipment. I know the UDub is working with Tacoma and the USGS to help improve that system. What do you think the timeline is for updating it and what do we need to do to make sure that we have safe evacuation routes?

Dr. VIDALE. Well, there is a plan to do the lahar monitoring on Rainier. My impression is it's not, the funding is not there yet. I mean, they're upgrading the Hood Stations and the Glacier Peak Stations because they have that in their existing budget. But there isn't funding at the moment to do the lahar——

Senator CANTWELL. Well my understanding is that Glacier Peak has next to nothing today.

Dr. VIDALE. Yes, it has almost nothing. That's correct.

Senator CANTWELL. But we have a volcano in our state that has——

Dr. VIDALE. Yeah, there are several volcanoes that are undercovered. There are hazardous volcanoes and two or three of them are well-covered and the rest are pretty sparse.

Senator CANTWELL. Okay, so back to what do we need to do then to improve the system for Tacoma and Mount Rainier?

Dr. VIDALE. Well I think for Rainier, my impression was it was on the order of a $1 million budget and they just don't have the funding yet. And so if they have funding they can do the plan. Until then, they'll be waiting.

Senator CANTWELL. Okay. We will definitely think that is a high priority here.

What about the early warning tsunami systems as it relates to areas of our state like Long Beach? We really need to be building vertical structures, is that correct? And what is the science telling us about these vertical structures and what we need to do?

Dr. VIDALE. Well there's continuing study of just, you know, how high we have to evacuate and how often. And next we have an M9 project at the University of Washington trying to probabilistically estimate what people have to watch out for. But right now I think they're building the first vertical evacuation tower on the coast of

Washington at a high school. It's just a challenge to find the funding to build these evacuation structures. So we know it's a problem. We know there are people who are going to be stuck, but these buildings cost a lot of money and the state is working on it.

Senator CANTWELL. Right.

And what do we do to make sure that we are actually getting an accurate, well, I think the community wants to have a plan. So just as you said, with the cost of the facility we are making them make certain choices. But in reality the impact is something that is going to be more than just one wave, correct?

Dr. VIDALE. Right.

Senator CANTWELL. And the devastation that could be left behind could leave them pretty isolated for a while. So you really need a vertical structure that is more than what the New Orleans Dome was, correct? It needs to be a better structure for housing and facilitating?

Dr. VIDALE. Yes.

Senator CANTWELL. Several days of a population, is that correct?

Dr. VIDALE. It's challenging to make the appropriate structures. And Japan, sort of, reset our expectations for the height of the wave that could come in. The wave in Japan was 30 or 40 meters in places, which was twice as much, well, three times as much as the Japanese had planned for. So suddenly these structures are more challenging to build.

So we, sort of, know what we need to build to be safe, but again, it's a matter of finding the resources and getting the community will to push it at all levels to make it happen.

Senator CANTWELL. Again, I don't know if it's so much the community. I just feel like we are planning for Cascadia by Committee, almost, and I feel like we need a General. I feel like we need an overseer of this because, again, you are doing great work. Scientists at a university working with local mayors and county commissioners in a county that has very little resources to plan for it. And yet, that is the front line of our response to something we know is going to happen. It is just a matter of when it is going to happen.

So I think, again, we were just down there for a community meeting. The community is doing great work, but again, these are big questions.

Dr. VIDALE. Yes, they're difficult. And you know, the state budget in Washington, as you'd know better than I do, is not that easy to find large sums of money to fix these problems.

Senator CANTWELL. But this will be a federal disaster. If you are going to affect the economies of Washington, Oregon, California and Alaska, it is going to have a devastating impact on the national economy as well.

I think this is a lot of information today, again, about making sure we get this, Madam Chair, right on the mapping and the early warning systems and the tsunami systems and then making sure that we continue to ask the questions about how we are going to move all of this together.

I don't know if you have more questions, so I will pass it back to you.

The CHAIRMAN. Thank you, Senator Cantwell.

I am just reminded this was some years ago that I had been advocating for funding for the volcano monitoring system, and I was written up in one of the Hill publications as one of those, oh my gosh, can you believe that there is a Senator who wants to monitor volcanoes? I was really mocked.

And then, I cannot pronounce the name of the volcano in Iceland that blew and literally shut down Europe, and all of sudden there was all this scrambling around. What are we doing to monitor volcanoes? And then I was apparently brilliant at that point in time. [Laughter.]

The CHAIRMAN. But it reminds me that unfortunately so much of what we are talking about here you cannot get the appropriate attention that we need to it until there is that natural disaster, until you have that big earthquake, until you have the volcano that shuts down air traffic—that is not how we should be operating. These are ways to help us with a little bit of an insurance policy.

I want to ask a couple more questions here and then we can wrap up, because I think there has been good discussion, certainly about some of the hazard mapping, and what more we can do when it comes to early warning.

Mr. Fogels, I wanted to ask one quick question about land conveyance and the issue in the state about BLM wanting to move on the state land conveyances but using a different methodology that the state has not yet signed off on regarding the GPS calibration stations. The fact that, quite honestly, we just do not have enough of these, so called, continuously operating reference sites, and the fact that when you do not have them you cannot get the accurate GPS coordinates.

[The information referred to follows:]

Alaska Continuous GPS
Legend

The CHAIRMAN. I know that what we are trying to do in the state is to get an independent peer review of the accuracy of the GPS-based land conveyances that might be finished. Can you just, real quickly, speak to the state's concern about the conveyance, this new proposal, that is coming out of BLM and the concern that we have with the impact to the state patents?

Mr. FOGELS. Yes, Senator, I can certainly do that.

As the Bureau of Land Management is in the process of conveying to the State of Alaska its remaining land entitlement, you know, we have a 105-million-acre land entitlement. We have about 100 million already in hand, but only about half of that has actually been patented to us. In order to patent that land, it has to be surveyed and then patented to us.

We can use the rest of the land as if we owned it right now, so it's really not that big of an issue in the immediate term. But at some point in the future this land has to be surveyed and patented. Right now the survey standards prescribe physical monumentation in the ground, you know, every so often throughout a memorandum agreement that we've had with the BLM and we believe is rooted in the Alaska Statehood Act.

The Bureau of Land Management wants to reduce its surveying costs by reducing the spacing of the physical monumentation and relying more on GPS coordinates. And I think we all agree, at some point in the future, it's probably silly to run around hammering in physical monumentation. At some point in the future, when we have the technology, we can replace that, but we do not believe we're there yet.

The ground controls I mentioned in my testimony in Alaska are poor, and that's what determines how accurately you can pinpoint those survey monuments with your GPS. And as I mentioned, not only are we inadequate in our coverage of these continuously operating reference stations, but we're in danger of losing almost half of them once the Earthscope stations disappear. So we'll be backsliding; we'll go even further back.

Before we really are convinced of the new technology that BLM will use for patenting our land, we'd like to see it. We're not convinced yet. We want to see better ground control in Alaska.

The CHAIRMAN. Yet one more example of why this Earthscope project, or the instrumentation there, is so important.

Back to mapping and then I want to direct a question to you, Dr. Leahy.

In your testimony, Mr. Fogels, you talk about the mineral potential in Alaska and the fact that we have only got about 17 percent of the state that has been mapped, geologically, much less with other mapping techniques whether it is airborne, geophysical survey. Why is it so important that we get this accurate mapping when it comes to our minerals?

Mr. FOGELS. Well Senator, there are a number of reasons.

I think one, just the geologic mapping, is a foundational data set that describes the Earth. And so, all of the geologic hazards that we've been discussing here in this Committee, I mean, if you don't have a good geologic map of your state, you're just behind the curve when you're trying to figure out where your hazards are or what

their potentials are. So the geologic mapping is important for hazards too and flooding and tsunami inundation mapping.

But as far as resource development, I think Director Kimball said, part of the USGS' mission is to provide for our mineral and energy security in the future. Alaska is vastly underexplored.

We have much more mineral potential to offer the nation, we have much more oil and gas potential and energy potential to offer the nation, and this mapping is critical to find that. We don't even know where a lot of this is yet.

Some examples of where we've used state and USGS mapping, the new, the recent discovery by Repsol and Armstrong on the North Slope that could produce up to 200,000 barrels of additional oil for TAPS a day, potentially. I mean, that was assisted by mapping, through the STATEMAP program.

The Pogo Gold project that's now employing 300 people was assisted in its discovery with this mapping whether it's airborne, geophysical or state mapping, the Livengood projects.

So we have a lot of success stories in Alaska, and we believe we have a lot more success stories in the future with better mapping.

The CHAIRMAN. I would agree.

Let me wrap this panel up with a question to you, Dr. Leahy. In your written testimony that I reviewed you speak about four main goals for USGS in mineral resources led with the need to assess the nature and the distribution of domestic mineral resources.

As you know I mentioned that to Director Kimball and we have a critical minerals bill that I have introduced. It is something I feel pretty strongly about.

In your observation, can the USGS be doing better when it comes to its assessment of minerals? And what would you recommend in terms of steps that can be done at the federal level to really strengthen our nation's mineral security?

Dr. LEAHY. Well I think, you know, all minerals occur in deposits, different types of deposits. The way you determine where those deposits are is through geologic mapping. If there is no map at the appropriate scale, it's very difficult to, kind of, guess that there might be a material that you're interested in. So geologic mapping is absolutely critical.

Now the U.S. has been playing catch up in terms of, kind of, filling in the geologic map of the country. It's an enormous effort. Tremendous progress has been made in the last 20 years but there's a great deal to be done. To me, that's a very high priority for the USGS, and obviously a state partnership is a vehicle to get it done.

Now can it happen immediately? That's impossible. We don't have the workforce to be able to do that. But certainly it could be accelerated and particularly in Alaska, but elsewhere as well.

The other thing I want to say is when you talk about minerals I think you have to maintain a global view. And I think you've got to be somewhat strategic in that global view in terms of what you're looking at.

For example, I think there are special studies and USGS is starting to do some of these. One that comes to mind is the rare earths or the critical minerals that you mentioned. But also there are geographic areas that are important for us to know about because they could be potential supplies or producers of supplies we need in

order to run our manufacturing or whatever. There isn't one that immediately jumps to mind. It's kind of a question mark globally. It would be good to be able to fill in that question mark.

I think we need to, you know, the USGS has a rather iconic graph they put out every year that shows the U.S. dependence on foreign production of minerals. The one thing I have not seen is how of those, what are the trends in those graphs that are produced on an annual basis? Which ones are increasing? Which ones are declining in terms of our dependence?

If you look at it in that context, I think you can start doing some pretty educated forecasting in terms of where are there going to be challenges for domestic supplies in the future.

In my mind, that's an analysis that should be done, and we should have a handle on forecasting where we see mineral disruptions in the future. Not that the minerals won't be there geologically, let me make that perfectly clear, but where the supply could be disrupted because of world events.

I think that the USGS is ideally situated, which it isn't in energy but it is in minerals, by having both the demand and the production supply or, the production side as well as the supply side. They do assessments of resources globally, so they know how much is available in terms of reserve or the resource base. But they also look at production statistics globally. Frankly, that's a big advantage in terms of doing some very innovative science, kind of, looking at both of those sides of the equation. That, I don't believe, is being done, or it's only being done in a few cases in a pilot area. So those are some of the things I would do.

The CHAIRMAN. Yes.

Dr. LEAHY. The other thing, and I'll just close with this comment, is there was some discussion of the mineral cycle. I think Director Kimball mentioned the mineral life cycle, she called it. I think there are some things that could be done in terms of greater collaboration if we want to look at minerals as a cycle, we really need to look at all the components, the discovery, the development, the production, the disposal, the reuse, the substitution and so forth.

Other federal agencies have responsibilities. DOE comes to mind in terms of doing substitution and so forth. I don't believe the collaboration and looking at the minerals cycle as an entity with various components within the Federal Government contributed to it is very strong, and I think that could be strengthened.

The CHAIRMAN. Very good.

Dr. LEAHY. Just a few thoughts.

The CHAIRMAN. Very helpful, I appreciate that.

Dr. LEAHY. Thank you.

The CHAIRMAN. I have to ask one last question. Hopefully this will be very quick. Dr. McCoy, in your comments you noted the need for a new space weather strategy and talk about the USGS geomagnetism program. Do you see a role for the Arctic of Alaska in this particular effort? It seems to me it is perfectly poised for it. But can you inform me just a little bit?

Dr. MCCOY. Sure.

The CHAIRMAN. Very briefly.

Dr. MCCOY. Sure.

Just off campus, we maintain the College International Geophysical Observatory.

The CHAIRMAN. Right.

Dr. MCCOY. It was built by USGS, but we operate it and we monitor geomagnetic activity. Large solar activity, Chrono mass ejections, can create ground induced currents, geomagnetically induced currents, that can take down power grids. It's a major concern.

The Administration has had a space weather initiative the last couple years as a new strategy that involves enhancing USGS funding in this area. So we're excited about that.

And—but this is—this could be an extreme hazard. In fact, I think Lloyd's of London has estimated a potential up to $5 trillion, globally, from a major space weather event. So USGS, it's a, they're a small part of the overall responsibility in the nation, but they're monitoring ground currents and measuring ground currents.

The CHAIRMAN. Can we predict that? Is that where you are going with this project, and this proposal, is the ability to predict when that might happen, or if?

Dr. MCCOY. There are several aspects. Some of it is prediction, looking at the sun, but also understanding the ground and the way currents are produced and having enough warning to provide, to do mitigation so we don't take out power grids.

The CHAIRMAN. Right.

Dr. MCCOY. Like what happened back in '89 in Quebec.

The CHAIRMAN. Right.

Yet another hazard. Add it to our list.

Thank you, gentlemen, for your testimony and for all that you are doing to help us be better prepared, particularly when Mother Nature does some crazy stuff.

Senator Cantwell.

Senator CANTWELL. Thank you, Madam Chair.

I just wanted to add, you know, we were mentioning Senator Stevens in a way that my predecessors, Senators Magnus and then Jackson, actually through this Committee on Insular Affairs, extended our ability to conduct investigations on the Outer Continental Shelf and to the oceans that we need to be doing now.

That was in 1961, and I am so glad that they did that. I think you and I are continuing to carry the torch for this, and I think today's hearing is all about how we need to make sure we are carrying the torch in the appropriations process.

The CHAIRMAN. Yes.

Senator CANTWELL. And make sure that these gentlemen get the funding we need to protect the public and to continue to look at these issues.

So I thank you for holding this important hearing that is very important to our region of the country. And thank you for your leadership, as you mentioned, on bringing up monitoring when people didn't quite understand the significance of it. So thank you for that.

The CHAIRMAN. Yes, we do have a Natural Hazards Caucus. Apparently I am a co-chair and was with Senator Landrieu when she was here in the Senate—and this was shortly after Katrina. The caucus hasn't done much of late, and maybe it is time to revisit,

at least from an educational perspective, what we might need to be doing. Anyway, I am just putting that out there.

But thank you, we appreciate it and you all.

[Whereupon, at 11:55 a.m. the hearing was adjourned.]

APPENDIX MATERIAL SUBMITTED

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Questions for the Record Submitted to the Honorable Suzette Kimball

Questions from Chairman Lisa Murkowski

Question 1: Growing Mineral Dependence: The USGS has collected data on our nation's foreign mineral dependence for close to 40 years now. How has that changed over that time? What are the drivers of our deepening foreign mineral dependence? Do you believe that dependence exposes our nation to any strategic vulnerabilities?

Response: There are a variety of factors that go into explaining why U.S. net import reliance has changed over time. Most all relate to global trade and market economics. Examples of such are provided in the USGS Fact Sheet on *Comparison of U.S. net import reliance for nonfuel mineral commodities—A 60-year retrospective (1954–1984–2014)*[1].

Analysis of 79 nonfuel mineral commodities showed that in 1954 the United States was greater than 50% net import reliant for 28 of those commodities and 100% net import reliant for 8. In 1984, the total number of commodities analyzed had increased to 91; the United States was greater than 50% net import reliant for 38 of those commodities and 100% net import reliant for 11. In 2015, 94 nonfuel mineral commodities were analyzed by the USGS; the United States was greater than 50% net import reliant for 47 of those commodities and 100% net import reliant for 19.

