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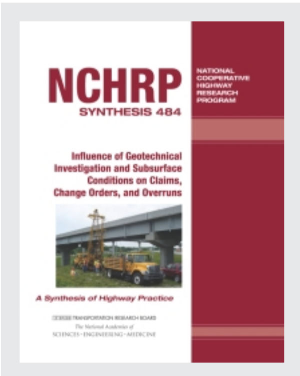

Influence of Geotechnical Investigation and Subsurface Conditions on Claims, Change Orders, and Overruns

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP SYNTHESIS 484

Influence of Geotechnical Investigation and Subsurface Conditions on Claims, Change Orders, and Overruns

A Synthesis of Highway Practice

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research is the most effective way to solve many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation results in increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

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FOREWORD

Highway administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to highway administrators and engineers. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire highway community, the American Association of State Highway and Transportation Officials—through the mechanism of the National Cooperative Highway Research Program—authorized the Transportation Research Board to undertake a continuing study. This study, NCHRP Project 20-5, "Synthesis of Information Related to Highway Problems," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute an NCHRP report series, *Synthesis of Highway Practice*.

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

By Jo Allen Gause
Senior Program Officer
Transportation Research Board

Subsurface conditions are frequently considered to represent significant elements of technical and financial risk for highway construction projects. Unfortunately, information quantifying these risks is rare. This Synthesis documents the extent and type of claims, change orders, and cost overruns from subsurface conditions for state departments of transportation (DOTs). The report also identifies practices used by agencies to reduce such claims, change orders, and cost overruns.

Information used in this study was gathered through a literature review and a survey of state DOTs. Follow-up interviews with agencies that have experience with reducing claims, change orders, and cost overruns from subsurface conditions provided additional information.

Andrew Z. Boeckmann and J. Erik Loehr, University of Missouri–Columbia, collected and synthesized the information and wrote the report. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

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CONTENTS

1 SUMMARY

5 CHAPTER ONE INTRODUCTION
Objectives, 5
Methodology and Outline, 5
Literature Review, 5
Survey, 5
Case Examples, 6
Difficulty of Evaluating Data Regarding Claims, Change Orders, and Cost Overruns, 6
Definitions, 6

7 CHAPTER TWO LITERATURE REVIEW
Transportation Agency Subsurface Investigation Practices, 7
AASHTO *Manual on Subsurface Investigations* and *LRFD Bridge Design Specifications*, 7
National Highway Institute *Manual on Subsurface Investigations*, 7
FHWA *Geotechnical Engineering Circular No. 5*, 7
Agency Subsurface Investigation Capabilities, 7
Geotechnical Change Orders at Indiana Department of Transportation, 8
Effect of Subsurface Investigation on Claims, Change Orders, and Cost Overruns, 9
Human Effects on Subsurface Conditions Claims, Change Orders, and Cost Overruns, 10
Effect of Contracting Practices on Subsurface Conditions Claims, Change Orders, and Cost Overruns, 10
Geotechnical Bid Documents: Lessons from the Tunneling Industry, 10
Design-Build Contracts, 11
Summary of Significant Findings, 12

13 CHAPTER THREE SURVEY RESULTS
Subsurface Condition Problems and Subsurface Investigation Practices, 13
Nature of Claims, Change Orders, and Cost Overruns, 16
Qualitative Information Regarding Claims, Change Orders, and Cost Overruns, 17
Quantitative Information Regarding Claims, Change Orders, and Cost Overruns, 19
Extent of Claims, Change Orders, and Cost Overruns Resulting from Subsurface Conditions, 22
Perceived Relationship Between Subsurface Investigation Practices and Claims, Change Orders, and Cost Overruns, 25
Summary of Significant Findings, 27

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29 CHAPTER FOUR CASE EXAMPLES
Florida Department of Transportation, 29
Drilled Shafts in Extremely Variable Geology, 29
Earthwork, 29
Florida DOT: Lessons Learned, 30
South Carolina Department of Transportation, 30
Geotechnical Design Manual, 30
Effect on Claims, Change Orders, and Cost Overruns, 30
South Carolina DOT: Lessons Learned, 30
Washington State Department of Transportation, 31
Agency Geotechnical Practice, 31
Occasional Claims, 31
Washington State DOT: Lessons Learned, 31
Indiana Department of Transportation, 32
Pavement Subgrade, 32
Driven Piling Specification Revisions, 32
Indiana DOT: Lessons Learned, 32
Minnesota Department of Transportation, 32
Agency Practice, 33
Claims, 33
Minnesota DOT: Lessons Learned, 33
Summary of Common Causes of Subsurface Conditions Claims, Change Orders, and Cost Overruns and Lessons Learned from All Case Examples, 33
Common Causes of Subsurface Conditions Claims, Change Orders, and Cost Overruns, 33
Summary of Lessons Learned, 33

35 CHAPTER FIVE CONCLUSIONS
Scope of Subsurface Investigation, 35
Causes of Subsurface Conditions Claims, Change Orders, and Cost Overruns, 35
Significance of Subsurface Conditions Claims, Change Orders, and Cost Overruns, 35
Practices to Reduce Subsurface Conditions Claims, Change Orders, and Cost Overruns, 36
Future Research, 37

38 REFERENCES

39 APPENDIX A SURVEY QUESTIONNAIRE (WEB-ONLY)

67 APPENDIX B SURVEY RESPONSES (WEB-ONLY)
Appendix B1 Summary Tables, 67
Appendix B2 Key for Summary Tables with Response Counts, 71
Appendix B3 Responses to Short Answer Questions, 77

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INFLUENCE OF GEOTECHNICAL INVESTIGATION AND SUBSURFACE CONDITIONS ON CLAIMS, CHANGE ORDERS, AND OVERRUNS

SUMMARY

Subsurface conditions are frequently considered to represent significant elements of technical and financial risk for infrastructure projects. Unfortunately, information quantifying these risks is rare. Such information is valuable for identifying both the scope of the problem and potential practices to reduce claims, change orders, and cost overruns. The objective of this Synthesis is to characterize the nature of claims, change orders, and cost overruns resulting from subsurface conditions for U.S. transportation agencies, and to identify practices used by agencies to reduce such claims, change orders, and cost overruns.

The information in this Synthesis is derived from a literature review, a survey of transportation agencies, and case examples from state agencies with experience reducing claims, change orders, and cost overruns resulting from subsurface conditions. The Synthesis addresses:

- The scope of subsurface investigation required by transportation agencies;
- Causes of claims, change orders, and cost overruns attributed to subsurface conditions;
- Ranges of costs and prevalence of claims, change orders, and cost overruns attributed to subsurface conditions; and
- Successful practices to reduce claims, change orders, and cost overruns.

The survey was sent to 55 agencies: every state department of transportation (DOT) including the District of Columbia and Puerto Rico and the three Federal Lands Highway divisions. The survey was directed to agency geotechnical engineers, many of whom shared responsibility for completing the survey with construction personnel. Fifty-one responses were received, including 46 from the DOTs, a response rate of 92% for the state agencies. The survey consisted of three parts: Part One addressed subsurface investigation practices; Part Two requested qualitative information about claims, change orders, and cost overruns; and Part Three requested quantitative information. Part Three was deemed to be optional because the information requested was difficult for many agencies to gather. Eleven agencies included responses to Part Three. Five of the agencies that indicated decreases in subsurface conditions claims, change orders, or cost overruns were selected as case examples, which were developed by reviewing agency documents and interviewing agency personnel.

Nearly 70% of responding agencies have minimum subsurface investigation requirements that are equal to or generally consistent with AASHTO specifications and guidelines. Fourteen percent of the responding agencies do not have minimum subsurface investigation requirements, 10% have requirements exceeding AASHTO specifications and guidelines, and the other responding agencies have requirements that are either materially different from AASHTO specifications and guidelines (6%) or less stringent than AASHTO specifications and guidelines (2%).

The most common causes of claims, change orders, and cost overruns resulting from subsurface conditions included:

- Pile overruns;
- Groundwater shallower than expected, affecting many types of construction;
- Seepage problems, including those requiring dewatering, which was identified as being notably more costly than other causes;

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- Misclassified or mischaracterized subgrade, resulting in quantity revisions related to pavements, earthwork, and removal and replacement requirements for foundations;
- Unanticipated rock excavation, especially that when encountering rock shallower than expected or encountering rock at foundation locations where it was not expected; and
- Mischaracterized rock for drilled shaft construction.

The survey revealed the following quantitative information regarding the frequency and cost of claims, change orders, and cost overruns attributed to subsurface conditions:

- The annual cost of change orders resulting from subsurface conditions was commonly in the millions of dollars and as much as $10 million per agency.
- The total share of claims, change orders, and cost overruns attributed to subsurface conditions out of all claims, change orders, and cost overruns was 5% by number and 7% by cost.
- The cost of subsurface condition change orders approaches 1% of the agencies' total budgets for new construction.
- Survey results indicated that the impact of subsurface conditions claims, change orders, and cost overruns is particularly significant on a project level. For instance, for one agency the cost of the average subsurface condition change orders alone consumed 7% of the associated project budget for one agency. The impact on some individual project budgets was likely much greater than 7% considering the variability of change orders.

Results of the Synthesis survey strongly suggest that, on average, claims, change orders, and cost overruns have neither increased nor decreased since 2005, although some agencies have observed increases and others decreases. This finding applies to all claims, change orders, and cost overruns, as well as to those attributed to subsurface conditions. The case examples were selected from agencies that reported decreases in subsurface conditions claims, change orders, and cost overruns. The case examples, along with some discoveries from the literature, revealed several practices reported as being effective for reducing claims, change orders, and cost overruns. Many of the effective practices summarized here do not require additional agency investment.

- In general, relatively modest changes to subsurface investigation practices can produce considerable reductions in claims, change orders, and cost overruns, particularly when the changes are tailored to a specific, recurring problem. For instance, Florida DOT reduced earthwork claims by requiring that plans show hard material that cannot be excavated using a backhoe with rock patterning rather than patterns associated with soil. Modest "directed" measures appear to be more effective and less costly to implement than "across-the-board" changes.
- Communication and training involving a broad spectrum of agency and contractor personnel (including designers, contractors, inspectors, and field crews) appear to be a critical component to realizing the benefits of improvements to site characterization practices. Examples of such communication include agency guidelines and specifications, contract and bid documents, and regular training opportunities.
- Improving subsurface investigation practice has clear benefits for design, even if substantial reductions in claims, change orders, and cost overruns are not achieved.
- Improving the accuracy of boring location information can be effective in reducing claims, change orders, and cost overruns, especially for construction sites with significant spatial variation.
- Implementing minimum standards for subsurface investigation and site characterization was reported to reduce claims, change orders, and cost overruns. After publishing its *Geotechnical Design Manual*, South Carolina DOT observed fewer claims associated with excavation equipment requirements and improved accuracy of plan earthwork quantities.

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The scarcity of published quantitative information regarding claims, change orders, and cost overruns attributed to subsurface conditions underscores the value of the survey findings of this Synthesis. The findings are motivation for additional research to reduce uncertainties regarding subsurface conditions claims, change orders, and overruns and helped to identify areas where modifications to agency practices could produce notable cost or performance improvements. Suggested research topics are introduced here:

- Investigation of improved methods of archiving, tracking, and coding claims, change orders, and cost overruns because they represent significant learning opportunities for agencies.
- It is important that specific risks of subsurface conditions claims, change orders, and cost overruns be quantified. This topic will require collection of project-level data regarding subsurface conditions claims, change orders, and cost overruns. The information collected for this Synthesis is derived from agency-level totals, whereas project-level information (causes of specific claims, change orders, and cost overruns and details regarding corresponding geotechnical investigations) is necessary to accurately quantify specific risks.
- Evaluation of the effect of geotechnical investigation scope requirements to establish a consistent level of risk of claims, change orders, and cost overruns for projects with varying geotechnical challenges.
- Identification of the most effective use of cone penetration testing, geophysical methods, and other alternative techniques within the scope of geotechnical investigations. Use of conventional boring explorations was reasonably consistent among survey agencies; however, the use of other types of investigation varied widely.
- Study of agency practices regarding communication and training related to geotechnical investigation and information is essential. Communication and training practices were reported as having a notable effect on subsurface conditions claims, change orders, and cost overruns.

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CHAPTER ONE

INTRODUCTION

Risks associated with geotechnical issues are significant for many construction projects and many if not most of these risks are directly or indirectly affected by the quantity and quality of subsurface investigations. Baynes (2010) found that the likelihood of experiencing geotechnical problems that significantly impact project costs or schedule on major infrastructure projects is between 20% and 50%. Other studies have found similar results for various sectors of the construction industry (e.g., Hoek and Palmeiri 1998; Clayton 2001).

Specific data regarding the extent of geotechnical issues experienced by U.S. transportation agencies are lacking, and the significance of subsurface conditions in the totality of claims, change orders, and cost overruns is uncertain. The information regarding the number, cost, and type of claims, change orders, and cost overruns attributed to subsurface conditions provided in this Synthesis is useful in defining the extent of the problem; a necessary first step toward solving any problem. There is no single approach to reducing risks associated with subsurface conditions; however, many approaches have been implemented by different transportation agencies with varying success and expense. This synthesis defines the extent of the problem and identifies potential solutions by documenting transportation agency experience.

OBJECTIVES

The purpose of this Synthesis is to document the frequency, cost, and type of claims, change orders, and overruns attributed to subsurface conditions in transportation infrastructure construction and identify measures taken by transportation agencies to reduce such claims, change orders, and cost overruns. These objectives were achieved by collecting information related to

- The scope of subsurface investigations required by transportation agencies;
- Causes of claims, change orders, and cost overrun attributed to subsurface conditions;
- The range of costs and prevalence of claims, change orders, and cost overruns attributed to subsurface conditions; and
- Measures taken to prevent or reduce risks of claims.

METHODOLOGY AND OUTLINE

Information was acquired three ways: a literature review, a survey of transportation agencies, and interviews regarding several detailed case examples. These activities are summarized here, and results for each are presented in chapters two, three, and four, respectively. Conclusions are presented in chapter five.

Literature Review

References relevant to each of the four objective topics were reviewed and are summarized in chapter two. The literature review begins by examining and summarizing U.S. transportation practices for subsurface investigation. Next it presents the experience of Indiana Department of Transportation (DOT) with geotechnical change orders, which was documented in previous research with objectives similar to those of this Synthesis (Prezzi et al. 2011). References related to the effect of subsurface investigation on claims, change orders, and cost overruns are also documented in this chapter. The literature review concludes by examining human effects (essentially, claims resulting from an engineering failure to recognize risks) and those effects related to contracting practices (i.e., project delivery mechanism and bid documents).

Survey

A three-part survey was administered electronically to 55 agencies, including the state transportation agencies for all 50 states, Puerto Rico, and the District of Columbia, as well as the three divisions of the FHWA Office of Federal Lands Highway. Fifty-one agencies responded to the survey, including 46 of the state DOTs, which corresponds to a response rate of 92% for the state agencies. Part One of the survey contained questions related to subsurface investigation practices; Part Two included general, mostly qualitative questions concerning claims, change orders, and cost overruns. Part Three requested specific quantitative information regarding claims, change orders, and cost overruns. Part Three was considered optional because the quantitative data requested are not readily available for many agencies owing to the difficulties explained here. The survey was distributed to agency geotechnical engineers; however, the survey instructions encouraged these engineers to share the survey with construction colleagues,

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especially for assistance with completing Parts Two and Three. The survey provided the following definitions to encourage consistency among responses:

- Claim: A claim is a legal demand by a contractor for additional compensation or time when the contractor believes he or she is entitled to it under the terms of the contract documents. Potential claim resolutions include denial or rejection, a change order for additional compensation or additional time, or other resolutions involving dispute review boards, mediators, or courts.
- Change order: A change order is a formal modification of the scope of work established in contract documents, often including adjustments to compensation and/or schedule.
- Cost overrun: A cost overrun refers to instances when the cost of a project or bid item at project completion exceeds its initially contracted cost.

Case Examples

Several agency survey responses noted success in reducing claims, change orders, and cost overruns attributed to subsurface conditions. Additional investigation into the practices and experiences of these agencies was performed by conducting interviews with agency personnel and reviewing available agency documents. The agency interviews were also used to compile a list of frequently encountered claims, change orders, and cost overruns attributed to subsurface conditions. Chapter four includes that list as well as a summary of lessons learned from each of the five agencies.

DIFFICULTY OF EVALUATING DATA REGARDING CLAIMS, CHANGE ORDERS, AND COST OVERRUNS

Several factors complicated the collection and evaluation of quantitative data regarding claims, change orders, and cost overruns. Primarily, these factors relate to how the agencies organize databases of claims, change orders, and cost overruns. First, agency definitions of claims, change orders, and cost overruns do not necessarily align with the definitions provided previously. Also, parsing out causes for each claim, change order, and cost overrun is difficult. Frequently, a single reason code is assigned to each incident, and "subsurface conditions" is not necessarily a typical reason code. Even when claims, change orders, and cost overruns attributed to subsurface conditions could be separated from the entire set of claims, change orders, and cost overruns, multiple causes are possible and some, such as design issues or agency communication issues, are not necessarily related to geotechnical investigation. Furthermore, all of these factors depend on unique agency practices and the perspectives of specific survey respondents.

The confounding of subsurface conditions claims, change orders, and cost overruns resulting from geotechnical investigation issues with those of design or communication issues was not unique to the quantitative portion of the survey; information from the literature review and case examples also indicates the overlap. Discussions throughout this Synthesis consider all causes of subsurface conditions claims, change orders, and cost overruns; however, the primary focus is on the scope of geotechnical investigations.

DEFINITIONS

This report makes frequent reference to the concept of risk, which is fundamental to construction claims, change orders, and cost overruns. For the purposes of this report, risk is defined as the product of the probability of an event occurring and the costs expected to be incurred if the event occurs. Thus, if the probability of experiencing pile overruns greater than 10 ft is 5% and the cost of 10-ft overruns totals $50,000, the risk of pile overruns greater than 10 ft is $2,500. None of the other references to risk used in this report are so specific as to define probabilities, and most do not include cost information; however, the concept is the same as that presented for the pile overrun example.

For the purposes of this report, the frequently used term geotechnical investigation refers to the process of identifying subsurface materials and describing their engineering properties through explorations including, but not limited to, borings, in situ test methods, and laboratory tests.

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CHAPTER TWO

LITERATURE REVIEW

Five topics of interest to the role of subsurface investigation on claims, change orders, and cost overruns were reviewed and provide the outline for this chapter.

- Transportation agency standards for subsurface investigation.
- A research report on geotechnical change orders at Indiana DOT.
- The effect of subsurface investigation on claims, change orders, and cost overruns.
- The human effect on claims, change orders, and cost overruns attributed to subsurface conditions.
- The effect of contracting practices (e.g., design-build project delivery mechanism) on claims, change orders, and cost overruns attributed to subsurface conditions.

TRANSPORTATION AGENCY SUBSURFACE INVESTIGATION PRACTICES

U.S. transportation agencies have varying requirements and practices for subsurface investigation. Details of agency requirements and practice are presented in chapters three and four. This section summarizes three sources of national guidance regarding subsurface investigation that have informed many of the state agency guidelines. This section also presents agency practices for performing subsurface investigation, especially with respect to in-house investigation versus investigation through subcontracting.

AASHTO *Manual on Subsurface Investigations* and *LRFD Bridge Design Specifications*

The AASHTO *Manual on Subsurface Investigations* (AASHTO 1988) presents information and recommendations related to site characterization for all types of transportation facilities. A major revision of the manual is currently underway. The manual's general recommendations, especially those for boring spacing and boring depth (Section 7), have been adopted by many state agencies. The recommendations for boring spacing and boring depth were also adopted in the Foundations Section (Section 10) of the AASHTO *LRFD Bridge Design Specifications* (AASHTO 2014).

National Highway Institute *Manual on Subsurface Investigations*

FHWA's National Highway Institute (NHI) offers a training course regarding subsurface investigations; the course manual (Mayne et al. 2001) is also referenced by the AASHTO *LRFD Bridge Design Specifications* (AASHTO 2014). The NHI manual includes similar information to that in the AASHTO *Manual on Subsurface Investigations*, but with significant updates resulting from advancements in technology and practice, especially those related to the cone penetration test (CPT) and geophysics.

FHWA *Geotechnical Engineering Circular No. 5*

FHWA published another manual that includes information regarding subsurface investigation, *Geotechnical Engineering Circular No. 5* (*GEC5*)*: Evaluation of Soil and Rock Properties* (Sabatini et al. 2002). As with the AASHTO and NHI subsurface investigation manuals, *GEC5* includes information on planning subsurface investigations; however, *GEC5* also devotes significant attention to interpretation of subsurface investigation data for design purposes. The AASHTO *LRFD Bridge Design Specifications* (AASHTO 2014) also refers to *GEC5* for information regarding subsurface investigations. A significant revision of *GEC5* is underway.

Agency Subsurface Investigation Capabilities

Badger (2015) surveyed 36 state transportation agencies regarding agency practices for subsurface investigation. Most agencies (30 of 36) have in-house capabilities; the remaining six contract all exploration services. Half of the surveyed agencies reported their field exploration program had decreased over the previous ten years. One respondent noted in-house capabilities were more common for small projects, which had been associated with relatively high administrative costs for processing contracts and payments for external subsurface investigations. Another respondent noted all in-house capabilities were eliminated in 2005 because of the need for equipment replacement and limited resources. One respondent whose agency now predominantly uses contract drilling instead of in-house capabilities noted less drilling is accomplished per project because the contract drilling cost is greater.

A 2007 NCHRP Synthesis survey of U.S. state and Canadian provincial transportation agencies found that nearly three-quarters of responding agencies used CPT on 10% or fewer of projects (Mayne 2007). Almost two-thirds of the respondents cited subsurface materials that were too hard to penetrate with CPT as an obstacle to its use. However, the same study found

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that 64% of agencies anticipated an increase in their use of CPT. Indeed, Badger's survey (2015) found that three-quarters of the 36 responding agencies used CPT, although the responses did not indicate how frequently each agency employed it.

GEOTECHNICAL CHANGE ORDERS AT INDIANA DEPARTMENT OF TRANSPORTATION

The causes and costs of geotechnical change orders at the Indiana DOT (INDOT) were studied by Prezzi et al. (2011) and Khan (2014) with objectives similar to those established in chapter one. The results of that project are summarized here to identify common sources of geotechnical change orders and their costs before those topics are explored more generally for all agencies in chapters three and four.

Prezzi et al. (2011) studied INDOT change orders associated with work done by the agency's geotechnical office over a 5-year period beginning in 2003. The work was motivated by an agency perception that change orders "attributed to geotechnical conditions" were "excessive" and perhaps increasing; the research was designed to quantify the number and cost of geotechnical change orders and to develop guidance for reducing them. The study included three components:

1. A national survey similar to that conducted for this synthesis.
2. Analysis of change order information from the ten largest contracts per year in each of INDOT's six districts (300 contracts total).
3. Thirteen interviews with agency project engineers and external consulting engineers familiar with INDOT projects and practices.

The national survey response rate was low and the survey results that were received were limited. Prezzi et al. (2011) focused primarily on results of the quantitative change order analysis. Several of the project's results are most pertinent to this synthesis topic:

- Quantitative analysis of change order data is complicated by difficulties associated with interpreting a large database of unique incidents that must be categorized by agency definitions. The authors chose to consider both "soil-related works" change orders; that is, all change orders associated with any construction activities or materials associated with geotechnical work (e.g., debris removal), as well as a more specific class of change orders with geotechnical causes, which were determined based on INDOT database reason codes; for example, Constructability: Soils Related. It was noted that the latter definition was more meaningful for geotechnical work because the former included change orders not directly related to geotechnical work.
- The average cost of geotechnical change orders was 1.3% of the estimated total construction costs.
- The cost of geotechnical change orders was just over 10% of the total cost of all change orders.
- Approximately one-quarter of the projects (84 of 300) included geotechnical change orders, with many of these projects including more than one geotechnical change order.

The project engineer and external consulting engineer interviews also produced information relevant to this synthesis. Four main causes for geotechnical claims based on the interviews were summarized, although some of the causes are associated more with design issues than with investigation problems:

- Failure to identify poor subgrade that was frequently attributed to inadequate site investigation, but also resulted from improper plan elevations.
- Pile overruns and underruns, which occur when the as-built driven pile depths are different from those shown on plans.
- Erosion control material quantity errors often associated with underestimating riprap and geotextile quantities as a result of mischaracterizing the soil drainage conditions.
- Mechanically Stabilized Earth wall construction, although the changes were mostly related to no geotechnical aspects such as wall geometry conflicting with surface drainage lines.

The interviewees also provided the following recommendations for reducing geotechnical change orders:

- More boreholes as well as more flexibility in planning subsurface investigations considering geology, prior site knowledge, and region.
- A design checklist addressing issues commonly encountered during construction.
- Expedient decisions when construction issues are encountered because time was perceived to dramatically increase the cost of change orders.

INDOT continued to track geotechnical change orders following the publication of the Prezzi report. In a presentation to the FHWA Midwest Geotechnical Conference, Khan (2014) presented data from 2009 to 2013 showing that the average annual total cost for geotechnical change orders was $10 million, approximately 17% of all change orders and just less than 1% of the total amount the agency spent on construction. Khan cited inadequate geotechnical investigation as a primary cause of geotechnical change orders. He also mentioned many of the factors from the Prezzi (2011) report listed earlier. More details of INDOT's experience with geotechnical change orders are presented in chapter four.

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EFFECT OF SUBSURFACE INVESTIGATION ON CLAIMS, CHANGE ORDERS, AND COST OVERRUNS

Gould (1995) provided useful information regarding how geotechnical construction risks are affected by subsurface investigation. Consistent with court and construction industry terminology, Gould defined two types of differing site condition claims, Type I and Type II. Type I changes refer to differences between encountered site conditions and those shown in contract documents, whereas Type II changes refer to a "surprise to all, not a discrepancy in the documents but an unusual physical condition beyond that reasonably expected." Gould noted that while additional subsurface exploration reduces the risk of Type II changes, it can increase the risk of Type I changes by "offering a larger target to an aggrieved contractor." Gould also identified four causes of changes that can occur even when a competent subsurface investigation is completed:

1. Surprise claims for incidents that defy experience with local geology and/or the construction task.
2. Incidents resulting from conditions that cannot be defined adequately from ordinary investigation methods; for example, Gould cites underpredicting the size of a boulder.
3. Claims resulting from properties that are misunderstood as a result of "limitation in the state of the art."
4. Incidents involving features that are too small to be discovered given the precision of the subsurface investigation.

Gould also provided detailed guidance for subsurface exploration practices to control claims. The guidance is presented as 11 specific practice suggestions, which are introduced by a warning that "exploration focused too narrowly on design may be insufficient for construction."

