Geohazards, Extreme Weather Events and Climate Change Resilience — Peer Exchange Report

Summary of May 2016 Peer Exchange, Atlanta, Georgia

U.S. Department of Transportation

Federal Highway Administration

Office of Infrastructure
FHWA-HIF-23-009

May 2016
Updated February 2023

Technical Report Documentation

1. Report No. FHWA-HIF-23-009	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Geohazards, Climate Change, and Extreme Weather Events — Peer Exchange Report		5. Report Date Updated February 2023 from May 2016 6. Performing Organization Code
7. Principal Investigator(s): See Acknowledgements for Authors andContributors Betsy Godfrey, Brian Zelenko, P.E., Erik Loehr[1], Ph.D., P.E.		8. Performing Organization ReportNo.
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12. Sponsoring Agency Name and Address Federal Highway Administration 1200 New Jersey Avenue, SE Washington, DC 20005		13. Type of Report and Period 14. Sponsoring Agency Code
15. Supplementary Notes FHWA Lead – Khalid Mohamed, P.E.		

16. Abstract

A Peer Exchange was held March 22–23, 2016, in Atlanta, Georgia, to gather experts from different fields relating to geologic hazards, climate change, extreme weather events, and geotechnical asset management (GAM). The purpose was to share perspectives and brainstorm ideas on how FHWA can best continue its geologic hazards program and research. Feedback from the Peer Exchange contributed to updating a draft work plan from Phase I of this study on geohazards, extreme weather events and climate change resilience. The Peer Exchange consisted of presentations from attendees, discussion based on these presentations, breakout sessions for more focused discussion, and brainstorming about suggested changes to the provided draft work plan for a future Phase III study on geologic hazards, extreme events, and climate change. This report provides a summary of the Peer Exchange meeting.

17. Key Words Geohazards, climate change, extreme weather events, geotechnical assets, transportation features		18. Distribution Statement No restrictions.	
19. Security Classif. (of this report) UNCLASSIFIED	20. Security Classif. (of this UNCLASSIFIED	21. No. of Pages 12	22. Price N/A

Form DOT F 1700.7(8-72) Reproduction of completed page authorized

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Introduction

The Federal Highway Administration (FHWA) conducted a Peer Exchange in 2016 as Phase II in developing suggested practices for State transportation agencies to create or maintain geohazard programs that consider extreme weather events and climate change resilience. The purpose of the March 22–23 Peer Exchange in Atlanta, GA, was to gather experts from different fields relating to geologic hazards, climate change resilience, extreme weather events, and geotechnical asset management (GAM) to share expertise, perspectives, and ideas.

The Peer Exchange consisted of presentations from many of the attendees, discussion based on these presentations, breakout sessions for more focused discussion, and brainstorming about changes to suggest for a draft work plan for a future Phase III geologic hazards, extreme events, and climate change study.

This report provides a summary of the Peer Exchange meeting and includes the group's suggestions for managing geohazards that affect transportation systems while considering climate change and extreme weather events. Although the Peer Exchange occurred in 2016, the FHWA believes that the findings and discussion at that time continue to provide value in ongoing efforts to develop policies and approaches to transportation management that account for climate change.

Attendees

The more than 20 Peer Exchange participants included subject matter experts (SMEs) in geotechnical engineering, climate science, socio-economic science, environmental engineering, hydraulics engineering, and asset management.

The private sector, FHWA, State Departments of Transportation, and academia were all represented, including SMEs from the Colorado Department of Transportation, Arizona State University, Carnegie Mellon University, Georgia Tech, Iowa State University, University of Idaho, University of Missouri, University of Texas, and University of Washington.