Although net import reliance alone does not necessarily equate to supply risk, the types of commodities, as well as their sources, are important factors used to evaluate risk. Domestic reserves and resources, governance risk, and trade restrictions, among others, are additional factors that should be considered when calculating supply risk and developing mitigation strategies.

Question 2: America right now is completely dependent on imports of graphite, for example, which is one of five commodities that we have on U.S soil, but do not currently produce. However, I know there is a huge deposit of graphite north of Nome, Alaska near Pilgrim Hot Springs.

a. Why are we unable to open domestic mines despite having significant mineral deposits?

[1] Fact Sheet 2015-3082, available at pubs.er.usgs.gov/publication/fs20153082

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Response: Exploration for and development of mineral resources in the U.S., and in most of the western industrialized world, is conducted by the private sector. Thus, the decision to explore for or develop a mineral resource is a business decision that must factor in the time and cost to find a viable resource, to explore in more detail to define an economic reserve, to comply with local, state and federal regulatory requirements, to build a mine and supporting infrastructure, to operate the mine at a profit, and to close the mine and reclaim the property. Because the minerals industry is a global industry, these business decisions are made in a global context. In some parts of the world the exploration and development of mineral resources are subsidized by governments or in some cases owned outright by state-owned enterprises. This can affect mineral commodity markets which impact private sector business decisions on what resources to pursue for development.

Question 3: In a November 2005 USGS Mineral Resources Program Planning document, your agency said it needed a budget of $52.5 million a year for the next five years through FY 2010 to conduct adequate mineral resource assessments in America. With inflation, that is 32 percent less than today's proposed budget for mineral resource work.

a. Why are your current budget proposals not a significant reduction in what is needed for this nation to really know what its mineral resources are?

   Response: Given changes in technology since 2005, which have created a dependence on a new suite of critical minerals, especially rare earth elements, the President's budget puts a strong emphasis on understanding new critical minerals. The President's FY 2017 budget for the USGS Mineral Resources Program provides funds to support research on identifying and evaluating new sources of critical minerals. The budget also funds collection, analysis and dissemination of data that document production and consumption for about 100 mineral commodities, both domestically and internationally, for 180 countries.

b. In your testimony on April 7, you said that a deputy assistant secretary would be appointed for minerals. When is this expected to happen?

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Response: The selection for Associate Director for Energy and Minerals was approved by the Department of the Interior and the Office of Personnel Management on April 22 and will be announced as soon as an entry on duty date has been established.

Question 4: Mineral Prioritization: The USGS releases a Mineral Commodities Summary report each year which provides a detailed summary of various mineral commodities over the past 5 years. To help better understand and the demand for these commodities, the USGS uses the following criteria; 1) How important is the commodity to our present economy and standard of living?; 2) How much of it do we have and to what extent is it economically, environmentally, and technologically available?; and 3) How and where can more be found both in the United States and elsewhere?

a. I'm trying to understand the extent of the USGS's vision when it comes to critical minerals needed for economic and strategic security. Is the USGS only examining a handful of select commodities through this identification process or is it being done on an industry-wide or even economy-wide basis?

Response: The work required to identify critical materials needed for U.S. industries and the U.S. economy in general was recently outlined in an NSTC interagency report entitled "Assessment of Critical Minerals: Screening Methodology and Initial Application." This report was authored in large part by scientists from the USGS National Minerals Information Center (NMIC), relies heavily on NMIC data, and provides a framework for identifying materials of interest. This early-warning screening assesses potential criticality (C) using a uniform methodology that results in a single value for each mineral commodity on a common 0 to 1 scale, where increasing values signal higher potential criticality. The assessment is based on the geometric mean of three fundamental indicators: supply risk (R), production growth (G), and market dynamics (M). These indicators were selected because they capture different aspects of availability and because of their complementary nature: R is a measure of the risk associated with geopolitical production concentration, G incorporates changes in the mineral's market size and reliance on geological resources, and M tracks the mineral's price sensitivity
to changes in its market.

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The early-warning screening has been applied to 78 mineral commodities for years 1996-2013. Results from this initial assessment reveal heterogeneity in the *C* indicator values across the minerals evaluated and over time. Certain minerals including bauxite, copper (Cu), and gold (Au), for example, have consistently low *C* values. In contrast, minerals such as germanium (Ge), the rare earths (Y, La-Lu), ruthenium (Ru), rhodium (Rh), and antimony (Sb) have some of the highest *C* indicator values. Most of the other minerals have moderate *C* indicator values, which, however, have mostly been increasing over the time period examined. Indeed, an overarching trend has been the overall increase in the *R* indicator, suggesting that production has become much more concentrated in countries with higher governance (geopolitical and regulatory) risk in year 2013 as compared to year 1996.

b. The USGS website states that it will provide updates for selected critical mineral commodities. Can you please tell me which selected critical mineral commodities the USGS plans to provide updates on and what are the Survey's criteria for selecting the specific critical mineral commodities?

Response: The USGS expects to soon release Professional Paper 1802, *Critical Mineral Resources of the United States—Economic and Environmental Geology and Prospects for Future Supply*, a timely publication that updates information published in 1973 in U.S. Geological Survey Professional Paper 820, *United States Mineral Resources*.

This publication presents domestic resource and geologic information on the following 23 mineral commodities currently viewed as important to the national economy and national security of the United States (in alphabetical order): antimony (Sb), barite (barium, Ba), beryllium (Be), cobalt (Co), fluorite or fluorspar (fluorine, F), gallium (Ga), germanium (Ge), graphite (carbon, C), hafnium (Hf), indium (In), lithium (Li), manganese (Mn), niobium (Nb), platinum-group elements (PGE), rare-earth elements (REE), rhenium (Re), selenium (Se), tantalum (Ta), tellurium (Te), tin (Sn), titanium (Ti), vanadium (V), and zirconium (Zr).

These commodities have historically been important for US manufacturing and defense industries and share supply vulnerabilities, either due to geographic

concentration of supply, or to being a by-product of some other commodity production.

c. How can we broaden the USGS' activities to provide updates on a wider range of commodities needed in current and future manufacturing processes?

Response: There are several areas of interest that the USGS would like to increase capacity to pursue. These include:

Exploration-- Because critical and strategic minerals are often very small volume commodities or are produced principally as byproducts, these materials often "fly under the radar" in such domestic and global analyses of major mineral exploration projects that are conducted by USGS NMIC. However, the Department is taking steps to explore the location of additional commodities. One example is the Department has granted awards to two Tribes in New Mexico to evaluate REE exploration on tribal lands, which could lead to future opportunities.

Byproduct potential from current major commodity production -- Quantifying the volume of potentially recoverable critical materials from byproduct streams which are currently not being recovered because of economic or technological constraints would be very useful in informing potential mitigation strategies to reduce supply chain risk. This kind of information is not currently being collected or analyzed in any systematic way.

Key downstream supply chain materials -- There are large gaps in information on metals, oxides, and other key precursor compounds which feed manufacturing processes to produce components for products such as electronics, automobiles, aircraft, and a whole host of defense applications. Collecting this information further down the supply chain could be accomplished using the same processes and procedures currently employed by the NMIC for mining and concentrate production.

Secondary Mining (Recycling)-- The USGS NMIC does some limited reporting of recycled mineral commodities. Much more could be done in this area and it will become increasingly important as above ground inventories (which are

poorly quantified) continue to grow and as increasing quantities of embedded materials become available as products reach the end of their useful life and become available for recycling.

Question 5: Resource Assessments: In the most recent Mineral Commodity Summaries report, for 2016, USGS notes that our nation now imports more than 50 percent of its supply of some 47 different mineral commodities.

a. Generally speaking, to what extent have we surveyed our lands to determine the extent of our own domestic mineral base?

Response: Although the USGS has completed a significant amount of work on inventorying known mineral resources and estimating the mineral resources that have yet to be discovered, there still remains much to be done to maintain an up-to-date understanding of our Nation's mineral resources, particularly critical mineral resources. Assessments for undiscovered mineral resources are dynamic and must be periodically updated to incorporate advances in knowledge and technology. Thus, even for regions or elements that have been previously assessed, there is an ongoing need for new data and analysis.

The first and only nationwide probabilistic (quantitative) assessment of undiscovered mineral resources in the U.S. for copper, lead, zinc, gold, and silver, was completed in 1996. Future assessments of domestic undiscovered mineral resources will focus on geologic provinces known to have permissive geology for critical mineral resources, rather than a nationwide assessment.

The USGS is currently doing the necessary foundational data collection and research that could lead to such assessments for:

- Rare Earth Elements (REE) and cobalt in the St. Francois terrane of SE Missouri;
- Copper, nickel and platinum group metals in concealed portions of the mid-continent rift;
- REE in clay-rich material in the Blue Ridge and Piedmont region of the southern Appalachians; and
- Critical minerals across multiple regions in Alaska

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b. Do we know what we have in places like Alaska, or are we still a long ways from having useful data to show the full picture?

Response: The USGS, in collaboration with the Alaska Division of Geological & Geophysical Surveys, is improving our understanding of the known mineral resource inventory of Alaska. There remains, however, considerable work to be done to better understand Alaska's potential for undiscovered mineral resources. Alaska is a vast region that is difficult to access; consequently the state is poorly mapped at scales necessary to fully evaluate mineral resource potential. The USGS has recently completed geophysical surveys to assist with on-going and planned geologic mapping efforts.

Question 6: Sage Grouse Withdrawals: The USGS cites the limited amount of exploration activity over the last few decades as a Critical Minerals Resource problem that must be addressed. Since exploration and new mining development are already either restricted or banned on more than half of all federally owned public lands, please tell me how the Department of the Interior's new 10-million-acre mineral withdrawal to protect sage grouse habitat will impact USGS's work of identifying key commodities necessary for existing and emerging technologies?

Response: At the request of the Bureau of Land Management (BLM), the USGS is currently conducting a mineral resource assessment, for all mineral commodities with known resources, in the 10-million acres of land being proposed for withdrawal from mineral entry to conserve sage grouse habitat. This work will inventory known mineral resources and assess the potential for undiscovered mineral resources. This information will be available to the Department of the Interior (as well as to the general public) for making informed decisions on the management of these Federal lands.

Question 7: In your response to my December 18 letter, you said that the USGS has recently produced a mineral resource assessment of six selected deposit groups in the Central Yukon Planning Area in Alaska. While I appreciate that the Survey has released the latest version of the agency's U.S. Mining Directory, I still find it odd that the USGS

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last year released a report mapping 96% of Afghanistan using hyperspectral imaging, while Alaska is still largely unmapped.

a. What will it take in the future for all the prospective mineral zones in Alaska to receive the same level of mapping that USGS has performed for Afghanistan? What is the likely cost and how long will it take at current funding levels?

Response: Conducting a hyperspectral survey of Alaska, with similar parameters as used for the USGS Afghanistan hyperspectral survey, would cost approximately $50M, or about the equivalent of the annual budget of the USGS Mineral Resources Program, for data collection alone. An additional $15M-$20M would be required for data processing. This would be a multi-year effort, as data can only be collected under cloud-free conditions, and data collection would likely be required over multiple summer field seasons.

Question 8: Earthquakes in the Arctic: This is a question that I asked Secretary Jewell, but since I haven't received a response yet, let me ask you directly. The President's 2013 Arctic strategy document emphasizes cooperative efforts with the State of Alaska to respond to natural and man-made disasters. In the last two years there have been significant swarms of earthquakes in the Bering Sea, Northwest Alaska, and the Arctic National Wildlife Refuge.

a. Does your agency have a plan to engage with the State to develop earthquake mitigation strategies for the Arctic region?

b. If not, will you commit to developing one?

Response: These questions would be most appropriately directed to Director of the National Earthquake Hazards Reduction Program (NEHRP) at the National Institute of Standards and Technology. Within the Department of the Interior, the USGS is a member of the four-agency NEHRP partnership but USGS does not have responsibility for developing earthquake mitigation strategies; that is the responsibility of NIST and FEMA.

The USGS responsibilities under NEHRP are to: conduct and support targeted

geoscience research investigations on earthquake causes and effects; produce national and regional seismic hazard maps and assessments; monitor and rapidly report on earthquakes and their shaking intensities in the United States and abroad; work to improve public understanding of earthquake hazards; and coordinate post-earthquake reconnaissance carried out and supported by NEHRP agencies and other organizations.

Question 9: Unconventional Oil and Gas: Is it fair to say that vast "in-place resources" – that is, irrespective of prices – of heavy oil, viscous oil, shale, tight gas, coalbed methane, methane hydrates, hydrocarbon gas liquids, and conventional crude oil and natural gas remain untapped in Alaska?

Response: The USGS Energy Resources Program (ERP) focuses assessment work on undiscovered, technically recoverable resources. Current USGS estimates of mean Alaska North Slope oil and gas resources from conventional, shale, coalbed gas, and gas hydrate reservoirs total about 18 billion barrels of liquids (oil plus natural gas liquids) and about 255 trillion cubic feet of natural gas. These large volumes of oil and gas that are considered technically recoverable using current technology suggest the existence of much larger "in-place resources." Estimates of heavy oil and viscous oil have not been completed because data necessary for making such estimates are not accessible for analysis because they are industry-proprietary information.

Question 10: Unconventional Oil and Gas: It is sometimes pointed out that most of the estimated shale resources in the United States exist under state and private land, not federal lands. But is that true of conventional resources on federal land in Alaska, per USGS estimates?

Response: The USGS has estimated that the largest assessed resources onshore Alaska are located in the Arctic National Wildlife Refuge (ANWR) 1002 Area. Estimates provided by BOEM suggest that the largest assessed resources overall are located in the Chukchi Sea and Beaufort Sea areas of the Outer Continental Shelf (OCS). Both are located on federal acreage.

Question 11: Unconventional Oil and Gas: Based on your assessments, which basin has the highest prospectivity in Alaska?

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Response: The USGS has estimated that the North Slope Basin contains the highest oil and gas prospectivity in both conventional and unconventional reservoirs in Alaska.

Question 12: Would the USGS be willing to partner with the State of Alaska to conduct a survey on very low oil permeability formations on the North Slope of Alaska?

Response: Yes, the USGS would be receptive to partnering with the State of Alaska to conduct a survey on very low oil permeability formations on the North Slope, subject to the availability of funds and other priorities. In fact, the USGS has a long history of collaboration with the State. We should note, however, that a critical element in such a partnership will be data accessibility – access to three-dimensional seismic and rock samples from cores (as well as the corresponding petrophysical data) will be essential in order to complete a proper assessment of these reservoirs.

Question 13: Soil Metal Mapping: The USGS recently released a series of maps showing soil metal values across the contiguous United States. These maps are very useful for land-use planning and mineral development. Currently no such maps exist for Alaska. Does USGS have any plans to complete a similar product set for Alaska?

Response: A soil geochemical landscapes project in Alaska would be the next step in establishing nation-wide up-to-date soil characterization. The USGS has heard from stakeholders about the usefulness of such a map.

Similar sampling density and protocol would be applied to be consistent with the CONUS data collection. With landscape changes underway due to climate change and land use, we look forward to working with the State of Alaska to provide soil baseline data to calibrate future change. Because Alaska is a vast region that is difficult to access, such an effort would require significant resources above what is currently appropriated.

Question 14: 3DEP in Alaska: I know USGS has entered into a partnership with the State of Alaska and some private firms to conduct the Alaska Mapping Initiative. Alaska desperately needs better elevation mapping. Many of the aviation charts are more than 50 years old and dangerously inaccurate in the state's mountain ranges for private aviation pilots, and also inaccurate for land use planning and development, flood forecasting, wetland protection, and basic scientific research. Oil companies have funded LIDAR

mapping of the entire corridor of the Trans-Alaska Pipeline, and the proposed route of a pending companion natural gas pipeline.