Mott MacDonald and Soil Mechanics, Ltd. (1994) studied the effect of subsurface investigation on construction cost overruns by examining results from a database of 58 transportation projects in the United Kingdom. Three-quarters of the projects had cost overruns greater than 10% of the contract value. The authors reported "about half" of the overruns resulted from geotechnical causes, the most common being (1) problems from seepage and groundwater, (2) encountering materials different in classification from those anticipated, and (3) removal and replacement of additional unsuitable material. The direct geotechnical cost overruns averaged 3% of contract cost, which the authors compared with an average of 1% of contract cost spent on site investigation. Indirect claims resulting from delay and disruption were more significant, amounting to 5% of contract cost. It was noted that while most of the direct costs would have been required even with an adequate site investigation, the indirect overruns could have been avoided.

The Mott MacDonald and Soil Mechanics, Ltd. 1994 report includes a graph of the total increase in final construction cost versus site investigation cost, with both quantities expressed as a percentage of the project award cost (Figure 1). The authors of this report refer to an "outer bound," although the upper bound included in Figure 1 was added by Clayton (2001). The shape of the upper bound line is strong evidence that increased subsurface investigation does indeed reduce risks associated with geotechnical construction. However, there are a significant number of projects with relatively

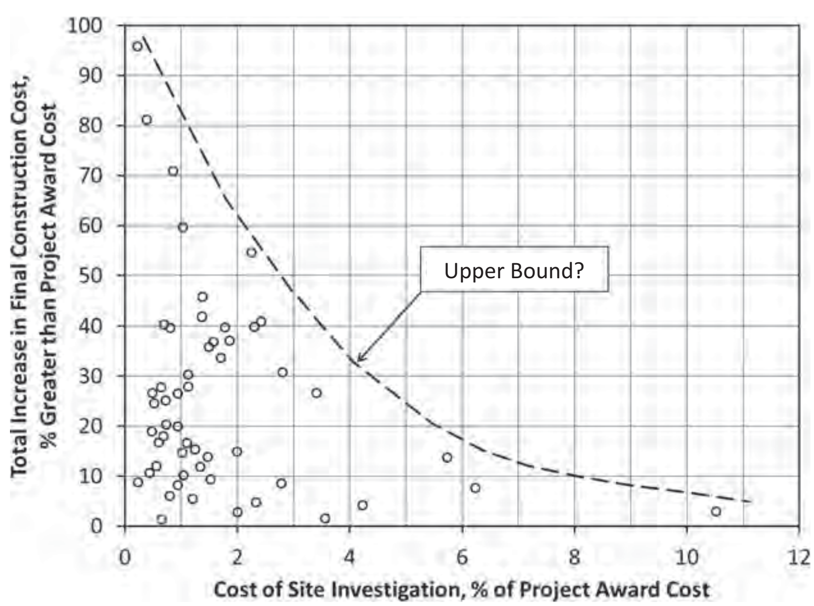

FIGURE 1 Graph of increases in construction cost for infrastructure projects as a function of cost of subsurface investigation (adapted from Clayton 2001 and Mott MacDonald and Soil Mechanics Ltd. 1994).

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limited subsurface investigation costs that experienced only modest cost overruns. These projects, and, in general, the vertical variation of the data points for a given level of subsurface investigation suggest there are other factors that affect the amount of the cost overrun. Part of the cost overrun variation results from some ground problems being more difficult to resolve than others; however, it is also likely that "better" subsurface investigation practices produce better site characterization and result in more useful information for design and construction.

A similar study was undertaken by the U.S. National Committee on Tunneling Technology (USNCTT), which studied the effect of geotechnical site investigation on construction changes and claims. USNCTT described differing site condition change orders and claims as "many" and "costly" (U.S. National Committee on Tunneling Technology 1984). Indeed, Gould (1995) summarized the data from the USNCTT study as including claims that amounted to 12% of the overall construction costs. The USNCTT study included 87 major tunneling projects constructed over a 20-year period. USNCTT examined the ratio of completed cost to engineer's estimate versus subsurface exploration quantity and cost data, which were available for 36 of the projects. The resulting plots reveal significant scatter, but USNCTT noted that engineer's estimates become more reliable as the subsurface exploration quantity and cost increase. USNCTT recommends 1.5 linear feet of borehole per route foot of tunnel; according to the study, the cost of such an investigation is roughly equivalent to 3% of construction cost.

Finally, improved subsurface investigation has other benefits for infrastructure projects. Many studies have noted that improved subsurface investigation results in design efficiencies as well (e.g., Hoek and Palmeiri 1998; Clayton 2001; Ching et al. 2014).

HUMAN EFFECTS ON SUBSURFACE CONDITIONS CLAIMS, CHANGE ORDERS, AND COST OVERRUNS

Interestingly, several studies have concluded that geotechnical risks are not exclusively attributable to ground conditions, but also involve human contributions. Based on the collective evaluation of several studies of geotechnical risks, Baynes (2010) concluded that "available information suggests that the ground conditions and the project staff responsible for the geo-engineering process are both significant sources of geotechnical risk and that the project staff may actually be the largest source." Clayton (2001) described this "human" aspect of geotechnical risk as follows:

> There are numerous ways in which the ground can cause problems for construction, for example due to chemical attack, heave, subsidence, groundwater flow, slope failure, excessive foundation settlement, and so on. Because of the considerable range of risks the ground can pose, it is relatively easy for an inexperienced or non-specialist designer, perhaps using routine procedures, to fail to recognise a critical mechanism of damage or failure that may threaten either the financial viability or health and safety of a project. If a mechanism of damage (a limit state) is not foreseen then it cannot be designed for, and it is often for this reason that ground-related problems occur.

Similar conclusions were reached by Moorehouse and Millet (1994) in an analysis of 37 geotechnical consulting cases involving failure, which the authors defined as "the results of the unfulfillment of a claim, promise, request, need, or expectation between and among any of the design and construction parties and the client." The study focused on engineering consulting services, but reached conclusions applicable to this synthesis. The second most common cause of failure, noted in 15 of the 37 cases, was "lack of disclosure of risks, uncertainties, and consequences," meaning the engineer failed to effectively advise owners or contractors about geotechnical risks that ultimately came to fruition. The most common cause of failure was "recommendation not followed by client or contractor," which has similar albeit more obvious roots in human error. The authors' recommendations emphasize the responsibility of management personnel to staff and train technical personnel appropriately and to "deal with the real need for intelligent disclosure of risks, uncertainties, and consequences."

The findings of Baynes (2010), Clayton (2001), and Moorehouse and Millet (1994) suggest that human effects are a primary cause of subsurface conditions claims, change orders, and cost overruns, likely equal in importance to the more tangible effects of geotechnical investigation and construction practices. Clear and transparent communication of risks, assumptions, expectations, and consequences among agency, contractor, and consulting personnel is likely critical to reducing subsurface conditions claims, change orders, and cost overruns.

EFFECT OF CONTRACTING PRACTICES ON SUBSURFACE CONDITIONS CLAIMS, CHANGE ORDERS, AND COST OVERRUNS

Even a quick reading of literature related to claims, change orders, and cost overruns attributed to subsurface conditions reveals that contractual issues play a significant role. Construction contracts allocate risks between owner and builder. Typically, subsurface risks are allocated to owners through a differing site condition clause. Contractual issues are not a focus of this synthesis; however, two contract topics—bid documents and design-build arrangements—are summarized here because of their relevance to the synthesis topic.

Geotechnical Bid Documents: Lessons from the Tunneling Industry

The high frequency of litigation encountered in tunneling practice has motivated the tunneling industry to advocate practices that reduce litigation. Gould (1995) summarized

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recommendations by the Underground Technology Research Council (UTRC) as follows:

- Include a changed-condition clause in the construction contract.
- Disclose fully in contract documents all geological data and interpretation.
- Eliminate disclaimers that discount the value of the included geotechnical data.
- Escrow bidding documents that show assumptions and pricing of the successful bidder.
- Include a geotechnical design summary report in contract documents.
- Establish in the contract a dispute review board for expeditious review and settlement of disputes.

The last recommendation, establishing a dispute review board (DRB), has gained favor in the tunneling profession since UTRC made its recommendation. The Eisenhower Tunnel in Colorado, constructed in the late 1970s, was one of the first projects to include a DRB; by 1990, the use of such boards was prevalent, with the cost of projects using DRBs amounting to 70% of all tunneling project costs (Gould 1995). Gould noted that schedule advantages of DRBs exceed simply avoiding delays associated with the court system: DRB members are familiar with the project background and progress; therefore, disputes can be resolved quickly using on-site personnel. UTRC estimated that the costs of maintaining a DRB ranges from 0.1% to 0.3% of total project construction cost.

The geotechnical design summary report is another of the UTRC recommendations that has been implemented, although its name has evolved to Geotechnical Baseline Report (GBR). Recommendations for GBRs were outlined by ASCE (2007) in an update to the original recommendations of the UTRC. The updates were primarily motivated by a desire to expand the application of GBRs beyond tunneling to include deep foundations and highways, among other types of construction. ASCE's Suggested Guidelines identify the GBR as the "single interpretative report" to be included with bid documents; all other factual information from subsurface investigations are to be included as a Geotechnical Data Report; however, it essential that the GBR prevail over the Geotechnical Data Report. The baseline of GBRs refers to the anticipated site conditions presented in the report. Contractors assume risks associated with conditions consistent with or more favorable than the baseline; owners assume risks associated with conditions less favorable than the baseline. The ASCE Suggested Guidelines provide additional recommendations for establishing baselines, including for design-build projects.

Design-Build Contracts

The 21st century has seen a significant increase in design-build contracts used for transportation construction, and FHWA featured design-build as a 2012 Every Day Counts initiative. Among many perceived benefits of design-build (e.g., accelerated project schedules, promotion of innovation, and efficiencies related to having designers and constructors on one team), one is especially relevant to this synthesis: the opportunity to reduce owner risks compared with arrangements typically assumed for design-bid-build contracts. This opportunity is primarily manifested by eliminating the risk of claims related to design errors; however, agencies may also shift some of the risks of subsurface conditions, typically assumed wholly by the agency, to the design-builder (Gransberg and Loulakis 2012).

Gransberg and Loulakis present a thorough review of contractual practices for geotechnical aspects of design-build projects in *NCHRP Synthesis 429*: *Geotechnical Information Practices in Design-Build Projects* (2012), which emphasizes the accelerated schedule of design-build projects, with contracts frequently awarded before subsurface investigation is complete, as requiring especially competent management of geotechnical risks. This synthesis cites four measures commonly employed by agencies to manage geotechnical risks on design-build projects:

1. Selecting only design-build teams with significant geotechnical experience.
2. Assigning the most qualified agency geotechnical personnel to design-build project oversight.
3. Limiting geotechnical designs to those in which the agency is confident.
4. Retaining quality management roles and responsibilities for geotechnical features in house.

This report devotes significant attention to the unique contractual issues associated with design-build projects. Frequently, the design-builder will have at least some if not substantial responsibility for developing and performing the subsurface investigation. In response, agencies have shifted some of the contractual risk for differing site conditions to the design-builder; however, 10 of 11 design-build contractors interviewed for the synthesis indicated that the ambiguity regarding how these shifts would be implemented was cause for concern. Only one agency, Washington State DOT (WSDOT), was identified by a contractor as having an unambiguous contract provision. WSDOT's "risk sharing clause" establishes a threshold dollar amount for differing site conditions for which design-builders assume risk; above the threshold, WSDOT assumes differing site condition risks.

Another contracting practice identified as effective was establishing a process for "expeditious resolution of discrepancies between pre-award and post-award geotechnical conditions." Both the expeditious review process and the risk sharing clause are similar to practices employed in the tunneling industry.

In his discussion of geotechnical risks and human factors, Clayton (2001) also alluded to design-build effects. He stated that increasing use of innovative contracting methods such

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as design-build, which "disperse design responsibility," is likely to increase ground-related problems unless changes are made to subsurface investigation practices. Clayton's prediction is consistent with the observations of Gransberg and Loulakis's (2012) of increased geotechnical risks. Unclear, however, is how design-build risks are to be mitigated and whether responsibility will be assigned to agencies or design-builders when they are not.

SUMMARY OF SIGNIFICANT FINDINGS

- AASHTO guidance regarding subsurface investigation is provided in the *Manual on Subsurface Investigations* (AASHTO 1988) and in the *LRFD Bridge Design Specifications* (AASHTO 2014). The recommendations in the AASHTO documents are consistent with one another.
- A survey of 36 state transportation agencies by Badger (2015) indicated that agency in-house subsurface investigation is common but decreasing, while use of the CPT is less common but increasing. Badger's survey found that three-quarters of the 36 responding agencies (27) used CPT.
- A study of INDOT change orders by Prezzi et al. (2011) found that quantitative analysis of change order data was complicated by database issues.
- The study by Prezzi et al. (2011) also found that the average cost of geotechnical change orders was 1.3% of the estimated total construction costs, that the cost of all geotechnical change orders was just over 10% of the total cost of all change orders, and that approximately one-quarter of the projects included geotechnical change orders.
- Gould (1995) described two types of differing site condition claims: Type I, which applies to discrepancies between conditions depicted by contract documents and actual conditions, and Type II, which are a "surprise to all." Additional site investigation reduces the risk of Type II claims, but may increase the risk of Type I changes.
- Clayton (2001) analyzed data from a study by Mott MacDonald and Soil Mechanics, Ltd. (1994) and found that the magnitude of subsurface conditions cost overruns decreases with increased site investigation expense relative to total construction cost. However, many projects with relatively limited site investigations experienced only modest cost overruns.
- The study by Mott MacDonald and Soil Mechanics, Ltd. (1994) found indirect costs associated with subsurface conditions claims, change orders, and cost overruns to be greater than direct costs.
- Studies by Baynes (2010), Clayton (2001), and Moorehouse and Millet (1994) suggest that human effects are a primary cause of subsurface conditions claims, change orders, and cost overruns.
- Gould (1995) described recommendations from the tunneling industry related to bid practices intended to reduce claims, change orders, and cost overruns. Most prominent were use of DRBs to resolve issues quickly and the creation of GBRs. GBRs are also recommended by ASCE (2007) because they provide a "single interpretive document."
- Geotechnical risks may be greater on design-build projects. Gransberg and Loulakis (2012) summarized four recommendations for managing geotechnical risks on design-build projects, including selecting consulting teams with significant geotechnical qualifications and retaining quality management in-house.

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CHAPTER THREE

SURVEY RESULTS

A three-part survey was administered to 55 agencies, including state transportation agencies for all 50 states, Puerto Rico, and the District of Columbia, as well as the three divisions of the Office of Federal Lands Highway. The complete survey questionnaire is provided in Appendix A, and complete survey results are presented in Appendix B. Part One of the survey contained questions related to subsurface investigation practices. Part Two included general, mostly qualitative questions about claims, change orders, and cost overruns. Part Three requested specific quantitative information regarding claims, change orders, and cost overruns, and was optional because it was anticipated that the quantitative data requested would not be readily available for many agencies. The survey was distributed to agency geotechnical engineers; however, the survey instructions encouraged the engineers to share the survey with construction colleagues, especially for help with completing Parts Two and Three. Fifty-one agencies responded to the survey, including 46 state DOTs, which corresponds to a response rate of 92% for the state agencies. Responding agencies are shown in the map in Figure 2. Of the 51 responding agencies, 11 included at least a partial response to Part Three. This chapter summarizes the results of the survey, including subsurface investigation practices; qualitative and quantitative information regarding the nature of claims, change orders, and cost overruns attributed to subsurface conditions; and the relationship between subsurface investigation practices and claims, change orders, and cost overruns.

SUBSURFACE CONDITION PROBLEMS AND SUBSURFACE INVESTIGATION PRACTICES

Several of the questions in Part One of the survey inquired generally about problems related to subsurface conditions the agencies might have experienced. As shown in Table 1, a majority of responding agencies (63%) stated they experienced a modest number of problems resulting from subsurface conditions, whereas only two agencies responded that they experienced frequent problems. Another question in Part One asked the respondent if his or her agency had experienced significant performance problems that could be attributed to subsurface conditions or site characterization practices. Forty-one percent of respondents indicated their agency had experienced such problems, whereas 53% indicated they had not. Together, the responses to these two questions indicated that two-thirds of agencies experience problems attributed to subsurface conditions, and the severity and frequency of the problems vary. The remaining one-third has infrequent and relatively insignificant problems related to subsurface conditions.

Responses from Table 1 are shown by agency in Figure 3. There are some geographic trends that can perhaps be explained by geologic regions. About half of the agencies with infrequent and relatively insignificant problems related to subsurface conditions are located in the Central Lowlands and Great Plains geologic regions of the Midwest. The agencies with modest or frequent subsurface condition problems are distributed throughout the rest of the country.

Most of the remaining questions in Part One address subsurface investigation practices. As shown in Table 2, slightly more than half of responding agencies indicated that site characterization is often difficult. Among these agencies, most cited highly variable subsurface conditions rather than difficult-to-characterize materials as the source of site characterization difficulty.

Responses from Table 2 are shown by agency in Figure 4. As noted for the frequency of subsurface conditions problems (see Figure 3), many of the agencies for which site characterization is generally not difficult are located in the Central Lowlands and Great Plains geologic regions of the Midwest. There is also a cluster of agencies in the Coastal Plain region of the South Atlantic states.

Most of the responding agencies (40, 78%) have a state-specific manual and/or specifications that describe requirements and practices for site characterization, and most of those agencies included an Internet link to access the manual. A list of the links is included in the short answer responses to Question 5 included with Appendix B3.

All respondents indicated that it is important that subsurface information be provided with project bid documents; a list of the required documents for each agency is also included with Appendix B3 (Question 6). The documents vary widely, with some agencies providing all available geotechnical information and reports and others limiting the information to boring logs only. Several agencies included Geotechnical Data Reports; however, none mentioned GBRs, which were discussed in chapter two. Several agencies also indicated that some geotechnical information is available for background information only.

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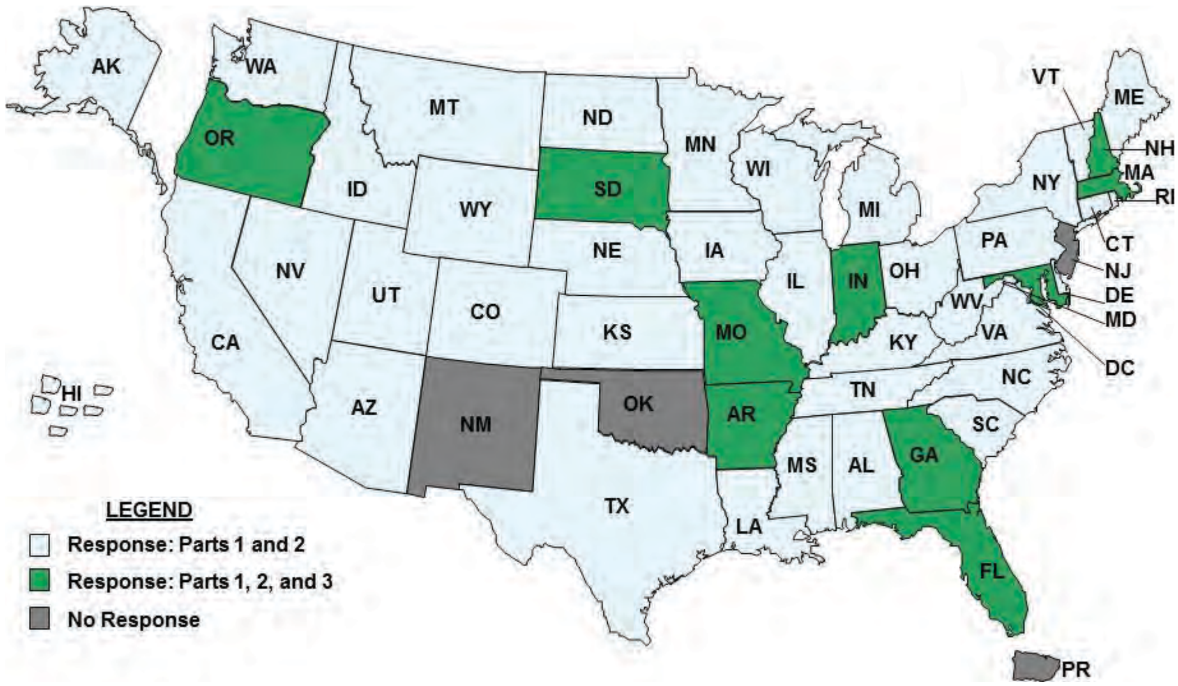

FIGURE 2 Survey agencies.

TABLE 1
AGENCY PROBLEMS FROM SUBSURFACE CONDITIONS

Response	Number	Percent
My agency experiences relatively few design, construction, and performance problems resulting from subsurface conditions	17	33
My agency experiences a modest number of design, construction, and performance problems resulting from subsurface conditions	32	63
My agency experiences frequent design, construction, and performance problems resulting from subsurface conditions	2	4

51 responses.

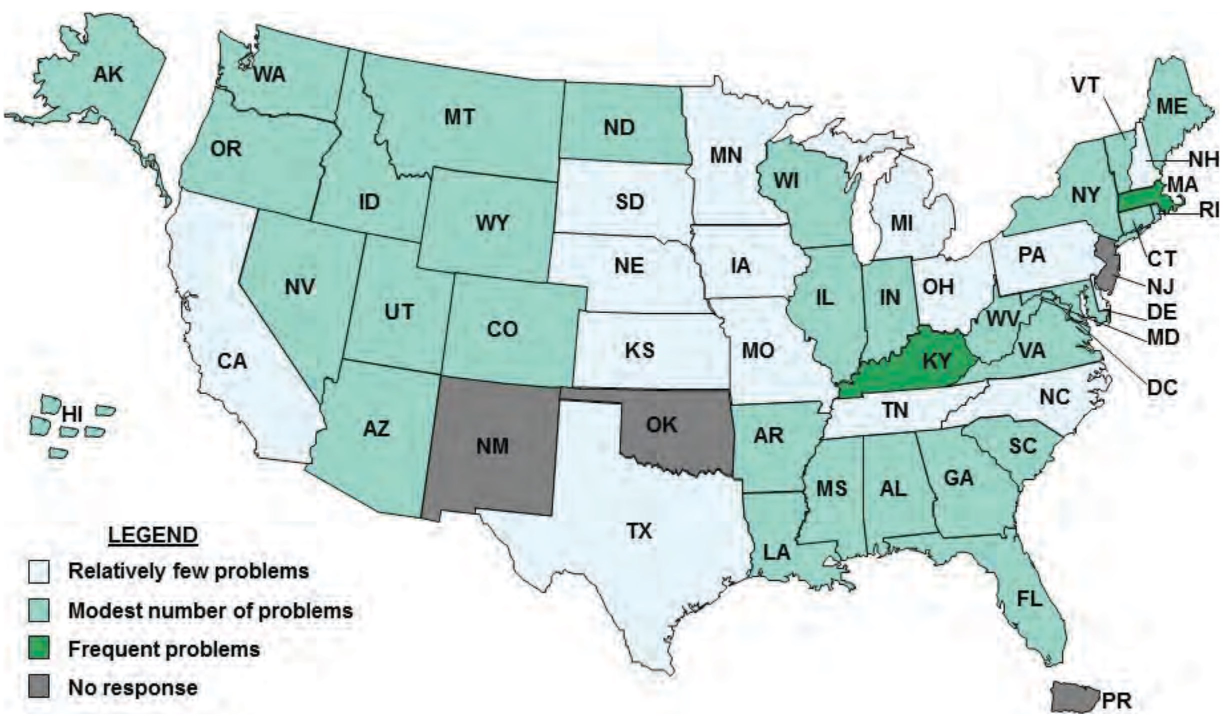

FIGURE 3 Frequency of subsurface conditions problems from agency survey responses.

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TABLE 2
DIFFICULTY OF SITE CHARACTERIZATION

Response	Number	Percent
Site characterization is generally not difficult	22	43
Site characterization is often difficult because of highly variable subsurface conditions	23	45
Site characterization is often difficult because select types of soil and rock are difficult to characterize	1	2
Site characterization is often difficult because of highly variable subsurface conditions *and* select types of soil and rock that are difficult to characterize	5	10

51 responses.

As shown in Table 3, minimum or suggested minimum subsurface investigation requirements for all projects are formally specified for most of the responding agencies (44, 86%). The other seven agencies do not formally specify minimum requirements. Among the 44 agencies that do specify requirements, 28 specify minimum requirements that are equal to or generally consistent with those prescribed in AASHTO specifications and guidelines. Agency requirements for five agencies exceed AASHTO requirements. Three agencies indicated that their subsurface investigation requirements are materially different from the AASHTO specifications and one that its requirements are generally less stringent than the AASHTO specifications. The 44 agencies that specify minimum requirements were also asked about the frequency of exceeding minimum requirements; with responses summarized in Figure 5. About one-half (23, 52%) responded that minimum requirements were occasionally exceeded, one-third (15, 34%) rarely exceed minimum requirements, and the rest (6, 14%) reported it was common to exceed minimum requirements.

Respondents were also asked about the use of geophysical methods (Figure 6) and how historic subsurface information was maintained (Figure 7). About one-half (27, 53%) of agencies reported occasionally using geophysical methods. Only five agencies (10%) reported they routinely use geophysical methods and only two (4%) never use geophysical methods. The rest (16, 31%) rarely use geophysical methods.