Agenda

The agenda provided time for presentations, discussion, breakout sessions, and review of the draft work plan. On the first day of the Peer Exchange, 11 participants shared presentations. The first presentation provided an overview of FHWA's geologic hazards program, including the background of the program, what was accomplished to date, and how to continue and improve the program. This presentation assisted in clarifying the purpose of the Peer Exchange meeting. The next presentation provided a summary of what was accomplished so far in the study on geologic hazards, extreme events and climate change, including findings from a literature review and initial work plan. Subsequent presentations covered topics such as geotechnical asset management, climate change, environmental adaptation to climate change, geologic hazard management program at the Colorado Department of Transportation, influence of rainfall on slope stability, case studies, the regional nature of most geologic hazard types, and socioeconomic aspects of a geologic hazards program.

Breakout Sessions

Attendees were divided into three groups to discuss and provide input on three general areas relating to geologic hazards, climate change, and extreme weather events. Each group then presented its conclusions and discussion points.

The objectives for the breakout sessions were to:

- Capture existing state-of-the-art and state-of-the-practice related to management of geologic hazards and the impact of extreme weather events and climate change.
- Identify major challenges to more effective management of geologic hazards.
- Capture important elements for developing a successful transportation geologic hazards program.

Group A – Identification and Assessment of Geologic Hazards

Group A was tasked with discussing the identification and assessment of geologic hazards. Topics werecovered for each broad category of geologic hazards (landslides, seismic activity, subsidence, and erosion, etc.). Discussion points for each of the geologic hazard groups included:

- Level of maturity
- Existing impact on transportation infrastructure
- Tools for identification and assessment of geologic hazards
- Performance measures with links to agency goals and metrics
- Contributions from related industries/segments
- Geologic hazards considerations during design and construction to produce resiliency
- Major challenges

Discussion summarized from Group A included:

- The potential impact of geologic hazards related to extreme weather events and climate change on transportation infrastructure will generally be high for landslides and subsidence, medium for erosion, and low for seismic activity.
- Effective adaption and management strategies exist for landslides. These strategies include remote sensing, although it was in a trial stage, and event trackers such as a program set up in Colorado.
- Adaption strategies and existing procedures are well-developed for seismic activity and scour. In fact, the more mature topic of performance-based seismic design approaches may be applicable to other geologic hazard areas.
- Remote-sensing and regional soil maps could assist in tracking and adapting for subsidence.
- Contributions from other industry sectors include utilizing and analyzing data from sources such as Google, USGS, local and State surveys, and pavement management systems.

Group B – Climate Change Impacts to Geologic Hazards

Group B discussion focused on the impact of climate change and extreme weather events to geologic hazards. Discussion points for each of the four geologic hazard categories, considering climate changeimpacts, included:

- Level of maturity
- Future impact on transportation infrastructure
- Contributions from related industries/segments
- Tools for identifying assets vulnerable to geologic hazards, climate change, and other factors
- Methods for developing adaption strategies considering climate change and other factors
- Methods to communicate geologic hazards information to decision makers (e.g., funding, messages to the

public, decisions based on risk factors)
- Methods to educate and communicate to the public about geologic hazards and risk
- Major challenges

Discussion summarized from Group B included:

- The level of maturity for assessing the impact of climate change to geologic hazards was generally intermediate for landslides and subsidence. It was discussed that a condition index for landslides would assist in adding maturity to the understanding of landslide potential and risk.
- The potential impact of landslides on transportation infrastructure as climate changes was considered immature, until there was more existing climate data, along with a better understanding of the link between climate change and occurrence of landslides.
- The potential impact of subsidence on transportation infrastructure was considered immature, although understanding of long-term regional subsidence was farther along than more site-specific types of subsidence, such as sinkholes.
- Adaptions strategies for landslides and subsidence are well established, but knowing where to adapt would be the challenge related to climate change.
- Useful contributions from other industry segments include climate models from climate scientists, advances in remote sensing and radar, and adaption strategies implemented by the nuclear, railroad, and dam industries.
- Educational and communication considerations include communicating geologic hazard management changes in ways that Departments of Transportation (DOTs) would support and accept them.
- The seismic/geo-seismic community had progressed through many of the risk and resilience issues related to seismic hazards over the past few decades; there are undoubtedly lessons from that experience that could be adapted and applied to landslide and subsidence hazards.
- Major challenges with understanding the impact of climate change on landslides include uncertainty in the sequencing of wet and dry periods and uncertainty in determining which currently stable slopes may become unstable with climate change.
- A major challenge with understanding the impact of climate change on subsidence includes lack of soil moisture projections.