The Alaska Mapping Executive Committee is doing a wonderful job of obtaining and producing moderate resolution IfSAR elevation data for the state. After this summer, I'm told just under 70% of the state will have been flown, with the hope being that the remaining 30% of the project can be completed within the next 2 to 3 years. But after the raw data is collected, then it has to be processed and formatted into different maps and data layers.

a. Please outline your vision for completing the next steps of the process, namely the hydrography layer and subsequent production of updated 1:25,000 scale topographic map series for the state.

   Response: At current funding levels for the National Geospatial Program (NGP) along with contributing Federal partners, it will take 6 years (2022) to complete statewide coverage of ifsar elevation data and 7 years (2023) to complete the statewide topographic maps for Alaska. If the $1.5 million proposed additional funds in the 2017 President's budget are enacted, it will take an estimated 5 years (2021) to complete the ifsar coverage and 6 years (2022) to complete all 11,243 Alaska US Topos. Under current funding, only major errors in the hydrography data set are being corrected for the majority of Alaska map production. Approximately 10% of the State's hydrography has been fully updated to meet the higher specifications, where funding contributions have supported such efforts.

b. What long-term plans and strategies are there to ensure essential geospatial data will be updated and maintained to remain current and accessible for the states?

   Response: The NGP updates and maintains national databases of foundational geospatial data layers and delivers them through The National Map (nationalmap.gov). These data support the creation of US Topo products as well as other derived mapping products and services. NGP will continue to investigate potential adoption of technologies that may positively augment our ability to provide national scale, current geospatial data. NGP will also

continue to be judicious with our program funds and seek collaborative leveraging wherever possible with other Federal, State, and local agencies whose missions rely on up-to-date geospatial data. This is done over multiple years with decadal strategies to make the data as useful as possible.

c. What support is planned for ongoing collaborative funding and cost sharing efforts to obtain and maintain essential geospatial framework data in Alaska and nationwide?

Response: The Alaska Mapping Executive Committee has a prioritized list of data layers needed to create a robust mapping foundation, and USGS will continue actively working with the AMEC to seek collaborative funding and support for the full suite of mapping needs. With regard to foundational geospatial data and services, USGS/NGP provides support in a number of ways. Through the Alaska Mapping Initiative the USGS is providing funding and technical support for acquisition, processing, and delivery of ifsar data in Alaska. The USGS has also provided funding, technical support, software tools, and training for the update and improvement of hydrography data in the State. Once ifsar acquisition has been completed, the intention is to support the improvement and maintenance of hydrography data. The NGP will also continue to work with data stewards for other key base geospatial layers in the State to ensure the best available data for each theme is incorporated into The National Map and derived products and services.

d. I know the President's FY 2017 budget proposes to increase funding by $1.5 million for Alaska, bringing the USGS funding for Alaska, so far, to $6.7 million. At that rate, how long will it take to publish updated elevation maps for all of Alaska?

Response: Alaska has many broad mapping needs that are not limited to topographic maps. For example, geologic maps are required to characterize critical minerals deposits, natural hazards, water resources, coastal erosion, oil and gas resources, and permafrost throughout Alaska. To date, the USGS National Cooperative Geologic Mapping Program and its STATEMAP partner the Alaska Division of Geological and Geophysical Surveys has produced detailed geologic maps for 17 percent of the state.

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The $1.5 million proposed increase relates to topographic mapping which is supported/implemented by the USGS National Geospatial Program (NGP). With the proposed increase and continued funding from our Federal partners, we estimate that it would take 5 years (2021) to complete statewide coverage of ifsar elevation data and 6 years (2022) to complete the statewide topographic maps for Alaska.

e. And will the maps be as accurate as the topographic maps that you are producing for the Lower 48 states and Hawaii?

Response: All Alaska topographic maps are compiled to meet the same National Map Accuracy Standards enjoyed by the rest of the nation, though the overall accuracy of any map depends in large part on the accuracy of the data sources used to generate the map. While the Alaska Mapping Initiative is dramatically modernizing key data themes across the State, many data sources used to compile topographic maps in Alaska are not comparable to data sources used in the Lower 48. Ifsar, for example, is a tremendous improvement over legacy elevation data in Alaska. Although it is ideal for Alaska in part because of its ability to observe through cloud cover, ifsar does not equal the fidelity of lidar data used elsewhere in the nation for acquiring elevation data. As a result, the accuracy of individual elevation points used to generate contours in Alaska is not equal to the accuracy, or density, of elevation points derived from lidar in the Lower 48. For other data themes NGP harvests the best available data sources to add other map layers - such as transportation, buildings, trails, and boundaries - to the topographic maps. Many of these datasets come from State and Federal partners, who continuously improve and update their contributed data layers for the project. While this follows the same procedure used for map compilation in the Lower 48, the availability, resolution, currency, and accuracy of the data provided in Alaska may not be equal to data used for topographic map compilation in other states. However, opportunity exists to continue modernizing map data across Alaska. For example, in areas where lidar is well suited for critical applications and terrain, such data would increase the positional accuracy of elevation data and other key data themes (e.g., hydrography) in those areas.

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Question 15: STATEMAP: Within the National Cooperative Geologic Mapping Program (NCGMP), the USGS has a valuable and highly productive cooperative geologic mapping program with the states called STATEMAP. STATEMAP leverages federal funding by requiring states to match federal grant dollars 1:1. This year $5.5 million, or roughly 20% of this program's funding was made available to the states. However, this year, as in most years, the states left a roughly equal amount of funding on the table as the USGS did not make sufficient funds available to fully leverage the available state funding.

a. Within the current budget constraints, can USGS increase the amount of funding available to the states under this program to fully leverage the available state funding?

   Response: Over the past 20 years, the NCGMP has served as a valuable State-Federal partnership that has greatly accelerated the production of critically needed geologic map information for our Nation. The reauthorization of the NCGMP in 2009 stipulates that, of any appropriated amount over that of FY 2005, half would be reserved for STATEMAP. The appropriated level of NCGMP, however, has remained at about $25 million since 2005.

b. During the 23 years of the NCGMP the states have produced almost 4,000 geologic maps covering over 500,000 square miles with only 20% of this program's funding. The bulk of the remaining funds are allocated to the federal portion of this program called FEDMAP. How many maps has the USGS published under FEDMAP during this time with its share of the funding?

   Response: A direct comparison of map production under STATEMAP and FEDMAP can be misleading. Federal funding for the STATEMAP component of NCGMP must by law be directed entirely to cost-sharing for preparation of geologic maps. All other activities that a State geological survey must address in its role as the State's geologic authority (including publication of those maps) are necessarily borne by other funding sources. In contrast, funds for geologic investigations under the FEDMAP component are not entirely directed to the preparation of geologic maps. In addition to the compilation and preparation of geologic maps, FEDMAP funds also are

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directed to: (1) publication costs for those maps, (2) applied studies that require fieldwork, geophysical data collection, and three-dimensional geologic modeling (often resulting in scientific publications rather than maps), (3) geologic studies in cooperation with other Federal agencies, (4) paleontologic and geochronologic investigations and age-dating (which support geologic mapping), (5) development of the Congressionally-mandated National Geologic Map Database, as well as (6) the duties and responsibilities connected with managing a national program.

Maps produced under STATEMAP are typically prepared at the most detailed mapping scale (1:24,000). In contrast, projects funded under the FEDMAP component tend to be of large regional scope. While fewer maps are produced, the area of coverage is substantial. For example, in 2012, 213 maps were published by state geological surveys covering about 73,000 square miles, while 22 maps were published by the USGS, covering about 50,000 square miles. For the time period 1996-2005, approximately 1,150 geologic maps were prepared with FEDMAP funding, covering an area of roughly 430,000 square miles.

Question 16: In the FY 2016 USGS budget, the Appropriations Committee rejected the USGS's proposed deletion of $2 million for mapping activities, and directed the Survey to continue geologic mapping activities in areas of the country where high mineral and energy resources remain unmapped at a reasonable scale. While you talked about this in your letter to me, could you describe in more detail how these funds are being utilized, and what parts of the country are being mapped as a result.

Response: The $2 million in funding supported ongoing mineral resource investigations, such as the hyperspectral surveys in Alaska.

Question 17: The National Geological and Geophysical Data Preservation Program (NGGDPP) is a very important collaborative program for the states that leverages federal funds, yet this program has been funded far below its authorized level since passage. In my home state of Alaska, the state for years was seeking funding to build a new storage facility for drilling cores. It finally gave up on federal funding and just paid for a new storage facility totally from state dollars.

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a. Why has the USGS not proposed more funding for larger projects, in addition to small data preservation projects?

Response: Annually, the NGGDPP awards approximately $800k to competing state geological surveys for preservation of geoscientific materials (for example, samples, logs, data, maps, photographs). Per Section 351 of the Energy Policy Act of 2005, which established the NGGDPP, the Federal share of project costs cannot exceed 50%. The minimum Federal to state 1:1 match requirement and limited federal funds prevent states from proposing larger projects.

Question 18: Alaska Volcano Observatory: Does USGS have plans to fund more maintenance of the analog seismic network that AVO is operating in Alaska? If so how much will be going to the system this year and next?

Response: To address public safety concerns, the USGS used funding received in 2015 to bring defunct and severely impaired networks back on line. This required some maintenance of existing analog telemetry links that USGS cannot use past 2020.The USGS will continue to maintain the existing analog telemetry until the networks are transitioned to digital or regulation prohibits use. The amount spent on analog telemetry will decline as the digital system matures. In FY16, USGS will spend about 70% of its field maintenance budget on restoring analog equipment. However, USGS will make no new capital investments in analog technology.

a. The Federal Communications Commission has decided to sell the frequencies that the current analog seismic monitors are transmitting on by 2020. How is the USGS planning to deal with the frequency issue? If you have to replace the current stations with digital transmitters because of the frequency issue, how much will it cost and will the agency have the money in its budget to pay to replace the entire system, which I'm told could cost upwards of $25 million to convert to digital technology?

Response: USGS radio telemetry networks fall under the direct jurisdiction of the National Telecommunications and Information Administration (NTIA) for radio spectrum allocation. Changes to the spectrum allocation made some USGS telemetry networks for volcano monitoring in Alaska non-compliant. NTIA

authorization permits USGS use of the deprecated frequencies until 2020, providing USGS more time to bring the system into compliance by transitioning the networks to new digital spectrum. Whenever possible, the USGS has made analog to digital conversions. The estimated cost of upgrading existing analog telemetry to a compliant digital system is $18.5 million over four years or $20.2 million over three years. Due to unpredictable weather in the Aleutian Islands and on the Alaskan Peninsula and limited availability of specialized vendor equipment, a four-year conversion plan may not afford the time to complete the transition before the NTIA waiver expires. Completing the conversion in three years, instead of four, requires the additional $4 million for increased logistical support costs (e.g., additional aircraft and boat charters to simultaneously deploy engineers and equipment to remote sites, contracts for instrument installations).At the current funding levels, the USGS will continue to maintain the existing analog telemetry until regulation prohibits this use and make analog to digital conversions whenever possible. Typically, the USGS converts six to eight stations to digital per year. The USGS is exploring options to address the regulations over radio frequency spectrum allocations, which require USGS to convert from the current analog frequencies by 2020.

b. The President's FY 17 budget proposed a tiny increase for the Volcano Hazards Program, just $117,000. My concern is that the AVO seismic network has been underfunded for several years. Right now two of the stations are offline and one is barely functioning. About 24% of the seismic monitors on Alaska volcanoes are not functioning – and while that is a big improvement over the 40% that were not working the year before, it still is a problem. What do you plan to do, to ensure proper funding for the AVO?

   Response: With the 2015 and 2016 funding increases, Alaska Volcano Observatory (AVO) is repairing moribund volcano monitoring networks to working order over the next 3 years.With funding in 2015 and 2016, Alaska Volcano Observatory (AVO) ismaking analog to digital station conversions with prioritization on Very-High-Threat and High-Treat volcanoes that currently have mixtures of analog and digital stations, where additional conversions will bring the entire network into NTIA compliance. The USGS has identified five Very High Threat and 27 High Threat volcanoes in Alaska. None of these 32 volcanoes has complete monitoring networks by National

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Volcano Early Warning System standards. The USGS estimates 237 additional monitoring instruments (e.g., seismometers, GPS receivers, and remote cameras) are needed to close the gaps.

Question 19: Alaska Earthquakes: As I mentioned to Secretary Jewell at a hearing earlier this year, Alaska was hit with a magnitude 7.1 earthquake in January. Fortunately the damage was fairly limited as it occurred in a sparsely populated area – Iniskin -- southwest of the Anchorage "Railbelt" region. But Alaska has been rocked on average once every 13 years since 1900 by a quake that is larger than 8.0 in magnitude. We faced the second largest earthquake ever recorded on March 27, 1964 in Southcentral Alaska (9.2).

a. In 2000 Congress authorized the Advanced National Seismic System to "establish and maintain an advanced infrastructure for seismic monitoring throughout the U.S. that operates with high performance standards." Some 16 years later, many of the baseline performance standards set by the program have not been achieved in Alaska. As other states move to establish early warning earthquake systems, what is the Survey doing to make sure Alaska has access to the instrumentation, technology and funding need to expand and modernize its seismic infrastructure?

Response: Over the past 15 years, the USGS has invested in earthquake monitoring and reporting, seismic hazard assessment and other earthquake loss reduction activities in Alaska, and maintains good collaborations with several stakeholder groups in the state.

Examples include: The USGS funds the Alaska Earthquake Center (AEC) at the University of Alaska Fairbanks (UAF) through a competitive cooperative agreement at about $600,000 per year; supports the Anchorage Strong Motion Network, a collaborative effort among the USGS, UAF, and Alaska Division of Geological & Geophysical Surveys, in which the network consists of more than 30 free-field stations, a borehole site, and several instrumented buildings and bridges; and supports a number of improvements to the Anchorage and Alaska regional seismic networks. In 2010, the USGS awarded UAF with $483,000 plus seismic equipment for upgrading these networks and has improved the Anchorage monitoring infrastructure. As a result, high-quality data on how shaking varied across the Anchorage urban area were successfully collected from the January

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2016, magnitude-7.1 earthquake. The USGS has also supported the Delaney Park geotechnical array in Anchorage, operated by the Univ. of California. Other USGS monitoring investments in Alaska include USGS National Network stations, other stations operated by the USGS National Strong Motion Project, and the services provided by the USGS National Earthquake Information Center.

b. Language was included in the FY 2016 omnibus bill for USGS to conduct a cost-benefit study related to earthquake monitoring in Alaska. What is the status of the report and when will its findings be available?

Response: A working group has been formed to conduct a cost-benefit study for monitoring improvements in Alaska; this task will be completed in the summer of 2016. The working group will consider the costs and benefits of seismic station adoptions, earthquake early warning, as well as improvements to existing monitoring operations. USGS will use the results of this study in its planning for future investment in seismic monitoring in Alaska.

Question 20: Alaska water research: Back in 2007 I sponsored and won approval of an Alaska Water Resources Act that was intended to have USGS conduct surveys of where water aquifers are located in urban population areas of Anchorage, the Mat-Su Valley, the Kenai Peninsula, and Fairbanks. In 2007 it appeared that Alaska was the only state that had not been the subject of USGS surveys of its aquifers for potable drinking water. To my knowledge the act was never implemented by USGS prior to its sunset date in 2012.

a. Is there any funding available today for USGS to conduct surveys of the extent of aquifers in areas of Alaska?

Response: Although the Alaska Water Resources Act passed in 2007, no funding was appropriated to implement the legislation and to conduct the studies described in the Act. Under other authorities, USGS cooperated with the Alaska Department of Natural Resources to assess shallow groundwater resources in the Mat-Su Valley. This work included development of a computer simulation model for analysis of regional-scale groundwater availability. Also in 2013, the USGS produced a paper providing an overview of the issues relevant to understanding groundwater statewide, highlighting the importance of groundwater to surface

water exchange in understanding groundwater availability in Alaska. There are no USGS funds currently identified to conduct surveys of the extent of aquifers in areas of Alaska.