Methods of maintaining historic subsurface information varied. Nearly one-third of responding agencies (16, 31%) maintain a geographic information system (GIS)-based database of subsurface information. Slightly more (20, 39%) maintain a non-GIS-based electronic database, and the remaining agencies keep paper copies. Twelve of the 15 agencies that

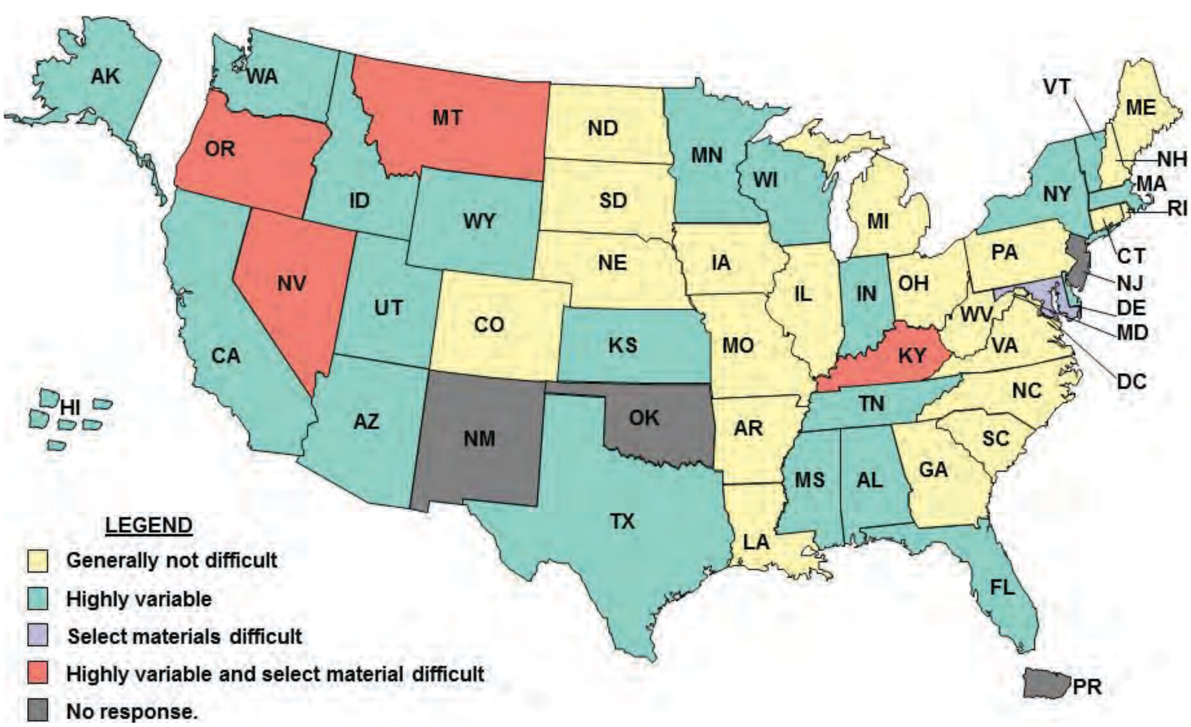

FIGURE 4 Sources of site characterization difficulty from agency survey responses.

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TABLE 3
MINIMUM SUBSURFACE INVESTIGATION REQUIREMENTS

Response	Number	Percent
Minimum requirements are those prescribed in AASHTO specifications and guidelines	7	14
Minimum requirements are documented in agency-specific provisions, but are generally consistent with those prescribed in AASHTO specifications and guidelines[1]	28	55
Minimum requirements are documented in agency-specific provisions, but substantially exceed those prescribed in AASHTO specifications and guidelines[1]	5	10
Minimum requirements are documented in agency-specific provisions, but are materially different from those prescribed in AASHTO specifications and guidelines[1] (e.g., involve different techniques and procedures than are addressed in AASHTO specifications)	3	6
General minimum requirements are documented in agency-specific publications, but are generally less stringent than those prescribed in AASHTO specifications and guidelines[1]	1	2
Minimum (or recommended minimum) requirements are not specified	7	14

51 responses.
[1]"AASHTO specifications and guidelines" was the phrase used in the survey question. This could be interpreted as either the *LRFD Bridge Design Specifications* (2014), or the *Manual on Subsurface Investigations* (1988); the documents have essentially the same investigation requirements.

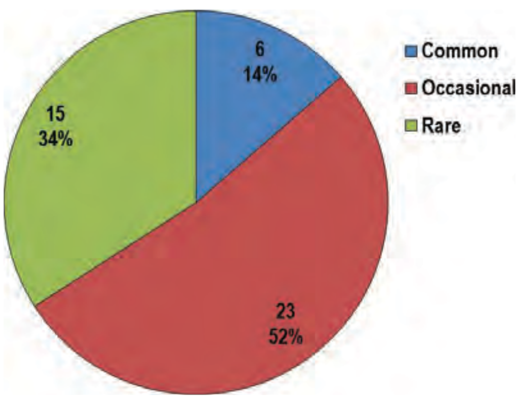

FIGURE 5 Frequency of exceeding minimum subsurface investigation requirements among the 44 agencies that specify requirements.

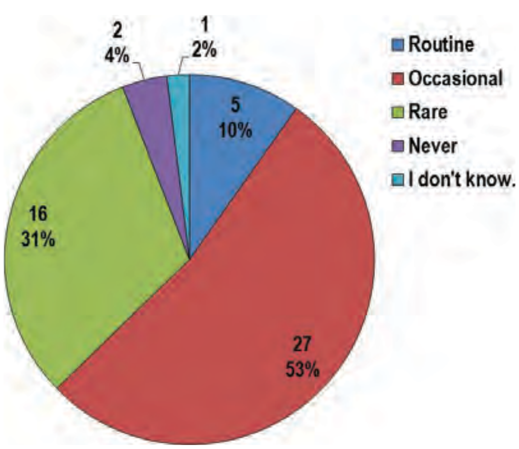

FIGURE 6 Agency use of geophysics (51 responses).

reported maintaining a paper database indicated that the historic records can be accessed when needed; the other three indicated accessing the historical records is difficult.

NATURE OF CLAIMS, CHANGE ORDERS, AND COST OVERRUNS

Parts Two and Three of the survey contained questions regarding the nature of claims, change orders, and cost overruns, including how problematic they are, how they've changed in the past 10 years, and how they are affected by project delivery mechanism. Most of the questions were asked a first time with respect to all claims, change orders, and cost overruns before repeating the question a second time to inquire specifically about claims, change orders, and cost overruns that can be attributed to subsurface conditions or site characterization practices. Although Part Two asked primarily qualitative questions about claims, change orders, and cost overruns, Part Three specified quantitative information. The difficulty

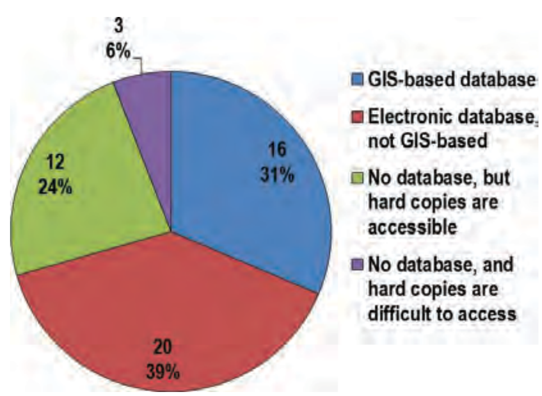

FIGURE 7 Agency maintenance of historic subsurface information (51 responses).

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TABLE 4
AGENCY LEVEL OF CONCERN REGARDING ALL CLAIMS, CHANGE ORDERS, AND COST OVERRUNS

Response	Number	Percent
Claims, change orders, and cost overruns are not considered to be a significant problem	8	16
Claims, change orders, and cost overruns are recognized as a problem, but are not a priority concern	13	26
Claims, change orders, and cost overruns are recognized as a problem and are a priority concern	23	46
Claims, change orders, and cost overruns are recognized as one of our agency's most significant problems	2	4
I don't know	4	8

50 responses.

of collecting and interpreting quantitative information regarding claims, change orders, and cost overruns was discussed in chapter one; the results from qualitative and quantitative questions are presented respectively in the first two sections. A third section synthesizes the information from both sets of questions to address the extent of claims, change orders, and cost overruns that can be attributed to subsurface conditions.

Qualitative Information Regarding Claims, Change Orders, and Cost Overruns

Nearly half of respondents indicated that claims, change orders, and cost overruns from all sources are a recognized problem and priority concern for their agencies (Table 4). For the other responding agencies, responses skewed toward indicating that claims, change orders, and cost overruns are less problematic, although two agencies noted that they are one of their agency's most significant problems. The sources of agency concerns are shown in Figure 8. Respondents were asked to select all sources of concern that apply from among the options listed in the figure. The concerns cited most frequently were agency budget and the time allocation of agency resources, although public perception was also a concern for more than one-third of respondents that indicated claims, change orders, and cost overruns are a recognized problem for their respective agencies.

Agency level of concern specific to subsurface conditions claims, change orders, and cost overruns is shown in Table 5. Nearly 40% of responding agencies indicated that these concerns are not considered to be a significant problem for their agency. The other responding agencies were almost evenly

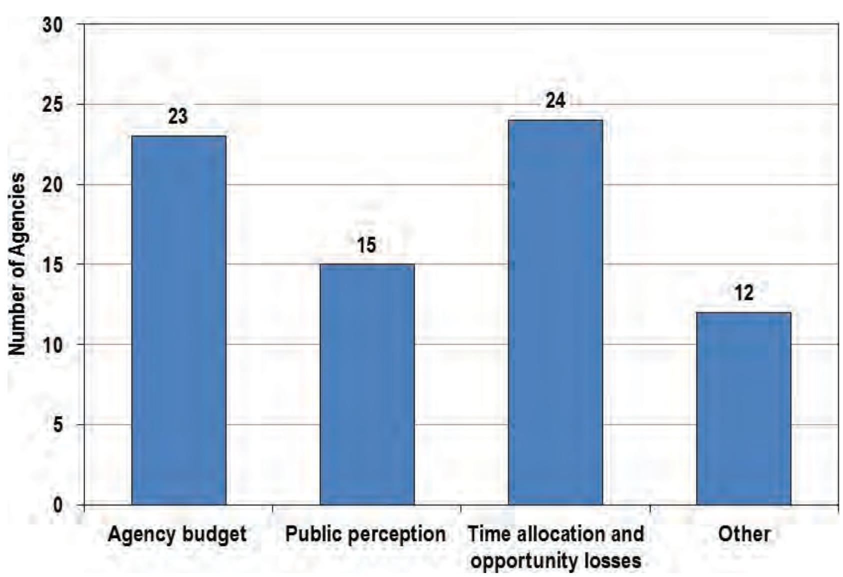

FIGURE 8 Agency sources of concern regarding all claims, change orders, and cost overruns. Respondents were allowed to select more than one response. In response to the previous question, 38 respondents indicated that claims, change orders, and cost overruns from all causes were a recognized problem for their respective agencies.

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TABLE 5
AGENCY LEVEL OF CONCERN REGARDING CLAIMS, CHANGE ORDERS, AND COST OVERRUNS RESULTING FROM SUBSURFACE CONDITIONS

Response	Number	Percent
Claims, change orders, and cost overruns resulting from subsurface conditions are not considered to be a significant problem	18	38
Claims, change orders, and cost overruns resulting from subsurface conditions are recognized as a problem, but are not a priority concern	15	31
Claims, change orders, and cost overruns resulting from subsurface conditions are recognized as a problem and are a priority concern	13	27
Claims, change orders, and cost overruns resulting from subsurface conditions are recognized as one of our agency's most significant problems	0	0
I don't know	2	4

48 responses.

split between such claims being a recognized problem but not a priority concern and being a recognized problem and a priority concern. None of the respondents indicated claims, change orders, and cost overruns resulting from subsurface conditions are one of his or her agency's most significant problems. The differences between responses regarding all claims, change orders, and cost overruns and those resulting from subsurface conditions are discussed further in Extent of Claims, Change Orders, and Cost Overruns Resulting from Subsurface Conditions later in this chapter.

Respondents were also asked if the frequency and/or magnitude of claims, change orders, and cost overruns from all sources have changed since 2005. As shown in Table 6, the most common response (18 of 50 respondents) was that the respondent did not know. Among the remaining respondents, 15 indicated that the magnitude and/or frequency of claims, change orders, and cost overruns has remained about the same; the remaining 17 were about evenly divided between having increased and having decreased, with more respondents indicating the changes were slight rather than significant. Respondents were also asked about the change in magnitude and/or frequency of claims, change orders, and cost overruns resulting from subsurface conditions in the past ten years. The results are shown in Table 7. Interestingly, more respondents were confident enough to select an answer, with nearly half indicating the magnitude and/or frequency had stayed the same. Other respondents were again about evenly divided between having increased and having decreased, with more respondents indicating the changes were slight rather than significant. The differences between responses regarding all claims, change orders, and cost overruns and those resulting from subsurface conditions are discussed further in Extent of Claims, Change Orders, and Cost Overruns Resulting from Subsurface Conditions later in the chapter.

Respondents were also asked if project delivery mechanism (design-bid-build, design-build, public-private partnership, construction manager/general contractor) is perceived to have a significant effect on the incidence or magnitude of claims, change orders, and/or cost overruns. The most common response, from 19 of 50 respondents (38%), was "I don't know." Among the other respondents, 17 (34%) reported that there is no effect and 14 (28%) that there is. These 14 respondents were

TABLE 6
CHANGES IN CLAIMS, CHANGE ORDERS, AND COST OVERRUNS FROM ALL SOURCES IN THE PAST TEN YEARS

Response	Number	Percent
The magnitude and/or frequency has decreased significantly	4	8
The magnitude and/or frequency has decreased slightly	5	10
The magnitude and/or frequency has remained about the same	15	30
The magnitude and/or frequency has increased slightly	5	10
The magnitude and/or frequency has increased significantly	3	6
I don't know	18	36

50 responses.

TABLE 7
CHANGE IN CLAIMS, CHANGE ORDERS, AND COST OVERRUNS RESULTING FROM SUBSURFACE CONDITIONS IN THE PAST TEN YEARS

Response	Number	Percent
The magnitude and/or frequency has decreased significantly	2	4
The magnitude and/or frequency has decreased slightly	6	12
The magnitude and/or frequency has remained about the same	22	45
The magnitude and/or frequency has increased slightly	6	12
The magnitude and/or frequency has increased significantly	1	2
I don't know	12	24

49 responses.

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TABLE 8
SUMMARY STATISTICS FOR CLAIMS, CHANGE ORDERS, AND COST OVERRUNS FROM ALL SOURCES

	Total Number			Total Cost		
Statistic	Claims	Change Order	Cost Overruns	Claims	Change Order	Cost Overruns
Number of Responses	8	9	6	8	9	7
Minimum	0.8	150	10	$0.02*	$5.1*	$2.6*
Maximum	75	6,355	209	$12.5*	$82.5*	$70.4*
Average	18	1,688	107	$3.1*	$37.8*	$29.8*
Standard Deviation	30	1,928	84	$4.7*	$27*	$23.5*

Values are average annual values for data from 2009 to 2013.
*In millions.

asked to explain the effect. The responses are included with the short answers in Appendix B. In their answers, respondents primarily referred to design-build versus design-bid-build, with five mentioning there are fewer claims, change orders, and cost overruns for design-build than for design-bid-build and four stating there are more. The other five respondents did not indicate whether the effect is negative or positive. Many respondents cited a change in risk allocation in their responses.

Respondents were also asked about the effect of project delivery mechanism for claims, change orders, and cost overruns related to subsurface conditions. The most common answer was that there is no effect, cited by 22 of 49 respondents (45%). Sixteen respondents (33%) selected “I don’t know” and 11 (22%) indicated there is an effect. These 11 were asked to explain this effect. The responses are included with the short answers in Appendix B. As for the question regarding all claims, change orders, and cost overruns, the respondents primarily referred to design-build versus design-bid-build, and the responses were split regarding whether the effect is negative or positive, with four respondents indicating there are more claims, change orders, and cost overruns for design-build than design-bid-build, and four that there are fewer. Three of the responses did not mention whether the effect is negative or positive. Many of the responses cited the same explanations given for all claims, although two respondents noted that there is less geotechnical information collected for design-build projects.

Quantitative Information Regarding Claims, Change Orders, and Cost Overruns

In Part Three of the survey, respondents were asked for specific quantitative information regarding the claims, change orders, and cost overruns that had occurred for their agencies during the past five years. As discussed in chapter one, such quantitative information is difficult to collect. The quantitative results presented in this section are therefore limited to data reported by 11 agencies. The discussion in chapter one also addressed the difficulties of interpreting such quantitative data. The difficulties largely relate to distinguishing those resulting from geotechnical investigation issues from those resulting from design, communication, or other issues.

All values cited in the body of this synthesis report have been averaged over the 5-year period (2009–2013) to report values in annual terms (e.g., if an agency reported that its change orders between 2009 and 2013 totaled $5 million, the average annual change order total would be $1 million). Information requested included the total number and total cost of each of the three categories (claims, change orders, and cost overruns), as well as the total contract costs for all projects on which the claims, change orders, and cost overruns were recorded, respectively.

Eleven respondents completed Part Three of the survey. Summary statistics for the results are presented in Tables 8–10.

TABLE 9
SUMMARY STATISTICS FOR CLAIMS, CHANGE ORDERS, AND COST OVERRUNS ATTRIBUTED TO SUBSURFACE CONDITIONS

	Total Number			Total Cost		
Statistic	Claims	Change Order	Cost Overruns	Claims	Change Order	Cost Overruns
Number of Responses	4	5	2	4	5	2
Minimum	0	6	3	$0	$1.0*	$0.3*
Maximum	7.8	125	21	$865,000	$10.3*	$1.0*
Average	2	46	12	$240,000	$3.4*	$0.7*
Standard Deviation	3.9	49	13	$419,000	$3.9*	$0.5*

Values are average annual values for data from 2009 to 2013.
*In millions.

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TABLE 10
AVERAGE COST PER OCCURRENCE OF CLAIMS, CHANGE ORDERS, AND OVERRUNS

	All Causes	Subsurface Conditions Only
Claims	$169,000	$120,000
Change Orders	$22,000	$74,000
Overruns	$279,000	$55,000

More detailed summary results are presented in Tables 11–14, as well as in Tables 15–17 for claims, change orders and cost overruns that can be attributed to subsurface conditions or site characterization practices. In addition, all data reported by the respondents are included in Appendix B. Four of the 11 responses did not include information specific to subsurface conditions, and several did not include information for all three categories of claims, change orders, and cost overruns. These missing data are indicated in the tables as empty cells. The tables also present the average cost of an individual occurrence for each category (e.g., the average cost of a change order) and percentages representing the cost of each category relative to the total agency budget for new construction and the cost of each category relative to total project costs.

Several noteworthy observations related to the magnitude and variability of the values presented in Tables 8–17 are listed here:

- Considering all causes, change orders occur most frequently, with an average annual rate of occurrence of 1,638, more than ten times either cost overruns (126) or claims (88).
- Total amounts spent on all change orders and cost overruns are considerably greater than that spent on all claims. Change orders and cost overruns typically amount to 3% to 5% each of an agency's total construction budget and as much as 18%.

TABLE 11
AVERAGE ANNUAL BUDGET FOR NEW CONSTRUCTION FOR ALL AGENCIES PROVIDING ANY RESPONSES TO PART 3

Agency	Average Annual Construction Budget
Arkansas	$526*
Eastern Federal Lands	$132*
Florida	—
Georgia	$850*
Indiana	$1,196*
Maryland	$493*
Massachusetts	$1,000*
Missouri	$960*
New Hampshire	$277*
Oregon	$928*
South Dakota	$325*

Data are from 2009 to 2013.
— = Data not provided in agency response.
*In millions.

- As observed for all sources, subsurface conditions change orders occur most frequently, with an average annual rate of occurrence (46) significantly more than either cost overruns (12) or claims (2).
- The total amounts spent on subsurface conditions change orders is considerably greater than that spent on claims or cost overruns attributed to subsurface conditions. Reported spending on change orders resulting from subsurface conditions approached 1% of the total agency budget for new construction.
- The average value of each individual claim, change order, and cost overrun is relatively consistent from

TABLE 12
AVERAGE ANNUAL DATA REGARDING CLAIMS FROM ALL SOURCES FOR DATA FROM 2009 TO 2013

Agency	Number	Annual Cost	Average Cost	Cost as Share of Agency Construction Budget	Total Contract Costs for Projects with Claims	Average Claim Cost as Share of Project Budget
Arkansas	2	$0.3*	$140,000	0.05%	$11*	2.5%
Eastern Federal Lands	2	$0.3*	$142,000	0.24%	$8*	3.8%
Georgia	6	$3*	$500,000	0.35%	$50*	6.0%
Massachusetts	75	$12.5*	$166,000	1.25%	—	—
Missouri	1	$0.2*	$240,000	0.02%	$2*	10.0%
New Hampshire	1	$0.02*	$19,000	0.01%	$3*	0.6%
Oregon	58	$8.2*	$143,000	0.89%	$145*	5.7%
South Dakota	2	$0.3*	$183,000	0.10%	—	—

*In millions.

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TABLE 13
AVERAGE ANNUAL DATA REGARDING CHANGE ORDERS FROM ALL SOURCES FOR DATA FROM 2009 TO 2013

Agency	Number	Annual Cost	Average Cost	Cost as Share of Agency Construction Budget	Total Contract Costs for Projects with Change Orders	Average Change Order Cost as Share of Project Budget
Arkansas	1,028	$26*	$25,000	4.9%	$797*	3.3%
Eastern Federal Lands	150	$23*	$150,000	17.4%	$225*	10.2%
Florida	6,355	$83*	$13,000	—	$2,694*	3.1%
Georgia	420	$50*	$119,000	5.9%	$1,100*	4.6%
Indiana	2,699	$61*	$23,000	5.1%	$1,196*	5.1%
Maryland	—	$25*	—	5.2%	—	—
Missouri	1,916	$5.1*	$3,000	0.53%	$1,200*	0.42%
New Hampshire	465	—	—	—	—	—
Oregon	1,426	$61*	$43,000	6.6%	$928*	6.6%
South Dakota	730	$6.9*	$9,000	2.1%	—	—

— = Data were not provided in agency response.
*In millions.

TABLE 14
AVERAGE ANNUAL DATA REGARDING COST OVERRUNS FROM ALL SOURCES FOR DATA FROM 2009 TO 2013

Agency	Number	Annual Cost	Average Cost	Cost as Share of Agency Construction Budget	Total Contract Costs for Projects with Cost Overruns	Average Overrun Cost as Share of Project Budget
Arkansas	134	$16.0*	$119,000	3.0%	$372*	4.3%
Eastern Federal Lands	24	$23*	$930,000	17.1%	$122*	18.5%
Florida	209	$51*	$241,000	—	$1,550*	3.3%
Georgia	—	$14*	—	1.7%	$1,080*	1.3%
Missouri	189	$33*	$174,000	3.4%	$653*	5.0%
New Hampshire	10	$2.6*	$264,000	0.9%	$56*	4.6%
Oregon	74	$70*	$951,000	7.6%	$431*	16.4%

— = Data were not provided in agency response.
*In millions.

TABLE 15
AVERAGE ANNUAL DATA REGARDING CLAIMS RESULTING FROM SUBSURFACE CONDITIONS FOR DATA FROM 2009 TO 2013

Agency	Number	Annual Cost	Average Cost	Cost as Share of Agency Construction Budget	Total Contract Costs for Projects with Claims	Average Claim Cost as Share of Project Budget
Eastern Federal Lands	0.2	$93,000	$467,000	0.07%	$1.59*	5.9%
Georgia	0	N/A	N/A	N/A	N/A	N/A
Massachusetts	7.8	$865,000	$111,000	0.09%	—	—
South Dakota	0	N/A	N/A	N/A	N/A	N/A

N/A = Not applicable since zero claims were filed.
— = Data were not provided in agency response.
*In millions.

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TABLE 16
AVERAGE ANNUAL DATA REGARDING CHANGE ORDERS RESULTING FROM SUBSURFACE CONDITIONS FOR DATA FROM 2009 TO 2013

Agency	Number	Annual Cost	Average Cost	Cost as Share of Agency Construction Budget	Total Contract Costs for Projects with Change Orders	Average Change Order Cost as Share of Project Budget
Eastern Federal Lands	5.6	$1.0*	$172,000	0.73%	$14.5*	6.6%
Georgia	42	$2.0*	$48,000	0.24%	$1,080*	0.19%
Indiana	125	$10*	$83,000	0.86%	$585*	1.8%
Maryland	6.8	$1.5*	$223,000	0.31%	—	—
Oregon	49.2	$2.2*	$45,000	0.24%	$299*	0.73%

— = Data were not provided in agency response.
*In millions.

TABLE 17
AVERAGE ANNUAL DATA REGARDING COST OVERRUNS RESULTING FROM SUBSURFACE CONDITIONS FOR DATA FROM 2009 TO 2013

Agency	Number	Annual Cost	Average Cost	Cost as Share of Agency Construction Budget	Total Contract Costs for Projects with Cost Overruns	Average Overrun Cost as Share of Project Budget
Eastern Federal Lands	3	$0.3*	$104,000	0.24%	$9.61*	3.2%
Georgia	21	$1.0*	$10,000	0.12%	$120*	0.83%

*In millions.

one agency to the next, when considering all causes as well as only those attributed to subsurface conditions. The average values are reported in Table 10. The magnitudes of these values suggest that the effect of claims, change orders, and cost overruns on individual project budgets could be substantial. When all causes are considered, overrun costs are most significant and change orders are considerably less than both claims and overruns. When only subsurface conditions are considered, there is less difference in average cost per occurrence.

- Variation in the numbers and costs of claims, change orders, and cost overruns reported to be considerable. This is understandable, because agencies have different program sizes, different practices, and different subsurface conditions, among other factors.
- Variation in the relative proportion of claims, change orders, and cost overruns may also suggest agencies have different procedures for reconciling disputes.

EXTENT OF CLAIMS, CHANGE ORDERS, AND COST OVERRUNS RESULTING FROM SUBSURFACE CONDITIONS

Uncertainty regarding the significance of subsurface conditions, in terms of overall cost and as a share of all claims, change orders, and cost overruns, is substantial. The information gathered from Parts Two and Three of the survey and summarized in the previous sections can be used to reduce some of the uncertainty, which is a principle objective of this Synthesis project.

Comparing the responses to the qualitative survey questions about the level of agency concerns is one method for evaluating the extent of claims, change orders, and cost overruns resulting from subsurface conditions. The responses to those questions were presented earlier and are summarized in Figure 9. On one hand, 12 of the 25 agencies that consider claims, change orders and cost overruns from all causes a priority concern or a most significant problem do not have the same degree of concern for those attributed to subsurface conditions; on the other hand, 13 agencies do consider subsurface conditions a priority concern, and 13 of 48 respondents (27%) acknowledge widespread concern. Concern for claims, change orders, and cost overruns resulting from subsurface conditions could never exceed concern for all causes: among the 25 agencies that consider claims, change orders, and cost overruns a priority or greater concern, 13 consider subsurface conditions to be an equal concern. That more than half of the agencies are concerned in particular about subsurface conditions is noteworthy.

