BUREAU OF RECLAMATION

# Geotechnical Research Roadmap

**Research and Development Office**
**Science and Technology Program**
**Final Report 8550-2020-02**

**U.S. Department of the Interior**
**Bureau of Reclamation**
**Research and Development Office**

**January 2021**

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# Acknowledgements

The Science and Technology Program, Bureau of Reclamation, sponsored the development of this roadmap.

| REPORT DOCUMENTATION PAGE | | | | | *Form Approved*<br>*OMB No. 0704-0188* |
|---|---|---|---|---|---|
| **T1. REPORT DATE:**<br>JANUARY 2021 | **T2. REPORT TYPE:**<br>RESEARCH | | | | **T3. DATES COVERED**<br>**NA** |
| **T4. TITLE AND SUBTITLE**<br>**Geotechnical Research Roadmap**<br>**Final Report 8550-2020-02** | | | | | **5a. CONTRACT NUMBER**<br>**5b. GRANT NUMBER**<br>**5c. PROGRAM ELEMENT NUMBER** 1541 (S&T) |
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| **7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**<br>Technical Service Center<br>U.S. Department of the Interior, Bureau of Reclamation,<br>PO Box 25007, Denver CO 80225-0007 | | | | | **8. PERFORMING ORGANIZATION REPORT NUMBER** |
| **9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)**<br>Research and Development Office<br>U.S. Department of the Interior, Bureau of Reclamation,<br>PO Box 25007, Denver CO 80225-0007 | | | | | **10. SPONSOR/MONITOR'S ACRONYM(S)**<br>**R&D:** Research and Development Office<br>**BOR/USBR:** Bureau of Reclamation<br>DOI: Department of the Interior<br>**11. SPONSOR/MONITOR'S REPORT NUMBER(S)** 8550-2020-02 |
| **12. DISTRIBUTION / AVAILABILITY STATEMENT**<br>**Final report can be downloaded from Reclamation's website: https://www.usbr.gov/research/** | | | | | |
| **13. SUPPLEMENTARY NOTES** | | | | | |
| **14. ABSTRACT** ***(Maximum 200 words)***<br>Reclamation is responsible for a significant amount of major and minor infrastructure across the Western United States, including about 450 dams and more than 10,000 miles of water conveyance structures. While the structures themselves vary in design, size, and type, all structures share a common theme of earth (rock, soil, or mixed) foundations and all utilize earth as a construction material. Reclamation has long been on the forefront of characterizing earth materials for use in civil structures through fundamental research and project related work. Growing geotechnical research has and continues to be fundamental to maintaining and improving the underpinning of Reclamation's infrastructure inventory. This report details a Geotechnical Research Roadmap for Reclamation's Science and Technology Program that can be used to assist in the development and evaluation of future research proposals. | | | | | |
| **15. SUBJECT TERMS:** Roadmap, geotechnical, research, soil, rock, foundations, construction material, dam | | | | | |
| **16. SECURITY CLASSIFICATION OF:** | | | **17. LIMITATION OF ABSTRACT** | **18. NUMBER OF PAGES** | **19a. NAME OF RESPONSIBLE PERSON** Evan J. Lindenbach |
| **a. REPORT**<br>U | **b. ABSTRACT**<br>U | **c. THIS PAGE**<br>U | U | 22 | **19b. TELEPHONE NUMBER**<br>303.445.2336 |

S Standard Form 298 (Rev. 8/98)
P Prescribed by ANSI Std. 239-18

# Bureau of Reclamation

## Research and Development Office
## Science and Technology Program

## Geotechnical Laboratory and Field Support, 86-68550

## Final Report 8550-2020-02

# Geotechnical Research Roadmap

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# Reclamation S&T Geotechnical Research Roadmap

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# Executive Summary

A research roadmap is proposed to further Reclamation's knowledge of geotechnical engineering as it relates to the specific mission of Reclamation: water and power delivery. The goal of this roadmap is to provide a strategy to advance geotechnical engineering practice for aging water storage and conveyance infrastructure, and power generation and transmission systems.

Research topics are proposed based on results of a Reclamation wide survey of engineers and scientists, and from comments provided during the review process. The big picture topics are presented below with detailed objectives. More detail about each topic is presented later in this report.

Filter and Berm Reliability and Improvements

1. Perform a "Lessons Learned" on past modifications that addressed static and seismic deficiencies
2. Create lab-scale models to further investigate structural modifications
3. Improve numerical modeling to accurately predict field performance

Data Collection, Analysis, and 3D Presentation

1. Improve 3D data visualization of Reclamation's infrastructure
2. Streamline the integration of field data collection and site investigation data into the design process to improve communication and data access
3. Implement technology on our field equipment to gather real-time data

Filter Sand

1. Perform a "Lessons Learned" on past project involving filter sand and develop a guide for our future work
2. Develop methods to improve the reliability of filter sand and determine other ways to improve performance and reduce overall costs

Dewatering

1. Perform a "Lessons Learned" on past dewatering projects and develop methods to improve our field scale tests and dewatering system designs
2. Investigate which drilling method(s) are preferable when installing pumping and/or monitoring wells for dewatering investigations. Develop an understanding of which geologic factors are important to consider when selecting a drilling method

Field Investigation Methods

1. Perform a "Lessons Learned" on past Reclamation site investigation project to identify potential process or method-based improvements. Similarly, develop case histories from the larger geotechnical engineering community and other disciplines (oil and gas, mining, etc), to look at best

practices in field data collection and how those practices could improve Reclamation's field investigations.
2. Develop methods to improve our drilling, sampling, and logging methods

Internal Erosion

1. Improve our ability to model field conditions in a laboratory setting
2. Improve methods to use laboratory testing and field monitoring/observations to inform the risk assessment process
3. Define sources of uncertainty in the risk assessment process. Use this to define research focused on increasing understanding and reducing uncertainty at each branch of the internal erosion PFM event tree
4. Develop methods to better monitor subsurface conditions that might be favorable to internal erosion
5. Improve methods to detect and mitigate weak zones (cracks, animal burrows, unfiltered or limited filtered exits, tree roots, …) on the surface that create favorable conditions for initiation of internal erosion

Improved Laboratory Testing

1. Improve methods to investigate and model internal erosion at the lab scale and field scale
2. Close the gaps between laboratory testing to numerical modeling to field scale performance
3. Develop new and improve existing lab and field scale tests to better understand the cyclic and post-cyclic behavior of soil
4. Investigate the erodibility of soil for structure reliability and sediment removal
5. Develop new and improve existing lab and field tests to investigate soil modulus
6. Improve our understanding of the static strength of soil, specifically with material oversize to lab equipment, or soil under unusual boundary conditions

The goal of this roadmap is to provide a framework for future geotechnical research. Next steps would include the development and submission of proposals that work towards addressing the needs statements and questions posed here. See the current Science and Technology Strategic Science Implementation Plan (SSIP) for more details about schedule, funding, priority, etc. (https://www.usbr.gov/research/st/docs/SSIP.pdf). The authors of this roadmap are available for further discussion and refinement of topics, and assistance with research prioritization.

# Introduction

Earth materials (soil, rock, or mixed) are the fundamental underpinning of all civil works. They comprise the foundations of structures and are often the materials used for construction. Man-made materials (steel, aluminum, etc.) have relatively fixed properties, which are in-turn relatively simply characterized by engineers for use in structures. Earth materials are fundamentally variable in their properties, both spatially and temporally, requiring a highly-specialized civil engineering sub-discipline accustomed to uncertainty, heterogeneity, and anisotropy.

To quote Karl Terzaghi, considered to be the father of geotechnical engineering:

> "Unfortunately, soils are made by nature and not by man, and the products of nature are always complex… As soon as we pass from steel and concrete to earth, the omnipotence of theory ceases to exist. Natural soil is never uniform. Its properties change from point to point while our knowledge of its properties are limited to those few spots at which the samples have been collected. In soil mechanics the accuracy of computed results never exceeds that of a crude estimate, and the principal function of theory consists in teaching us what and how to observe in the field."

The field of geotechnical engineering is critical to the reliability of infrastructure and must inherently include a quantification of uncertainty. Targeted research can be used to help constrain this uncertainty and improve the reliability of civil infrastructure.

A research roadmap is proposed to further Reclamation's knowledge and practice of geotechnical engineering as it relates to the specific mission of Reclamation: water and power delivery. The goal of this roadmap is to provide a strategy to forward geotechnical engineering practice for aging water storage and conveyance infrastructure, and power generation and transmission systems.

This roadmap is an extension of a previous effort developed to improve infrastructure sustainability (Merten et al., 2014), which focused on identifying ways to improve the service life of existing infrastructure through new/improved tools and technology. This roadmap was developed at the request of the Science and Technology Program to provide more resolution about how geotechnical research can be used to address needs identified in the previous effort and improve Reclamation's state-of-practice regarding geotechnical engineering.

The geotechnical roadmap is broken down into three main categories: 1) operations and maintenance (O&M), and construction, 2) field explorations, and 3) laboratory characterization of geomaterials. Technical feedback and professional opinions were solicited from knowledgeable personnel across

Reclamation for each of the three categories with the obtained data synthesized and summarized in this report.

Because Reclamation's infrastructure is essentially irreplaceable, the need for the sustainability and resiliency of our infrastructure is a continued challenge that requires multi-year to decadal predictions. Note that the information presented herein is focused on geotechnical research which fundamentally touches all of Reclamation's infrastructure (dams, canals, pipelines, appurtenant structures, etc.) as it focuses on the interaction between structures and the earth.

# Methods

Senior engineers within the Geotechnical Laboratory and Field Support group (GLFS) in Reclamation's Technical Service Center (TSC) developed a series of questions to gather information about three primary geotechnical research topics: 1) operations and maintenance (O&M) and construction, 2) field explorations, and 3) laboratory characterization of geomaterials.

A questionnaire was developed by GLFS and sent out to parties across Reclamation with responses gathered through the online platform Survey Monkey. The survey was started in August 2019 and kept open for more than 6 weeks. Input was solicited and obtained from the Regions and the TSC, with data collected from geologists, engineers, and scientists. More than 70 Reclamation employees participated in the survey.

The survey included the three main sections as detailed above. At the start of each section, the respondents were asked to identify if they were qualified to answer questions within the section. Respondents did not have the opportunity to answer questions within sections outside of their qualifications. Some questions were repeated between sections to gather data from a variety of respondents under varying themes.

The responses were then gathered and analyzed by the authors, with the data used to inform the research needs/priorities identified in the later sections. Qualitative and quantitative input was used to develop the conclusions presented herein. No statistical analysis of the data was performed; the conclusions presented in this report directly represent the output from the survey. The survey questions along with responses are included as Appendix A.

A draft of this report was prepared and sent for peer review both within and outside of Reclamation. Reviewer feedback, including some specific research topics, was incorporated in this final report.

# Definitions

This section includes definitions of geotechnical terms and subject areas that could be outside of the typical knowledge for Reclamation personnel. It is assumed that the reader of this roadmap is familiar with Reclamation's infrastructure and the general terms used by Reclamation employees (canals, dams, etc.).

## Advanced Laboratory Testing

Advanced laboratory tests are used by geotechnical engineers to further constrain material properties used within numerical models and design activities. The goal of any laboratory test is to simulate the boundary and loading conditions experienced by the field scale geologic unit in a controlled, repeatable test. Advanced techniques can develop estimates of ranges of parameters for use in numerical modeling and design. The advanced techniques represent the state-of-the-art for geotechnical material characterization.