Question 21: The following text appears on the USGS website: "USGS biologists revolutionized thinking about managing wildlife resources, which has provided a sound scientific basis that lets waterfowl conservation and recreational hunting work in tandem as adaptive management, not as conflicting interests."

I share an interest of many Alaskans in the black brant, which is a subspecies of goose that breeds in Alaska and winters in Baja California, and have a few questions about the species.

a. Has USGS conducted any studies regarding the migration and winter habitat of the black brant? And, if not, has USGS compiled information about studies by others on this subject?

   Response: The Pacific Black Brant is a subspecies of black brant that breeds in Alaska and winters in multiple locations along the Pacific Coast, including Alaska. Izembek Lagoon, Alaska, is the primary fall (supporting >95% of the population) and spring (supporting 70-80% of population) staging area for Pacific Black Brant nesting in western Alaska. Fall migration typically involves a mass departure from Izembek Lagoon with a direct transoceanic migration to the west coast of the U.S. and/or Mexico. Historically, most brant wintered in southern California and Mexico, but the number of brant wintering in these locations is declining and a greater number are now overwintering in Alaska. Spring migration tends to follow the coast in a series of shorter migration movements utilizing coastal estuaries along the U.S. and Canada as staging locations.

   The USGS has conducted and participated in multiple studies regarding migration and wintering of Black Brant. In recent years, Izembek Lagoon has become a significant wintering area for brant, with numbers of birds increasing from less than 5,000 in the early 1980's to greater than 50,000 in the mid-2010's. Similarly, Bahia San Quintin in Baja California, Mexico, supports 50-60% of Pacific Black Brant during winter. A comprehensive list of relevant studies can

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be found on the USGS website at:http://alaska.usgs.gov/science/biology/waterfowl/geese.php#BLBR.

b. How many miles of roads are located along the black brant migration route, or located within black brant wintering habitat in California and Mexico?

Response: To our knowledge, there are no assessments of the number of miles of roads located along the black brant migration route or within black brant wintering habitats.

Question 22: Arctic: The USGS FY 2017 budget proposes an increase of $8.8 million for USGS activities related to the Arctic.

a. Can you talk in more detail on the agency's Arctic priorities?

b. What specific research and activities are you proposing to conduct next year if this initiative is funded?

Response: The USGS would support research and development efforts focused on the Arctic through a multidisciplinary approach designed to both individually understand and holistically evaluate ecosystem processes and interactions in the Arctic in order to provide the objective science needed for effective management of Arctic resources.

Here are some examples of such work:

- The Environments Program would use the $1 million increase requested in FY 2017 to analyze certain fish habitats and polar bear populations.
- The National Climate Change and Wildlife Science Center would use the $500,000 increase requested in 2017 to analyze glacier loss and impacts, especially on salmon.
- The Land Remote Sensing Program is requesting an increase of $1.86 million to use remote sensing to predict permafrost melt.
- The proposed increase of $3.5 million for the Natural Hazards Mission Area would accelerate work in underserved Arctic communities, particularly relating to coastal change.

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- The Water Availability and Use Science Program is requesting an additional $1.95 million for the to assess hydrological changes in a warming Arctic.

c. Is this new money, or money being shuffled from existing programs?

Response: The $8.8 million increase requested in the 2017 President's Budget is a request for new funding.Additionally, an increase of $1.5 million within the National Geospatial program for Alaska map modernization will be used in the Arctic region and a proposed decrease in the Mineral Resources program reduces Arctic spending by $500,000. Including the Alaska map modernization funding to be used in the Arctic, the President's budget request includes an increase of $9.8 million for USGS Arctic.

d. Will this research improve our understanding of the resource potential in the Arctic, for either oil or gas or mineral development, or is all of your pending research aimed at other types of research?

Response: In the 2017 President's Budget Request, no funding increase was identified specifically in support of Arctic oil and gas resource assessments. The USGS Energy Resources Program (ERP), within the USGS Energy and Mineral Resources Mission Area, conducts oil and gas resource assessments across the Nation. However, the ERP has several ongoing active projects in the Arctic, including research on unconventional oil and gas (UOG), which will continue with base program funds. These funds will allow for continued studies of shales and other tight formations on the Alaskan North Slope that will help underpin more accurate resource assessments and reduce the uncertainty associated with resource development.

Question 23: Alaska Seismic Network stations/Earthscope: Right now there are several slightly different seismic networks at work in Alaska. Alaska has a little over 100 seismic stations operated by the USGS and the State Seismologist/University of Alaska, partially with grant funding from USGS. The State is about to get more stations, for a total of 260 as a result of the Earthscope project already funded by the National Science Foundation, which is paying to install 260 stations statewide to conduct the first two-year study of hidden "fault" zones in Alaska – the last place in the nation where the Earthscope survey still needs to be conducted. That network will be fully installed by summer 2017. It will

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operate for two years and then NSF will want to get rid of the stations for a nominal cost. The State, according to State geologist Steve Masterman, will want to acquire many of the stations as the backbone of a beefed-up state seismological network. While NSF might be willing to sell the stations somewhat cheaply to Alaska rather than pay for decommissioning, the question is funding to operate them given Alaska's fiscal crisis.

a. Alaska is predicting it will cost about $2.5 million a year to operate and maintain just 100 of the stations. Can USGS provide additional grant funding to help maintain and operate that network – the backbone for an early warning quake network for the North Pacific?

Response: The USGS would be willing to work with the State of Alaska, the National Science Foundation and the Congress to develop a plan to maximize the long-term benefit of NSF's investment in the Earthscope Transportable Array in Alaska. Our understanding is that NSF plans to fund the deployment in Alaska into FY 2019, subject to the availability of funds. The USGS Earthquake Hazards Program does not have flexibility to divert resources at current funding levels. USGS funding does not currently support any portion of the NSF investment in ETA in Alaska. I plan to discuss this matter with the Alaska state geologist and other officials.

Question 24: On top of the seismic monitoring network, there are the 140 separate stations of the Plate Boundary Observatory. Some of these stations are operated in connection with the earthquake monitors, but these are GPS stations that actually measure crustal deformation and are most useful for giving a pre-warning of both earthquakes and volcanic eruptions. The stations also are a major component of the Continuously Operating Reference Stations (CORS), which are the quality control for GPS surveying and navigation and form the geodetic control network in Alaska. There is a growing dispute between Alaska and the BLM over the types of land surveys needed for the government to finish conveying to Alaska and Native corporations their land conveyances under the Alaska Statehood Act and the Alaska Native Claims Settlement Act. There is a technical dispute over the accuracy of GPS surveying techniques, but the dispute is partially the result of the state's concerns that there are just not enough CORS stations in Alaska to guarantee the accuracy of GPS land surveys and patents. My questions are:

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a. Does USGS have any plans for maintaining and more fully funding the Plate Boundary Observatory in Alaska and any plans to actually add more CORS stations in Alaska?

   Response: No. The USGS is not a land surveying entity and does not operate any GPS reference stations in Alaska. CORS is a NOAA/National Geodetic Survey project. The USGS cannot comment on plans for long-term survey reference sites in Alaska.

b. Do you have any opinion on the accuracy in Alaska of using GPS surveys for land patenting at the present time? If the number of CORS stations were increased, would the process be more accurate and how many more stations will be needed to reach a level of accuracy needed for land conveyance patents in your opinion?

   Response: No. The USGS is not a land surveying entity and does not operate any GPS reference stations in Alaska. CORS is a NOAA/National Geodetic Survey project and the USGS cannot comment on the conditions and capabilities of the system.

Questions from Senator Joe Manchin III

Question 1: In 2004, Josh Bolten, the Director of the Office of Management and Budget issued a bulletin to all government departments and agencies entitled "Final Information Quality Bulletin for Peer Review." The bulletin is meant ensure the credibility of scientific information that is released by the federal government. The OMB granted agencies broad discretion in the manner in which a document would be considered either "Highly Influential Scientific Assessment" or "Influential Scientific Information." It is my understanding that the classification of "highly influential scientific assessment" is considered more influential.

While the USGS is a non-regulatory, fact-finding agency you have noted in your testimony before this committee that the USGS works closely with other regulatory agencies, such as the EPA, to "complement their research activities and contribute sound science for their decision making."

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Director Kimball, can you tell us how the USGS determines if a research product is deemed "Influential Scientific Information" or a "Highly Influential Scientific Assessment"?

Response: In determining if USGS research is influential or highlight influential, we: refer to the OMB definitions of for "Influential Scientific Information" or a "Highly Influential Scientific Assessment," and rely on our knowledge of the importance of the topic to society. In addition, we provide our managers and authors with supplemental guidance from the OMB and with internal guidance, processes, and tools developed in-house to help in making those determinations.

Question 2: Director Kimball, on March 28th, 2016 the USGS published a projected forecast for seismic activity in the Central and Eastern United States for 2016. This report examined natural and human caused or "induced" seismic activity —meaning earthquakes attributed to human activity. The report also included a projected forecast for earthquakes in these areas. The report states that earthquake rates were stable between 1980-2010 in the Central and Eastern US followed by a "marked" increase in earthquakes since 2010, with various scientific studies demonstrating that a "majority" of earthquakes are attributed to wastewater injection activities in deep disposal wells.

The report acknowledges there is limited evidence to indisputably conclude the increase is caused by human activities such as fracking.

I suppose my first question whether this report is considered by the USGS to be "Influential Scientific Information or a Highly Influential Scientific Assessment?"

> **Response**: While certainly newsworthy, the report did not meet the technical determination of an "Influential Scientific Information" or "Highly Influential Scientific Assessment." This is because it was based on previously published information and is based on a 1-year model that will be subject to updates.

My second question, Director Kimball, is that Perry, Ohio was one of the Zones of Induced Seismicity examined in this report. Given the proximity of Perry, Ohio to West Virginia and the fact my state sits on similar geological formations for purposes of natural gas extraction as Ohio, did you find any evidence in your report to suggest human-caused seismic activity other than that in the Ohio location?

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Response: USGS identified 21 zones within which peer-reviewed papers had identified seismicity as likely being induced. Seismicity outside of those zones was considered to be natural and treated as such in the analysis. USGS is not aware of any peer-reviewed studies that identify seismicity within West Virginia as being induced.

Questions from Senator Bill Cassidy

Question 1: USGS' budget request includes funding for research on the potential impacts of oil production from unconventional sources – including threats of induced seismicity and potential impacts of oil and gas development on water and ecosystems.

Recently USGS released a 1-year seismic hazard forecast for the central and eastern United States for 2016, which included for the first time, potential ground shaking hazards from both human-induced and natural earthquakes.[2]

Stanford professor Mark Zoback and Ph.D student Rall Waslsh released a study last summer that does not attribute the rise in earthquakes in Oklahoma with oil production from unconventional sources using unconventional methods such as hydraulic fracturing. Instead, their study shows that increased rate of injection of wastewater from well formations using conventional oil extraction techniques[3] has been the primary cause of the recent increase in earthquakes in the central United States.

However, media reports seem to suggest otherwise, linking fracking with earthquakes with headlines such as "7 Million Americans At Risk of Fracking-Related Earthquakes, USGS Says."

- Based upon USGS' work, can you confirm for me that hydraulic fracturing (or "fracking") is rarely responsible for the cause of felt earthquakes?

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[2] This one-year outlook for the nation's earthquake hazards is a supplement to existing USGS assessments that forecast earthquake shaking over 50 years.

[3] Ker Than. *Oklahoma earthquakes linked to oil and gas wastewater disposal wells, say Stanford Researchers*, Stanford Report (June 18, 2015)

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Response: The cited headline is misleading; USGS has been very clear in its scientific publications and media advisories to explain that most induced earthquakes large enough to be felt at the surface are not triggered by the stimulation step that is part of the hydraulic fracturing process, but rather by the injection of wastewater (flowback and produced waters) attendant with the process. In the United States, earthquakes induced by fracking have only rarely been large enough to be felt at the surface (magnitudes no larger than 3.0). There have been no reports of damage due to fracking-induced earthquakes in the U.S.

- Regardless of how it is portrayed in the media, isn't it true that wastewater disposal - an activity permitted under the federal Safe Drinking Water Act - is the primary cause of the recent increase in earthquakes in the central United States?

Response: Yes. Wastewater disposal by deep injection seems to account for all of the cases of damage by induced earthquakes associated with modern oil and gas activities.

- Isn't it also true that relative to the number of injection wells in the United States, which are close to 40,000, very few injection wells have been linked to induced seismicity and that the risk from these wells if very low?

Response: Roughly one well in a thousand seems to induce earthquakes large enough to be of concern to the public. However, high injection rate wells (>300,000 barrels/month) are much more likely to be associated with earthquakes than lower rate wells; these may account for 10% of the wells associated with earthquakes.

- Why didn't USGS prepare a similar analysis several years ago when the number of earthquakes in the central US was ballooning?

Response: By the end of 2011, it was clear that within the central and eastern U.S. the earthquake activity was increasing and that the likely cause was fluid injection related to the modern boom in oil and gas production. In response to this, the USGS initiated a new effort to investigate these new sources of earthquake activity. Motivating the USGS hazard assessment that was described in the recently released

report required convincing a large body of stakeholders that the new earthquake sources were due to human activities.

It also required developing new technical approaches specific to these new sources of hazard. The 2016 report represents the first short-term forecast of earthquake hazard that the USGS has produced other than a large-earthquake aftershock forecast. It is a robust product, thoroughly reviewed and vetted by experts in the field, and rigorously reviewed for scientific integrity.

- Since risk must focus on both hazards and exposure level(s), what are the risks associated with these seismic events relative to their proximity to both people and property?

Response: The USGS Open-File Report is only intended to assess the hazard, not the risk. Risk is assessed by state and local government agencies, among others; it requires local knowledge of building fragility, proximity to critical facilities, and the like.

- Do all of these earthquakes have a similar intensity?

- Do all of these earthquakes reach surface level?

Response: No. Intensity is a measure of earthquake shaking effects. Whereas magnitude is a measure of the size of an earthquake, the intensity of that earthquake depends mostly on how far from the earthquake the intensity is measured. Intensity gets smaller with greater distance from the epicenter.

Large earthquakes can involve fault slip that extends from depth to the surface, causing visible breaking of the ground; however, to date all earthquakes identified as induced have occurred on buried faults with no surface rupture.

- What action can concerned citizens take to prevent injury or property damage?

Response: Anyone living where earthquakes, natural or induced, occur should be prepared for earthquake shaking. There is a large body of literature that describes how to be prepared for earthquake effects, for example at fema.gov/earthquake.

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- Will the USGS prepare an assessment for 2017 of the risk of damage from earthquakes in 2017?

Response: The USGS 1-year hazard assessment published in March 2016 was an experimental product; we have not committed to publish an annual assessment of induced earthquake hazard in the United States. The Administration has requested an increase of $700,000 in FY 2017 for our work on induced seismicity—which, if funded, would support such an annual assessment.

Question 2: The Safe Drinking Water Act, Underground Injection Control program, obligates either states or the EPA to regulate wells that dispose of oil and gas field waste or brine (UIC, Class II wells).

Both state and federal regulators use procedures to mitigate seismicity including avoiding injection near existing faults, and reducing injection volumes or pressures or terminating injection if earthquakes are tied to an injection well.

- What actions are state regulators in Oklahoma and Kansas taking to reduce the man-made earthquake risk?

  Response: In both states, regulators are using earthquake data recorded on regional and local seismic networks to associate wastewater injection operations to nearby earthquakes. On this basis, well operators are being required to either reduce injection rates or to terminate injection. This seismic monitoring approach to regulation seems to be effective. Additional information may be obtained from the relevant state regulatory agencies.

- Have any risk reduction and mitigation strategies required by state regulators been conducted in collaboration with affected stakeholders such as industry, academia and environmental organizations?

  Response: This question would be most appropriately directed to EPA—the USGS is not a regulatory agency and does not track state regulation of wastewater injection.