The responses to qualitative survey questions about the ten-year change in claims, change orders, and cost overruns

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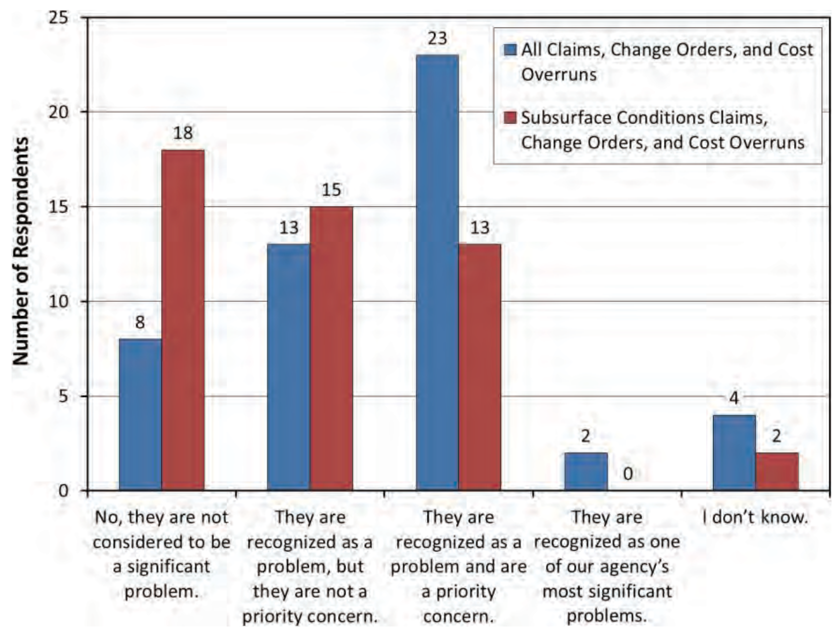

FIGURE 9 Agency concern regarding claims, change orders, and cost overruns.

from all causes and from subsurface conditions are plotted side by side in Figure 10. More agencies have seen no significant change than have observed a change, and the number of agencies that have observed an increase is approximately equal to the number that has observed a decrease. This suggests that, on average, claims, change orders, and cost overruns have neither increased nor decreased during the last ten years. There appears to be more uncertainty regarding the ten-year change in all sources than the change in those attributed to subsurface conditions, with 18 respondents selecting "I don't know" for all sources and 12 "I don't know" for subsurface conditions.

That claims, change orders, and cost overruns, including those resulting from subsurface conditions, have not, on average, changed considerably in ten years could indicate that their significance has remained steady; however, there are other possible explanations. Changes in construction practices and technology have likely affected the nature of claims, change orders, and cost overruns, reducing some causes while introducing new ones. Changes in construction program size could also affect their significance.

In Part Two of the survey, respondents were also asked to estimate the proportion of claims, change orders, and cost

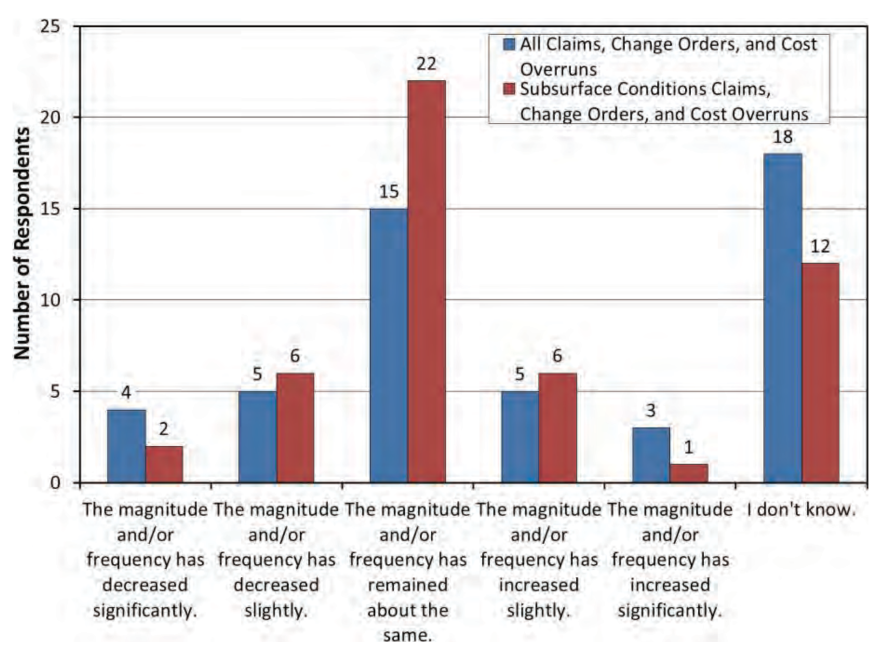

FIGURE 10 Perceived ten-year change in claims, change orders, and cost overruns.

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TABLE 18
AGENCY *ESTIMATE* OF PROPORTION OF CLAIMS, CHANGE ORDERS, AND COST OVERRUNS CAUSED BY SUBSURFACE CONDITIONS

Response	Number	Percent
Less than 20%	30	64
20%–40%	14	30
40%–60%	3	6
60%–80%	0	0
Greater than 80%	0	0

overruns that can be attributed to subsurface conditions or site characterization practices. The responses are presented in Table 18. Nearly two-thirds of respondents (30 of 47) estimated that less than 20% can be attributed to subsurface conditions, with 14 agencies estimating the percentage to be between 20% and 40% and three estimating between 40% and 60%.

Responses from Table 18 are shown by agency in the map of Figure 11. Geographic trends are less apparent than those observed based on the distribution of agencies experiencing subsurface conditions (Figure 3) and site characterization difficulties (Figure 4). Three of the 14 agencies estimating 20% to 40% resulting from subsurface conditions are in Southeastern states, but otherwise the geographic distribution of the estimates appears to be random.

The estimates from Part Two can be evaluated by considering the quantitative information regarding claims, change orders, and cost overruns presented in the previous section (Tables 12–17). Figure 12*a* presents the number of claims experienced annually by the four agencies that provided data for both all claims and for claims that could be attributed to subsurface conditions or site characterization practices. Figures 12*b* and *c* present similar information, but for change orders and cost overruns, respectively. The plots of Figure 13 are similar to those of Figure 12; however, for costs (rather than numbers) of claims (Figure 13*a*), change orders (Figure 13*b*), and overruns (Figure 13*c*).

The results shown in Figures 12 and 13 include percentage values for each agency corresponding to the proportion of claims, change orders, and cost overruns that are attributed to subsurface conditions. These values are repeated in Table 19 by number on the left side and by cost the right side. Average values are also shown. The first row of average values is the sum of all reported subsurface conditions claims, change orders, and cost overruns, respectively, out of all claims, change orders, and cost overruns. The second row of average values is similar to the first, but is irrespective of category; all claims, change orders, and cost overruns are considered together. Both rows of averages are averages of all data rather than averages of agency values.

The second row of averages shown in Table 19 is especially important. By number, 5% of all reported claims, change orders, and cost overruns were attributed to subsurface conditions; by cost, 7% were attributed to subsurface conditions. The calculated shares support the majority response shown in Table 18 that less than 20% of claims, change orders, and overruns are attributed to subsurface conditions.

There is variation in the potential interpretations of the quantitative results from Part Three of the survey. On one hand, subsurface conditions account for a relatively small percentage

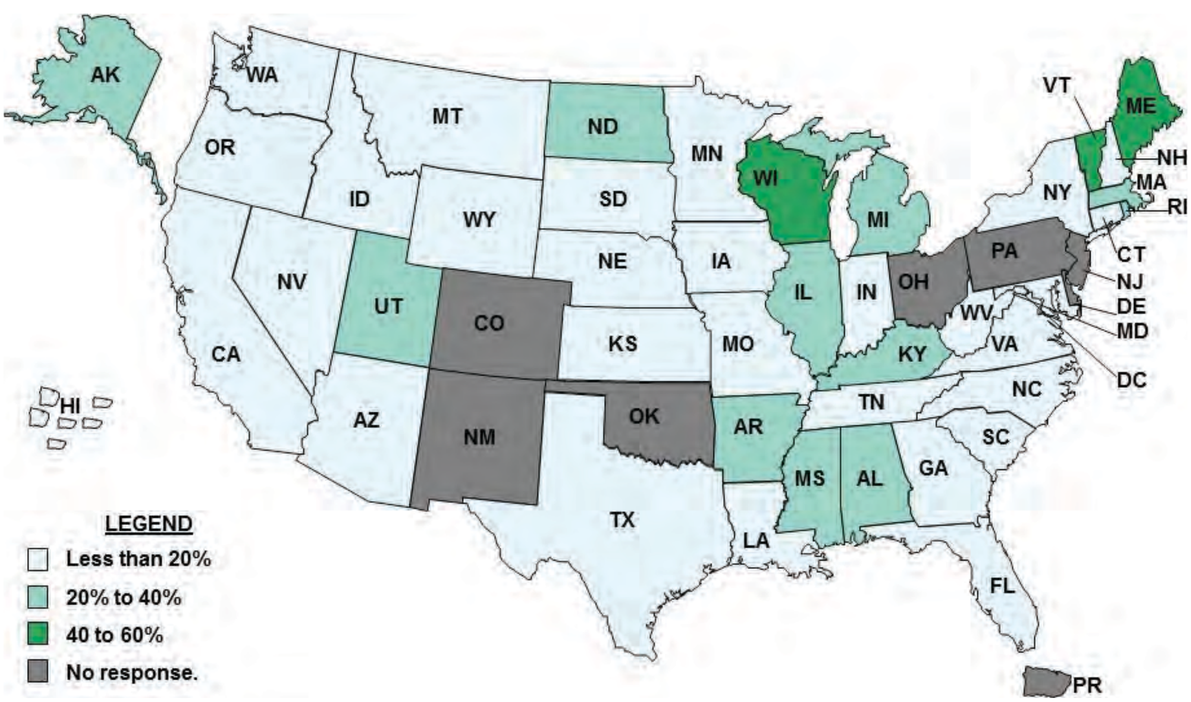

FIGURE 11 Agency *estimate* of proportion of claims, change orders, and cost overruns caused by subsurface conditions.

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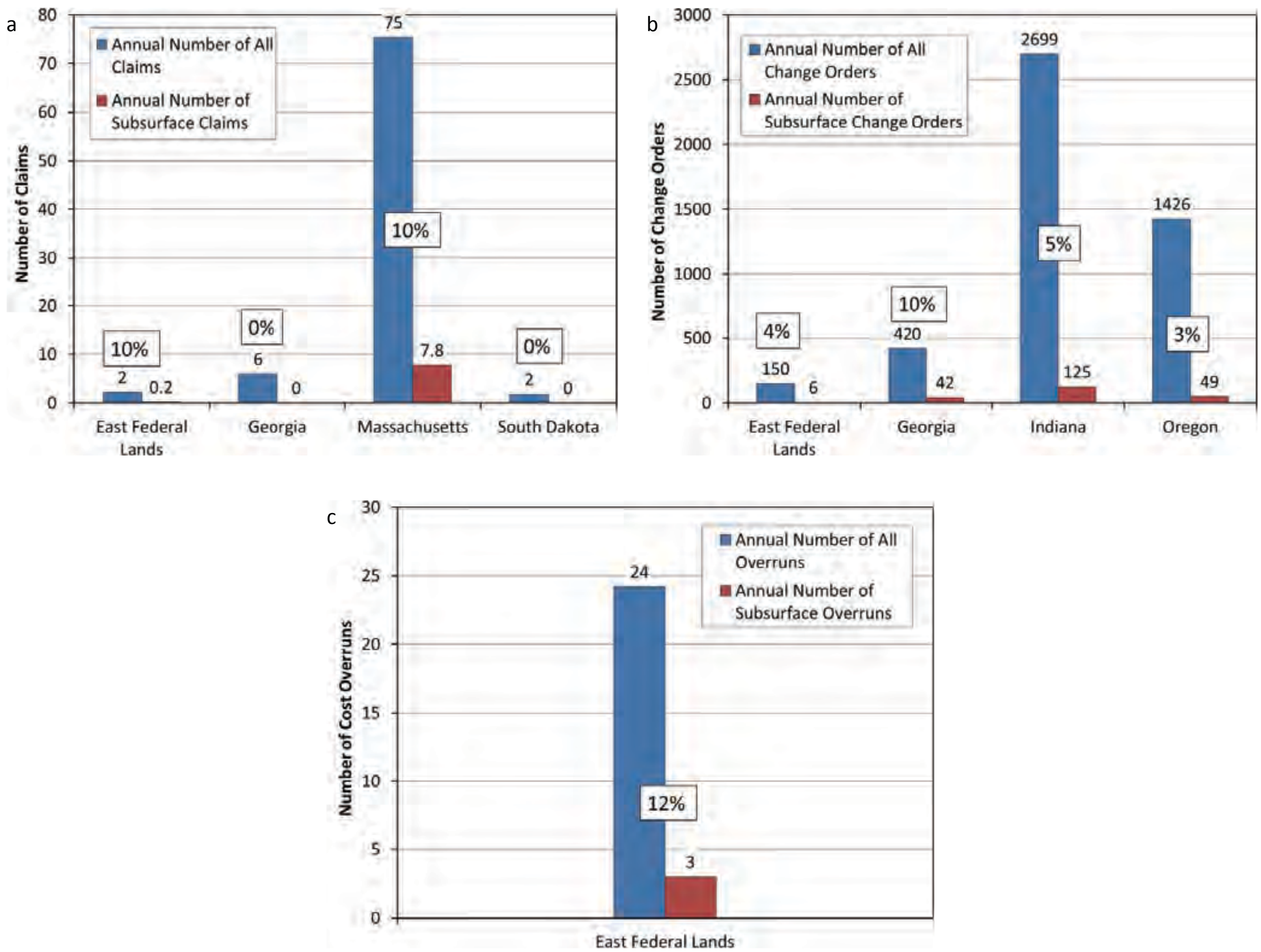

FIGURE 12 Annual number of (a) claims, (b) change orders, and (c) cost overruns.

of claims, change orders, and cost overruns; 5% by number and 7% by cost. On the other hand, several measures of the total cost of subsurface conditions indicate that their cost is substantial. This annual cost of subsurface conditions change orders alone was commonly in the millions of dollars and as much as $10 million for the reporting agencies, representing a considerable portion of individual project budgets, especially relative to project contingency funds, which are often limited. The costs also consume a significant portion of agencies' total budgets for new construction. The two agencies that reported total costs for all categories, claims, change orders, and cost overruns attributed to subsurface conditions summed to 0.35% and 1.0% of the total agency budget for new construction.

PERCEIVED RELATIONSHIP BETWEEN SUBSURFACE INVESTIGATION PRACTICES AND CLAIMS, CHANGE ORDERS, AND COST OVERRUNS

The survey results also shed light on the effect of subsurface investigation practices on reducing subsurface conditions claims, change orders, and cost overruns, which is another principle objective of this Synthesis project. The topic is examined in this section by considering information provided in Part One regarding the effect of any recent changes to agency subsurface investigation practices and the effect of agency practices that incentivize subsurface investigation. The effect of subsurface investigation practices is addressed further in chapter four, which examines in detail specific practices from five agencies selected for further examination.

In Part One of the survey, 18 respondents (35%) indicated that their agencies had implemented specific changes to site characterization practices during the last five years. The respondents' summaries of the changes are included with Appendix B. Three common revisions were each cited by at least four of the 18 agencies: increased use of CPT, modifications associated with agency design policies transitioning from allowable stress design to Load Factor and Resistance Design (LFRD), and increased frequency of explorations. These respondents were asked about the effect of such changes on the number of claims, change orders, and cost overruns, and the results are shown in

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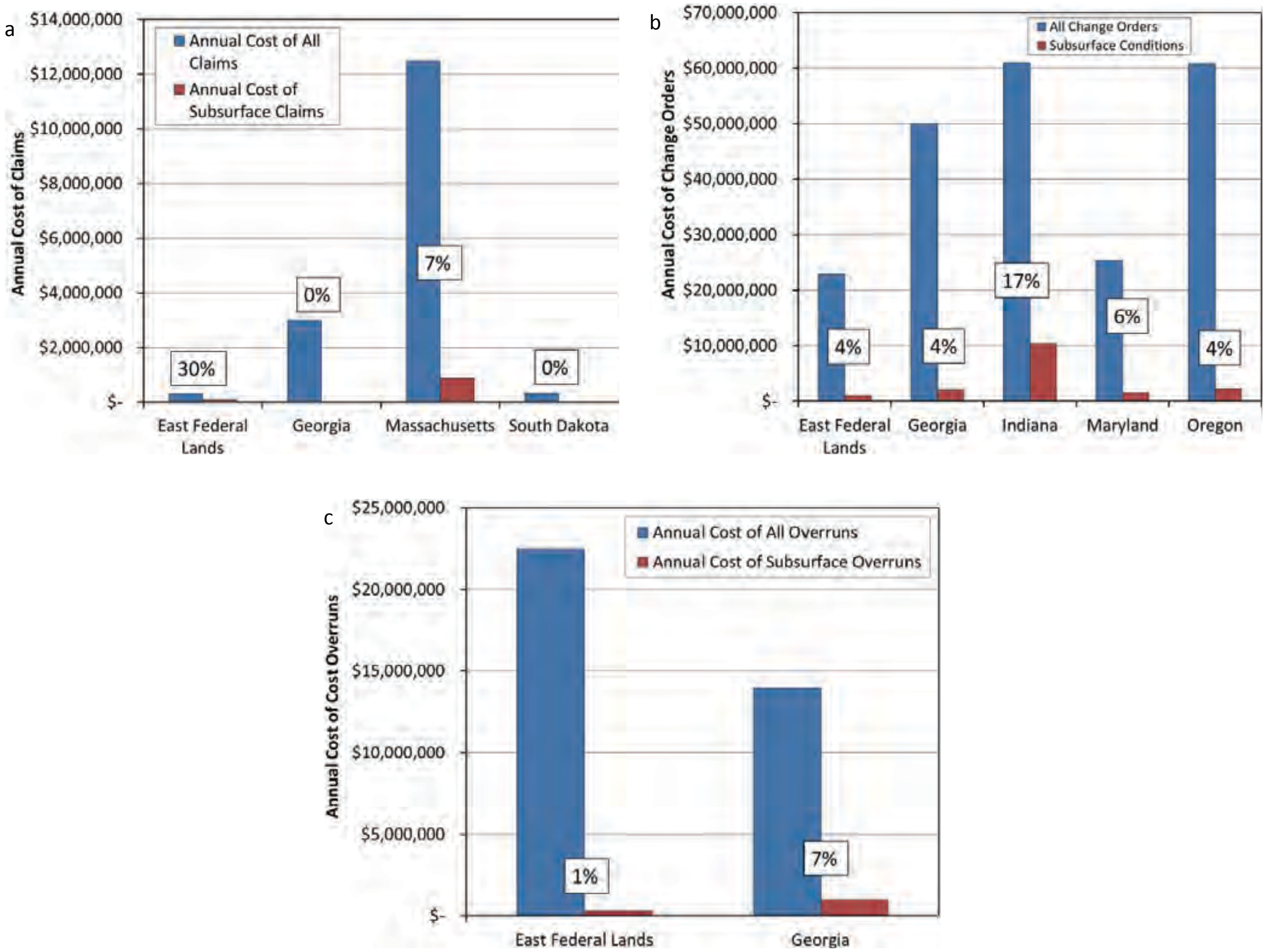

FIGURE 13 Annual cost of (a) claims, (b) change orders, and (c) cost overruns.

TABLE 19
PERCENTAGES OF CLAIMS, CHANGE ORDERS, AND COST OVERRUNS ATTRIBUTED TO SUBSURFACE CONDITIONS

	Percentage By Number			Percentage By Cost		
	Claims	Change Orders	Cost Overruns	Claims	Change Orders	Cost Overruns
Eastern Federal Lands	10%	4%	12%	30%	4%	1%
Georgia	0%	10%	—	0%	4%	7%
Indiana	—	5%	—	—	17%	—
Maryland	—	—	—	—	6%	—
Massachusetts	10%	—	—	7%	—	—
Oregon	—	3%	—	—	4%	—
South Dakota	0%	—	—	0%	—	—
Average, All Responses	9.4%	4.7%	12%	5.9%	7.8%	3.6%
Average, All Responses and All Categories		4.9%			7.2%	

— = Data were not provided in agency response.

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TABLE 20
PERCEIVED IMPACT OF REVISIONS TO SITE CHARACTERIZATION PRACTICES ON CLAIMS, CHANGE ORDERS, AND OVERRUNS

Response	Number	Percent
Changes have led to a noticeable increase in the occurrence of claims, change orders, and overruns	0	0
Changes have led to a marginal increase in the occurrence of claims, change orders, and overruns	0	0
Changes have not noticeably affected the occurrence of claims, change orders, and overruns	7	39
Changes have led to a marginal decrease in the occurrence of claims, change orders, and overruns	4	22
Changes have led to a noticeable decrease in the occurrence of claims, change orders, and overruns	2	11
Insufficient experience to respond	5	28

Table 20. Nearly one-quarter of respondents whose agencies had an updated site characterization practice indicated a marginal decrease in the occurrence of claims, change orders, and overruns, and two agencies (11%) indicated a noticeable decrease. These two agencies, Florida and Indiana, are discussed in case examples in chapter four.

Eight respondents (16%) noted that their agency's design code contains provisions that incentivize specific site characterization activities and/or performing site characterization in excess of minimum requirements. The respondents were asked to summarize the provisions and their descriptions are included in Appendix B. The respondents' perception of the success of these activities is summarized in Table 21. None of the eight respondents indicated that the provisions had resulted in fewer claims, change orders, or overruns; however, cite design efficiencies resulting from the use of greater resistance factors (or lower factors of safety).

SUMMARY OF SIGNIFICANT FINDINGS

- Nearly 70% of responding agencies specify minimum subsurface investigation requirements that are equal to or generally consistent with requirements prescribed in the AASHTO *LRFD Bridge Design Specifications* (2014) and the AASHTO *Subsurface Investigation Manual* (1988). Among the other agencies, the most common response was minimum requirements that substantially exceed those prescribed in the AASHTO *Specifications*.
- Approximately half of the responding agencies reported that site characterization is difficult because of highly variable subsurface conditions, and approximately half reported that site characterization is not difficult. A small percentage of agencies also indicated that site characterization is difficult because select types of soil and rock are difficult to characterize.
- In the Midwest, some agencies in the Central Lowlands and Great Plains geologic regions reported experiencing fewer problems relating to subsurface conditions and less difficulty with site characterization than most other agencies. In the South Atlantic, some agencies in the Coastal Plain geologic region reported less difficulty with site characterization than most other agencies.
- Three-quarters of responding agencies recognize claims, change orders, and cost overruns from all sources as a significant problem. Slightly more than half recognize claims, change orders, and cost overruns attributed to subsurface conditions as a significant problem.
- Most responding agencies perceive that the magnitude and frequency of claims, change orders, and cost overruns has remained steady over the last decade, although some have noticed a decrease and others an increase in the magnitude and frequency.

TABLE 21
PERCEIVED SUCCESS OF SITE CHARACTERIZATION INCENTIVES TO REDUCING CLAIMS, CHANGE ORDERS, AND OVERRUNS

Response	Number	Percent
Practice has not noticeably affected the occurrence of claims, change orders, and overruns	4	50
Practice has produced marginal reduction in the occurrence of claims, change orders, and overruns	0	0
Practice has produced substantial reduction in the occurrence of claims, change orders, and overruns	0	0
Insufficient experience to respond	2	25
I don't know	2	25

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- Change orders attributed to subsurface conditions are significantly more frequent than claims or cost overruns. The same trend was observed among claims, change orders, and cost overruns resulting from all causes. There was a less significant difference among the average cost per individual occurrence of subsurface conditions claims, change orders, and cost overruns, which is contrary to the trend observed considering all causes, for which change orders were considerably less costly on average than claims and cost overruns.
- By number, 5% of all claims, change orders, and cost overruns reported in the survey were attributed to subsurface conditions, and by cost, 7% were attributed to subsurface conditions.
- Cumulative costs for claims, change orders, and cost overruns attributed to subsurface conditions represented up to 1% of total agency construction budgets.
- Individual, project-level data were not collected; however, total annual agency costs of subsurface conditions change orders, for example, represented as much as 7% of the total agency spending on all projects associated with the change orders. The impact on some individual project budgets is likely much greater than 7%.

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CHAPTER FOUR

CASE EXAMPLES

The survey results presented in chapter three were used to select five agencies for further examination. The agencies were primarily identified based on responses that indicated agency success in reducing claims, change orders, and overruns resulting from subsurface conditions. The agencies selected were Indiana, Florida, Minnesota, Washington State, and South Carolina DOTs. For each agency, the geotechnical engineer survey contact was interviewed and agency documentation was reviewed to identify how agency practice has reduced claims, change orders, and claims due to subsurface conditions.

FLORIDA DEPARTMENT OF TRANSPORTATION

In the survey, Florida DOT (FDOT) indicated that recent changes to site characterization practices had led to a noticeable decrease in the occurrence of claims, change orders, and overruns. The changes in site characterization practices noted in the survey included increasing boring frequency for highly variable sites, performing borings at locations of every nonredundant drilled shaft, and requiring more accurate surveying for boring locations. Based on information from the agency interview, each revision has been successful in reducing a particularly problematic type of claim that the DOT had previously been experiencing.

Drilled Shafts in Extremely Variable Geology

During construction of an elevated portion of the Lee Roy Selmon Crosstown Expressway in Tampa in 2004, one of the bridge piers suddenly sank more than 10 ft (Graham et al. 2013). The karstic limestone geology in central Florida is notoriously variable, with depths to competent rock varying significantly. Based on a boring that was approximately 8 ft from the failed shaft location, the shaft would have been socketed 2 ft into hard material with standard penetration test (SPT) blow counts of 50 blows for less than 2 in.; however, coring through the shaft after failure indicated more than 10 ft of soft material below the shaft (L. Jones, Florida Department of Transportation, Tallahassee, personal communication, May 2015). Similar, but far less extreme, problems were encountered for other piers on the project, which were eventually retrofitted with micropiles and "sister" drilled shafts as documented by Graham et al. (2013).

In response to the Lee Roy Selmon project and other projects with contractor claims of differing conditions for drilled shafts, FDOT implemented stricter requirements for foundation subsurface investigation (FDOT 2015):

- Bridge boring locations must be surveyed.
- One boring is required at the location of every nonredundant drilled shaft.
- At variable sites or sites in karstic areas, two borings are required for each nonredundant shaft larger than 8 ft in diameter. These areas include "known variable geologic areas and those determined to be (difficult to predict based on other borings) variable during the subsoil exploration program."
- Also at variable sites, all shafts (including redundant shafts) must be within 20 ft of a boring location.

FDOT indicated in the agency interview that the revisions have led to considerably fewer claims for drilled shaft excavations, although detailed quantitative information is unavailable.

Earthwork

FDOT has historically encountered frequent claims from contractors having to excavate more unsuitable material (e.g., highly plastic clays, and organic material) than indicated by contract borings. The unexpected unsuitable material problem was frequently encountered for retention pond projects; often when problems were encountered, grout mounds indicating the actual boring location would be observed far from the intended boring location and outside the limits of the pond excavation. When a retention pond excavation was begun, the improperly located borings frequently resulted in surprises. The extent of the issue was significant, requiring additional excavation on the order of acre-ft. To resolve this, FDOT began requiring pond borings to be located by handheld Global Positioning System survey with an accuracy of ±10 ft and increased the boring frequency to 1 per 40,000 ft^2 of pond surface area. The changes have resulted in significantly fewer earthwork claims, although detailed quantitative information is unavailable.