## Cone Penetrometer Test

A specially designed and instrumented cone is pushed into soils to measure tip and sleeve resistance (at a minimum), which can be used to estimate material type and physical and engineering properties. This test can incorporate different sensors and measurement techniques to gather a robust record of subsurface data.

## Cyclic Testing

A laboratory boundary condition where stress and/or strain is applied in a cyclic manner at a specified rate to determine characteristics for use in modeling and design. Within Reclamation this is typically used for earthquake engineering purposes, and in the larger geotechnical community also envelope loading due to rail lines and wave action. Intact (i.e., relatively undisturbed) soil samples are obtained from the field and tested under the cyclic boundary condition to determine parameters such as modulus degradation and damping curves, pore pressure generation response, cyclic strength, post-cyclic strength, and post-cyclic settlement.

## Dewatering

The design and implementation of a system to locally lower the ground water table to allow for construction to occur below the groundwater table in a dry environment. These systems can include passive (e.g., ground freezing) and active (e.g., well point) measures to limit migration of groundwater into an excavation below the phreatic surface. Excavations with excessive seepage can have significant stability issues and can limit the ability for safe and high quality construction. Dewatering investigations must characterize geologic uncertainty

along with hydraulic heterogeneity/anisotropy of the subsurface. A variety of field scale tests (pump out, etc.) are used to design dewatering systems.

## Erodibility

Quantification of the erodibility potential of geomaterials due to imparted hydraulic stresses. This can be a function of soil chemistry (dispersive processes where soil particles repel each other) and/or a function of hydraulic shear stresses (typically quantified with detachment coefficient and critical shear stress). Erodibility typically refers to surficial erosion processes and is distinct from Internal Erosion (see below).

## Filter Sand

Sand used as a construction material to limit migration of finer soil particles. The central core of a dam is typically fine-grained (clay or silt) with the outer shell zones being more coarse-grained (gravel to cobbles to boulders). A layer of sand is commonly placed between the finer-grained and coarser-grained materials to decrease the probability of particle migration under the imposed hydraulic gradient due to the reservoir.

## Internal Erosion

Internal erosion is the erosion of embankment or foundation material when subjected to a hydraulic gradient. This is a different process than diffuse or point-source seepage. Internal erosion is known to progress to a breach-type failure and, as a primary failure mechanism for embankment dams, requires immediate mitigation upon location.

Mechanisms of internal erosion include scour, internal instability of soils, internal migration (stoping), and backwards erosion piping. Scour is caused by concentrated flow at an erodible surface, such as the dam/foundation contact. Internal instability refers to the erosion of the finer-grained material through the coarser-grained soil matrix. This process can progress as suffusion (particles removed without a change in overall volume) or suffosion (decrease in volume as particles rearrange under the imparted stresses). Internal migration, also referred to as stoping, is the downward migration of soil particles when the soil is unable to sustain a roof supporting a void or a pipe. Stoping can be manifest as sinkholes on the slopes or crest of an embankment. Backwards erosion piping, “piping” occurs as concentrated seepage erodes embankment or foundation material. “Piping” progresses backward (upstream) from the toe of an embankment, toward the highest gradient, forming a “pipe” shaped void.

## Oversize Material

Laboratory testing is designed to simulate the anticipated field-scale boundary conditions. As the field scale often involves very large materials (cobbles or boulders in soil, large scale features in the rock mass), the laboratory tests are generally scaled down versions of field boundary condition. In the case of soil, large particles cannot be included in the soil samples as they have an outsize effect on the testing; for example, including a 6-inch diameter cobble in a 12-inch square direct shear box would only test the shear strength of that cobble and would not be representative of the field scale conditions. In this document, material larger than what can be tested in the standard laboratory equipment (per accepted industry standards) is termed oversize material or material oversize to the laboratory equipment.

## Piezometers

Tools used to monitor groundwater elevation, pressure in artesian units, or the phreatic water surface through a water retaining embankment. A variety of piezometers are used in the geotechnical industry depending on the application.

## Standard Penetration Test

A very common geotechnical field test in U.S. practice where a sampler of a standardized size is driven into soil via repeated impacts with a standardized drop hammer. The test is used to indirectly estimate subsurface material properties, such as density and liquefaction potential.

# Survey Results

Data for each category is summarized in this section with proposed research topics to fill the identified data gaps presented in the next section. Data presented below is a summary of the entire data set given in Appendix A.

## Geotechnical Aspects of O&M and Construction

Of the 71 respondents, 51 self-identified as being qualified to answer questions in these topic areas.

1. Respondents were asked to identify structures requiring the most maintenance. The top 2 responses (in rank order) were:
    a. Dams
    b. Canals
2. Respondents were asked to identify common challenges. Results are summarized by the following list (distilled from respondent qualitative responses, see Appendix A for the full list):
    a. Foundation condition uncertainty

   b. Adequate material quantities
   c. Working below groundwater level – water control
   d. Filter sand quality
   e. Excavation of hard rock
   f. Uncertainty regarding the efficacy of filter/berm designs for slope stability
3. Respondents were asked to identify a subject area that could benefit from a thorough past performance evaluation. The top 2 responses were:
   a. Filter sand
   b. Dewatering

## Geotechnical Field Explorations

Of the 71 respondents, 37 self-identified as being qualified to answer questions in these topic areas.

1. Respondents were asked to identify the most common types of field exploration methods. The top 5 responses were:
   a. Sampling of soil
   b. Drilling
   c. Standard penetration test (SPT)
   d. Sampling of rock
   e. Cone penetration test (CPT)
2. Respondents were asked to identify needed improvements to field investigation procedures and reporting. Results are summarized by the following list:
   a. Timely presentation of field data to design team
      i. Electronic logging
      ii. UAS surveys
      iii. Improved workflow efficiency and data presentation
   b. Comprehensive spatial-temporal data collection and coverage
   c. Software for logging and visualizing subsurface materials
   d. Design and implementation of pump-tests for dewatering
   e. Data validity testing for fully-grouted vibrating-wire piezometers
3. Respondents were asked to identify the greatest challenges for incorporating field/lab data into design. The top 3 responses were:
   a. Spatial variability
   b. Timely availability of data
   c. Data visualization
4. Respondents were asked to identify methods to improve dewatering investigations. Results are summarized by the following list:
   a. Timely dissemination of data
   b. Better data collection methods
   c. Case histories
5. Respondents were asked to identify topics in need of a past performance evaluation. The top 3 responses were:

   a. Drilling and sampling methods
   b. Filter Sand
   c. Dewatering
6. Respondents were asked to identify the best methods to improve Reclamation's geotechnical investigations. The top 3 responses were:
   a. 3D visualization of subsurface data
   b. Improved field-testing procedures
   c. Improved field logging capabilities

## Geotechnical Laboratory Characterization

Of the 71 respondents, 26 self-identified as being qualified to answer questions in these topic areas.

1. Respondents were asked to identify the greatest challenges to incorporate field/lab data into design. The top 3 responses were:
   a. Spatial variability
   b. Timely availability of data
   c. Data visualization
2. Respondents were asked to identify dewatering design improvement areas. Results are summarized by the following list:
   a. Reliability
   b. Improved pump tests
   c. Improved subsurface characterization
3. Respondents were asked to identify topics in need of a past performance evaluation. The top 3 were:
   a. Filter Sand
   b. Dewatering
   c. Canal lining
4. Respondents were asked to identify the most important lab scale research topics. The top 5 were:
   a. Cyclic behavior of soil
   b. Erodibility of soil
   c. Internal erosion
   d. Static strength of soil
   e. Soil modulus
5. Respondents were asked to identify the best methods to improve Reclamation's geotechnical investigations. Results are summarized by the following list:
   a. Improved field-testing procedures
   b. 3D visualization of subsurface data
   c. Advanced laboratory testing (i.e. bender elements, resonant column, acoustic emissions, etc.)

# Research Roadmap Topics

Research topics are proposed based on the survey results. Along with the proposed topics, key concepts and ideas are presented with the research concept. The topics presented below should be considered the first-step in the geotechnical research roadmap effort. The topics below are the high-level ideas and a full research plan may require additional development.

These topics are meant to be applied directly at Reclamation projects and should be tied to design efforts and improvements in risk analysis and safety standards.

## Filter and Berm Reliability and Improvements

The typical solution to address potential slope instability issues (static or cyclic) is to place a large buttress of earthfill material and/or a shear key of rockfill, soil cement, roller compacted concrete, etc. at the toe of a structure along with improving existing or constructing new filter sand and gravel drainage layers to limit internal erosion issues if a slump were to occur. This design works well on paper but evidence of actual performance is minimal. Future research should focus on a literature review of past performance leading into scale model tests, ideally in a centrifuge or similar equipment that can impart known stresses to the model. This work can then be modeled using typical finite element software to "model the model" and can confirm codes and constitutive models against lab shear tests and centrifuge models of known properties.

## Data collection, analysis, and 3D presentation

A reoccurring theme across all research categories is the need to improve geologic data collection (i.e., site characterization) efficiency (from field to design team) and to present the data in a 3D format for improved visualization. Possible research topics in this field include: geologic logging using standardized forms/software on tablets with connectivity to the design team, development or use of software for data visualization (tying into the RISE and BORGIS databases), and real-time data collection on the drill rig (i.e. drill parameter recorder technology).

Specific research topics posed during the review process include development of data quality indices for geospatial data sets and improved methods for statistical evaluations of geotechnical data for use in design. Additionally, Reclamation should investigate the reliability of fully grouted vibrating wire piezometers for dam performance monitoring.

## Filter Sand

Filter sand is used in many of Reclamation's water retaining structures but supplies of quality material are diminishing. There is a need for better understanding about past performance (adverse cementation leading to cracking, compatibility of materials to limit particle migration, material durability, etc.). There is also a need for research into in-situ performance of filter sand as currently specified, what materials could possibly replace filter sand (geotextiles, etc.), or what materials could be added to filter sand to improve performance and reduce overall costs.

Detailed research topics posed during the roadmap review include a focus on the self-healing stages of internal erosion risk analysis as it relates to upstream crack-stopper materials and the ability of non-standard filter materials to deform with embankment materials.

## Dewatering

Across the research categories it is clear that additional work on dewatering is needed, from a better understanding of past-performance/lessons learned, to improvements in pump tests and other field scale tests, to design of dewatering systems. This topic would also benefit from the real-time data collection and dissemination efforts as detailed previously.

Specific research topics posed during the review process include improved mapping of high permeability spatial layers that control the dewatering efficacy and higher resolution in situ profiling of critical subsurface units.

## Field Investigation Methods

In conjunction with improving subsurface data collection and presentation, an effort should be put forward to investigate case histories of subsurface investigations and how they can be improved with new tools and technology. This would include communication with other industries (oil and gas, mining, international best practice communities, etc.) to look at best practices in field data collection and how those practices could improve Reclamation's field investigations.

Other areas of specific need within this topic as posed by reviewers are: improved methods for void detection and assessment of in-situ seepage conditions, refining methods for rock mass permeability for a dam seepage analysis, better assessments of the conditions at contacts between embankments and irregular rock foundations to determine how well gaps are sealed, improved methods for investigating gravelly soils and their susceptibility to liquefaction (e.g., instrumented Becker Penetrometer Test), improved geophysical tools for downhole and surface investigations, evaluating the effect of vibrations induced by sonic drilling on subsequent SPT and CPT measurements, determining the loss

in energy delivered to SPT sampler due to drilling method and drill string length, evaluating the use of CPT for seismic wave velocity profiling, the use of the vane shear test to evaluate rate effects and rate of strain softening in soft sensitive clays, and refined methods used to characterize well-graded soils, including evaluation of penetration resistance and in-situ density.