Group C – Programming for Mitigation, Management, and Communication

Group C focused on discussing programming for mitigation and management of geologic hazards. Discussion points included:

- Linking performance assessment and risk to existing agency goals
- What guidance would support State DOTs in developing and improving a geologic hazards program
- Cross-asset considerations
- Cost-effective tools for monitoring and managing infrastructure vulnerable to geologic hazards
- Methods for evaluating system risk assessment
- Programming for risk reduction
- Methods to communicate geologic hazards information to decision makers (e.g., funding, messages to the public, decisions based on risk factors)
- Methods to educate and communicate to the public about geologic hazards and risk
- Understanding and communicating socioeconomic geologic hazards impact
- Level of maturity
- Contributions from related industries/segments
- Major challenges

Discussion summarized from Group C included:

- It is important to focus on how information is being communicated. For example, if information comes from maintenance crews, proper training should be done. Remote sensing could also be more widely used to gather inventory data relevant to geologic hazards.
- A challenge exists with cross-asset considerations and lack of communication. For example, the design of a culvert may not consider or claim responsibility for a debris flow that overwhelms the culvert. Another example was highways that are part of the flood control system in Texas but were not designed for that purpose.
- Existing risk registers and assessment methods from other industries (e.g., oil/gas, tunneling) could assist State DOTs to assess system risk from geologic hazards.
- A challenge was that a geologic hazard program would be new for most State DOTs and may be met with resistance. FHWA can only guide State DOTs in geologic hazard programs rather than require certain methodologies. There may only be 10 to 12 States that have budgets available to handle geologic hazards.
- Communication is important for building collaboration between State DOTs and FHWA.
- Remote sensing, instrumentation and LiDAR surveys could be useful in identifying deterioration of geotechnical assets and programming for risk reduction.

Breakout Session Synopsis Discussion

After the breakout sessions, all the groups reconvened and reported on their findings. During the full-team discussion, participants made these observations or suggestions:

- Basic definitions would be beneficial for terms like “extreme events,” “resiliency,” “risk,” and “climate change.” Some of these terms were already standardized within FHWA and other agencies, but could be made more clear and put into the context of geologic hazards. This should be included in the work plan prior to the first task. Existing practices and agencies may have a wide range of definitions for these terms and consolidating them would put people at the same starting point before the other tasks begin.
- Managing assets for each State DOT can be highly variable due to constrained budgets. Innovative approaches to managing geologic hazards in light of State-specific issues and budgets should be considered.
- Consideration of the interdependence of features in accounting for climate change in design is complex. It had not been addressed in AASHTO and/or as resistance factors in engineering design.
- Extreme events can be weak links in existing practices, especially in cross-asset interactions and consequences.
- Colorado DOT used a GMP (Geohazards Management Plan) that was assigned an annual budget and used a corridor approach with performance measurements by segments using as considerations: importance, road user costs, maintenance, safety, and social matrix.
- Iowa DOT used risk evaluation and infrastructure payoff concepts in the evaluation of an adaptation cost (detect and adapt philosophy).

Updated Preliminary Study Work Plan

Participants provided feedback and discussed the initial work plan. From this discussion, the work plan was updated to address relevant comments and conclusions from the participants. The updated preliminary study work plan (PSWP) was developed to address significant decision-making issues from the perspective of State and Federal transportation agencies that serve public transportation. The plan was generally consistent with asset management and resiliency principles, including adaptation for climate effects; recognizes the importance of socioeconomic factors; and was expected to be suitable for integration with future developments of geotechnical asset management systems. The goal of the PSWP was to provide information to allow agencies to better address geologic hazards in the future.