The agency has made other similar adjustments to its *Soils and Foundations Handbook* (FDOT 2015) to reduce earthwork claims. For example, the manual requires retention pond plan sheets to show shallow hard materials with rock patterning to indicate materials that cannot be excavated with a typical backhoe. In addition, the manual requires materials

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encountered in pond borings to be assigned different stratigraphic units from materials encountered in roadway borings to prevent claims associated with a contractor assuming pond material could be used as embankment fill or pavement subgrade. The pond material is typically too soft for such applications, even when the pond material classification is the same as material encountered in the roadway borings.

Florida DOT: Lessons Learned

The reduction in claims experienced by FDOT provides two valuable lessons. First, boring information is only as good as its location information, especially at sites where spatial variability is significant. Having accurate boring location information was helpful in reducing claims associated with foundations as well as earthwork. Second, targeted subsurface investigation practices such as increasing boring location accuracy and increasing boring frequency for specific problematic design elements can effectively address specific subsurface claim, change order, or cost overrun issues. Focused efforts such as those implemented by FDOT are likely easier and less costly to implement than across-the-board measures.

SOUTH CAROLINA DEPARTMENT OF TRANSPORTATION

Based on responses to Part Two of the survey, subsurface conditions claims, change orders, and cost overruns are a recognized problem and priority concern for South Carolina DOT (SCDOT). In the agency interview, SCDOT indicated that it addressed concerns regarding subsurface claims, change orders, and cost overruns by implementing a new *Geotechnical Design Manual* (2010), which has resulted in a general decrease. The manual and its effect on claims, change orders, and cost overruns is detailed in the following sections.

Geotechnical Design Manual

SCDOT first published its *Geotechnical Design Manual* in 2008 (SCDOT 2010). Prior to its publication, the agency had rule of thumb guidelines for subsurface investigation; however, the guidelines were not enforceable and subsurface investigation decisions were left to the engineer of record on a project-by-project basis.

Chapter four of the manual, "Subsurface Investigation Guidelines," outlines requirements for two phases of investigation, preliminary and final. The preliminary investigation includes collection of shear wave velocity data for use with the agency's guidelines for seismic design as well as laboratory testing associated with earthwork design (Standard Proctor tests and consolidated-undrained triaxial tests with pore pressure measurements on compacted specimens). The final investigation requirements vary with project type, as do the minimum testing requirements. For example, nonredundant drilled shafts require one boring per shaft, two borings per bent multiple-shaft bents, and one boring per bent for driven pile bents. CPT and dilatometer tests (DMT) can be substituted for borings for up to half of the required locations. In the agency interview, SCDOT indicated that its projects frequently include multiple CPT soundings as supplemental information rather than for substitution. In the state's Lowcountry Region and some additional counties the agency requires rotary wash boring methods.

Other chapters of the manual also affect SCDOT site characterization practices. In Chapter 7, "GeoMechanics," the manual defines site variability levels based on the coefficient of variation of shear strength samples. The site variability level is considered when selecting geotechnical resistance factors, as outlined in Chapter 9.

Effect on Claims, Change Orders, and Cost Overruns

During the agency interview, SCDOT discussed the effect of its manual on claims, change orders, and cost overruns. In general, the manual has improved agency practice by providing standard minimum guidelines for subsurface investigation as well as technical background information to justify the subsurface investigation requirements. Specifically, the manual's requirements have helped reduce several persistent types of claims, change orders, and cost overruns. One of the most significant decreases was for rock excavation for drilled shaft construction. The manual guidelines have resulted in better characterization of the strength and hardness of material to be excavated, which makes it easier for the contractor to select proper tooling. The benefits have also carried over into embankment construction on soft soils. Because preliminary investigation requirements include characterization of subsurface materials for earthwork designs, contractors have a better sense of whether soil close to the proposed embankment can be used for embankment construction or if a long-distance haul will be required to transport more appropriate borrow material further from the proposed embankment. The borrow material information is also available earlier in the project cycle because of the preliminary investigation requirements. Finally, SCDOT noted that the manual has reduced instances of value engineering. Prior to the manual's publication, contractors would frequently do their own subsurface investigation and propose a value engineered design, especially for large projects.

South Carolina DOT: Lessons Learned

The experience of SCDOT illustrates the benefits of establishing standard minimum subsurface investigation and site characterization guidelines. The requirements result in contractors being more prepared for the subsurface materials they will encounter at the project site, which has reduced incidents related to drilled shaft excavation and improved the accuracy of earthwork quantities for SCDOT. Publication of

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standard practices for subsurface investigation and geotechnical design, including resistance factors that consider site variability, also produced design efficiencies, as evidenced by the reduction in value engineered projects.

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION

Claims, change orders, and cost overruns attributed to subsurface conditions are not currently considered a significant problem for Washington State DOT (WSDOT), as noted in the agency's survey response. However, the agency experienced several projects with large geotechnical claims in the 1960s and 70s, prompting it to centralize major geotechnical work in the 1980s (Badger and Ybarra 2015). Further centralization occurred throughout the 1980s and 1990s, primarily motivated by efficiency. Based on an interview with the agency, the resulting program has been effective at managing claims, change orders, and cost overruns attributed to subsurface conditions through a strategy that seeks to "minimize risk and balance cost as much as possible."

Agency Geotechnical Practice

In addition to centralizing geotechnical operations in the 1980s, the agency modernized its drilling equipment to include, for example, rotary wash boring equipment and wireline casing advancers. The agency also uses track drills, skid drills, and barges to perform subsurface investigation in areas with limited access, which are frequently encountered in the state. The agency performs most of its own subsurface investigations, except when access is extremely difficult (e.g., a helicopter is required) or when specialized equipment such as a percussive hammer or rotary vibratory drill is necessary. Other than those exceptions, the agency's subsurface investigation is internal, even when geotechnical design is external, which is the case for approximately one-quarter of all projects. WSDOT's drill crews do not typically include a geologist or an engineer; instead, crew training is emphasized, and engineers and geologists examine all samples with borehole logging personnel (crew inspectors), resulting in a relatively active editing process for boring logs.

The benefits of in-house and centralized subsurface investigation were outlined by Badger and Ybarra in a presentation at TRB's 94th annual meeting in January 2015. The presenters noted that subsurface investigation costs typically account for 50% to 80% of the total cost of geotechnical work. Keeping those expenses in house allows the agency to "closely monitor costs and production," and centralization of the work has benefitted the agency's training efforts for drilling personnel.

Agency subsurface investigation requirements are presented in the *Geotechnical Design Manual* (WSDOT 2014). The manual and the subsurface investigation requirements it includes are primarily organized by feature (e.g., Chapter 8 "Foundations," Chapter 9 "Embankments," etc.). The subsurface investigation requirements reference AASHTO's *LRFD Bridge Design Specifications* (2014); however, the agency has supplemental requirements. For example, the manual notes one boring per drilled shaft may be necessary at sites with large boulders, karst, or mine voids. The manual also requires establishing a well-defined groundwater regime with piezometer data for each drilled shaft foundation location.

Occasional Claims

Although WSDOT's site characterization practices have successfully reduced claims, the agency still occasionally encounters differing site condition claims, because the amount of drilling that would be required to prevent all claims would be cost-prohibitive. Some of the occasional subsurface claims encountered by WSDOT included:

- One of the more frequent issues encountered by the agency occurs when construction encounters soils that are more fine-grained than anticipated requiring, for example, more overexcavation for a retaining wall or shallow foundation.
- Foundation and retaining wall construction is also associated with claims, change orders, and cost overruns attributed to groundwater location. Overexcavation, a working platform, or pumping can be required when the construction groundwater location is different from that indicated by the subsurface investigation. The agency also indicated in the interview that dewatering claims are among the most costly of the subsurface condition claims encountered by WSDOT.
- The most recent subsurface change order encountered by WSDOT involved a soil nail wall for which the contractor had to abandon shotcrete and move to vertical elements because sand at the site was cleaner than anticipated. The project geology involves a braided stream channel; laboratory analysis of boring samples indicted 10% to 15% fines; however, field conditions are closer to 7%.

Washington State DOT: Lessons Learned

WSDOT's reported success in limiting claims, change orders, and cost overruns attributed to subsurface conditions is evidence of the importance of agency exploration and design guidelines, as well as the potential value of in-house, centralized drilling operations, including equipment capable of accessing all relevant investigation locations. The agency credits its drilling program, training of borehole logging personnel, and lab testing program for limiting claims, change orders, and cost overruns. The agency's lab efforts for material characterization are especially significant in a state where fines contents frequently fall between 35% and 65%. Success aside, the occasional claims encountered by the agency are a

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reminder that some claims, change orders, and cost overruns attributed to subsurface conditions are inevitable and that a target of zero claims is impractical.

INDIANA DEPARTMENT OF TRANSPORTATION

Indiana DOT (INDOT) was selected as a case example for several reasons. First, the agency has expressed interest in the synthesis topic as demonstrated by the research of Prezzi et al. (2011) and the presentation by Khan (2014), both described in chapter two. Second, INDOT's survey response noted that changes in site characterization practice including implementation of LFRD, decreasing boring spacing, implementing new laboratory and field tests, increasing use of CPT, and introduction of several better technologies for compaction and ground improvement had led to a noticeable decrease in claims, change orders, and cost overruns. The agency interview identified how each of these practice changes had affected claims, change orders, and cost overruns. Based on the interview, the most significant changes and their effects are described in the following sections.

Pavement Subgrade

Change orders associated with subgrade preparation are one of the most significant sources of claims, change orders, and cost overruns attributed to subsurface conditions encountered by INDOT. The agency has addressed the problem through a series of specification and subsurface investigation revisions. One of the first specification revisions was to provide a formal definition for "unsuitable" material that might be encountered by a contractor during excavation of subgrade. Previously, the specifications included no definition of the term and contractors would successfully file change orders as a result of this ambiguity. These change orders have been reduced since current specifications that provide moisture content-dry density criteria to define unsuitable have been adopted (INDOT 2014, 2016).

More recent efforts to reduce change orders attributed to pavement subgrade include implementation of tighter specification language. Recent specification revisions have also been paired with the improvements to subsurface investigation practice summarized earlier, and the combined effect has been to reduce the number of change orders. INDOT's subgrade specification previously allowed the contractor significant flexibility in choosing subgrade options, which could include various forms of chemical modification, removal and replacement with aggregate, geogrid with aggregate, or conventional compaction techniques to achieve density and moisture requirements. Change orders frequently occurred when the option selected by the contractor did not stabilize the subgrade; for example, lime kiln dust would not stabilize the soils encountered; therefore, the contractor would file a change order for the cost of substituting cement for kiln dust. To prevent this, INDOT has started collecting more subsurface information and has limited contractor subgrade options in the standard specifications (INDOT 2014, 2016). Based on available subsurface information for a given project, some options that had been allowed for all projects are now only allowed by special provision (e.g., stabilization by lime and fly ash). In the agency interview, INDOT also emphasized the importance of internal agency communication and training associated with these revisions. Previously, engineers developing roadway and paving plans were frequently unaware of what geotechnical information was available for a project. INDOT reported that as a result of training the same engineers now request a geotech report immediately upon starting any new roadway or paving project.

Driven Piling Specification Revisions

Although not directly related to subsurface investigation, one of the practice updates used by INDOT that was most effective in reducing claims was implementation of revised driven pile specifications. The pile driving specification changes predate the Prezzi report and the ten-year time period covered with the survey described in chapter three. In the late 1990s, the agency updated its driven pile specification to require pile driving analysis for most projects and Gates Formula for some smaller projects. Previously, the agency had used the *Engineering News* (ENR) pile driving formula and experienced significant costs associated with pile overruns and underruns. Since implementing the specification revisions, INDOT has experienced very few change orders related to pile overruns.

Indiana DOT: Lessons Learned

Perhaps the most important lesson provided by INDOT is that effective subsurface investigation practice is only successful when it is coupled with effective specification language. Prescriptive specifications can find success when sufficient subsurface information is collected; alternatively, without sufficient subsurface information, project specifications may result in change orders when they include; for example, subgrade options that are incompatible with potential site soils. For INDOT, effective subsurface investigation practice requires including sufficient intra-agency training and communication so that all designers know how to use geotechnical information.

MINNESOTA DEPARTMENT OF TRANSPORTATION

Subsurface conditions claims, change orders, and cost overruns have decreased significantly for Minnesota DOT (MnDOT) according to results from Part Two of the survey.

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Agency Practice

MnDOT attempts to perform all subsurface investigations in-house, but uses subcontracts to complete approximately 20% of the work in order to accommodate agency workload limitations. MnDOT's subsurface investigation guidelines are published in the agency's 2013 *Geotechnical Engineering Manual* (2013). The minimum exploration requirements (number and depth) for all applications (foundations, slopes, walls, etc.) are largely consistent with AASHTO's *LRFD Bridge Design Specifications* (2014). However, the minimum requirements largely focus on SPT borings, and the agency regularly supplements the SPT borings with a significant number of CPT soundings for all applications. The agency has three CPT rigs, which are the most frequently used pieces of equipment in its subsurface investigation fleet. When MnDOT first began using CPT around 2001, CPT soundings and SPT borings were frequently performed side by side. Since that time, the agency has become sufficiently familiar with CPT "signatures" to recognize material types, which allows the agency to exclusively use CPT for some small earthwork projects; for bridge projects, CPT soundings are primarily supplemental. CPT use increases the density of subsurface investigation locations, although there are no specific data to support such a reduction in claims, change orders, and cost overruns as a result of increased CPT use. MnDOT has also increased use of the design-build delivery mechanism, which now accounts for 10% to 20% of total agency construction.

Claims

In the agency interview, MnDOT provided information about the most frequently encountered subsurface conditions claims, change orders, and cost overruns. A common cause for subsurface conditions claims occurs during construction of sound barrier walls when predrill holes for foundations encounter unanticipated cobbles. Pile overruns, which occur when pile foundations are driven deeper than anticipated, are also common. The agency also mentioned higher than anticipated groundwater as a frequent claim for installation of storm sewers and utilities or any other construction requiring trenching.

The survey response indicated that claims, change orders, and cost overruns are less common on design-build projects than on design-bid-build projects. It was also noted that contractors conduct themselves differently on design-build projects with respect to mitigating delays.

Minnesota DOT: Lessons Learned

Since its introduction in 2001, MnDOT has significantly increased the use of CPT. CPT is now frequently used to supplement SPT borings, resulting in greater density of subsurface investigation locations. MnDOT has also increased the use of the design-build delivery method, which the agency noted is associated with fewer claims, change orders, and cost overruns than design-bid-build projects.

SUMMARY OF COMMON CAUSES OF SUBSURFACE CONDITIONS CLAIMS, CHANGE ORDERS, AND COST OVERRUNS AND LESSONS LEARNED FROM ALL CASE EXAMPLES

Common Causes of Subsurface Conditions Claims, Change Orders, and Cost Overruns

The agency interviews focused primarily on methods of reducing claims, change orders, and cost overruns attributed to subsurface conditions; however, the conversations also revealed common causes. The following list summarizes some of the most frequent situations and applications associated with subsurface conditions claims, change orders, and cost overruns.

- Pile overruns and underruns.
- Higher than expected groundwater for
  - Retaining walls,
  - Earthworks,
  - Utility and sewer work, and
  - Drilled shaft installation.
- Misclassified or mischaracterized subgrade for
  - Pavements,
  - Embankments, and
  - Retention ponds.
- Unanticipated rock during foundation construction; such claims are especially frequent for sound barrier walls and other secondary structures with relatively small loads, relatively large numbers of foundations, and relatively sparse borings compared with more significant structures.
- Mischaracterized rock for drilled shaft construction, leading to improper equipment selection and construction delays.

The cost of claims, change orders, and cost overruns associated with the situations listed previously varies depending on the scope of the project and the degree of difference between anticipated and encountered conditions. Claims, change orders, and cost overruns associated with installation of dewatering systems were noted as being particularly costly.

Summary of Lessons Learned

Experiences of the five agencies described in this chapter vary substantially; however, each provides valuable lessons regarding methods for reducing claims, change orders, and cost overruns attributed to subsurface conditions.

- Modest changes to subsurface investigation practices can produce significant reductions, particularly when

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the changes are tailored to a specific, recurring claim, change order, or cost overrun.

- Development of minimum standards for subsurface investigation and site characterization can result in more accurate plan quantities and better prepared contractors.
- In-house, centralized drilling and laboratory services provide a consistent standard of care, potentially associated with reduced claims, change orders, and cost overruns, especially when accompanied by robust training of agency personnel.
- Intra-agency training and communication to improve the implementation of subsurface information can be effective in reducing claims, change orders, and cost overruns attributed to subsurface conditions.
- The accuracy of boring locations can effectively reduce the occurrence of claims, change orders, and cost overruns, especially in locations with significant spatial variability.
- Implementation of minimum standards for subsurface investigation and site characterization can also produce design efficiencies.
- Drilling equipment capable of accessing difficult-to-reach locations is valuable, particularly for states with considerable areas of difficult terrain.
- Specification language that is incompatible with subsurface investigation and site characterization results or the lack thereof can result in claims, change orders, and cost overruns.

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CHAPTER FIVE

CONCLUSIONS

Geotechnical risks in infrastructure construction are widely acknowledged to be significant; however, information quantifying the risks is rare and information quantifying the risks in the context of subsurface investigation scope even rarer. This Synthesis reviews the nature of subsurface risks and geotechnical investigations for U.S. transportation agencies and identifies practices the agencies can implement to reduce the risks. It consists of a literature review, a survey of transportation agencies, and case examples of select agencies. This chapter provides a brief summary of each before presenting the most important conclusions, organized by topic.

The literature review (chapter two) included five topics: (1) national subsurface investigation standards as well as agency subsurface investigation capabilities; (2) previous research at the Indiana Department of Transportation regarding geotechnical change orders; (3) previous studies investigating the effect of subsurface investigation on claims, change orders, and cost overruns; and literature regarding (4) human effects and (5) contracting practice effects attributed to subsurface conditions. Results of the survey are presented in chapter three. Fifty-five agencies were contacted for the survey; 51 responded (93%). The survey consisted of three parts and was sent to geotechnical engineers, many of whom shared responsibility for completing the survey with construction personnel. Five agencies that indicated success in reducing claims, change orders, and cost overruns attributed to subsurface conditions were identified for further examination. Case examples for these five agencies were presented in chapter four.

SCOPE OF SUBSURFACE INVESTIGATION

- Nearly 70% of responding agencies specify minimum subsurface investigation requirements that are equal to or generally consistent with requirements prescribed in the 2014 AASHTO *LRFD Bridge Design Specifications* and the 1988 AASHTO *Subsurface Investigation Manual*. Five of the responding agencies (10%) have minimum requirements that substantially exceed those prescribed in the AASHTO *Specifications*, three have requirements that are materially different from the AASHTO *Specifications*, and one reported having requirements that are generally less stringent than the AASHTO *Specifications*.
- Slightly more than half of the responding agencies reported that scopes for subsurface investigations occasionally exceed the minimum requirements, whereas relatively few agencies mentioned that scopes for subsurface investigations commonly exceed minimum requirements. Approximately one-third of the responding agencies noted that scopes for subsurface investigations rarely exceed the minimum requirements.
- Approximately half of the responding agencies reported that site characterization is difficult because of highly variable subsurface conditions, whereas approximately half reported that site characterization is not difficult. A small percentage of agencies also indicated that site characterization is difficult because select types of soil and rock are difficult to characterize.
- A small number of agencies have specifications that incentivize additional site characterization by prescribing different resistance factors for different levels of investigation.
- Other studies have indicated agency in-house subsurface investigation is common but decreasing, whereas use of the cone penetration testing (CPT) is less common but increasing. Badger's survey in 2015 found that three-quarters of the 36 responding agencies used CPT.

CAUSES OF SUBSURFACE CONDITIONS CLAIMS, CHANGE ORDERS, AND COST OVERRUNS

Claims, change orders, and cost overruns attributed to subsurface conditions most frequently fall under the heading of differing site conditions; however, the combinations of project applications and geologic settings that are associated with differing site conditions are diverse. The most common causes identified in the survey and case examples included pile overruns, higher than expected groundwater, misclassified or mischaracterized subgrade, unanticipated rock encountered during foundation construction, and mischaracterized rock for drilled shaft construction. These are consistent with causes identified in previous studies. In interviews, several agencies noted that subsurface investigation cannot completely remove the risk of claims, change orders, and cost overruns, a position that is supported by literature.

SIGNIFICANCE OF SUBSURFACE CONDITIONS CLAIMS, CHANGE ORDERS, AND COST OVERRUNS

The survey data shed light on the magnitude and frequency of claims, change orders, and cost overruns attributed to subsurface conditions among U.S. transportation agencies. Many of the conclusions are based on quantitative data provided by

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seven agencies. The number of agencies providing such quantitative data was limited because such data are difficult to extract from databases of all claims, change orders, and cost overruns.

- Three-quarters of responding agencies recognize claims, change orders, and cost overruns from all sources as a significant problem. Slightly more than half reported subsurface conditions as a significant problem.
- Most responding agencies perceive that the magnitude and frequency of claims, change orders, and cost overruns has remained steady over the last decade, although some agencies have perceived some decrease and others an increase in the magnitude and frequency.
- Change orders attributed to subsurface conditions are considerably more frequent than claims or cost overruns. The same trend was observed among claims, change orders, and cost overruns attributed to all causes. There was less difference among the average cost per individual occurrence, although claims were somewhat more costly than change orders or cost overruns, which is contrary to the trend observed considering all causes, for which change orders were considerably less costly on average than claims and cost overruns. Considering both the frequency and the average cost per occurrence, subsurface conditions change orders have the largest impact on agency budgets.
- By number, 5% of all claims, change orders, and cost overruns reported in the survey were attributed to subsurface conditions; by cost, 7% were attributed to subsurface conditions. These values are consistent with the majority response to a survey question requesting estimates of the percentage of claims, change orders, and cost overruns attributed to subsurface conditions: 30 of 47 respondents estimated less than 20%. That slightly more than one-third of respondents estimated greater than 20% suggests there is a perception among some agencies or some personnel that greater percentages of claims, change orders, and cost overruns can be attributed to subsurface conditions than the quantitative data suggest.
- Cumulative costs for claims, change orders, and cost overruns attributed to subsurface conditions represented up to 1% of total agency construction budgets. The impact on individual project budgets is likely far greater. Individual, project-level data were not collected; however, total annual agency costs of subsurface conditions change orders, for example, represented as much as 7% of the total agency spending on all projects associated with the change orders. The impact on individual project budgets was therefore likely much greater than 7% for some projects, because 7% is an average of many projects and the variability of claims, change order, and overrun data was observed to be considerable. The impact of a change order costing even 7% of the project budget is likely significant, especially relative to project contingency funds, which are often limited.
- Problems related to subsurface conditions claims, change orders, and cost overruns do not follow any obvious geographic patterns. However, there do appear to be regions of the country, particularly the Midwest and South Atlantic, where site characterization is less difficult and subsurface condition problems are less prevalent; trends that are likely explained by geologic regions.
- The reported relative costs of subsurface conditions claims, change orders, and cost overruns were generally consistent with values reported in previous studies focusing on transportation projects and less than values reported for other construction sectors.
- The quantitative data reported in the survey included only direct costs of claims, change orders, and cost overruns. A similar study by Mott MacDonald and Soil Mechanics, Ltd. in 1994 found indirect costs to be greater than direct costs.

PRACTICES TO REDUCE SUBSURFACE CONDITIONS CLAIMS, CHANGE ORDERS, AND COST OVERRUNS

Practices that were effective in reducing claims, change orders, and cost overruns attributed to subsurface conditions were discovered in the literature review, survey, and case examples and are summarized here.

- Improvements implemented by agencies have had mixed effects on the occurrence of claims, change orders, and cost overruns, with some agencies experiencing substantial reductions in the occurrence, whereas others have not experienced such reductions or are still evaluating the effects.
- Targeted improvements to subsurface investigation practices to address specific issues leading to claims, change orders, and cost overruns appear to be more successful and less costly to implement than across-the-board changes to practice.
- Communication and training involving a broad spectrum of agency and contractor personnel (including designers, contractors, inspectors, and field crews) appear to be key elements to realizing the benefits of improvements to site characterization practices. Such communication may include improvements to agency guidelines, specifications, and standards; improvements to agency design, bid, and contract documents; and regular training opportunities. These factors, essentially the human factors emphasized in literature, may be significant when geotechnical risks are especially significant, such as for design-build projects.
- Conduct of subsurface investigations by well-trained agency personnel appears to aid in improving site characterization and in reducing claims, change orders, and cost overruns.
- Even if improvements to subsurface investigation practices do not produce substantial reductions in claims, change orders, and cost overruns, they have often led to substantial improvements to design efficiencies.