## Improved Laboratory Testing

Advanced laboratory tests, particularly those to characterize soil behavior under static and cyclic loading, and varying states of stress, should be investigated. Detailed needs distilled from the survey and identified in the review process are described below.

### Cyclic behavior of soil

Laboratory testing procedures using advanced equipment such as resonant column should be investigated. This should include bender element testing and acoustic emissions to localize strain measurements and develop a deeper understanding of failure mechanics. Focus should be given to strength and deformation characteristics before, during, and after cyclic loading with the goal of developing a framework for the evaluation of soil and rock on any scale. An emphasis should be placed on investigating large-strain behavior including the effects of strain rate and material nonuniformity, and the mechanics of softening of clayey soils and intermediate geomaterials.

### Erodibility of soil

Erodibility of soil should be investigated at the lab scale using typical hole erosion test (HET) and jet erosion test (JET) systems with an emphasis on developing robust relationships describing soil erodibility to better define infrastructure reliability and reservoir sediment erosion processes.

Specific needs posed during the review process included improving the ability to predict and characterize breach processes, and a better understanding of the mechanical and erosion characteristics of soil cement.

### Internal erosion

Internal erosion is one of the leading causes of dam and levee failures in the United States and internationally. It is also one of the most difficult failure mechanisms to assess risk due to its complexity and the variability of soil, hydraulic conditions, and stress conditions within the embankment – based on our current understanding, it is essentially a stochastic process. Internal erosion should be studied from the lab scale to the field performance scale to inform the risk assessment processes. This should include identifying critical observations, monitoring data, and tests. Beyond the risk assessment, efforts should be put forward to continue to develop efficient mitigation methods against internal erosion.

The topic of internal erosion resistance/susceptibility as related to the site geologic conditions was posed during the review process.

### Static strength of soil

Advanced static strength testing of soil is needed with improved scale and boundary conditions. One key topic of interest is the behavior of soils with material oversize to typical testing equipment. Larger equipment should be constructed and testing on multiple scales of samples performed. Data should be analyzed and predictive relationships developed such that typical laboratory scale data can be scaled for oversize material.

### Soil modulus

Defining the deformation characteristics under a wide-range of stress-states is critical for numerical modeling of our facilities. These models are needed to predict the long-term performance of our structures. Soil modulus should be investigated at the lab scale with an emphasis at tying the data to the field scale.

### Laboratory Testing to Numerical Modeling to Field Scale Performance ("Modeling of Models")

Additional work should focus on closing the gaps within the loop of lab scale to numerical models to field scale. Closing the gaps between the lab tests, numerical models, and the field scale performance remains one of the fundamental unresolved workflow for all engineering problems but is particularly glaring in geotechnical engineering. Work should focus on developing improved model inputs, model processes, and tying model outputs to actual field performance.

Closing the gaps between laboratory scale testing and numerical modeling could include the development of more robust constitutive models to describe geomaterial behavior under varying loading conditions.

Closing the gaps between numerical modeling and field scale performance could include more larger-scale laboratory models subjected to varying boundary conditions with the performance used to constrain predictive numerical models.

Areas of specific needs posed by the reviewers within this topic include improving understanding of soil-structure interaction during seismic loading, a refined understanding of transverse embankment cracks due to consolidation settlement or dynamic deformation (a three-dimensional problem), improved constitutive models, better ability to predict earthquake induced deformations, and better liquefaction triggering models.

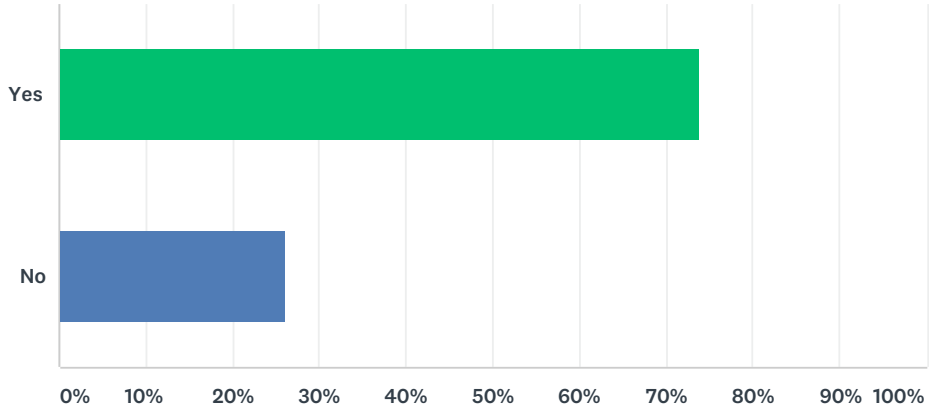
# References

Merten, B.J., and von Fay, K. (2014). "Research Priorities to Enhance Dam Infrastructure Sustainability," Technical Memorandum No. MERL-2014-56.

# Appendix A – Survey Results

# Q1 Are you qualified to answer questions related to the geotechnical aspects of O&M and construction?

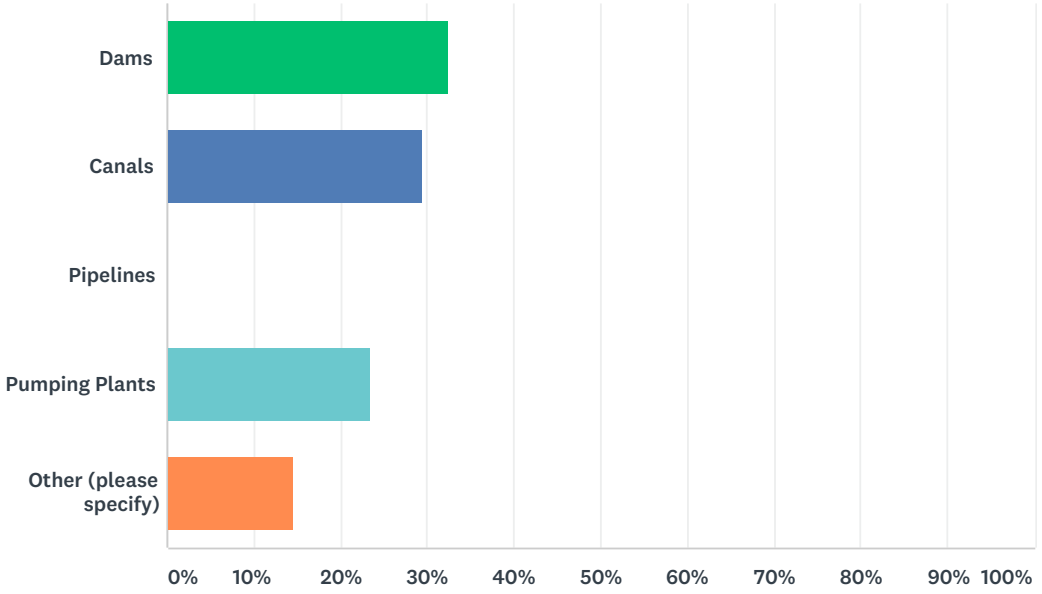
Answered: 69 Skipped: 1




| ANSWER CHOICES | RESPONSES | |
|---|---|---|
| Yes | 73.91% | 51 |
| No | 26.09% | 18 |
| TOTAL | | 69 |

# Q2 What type of structure requires the most routine maintenance?

Answered: 34 Skipped: 36




| ANSWER CHOICES | RESPONSES | |
|---|---|---|
| Dams | 32.35% | 11 |
| Canals | 29.41% | 10 |
| Pipelines | 0.00% | 0 |
| Pumping Plants | 23.53% | 8 |
| Other (please specify) | 14.71% | 5 |
| TOTAL | | 34 |

| # | OTHER (PLEASE SPECIFY) | DATE |
|---|---|---|
| 1 | Roads | 8/20/2019 10:54 AM |
| 2 | N/A | 8/13/2019 5:05 AM |
| 3 | Spillways | 8/7/2019 3:30 AM |
| 4 | I deal with dams mostly, so I know the most about them (and would say they require the most routine maintenance), but due to my lack of knowledge about the other types of structures, I would say my understanding of those other needs is limited. | 8/7/2019 2:05 AM |
| 5 | They all require routine maintenance, but it is a difficult question as, for example, not sure how to compare maintenance at a pumping plant to a canal that is 10's of miles long. | 8/7/2019 1:31 AM |

# Q3 What type of fixes work best? Which don't work?

Answered: 23 Skipped: 47

| # | RESPONSES | DATE |
|---|---|---|
| 1 | Permanent modular repairs. Simple to maintain | 9/30/2019 7:37 AM |
| 2 | Depends on the issue. Taking care of maintenance issues promptly is critical. | 8/26/2019 3:56 AM |
| 3 | Depends on the issues. | 8/19/2019 8:22 AM |
| 4 | This is an odd question without the nature of the problems being specified or even suggested. | 8/15/2019 3:52 AM |
| 5 | N/A | 8/13/2019 5:05 AM |
| 6 | varies case by case. i.e. I've seen areas where relief wells for seepage control are very effective and others where they are a not functioning properly at all. | 8/12/2019 3:53 AM |
| 7 | It will take years to determine the effectiveness of the toe drain/filter diaphragm modifications performed by Reclamation. The modifications are being implemented at an alarming rate and little is known about the effectiveness of these large modifications in the Reclamation inventory. It is still too early to know if these filters are performing as intended. There is much skepticism at the regional and area office level that these modifications will be effective, or whether we have simply changed the dynamics of preferred seepage paths. Have we increased other PFM's through these modifications? | 8/12/2019 2:42 AM |
| 8 | What works is replacement of concrete canal lining with reinforced steel and engineered fill behind the canal lining. What doesn't work is lime treated soil, or fat clay wet up to 5% wet of optimum then compacted in place. | 8/8/2019 2:36 AM |
| 9 | Pumping Plant maintenance is outside my area of expertise. For Dam modifications, typically filter drains for static PMFs and stability berms for seismic PFMs | 8/7/2019 6:33 AM |
| 10 | Joint rehabilitation, underslab and void grouting, and underdrain replacement. | 8/7/2019 3:30 AM |
| 11 | Concrete lining, but it is expensive. Surface patches buy time. | 8/7/2019 2:48 AM |
| 12 | Again, I mostly deal with dams. I have found that interim fixes, or fixes that do not address the root problem often create other problems. The best kinds of fixes are the ones that are designed (and constructed) with the intention of not needing to come back to fix this problem. (i.e. fix it once) | 8/7/2019 2:05 AM |
| 13 | Seepage: Drains and filters or cutoff Erosion: Slope / embankment repair | 8/7/2019 1:33 AM |
| 14 | Fixes that are well thought out a mitigate the problem as opposed to temporary patches. However, funding often a factor. | 8/7/2019 1:31 AM |
| 15 | Replacement works Retrofitting has problems | 8/7/2019 1:22 AM |
| 16 | Filtered toe drain systems. | 8/7/2019 1:20 AM |
| 17 | the question is too general | 8/6/2019 8:41 PM |
| 18 | Fixes consistent with original design specifications are most effective. Ad hoc retrofits are typically quick solutions, but not effective. | 8/6/2019 1:51 PM |
| 19 | TBD the canal program is still in the works. | 8/6/2019 9:24 AM |
| 20 | Cut off walls (sheet pile, slurry trenches etc) typically work well. Liners can work, but can hide developing problems. Installing a filter material to prevent the transport of fines can work but can inhibit flow forcing seepage through another path. | 8/6/2019 9:07 AM |
| 21 | Regularly scheduled planned outages are far less problematic than unexpected outages. | 8/6/2019 8:57 AM |
| 22 | Best: Excavate all/most of the the soil that is causing problems and replace it with soil that doesn't cause problems. Okay: Construct a shear key block in the soil that is causing problems. Not that good: 1.) Jet grouting that shear key block -- doesn't always work. 2.) Dynamic compaction -- might work in the shallow soils. 3.) Stone columns -- doesn't seem to work out all the time. | 8/6/2019 8:21 AM |
| 23 | modification | 8/6/2019 8:13 AM |