Participants recommended that prior to embarking on the PSWP, consideration should be given to identifying such terms as "extreme events," "resiliency," "risk," "adaptation," "monitoring," and "climate change." Some of these terms were already standardized within FHWA and other agencies, but should be clearly consolidated and put into context of geologic hazards. Since the Peer Exchange in 2016, the term "resilience" was statutorily defined in 2021 throughout Title 23 of the U.S. Code, at 23 U.S.C. § 101(a)(24), by Sec. 11103 of the Bipartisan Infrastructure Law, enacted as the Infrastructure Investment and Jobs Act, Pub. L. 117-58 (Nov. 15, 2021)).[1]

Participants also recommended that specific tasks within the plan help agencies address the following questions:

1. How should agencies identify and characterize significant geologic hazards for individual assets, individual projects and individual corridors?
    - Should include synthesis of agency best practices to catalog, inventory, and understand the criticality of both hazard "sites" and geotechnical assets, and discuss the impact these inventories have had. Include an understanding of the criticality (i.e., nuisance or catastrophe) of hazard sites.
    - Should include synthesis of current available data types for use in evaluation of geologic hazard sites, data that is expected to become available in the near term (5 to 10 years), and the anticipated value of this data to agencies.
    - Should include guidance, including selected case histories, for use of historical data, data mining, instrumentation monitoring, various hazard maps, remote sensing, and GIS.
    - Should include research to develop and guidance to describe the information required to facilitate effective decision making at the asset, project, corridor, and system levels. This may include guidance (e.g., templates) to agencies to collect maintenance data relative to geologic hazards, life-cycle deterioration curves, selected case histories, and guidance similar to the Infrastructure Resiliency Indicator Framework developed by the Los Angeles Metro in 2015 (Appendix A-98).
    - Should include information for defining a design or extreme event for non-structure assets or hazards. For such an event, is it possible to identify, characterize, and determine if needed, significant geologic hazards while understanding risk as it relates to some probability of occurrence?
    - Should include a review of performance based seismic design approaches currently in use and an

[1] Under 23 U.S.C. § 101(a)(24), with respect to a project, "resilience" means a project with the ability to anticipate, prepare for, and/or adapt to changing conditions and/or withstand, respond to, and/or recover rapidly from disruptions, including the ability (A) to resist hazards or withstand impacts from weather events and natural disasters, or reduce the magnitude or duration of impacts of a disruptive weather event or natural disaster on a project; and (B) to have the absorptive capacity, adaptive capacity, and recoverability to decrease project vulnerability to weather events or other natural disasters.

evaluation of how they may be applicable to other geologic hazard areas.

2. How should agencies assess risks associated with the identified geologic hazards and hazard sites?

    - Should include research to develop and/or adapt methods for quantitatively assessing both consequences and likelihoods, including life-cycle and environmental costs, based on assessment of existing or planned assets, features, and elements and projected performance expectations.
    - Should address guidance for evaluating risks placed in context of agency goals and priorities (FAST Act). This may include the Geotechnical Asset Risk Cube developed by FHWA (Appendix A-26, 27) or other methods.
    - Should address risks, including socio-economic risks, from the perspective of individual assets, individual projects, individual corridors, and entire "systems" or networks.
    - Should consider risks for individual hazard sites, including guidance on understanding the criticality of a hazard site, as well as cumulative risk from multiple "correlated" hazard sites (i.e., "system" risk).
    - Should include evaluation of risk to either that of an event occurring or that which restricts use of the infrastructure or system.

3. How should agencies assess whether climate change and/or extreme climate events will increase, decrease, or have little influence on risks from identified geologic hazards?