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FUTURE RESEARCH

This Synthesis presents findings that significantly reduce uncertainty regarding subsurface conditions claims, change orders, and cost overruns, especially at an agency level. It has also identified several challenges, particularly related to recordkeeping and project-level data, which make further reduction in uncertainty difficult. In addition, this Synthesis describes several areas where modifications to agency practices could produce notable cost reductions or performance improvements. The findings are therefore motivation for future research. Ideas for future research are introduced here:

- Many of the difficulties in collecting quantitative data regarding subsurface conditions claims, change orders, and cost overruns resulted from agency practices for documentation. The use of database reason codes (e.g., as documented for the Indiana Department of Transportation), and specifically the practice of assigning a single reason code to each make it difficult to isolate projects with true subsurface conditions claims, change orders, and cost overruns. Alternative methods of archiving, tracking, and coding could be explored to improve the accuracy of, and increase opportunities for, efforts that rely on databases of claims, change orders, and cost overruns. The improved database would be an extremely valuable tool for agencies to track project risk sources and regularly evaluate and improve practices. Claims, change orders, and cost overruns are a significant learning opportunity for agencies, as several case example agencies have demonstrated with targeted improvements that have successfully addressed specific issues leading to claims, change orders, and cost overruns. Database improvements would also benefit the other research efforts suggested here.
- Because of difficulties in collecting quantitative data, the information presented in this Synthesis was gathered at an agency level, not a project level. The agency-level data are useful for broadly defining the significance of subsurface conditions claims, change orders, and cost overruns; however, project-level data are necessary to evaluate the effects of specific subsurface investigation risk practices. Project-level data regarding the details of subsurface investigation (number and type of investigations, cost, etc.) and the specific cause and cost of corresponding subsurface conditions claims, change orders, and cost overruns could be collected. Project-level data are necessary for many of the following ideas.
- The list of frequently encountered subsurface conditions claims, change orders, and cost overruns from this Synthesis study was developed primarily from the reports of the case example agencies. A more intensive study of subsurface conditions causes of claims, change orders, and cost overruns could be conducted and incorporate cost information. Results would include a more robust list of subsurface conditions issues, which would be valuable in its own right and could also be used to quantify construction risks. Quantified construction risks are necessary for any rigorous effort to evaluate methods for reducing claims, change orders, and cost overruns, including several subsequent research ideas.
- Agency communication and training were identified as critical to realizing the benefits of improvements to site characterization practices. Additional information regarding specific agency communications and training practices related to geotechnical investigation would help identify the most effective practices and, in turn, allow agencies to fully realize the benefits of other site characterization practices, a possible topic for a new NCHRP Synthesis study.
- For most agencies, subsurface investigation requirements are consistent with the 2014 AASHTO *LRFD Bridge Design Specifications* and the 1988 AASHTO *Subsurface Investigation Manual*, both of which recommend a minimum number of borings for each project location (e.g., bridge bent and length of retaining wall) without considering variations in project-specific ground conditions or geologic risks. Research could be conducted to identify the level of geotechnical investigation scope that produces a consistent level of risk of claims, change orders, and overruns as a function of site conditions. Results of such work would also demonstrate the economic value of subsurface investigation and could help agencies establish an appropriate contingency level for geotechnical construction.
- Use of CPT, geophysical methods, and other alternative investigation techniques was found to vary widely among agencies. Research could be conducted to identify the most effective use of alternative investigation techniques. The objective would be to identify appropriate replacement rates (alternative investigations instead of conventional borings) for various types of construction and ground conditions. The results could also be used to evaluate the economic benefit of alternative investigation techniques.
- Although use of alternative investigation techniques varied considerably, the agencies generally perceived such techniques as having improved overall geotechnical investigation practice. Such reports motivate additional investment into continued development of new and emerging techniques for subsurface investigation (e.g., various geophysical methods and in situ testing methods) to benefit highway design and construction applications.

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APPENDIX A

Survey Questionnaire (Web-Only)

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NCHRP Synthesis 46-04: The Impact of Geotechnical Investigation Scope on Construction Claims, Change Orders, and Overruns

Dear:

The Transportation Research Board (TRB) is preparing a synthesis on the impact of geotechnical investigation scope on construction claims, change orders, and overruns. This is being done for NCHRP, under the sponsorship of the American Association of State Highway and Transportation Officials, in cooperation with the Federal Highway Administration.

Construction claims and change orders due to unanticipated or variable subsurface conditions frequently lead to significant project cost increases and/or schedule delays. The goal of the study is to evaluate and document the magnitude, frequency, and nature of claims, change orders, and overruns resulting from subsurface conditions, and to examine the effect of geotechnical investigation practices on these undesirable outcomes. This survey is the most critical component of the project effort. We are particularly interested in identifying practices that have been successful in reducing such occurrences.

The survey is broken into three parts. Part One contains questions related to subsurface investigation practices. Part Two includes general, mostly qualitative questions about claims, change orders, and cost overruns. An **optional** Part Three requests specific quantitative information regarding claims, change orders, and cost overruns. We anticipate that for some agencies, the information requested in Part Three may not be readily available. If **quantitative information requested regarding claims, change orders, and/or cost overruns is not readily available, please skip to the end to submit the partially completed survey** rather than abandoning the survey altogether. No responses will be received until you click to submit the survey.

Your cooperation in completing the questionnaire will ensure the success of this effort. **If you are not the appropriate person at your to complete this questionnaire, please forward it to the correct person.** State geotechnical engineers are, in large part, the primary contacts for this survey. It is likely that state construction engineers are better equipped to respond to Parts Two and Three of the survey. To address this, **participants are encouraged to share the survey response effort among personnel by following the Instruction 3 below.**

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Please complete and submit the survey by February 11. We estimate that Parts One and Two of the survey will each take approximately 20 minutes to complete. The completion time for optional Part Three may be considerable, but it will vary greatly depending on the availability and accessibility of data. If you have questions, please contact the principal investigator, Andy Boeckmann, at 573-424-0017 or boeckmanna@missouri.edu. Any supporting materials or additional documents that might be useful for this study would be much appreciated and can be sent directly to Andy by email or using the postal address at the end of the survey. Thank you for participating in the survey!

QUESTIONNAIRE INSTRUCTIONS

1. To view and print the entire questionnaire, Click on the following link and print using "control p" //surveygizmolibrary.s3.amazonaws.com/library/64484/NCHRP_Synthesis_4604_Survey.pdf
2. To save your partial answers and complete the questionnaire later, click on the "Save and Continue Later" link in the upper right hand corner of your screen. A link to the incomplete questionnaire will be emailed to you from *SurveyGizmo.* To return to the questionnaire later, open the email from *SurveyGizmo* and click on the link. We suggest using the “Save and Continue Later” feature if there will be more than 15 minutes of inactivity while the survey is opened, as some firewalls may terminate due to inactivity.
3. To pass a partially completed questionnaire to a colleague, click on the on the “Save and Continue Later" link in the upper right hand corner of your screen. A link to the incomplete questionnaire will be emailed to you from *SurveyGizmo.*” Open the email from *SurveyGizmo* and forward it to a colleague.
4. To view and print your answers before submitting the survey, click forward to the page following Question 42. Print using “control p.”
5. To submit the survey, click on “Submit” on the last page.

QUESTIONNAIRE DEFINITIONS

For the purposes of this survey, the following definitions are used:
• **Claim:** A claim is a legal demand by a contractor for additional compensation or time when the contractor believes he/she is entitled to it under the terms of the contract documents. Potential claim resolutions include denial/rejection, a change order for additional compensation or additional time, or other resolutions involving dispute review boards, mediators, or courts.
• **Change order:** A change order is a formal modification of the scope of work established in contract documents, often including adjustments to compensation and/or schedule.
• **Cost overrun:** A cost overrun refers to instances when the cost of a project or bid item at project completion exceeds its initially contracted cost.
• **Site characterization:** The process of identifying and describing below-ground features via subsurface investigation, including, but not limited to, exploratory borings and laboratory testing. The description of features includes assignment of geotechnical design parameters.

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Thank you very much for your time and expertise!

Please enter the date (MM/DD/YYYY).

Calendar

Please enter your contact information.

First Name *

Last Name *

Title

Agency/Organization *

Street Address *

Suite

City

State *

Zip Code *

Country

Email Address *

Phone Number *

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Part One

1. Please select the response that best describes your agency's experience with site characterization:

- Site characterization is generally not difficult.
- Site characterization is often difficult because of highly variable subsurface conditions.
- Site characterization is often difficult because select types of soil/rock are difficult to characterize.
- Site characterization is often difficult because of highly variable subsurface conditions AND select types of soil/rock that are difficult to characterize.

2. Please select the response that best describes the design, construction, and performance problems your agency has experienced as a result of subsurface conditions:

- My agency experiences relatively few design, construction, and performance problems resulting from subsurface conditions.
- My agency experiences a modest number of design, construction, and performance problems resulting from subsurface conditions.
- My agency experiences frequent design, construction, and performance problems resulting from subsurface conditions.

3. Does your agency formally specify minimum (or recommended minimum) subsurface investigation requirements for all projects?

- Yes
- No
- I don't know.

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LOGIC Hidden unless: Question “Does your agency formally specify minimum (or recommended minimum) subsurface investigation requirements for all projects?” #3 is one of the following answers (“Yes”)

Please select the item below that best describes the minimum requirements:

- ○ The minimum requirements are those prescribed in AASHTO specifications and guidelines.
- ○ The minimum requirements are documented in agency-specific provisions, but are generally consistent with those prescribed in AASHTO specifications and guidelines.
- ○ The minimum requirements are documented in agency-specific provisions, but substantially exceed those prescribed in AASHTO specifications and guidelines.
- ○ The minimum requirements are documented in agency-specific provisions, but are materially different from those prescribed in AASHTO specifications and guidelines (e.g., involve different techniques and procedures than are addressed in AASHTO specifications and guidelines).
- ○ Other, please specify: ____________

LOGIC Hidden unless: Question “Please select the item below that best describes the minimum requirements:” is one of the following answers (“The minimum requirements are documented in agency-specific provisions, but are materially different from those prescribed in AASHTO specifications and guidelines (e.g., involve different techniques and procedures than are addressed in AASHTO specifications and guidelines).”)

You indicated your agency implements unique subsurface investigation practices that materially differ from those described within AASHTO subsurface investigation guidelines and testing standards. Please briefly describe the unique agency practice(s):

4. If minimum subsurface investigation requirements are formally specified, is it common for the actual scope of subsurface investigations to exceed the minimum requirements for specific projects?

- Minimum requirements are not formally specified.
- Yes, the scope for subsurface investigations commonly exceeds the minimum requirements.
- Yes, the scope for subsurface investigations occasionally exceeds the minimum requirements.
- No, the scope of subsurface investigations rarely exceeds the minimum requirements.
- I don't know.

5. Does your agency have a “state-specific” manual and/or specifications that describe requirements and practices for site characterization?

- Yes
- No
- I don't know.

LOGIC Hidden unless: Question “Does your agency have a “state-specific” manual and/or specifications that describe requirements and practices for site characterization?” #5 is one of the following answers (“Yes”)

Please share your agency's “state-specific” manual and/or specifications.

- Manual is not available for sharing.
- Upload the document(s)
- Link to the document(s):

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LOGIC Hidden unless: Question "Please share your agency's "state-specific" manual and/or specifications." is one of the following answers ("Upload the document(s)")
Please upload the document(s) using the buttons below.

Browse... Choose File No file selected Upload

LOGIC Hidden unless: Question "Does your agency have a "state-specific" manual and/or specifications that describe requirements and practices for site characterization?" #5 is one of the following answers ("No")
Please briefly describe any differences in practices or requirements for site characterization relative to those prescribed in the AASHTO LRFD Bridge Design Specifications.

6. Does your agency require geotechnical information be included with bid documents for bridge projects?

- Yes
- No
- I don't know.

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LOGIC Hidden unless: Question "Does your agency require geotechnical information be included with bid documents for bridge projects?" #6 is one of the following answers ("Yes")
Please describe the geotechnical information required to be included with bridge project bid documents.

Part One, cont'd

7. Select the answer that best describes your agency's historical use of geophysical methods for site characterization:

- My agency routinely uses geophysical methods for site characterization.
- My agency occasionally uses geophysical methods for site characterization.
- My agency rarely uses geophysical methods for site characterization.
- My agency never uses geophysical methods for site characterization.
- I don't know.

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8. Does your agency maintain a database of subsurface information? Select the response that best describes your agency capabilities.

- Yes, my agency maintains a GIS-based database of subsurface information.
- Yes, my agency maintains an electronic database of subsurface information, but the database is not GIS-based.
- No, my agency does not maintain a database of subsurface information, but we do retain hard copy records from past projects that can be accessed when needed.
- No, my agency does not maintain a database of subsurface information, and it is difficult to access historical records of subsurface information.
- I don't know.

9. Has your agency implemented specific changes to site characterization practices in the last five years?

- Yes
- No
- I don't know.

LOGIC Hidden unless: Question "Has your agency implemented specific changes to site characterization practices in the last five years?" #9 is one of the following answers ("Yes")
Please briefly describe the specific changes that have been implemented:

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LOGIC Hidden unless: Question "Has your agency implemented specific changes to site characterization practices in the last five years?" #9 is one of the following answers ("Yes")
Please select the statement below that best describes the perceived impact of the specific changes in terms of the number of claims, change orders, and overruns.

- The changes have led to a noticeable increase in the occurrence of claims, change orders, and overruns.
- The changes have led to a marginal increase in the occurrence of claims, change orders, and overruns.
- The changes have not noticeably affected the occurrence of claims, change orders, and overruns.
- The changes have led to a marginal decrease in the occurrence of claims, change orders, and overruns.
- The changes have led to a noticeable decrease in the occurrence of claims, change orders, and overruns.
- Insufficient experience to respond.
- I don't know.

10. Are there provisions in your agency's design code that provide incentives for performing site characterization in excess of the minimum requirements or for performing specific site characterization activities? Example incentives might include permitting use of more advantageous load or resistance factors for projects with more extensive site investigations or for relaxation of some site characterization requirements if special techniques or procedures are used (e.g., geophysics).

- Yes
- No
- I don't know.

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LOGIC Hidden unless: Question "Are there provisions in your agency's design code that provide incentives for performing site characterization in excess of the minimum requirements or for performing specific site characterization activities? Example incentives might include permitting use of more advantageous load or resistance factors for projects with more extensive site investigations or for relaxation of some site characterization requirements if special techniques or procedures are used (e.g., geophysics)." #10 is one of the following answers ("Yes")
Please briefly describe the provisions in the text box below.

LOGIC Hidden unless: Question "Are there provisions in your agency's design code that provide incentives for performing site characterization in excess of the minimum requirements or for performing specific site characterization activities? Example incentives might include permitting use of more advantageous load or resistance factors for projects with more extensive site investigations or for relaxation of some site characterization requirements if special techniques or procedures are used (e.g., geophysics)." #10 is one of the following answers ("Yes")
If possible, please provide a link or an attachment to the specific provisions.

- Provisions are not available for sharing.
- Upload document
- Link to provisions:

LOGIC Hidden unless: Question "If possible, please provide a link or an attachment to the specific provisions." is one of the following answers ("Upload document")
Please upload the provisions.

Browse... Choose File No file selected Upload

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LOGIC Hidden unless: Question "Are there provisions in your agency's design code that provide incentives for performing site characterization in excess of the minimum requirements or for performing specific site characterization activities? Example incentives might include permitting use of more advantageous load or resistance factors for projects with more extensive site investigations or for relaxation of some site characterization requirements if special techniques or procedures are used (e.g., geophysics)." #10 is one of the following answers ("Yes")
When was this practice implemented?

LOGIC Hidden unless: Question "Are there provisions in your agency's design code that provide incentives for performing site characterization in excess of the minimum requirements or for performing specific site characterization activities? Example incentives might include permitting use of more advantageous load or resistance factors for projects with more extensive site investigations or for relaxation of some site characterization requirements if special techniques or procedures are used (e.g., geophysics)." #10 is one of the following answers ("Yes")
Please select the statement below that best describes the perceived success of the practice in reducing the number of claims, change orders, and overruns?

- Practice has not noticeably affected the occurrence of claims, change orders, and overruns.
- Practice has produced marginal reduction in the occurrence of claims, change orders, and overruns.
- Practice has produced substantial reduction in the occurrence of claims, change orders, and overruns.
- Insufficient experience to respond.
- I don't know.

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11. Has your agency experienced significant performance problems that can be attributed to subsurface conditions or site characterization practices? Performance problems can be related to design issues, QA/QC issues, or any issue that can be attributed to subsurface conditions or site characterization practices.

- Yes
- No
- I don't know.

LOGIC Hidden unless: Question "Has your agency experienced significant performance problems that can be attributed to subsurface conditions or site characterization practices? Performance problems can be related to design issues, QA/QC issues, or any issue that can be attributed to subsurface conditions or site characterization practices." #11 is one of the following answers ("Yes")

Please briefly describe the performance problems and the perceived source of the problems.

12. Does your agency have notable examples where site characterization practices have led to accelerated project delivery or reduced costs for construction and operation of transportation facilities?

- Yes
- No
- I don't know.

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LOGIC Hidden unless: Question “Does your agency have notable examples where site characterization practices have led to accelerated project delivery or reduced costs for construction and operation of transportation facilities?” #12 is one of the following answers (“Yes”)

Please briefly list the projects and provide an estimate of the magnitude of the cost savings that were achieved.

Part Two

Questions 13 through 16 relate to claims, change orders, and cost overruns from ***all* sources/causes.**

13. Are claims, change orders, and cost overruns considered to be a significant concern within your agency?

- No, they are not considered to be a significant problem.
- They are recognized as a problem, but they are not a priority concern.
- They are recognized as a problem and are a priority concern.
- They are recognized as one of our agency’s most significant problems.
- I don’t know.

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14. If claims, change orders, and cost overruns are a recognized problem within your agency, what is the primary source of concern regarding the claims, change orders, and cost overruns? Please select all that apply.

- ☐ They are not a recognized problem.
- ☐ They significantly impact the agency budget.
- ☐ They significantly impact public perception of the agency.
- ☐ They significantly impact time allocation of agency resources, resulting in opportunity losses.
- ☐ Other ________

15. Has the magnitude and/or frequency of claims, change orders, and overruns changed over the past 10 years?

- ○ Yes, the magnitude and/or frequency has decreased significantly.
- ○ Yes, the magnitude and/or frequency has decreased slightly.
- ○ No, the magnitude and/or frequency has remained about the same.
- ○ Yes, the magnitude and/or frequency has increased slightly.
- ○ Yes, the magnitude and/or frequency has increased significantly.
- ○ I don't know.

16. Is project delivery mechanism (design-bid-build, design-build, public-private partnership, construction manager/general contractor) perceived to have a significant effect on the incidence or magnitude of claims, change orders, and/or cost overruns? Note this refers to all claims, not just those that could be attributed to subsurface conditions.

- ○ Yes
- ○ No
- ○ I don't know.

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LOGIC Hidden unless: Question "Is project delivery mechanism (design-bid-build, design-build, public-private partnership, construction manager/general contractor) perceived to have a significant effect on the incidence or magnitude of claims, change orders, and/or cost overruns? Note this refers to all claims, not just those that could be attributed to subsurface conditions." #16 is one of the following answers ("Yes")
Please explain the perceived effect.

Part Two, cont'd

Questions 17 through 21 relate to claims, change orders, and cost overruns that can be attributed to subsurface conditions or site characterization practices.

17. Are contractors prevented from filing claims against your agency based on changed conditions related to ground conditions or based on unforeseen subsurface conditions?

- Yes
- No

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LOGIC Hidden unless: Question "Are contractors prevented from filing claims against your agency based on changed conditions related to ground conditions or based on unforeseen subsurface conditions?" #17 is one of the following answers ("Yes")

What is the basis for preventing such claims?

- State statutes.
- Contract provisions.
- Both state statutes and contract provisions.
- Other, please specify

18. What percentage of claims, change orders, and cost overruns experienced by your agency can be attributed to subsurface conditions or site characterization practices? Please estimate or calculate the percentage of such claims, change orders, and cost overruns by number (i.e., quantity or frequency), not cost.

- Less than 20 percent.
- 20 to 40 percent.
- 40 to 60 percent.
- 60 to 80 percent.
- Greater than 80 percent.

19. Are claims, change orders, and overruns resulting from subsurface conditions or site characterization practices considered to be a significant concern within your agency?

- No, they are not considered to be a significant problem.
- They are recognized as a problem, but they are not a priority concern.
- They are recognized as a problem and are a priority concern.
- They are recognized as one of our agency's most significant problems.
- I don't know.

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20. Has the magnitude and/or frequency of claims, change orders, and overruns that can be attributed to subsurface conditions or site characterization practices changed over the past 10 years?

- Yes, the magnitude and/or frequency has decreased significantly.
- Yes, the magnitude and/or frequency has decreased slightly.
- No, the magnitude and/or frequency has remained about the same.
- Yes, the magnitude and/or frequency has increased slightly.
- Yes, the magnitude and/or frequency has increased significantly.
- I don’t know.

21. Is project delivery mechanism (design-bid-build, design-build, public-private partnership, construction manager/general contractor) perceived to have a significant effect on the incidence or magnitude of claims, change orders, and/or cost overruns that can be attributed to subsurface conditions or site characterization practices?

- Yes
- No
- I don’t know.

LOGIC Hidden unless: Question “Is project delivery mechanism (design-bid-build, design-build, public-private partnership, construction manager/general contractor) perceived to have a significant effect on the incidence or magnitude of claims, change orders, and/or cost overruns that can be attributed to subsurface conditions or site characterization practices?” #21 is one of the following answers (“Yes”)
Please explain the perceived effect.

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Optional Part Three

Page exit logic: Page Logic
IF: Question "Are records of claims, change orders, and/or cost overruns for your agency readily available?" #22 is one of the following answers ("No, and I'm ready to submit my responses from previous pages.") **THEN:** Jump to page 11 - Summary of Responses & Submit Button Flag response as complete

The remaining questions request quantitative information regarding the total number and total costs of claims, change orders, and cost overruns. We recognize such information may not be readily available. **If the information is not readily available, you can proceed with estimates, or you can submit your responses from the previous pages and exit the survey by selecting the last response to Question 22 below.**

22. Are records of claims, change orders, and/or cost overruns for your agency readily available?

- ○ Yes, at least some records are available.
- ○ No, but I can provide reasonable estimates.
- ○ No, and I'm ready to submit my responses from previous pages.

Optional Part Three, cont'd

Page exit logic: Page Logic
IF: Question "If you realize none of the information requested on this page is available, please check the box below and click "Next" at the bottom of this page to skip to the final page of the survey." is one of the following answers ("I don't have the information requested on this page, and I'm ready to submit all previous responses.") **THEN:** Jump to page 11 - Summary of Responses & Submit Button

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Questions 23 through 32 relate to quantifying the total number and total costs of claims, change orders and cost overruns experienced by your agency since 2009. Responses to these questions should reflect **all claims**, not just those related to subsurface investigations. Questions 34 through 42 will solicit similar responses for claims associated with subsurface conditions and site characterization practices.

We recognize that both records availability and claims filing processes and definitions vary from agency to agency. Please use the comment field at the bottom of this page to add any explanation, qualification, or clarification to your responses. If only some of the data is readily available, please fill in the appropriate fields and leave the others blank.

If you realize none of the information requested on this page is available, please check the box below and click "Next" at the bottom of this page to skip to the final page of the survey.

☐ I don't have the information requested on this page, and I'm ready to submit all previous responses.

23. Please report your agency's total budget for new construction since 2009. "New construction" here refers to capital improvements and excludes expenditures related to maintenance, safety, and rehabilitation.

24. How many total claims has your agency experienced since 2009?

25. What is the cumulative cost of all claims since 2009?

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26. What is the cumulative total contract cost for all projects associated with all claims since 2009?

27. How many change orders has your agency issued since 2009?

28. What is the cumulative cost of all change orders your agency has issued since 2009?

29. What is the cumulative total contract cost of all projects associated with all change orders issued since 2009?

30. How many projects have had cost overruns since 2009?

31. What is the cumulative cost of all overruns since 2009?

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32. What is the cumulative total contract cost for all projects that have had cost overruns since 2009?

Please use the comment field below to add any explanation, qualification, or clarification to your responses.

Optional Part Three, cont'd

Page exit logic: Page Logic
IF: Question "Does your agency keep data related to or that could otherwise be used to identify claims, change orders, and cost overruns that resulted from subsurface conditions or site characterization practices?" #33 is one of the following answers ("No, and I'm ready to submit my responses from previous pages.") **THEN:** Jump to page 11 - Summary of Responses & Submit Button Flag response as complete

The remaining questions request the same quantitative information (total number and total costs of claims, change orders, and cost overruns) from the previous page, but the requests are specific to claims, change orders, and cost overruns that have resulted from subsurface conditions or site characterization practices. We recognize such information may not be readily available. **If the information is not readily available, you can proceed with estimates, or you can submit your responses from the previous pages and exit the survey by selecting the last response to Question 33 below.**

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33. Does your agency keep data related to or that could otherwise be used to identify claims, change orders, and cost overruns that resulted from subsurface conditions or site characterization practices?

- ○ Yes, at least some records are available.
- ○ No, but I can provide reasonable estimates.
- ○ No, and I'm ready to submit my responses from previous pages.

Optional Part Three, cont'd

Page exit logic: Page Logic
IF: Question "If you realize none of the information requested on this page is available, please check the box below and click "Next" at the bottom of this page to skip to the final page of the survey." is one of the following answers ("I don't have the information requested on this page, and I'm ready to submit all previous responses.") **THEN:** Jump to page 11 - Summary of Responses & Submit Button

Questions 34 through 42 relate to quantifying the number and costs of claims, change orders and cost overruns experienced by your agency that have resulted from subsurface conditions or site characterization practices since 2009. Responses to these questions should reflect **only those claims that can be attributed to subsurface conditions or site characterization practices.**

We recognize that both records availability and claims filing processes and definitions vary from agency to agency. Please use the comment field at the bottom of this page to add any explanation, qualification, or clarification to your responses. If only some of the data is readily available, please fill in the appropriate fields and leave the others blank.

If you realize none of the information requested on this page is available, please check the box below and click "Next" at the bottom of this page to skip to the final page of the survey.

- ☐ I don't have the information requested on this page, and I'm ready to submit all previous responses.

34. How many of the claims experienced by your agency had causes that can be attributed to subsurface conditions or site characterization practices?

35. What is the cumulative cost of claims that can be attributed to subsurface conditions or site characterization practices?

36. What is the cumulative total contract cost for projects associated with claims that can be attributed to subsurface conditions or site characterization practices?

37. How many of the change orders issued by your agency had causes that can be attributed to subsurface conditions or site characterization practices?

38. What is the cumulative cost of change orders that can be attributed to subsurface conditions or site characterization practices?

39. What is the cumulative total contract cost for projects associated with change orders that can be attributed to subsurface conditions or site characterization practices?

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40. How many of the projects with cost overruns had causes that can be attributed to subsurface conditions or site characterization practices?

41. What is the cumulative cost of overruns that can be attributed to subsurface conditions or site characterization practices?

42. What is the cumulative total contract cost for projects with cost overruns that can be attributed to subsurface conditions or site characterization practices?

Please use the comment field below to add any explanation, qualification, or clarification to your responses.

Optional Part Three, cont'd

In addition to the cumulative totals of claims, change orders, and cost overruns requested in previous questions, we are also interested in additional information **specific to individual claims, change orders, and cost overruns** that can be attributed to subsurface conditions or site characterization practices, dating back to 2009. A list of the types of information of interest is included below. Please note we are not requesting the data but inquiring about its availability.

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43. Is the type of information requested below readily available?

- Yes
- No
- I don’t know.

LOGIC Hidden unless: Question “Is the type of information requested below readily available?” #43 is one of the following answers (“Yes”,“I don't know.”)

Please enter contact information for the agency contact from whom we can request such information.