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- Are there economically viable alternatives to injecting produced water, for example processing and reuse?

  Response: The USGS does not have information on the economic viability of alternatives to wastewater reinjection though we are aware that other agencies, such as the Department of Energy, are investigating such alternatives.

- Is the earthquake risk likely to decline in Oklahoma and Kansas as production declines due to low oil prices?

  Response: It seems likely that as oil (and gas) prices decline, demands for wastewater injection/disposal would also decline, and therefore lower the chances of earthquake triggering. However, the earthquake triggering phenomena is complicated and we know of no published study that has confirmed these associations.

- Dr. Zoback suggested that injecting the wastewater back into the producing well formation as a way to mitigate any risks associated with wastewater injections.

  - Has USGS conducted any research or studied the viability of this technique to reduce the occurrence of seismic activity?

    Response: USGS has not field-tested this possible hazard mitigation technique, but our research generally supports this statement. In fact, about three-quarters of wastewater is, and has been in the past, injected into oil and gas reservoirs to enhance production (~856 Mbbl/year), yet there are very few cases of seismicity resulting from such operations.

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Questions from Senator Mazie K. Hirono

Question 1: *Rapid 'Ohi'a Death*

The Ohi'a tree is a native species that is an anchor to Hawaii's rainforests and is currently being threatened by Rapid Ohi'a Death, or ROD. As of early 2016 ROD, which has a 100% mortality rate for infected trees, has impacted 34,000 acres of native forests on Hawaii Island. As you can imagine, this crisis situation requires a coordinated effort by local, state, and federal efforts, including the USGS.

Can you provide an update on the models that USGS scientists have been constructing to predict the spread of the fungus that causes ROD? When will these models be ready to implement and how has the recent prediction by scientists that burrowing beetles are spreading ROD impacted model development?

Response: The USGS is starting an effort to analyze data on the location and characteristics of sites with confirmed ROD cases to characterize the physical and biological factors that affect distribution of ROD across landscapes on Hawai'i Island. We are currently working with our partners at the USDA-Forest Service, University of Hawai'i, and the Hawai'i Division of Forestry and Wildlife to compile and organize the widespread information collected to date on the location, tree data, and habitat characteristics of confirmed ROD sites and adjacent areas, as well as data on the distribution of ROD that was collected during recent aerial surveys. If available, information of the distribution and spread of ROD by insects and other vectors will be included in the analysis. The data will be used to identify both spatial and temporal characteristics of the distribution, spread, and habitat characteristics of the *Ceratocystis* pathogen on the island of Hawai'i, and to assess its severity and impacts on 'ohi'a forest types within a range of moisture and elevation regimes.

We expect that our models will allow us to make predictions about the potential spread of the pathogen into other forested areas throughout the Hawaiian archipelago. Effective management requires a clear understanding of the potential distribution of *Ceratocystis*, along with rates and patterns of ongoing spread and subsequent 'Ohi'a tree mortality. This information will help identify options that may be taken to reduce the potential for spread of *Ceratocystis* into other important natural resource areas, particularly those supporting important ecological, economic, and cultural areas.

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We have also started the development of genetic methods for the detection of the fungus that is causing ROD. We have developed and tested a lab method and are now working on three things: 1) we are refining the method to distinguish between the two strains of the ROD-causing fungus; 2) we are collaborating with the USDA Agricultural Research Service on analysis of field samples and validation of methods, and; 3) we are modifying the methodology so that the analysis can be done rapidly in the field.

Question 2: *Alibizia Work*

USGS, in collaboration with UH-Hilo, worked to collect satellite imagery of the forest canopy in Puna, on Hawaii Island, following Tropical Storm Iselle in the fall of 2014. This imagery was gathered to assess the most heavily impacted areas and develop a model of tree canopy conditions that were impacted during the storm.

Can this model be used to identify the highly invasive albizia trees in areas with canopy conditions (species composition, height, and density) similar to those impacted by Iselle in order to locate and remove albizia trees to mitigate impact from future storms? What other steps can be taken to identify albizia trees and potential hazard locations for the future?

Response: Yes, Pictometry Satellite Imagery can be used to detect albizia trees in areas with canopy conditions similar to those impacted by Iselle. Scientists at the USGS Pacific Island Ecosystems Research Center, in collaboration with staff at the University of Hawai'i at Hilo's Cooperative Studies unit, are currently analyzing data collected from pre-and post-hurricane dates in the lower portion of the district of Puna where hurricane Iselle has its greatest impact when it made landfall in August 2014. Pre-Iselle data was collected by the University of Hawaii, and post-Iselle data is based on Pictometry Satellite Imagery.

Our study area in the Puna District covers 28,417 acres, and included some of the most heavily wind-damaged forests near Pahoa, Nanawale, Lava Tree State Park, the Pahoa Kapoho Road, and Pohoiki Road. Fallen trees cover 346 acres of the study area. An Albizia map produced by UH Hilo indicated that 2,686 acres was covered by Albizia forest in 2014; thus we can calculate that about 12.9% of the Albizia forest in the study area was blown down during the 2014 storm. Although we cannot determine for sure if

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Iselle caused all of these trees to fall based on these snapshots in time, the timing is suggestive since these fallen trees are no longer visible in more recent imagery taken in January 2016 due to vegetation regrowth.

Our work is now focused on evaluating the characteristics of damaged versus undamaged areas. We have plots in damaged and undamaged areas, and are determining the percent cover, tree height, and species composition using very high-resolution aerial imagery. For each plot we are also identifying site characteristics (e.g., proximity to roads or non-forest lands, slope of the land) and habitat characteristics (e.g., soil and lava type and age, rainfall, elevation) to be used as variables in our analysis of the spatial patterns of impact from hurricane Iselle. The results of this study should help us to construct a spatial model that can help predict other areas throughout the State that may suffer from similar impacts from future hurricanes.

Question 3: *Water Resources Data Collection*

Freshwater availability is a growing concern in our nation, but especially in Hawaii as an island state that is affected by increased temperatures and decreased rainfall events. USGS's stream gages have played an important part in monitoring the current and historic freshwater availability in the state.

How can we leverage this tool to encourage our communities to embrace a culture of freshwater conservation?

Response: In a 2004 publication, the USGS showed that streamflow at all seven long-term streamflow stations in Hawaii declined significantly during 1913 - 2002. Similarly, streamflow declined at most other stations with 50 years or more of record. Streamflow declines corresponded to declining rainfall, which likely is reflected in a reduction in groundwater storage and recharge. The USGS currently is working with the Hawaii Community Foundation and the Aloha+ Challenge Dashboard on these issues. Continued long-term monitoring and the evaluation of the inter-relationship of groundwater, surface water and climate is key to documenting changes in water availability and to making sound decisions. However, the number of streamgages in Hawaii, which are key to assessing island water resources, has been reduced from about 200 streamgages in the 1960's to about 70 today.

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Question 4: *USGS Facilities in Hawaii and the Pacific*

Many USGS facilities are over 40 years old and outmoded. However, the mission of some USGS organizations such as the National Wildlife Health Center and its Honolulu Field Station are expanding in Hawaii and the Pacific and are in need of modernized laboratory spaces.

In light of this, what are USGS's plans for modernization of facilities?

Response: The science the National Wildlife Health Center (NWHC), the Honolulu Field Station (HFS), and other United States Geological Survey (USGS) Science Centers perform is vital to the management of this nation's natural resources, and to the protection of public health, the economy and national security. The USGS is aware of the need to modernize many of our facilities, including the NWHC. The USGS is currently working to identify the modernization needs of its mission critical portfolio to continue to accomplish the bureau's scientific mission and will continue to evaluate and address modernization issues as the budget process allows.

Question from Senator Elizabeth Warren

Question: Last month, researchers at USGS published a paper suggesting that a static model for future sea level rise is insufficient. Although sea level rise will submerge many landscapes along the Atlantic Coast, large portions of the coastline sea level rise may instead be altered and disrupted in response to rising sea levels.

Good information about the precise effects of sea level rise will be critical to mitigating against its impact, and the paper indicates that these effects may not be simple to predict. Given that, what next research steps are necessary and how can USGS help us better understand the impact of climate change and sea level rise on the Atlantic Coast?

Response: Evaluating the variable response to sea-level rise (SLR) beyond a static model highlights a number of research areas that will improve assessments and forecasts of the vulnerability of ecosystems, landscapes, communities and infrastructure to climate change and sea-level rise. Research that identifies feedbacks between the geologic, oceanographic and hydrologic processes that drive erosion, flooding, and recovery of coastal systems is a fundamental need that informs our understanding of coastal

resilience. We also require better knowledge of ecological responses to coastal change, such as thresholds at which wetlands may no longer be able to migrate inland or accrete vertically, which determine their sustainability and ability to provide critical ecosystem services. Quantifying ecosystem benefits, from assessing the value of mainland coastal protection afforded by barrier islands to estimating the impact of habitat loss on our economy, puts a dollar amount on what we stand to lose in the face of climate change and can be used to quantify tradeoffs in different adaptation pathways. We know that impacts to coastal areas occur at both short (storm events) and long (SLR) timescales, but research is needed to integrate these timescales to provide robust forecasts of hazards and vulnerability useful for planning. As climate change impacts are increasingly felt, people will to continue to modify coastal environments depending on the level of the threat and resources available to them; we still have much to learn about how these modifications affect coastal processes and environments, as well as how to anticipate and include human actions in our coastal hazard forecasts. As we address research needs to enhance decision support, we also need to build baseline data and observational capacity to make consistent products available throughout the Atlantic coast, and for vulnerable coasts nationwide. Finally, we must invest in delivering our research findings in ways that are actionable by a broad spectrum of decision makers from federal agencies to local emergency responders.

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Questions from Chairman Lisa Murkowski

Question 1: Earthquakes Monitoring: Can you tell me about the operations of the Alaska Earthquake Center? How much of the Center's budget is currently being provided by USGS and how much is coming from the state and from private businesses? I've heard in the past from Michael West, the state's seismologist, that more than half of the budget has come from the state and private businesses that have paid the Alaska Earthquake Center to record quakes along the Trans-Alaska Pipeline, and in other potential development zones.

a. Do you know how Alaska's contribution to the operation of its seismic network might compare to other states in the Lower 48?

Answer: The respective levels of funding provided by the USGS and Alaska and six various western states for seismic monitoring is shown in the table below. The western states receive the majority of USGS funding for seismic monitoring of the country as a whole. This comparison shows that the Alaska network receives the lowest percentage of USGS support among these examples.

In addition to the funding included in the table, the USGS also funds the Mid-America Integrated Seismic Network through the Universities of South Carolina, Memphis and Saint Louis (combined $995,000), and the Northeast Seismic Network through Columbia University ($315,000). Many of these networks are operated from academic institutions that provide indirect support in the form of facilities and faculty salaries that are hard to quantify and are thus excluded from this comparison. Also excluded are seismic monitoring activities in conjunction with volcano monitoring.

For Alaska, the "Other" category of funding includes NOAA support for tsunami monitoring in the amount of $240,000. The Alaska Earthquake Center does receive funding from private sources including Alyeska Pipeline Service Company and the Bradley Lake Hydroelectric Project. These funds are not included as they provide support for specific facilities, and generally do not support the broader network. Similarly, these kinds of "Other" funds are not included for the other states.

The Arizona seismic network is funded from overhead charges on other federal grants the Arizona Geological Survey receives. Costs for earthquake early warning systems in California and the Pacific Northwest are not included in this comparison.

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State	Total Cost	USGS	State	Other	# Stations	Data Sources
California	$ 15,070,913	59%	41%	0%	1300	California Geological Survey
Alaska	$ 1,670,000	38%	48%	14%	140	Alaska Earthquake Center
Utah	$ 2,400,000	64%	32%	4%	200	USGS & Utah Geological Survey
Washington & Oregon	$ 1,965,000	75%	25%	0%	350	USGS & Washington & Oregon Geological Surveys
Arizona	$ 45,000	0%	0%	100%	8	Arizona Geological Survey
Nevada	$ 505,000	100%	na	-	130	USGS

Question 2: Land Conveyance: In recent years the BLM has wanted to move to making state land conveyances and ensure that patents for transfers rely on GPS-based surveys. I know the state has expressed real concerns about the accuracy of those surveys. Apparently the state's concerns are that there currently aren't enough GPS calibration stations in Alaska, so-called Continuously Operating Reference Sites. I know that the state and BLM are seeking an independent peer review of the accuracy of GPS-based land conveyances in Alaska that might be finished late this year.

a. Can you explain more about the state's concerns and exactly why the state does not want BLM to switch to this new conveyance system without the state's agreement on the accuracy of the land patents?

Answer: The State of Alaska has best expressed its views on the survey of Alaska's remaining statehood land entitlement to the Bureau of Land Management (BLM) via extensive written correspondence, and examples of this correspondence are attached for introduction into the record to provide detailed explanations of the State's interests. The State understands the primary motivation for BLM's novel survey proposal (to be conducted only in the State of Alaska and only on land it is responsible for patenting in accordance with Section 6(g) of the Alaska Statehood Act) is based upon anticipated immediate cost savings to BLM, and is concerned the desire to achieve these cost savings may compromise technical standards and thus the State's valid interests. Most simply, the State is concerned this proposal may be a cost transfer from BLM to the State rather than an actual cost reduction, which would be inconsistent with the federal government's responsibilities in the Alaska Statehood Act. Additionally, BLM continues to ignore the provisions of ANILCA that affirm the State of Alaska has sole authority to accept (and thus not accept) protraction surveys in lieu of field survey for patent of its statehood land entitlement.

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Question 3: Minerals: In your prepared testimony you talk about Alaska's likely bounty of minerals. Having the second largest coal reserves in the world, the fifth-most copper and gold reserves, the sixth-most zinc, the eighth-most lead and the ninth most silver is pretty impressive. Unfortunately as you say in your testimony only about 17% of the state has been mapped geologically, much less with other modern techniques. We have heard in testimony the benefits of geologic mapping to natural resource development.

a. Can you provide any specific examples of this in Alaska?

Answer: Geologic maps at an appropriate scale constitute a fundamental informational layer for geologists to understand the geology of an area and potential locations of mineral and energy accumulations. Alaska is not even completely mapped at a regional scale of 1:250,000, and estimates of the percentage mapped at a scale usable for resource development and geologic hazard analyses (1:63,360 or larger) vary between 8% (by the USGS) and 17% (by the Alaska Division of Geological and Geophysical Surveys). The low percentage of map coverage, current mapping rates and the size of the state indicates it will take at least 400 years to complete mapping Alaska at a scale appropriate for natural resource development and geologic hazard assessments. This is materially impacting mineral and energy development, and community sustainability in the state.

Here are four recent examples of natural resource developments benefitting from geologic mapping in Alaska:

1. Repsol and Armstrong Oil recently announced a significant oil discovery on the North Slope with announced contingent resources of between 500 million and 3.7 billion barrels of oil. The exploration geologists who made this discovery used the Umiat geology map produced by Alaska's Division of Geological & Geophysical Surveys. Company geologists used this map to tie surface exposures and mapped folds and faults that control the surface distribution of rock units to the geophysical and drillhole information. Understanding the geology on surface as defined by a geology map greatly informs the interpretation of subsurface data and provides greater confidence in subsurface interpretations necessary for resource calculations. Production of this map was made possible with funding from the USGS STATEMAP program and the State of Alaska. This discovery may open additional areas to exploration that were previously not considered prospective. This is an example of how a geologic map can help with an oil discovery and change perception about the potential for additional oil discoveries in an area, thereby driving additional exploration and potentially discoveries.