# Q4 What are you currently constructing? What challenges do you face during construction?

Answered: 24 Skipped: 46

| # | RESPONSES | DATE |
|---|---|---|
| 1 | NA | 9/30/2019 7:37 AM |
| 2 | new spillway. Cutoff walls. Secant piles. Control of water is the biggest challenge. Including Dewatering and unwatering | 8/26/2019 3:56 AM |
| 3 | Nothing at the moment. | 8/19/2019 8:22 AM |
| 4 | Boca Dam seismic modifications - identifying appropriate filter requirements while considering costs of various material sources, dewatering. | 8/14/2019 9:15 AM |
| 5 | Modifications to a dam. Poorly written specs and lack of sufficient staff. | 8/13/2019 6:44 AM |
| 6 | Projects: - Seismic berms and shear keys - Sand and gravel chimneys Challenges: - control of water - field-fitting/modifications (more of a contractual issue) | 8/13/2019 5:05 AM |
| 7 | Working on major repairs at a dam. Most of the challenges are associated with the inability to take system outages to complete work. | 8/12/2019 3:53 AM |
| 8 | Retrofitting dams with "state of the art" toe drain and filter diaphragms are the primary challenge. The major challenge with the modifications is constructibility, and unpleasant surprises with foundation conditions during construction. Reclamation sets the contractors up for failure with designs that aren't easily constructible as designed, including excavations without dewatering, slope stability, and limited preconstruction/construction/post construction investigations. | 8/12/2019 2:42 AM |
| 9 | Pipelines, water treatment plants and pumping plants. The use of native material vs select material hauled in. I believe native material give a better product than the use of select material around the pipeline, just from my past experience from NGWSP Block 9-11. | 8/8/2019 2:36 AM |
| 10 | Nothing personally, working on field work and report writing for sisk. | 8/7/2019 11:41 AM |
| 11 | filter drains and stability berms. Adequate borrow materials, qualified contractors to complete the work. | 8/7/2019 6:33 AM |
| 12 | Spillway underdrain systems rehabilitation, and a chimney filter on the downstream slope of an existing dam. | 8/7/2019 3:30 AM |
| 13 | I am involved with a decent number of embankment dam modifications. There are different challenges with each region. PN recently had a significant staffing issue with Howard Prairie, but so far, has been able to use a rotating cast of personnel to fill in. Communication has been critical to the success thus far. GP seems to often have contractual issues (lack of enforcement of the spec, lack of understanding, requiring modifications to the spec for negligible changes) and so getting them on board with the design early on is important so they understand why TSC is designing things a certain way. | 8/7/2019 2:05 AM |
| 14 | New toe drain and filter system. Working below the groundwater. Developing and implementing an acceptable unwatering program. | 8/7/2019 1:33 AM |
| 15 | Currently Involved in a seismic retrofit of a dam and a fish passage facility. | 8/7/2019 1:31 AM |
| 16 | Pipeline | 8/7/2019 1:22 AM |
| 17 | Dam mods. Many contractors like to use fully-grouted vibrating-wire piezometer (FGVWP) installations because they can be done faster and cheaper. However, BOR has concerns about data validity regarding these installations. It would be very beneficial if a FGVWP test program could be done to check out data validity questions. The geotechnical engineering profession has a great need for this testing and information. | 8/7/2019 1:20 AM |
| 18 | new spillway. The big challenges are the limited experience | 8/6/2019 8:41 PM |

| | | |
|---|---|---|
| 19 | Reclamation constructions canal (and other facility) improvements across the agency. Our office is responsible for the policy and agency oversight over facility operations, maintenance, and replacement for the agency. | 8/6/2019 1:51 PM |
| 20 | Currently involved in more designs than active construction. | 8/6/2019 9:24 AM |
| 21 | Multiple pipelines, dam modifications, canal assessments. Limited inspection resources, lack of knowledgeable inspectors, work load does not allow for engagement in active construction projects, historic files are unavailable, lessons learned from previous projects are not documented or taught | 8/6/2019 9:07 AM |
| 22 | Currently I have the following items under construction: modifications to an existing embankment dam including the extension of the existing outlet works and new intake structure; modifications to an existing outlet works including gate replacement and upstream tunnel repair; construction of a new spillway, and seismic modifications to an existing spillway. I currently have multiple other projects in various stages of planning and design. We work on large multi-disciplined projects and often have less design data than optimal. | 8/6/2019 8:57 AM |
| 23 | Nothing at the moment. | 8/6/2019 8:21 AM |
| 24 | Howard Prairie, inconsistent/unclear contractor specifications | 8/6/2019 8:13 AM |

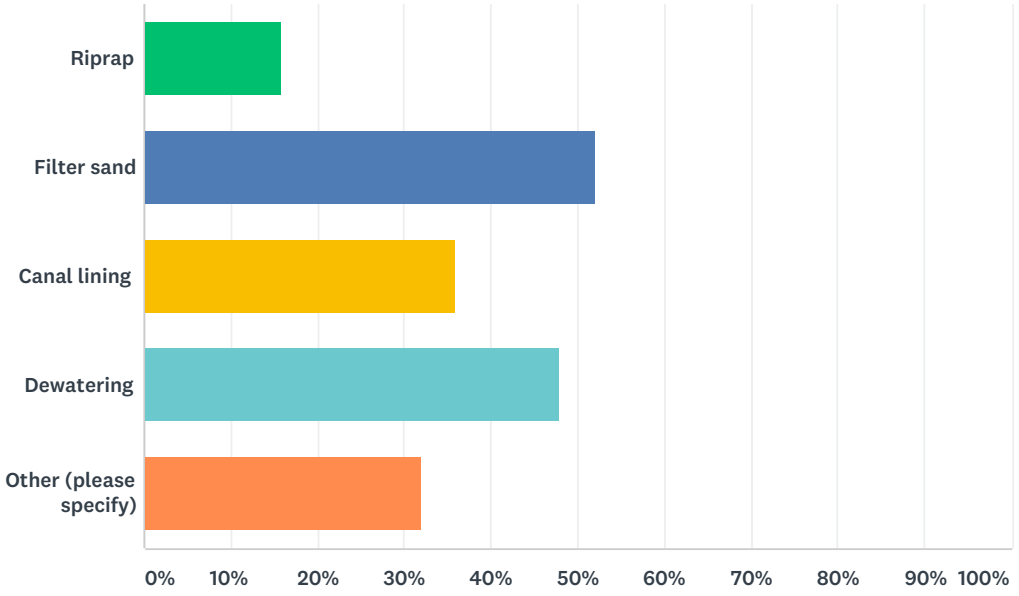
# Q5 Are there geo-material related challenges that reoccur with contractors?

Answered: 23 Skipped: 47

| # | RESPONSES | DATE |
|---|---|---|
| 1 | Filter sand fines content | 9/30/2019 7:37 AM |
| 2 | Not many. Usually they can find the geo material unless it is very specific and unique. Designers should try to specify common materials if possible | 8/26/2019 3:56 AM |
| 3 | exceeding fines limit for filters seems fairly common | 8/14/2019 9:15 AM |
| 4 | Yes. When we have issues with the materials not meeting the spec requirements the contractors like to continue work until the COR can get involved. Sometimes this can take a lot of time and material gets placed and left in-place. The construction inspector are not given the respect they should by the contractors and they have little authority to insure the contractors are meeting the spec requirements. | 8/13/2019 6:44 AM |
| 5 | water control | 8/13/2019 5:05 AM |
| 6 | Contractors typically try to not follow material requirements to save some money (gradation, compaction, etc.) I've not seen any other challenges. | 8/12/2019 3:53 AM |
| 7 | The geo-material challenges include very poor foundation materials discovered during construction. | 8/12/2019 2:42 AM |
| 8 | Yes, contractors blow and go and when you come upon material changes, ie fat clay or shale where different construction procedures are required, the contractor will continue to ignore any material change and will not obtain and additional testing to verify the change in soil. | 8/8/2019 2:36 AM |
| 9 | maybe | 8/7/2019 11:41 AM |
| 10 | materials that do not meet specification requirements. Segregation of materials during transport and placement. contamination of materials. Incorrect placement of materials. | 8/7/2019 6:33 AM |
| 11 | Filter sand quality. Understanding of dewatering needs at the toe of exiting dams | 8/7/2019 3:30 AM |
| 12 | There can be a lack of understanding about how geosynthetics are used (you can have a relatively weak geotextile, or you can have a very strong geotextile, not all geotextiles are the same in terms of strength, filtration, etc), why they should be protected, how they should be tested. | 8/7/2019 2:05 AM |
| 13 | Obtaining acceptable filter materials | 8/7/2019 1:33 AM |
| 14 | Compaction control, particularly for soils that contain oversize particles and materials meeting specifications (gradations). | 8/7/2019 1:31 AM |
| 15 | Yes, excavation of hard rock | 8/7/2019 1:22 AM |
| 16 | The use of grout as the influence zone in fully grouted vibrating-wire piezometer installations. | 8/7/2019 1:20 AM |
| 17 | N/A | 8/6/2019 8:41 PM |
| 18 | This is a site specific question. In certain cases, yes, but this depends on the installation. | 8/6/2019 1:51 PM |
| 19 | NA | 8/6/2019 9:24 AM |
| 20 | Projects with difficult soils or rock (too hard, too soft, expansive, collapsible, erosive, etc.) usually result in claims indicating that the contractor did not read the geology sections of the specifications. | 8/6/2019 9:07 AM |
| 21 | I haven't experienced consistent geo-material-type challanges with any one material. However, I have experienced constructability related issues with a geomembrane and have had significant difficulty with a synthetic biopolymer during a recent slurry wall application. | 8/6/2019 8:57 AM |
| 22 | Yes, but if specifications are followed, usually things go well. | 8/6/2019 8:21 AM |
| 23 | yes | 8/6/2019 8:13 AM |

# Q6 What two geotechnical topics could use a past-performance evaluation to guide future work?

Answered: 25 Skipped: 45




| ANSWER CHOICES | RESPONSES | |
|---|---|---|
| Riprap | 16.00% | 4 |
| Filter sand | 52.00% | 13 |
| Canal lining | 36.00% | 9 |
| Dewatering | 48.00% | 12 |
| Other (please specify) | 32.00% | 8 |
| Total Respondents: 25 | | |

| # | OTHER (PLEASE SPECIFY) | DATE |
|---|---|---|
| 1 | No past performance evaluations are being performed on toe drain/filter diaphragm modifications. And the modifications continue at an alarming rate. | 8/12/2019 2:42 AM |
| 2 | Native material vs select material | 8/8/2019 2:36 AM |
| 3 | Riprap that weathers, cementisious filter sand, lack of data for dewatering design | 8/7/2019 6:33 AM |
| 4 | This is just a note, the dewatering program and methods at Reclamation are currently being revamped and re-evaluated due to staff turnover. I recommend that any past-performance evaluations piggy back with existing efforts. | 8/7/2019 2:05 AM |
| 5 | Sample filter sand installations to see if calcification / blinding is occurring | 8/7/2019 1:33 AM |
| 6 | Evaluation of soil and rock properties | 8/7/2019 1:22 AM |
| 7 | Data validity for fully grouted vibrating-wire piezometer installations. | 8/7/2019 1:20 AM |
| 8 | semi-pervious fill | 8/6/2019 8:13 AM |