    - Should utilize latest estimates for impacts from climate change and FHWA's synthesis document, "Engineering Approaches for Climate and Extreme Weather Resilience" (2016), which includes case histories and guidance from HEC-25 and 17, as a basis.
    - Should include consideration of the uncertainty associated with those estimates and allow for adjustments as climate projections become more refined.
    - Should consider methods for identifying regional trends/projections in climate and extreme weather events.
    - Should provide consideration for looking at risk as a function of the stability of a hazard.
    - Given some collection of risks and agency goals, priorities, and need for resiliency, how should an agency decide whether and how to address specific hazards, and to what level and at what cost?
    - Should consider perspectives for individual assets, individual corridors, and entire systems or networks.
    - Should be integrated with consideration for other, non-geo risks (i.e., risks attributed to bridges, pavements, tunnels, and other structures) and include socioeconomic and life- cycle impacts.
    - Should address how an agency should identify some "target" or "acceptable" risk for individual projects (e.g., Los Angeles Metro's "Safe-to-Fail" principle), individual corridors, and entire systems (perhaps a separate task).
    - Necessarily includes means for prioritizing risks, but doing so such that reduction in overall risk is achieved.
    - Should allow for States to have some freedom in determining how much cost to associate with different hazards and consequences and how much risk to accept given the regional nature of most hazard types.
    - Should include consideration of how risks are communicated to the public.

4. For a given hazard "site," how should agencies evaluate appropriate method(s) and appropriate levels for remediation to achieve desired corridor and system risk and resiliency levels?
    - Identify and characterize type of geologic risk.
    - Evaluate climate change stressors and impacts.
    - Develop methods for prioritization of risks and selection of appropriate risk management measures.
    - Identify risk mitigation alternatives and appropriate methods for remediation.
    - Perform life cycle cost analysis for the selected mitigation alternatives.
5. How should agencies assess and/or update hazard condition/risk and resiliency over time, as mitigation measures are taken, as conditions may deteriorate, and as risks may increase or decrease?
    - Should address record keeping and monitoring to allow for improvements and adjustments to geologic hazard programs as they evolve.

Finally, participants recommended that the work plan could also include development of "hazard specific" documents to address specific hazards as related to climate change. Substantial knowledge already exists about means to mitigate geologic hazards; however, current practices on mitigation methods are generally based on achieving some broadly accepted criteria that may or may not be appropriate in the context of asset management (e.g., when asset management decisions might suggest a partial mitigation). Participants suggested there is therefore value in looking specifically at a few select hazards and mitigation methods that are likely to be influenced by climate change to evaluate whether current guidance for mitigation is sufficient for application within an asset management framework. This is a relatively low priority recommendation because it is of little value without the broader framework and decision-making protocols, but it is a topic that should eventually be addressed.

The following table summarizes possible or planned research and development tasks proposed during the discussions.

Task #	Task Name	Objective	Deliverable(s)
1	Hazard Identification and Characterization	Develop suggested practices for agencies to identify and characterize geologic hazards.	Suggested practices document Inputs for Task 2
2	Risk Assessment	Develop procedures for quantitative assessment of geologic hazard risks.	Research report Inputs for Task 4
3	Climate Change Influence	Identify methods used to characterize climate change impacts.	Research report Inputs for Task 4
4	Programming for Risk Management	Develop methods for prioritizing risks and selecting appropriate risk management measures.	Analytical tool for simulation and decision making for programming of risk reduction Research report
5	Mitigation Alternatives	Identify mitigation alternatives to assist agencies in selecting appropriate methods for remediation of specific sites.	Research report
6	System Operation andMaintenance	Develop suggested practices to assist agencies with development of appropriate operation and maintenance procedures to maintain a geologic hazards management system.	Informational document and “implementation guide” for long-term implementation of practices from this program
7	Hazard-Specific Practices	Develop suggested practices for selected specific geologic hazards that are expected to increase as a result of climate change.	To depend on specific hazards selected