2. Company geologists at the Pogo mine credit geological mapping and interpretations, again by the Alaska's Division of Geological & Geophysical Surveys for the discovery of 2.2 million ounces of gold at the Pogo gold mine. These ounces equate to 6-7 years of mining for the 320 people who work there, in addition to the numerous businesses supported by the mine. The mapping defined

the ages of faulting and igneous intrusions that led company geologists to explore a previously untested area. The company continues to explore in that area and there is a considerable likelihood that additional reserves will be added. This geologic map was aided by a State-funded airborne geophysical survey that provided improved geologic understanding between the sparse outcrops in the area. This is an example where geophysical surveys in an area of sparse exposure, coupled with detailed geological mapping and age dating provided the information necessary to discover additional mineral resources. This project was jointly funded by the USGS STATEMAP program and the State of Alaska.

3. Company geologists with International Tower Hill (a small mining company) credit the geologic understanding gained from geologic mapping by Alaska's Division of Geological & Geophysical Surveys in the Livengood mining district for the discovery of the main orebody at the Money Knob gold deposit, which contains over 20 million ounces of gold. In a letter to the Alaska Division of Geological & Geophysical Surveys, the company wrote:
"It was the combination of structural and stratigraphic ideas that came out of the state mapping program that first led to our exploration though the Cambrian thrust sheet and eventually the discovery of the main body of mineralization. There is no question that the data was instrumental to the discovery."
The geologic mapping changed the interpretation of the rock units, and led to a recognition of the potential for intrusion-related gold deposit. In turn, this led to targeting of initial drill holes, and the resultant discovery. As with the previous two examples, this was jointly funded by the USGS STATEMAP program and the State of Alaska.

4. In late 2015 Freegold Ventures announced a copper-gold discovery at their Shorty Creek property in Interior Alaska. This discovery was based on a 1998 airborne geophysical survey by the Alaska Division of Geological & Geophysical Surveys, funded by the State of Alaska. Modern re-analysis and modeling of the geophysical data showed that previous drilling had failed to penetrate the geophysical anomaly. Deeper drilling by the company intercepted over 300' of copper-gold mineralization with a grade of 0.71% Cu-equivalent. There is very poor rock exposure in this area, and the mineralization that was encountered by drilling does not outcrop on the surface. Without the high-quality geophysical mapping this discovery would not have been made. This is also an example of the benefit of obtaining, and maintaining high-quality data that can be re-evaluated as modeling and computing software and capabilities improve over time.

Question 4: 3DEP Mapping: Can you talk more about the importance of completing elevation mapping in Alaska? My understanding is that current elevation maps are grossly in error and dangerous for everything from commercial aviation to flood predictions, partially because they are 50 years old, partially because it was hard to map

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from the air in heavily forested areas prior to the development of LIDAR and IfSAR, and, of course, 129 million acres of Alaska are covered by commercial forest lands. Just what are the real world results that affect Alaskans because of the lack of good elevation mapping?

Answer: 3D elevation data is fundamental to a robust geospatial infrastructure and is foundational to many other key sets of data that are built from it. Lives are quite literally at stake when elevation data is lacking, because it is critical for modern aviation safety; flood and tsunami forecasting; emergency response; landslide and coastal erosion assessment; earthquake and volcano assessment; civil engineering, pipeline, utility, and transportation planning; navigation system management; forest land and resource management; renewable energy planning; and much more. Elevation is an also indispensable component for predictive modeling, and is required for a mature GIS that is able to realize its predictive and prescriptive potential. When elevation data is incomplete or inaccurate, reliable predictions of the impact of land management decisions cannot be made.

Accurate 3D elevation data also helps ensure water-based safety through supporting reliable navigation and location systems; risk assessment and mitigation planning; and responsible development that is consistent with public health and downstream effects. It is used to generate effective wildfire containment strategies, plan transportation routes, and identify best locations for communications towers, wind farms and hydrologic power sites. It can also be used to visualize view shed impacts of proposed developments.

Accurate elevation data that is considered essential for business in the rest of the U.S. is still unavailable for large parts of Alaska, although great progress has been made in the past six years. Currently 30% of the state remains unmapped with modern 3D elevation data. Not only does this hamper the ability to make responsible land use decisions in these areas, but commercial industry does not have the input required to generate new and innovative solutions for navigation, responsible resource conservation and development, and renewable energy.

Until recent efforts to gather uniform, accurate, statewide elevation data for Alaska, the National Elevation Dataset (NED) derived from 1950's era topographic maps was the only available elevation dataset except for extremely limited, project-specific areas. The surface of the moon and Mars were better mapped than Alaska. Vertical inaccuracies in the NED for Alaska were orders of magnitude greater than that of other states, hundreds of meters as opposed to a maximum vertical inaccuracy of 15 meters. This data, with ridgelines and mountain ranges reportedly displaced by as much as two nautical miles, did not satisfy Alaska user requirements or national priorities. (David F. Maune, PhD, PSM, PS, GS, CP, CFM, 2008). Since 2010, over 70% of the state has been mapped with accurate Interferometric Synthetic Aperture Radar data, or IFSAR, which uses radar sensors on fixed wing aircraft to collect highly accurate elevation data.

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The most consequential real world result may be safe aircraft operations. Inaccurate topographic data prevents pilots from knowing their position relative to the terrain and can be deadly in steep, mountainous topography where adverse and unpredictable weather is the norm – especially the case in a State that has more than three times the number of privately licensed pilots per capita than of any other state.

In a tragic and specific example, in 2010, an F-22 Raptor crashed southwest of the Denali Highway in harsh terrain that posed challenges including potential avalanche risk for recovery efforts, and toxic runoff into an adjacent stream if recovery of hazardous materials from the crash site were not recovered. Newly collected, unprocessed 3DEP IfSAR elevation data was rushed by USGS to aid the recovery effort because it was not already available. Accurate 3D modeling and visualization of the crash site enabled safe recovery operations to commence, including identification of suitable landing sites and staging areas. Without the IfSAR data, the NED would have been the only other alternative and was found to be in error by 90+ meters.

The cost of the aircraft alone was $150M, if improved elevation data helps even one such aircraft avoid a crash in the future, the entire effort would pay for itself more than double. In addition to this cost savings, using IfSAR data to aid recovery efforts afforded recovery personnel greater safety during operations and avoided stream remediation costs by the safe removal of crash site debris. Cost avoidance estimated for the National Requirements for Enhanced Elevation Data USGS Open-File Report 2013-1237 by E-Terra were conservatively $3M annually; with $24 M annual cost avoidance benefit projected (G.I. Snyder et al, 2012).

Alaska is also the only state within the Arctic Circle, and is disproportionately impacted by the effects of climate change including permafrost thawing, greater wildfire risk, increased sea storm severity, and coastal erosion. Over 70% of Alaska's population lives in coastal areas, and many villages are at risk from severe wind and waves that are no longer suppressed by sea ice and are more damaging than ever. Villages such as Kivalina are falling into the sea. 3D elevation data is used to map flood inundation areas and plan for evacuation and relocation, plan operations and containment strategies for fighting wildfires, and is used to measure ongoing changes in the landscape.

The need for a complete, accurate, elevation dataset in Alaska is great and time is of the essence. Nationally the annual benefits of 3D elevation are in the millions; in Alaska annual benefits to the state are estimated to be at least $15 million due to improved safety, informed decision making, and eliminating redundant, labor intensive efforts to derive elevation information from outdated sources or maintain agency or project-specific

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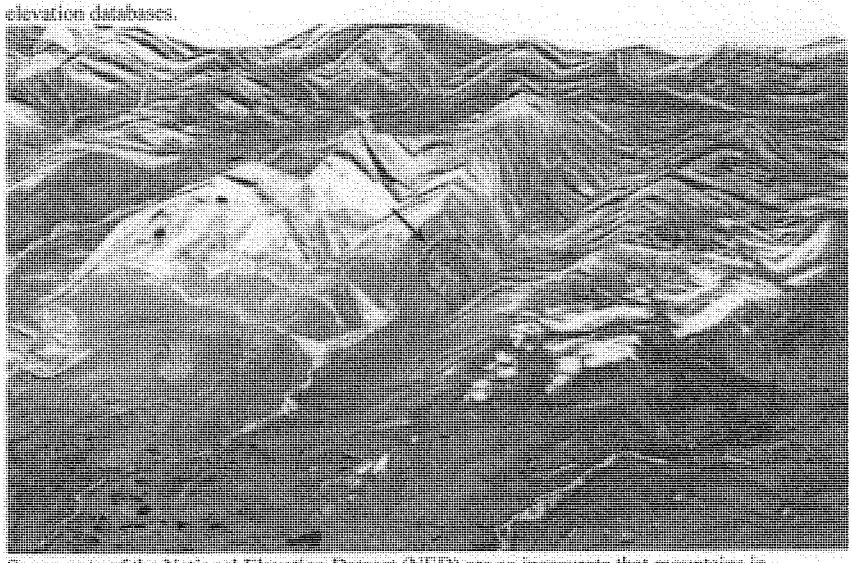
elevation databases.



Some parts of the National Elevation Dataset (NED) are so inaccurate that mountains in Alaska are shown miles away from their true location, and rivers appear to flow up and over hills, as shown near the arrow on the figure above. Satellite image provided by the University of Alaska Fairbanks (G.I. Snyder et al, 2012).

Cited in this response:

David F. Maune, PhD, PSM, PS, GS, CP, CFM. (2008). *Digital Elevation Model (DEM) Data for the Alaska Statewide Digital Mapping Initiative (SDMI).* Fairfax, VA: Dewberry.

G.I. Snyder, L. S. et al (2012). *National requirements for enhanced elevation data.* U.S. Geological survey: Open-File Report 2013-1237, 371 p. http://pubs.usgs.gov/of/2013/1237/

Question 5: Oil Discovery on the North Slope: I have heard of a significant oil discovery on Alaska's North Slope. Can you explain how much oil may be present on the North Slope that is yet to be discovered?

Answer: To Alaska's benefit, joint exploration by Repsol and Armstrong in the eastern Colville River delta area of the central North Slope has yielded important new oil discoveries. Since 2012 the companies have drilled 12 wells and sidetracks on leases now incorporated into the Pikka Unit, plus three additional wells to evaluate prospects

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outside the unit. Shortly after the 2012-2013 winter drilling season, the companies announced they had encountered oil in three wells at multiple depths. Three more exploration wells in early 2014 prompted the partnership to announce additional "positive results" warranting consideration of the discoveries for economic development. Following another successful three-well drilling season in early 2015, the companies released more specific information, stating that four wells had encountered a Jurassic Alpine sandstone oil pool covering more than 15,000 acres, and an additional seven wells had penetrated a Cretaceous Nanushuk Formation oil pool with good reservoir properties and an oil column more than 650 feet thick extending across more than 25,000 acres.

Exploration drilling in the Pikka Unit has also confirmed oil in four additional reservoir intervals, but the Nanushuk and Alpine pools are the largest and are targeted for simultaneous initial development in the companies' proposed Nanushuk development project. The U.S. Army Corps of Engineers is preparing the project Environmental Impact Statement, currently in the scoping phase. The proposed project includes four gravel pads to accommodate three drill sites, a central processing facility, and an operations center. Maps and other details can be found at http://www.nanushukeis.com/projects/nanushukeis/projectdescription.html.

Third-party estimates of contingent recoverable oil volumes for the Pikka Unit as a whole were announced by the partners in late 2015. The estimates are provisional, and span a wide and range, with 90% probability of at least 497 million barrels, 50% probability of at least 1.4 billion barrels, and 10% probability of 3.8 billion barrels or more. These contingent resource categories, though subject to revision pending further exploration, would represent 1P (proven), 2P (Proven + Probable), and 3P (Proven + Probable + Possible) reserves when the project is sanctioned for commercial development. With estimated production rates of up to 120,000 barrels of oil per day, the Nanushuk project would represent the largest new North Slope oil development in many years, providing essential new oil revenues and materially stemming the TAPS throughput decline.

As for oil and gas remaining to be discovered in the Arctic Alaska region, DNR relies on detailed assessments conducted by the USGS and BOEM, both of which produce probabilistic estimates of undiscovered, technically recoverable resources. USGS assessments are limited to onshore lands and state waters, whereas BOEM is responsible for the federal offshore of the Outer Continental Shelf (OCS). Altogether, the most recent compilation of multiple federal assessments, including unconventional as well as conventional plays, indicates that Arctic Alaska hosts estimated mean undiscovered, technically recoverable resources of 42 billion barrels of oil and gas liquids plus more than 363 trillion cubic feet (TCF) of natural gas. Of this, approximately 18.3 billion barrels of oil and gas liquids plus 255 TCF of gas are assessed onshore and in state waters, of which nearly 17.1 billion barrels and 110 TCF represent conventional plays and almost 1.3 billion barrels plus more than 145 TCF represent unconventional resources (shale oil, shale gas, hydrates, and coal bed methane). Unconventional plays are not assessed in the OCS; BOEM estimates that the Beaufort and Chukchi shelves host

mean undiscovered, technically recoverable conventional resources of approximately 23.8 billion barrels oil and gas liquids plus 108 TCF of gas.

It would be entirely speculative to attempt to estimate the fraction of these totals that might eventually be discovered by drilling and the subset of the discovered resource that will be commercially viable to develop. Those figures depend on many future conditions that are difficult to forecast, including future commodity prices, regulatory certainty relative to leasing and permitting, legal and environmental challenges, pace of exploration investment, and the commercial and operational longevity of the Trans-Alaska Pipeline System.

THE STATE of ALASKA
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June 26, 2014

Mr. Bud Cribley
State Director
Bureau of Land Management
222 West Seventh Avenue, #13
Anchorage, Alaska 99513-7504

Dear Mr. Cribley,

Thank you for the opportunity to review the draft proposal presented by BLM for revised documentation requirements to expedite the patent of state selections. The proposed process is indeed a significant departure from the existing, well-established process. Further, the state understands the motivation and desire of the BLM and the DOI to proceed in the implementation of this process.

The State, however, is curious about BLM's authority to unilaterally implement this new and untested manner of conveyance, particularly in Alaska. Based on our research of the pertinent federal laws and regulations, our understanding is that conveyance without survey can only be done with the patentee's explicit approval. The proposed conveyance process relies on a planning tool that is specifically identified as "not a survey" by BLM's own regulatory manual. The amended protraction diagram outlined in the information provided to the State is specifically identified as a planning tool, not a survey, in sections 3-145 through 3-147 of the Manual of Surveying Instructions 2009.

The proposed program presented to the State would significantly reduce the cost of survey to the BLM while passing along those same costs to the State of Alaska. The State is not insensitive to the desires of the BLM to reduce costs and expedite the conclusion of the state land entitlement issue. We would be willing to explore options that expedite the conveyance process, but that do so in a manner that is beneficial to both the BLM and the State. However, before these discussions can continue, the State needs a clear understanding of the BLM's basis for proposing a conveyance process that radically departs from the applicable legal standards and those in place at the time of the passage of the Alaska Statehood Act.

I look forward to continuing the conversations in the near future.

Sincerely,

Brent Goodrum
Director, Division of Mining, Land and Water

THE STATE of ALASKA
GOVERNOR BILL WALKER

Department of Natural Resources
COMMISSIONER'S OFFICE
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January 26, 2015

Bud Cribley, State Director
Bureau of Land Management
Alaska State Office
222 W. 7th Ave, #13
Anchorage, AK 99501

Dear Mr. Cribley,

I write in response to a meeting recently held between members of your staff and the Division of Mining, Land and Water. During that meeting, BLM informed DMLW that there are patents being prepared for the state that do not conform with the 1973 Memorandum of Understanding (MOU) regarding monumentation.

This action is counter to the discussion we have had in previous meetings. Your office has provided examples of protraction diagrams that were to be passed to the state as patents and the State has expressed its concerns with this practice. The State has raised questions regarding the BLM's authority to impose this type of conveyance document and the relative accuracy of the product provided. During a meeting with Kip Knudson, the State's concerns were raised and a path forward identified. Included in our discussion, was a review of legal authority by our respective legal counsel and a technical review by BLM and State surveyors. The technical review has been postponed until such time as the legal authority issue could be thoroughly discussed.

Although the State has received no official notice that the BLM is unilaterally cancelling the 1973 MOU, the actions taken by the BLM would indicate that this is the case.