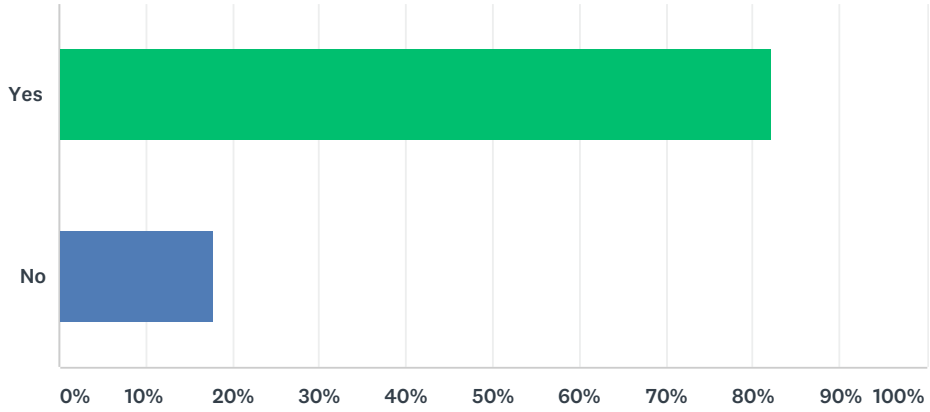
# Q7 What question should we have asked? What is the answer?

Answered: 14 Skipped: 56

| # | RESPONSES | DATE |
|---|---|---|
| 1 | What groundwater conditions may we encounter. How will we deal with them. Do we have enough data? | 8/26/2019 3:56 AM |
| 2 | What are the most common geotechnical issues observed in your projects? seepage and liquefiable soils. | 8/12/2019 3:53 AM |
| 3 | What post-modification material problems might be anticipated in the coming years on recently modified facilities? | 8/12/2019 2:42 AM |
| 4 | N/A | 8/8/2019 2:36 AM |
| 5 | How does BOR avoid change condition claims related to geo-materials and construction. GBR's good or bad? | 8/7/2019 6:33 AM |
| 6 | What research (or information) would reduce uncertainty and improve confidence for geotechnical risk analysis? I think there is considerable uncertainty with liquefaction and seismic soil residual shear strength and deformation moduli. I think you could also ask what dam safety issue evaluations (IE's) are you currently working on or work on the most? I'm working on two seismic IE's I seem to work on those the most. | 8/7/2019 3:30 AM |
| 7 | Something related to testing and/or testing knowledge for construction. It seems like there is a lack of basic understanding in the office and the field when it comes to the nuts and bolts of sand cones, in-place density tests, and other field tests often required during construction. | 8/7/2019 2:05 AM |
| 8 | ? | 8/7/2019 1:33 AM |
| 9 | Not sure yet. | 8/7/2019 1:31 AM |
| 10 | what specific geo-material problems recur regarding #5 Excavation of hard rock | 8/7/2019 1:22 AM |
| 11 | What would be a very-cost effective and important study to engage in - something that has a high benefit to cost ratio? Answer: Data validity test program for fully grouted vibrating-wire piezometer installations. | 8/7/2019 1:20 AM |
| 12 | What advance technologies are available for inspections, planning data, and construction? What is the return on investment for using these technologies? | 8/6/2019 1:51 PM |
| 13 | The questions were a little general. I may have created more of a survey tree where questions got a little more specific based upon the answers provided. | 8/6/2019 8:57 AM |
| 14 | a clearer objective for conducting this survey would be nice | 8/6/2019 8:13 AM |

# Q8 Are you qualified to answer questions related to geotechnical field explorations?

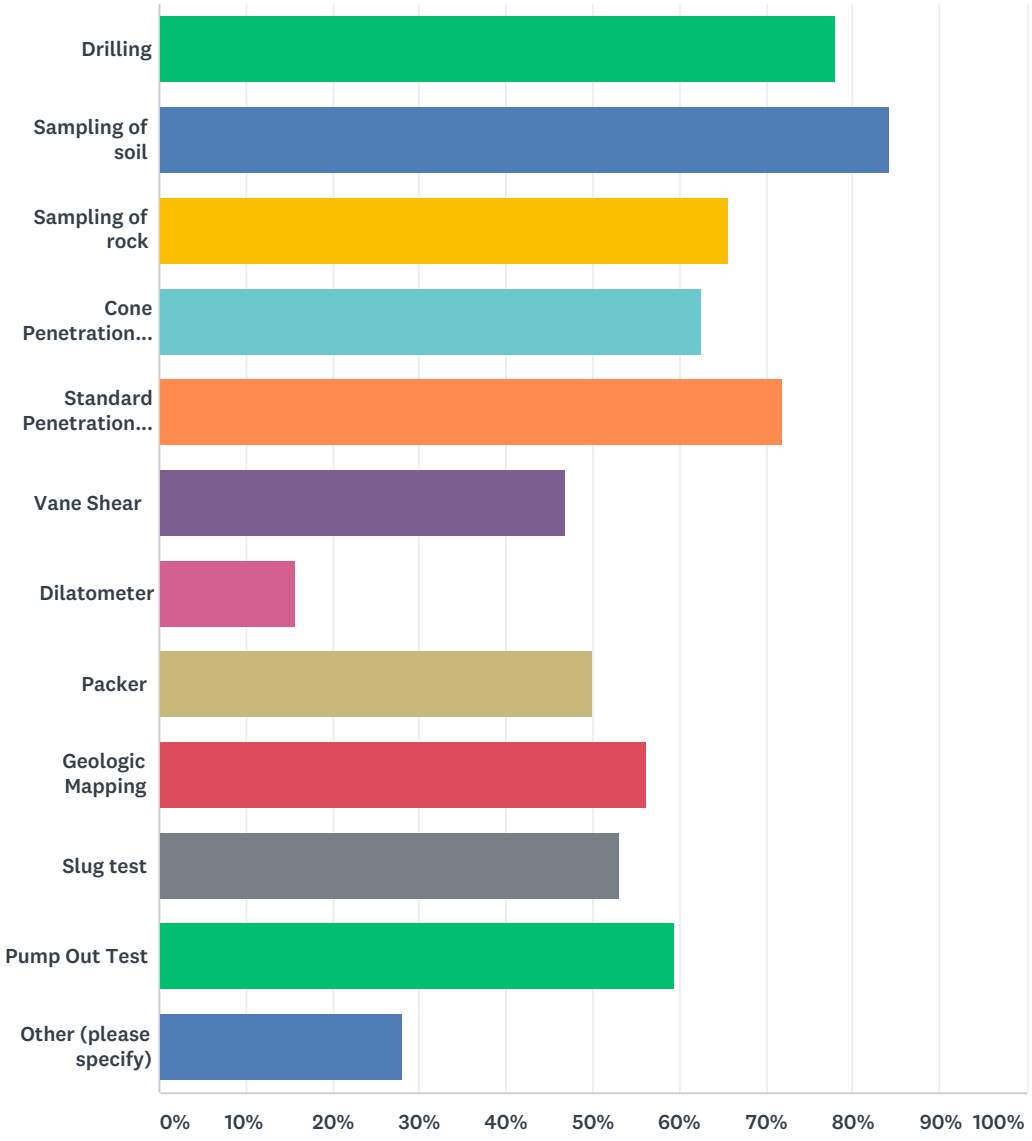
Answered: 45 Skipped: 25




| ANSWER CHOICES | RESPONSES | |
|---|---|---|
| Yes | 82.22% | 37 |
| No | 17.78% | 8 |
| TOTAL | | 45 |

# Q9 What kind of field investigations do you perform? (choose all that apply)

Answered: 32 Skipped: 38




| ANSWER CHOICES | RESPONSES | |
|---|---|---|
| Drilling | 78.13% | 25 |
| Sampling of soil | 84.38% | 27 |
| Sampling of rock | 65.63% | 21 |
| Cone Penetration Testing | 62.50% | 20 |
| Standard Penetration Testing | 71.88% | 23 |
| Vane Shear | 46.88% | 15 |
| Dilatometer | 15.63% | 5 |

| | | |
|---|---|---|
| Packer | 50.00% | 16 |
| Geologic Mapping | 56.25% | 18 |
| Slug test | 53.13% | 17 |
| Pump Out Test | 59.38% | 19 |
| Other (please specify) | 28.13% | 9 |
| Total Respondents: 32 | | |

| # | OTHER (PLEASE SPECIFY) | DATE |
|---|---|---|
| 1 | Geophysical/Remote Sensing mapping & imaging | 8/19/2019 8:46 AM |
| 2 | I haven't performed any of these in 20 years, but I frequently use results of all. | 8/15/2019 3:56 AM |
| 3 | test pits | 8/14/2019 9:19 AM |
| 4 | testing of concrete properties | 8/12/2019 3:55 AM |
| 5 | Test pits | 8/8/2019 2:46 AM |
| 6 | I don't actually do these, but I request them | 8/7/2019 3:52 AM |
| 7 | Do not personally perform these explorations, but have directed their use or evaluated the results of the investigations. | 8/7/2019 1:42 AM |
| 8 | Instrumented monitoring | 8/7/2019 1:24 AM |
| 9 | Our office identifies and funds the conducting of drilling programs for Reclamation | 8/6/2019 1:56 PM |