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Types of information of interest for individual projects with claims related to subsurface conditions or site characterization practices dating back to 2009:

- Type of project (bridge, roadway, other)
- Project bid cost
- Final project cost
- Project contract arrangement (design-bid-build, design-build, public private partnership, construction manager/general contractor, other)
- Claim filed by prime or sub?
- Project dates (start, end, and date of claim, change order, or overrun)
- Cost of the resolved claim, change order, or overrun
- Brief description of the nature/cause of the claim, change order, or overrun, including the type of geotechnical element
- Any additional, non-subsurface conditions claim, change order, or overruns for the project?
- Cost/magnitude of the subsurface investigation (performed *prior to* claim, change order, or cost overrun)
- Any available subsurface investigation data (e.g., a geotechnical report).
- A point of contact for the project.

Thank You!

Thank you for taking our survey. Your response is very important to us. If you have any questions or comments, please feel free to contact the prinicipal investigator, Andy Boeckmann:

- E-mail: boeckmanna@missouri.edu
- Phone: 573-884-7613
- Mailing Address: Andrew Boeckmann, E2509 Lafferre Hall, Columbia, MO 65211

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APPENDIX B

Survey Responses (Web-Only)

RESPONDING AGENCIES

Agencies responding to the survey are shown in Figure 2 in chapter three. Additional responses were received from the Washington, D.C. DOT and the Central, Eastern, and Western Federal Lands Highway Divisions.

APPENDIX B1—SUMMARY TABLES

Three large summary tables provide the responses to all questions for all respondents. The first table contains responses to Parts One and Two. Responses on this table are coded with numbers corresponding to the relatively lengthy selections from the question response options. The key for these numbers is provided in Appendix B2. This first table is a convenient method for identifying an agency's response to a particular question quickly, or for evaluating all responses to a particular question quickly. The other two tables in Appendix B1 include data from Part Three of the survey.

APPENDIX B2—KEY FOR SUMMARY TABLES WITH RESPONSE COUNTS

APPENDIX B3—RESPONSES TO SHORT ANSWER QUESTIONS

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	Part 1 - Geotech																Part 2 - Construction								
	1	2	3	3b	4	5	5b	6	7	8	9	9b	10	10b	11	12	13	14	15	16	17	18	19	20	21
Agency	Difficulty	Problems	Min Req's?	AASHTO?	Exceed?	State Specific?	Share	Bid Docs?	Geophysics?	Database?	Changes?	Result of Changes?	Incentives?	Result of Incentives?	Sig Problems?	Sig Benefits?	Claims a Problem?	Sources of Concern?	Freq changed?	D-B Effect?	Ground claims allowed?	% Due to Subsurface	Subsurface a Problem?	Subsurf Freq changed?	Susurf D-B Effect?
Alabama	2	2	1	2	3	1	3	1	3	1	2	#N/A	2	#N/A	1	2	2	2 4	5	2	2	2	2	4	2
Alaska	2	2	1	1	4	1	3	1	2	1	2	#N/A	2	#N/A	2	1	2	5	3	2	2	2	2	3	2
Arizona	2	2	1	3	3	1	3	1	2	2	2	#N/A	2	#N/A	2	1	5	5	6	3	2	1	5	6	3
Arkansas	1	2	2	#N/A	4	2	#N/A	1	4	1	2	#N/A	2	#N/A	1	2	2	2 3 4	3	2	2	2	1	3	2
California	2	1	2	#N/A	1	2	#N/A	1	2	1	2	#N/A	2	#N/A	2	3	3	5	6	3	2	1	3	6	3
Colorado	1	2	1	2	4	1	1	1	2	3	1	6	3	#N/A	2	3	5	5	6	3	2	#N/A	5	6	3
Connecticut	1	2	1	2	4	1	3	#N/A	2	1	2	#N/A	2	#N/A	2	2	2		6	3	2	1	1	2	3
DC	2	2	2	#N/A	1	1	1	1	3	2	2	#N/A	2	#N/A	2	2	3	2	4	2	2	2	2	2	2
Delaware	2	1	1	1	3	1	3	1	5	2	2	#N/A	3	#N/A	1	1	5	5	6	3	#N/A	#N/A	#N/A	#N/A	#N/A
FHWA Centra	2	2	1	2	3	1	3	1	1	2	1	6	2	#N/A	2	2	3	2 4	4	2	2	2	3	4	2
FHWA Easter	1	1	1	2	4	1	3	1	1	2	2	#N/A	2	#N/A	2	3	3	2 3	3	2	2	2	2	3	2
FHWA Weste	4	1	1	5	2	2	#N/A	1	2	2	1	6	2	#N/A	1	3	2	5	6	3	2	1	1	6	2
Florida	2	2	1	2	3	1	3	1	3	4	1	5	2	#N/A	#N/A	2	1	1	1	1	2	1	1	3	2
Georgia	1	2	1	2	3	1	3	1	2	1	2	#N/A	2	#N/A	2	2	3	2 3 4	2	2	1	1	1	3	2
Hawaii	2	2	2	#N/A	1	2	#N/A	1	2	3	2	#N/A	2	#N/A	3	2	2	2 4	6	3	#N/A	1	2	6	3
Idaho	2	2	1	4	3	1	3	1	2	4	2	#N/A	1	4	1	2	3	2 3	6	3	2	1	#N/A	6	3
Illinois	1	2	1	4	4	1	3	1	3	3	2	#N/A	2	#N/A	3	2	1	1	3	1	2	2	1	3	1
Indiana	2	2	1	5	3	1	3	1	2	2	1	5	2	#N/A	1	1	3	5	2	3	2	1	2	2	3
Iowa	1	1	1	2	4	1	3	1	3	3	1	3	2	#N/A	2	2	3	2 4	6	3	2	1	1	6	3
Kansas	2	1	1	2	2	1	3	1	2	2	2	#N/A	2	#N/A	2	2	1	3 4	3	3	2	1	3	4	3
Kentucky	4	3	1	2	3	1	3	1	2	1	1	3	2	#N/A	1	3	3	2 3 4	3	3	2	2	3	3	3
Louisiana	1	2	1	1	4	2	#N/A	1	4	1	1	3	2	#N/A	1	1	2	4 5	4	1	2	1	2	4	2
Maine	1	2	1	1	4	1	3	1	2	2	1	6	2	#N/A	2	1	3	2 3 4	3	1	2	3	3	3	1
Maryland	3	2	1	3	3	2	#N/A	1	2	1	2	#N/A	2	#N/A	2	2	2	1	3	2	2	1	1	3	2
Massachusett	2	3	1	2	4	1	3	1	2	3	2	#N/A	2	#N/A	1	3	3	2 3 4	2	2	2	2	3	3	2
Michigan	1	1	1	2	3	1	3	1	3	3	2	#N/A	2	#N/A	1	1	3	2 4	4	3	2	2	1	4	2
Minnesota	2	1	1	3	4	1	3	1	2	1	2	#N/A	2	#N/A	2	3	2	5	1	1	2	1	2	1	1
Mississippi	2	2	1	2	2	2	#N/A	1	2	2	2	#N/A	2	#N/A	1	3	3	2 3 4	6	1	2	2	3	6	1
Missouri	1	1	1	2	3	1	3	1	2	2	1	3	1	1	2	1	1		1	1	2	1	1	3	2
Montana	4	2	1	2	3	1	3	1	2	2	1	4	2	#N/A	2	2	1	1	2	2	2	1	1	2	2
Nebraska	1	1	1	2	3	1	2	1	3	2	1	3	2	#N/A	2	2	3	2 3	6	3	2	1	1	3	3
Nevada	4	2	1	5	3	2	#N/A	1	1	3	2	#N/A	1	1	1	1	3	5	3	1	2	1	3	3	1
New Hampsh	1	1	2	#N/A	1	2	#N/A	#N/A	2	2	2	#N/A	2	#N/A	2	1	1		3	1	2	1	1	3	1
New Jersey	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
New Mexico	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
New York	2	2	1	2	4	1	3	1	2	2	2	#N/A	2	#N/A	1	2	2	5	6	1	2	1	2	6	1
North Carolina	1	1	1	5	3	1	3	1	2	1	1	6	2	#N/A	3	2	2	4	1	2	1	1	1	1	2
North Dakota	1	2	1	1	4	1	3	1	3	2	2	#N/A	2	#N/A	2	2	3	4	5	3	2	2	3	3	3
Ohio	1	1	1	2	4	1	3	1	3	1	2	#N/A	2	#N/A	2	3	#N/A		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Oklahoma	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Oregon	4	2	1	2	3	1	3	1	3	3	1	3	2	#N/A	1	2	2	1 3 4	3	2	2	1	2	3	2
Pennsylvania	1	1	1	3	3	1	1	1	3	2	2	#N/A	1	5	2	1	5		6	3	2	#N/A	3	6	3
Puerto Rico	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Rhode Island	1	2	1	1	2	1	3	1	3	4	2	#N/A	2	#N/A	2	2	4	2 3 4	6	2	2	2	2	6	2
South Carolin	1	2	1	3	4	1	3	1	3	2	1	4	1	1	1	1	3	2 3 4 5	6	1	2	1	3	2	1
South Dakota	1	1	2	#N/A	1	2	#N/A	1	2	3	2	#N/A	2	#N/A	2	2	1	1	3	2	2	1	1	3	2
Tennessee	2	1	2	#N/A	#N/A	1	1	1	3	2	2	#N/A	2	#N/A	2	3	3	4	6	3	2	1	2	2	3
Texas	2	1	1	5	2	2	#N/A	1	3	3	2	#N/A	2	#N/A	1	2	3	2 3 4	6	3	2	1	1	3	3
Utah	2	2	1	1	4	1	2	1	2	3	2	#N/A	2	#N/A	1	2	3	2 4	3	1	2	2	3	3	1
Vermont	2	2	1	2	2	1	3	1	2	1	1	4	2	#N/A	2	1	3	2 4	4	1	2	3	2	4	1
Virginia	1	2	1	2	3	1	3	1	2	1	1	3	1	4	1	3	2	4	3	2	2	1	2	3	1
Washington	2	2	1	2	3	1	3	1	1	1	2	#N/A	1	5	1	1	3	2 3 4	5	1	2	1	1	3	2
West Virginia	1	2	1	2	3	1	3	1	1	2	2	#N/A	2	#N/A	1	2	1	1	6	3	2	1	1	6	3
Wisconsin	2	2	1	5	3	1	2	1	3	1	2	#N/A	2	#N/A	2	2	3	2	2	2	2	3	3	5	2
Wyoming	2	2	1	2	3	1	1	1	2	3	1	4	1	1	1	1	4	2	3	2	2	1	2	3	2

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Part 3 - All Claims, Change Orders, and Cost Overruns

Agency	23 Total Burdget for New Const	24 Total Claims	25 Cumulative Cost of Claims	26 Cumulative Contract Cost for Claims Proj	27 Number of C.O.s	28 Cumulative Cost of C.O.s	29 Cumulative Contract Cost for C.O. Proj	30 Number of Overrun Projects	31 Cumulative Cost of Overruns	32 Cumulative Contract Cost for Overrun Pr
Alabama										
Alaska										
Arizona										
Arkansas	$2,631,998,578	10	$1,403,125.01	$56,219,846.74	5141	$129,409,984.18	$3,983,188,127.09	670	$79,887,955.89	$1,859,489,863.58
California										
Colorado										
Connecticut										
DC										
Delaware										
FHWA Centra										
FHWA Easter	659,503,578.20	11	1,566,256.22	41,505,834.86	751	114,459,911.80	1,126,147,224.63	121	112,484,791.10	607,960,778.10
FHWA Weste										
Florida		?	?	?	31,777	$412,376,072.93	$13,468,849,347.87	1046	$252,510,247.11	$7,751,183,814.81
Georgia	4.25B (+/-)	30 (+/-)	15M (+/-)	250M (+/-)	2100 (+/-)	250M (+/-)	5.5B (+/-)		70M (+/-)	5.4B
Hawaii										
Idaho										
Illinois										
Indiana	2009 -2013....$5,981,384,378; average per year =$1,196,276,875.00	total claim from 2009 -2013 = 13,495; average per year = 2699	total cost from 2009 -2013= $304,812,465; Average per year =$60,962,493.00	2009 -2013....$5,981,384,378; average per year =$1,196,276,875.00	2009 - 2013 = #13,495; average = # 2699 per year	total cost from 2009 -2013= $304,812,465; Average per year =$60,962,493.00	2009 - 2013 cost = $5,981,384,375.00	not availble	total cost from 2009 -2013= $304,812,465; Average per year =$60,962,493.00	not availble
Iowa										
Kansas										
Kentucky										
Louisiana										
Maine										
Maryland	$2,463,368,000	?	?	?	?	127068000	?	?	?	?
Massachuset		377	$62,447,370							
Michigan										
Minnesota										
Mississippi										
Missouri	4.8 billion	4	958000	9553000	9582	25275000	6 billion	945	164000000	3263000000000
Montana										
Nebraska										
Nevada										
New Hampsh		ns from FY2009 (inclusive) throu			84 from FY 2009 through 11/24/2					
New Jersey	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
New Mexico	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
New York										
North Carolin										
North Dakota										
Ohio										
Oklahoma	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Oregon	$4,637,526,502	288	$41,122,109	$724,534,540	7,129	$303,857,082	$4,637,526,502	370	$351,898,292	$2,152,902,786
Pennsylvania										
Puerto Rico	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Rhode Island										
South Carolin										
South Dakota	+/- $325Million per year	9	+/- $1.65 Million	Not Available	3,649	$34.3 Million	Not available	Not available	not available	not available
Tennessee										
Texas										
Utah										
Vermont										
Virginia										
Washington										
West Virginia	850 million	na	na	na	na	na	na	na	na	na
Wisconsin										
Wyoming										

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Part 3 - Subsurface Claims, Change Orders, and Cost Overruns

	34	35	36	37	38	39	40	41	42
Agency	Total Claims	Cumulative Cost of Claims	Cumulative Contract Cost for Claims Proj	Number of C.O.s	Cumulative Cost of C.O.s	Cumulative Contract Cost for C.O. Proj	Number of Overrun Projects	Cumulative Cost of Overruns	Cumulative Contract Cost for Overrun Pr
Alabama									
Alaska									
Arizona									
Arkansas									
California									
Colorado									
Connecticut									
DC									
Delaware									
FHWA Centra									
FHWA Easter	1	466,923.55	7,967,260.26	28	4,825,993.56	72,751,278.79	15	1,556,037.43	48,031,061.35
FHWA Weste									
Florida									
Georgia	0	0	0	210 (+/-)	10M	5.4B	105	5M	600M
Hawaii									
Idaho									
Illinois									
Indiana	2009-2013= 625; average 125 per year	2009 - 2013= $51,719,015	2009 - 2013 = $2,924,330,145.00	@009 - 2013= 625 NOS.	2009 - 2013= $51,719,015	2009 - 2013 = $2,924,330,145.00	not availble	2009 - 2013= $51,719,015	2009 - 2013 = $2,924,330,145.00
Iowa									
Kansas									
Kentucky									
Louisiana									
Maine									
Maryland	?	?	?	34	$7,577,000	?	?	?	?
Massachuset	39	$4,325,214							
Michigan									
Minnesota									
Mississippi									
Missouri									
Montana									
Nebraska									
Nevada									
New Hampsh									
New Jersey	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
New Mexico	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
New York									
North Carolin									
North Dakota									
Ohio									
Oklahoma	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Oregon	Not available	Not available	Not available	246	$10,949,562	$1,494,574,813	Not available	Not available	Not available
Pennsylvania									
Puerto Rico	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Rhode Island									
South Carolin									
South Dakota	0 since 2009.	0	0	Not available	not available	not available	not availabel	not available	not available
Tennessee									
Texas									
Utah									
Vermont									
Virginia									
Washington									
West Virginia	na	na	na	na	na	na	na	na	na
Wisconsin									
Wyoming									

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APPENDIX B2—KEY FOR SUMMARY TABLES WITH RESPONSE COUNTS

Tables for each question of Parts One and Two are presented. The tables are similar to the ones presented throughout chapter three of the Synthesis. The number "code" from Appendix B1 is listed with the accompanying question selection.

Question 1

Please select the response that best describes your agency's experience with site characterization:	**Key**	**Number of Responses**	
Site characterization is generally not difficult.	1	22	43%
Site characterization is often difficult because of highly variable subsurface conditions.	2	23	45%
Site characterization is often difficult because select types of soil/rock are difficult to characterize.	3	1	2%
Site characterization is often difficult because of highly variable subsurface conditions AND select types of soil/rock that are difficult to characterize.	4	5	10%

Question 2

Please select the response that best describes the design, construction, and performance problems your agency has experienced as a result of subsurface conditions:	**Key**	**Number of Responses**	
My agency experiences relatively few design, construction, and performance problems resulting from subsurface conditions.	1	17	33%
My agency experiences a modest number of design, construction, and performance problems resulting from subsurface conditions.	2	32	63%
My agency experiences frequent design, construction, and performance problems resulting from subsurface conditions.	3	2	4%

Question 3

Does your agency formally specify minimum (or recommended minimum) subsurface investigation requirements for all projects?	**Key**	**Number of Responses**	
Yes	1	44	86%
No	2	7	14%
I don't know.	3	0	0%

Question 3b

If yes, please select the item below that best describes the minimum requirements:	**Key**	**Number of Responses**	
The minimum requirements are those prescribed in AASHTO specifications and guidelines.	1	7	16%
The minimum requirements are documented in agency-specific provisions, but are generally consistent with those prescribed in AASHTO specifications and guidelines.	2	28	64%
The minimum requirements are documented in agency-specific provisions, but substantially exceed those prescribed in AASHTO specifications and guidelines.	3	5	11%
The minimum requirements are documented in agency-specific provisions, but are materially different from those prescribed in AASHTO specifications and guidelines (e.g., involve different techniques and procedures than are addressed in AASHTO specifications	4	3	7%
Other, please specify:	5	0	0%
The general minimum requirements are documented in agency specific publications, but are generally less stringent than those prescribed in AASHTO specifications and guidelines.	6	1	2%

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Question			**4**
If minimum subsurface investigation requirements are formally specified, is it common for the actual scope of subsurface investigations to exceed the minimum requirements for specific projects?	**Key**	**Number of Responses**	
Minimum requirements are not formally specified.	1	0	0%
Yes, the scope for subsurface investigations commonly exceeds the minimum requirements.	2	6	14%
Yes, the scope for subsurface investigations occasionally exceeds the minimum requirements.	3	23	52%
No, the scope of subsurface investigations rarely exceeds the minimum requirements.	4	15	34%
I don't know.	5	0	0%

Question			**5**
Does your agency have a "state-specific" manual and/or specifications that describe requirements and practices for site characterization?	**Key**	**Number of Responses**	
Yes	1	40	78%
No	2	11	22%
I don't know.	3	0	0%

Question			**5b**
If yes, please provide a link(s) to an online version of the manual or specifications, or upload the document(s) as an attachment below.	**Key**	**Number of Responses**	
Manual is not available for sharing.	1	5	13%
Upload the document(s)	2	3	8%
Link to the document(s):	3	32	80%

Question			**6**
Does your agency require geotechnical information be included with bid documents for bridge projects?	**Key**	**Number of Responses**	
Yes	1	49	100%
No	2	0	0%
I don't know.	3	0	0%

Question			**7**
Select the answer that best describes your agencies historical use of geophysical measurements for site characterization:	**Key**	**Number of Responses**	
My agency routinely uses geophysical methods for site characterization.	1	5	10%
My agency occasionally uses geophysical methods for site characterization.	2	27	53%
My agency rarely uses geophysical methods for site characterization.	3	16	31%
My agency never uses geophysical methods for site characterization.	4	2	4%
I don't know.	5	1	2%

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Question 8

Does your agency maintain a database of subsurface information? Select the response that best describes your agency capabilities.	**Key**	**Number of Responses**	
Yes, my agency maintains a GIS-based database of subsurface information.	1	16	31%
Yes, my agency maintains an electronic database of subsurface information, but the database is not GIS-based.	2	20	39%
No, my agency does not maintain a database of subsurface information, but we do retain hard copy records from past projects that can be accessed when needed.	3	12	24%
No, my agency does not maintain a database of subsurface information, and it is difficult to access historical records of subsurface information.	4	3	6%
I don't know.	5	0	0%

Question 9

Has your agency implemented specific changes to site characterization practices in the last five years?	**Key**	**Number of Responses**	
Yes	1	18	35%
No	2	33	65%
I don't know.	3	0	0%

Question 9b

Please select the statement below that best describes the perceived impact of the specific changes in terms of the number of claims, change orders, and overruns.	**Key**	**Number of Responses**	
The changes have led to a noticeable increase in the occurrence of claims, change orders, and overruns.	1	0	0%
The changes have led to a marginal increase in the occurrence of claims, change orders, and overruns.	2	0	0%
The changes have not noticeably affected the occurrence of claims, change orders, and overruns.	3	7	39%
The changes have led to a marginal decrease in the occurrence of claims, change orders, and overruns.	4	4	22%
The changes have led to a noticeable decrease in the occurrence of claims, change orders, and overruns.	5	2	11%
Insufficient experience to respond.	6	5	28%
I don't know.	7	0	0%

Question 10

Are there provisions in your agency's design code that provide incentives for performing site characterization in excess of the minimum requirements or for performing specific site characterization activities? Example incentives might include permitting use of more advantageous load or resistance factors for projects with more extensive site investigations or for relaxation of some site characterization requirements if special techniques or procedures are used (e.g., geophysics).	**Key**	**Number of Responses**	
Yes	1	8	16%
No	2	41	80%
I don't know.	3	2	4%

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Question			**10b**
Please select the statement below that best describes the perceived success of the practice in reducing the number of claims, change orders, and overruns.	**Key**	**Number of Responses**	
Practice has not noticeably affected the occurrence of claims, change orders, and overruns.	1	4	50%
Practice has produced marginal reduction in the occurrence of claims, change orders, and overruns.	2	0	0%
Practice has produced substantial reduction in the occurrence of claims, change orders, and overruns.	3	0	0%
Insufficient experience to respond.	4	2	25%
I don’t know.	5	2	25%

Question			**11**
Has your agency experienced significant performance problems that can be attributed to subsurface conditions or site characterization practices? Performance problems can be related to design issues, QA/QC issues, or any issue that can be attributed to subsurface conditions or site characterization practices.	**Key**	**Number of Responses**	
Yes	1	21	42%
No	2	26	52%
I don’t know.	3	3	6%

Question			**12**
Does your agency have notable examples where site characterization practices have led to accelerated project delivery or reduced costs for construction and operation of transportation facilities?	**Key**	**Number of Responses**	
Yes	1	15	29%
No	2	25	49%
I don’t know.	3	11	22%

Question			**13**
Are claims, change orders, and cost overruns considered to be a significant concern within your agency?	**Key**	**Number of Responses**	
No, they are not considered to be a significant problem.	1	8	16%
They are recognized as a problem, but they are not a priority concern.	2	13	26%
They are recognized as a problem and are a priority concern.	3	23	46%
They are recognized as one of our agency’s most significant problems.	4	2	4%
I don’t know.	5	4	8%

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Question 14

If claims, change orders, and cost overruns are a recognized problem within your agency, what is the primary source of concern regarding the claims, change orders, and cost overruns? Please select all that apply.	**Key**	**Number of Responses**	
They are not a recognized problem.	1	7	14%
They significantly impact the agency budget.	2	23	46%
They significantly impact public perception of the agency.	3	15	30%
They significantly impact time allocation of agency resources, resulting in opportunity losses.	4	24	48%
Other	5	12	24%

Question 15

Has the magnitude and/or frequency of claims, change orders, and overruns changed over the past 10 years?	**Key**	**Number of Responses**	
Yes, the magnitude and/or frequency has decreased significantly.	1	4	8%
Yes, the magnitude and/or frequency has decreased slightly.	2	5	10%
No, the magnitude and/or frequency has remained about the same.	3	15	30%
Yes, the magnitude and/or frequency has increased slightly.	4	5	10%
Yes, the magnitude and/or frequency has increased significantly.	5	3	6%
I don’t know.	6	18	36%

Question 16

Is project delivery mechanism (design-bid-build, design-build, public-private partnership, construction manager/general contractor) perceived to have a significant effect on the incidence or magnitude of claims, change orders, and/or cost overruns? Note this refers to all claims, not just those that could be attributed to subsurface conditions.	**Key**	**Number of Responses**	
Yes	1	14	28%
No	2	17	34%
I don't know.	3	19	38%

Question 17

Are contractors prevented from filing claims against your agency based on changed conditions related to ground conditions or based on unforeseen subsurface conditions?	**Key**	**Number of Responses**	
Yes	1	2	4%
No	2	46	96%

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Question			**18**
What percentage of claims, change orders, and cost overruns experienced by your agency can be attributed to subsurface conditions or site characterization practices? Please estimate or calculate the percentage of such claims, change orders, and cost overruns by number (i.e., quantity or frequency), not cost.	**Key**	**Number of Responses**	
Less than 20 percent.	1	30	64%
20 to 40 percent.	2	14	30%
40 to 60 percent.	3	3	6%
60 to 80 percent.	4	0	0%
Greater than 80 percent.	5	0	0%

Question			**19**
Are claims, change orders, and overruns resulting from subsurface conditions or site characterization practices considered to be a significant concern within your agency?	**Key**	**Number of Responses**	
No, they are not considered to be a significant problem.	1	18	38%
They are recognized as a problem, but they are not a priority concern.	2	15	31%
They are recognized as a problem and are a priority concern.	3	13	27%
They are recognized as one of our agency's most significant problems.	4	0	0%
I don't know.	5	2	4%

Question			**20**
Has the magnitude and/or frequency of claims, change orders, and overruns that can be attributed to subsurface conditions or site characterization practices changed over the past 10 years?	**Key**	**Number of Responses**	
Yes, the magnitude and/or frequency has decreased significantly.	1	2	4%
Yes, the magnitude and/or frequency has decreased slightly.	2	6	12%
No, the magnitude and/or frequency has remained about the same.	3	22	45%
Yes, the magnitude and/or frequency has increased slightly.	4	6	12%
Yes, the magnitude and/or frequency has increased significantly.	5	1	2%
I don't know.	6	12	24%

Question			**21**
Is project delivery mechanism (design-bid-build, design-build, public-private partnership, construction manager/general contractor) perceived to have a significant effect on the incidence or magnitude of claims, change orders, and/or cost overruns that can be attributed to subsurface conditions or site characterization practices?	**Key**	**Number of Responses**	
Yes	1	11	22%
No	2	22	45%
I don't know.	3	16	33%

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APPENDIX B3—RESPONSES TO SHORT ANSWER QUESTIONS

Some responses to the short answer questions were quite long, so the responses to all short answer questions are presented in their own section of the appendix.