Please be aware that the State reiterates its opposition to the unilateral cancellation of the MOU without notice. Since no written notice has been received regarding the cancellation of the MOU and no alternative process has been agreed to by the State, the State of Alaska will not accept conveyance of entitlement land whose survey is inconsistent with the current MOU regarding surveys, unless it otherwise meets the more stringent requirements of federal law regarding surveys. The State will only accept conveyance of entitlement lands using protraction diagrams where the State has specifically elected such a conveyance as provided for in section 906(d)(5) of ANILCA.

Sincerely,

Mark D. Myers,
Commissioner

cc: Kip Knudson, Director of State and Federal Relations, Governor's Office
Brent Goodrum, Director, Division of Mining, Land & Water

THE STATE of ALASKA
GOVERNOR BILL WALKER

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July 1, 2015

Mr. Bud C. Cribley
222 West 7th Avenue #13
Anchorage, Alaska 99513

SUBJECT: Survey Methodology of Alaska's Statehood Land Entitlement

Dear ~~Director~~ Bud Cribley:

I would like to thank you for the opportunity to review and comment on the Bureau of Land Management (BLM)'s newly proposed Direct Point Position Survey (DPPS) methodology of patenting State of Alaska land entitlement. I very much appreciated the opportunity to discuss this novel proposal with BLM's national Chief Cadastral Surveyor, Don Buhler; his policy assistant, Bob Dahl; members of your Alaska BLM Cadastral Survey team; as well as acting Deputy Director for Cadastral Survey, Erika Reed; and your Regional Solicitor Elizabeth Gobeski.

This proposal was presented as saving both time and money for the federal government, and accelerating the State's receipt of its entitlement lands. Upon reflecting on our conversations and conferring with my staff, there are a number of issues that I believe merit further review, discussion, and understanding as we continue to move forward.

Historical Background

It is no secret that Alaskans desire to have more local control in managing the State's affairs. The desire for local control of the ownership and use of land played a fundamental role in Alaska's long journey to statehood, and continues to be a significant issue today.

Prior to statehood, the federal government owned 99.8% of the land in Alaska. Congress recognized that such a disproportionate federal land-ownership pattern would suffocate the State's ability to grow the most basic of industries, and granted Alaska the unique opportunity to select its land entitlement. Over the various circumstances of the first thirty-five years of statehood, the State selected land that would suit multiple uses and offered multiple resource values to reflect the State's policy of making land and resources available for maximum use consistent with the public interest.

The state land selections were undertaken with great care and planning, and we have made significant progress in the fifty-six years that we have been working on entitlement issues. However, we need to take the next step towards final transfer and survey of entitlement lands. As I understand from our conversations, as well as numerous presentations by BLM and

Department of the Interior (DOI) leadership, the federal government shares and supports this goal.

The Primary Current Challenge

One of the largest obstacles to Alaska attaining its promised statehood land entitlement is the continued existence of "temporary" Public Land Orders (PLOs). Many of these PLOs were issued more than forty years ago, and are still in place today even though their original intended purposes – including maintaining the availability of lands for the now completed Alaska Native Claims Settlement Act (ANCSA) Corporation land selections – were fulfilled decades ago. These longstanding PLOs continue to prevent high priority top-filed state land selections from attaching to the land in fulfillment of the State's land entitlement.

Lifting these "temporary," yet functionally perpetual, PLOs is the primary action the Secretary of the Interior can take to promote progress on land entitlement issues. To demonstrate a sincere commitment to progress on the entitlement, BLM and DOI should develop transparent processes with definitive timelines to lift these obsolete PLOs.

The Importance and History of Federal Surveys

Section 6(g) of the statehood compact requires the Secretary of the Interior to survey the exterior boundaries of state-selected land and issue a patent for the selected land in terms of the exterior boundary survey. Survey is a federal obligation grounded in law and long-standing practice.

As you know, the tentative approval of land selections transfers management authority to the State and allows the State to utilize the land in ways that will benefit the people of Alaska. This transfer of management authority occurs prior to survey, so survey does not have to be completed for the State to begin to benefit from entitlement lands.

However, a functional survey must be done to complete transfer and is critical for full use of the State's land. For example, furthering the development of and expansion of local governments and communities is a basic tenet of the Alaska Statehood Act, and this can only be achieved through the legal and proper conveyance of fully surveyed land.

The BLM Manual of Instruction for the Survey of the Public Lands of the United States (1947) in place when Alaska became a state in 1959 directed that survey monumentation would be placed at all angle points and at intervals of *every half mile* around the exterior boundaries of townships. Given the size of the tracts and total acreage to be conveyed in Alaska, placing markers every half mile around the exterior boundaries of selected areas represents an incredible federal obligation in Alaska.

The weight of this obligation became apparent shortly after statehood and resulted in embarrassingly slow progress on transferring final title to the new State. Consequently, Assistant Secretary John A. Carver of DOI traveled to Alaska in July of 1963 to work with state officials to address the issues of selection size, perimeter surveys, and monumentation interval.

During these extensive discussions, the parties agreed to a compromise wherein the State would make selections in basic single township blocks and BLM would provide perimeter

monumentation every two miles around the individual township boundaries – a significant concession from the prior half-mile spacing for monuments. This agreed-upon criterion was later confirmed through a Memorandum of Understanding (MOU) signed in 1973 between the BLM and the State.

The State did not make this compromise without reason. The 1973 MOU provided a hope of acquiring title to its selections more rapidly, and included additional provisions providing for acceptance of surveys with even less monumentation, or with no monumentation at all – at the State's discretion. However, by 1981, the State notified BLM that we would no longer accept lands patented without benefit of field survey and monumentation because it was critical to the State's interests. Subsequent surveys that followed were conducted under the compromise "two mile" criteria agreed to by Assistant Secretary Carver and the 1973 MOU.

The Current Survey Proposal

The 1973 MOU represents a carefully negotiated compromise – where the federal survey obligation was lightened, with the consent of the State, to provide the benefit to the State of speeding final survey. As I understand it, the federal government is now seeking to lighten its fundamental entitlement obligation of survey yet again, this time by proposing the use of new technological methods.

BLM has presented the state with a proposal to use a Direct Point Positioning Survey (DPPS) methodology to reduce federal expense and expedite the final patenting associated with the State's remaining entitlement in lieu of the established method of ground survey using the two mile monumentation that has been the standard in Alaska. As proposed, this new method would be selectively applied being used only in Alaska at this time and not in other states with existing federal survey obligations, only on state-entitlement land, and only in certain parts of the state as BLM has already acknowledged that the technology would not be appropriate, and would not provide cost-efficiencies, for areas such as Southeast Alaska. Additionally, as was the case for the 1973 MOU, any such compromise must receive the endorsement and agreement of the State.

The Challenges of Data and Technology Gaps in Alaska

DPPS substitutes the on-the-ground information used in traditional surveying practice with complex data-based calculations and projections. In order for DPPS to be practical, surveyors will need to rely upon comprehensive data and information from the National Geodetic Survey (NGS), the National Spatial Reference System (NSRS), and the Continuously Operating Reference Stations (CORS), among other systems.

This is a huge challenge in Alaska given that our current state of mapping and land position data is not even close to national standards. DOI itself has long recognized that the state of Alaska ha not been adequately mapped at suitable scale. According to the U.S. Geologic Survey, "Alaska i the only State that does not have current digital statewide map coverage at a scale comparable to the rest of the United States. The majority of the USGS topographic maps of Alaska in the current collection are 40 to 50 years old." While DOI, the National Oceanic and Atmospheric Administration (NOAA) and other agencies in cooperation with the State have been diligently working toward improved mapping of the state, it is far from complete.

To provide a technical example, there is insufficient densification of the CORS network within the state of Alaska, but the proposed DPPS methodology would rely heavily upon this kind of information. Furthermore, despite the great cooperative work being done by the federal agencies, there is currently no reliable Digital Elevation Model for approximately half of the State, and a realistic geoid model for Alaska does not yet exist. These are significant technical hurdles that generate a great degree of uncertainty for the functionality of DPPS.

The DPPS methodology may be very promising in theory, and with data-collection and technological advances may someday provide a truly efficient and cost-effective improvement to survey methods. However, upon initial examination, the lack of these essential support and data systems make Alaska inappropriate to use as even a test case for the proposed DPPS experiment.

Another significant challenge is the application of this uncertain methodology to only some of the State's land. The majority of the State's entitlement has already been surveyed using traditional, time-proven methods and with physical monuments consistent with BLM's Manuals of Instructions for Surveys and the 1973 MOU between BLM and the State of Alaska. DPPS deviates from the U.S. Land Tenure System where on the ground surveys and physical monuments control property boundaries for selections distributed all throughout the State, adjacent to parcels on which DPPS is proposed to be used. These parcels are also adjacent to the approximately 45 million acres of ANCSA Corporation lands, which are also monumented under law at all angle points and every 2 miles around the exterior of ANCSA selected lands.

Maintaining uniform land records through accurate survey is critical for Alaska's complex patchwork of state, federal, ANCSA corporation, and private land ownership. With the interfacing concerns summarized above, DPPS may not be consistent with the numerous existing survey boundaries already established all throughout the State.

The State's Fundamental Concerns

In this context, the DPSS proposal does not appear to be a win-win proposition. BLM's motivation seems to be to deploy new technology to cut costs, which the State fully understands and supports. However, with the data limitations highlighted above, application of this novel method may mean the estimated $500 million in BLM cost reduction is simply a $500 million cost transfer to the State for survey activities that the federal government is obligated to perform.

Unfortunately, Alaska is currently faced with challenging fiscal uncertainty which makes such a potential cost transfer even more concerning. In an environment where declining revenue has resulted in budget cuts to many State programs, services and positions, it would be irresponsible to expose the State to absorbing the risks and costs of experimenting with an untested land survey methodology.

In summary, I maintain that survey methodologies for the statehood entitlement cannot be implemented without the full consent and agreement of the State of Alaska. Until it is abundantly clear that DPPS is appropriate for providing certainty to the State of Alaska and the technologies necessary for its implementation are well demonstrated, I cannot recommend this consent.

Moving Forward

To be clear, the State supports technological progress and the need to provide federal cost savings when possible. However, the magnitude of the proposed deviation from current practice; the intent to utilize this new method solely in Alaska at this time; and the fact that the methodology is still very much in flux and has not been fully documented or articulated all demand that the proposed methodology must be rigorously and independently evaluated before being implemented anywhere.

I strongly recommend that this proposal be thoroughly peer reviewed by leading scientific organizations such as the National Academy of Sciences, the National Society of Professional Surveyors and technical specialists from NOAA's National Geodetic Survey.

Secondly, if such a dynamic change is to be made to federal surveying standards, a comprehensive public process should be initiated and made available for public stakeholders' education and input. Rushing to implement such a novel survey and land conveyance methodology without thorough vetting may prove to be detrimental to all parties involved: the State, the BLM, other potentially affected land owners, and the general public.

I want to repeat that the State is not wholly opposed to the concept of the proposed DPPS methodology, and in fact stands to benefit from technological advancement that supports more efficient land surveys. However, the State has a statutory obligation to utilize legally reliable and technically accurate surveys and land records. As state officials, we would be remiss to introduce uncertainty into the process that could delay the utilization of land that the State has already been working for half a century to receive.

I strongly believe that we share the common goal and desire for the state of Alaska to fully realize its complete land entitlement as envisioned by our country's leaders at the time of statehood and yearned for by Alaskans yet today. I also believe that through a transparent and open process that we can work together to find an equitable solution that would serve our nation and Alaskans sufficiently well for generations to come. The sooner that statehood entitlement lands are conveyed and patented, the sooner that the focus of future federal resources can be directed to other necessary activities. I sincerely look forward to our continued dialogue and partnership on this very important endeavor.

Very Respectfully,

Brent Goodrum
Director, Division of Mining, Land and Water

Cc: Bill Walker, Governor
Mark Myers, Commissioner, Department of Natural Resources

THE STATE of ALASKA
GOVERNOR BILL WALKER

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September 18, 2015

Mr. Bud C. Cribley
State Director
Bureau of Land Management
222 West 7th Avenue, #13
Anchorage, Alaska 99513

SUBJECT: Recent Meetings Regarding Survey Methodology for Alaska's Statehood Land Entitlement

Dear Director Cribley:

Thank you for our recent meeting on September 11, 2015 regarding BLM's proposal for using new survey methodology for transferring Alaska's remaining statehood land entitlement and I look forward to meeting with you and your team in the immediate future on September 23, 2015 to continue technical discussions on this issue. Please be assured that we want to see resolution of our differences in approach expeditiously and cooperatively as we move forward with surveying and final patenting of the state's entitlement. We do not feel it is in either party's best interest to resort to litigation or political intervention to settle these disputes and will continue to work with you to find solutions. I look forward to a written response to both this letter and the July 1, 2015 letter to you from Director Goodrum.

While I appreciate your sincerity and candor, I remain entirely unconvinced that, without comprehensive validation method and peer review processes by scientific and technical expert organizations, the proposed use of the Direct Point Position Survey (DPPS) methodology for patenting State of Alaska land entitlement is appropriate and ready for use in Alaska.

It is not in the State's best interest to accept land and, ultimately, not in BLM's best interest to convey land relying on yet untested and unproven methodologies. As stated in the July 1 letter, we recognized and support the federal need to reduce costs and save money associated with the statehood entitlement survey program. However, while this new methodology may initially appear cost effective for the federal government, right now we simply do not know what the ultimate costs and risks to the State may be. We have a responsibility to a host of parties – future landowners seeking title insurance, corporations using State lands, unknowing trespassers, and even potential future federal government users to ensure that patents, and the surveys and legal descriptions underlying them, are robust and reliable.

One only needs to look at the issues that have historically arisen throughout the Western United States as a result of inaccurate land surveys to see the potential gravity of this concern. These errors caused disagreement and litigation that, in cases, took years to resolve and sometimes

could only be addressed through individual acts of the U.S. Congress. As BLM well knows, such Congressional acts are accompanied by a substantial administrative burden on the federal resource agencies and, even more importantly, create significant burdens on private landowners and Native Corporations.

As stated above, I feel that validations and peer reviews of the methodology are absolutely essential before proceeding. A potential starting point is a joint effort to do tests of the new approach. BLM and DNR could assemble a validation team to consider legal and technical problems inherent in controlling boundaries with coordinates and paper platting, and test the field locations of the new DPSS boundaries under varying methods and time periods. We would appreciate further discussion with you regarding this possibility.

It should be noted that our core concerns with BLM's proposal are the integrity of the proposed untested survey methodology and the associated transfer of cost liability to the State and future landowners. However, the State recognizes we must cooperatively work to integrate and understand new and innovative technologies, and it would be beneficial to our interest if these methods received their required due-diligence testing in Alaska's unique geographical circumstances.

The issues raised by Director Goodrum in his prior letter continue to be critical to the State – most of all the lifting of the attached list of outdated Public Land Orders (PLOs). These administrative hold-overs prevent statutorily authorized state selections from attaching to high priority lands in areas where Alaskan Native Claims Settlement Act land selections have been totally completed. As the State demonstrates good-faith to study and participate in review of new methodologies to dramatically reduce federal survey costs, the Department of Interior and BLM should show corresponding good faith and begin to lift these withdrawals to advance resolution of the State's entitlement.

We will continue to work and meet with you as often as necessary to satisfactorily resolve our mutual concerns.

Sincerely,

Dr. Mark Myers
Commisioner

Attached: July 1, 2015 letter from Director Brent Goodrum
List of assorted PLOs affecting state land selections

THE STATE of ALASKA
GOVERNOR BILL WALKER

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January 13, 2016

Mr. Bud C. Cribley
222 West 7th Avenue #13
Anchorage, Alaska 99513

SUBJECT: Negotiations Regarding Survey of Alaska's Remaining Statehood Land Entitlement

Dear ~~Director~~ Bud Cribley:

Thank you for your December 15, 2015 response to my July 1, 2015 letter regarding the Bureau of Land Management's (BLM) survey methodology for the State of Alaska's remaining land entitlement. I was also pleased with our open discussion on September 21 and am optimistic that future discussions will continue to make progress on this issue. I understand from your letter that BLM has provided 30 days notice to renegotiate the 1973 and 2012 Memoranda of Understanding (MOUs). The State recognizes the BLM's desire for efficiency and cost savings and we are committed to negotiating with you to explore possibilities that will be beneficial to both BLM and the State of Alaska – but we want to assure that the survey standards are not compromised and that the incorporation of new technology and alternative methodologies have been properly reviewed and validated prior to implementation.