# Q10 What improvements could be made to the field investigation procedures and data reporting?

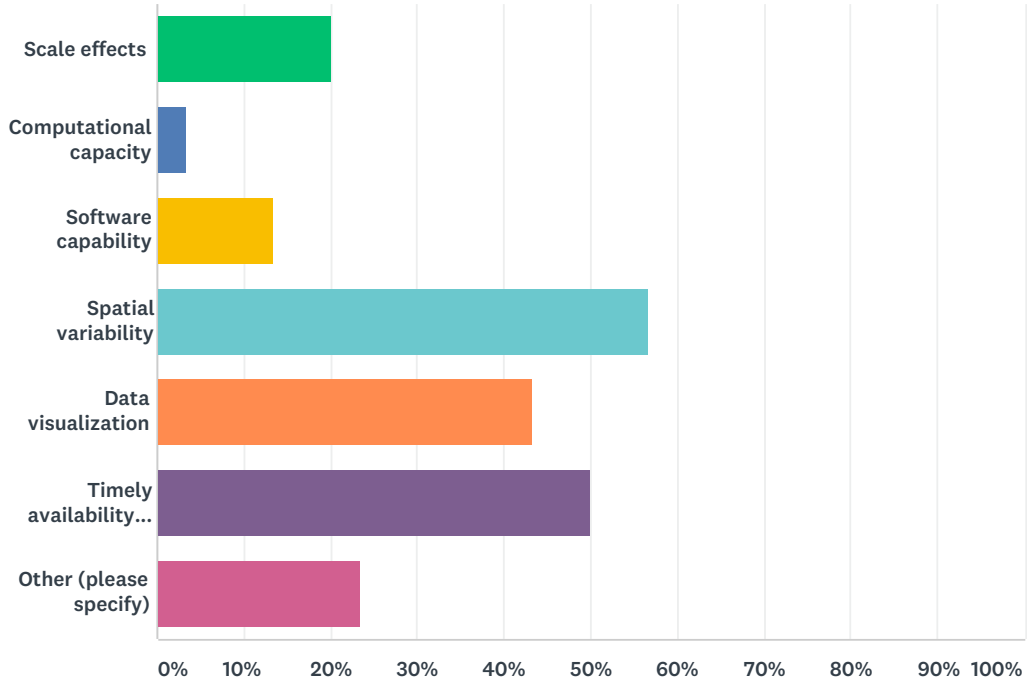
Answered: 27 Skipped: 43

| # | RESPONSES | DATE |
|---|---|---|
| 1 | Faster turn around of field data to lab to design team. Designs seem to always be ahead of field data. | 9/30/2019 7:39 AM |
| 2 | More timely development of FERs, as well as ensuring that all key design team members from project office are involved. | 8/26/2019 5:59 AM |
| 3 | Ensure that the current geology is reviewed and what drilling and sampling techniques have been successful and unsuccessful | 8/26/2019 4:01 AM |
| 4 | Data reporting: I would like to see a method to more effectively share video collected in the field. Small cameras and even cell phone cameras can easily capture video of shallow boreholes, for example on spillways, but it can be difficult to disperse this information. | 8/20/2019 12:36 PM |
| 5 | -Integration of new sensing technologies into SOPs for Reclamation. -Speed/efficiency of data collection and post-processing workflows. -More comprehensive spatio-temporal data coverage. -Better integration with overall programmatic efforts. | 8/19/2019 8:46 AM |
| 6 | Faster geologic report writing. | 8/19/2019 8:24 AM |
| 7 | improve schedule to get geology reports from Regions | 8/14/2019 9:19 AM |
| 8 | I recommend a more comprehensive software for logging and visualizing subsurface materials | 8/13/2019 5:42 AM |
| 9 | Have Reclamation follow ASTM standards and begin phasing out the use of the earth manual. | 8/12/2019 4:02 AM |
| 10 | Timing is the most difficult in collecting and receiving data. This may not be able to be "improved" however as things take time. | 8/12/2019 3:55 AM |
| 11 | I don't really have any comments on this as I feel that this is one area that Reclamation still does well. | 8/8/2019 2:46 AM |
| 12 | Being prepared before heading out. Everything is go go go, noone takes the time to think and prepare before going out that money is wasted. Sending data in real time can be good and bad. Later we could decide something is classified or identified as something different, which could change the entire outcome. | 8/7/2019 11:47 AM |
| 13 | The engineers need a better understanding of how field samples are collected and what the data really means. The geologist need to understand what the engineer design data needs are and how they interpret the data. | 8/7/2019 6:41 AM |
| 14 | Data collection being collected digitally with a geologic log being generated in real time. | 8/7/2019 5:41 AM |
| 15 | Collecting relatively undisturbed samples of fine grain low plastic soils. Designing and conducting adequate pump testing for use in dewatering design. | 8/7/2019 3:52 AM |
| 16 | Using standardized forms across Reclamation for slug tests and pump out tests. Also, improving understanding of the difference between a slug test, and the rock permeability testing outlined in Reclamation's engineering geology handbook and the groundwater manual. | 8/7/2019 2:16 AM |
| 17 | Things that work well are having standardized forms (which has been typical in the past). Ongoing communication between those in field and office, so changes can be made as needed or based on preliminary results. | 8/7/2019 1:42 AM |
| 18 | More timely distribution of geologic investigation reports | 8/7/2019 1:36 AM |
| 19 | Data validity testing program regarding fully grouted vibrating-wire piezometer installations. | 8/7/2019 1:24 AM |
| 20 | My project flows from design to build and has little time for data collection and evaluation before construction | 8/7/2019 1:23 AM |
| 21 | From a business line standpoint clear protocol and data standards for reporting field investigations would improve consistency in drilling programs performs across the agency. | 8/6/2019 1:56 PM |

| | | |
|---|---|---|
| 22 | Projects should be scheduled to allow time for field investigations to be finalized and the resulting data to be used in the project. Educate management, team leaders etc. of the time required for permitting, performance and documentation of field investigations. Standardization of intact sampling. Depending on the geotechnical engineer some projects want CA sampler, Shelby tube sample, lexan tube sample etc. There are definite advantages to one kind over the other however, the type of sampling is determined by personal preference rather than technical reasons. | 8/6/2019 9:22 AM |
| 23 | My initial thoughts on this subject are more programmatic and not applicable. | 8/6/2019 9:01 AM |
| 24 | Streamline resources for engineering parameters obtained by various methodology; couple with typical uses for various engineering parameters. | 8/6/2019 8:33 AM |
| 25 | UAV surveys for geologic mapping, tablet-based drillhole logging | 8/6/2019 8:22 AM |
| 26 | incorporating technology and electronic devices to collect data | 8/6/2019 8:19 AM |
| 27 | Additional technical training for field staff, more modern (electronic) logging and data collection methods, greater number of field staff to enable quicker turnaround on field data analysis and more project continuity. | 8/6/2019 7:52 AM |

# Q11 What do you see as the two greatest challenges to incorporate field and lab data into final design?

Answered: 30 Skipped: 40



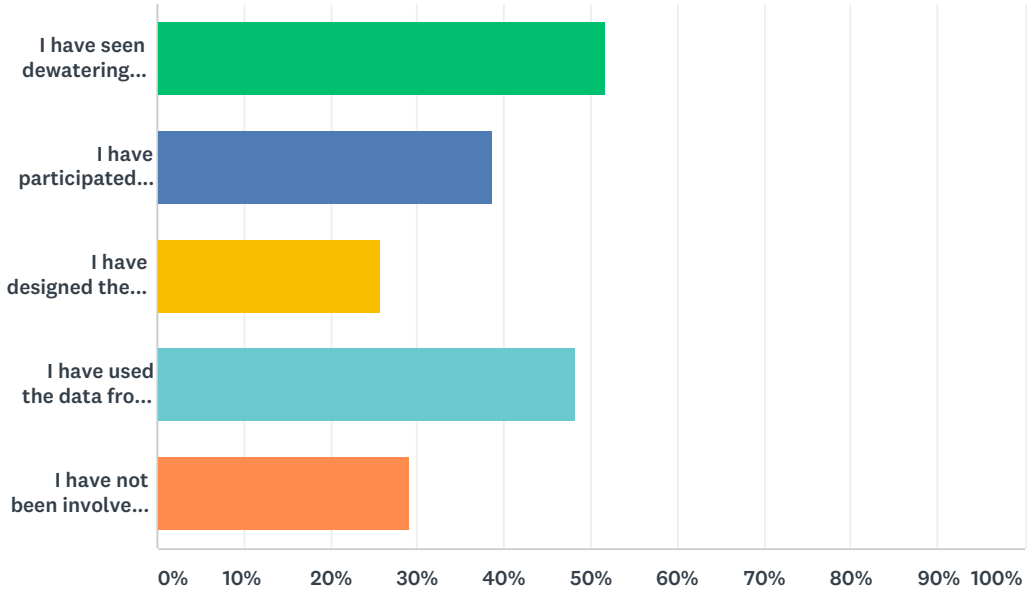

| ANSWER CHOICES | RESPONSES | |
|---|---|---|
| Scale effects | 20.00% | 6 |
| Computational capacity | 3.33% | 1 |
| Software capability | 13.33% | 4 |
| Spatial variability | 56.67% | 17 |
| Data visualization | 43.33% | 13 |
| Timely availability of data | 50.00% | 15 |
| Other (please specify) | 23.33% | 7 |
| Total Respondents: 30 | | |

| # | OTHER (PLEASE SPECIFY) | DATE |
|---|---|---|
| 1 | Lack of communication between divisions and groups | 8/19/2019 8:46 AM |
| 2 | The big problem is performing field investigations after the final design is already realized. Field investigations seem to be limited by budget and the dam safety office and the design engineers don't have the data they need to conduct the design. The biggest challenge therefore is schedule and budget driven projects. Geologic field investigations seem to be led by the lab instead of the geologists. | 8/12/2019 4:54 AM |
| 3 | Sometimes there is so much data presented, it's difficult to decipher which information is needed for certain calculations | 8/12/2019 3:55 AM |
| 4 | Getting the comments from lab data into the specs during spec reviews. | 8/8/2019 2:46 AM |

| | | |
|---|---|---|
| 5 | Selecting parameters based on wide ranges of results to represent various soil units. (Could be what is meant with spatial variability above) | 8/7/2019 3:52 AM |
| 6 | Data validity testing program regarding fully grouted vibrating-wire piezometer installations. | 8/7/2019 1:24 AM |
| 7 | Management | 8/6/2019 9:22 AM |

# Q12 What has been your experience with dewatering field explorations? (choose all that apply)

Answered: 31 Skipped: 39




| ANSWER CHOICES | RESPONSES | |
|---|---|---|
| I have seen dewatering field explorations performed | 51.61% | 16 |
| I have participated in dewatering field explorations | 38.71% | 12 |
| I have designed the dewatering field explorations | 25.81% | 8 |
| I have used the data from the dewatering field explorations | 48.39% | 15 |
| I have not been involved with dewatering related field explorations | 29.03% | 9 |
| Total Respondents: 31 | | |

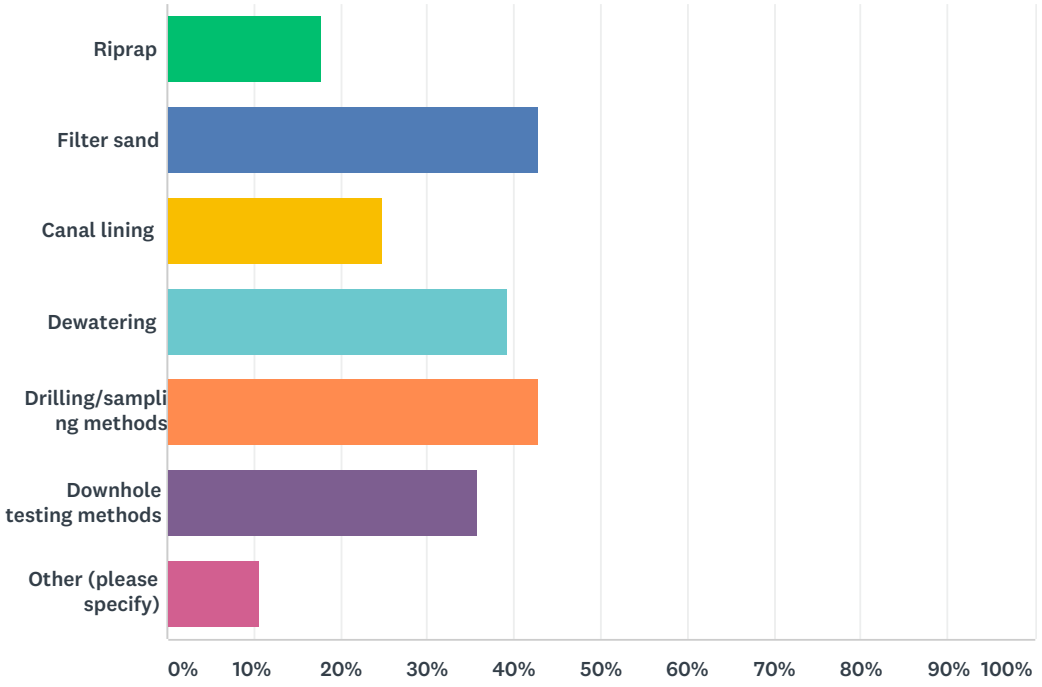
# Q13 What could be improved in dewatering field explorations?