3. Other (Please select the item below that best describes the minimum requirements)

Indiana	INDOT Geotechnical Manual consistent with FHWA & AASHTO
Texas	Frequency of sampling is similar to AASHTO guidelines, Texas primiarially uses the Texas Cone Penetrometer insitu test for assessing the strength of the profile. This is supplemented as needed with conventional sampling and laboratory testing.
Nevada	FHWA Manuals plus AASHTO design specifications
North Carolina	NCDOT guidelines (Manual)
Wisconsin	The general minimum requirements are documented in angency-specific publications, but are generally less stringent that those prescribed in AASHTO specs and guidelines.
FHWA Western Federal Lands	Federal Lands Highway Project Development and Design Manual (PDDM) Chapter 6 and Technical Guidance Manual (TGM)

3. Please briefly describe unique agency practices (Please select the item below that best describes the minimum requirements)

Illinois	We provide slightly less than AASHTO but provide a field unconfined compressive strength. our biggest problem is getting the boring at the substructure location due to traffic and rig access.

5. Link to "state-specific" manual and/or specifications:

Alabama	http://www.dot.state.al.us/mtweb/Testing/testing_manual/doc/pro/ALDOT398.pdf
Alaska	http://www.dot.state.ak.us/stwddes/dcspubs/index.shtml#
Arizona	http://azdot.gov/business/engineering-and-construction/MaterialsGroup
Colorado	Manual is not available for sharing.
Connecticut	http://www.ct.gov/dot/lib/dot/documents/dpublications/gtman_3-05.pdf#42832
DC	Manual is not available for sharing.
Delaware	http://www.deldot.gov/information/pubs_forms/manuals/bridge_design/pdf/bdm-06-substructure-design.pdf
FHWA Central Federal Lands	PDDM-TGM (search)
FHWA Eastern Federal Lands	http://flh.fhwa.dot.gov/resources/manuals/pddm/
Florida	http://www.dot.state.fl.us/structures/Manuals/SFH.pdf
Georgia	http://www.dot.ga.gov/PS/DesignManuals/DesignGuides
Idaho	http://itdportal/sites/DES/Materials%20Construction/Manuals/Materials%20Manual/Materials%20Manual%20Printable-%20July%202011.pdf
Illinois	http://idot.illinois.gov/Assets/uploads/files/Doing-Business/Manuals-Guides-&-Handbooks/Highways/Bridges/Geotechnical/Geotechnical%20Manual.pdf
Indiana	http://www.in.gov/indot/files/GTS_2010GTSManual_2012.pdf
Iowa	http://www.iowadot.gov/design/dmanual/manual.html?reload
Kansas	on kdot website
Kentucky	http://transportation.ky.gov/Organizational-Resources/Policy%20Manuals%20Library/Geotechnical.pdf
Maine	http://www.maine.gov/mdot/technicalpubs/bdg.htm
Massachusetts	The massdot bridge manual edition 1.2 is available on the massdot website. A massdot geotechnical manual is currently a working draft and not available online but chapter 5 can be shared.
Michigan	http://www.michigan.gov/documents/GeotechnicalInvestigationsAnalysis_116819_7.pdf
Minnesota	http://www.dot.state.mn.us/materials/geotmanual.html
Missouri	http://epg.modot.org/index.php?title=Category:321_Geotechnical_Engineering
Montana	http://mdtinfo.mdt.mt.gov/mdt/manuals.shtml
Nebraska	**Uploaded manual.**
New York	https://www.dot.ny.gov/divisions/engineering/technical-services/geotechnical-engineering-bureau/gdm
North Carolina	https://connect.ncdot.gov/resources/Geological/Documents/08-04-04_Subsurface%20Investigations%20Manual.pdf
North Dakota	http://www.dot.nd.gov/manuals/design/designmanual/chapter7/DM-07_tag.pdf
Ohio	http://www.dot.state.oh.us/Divisions/Engineering/Geotechnical/Pages/SGE.aspx
Oregon	http://www.oregon.gov/ODOT/HWY/GEOENVIRONMENTAL/pages/geotechnical_design_manual.aspx
Pennsylvania	Manual is not available for sharing.
Rhode Island	http://www.dot.ri.gov/documents/about/research/Geotechnical.pdf
South Carolina	http://www.scdot.org/doing/structural_Geotechnical.aspx
Tennessee	Manual is not available for sharing.
Utah	**Uploaded manual.**
Vermont	http://vtransengineering.vermont.gov/sites/aot_program_development/files/documents/materialsandresearch/MandRSoilEI_11-01_VTrans_Subsurface_Investigation_Process.pdf
Virginia	http://www.virginiadot.org/business/resources/bu-mat-moi-3.pdf
West Virginia	http://www.transportation.wv.gov/highways/engineering/files/WVBDML%202006.pdf
Wisconsin	**Selected "Upload manual", but I don't see it?**
Wyoming	Manual is not available for sharing.

5. Please briefly describe any differences in practices or requirements for site characterization relative to those prescribed in the AASHTO LRFD Bridge Design Specifications.

California	Based on my experience we perform similar practices for site characterization as perscribed in the AASHTO LRFD BDS.
FHWA Western Federal Lands	Geologic site interpretation is a key component in evaluating the type and frequency of the subsurface characterization program. We investigate for many more wall structures than for bridge structures.
Louisiana	Two exploration points are now commonly prescribed for bridges ~100' long as opposed to only one.
Mississippi	GEC 5, TMD20-14
Nevada	If FHWA Manuals requirements exceed AASHTO's, we generally use FHWA requirements.
Texas	See above under question 3.

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6. Please describe the geotechnical information required to be included with bridge project bid documents.

Alabama	Boring logs are always included in the plans and the contractor is given notice that they can request a copy of the foundation report from our office. In a few rare instances, the report has been included in the contract documents.
Alaska	Boring logs are attached to the bridge drawings and sealed by the State Foundation Engineer. Foundation Geology Report is made available to bidders.
Arizona	Geotechnical Foundation Report Geotechnical Data Report
Arkansas	Report
California	Boring Records Log of Test Borings Laboratory test data Down hole geophysical data Rock cores
Colorado	Reviewed, accepted, and PE stamped geotechnical report.
DC	-Boring logs -Soil characteristics/classification -Soil tests -Dewatering plan
Delaware	borings log and GWT
FHWA Central Federal Lands	Bridge Foundations reports that include boring information and seismic information in high seismic areas.
FHWA Eastern Federal Lands	Boring logs and a subsurface profile is included in the bridge plans. A geotechnical engineering report is included in the bid package as information to bidders.
FHWA Western Federal Lands	Physical data includes all geotechnical reports and memoranda written and compiled for each project. The reports/memos contain the description of the surface and subsurface investigations, the results of the investigations, interpretation/characterization of subsurface materials and conditions including geologic interpretation and mapping, laboratory test results and interpretations of soil and rock tests, evaluation of hazards (geologic hazards including geochemical such as acid rock drainage and asbestos (typically of greatest concern for mass rock excavation and utilization in grading projecs but possible consideration for bridge projects)), seismic analysis, site specific geologic and geotechnical construction considerations, FLMA/partner agency restrictions and requirements
Florida	Cone sounding, test boring and lab testing results; muck probe results, foundation requirements, shallow foundation size and bearing elevation, deep foundation type and minimum tip elevation, required bearing resistance.
Georgia	Bridge Foundation Investigations and soils reports for info only
Hawaii	Boring informaion and reference to the geotechnical report are included in the project plans.
Idaho	Boring logs, descriptions of subsurface condition, field test results, any subsurface condition that may cause problems during construction.
Illinois	just boring logs and rock cores
Indiana	Geotechnical Report as well as a table showing loading conditions and pile driving criteria for each support.
Iowa	Subsurface soil profile sheets that depict all borings performed.
Kansas	all geotechnical reports and design memos
Kentucky	Subsurface Data Sheets which contain laboratory test data & soil classifications and SPT blow counts & CPT data (when applicable)
Louisiana	Boring log data which includes location, soil classification, Atterberg Limits, moisture content, unit weight, SPT value/UU strength value, %passing #200
Maine	Project-specific Geotechnical Design Reports for highway and bridge projects are posted as PDF's on our agency's website along with the bid documents.
Maryland	Boring and Drive Tests Sheets are part of the bid plans that present the soil description and SPT information and if rock is encountered, recovery, a rock classifcation, and RQD is supplied. plan sheets
Massachusetts	Boring, test pit and probe logs are on all plan sets. Geotechnical Reports are provided/refrenced bid docs. Deep foundation testing are routinely performed during construction but requirements specified on plans.
Michigan	Soil boring logs, field testing and laboratory testing is included in the bid documents (all factual information).
Minnesota	Abbreviated boring logs plotted on bridge survey sheets.
Mississippi	Geotechnical report for subject bridge.
Missouri	Boring logs
Montana	we include the boring logs for all projects where a subsurface investigation occurs
Nebraska	Boring Logs and estimated pile lengths and bearing capacity are provided on the bridge plans
Nevada	Boring logs are also included on the plans, and geotechnical report is available on line and reference by the Special Provisions and the General Notes on the plans.
New York	Any and all geotechnical information used in the design of the bridge project. Boring logs, laboratory testing, and any other factual information.
North Carolina	We include with the bid documents for information purposes only. They are not part of the bid document.
North Dakota	Boring Logs
Ohio	Required information is outlined in our Specifications for Geotechnical Explorations, linked in question 5.b above
Oregon	Geotech logs in bid plans, reference to geotech reports in bid plans
Pennsylvania	Plotted Test Boring Logs are a part of the Structure Plans. Geotechnical design parameters (soil or rock) used for design. Temporary excavation support parameters. Soil profile plans and applicable geologic cross sections are provided on large projects or projects with complicated geologic conditions.
Rhode Island	The Geotechnical Data Report is included with the bid documents
South Carolina	Geotechnical Data Report
South Dakota	Subsurface sheet detailing site characteristics.
Tennessee	Project Geotechnical Report and all related Special Provisions.
Texas	Soil borings, TCP penetration tests, soil description, water suface elevation, critical laboratory test results.
Utah	Soil Data Sheets, Lab Data for DB projects, pile driving requirements, minimum driving resistance, minimum hammer energy
Vermont	Boring logs and locations are shown ont he plan sheets. Geotechnical engineering reports are included in the contract documents on more complex bridge and roadway projects. Geotechnical data reports with design criteria are included in the contract documents for projects with large mast arm and sign support foundations.
Virginia	Boring logs are nailed to the bid documents. Geotechnical report for information only and available upon request.
Wisconsin	A graphic representation of the borings are included in the bridge plan. The Geotech report is NOT included.
Wyoming	* Geotech report and table summarizing recommendations for footings, piling and drilled shafts * Log boring sheet plan view and section summarizing the site and drill holes

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9. Has your agency implemented specific changes to site characterization practices in the last five years?

Colorado	Using new drilling techniques to obtain core for strength testing and description. Producing a manual of practice for guidance.
FHWA Central Federal Lands	Developed new soil and rock characterization manual for CFL.
FHWA Western Federal Lands	Upgraded the seismic analysis for bridge foundations. Added direct shear test apparatus to our internal lab testing capabilities. Developed standard description guidelines for soils and rocks. Introduced use of Lidar imagary as standard practice. Currently actively progressing with development of GIS database for site evaluation and investigation data.
Florida	Increase frequency of borings for highly variable sites, berform borings at every drilled shaft when nonredundant, require surveyor location of bridge borings & hand-held GPS location of roadway & pond borings, require borings for deep foundations to extend well below anticipated tip elevations
Indiana	LRFD based design, cut down the spacing of borings, introduced new lab & field testing, eliminated the use of nuclear gauge for compaction testing, increased the use of CPT testing, use of DCPT & LWD testing for compaction control, used intelligent compaction on several projects, increase the use of chemical modification of foundation & subgrade soils etc.
Iowa	Number of borings and boring depths were adjusted to be more compatible with LRFD-substructure guidelines.
Kentucky	More use of CPT.
Louisiana	gINT electronic data is now a deliverable upon completion of exploration SPT Hammer energy is measured and reported SPT standard is being enforced, not allowing the test to end with premature blows as had been the case.
Maine	For high risk geotechnical sites a supplemental QA check has been implemented to assure adequate exploration and design analyses are conducted.
Missouri	MoDOT collects and runs more soil strength and rock core tests to conform with recommendations from University of Missouri study on LRFD resistance factors.
Montana	we use more in-situ methods, geophysical, and the SPT is not relied on as much as it used to be
Nebraska	Have added use of cpt.
North Carolina	We are in the process of increase using CPT and more soil testing.
Oregon	greater care in landsldie prone areas
South Carolina	Greatly increased with the implementation of LRFD, seismic, and our new design manual
Vermont	We now take borings on all roadway projects whenever a reclaimation alternative is being considered.
Virginia	re-issued the geotechnical engieering manual of instructions (see provided link).
Wyoming	We have increased the amount of insitu testing and sampling for bridges, landslides and some roadway investigations.

10. Briefly describe provisions (Are there provisions in your agency's design code that provide incentives for performing site characterization in excess of the minimum requirements or for performing specific site characterization activities?)

Idaho	Reduce required number of test hole if geophysic tests are performed.
Missouri	Use results from University of Missouri LRFD study.
Nevada	AASHTO LRFD Design Specifications
Pennsylvania	Higher resistance factors (0.55 vs 0.45 for spread footing on soil) and lower factors of safety (1.3 vs 1.5 for global slope stability) are permitted for better site characterization.
South Carolina	We allow them but by approval. Typically our minimums are very substantial to begin with. They are in our manual.
Virginia	enhanced strength data beyond SPT n-value will allow the use of greater strength (or lower safety factor) in design. In-situ testing can be used in lieu of up to 50 percent conventional borings.
Wyoming	* A database of laboratory and field testing data for soil and bedrock is maintained * A database of PDA and WEAP and design data is maintained for Bridges * (These data records are in progress)

10. Link to provisions (Are there provisions in your agency's design code that provide incentives for performing site characterization in excess of the minimum requirements or for performing specific site characterization activities?)

Idaho	Provisions are not available for sharing.
Missouri	http://epg.modot.org/index.php?title=751.37_Drilled_Shafts
Pennsylvania	ftp://ftp.dot.state.pa.us/public/PubsForms/Publications/PUB%2015M.pdf
South Carolina	http://www.scdot.org/doing/structural_Geotechnical.aspx
Virginia	http://www.virginiadot.org/business/resources/bu-mat-moi-3.pdf
Wyoming	Provisions are not available for sharing.

10. When were provisions established? (Are there provisions in your agency's design code that provide incentives for performing site characterization in excess of the minimum requirements or for performing specific site characterization activities?)

Missouri	approximately 4 to 5 yrs ago
Nevada	Long standing practice as code allowed.
Pennsylvania	I don't know.
South Carolina	2008
Virginia	2012
Wyoming	2009

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11. Has your agency experienced significant performance problems that can be attributed to subsurface conditions or site characterization practices?

Alabama	Before letting a project, the geotechnical section was not provided the time required to perform a thorough geotechnical investigation and once the project was let, significant problems in the subsurface were found at a significant expense to the state.
Arkansas	We have had significant issues with unstable cut slopes.
Delaware	may be at the bridge design
FHWA Western Federal Lands	Primarily the identification of the extent of weak subgrade soils that require subexcavation during construction. Project Managers are reluctant to agree to the Preliminary Engineering expense of extensive ennough subgrade investigations to accurately delineate the length, width, and depth of weak subgrade soils. Lack of detail often results in contract change orders, usually to increase the amount of subexcavation
Idaho	Significant settlements of bridge approach embankments due to existence of soft, organic soils.
Indiana	poor subgrade soils, compaction, and poor drainage etc.
Kentucky	Pile Overruns, Subgrade Problems, Long-Term Slope Stability Problems, Shale Breaking Down in Embankments
Louisiana	Single borings on 100' bridges have been standard practice for many years. With the switch to LRFD methods our design group requested that an additional boring be taken to bound the bridge site to reduce the risk of driving piles in unknown site conditions
Massachusetts	Obstructions. lack of anticipated capacity or ease of perceived drilling conditions. greater than anticipated capacity or difficult perceived drilling conditions. constructability issues associated with ground known or unknown subsurface or substructure conditions.
Michigan	Slope stability issues in existing slopes and constructed slopes.
Mississippi	Lack of adequate boring information has resulted in excess overexcavation, unexpected rock excavation, etc.
Nevada	Unanticipated soft subgrade conditions Caliche Boulders Caving soils
New York	Unknown underground conditions always affect the performance of projects.
Oregon	Landslide failures, unanticiapted
South Carolina	The manual was an attempt to reduce these.
Texas	Misscharacterization of the soil profile. This resulted in the need for additional soil borings, redesign and delays to the project schedule.
Utah	On DB projects, inadequate characterization of liquefaction, lateral spread and seismic slope instability.
Virginia	Depending on whom you ask, the answer is either yes or no. . . I (Carl Benson) will say yes. The performance problem that I see relates to whether the boring log correctly conveys the nature of the subsurface conditions. Consider two cases, the presence of voids and the depth to unscourable rock. Regarding the former, if a driller is committed to coring runs that are equal to the length of the core barrel, a simple block-off of water pressure half-way through the run could easily result in ground-up rock core and loss of recovery. Often we'll see water loss in limestone at some depth that corresponds to low recovery. Such water loss is often considered a void. Then at a lower depth, we'll see another interval of water loss, which would seem to negate the presence of the upper void. Regarding the latter matter of scour, I'll offer the following: HEC-18 seems to imply that RQD >50 is non-scourable. Well, in typical geotechnical exploration for earthwork and grading, we are reluctant to put on the core barrel until we have auger refusal. Is that the best approach for scour evaluation? It is quite likely that we should put on the core barrel at the first opportunity (i.e., residuum with 60/6" or such). If we auger grind rock at abutments, we'd never know whether an otherwise excavatable rock is prone to scour.
West Virginia	
Wyoming	We have good success in characterizing soil and bedrock conditions for surfacing sources, structures and landslide and rockfall designs. We have had some issues in predicting soft soil improvement and rock excavation which can vary depending on weather and contractor issues.

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12. Does your agency have notable examples where site characterization practices have led to accelerated project delivery or reduced costs for construction and operation of transportation facilities?

Alaska	Brotherhood Bridge Widening, in Juneau, Alaska. Deep soil borings and advanced liquefaction analysis resulted in a reduction
Arizona	ADOT projects No H8479, H8480 We have completed geotechnical investigation and recommendations before the design stage, thus expedidited the project schedule and potentially identified significant cost savings for construction.
Delaware	use CPT and SPT
Indiana	Performing more borings upfront (CPT &SPT)to better describe the site conditions and the utilization of chemical modification for the treatment of poor & wet foundation and pavement subgrade soils has significantly reduce the time for construction.
Louisiana	Data for our Interstate Median Cable Barrier Projects have been primarily CPT data, which is a economical and rapid test compared to a conventional boring. Cost savings for these are estimated to be ~40% compared to conventional borings of equal depth. This cost savings is increased when accomplishing the task with in-house crews versus consultants. We have several large projects that are either design-build or have been paid for by a private entity(casino) that have used a mixture of full-depth borings and CPT to characterize the site, which has reduced the amount of cost and field time for geotech exploration. These are the I-49 Ambassador Caffery Interchange, I-49 LA 318 Interchange, and the I-220 Cove lane Interchange.
Maine	Comprehensive geotechnical investigations and supplemental boring programs based on requests of proposers have allowed accelerated project delivery using the design-build project delivery method.
Michigan	All Design-Build project in MDOT that the majority of the geotechnical investigations done prior to advertising the project. This reduces unknowns, reduces cost and shortens the project time line since there is usually significant time and cost associated with drilling, sampling and testing.
Missouri	performed Geotechnical baseline borings and report for design-build project for the final phase of the Route 364 extension in St. Charles Co in Missouri.
Nevada	Moana I 580 Interchange. $2 million savings. This was a CMAR project. CMAR provided the means to discuss potential risks with contractor and perform additional investigation to reduce risks. Another example is the use of O cell testing to reduce the size of drilled shafts for the proposed CC 215/US 95 Interchange, resulting in a $4 million cost saving.
New Hampshire	Geophysics were proved to save money on projects where less explorations were required. Additionally down hole televiewer has aided significantly in the rock characterization for the design of bridge foundations.
Pennsylvania	I cannot estimate magnitude however we have spent millions of extra dollars on construction in karst in the past and now with a combination of site charactization techniques (many borings, groundwater monitoring and geophysics) our projects go without significant unexpected conditions.
South Carolina	We do not track
Wyoming	Efficient and effective geotechnical practices and experienced personnel generally result in a reduction in cost overruns, change of conditions and claims for many projects, i.e., all types of structures, surfacing sources and landslide and rockfall designs. The Geology Program uses an accelerated project delivery procedure for letting emergency landslide and similar projects.
Vermont	Early charaterization of the foundation support conditions helps in the decision process to reuse existing foundations. When exisiting foundations can be reused, project delivery is accelerated and a savings of up to 40% of the project cost can be realized.

14. Other (If claims, change orders, and cost overruns are a recognized problem within your agency, what is the primary source of concern regarding the claims, change orders, and cost overruns?)

Alaska	They have a potential to significantly impact the budget but have not in recent history.
Arizona	I don't know
California	Claims and change orders in my experience do not regularly delay projects, but the claims process after a project is complete can continue for years.
Colorado	Don't know
Delaware	I don't know
FHWA Western Federal Lands	Increased costs during construction mean that the owner agency needs to provide additional matching funds under the current funding legislation for Federal Lands projects.
Indiana	Budget and time delays during construction
Louisiana	Some change orders violate the designer's intent and should require the Project Engineer who makes the change to re-stamp the plan change - If we are even notified about the change at all.
Minnesota	Project Budget and most important impact to the critical path on a project.
Nevada	They significantly impact project budgets and schedules.
New York	They create changes that affect the stability and budgeting for the Capital Program.
South Carolina	time of construction,delays

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16. Design-build (all claims): Please explain the perceived effect.

Florida	With the delivery mechanisms noted, the liability of discovery and corrective action falls solely on the Contractor.
Illinois	claims will be reduced
Louisiana	DB is perceived to have fewer claims than DBB due to more communication regarding specifications and procedures and what is allowable and what is not.
Maine	The perception is that design-build and CMGC contracting methods reduce claims, change orders and cost overruns. While our agency has completed several design-build contracts, we are just now embarking on the first significant CMGC contract.
Minnesota	contract overages due to claims, changes order and overruns are less on design build projects than on bid build projects. Also, it is apparent that the contractors conduct themselves differently on design build projects vs bid build pertaining to the way that they mitigate delays.
Mississippi	It isn't a perceived effect. Each delivery method comes with its own probability and cost for overruns, claims, and change orders.
Missouri	For design-build projects MoDOT has a team that works with the DB construction-design team to alleviate change orders and claims.
Nevada	No experience with PPP. Design-bid-build often results in greatest incidence or magnitude of claims, change orders or cost overruns. Design build allows us to select a good design build team, but subsurface characterization becomes a cost that is often minimized during the design build process. CMR seems to have the least incidence or magnitude of claims, change orders or cost overruns. Risks are determined early allowing for additional site characterization to reduce risks.
New Hampshire	The baseline geotechnical report has variability and is not as "complete" as a a design bid build.
New York	Some believe that Design-Build will lessen the Department's responsibility for change orders, and some believe that Design-Build will create more situations that require change orders.
South Carolina	Less claims
Utah	We seem to have had our worst experience with DB projects.
Vermont	There is a change in risk alocation and with that change comes and increase in claims. Also, for our Agency, some of these contracting methods are relatively new so there is a learning curve that all parties go through with any new process.

21. Design-build (subsurface claims): Please explain the perceived effect.

Illinois	claims will be reduced
Maine	The perception is that design-build and CMGC contracting methods reduce claims, change orders and cost overruns. While our agency has completed several design-build contracts, we are just now embarking on the first significant CMGC contract.
Minnesota	same answer as the previous question.... again the big thing is the way the contractors conduct themselves when mitigating delays on design build vs bid build
Mississippi	Same answer as previous question.
Nevada	No experience with PPP. Design-bid-build often results in greatest incidence or magnitude of claims, change orders or cost overruns. Design build allows us to select a good design build team, but subsurface characterization becomes a cost that is often minimized during the design build process. CMR seems to have the least incidence or magnitude of claims, change orders or cost overruns. Risks are determined early allowing for additional site characterization to reduce risks.
New Hampshire	The incidence of claims is higher on design build as the baseline geotechnical reports are not the same as a design bid build.
New York	See previous answer to similar question.
South Carolina	less claims
Utah	It seems like we have seen a higher incidence and magnitude of claims on DB projects.
Virginia	following scope validation (180 days after contract award) there is no further claim period on design-build projects.
Vermont	Same comment as 16.

After 32. Please use the comment field below to add any explanation, qualification, or clarification to your responses.

FHWA Eastern Federal Lands	The answer to Q. #23 includes projects classified as Emergency Relief of Federally Owned Roads (ERFO), which could be considered reconstruction work. Also, the answer to Q. #23 includes projects awarded from 2010 through end of 2014. Q. #27 through #29 include projects awarded prior to 2010, but sill active in 2010 and through 2014. Q. #30 and #32 include projects closed from 2010 to end of 204.
Florida	All claim information is stored as scanned images in our EDMS. searchable records are not readily available. However, one could build a database of the claim information but it would take a great deal of resources to complete.
Georgia	estimates base upon percentages of performance measures tracked by GDOT.
Indiana	1) There are contracts that were let in 2012 and 2013 that are still under construction that may incur additional change orders. 2) All change orders recorded for the contracts let from 7/1/2008 (FY 2009) to 6/30/2013 (FY 2013). 3) These data had a lot of filtration and customization for the purpose intended.
Maryland	Maryland SHA only tracks Change Orders. We do not track claims or overruns.
South Dakota	When it asked total number of CCOs since 2009, I wasn't positive if that meant to include 2009. The data I provided is from 1/1/2010 to 12/31/2014. Data could be increased by 20% if you meant to include 2009 in the data set.

After 42. Please use the comment field below to add any explanation, qualification, or clarification to your responses.

FHWA Eastern Federal Lands	The answer to Q.#38 also includes change orders that were and were not due to subsurface conditions or site characterization practices. Some changes orders include multiple change items, some of which are not related to subsurface conditions. The sum of the changes related only to the earthwork items is $1,556,037, which is the answer to Q. #41. Also, responses to Q. 37 to 42 are for projects within a time frame from 2010 to end of 2014.
Georgia	estimates based on limited internal tracking
Indiana	These data are collected and customized for the purpose of presentation and are not populated in one location. The numbers can be changed depending the criteria chosen such as based on letting year or actual year when the CO took place or the year the project was completed.
Maryland	Maryland SHA just tracks costs for Change orders with coding that relates to differing site conditions.
Oregon	Oregon DOT does not track claims or overruns related to subsurface conditions.

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Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FAST	Fixing America's Surface Transportation Act (2015)
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TDC	Transit Development Corporation
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation

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