Your requested topics for our negotiations were the amount of on-the-ground monumentation for state selections and the style of survey record. In addition to these items, I recommend negotiations between the DNR Commissioner and yourself include other ideas which are detailed below that support reductions in federal obligations for monumentation required under Section 6(g) of the Statehood Act.

The Statehood Act rather than these MOUs fundamentally controls the continuing obligations of the federal government to survey state land selections, but the MOUs capture and document the compromises and implementation processes mutually agreed upon by the State of Alaska and the Department of Interior/BLM shortly after Alaska's entry into the Union. In practice, these agreements have served both parties for over half a century, and are grounded in official statements contemporaneous with the Statehood Act, such as Department of the Interior Assistant Secretary Carver's August 19, 1963 letter to DNR Commissioner Holdsworth addressing fulfillment of section 6(g) of the Alaska Statehood Act on the issues of selection size, perimeter surveys, and monumentation interval.

Historically, the United States government has the responsibility of surveying the public lands of the United States to further the orderly development of lands, as well as to accurately describe

lands to which it passes title. These longstanding agreements brokered by Assistant Secretary Carver and Commissioner Holdsworth and other federal and state officials deal with how the State made its selections – in single township blocks, and how BLM agreed to and has surveyed those selections, with average two-mile perimeter monumentation around the exterior boundaries of each individual township selection. The State's selections have been made under this compromised size. It is important that we negotiate in good faith about the level of survey for each selection, because the Statehood Act directs each individual selection to be surveyed.[1] Aggregation of multiple state selections on a large scale is not an issue the State can agree to revisit. BLM's proposed aggregation of hundreds of state selections would result in very large blocks of land that have no physical, on-the-ground monumentation for dozens of miles, resulting in potentially huge costs for re-surveys for future lessees and users of this land.

We understand and sympathize with your desire to reduce costs, and agree that the number of monuments placed in the ground is the driver for most of the existing cost. We acknowledge that, if proven viable, using the proposed DPPS methodology would likely reduce the time to complete state surveys and patent remaining entitlement; but, we remain steadfast in our requirement to systematically evaluate the validity of DPSS before accepting any patents that are sent to the State by the BLM under this new proposed methodology. As you state, DPPS may reduce the duration of this program from 30 years to 20 years, we believe that taking the necessary time to address the State's concerns before rushing into this decision is consistent with the goal of accelerating final patent issuance.

We also propose that our negotiations be conducted while the vetting of DPPS continues. As you discussed on September 21, 2015, there may be alternatives to DPPS. We believe it is premature to commit to DPPS until it is demonstrated that it is as technically sound or better than existing survey methods. Currently, the State remains concerned that the proposed DPPS methodology may create a host of problems associated with ambiguous and unstable boundaries.

As you are aware, the State of Alaska is working with the National Society of Professional Surveyors (NSPS), who is also in communication with your staff and BLM Washington Cadastral Survey, in order to conduct an independent assessment of the proposed DPPS methodology. This independent review – requested by the State – is in the very early stages. It is our understanding that NSPS has been awaiting a couple of months for materials that BLM is preparing, and we should work together to ensure this independent assessment moves forward expeditiously.

Additionally, we have previously communicated the State of Alaska's requirement to field test BLM's proposed DPPS methodology to validate expectations of improved accuracy, consistency, and repeatability for survey data – at a cheaper cost – that the DPPS generates. We are fully aware that GPS as a measurement tool is a proven technology; however, the controlling of property boundaries by the National Spatial Reference System (NSRS) in the proposed manner is not. The only way to validate these claims is by field testing and expert objective technical analysis. Our intention is to conduct this analysis upon completion of the independent

[1] In fact, the State has further compromised on BLM's mandated survey responsibilities by generally selecting lands no smaller than townships when the Statehood Act allows selections as small as ¼ township.

assessment so that we may consider and incorporate any of the assessment team's findings or suggestions.

If the DPPS methodology is ultimately shown to be effective, then we can confidently move forward to achieve cost and time savings knowing that we have a foundation of objective and technical analysis. If the DPSS methodology proves ineffective or imprecise because of some of the limitations and concerns raised by the State without a thorough field testing and demonstration, it will undermine the long history of BLM work in the cadastral field and call into question the use of this new survey methodology not only for land conveyances but also other realty activities where this methodology may be beneficial, such as: permits to drill, rights-of-way, land sales, and land exchanges. Jeopardizing the credibility and reputation BLM has rightly earned over the decades as the authoritative source of cadastral information is a substantial risk to federal interests.

The State has recently received some of the materials requested from your staff, such as the draft policy for (re)surveys. It is essential that we receive the remaining information we requested for our testing of DPPS and making valid cost estimates to compare future survey differences for parcels created under current standards versus DPPS surveys. While we remain concerned that the costs passed on to subsequent landowners may be a burden when compared to existing survey methods, this material will help us better assess this issue.

Additionally, your office recently provided data for Group 948, but before we begin to plan our field validation we also need the data for the eight group surveys conducted in 2014 and 2015 under the proposed DPPS methodology. We look forward to working with you to share and understand this technical data. As discussed above, we plan to conduct these field tests after the completion of the NSPS peer review has identified relevant issues for field validation and confirmation.

In this context, the State is eager to engage in mutually beneficial negotiations about survey methods that maximize the use of technology and limit costs and time. We would like to propose the following ideas and topics to include in our discussions to promote fair but cost-effective and efficient surveys:

- Lifting of Public Land Orders and federal withdrawals that unnecessarily delay the conveyance of over five million acres of remaining land entitlement;
- "Right-sizing" of Tentatively Approved lands as they convert to patent;
- Modifying minimum monumentation standards to meet the needs of each agency (such as monumentation based on anticipated use or location);
- Setting up a "monument bank" from which the State could receive some number of additional monuments as needed;
- Support and funding for improvements to control networks in Alaska;
- Caps on the greatest distance between monuments and the greatest distance from a platted parcel to a marked corner which was tied to the original NSRS datum; and
- A number of other ancillary topics, as well as topics relevant to BLM's interests and authorities.

The State believes that a fair balance of these ideas can result in significant immediate federal cost savings without rushing utilization of the unproven DPPS methodology, and potentially without compromising the State's interests. That said, utilizing some or all of these concepts in concert with an appropriately timed implementation of a demonstrated and proven DPPS or DPPS-like system in the future should certainly be considered in our discussions and negotiations.

As communicated previously, the most significant obstacle to accelerating the completion of the State's remaining land entitlement is the revocation of long standing Public Land Orders (PLOs) that prevent the state from accurately prioritizing those lands most economically beneficial to the state's future. These obsolete PLOs inhibit the state's ability to adequately explore and determine mineral potential by prohibiting location of minerals on lands which are segregated through the PLO. The BLM's own report to Congress in 2006 indicated that the withdrawals "are an unnecessary encumbrance on the public land records complicating interpretation of title records by the public". The same report summarized, "there are more than 158,958,000 acres of d-1 withdrawals in Alaska... Approximately 152,181,400 acres or 95% of these withdrawals could be lifted consistent with the protection of the public's interest." The State and BLM are in complete agreement on this recommendation, and federal action needs to be taken.

Note: by separate correspondence Department of Natural Resources Commissioner, Mark Myers, is submitting to Deputy Secretary of Interior, Mike Connor, a list of critical PLOs to be lifted by the Secretary of Interior. The PLOs include: 5150, 5174, 5180, 5181, 5184, and 5187.

Thank you for your letter and the materials you have provided. We commit to continued good faith discussions to reduce future survey cost obligations and to achieve meaningful time savings associated with the completion of the State of Alaska's remaining land entitlement. I look forward to engaging in productive negotiations on these survey issues with you in the near future and am available to work with the Commissioner's Office to schedule our initial negotiations at your request.

Very Respectfully,

Brent Goodrum
Director, Division of Mining, Land & Water

Cc: Mark Myers, Commissioner, Department of Natural Resources

U.S. Senate Committee on Energy and Natural Resources
April 7, 2016
Hearing: Oversight of the U.S. Geological Survey
Question for the Record Submitted to Dr. Robert McCoy

Question from Chairman Lisa Murkowski

Question: What does the University of Alaska need to more fully support seismic, volcanic, and other physical monitoring within Alaska?

The Geophysical Institute at the University of Alaska Fairbanks is the state's pre-eminent source of geophysical monitoring. For 70 years, the GI has served the state with base data and expert evaluation in support of natural hazards monitoring including earthquakes, tsunamis, volcanoes, coastal erosion, permafrost degradation, and space weather. These monitoring activities provide direct societal benefit, along with research and educational opportunities.

The monitoring activities of the GI can be improved through a combination of authorizations, appropriations and advocacy that will enhance our existing strong operations. The coming opportunity to leverage the assets of the National Science Foundation (NSF) EarthScope project will increase capabilities across disciplines, and allow us more fully support seismic, volcanic and other physical monitoring within Alaska. Long-term operation of seismic and geodetic instruments installed by NSF for EarthScope will improve seismic, volcanic and tsunami monitoring and hazard assessment, provide a foundation on which to build future earthquake early warning capability, and will benefit other government agency functions including geospatial information, weather forecasting, and nuclear test verification. Combined with strong federal authorizations and select appropriations, the GI and the University of Alaska are well positioned to lead the state into a new era of natural hazards monitoring.

Improving earthquake and tsunami monitoring
For the past half a century, seismic monitoring in Alaska has been a joint state-federal partnership. This partnership was formalized thirty years ago with the founding of the Alaska Earthquake Center. Today, AEC provides Alaska's earthquake monitoring under the auspices of the Advanced National Seismic System. The center also provides the majority of the Alaska data used by NOAA's tsunami warning program. Both the earthquake and tsunami efforts have long been hobbled, however, by a lack of instrumentation across vast swaths of Alaska. In western and northern Alaska, there is simply no instrumentation to measure and report earthquakes. Seismic coverage across the populated and highly active southern coast of the state is generally quite effective. However this is the region that occasionally spawns truly massive earthquakes and tsunamis, and the current network is not equipped to handle such large events. The lack of high-rate real-time GPS data (commonplace in other seismically active parts of the country) means it would be difficult to rapidly determine the magnitude of an earthquake in the magnitude 8-9 range. The existing network has also almost no continuity of operations capability. A single server failure can bring down the majority of earthquake monitoring in Alaska, without any type of failover capability or redundant data. As was

U.S. Senate Committee on Energy and Natural Resources
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learned during the 2011 Japan earthquake, the consequences of not knowing how large the earthquake and tsunami might be can have deadly consequences.

Leveraging assets of the EarthScope project for long-term operation provides a mechanism to fix nearly all of these problems. Maintaining a subset of the seismic stations in the EarthScope USArray project will allow us to deliver meaningful earthquake products to all of mainland Alaska. The National Science Foundation's $40M investment in this facility has provided a highly cost effective path forward. Current estimates of $3.4M/year would allow the Alaska Earthquake Center to achieve the basic earthquake detection performance standards defined by the Advanced National Seismic System. Achieving this will support development by allowing industry and communities to better tailor infrastructure to the seismic hazard and facilitate rapid decision-making in the aftermath of significant earthquakes. The EarthScope Plate Boundary Observatory provides a clear path for spreading high-rate real-time GPS across Alaska. Modest upgrades to the existing instrumentation and telemetry would position the Alaska Earthquake Center, and others, to begin integrating GPS data into real-time processing and warning. NSF is likely to continue support for operation of much of the Plate Boundary Observatory for the next several years to address long-term science goals, but upgrades to real-time and more modern instrumentation will need to be supported from other sources. Depending on the ultimate level of NSF support, which will not be known with certainty until 1.5-2 years from now, an additional $1.5-2.5M/year would provide upgrades to real-time data, densification of the network where needed, and provide Alaska-focused services aimed geospatial users. The GI and partner organizations have the expertise needed to provide those services. The opportunities to extend USArray and PBO into modern long-term facilities will bring the facilities upgrades and diversification needed to ensure robust continuity of operation.

Alaska is net yet poised to provide Earthquake Early Warning. But it is these same steps that are needed to lay a foundation for Earthquake Early Warning—comprehensive seismic network coverage, coupled with high-rate real-time GPS, fast robust data communication, and strong continuity of operations. As the nation's earthquake attention turns increasingly to Earthquake Early Warning, Alaska is the one place where these systems can be routinely tested against large earthquakes. The geophysical Institute at the University of Alaska is well-positioned to lead the state in these endeavors.

Improving volcano monitoring
Volcanic monitoring in Alaska is also a joint state-federal partnership, with the Alaska Volcano Observatory (AVO) being a cooperative effort of the US Geological Survey, the Geophysical Institute, and the State of Alaska Division of Geological and Geophysical Surveys. These three agencies have a demonstrated 30-year record of strong cooperation, and each brings unique strengths to the partnership. Over the last decade, AVO suffered a drastic reduction in budget, which led to a substantial loss of personnel, deferred maintenance on monitoring networks, and reduced performance and capability. All of

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these losses are slowly but steadily being reversed as the level of support for AVO has increased over the last 3 years. Even with recent budgetary gains, AVO remains about $3M/year below the budget level that would have resulted from adjusting AVO's typical mid-2000s budget for inflation.

The GI's work as part of AVO is funded by the US Geological Survey as part of the overall AVO budget. Most of the faculty, staff and students who work with AVO have only a portion of their salary supported by AVO. This allows us great flexibility in providing our expertise to AVO, and it also means that knowledge gained from volcano monitoring for AVO can also be applied readily to other monitoring problems and for basic research and education. Restoring the AVO budget to the level it maintained in the early to mid-2000s, plus inflation adjustments, would allow the GI to expand its role in AVO monitoring activities and better pursue synergies between AVO and the Alaska Earthquake Center.

AVO's monitoring networks consist of tight clusters of instruments on and immediately around active volcanoes. This makes them complementary to the regional and comprehensive coverage of the state required for the Alaska Earthquake Center to carry out its mission. All relevant data are promptly shared. AVO will benefit when Alaska Earthquake Center takes over long-term operation of USArray stations around Cook Inlet and along the Alaska Peninsula; increased funding would also enable more effective sharing of information for monitoring volcanoes where AVO has no dedicated network of its own.

AVO depends heavily on the continued operation of Plate Boundary Observatory GPS sites on Akutan, Augustine, Shishaldin, and Westdahl volcanoes. These sites measure the swelling up of these volcanoes that generally occurs prior to eruption, along with other ground movements that inform us about the movement of magma beneath them. AVO's modern digital broadband seismic networks at these volcanoes depend heavily on co-located sites and shared power and/or communications. With the likely reduction in NSF support for these sites, it is critical for AVO's operations that funding be found to maintain them, and to expand this valuable instrumentation to additional volcanoes. All GPS monitoring for AVO is carried out by personnel from the GI.

Authorizations
The federal hazard programs authorized by congress have a larger impact on Alaska than most states. Two programs are in need of reauthorization. The expiration of the Tsunami Warning, Education and Research Act (TWERA) and the National Earthquake Hazards Reduction Program (NEHRP) have both had direct, and damaging, impacts on the GI's ability to provide robust monitoring. The introduction of the National Volcano Early Warning System (NVEWS) is exciting and potentially opens a new door on volcano monitoring. Authorization and full appropriation of NVEWS would enhance volcano monitoring nationwide. In Alaska, it would result in the addition of monitoring capability

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at a few more volcanoes where the threat level justifies it, and would make the monitoring networks more robust.