Answered: 24 Skipped: 46

| # | RESPONSES | DATE |
|---|---|---|
| 1 | Reliability | 9/30/2019 7:39 AM |
| 2 | More timely dissemination of data for the design engineers. | 8/26/2019 5:59 AM |
| 3 | Review and Understand the subsurface conditions. Ensure the screening and test method will provide useful results | 8/26/2019 4:01 AM |
| 4 | N/A | 8/20/2019 12:36 PM |
| 5 | not sure- this would be a good area to brainstorm with geotechs/engineers to identify technical challenges that geophysics/RS might be able to help resolve | 8/19/2019 8:46 AM |
| 6 | N/A | 8/13/2019 5:42 AM |
| 7 | Everything! | 8/12/2019 4:54 AM |
| 8 | Train the O&M personnel on why certain dewatering methods work better than others. This would improve their knowledge and make field explorations more effective. | 8/12/2019 4:02 AM |
| 9 | I have not heard any complaints as of now. | 8/12/2019 3:55 AM |
| 10 | This is one area that I would not have any input, as I have seen and participated, but not done enough to have input. | 8/8/2019 2:46 AM |
| 11 | Better collection of data in the field. Groundwater models are only as good as the confidence of the data being put into the model. | 8/7/2019 6:41 AM |
| 12 | implement a staged approach. a few Test borings and slug test should be performed prior to desinging a pump well to ensure adequate pump well diameter, filter sand gradation and pump size. Additionally the drilling using a drilled shaft (cassion) approach should be utilized to minimize smearing within the hole | 8/7/2019 3:52 AM |
| 13 | Standardizing the forms used across regions and TSC, making sure the same core people from TSC have input into dewatering field explorations, making sure that those designing, using the data from, and conducting the dewatering field explorations understand the final design intent of the dewatering system. Compartmentalizing the dewatering field exploration from the design team has, can, and will lead to data gaps in the dewatering design, which will have significant ramifications in terms of construction costs and schedule delays. We need to make sure those designing the dewatering system are involved in every part of the dewatering field explorations. | 8/7/2019 2:16 AM |
| 14 | I have not directly been involved in design or collection of data for dewatering design, only from standpoint of being on project with dewatering. But from that perspective, key thing I see is that more field data always helps better define the design. | 8/7/2019 1:42 AM |
| 15 | ? | 8/7/2019 1:36 AM |
| 16 | Study case histories. | 8/7/2019 1:24 AM |
| 17 | No recommendation | 8/7/2019 1:23 AM |
| 18 | Improved understanding of the applicability of resulting data collected to the fundamental operations of a facility. | 8/6/2019 1:56 PM |
| 19 | Allow enough time allocated for field activities to be permitted, performed and documented. | 8/6/2019 9:22 AM |
| 20 | Again, my initial thoughts are more programmatic and not applicable. | 8/6/2019 9:01 AM |
| 21 | Improve resources for designing test; develop standard language for development of wells (drillers don't read a referenced ASTM) | 8/6/2019 8:33 AM |
| 22 | Better initial understanding of subsurface geology, geometry, and permeability | 8/6/2019 8:22 AM |
| 23 | ? | 8/6/2019 8:19 AM |
| 24 | We need to do more testing. | 8/6/2019 7:52 AM |

# Q14 What two geotechnical topics could use a past-performance evaluation to guide future work?

Answered: 28 Skipped: 42

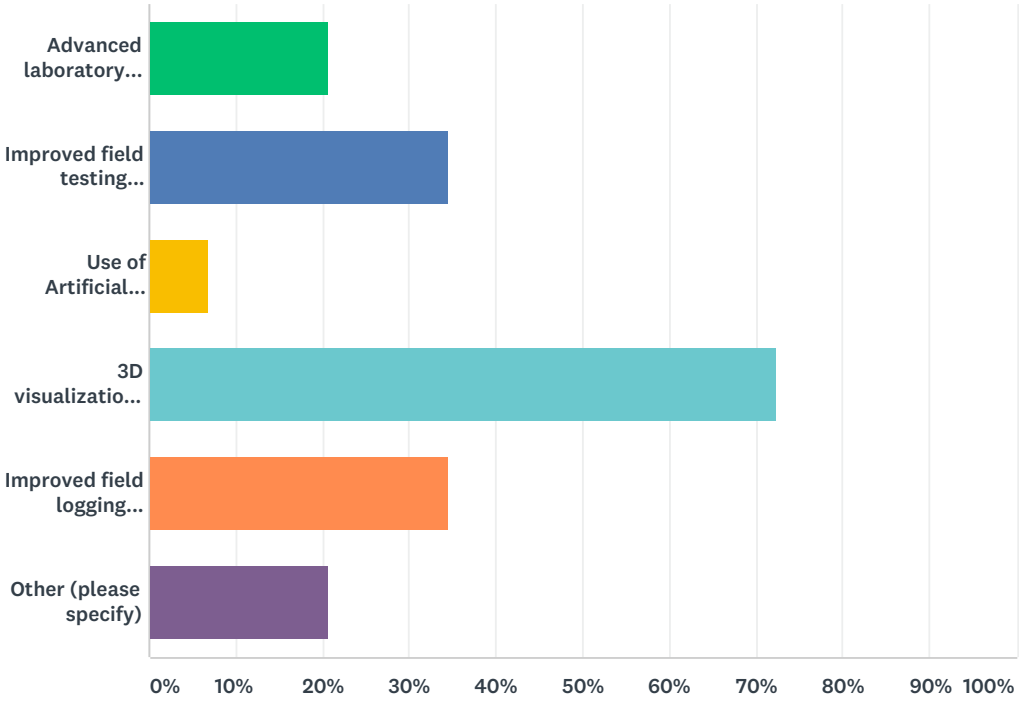



| ANSWER CHOICES | RESPONSES | |
|---|---|---|
| Riprap | 17.86% | 5 |
| Filter sand | 42.86% | 12 |
| Canal lining | 25.00% | 7 |
| Dewatering | 39.29% | 11 |
| Drilling/sampling methods | 42.86% | 12 |
| Downhole testing methods | 35.71% | 10 |
| Other (please specify) | 10.71% | 3 |
| Total Respondents: 28 | | |

| # | OTHER (PLEASE SPECIFY) | DATE |
|---|---|---|
| 1 | See my previous response on doing a past-performance evaluation for dewatering; involve TSC designers as the dewatering design team is working on re-evaluating past projects and methods. | 8/7/2019 2:16 AM |
| 2 | Long-term performance of filter sand (blinding??) | 8/7/2019 1:36 AM |
| 3 | Data validity testing program regarding fully grouted vibrating-wire piezometer installations. | 8/7/2019 1:24 AM |

# Q15 What do you see as the two best methods to improve Reclamation's geotechnical investigations?

Answered: 29 Skipped: 41




| ANSWER CHOICES | RESPONSES | |
|---|---|---|
| Advanced laboratory testing (i.e. bender elements, resonant column, acoustic emissions, etc.) | 20.69% | 6 |
| Improved field testing procedures | 34.48% | 10 |
| Use of Artificial Neural Networks in data analysis | 6.90% | 2 |
| 3D visualization of subsurface data | 72.41% | 21 |
| Improved field logging capability | 34.48% | 10 |
| Other (please specify) | 20.69% | 6 |
| Total Respondents: 29 | | |

| # | OTHER (PLEASE SPECIFY) | DATE |
|---|---|---|
| 1 | None of those seem relevant to the problems we are having with dewatering. It needs to start with basic common sense. | 8/12/2019 4:54 AM |
| 2 | Archival of data, use of GIS | 8/7/2019 6:41 AM |
| 3 | Statistical evaluation of available data. | 8/7/2019 3:52 AM |
| 4 | Not sure. | 8/7/2019 1:42 AM |
| 5 | Data validity testing program regarding fully grouted vibrating-wire piezometer installations. | 8/7/2019 1:24 AM |
| 6 | Training/education of standards, create a library of reports and documents from past work. | 8/6/2019 9:22 AM |

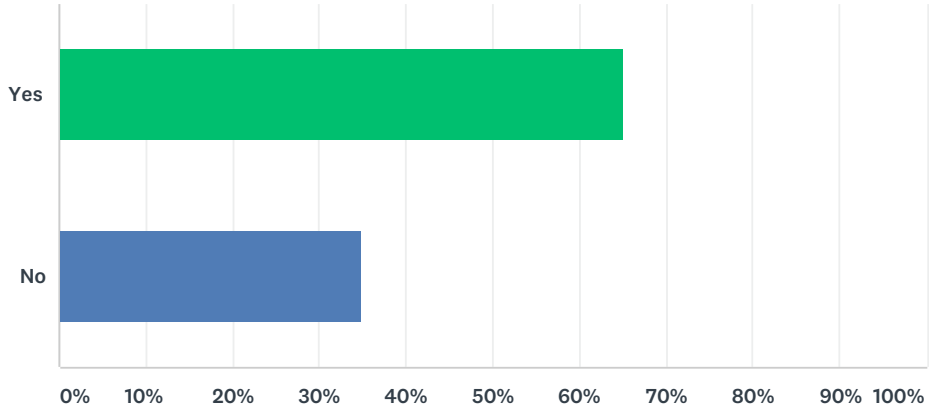
# Q16 What question should we have asked? What is the answer?

Answered: 10 Skipped: 60

| # | RESPONSES | DATE |
|---|---|---|
| 1 | Have we used this method successfully in this type of material | 8/26/2019 4:01 AM |
| 2 | How can geophysical imaging be better utilized to help inform and guide geologic and geotechnical investigations, or to maximize the value of information from each other? Answer: Always perform geophysics first, then geologic/getech data collection based on results of geophysics, targeting anomalous zones/areas of concern or interest. Then follow up with data integration, calibration, and determine suitability for development of site-specific correlation relationships (e.g., regression between s-wave tomography velocity and shear strength or other parameter of interest). ~OR~ How can geotech/geologic/geophysical field explorations be more fully utilized by engineers in subsequent modeling efforts? What specific data deliverables are needed/would be more easily used by engineers, for sake of parameterizing models or for minimizing uncertainty? Answer(?): Better communication of needs from engineers, and better integration and presentation of data/results from geo folks? More portable/useful electronic deliverable file formats? | 8/19/2019 8:46 AM |
| 3 | N/A | 8/8/2019 2:46 AM |
| 4 | How can communication be improved between geotech, geology, the Region and the lab to better geotechnical investigations. | 8/7/2019 6:41 AM |
| 5 | Field exploration is constrained by costs and timelines. Anything that can improve efficiency of collecting data, or ways to collect as much information as possible from an individual drillhole using multiple techniques. | 8/7/2019 1:42 AM |
| 6 | ? | 8/7/2019 1:36 AM |
| 7 | None. | 8/7/2019 1:24 AM |
| 8 | Can lidar work for my projects? Yes | 8/7/2019 1:23 AM |
| 9 | How do the drilling programs and processes differ across Reclamation? Is there a need or opportunity to standardize? Is there a central data system or resource for past analysis of each Reclamation facility. | 8/6/2019 1:56 PM |
| 10 | NA | 8/6/2019 9:01 AM |

# Q17 Are you qualified to answer questions related to geotechnical laboratory work and how it relates to design?

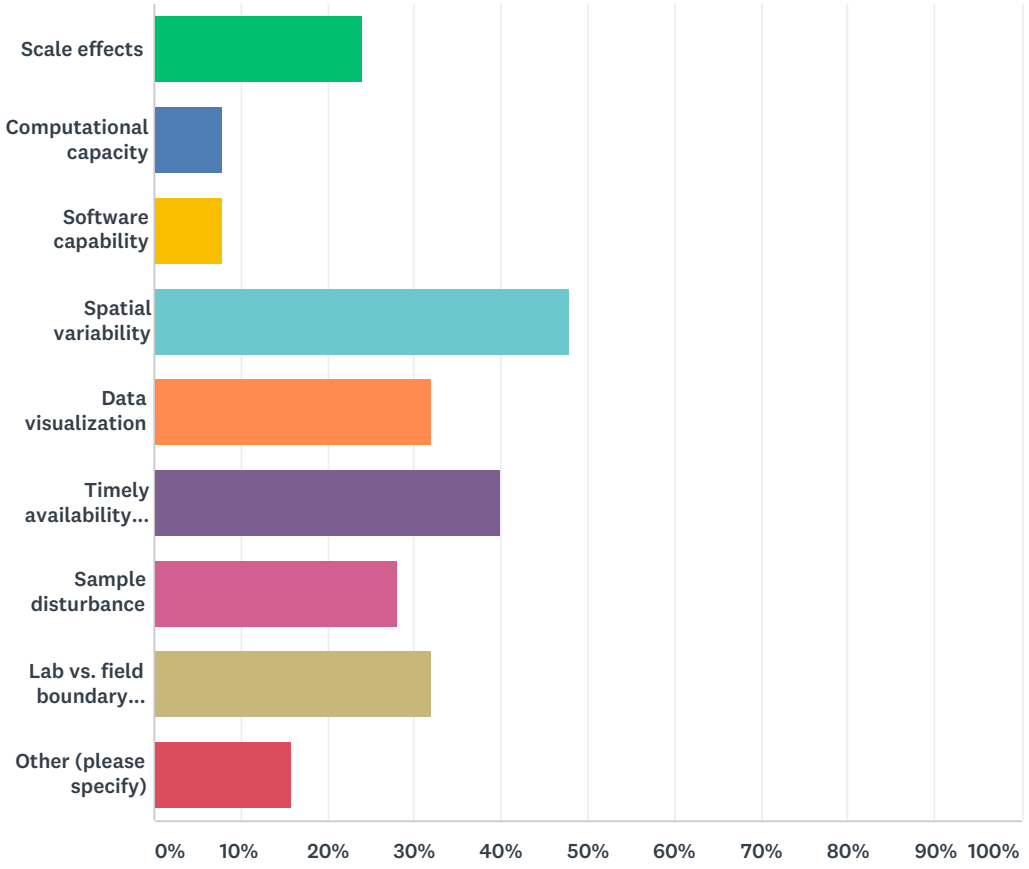
Answered: 40 Skipped: 30




| ANSWER CHOICES | RESPONSES | |
|---|---|---|
| Yes | 65.00% | 26 |
| No | 35.00% | 14 |
| TOTAL | | 40 |

# Q18 What do you see as the three greatest challenges to incorporate field and lab data into final design?

Answered: 25 Skipped: 45



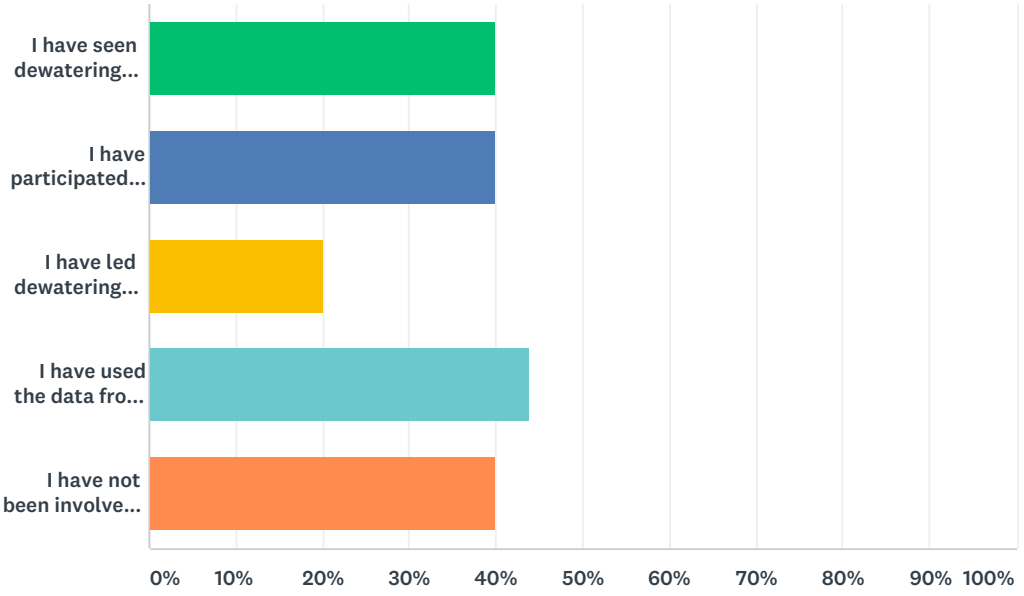

| ANSWER CHOICES | RESPONSES | |
|---|---|---|
| Scale effects | 24.00% | 6 |
| Computational capacity | 8.00% | 2 |
| Software capability | 8.00% | 2 |
| Spatial variability | 48.00% | 12 |
| Data visualization | 32.00% | 8 |
| Timely availability of data | 40.00% | 10 |
| Sample disturbance | 28.00% | 7 |
| Lab vs. field boundary conditions | 32.00% | 8 |
| Other (please specify) | 16.00% | 4 |
| Total Respondents: 25 | | |

| # | OTHER (PLEASE SPECIFY) | DATE |
|---|---|---|
| 1 | None of the above. The problems stem from a lack of common sense and experience. | 8/12/2019 5:00 AM |

| | | |
|---|---|---|
| 2 | Ensure comments get into the specs during spec reviews | 8/8/2019 2:50 AM |
| 3 | relation of old data a process to new testing and data, statisitcal evaluation wide ranges of results (including field and laboratory together) | 8/7/2019 3:57 AM |
| 4 | 1) Cost to complete testing (sampling and lab work). 2) Scope/level of investigation requested vs. what is required to adequately design a project. | 8/6/2019 9:08 AM |

# Q19 What has been your experience with dewatering design? (choose all that apply)

Answered: 25 Skipped: 45




| ANSWER CHOICES | RESPONSES | |
|---|---|---|
| I have seen dewatering design performed | 40.00% | 10 |
| I have participated in dewatering design | 40.00% | 10 |
| I have led dewatering design efforts | 20.00% | 5 |
| I have used the data from the dewatering design | 44.00% | 11 |
| I have not been involved with dewatering design | 40.00% | 10 |
| Total Respondents: 25 | | |

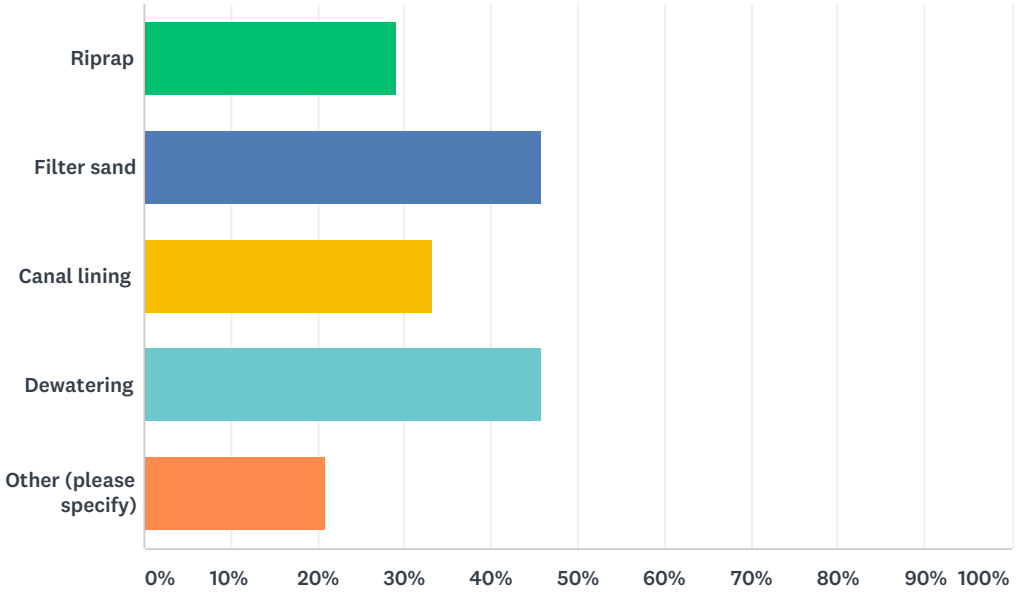
# Q20 What could be improved in dewatering design? What are the unanswered questions?

Answered: 20 Skipped: 50

| # | RESPONSES | DATE |
|---|---|---|
| 1 | Reliability | 9/30/2019 7:40 AM |
| 2 | N/A to me | 8/19/2019 8:18 AM |
| 3 | More in-house expertise. We are getting good experiences recently by designing our own dewatering systems. | 8/14/2019 9:22 AM |
| 4 | N/A | 8/13/2019 5:44 AM |
| 5 | A basic knowledge of groundwater conditions at the site. Field investigations designed to understand baseline conditions. Experience with dewatering design seems to be lacking or even non-existent in Reclamation. | 8/12/2019 5:00 AM |
| 6 | N/A. | 8/12/2019 4:04 AM |
| 7 | It is difficult to design dewatering effectively unless the testing is in the exact location as the intended dewatering work. There are so many unknowns towards the beginning of the project (usually when the FER is being developed) that if the design were to change, conditions for dewatering may change drastically. | 8/12/2019 4:03 AM |
| 8 | N/A | 8/8/2019 2:50 AM |
| 9 | This question has been answered previously | 8/7/2019 8:13 AM |
| 10 | adequate pump testing | 8/7/2019 3:57 AM |
| 11 | We need better design intent, and design data, sharing across groups from the lab, to the designer, to construction personnel. There will always be unanswered questions in dewatering design, that is the nature of that type of work. It would be best for everyone involved to realize that you can never be 100% correct, so you need to design the dewatering systems to be flexible. That design flexibility still requires quality field data, but it also requires a lot of solid communication between the people gathering the data, the people using the data, and the people making decisions about the project overall. | 8/7/2019 2:31 AM |
| 12 | This ties back to exploration, in the better the site and materials are characterized, the better the design results will be. | 8/7/2019 1:47 AM |
| 13 | Additional pumping tests during field investigation and design. use of resistivity instruments to monitor groundwater level changes during pumoing tests. | 8/7/2019 1:39 AM |
| 14 | No recommendation | 8/7/2019 1:23 AM |
| 15 | Lessons learned and education of standards. What are the best methods for the conditions. | 8/6/2019 9:28 AM |
| 16 | I have not been with dewatering design. | 8/6/2019 9:27 AM |
| 17 | This appears to be a very challenging model/science, and the results are widely varied (resulting in significant ranges on the schedule and budget to complete). Any methods that could be used to reduce the uncertainty, without substantially increasing the design time, would be beneficial. | 8/6/2019 9:08 AM |
| 18 | See previous answers | 8/6/2019 9:04 AM |
| 19 | ? | 8/6/2019 8:23 AM |
| 20 | NA | 8/6/2019 7:54 AM |

# Q21 What two geotechnical topics could use a past-performance evaluation to guide future work?

Answered: 24 Skipped: 46

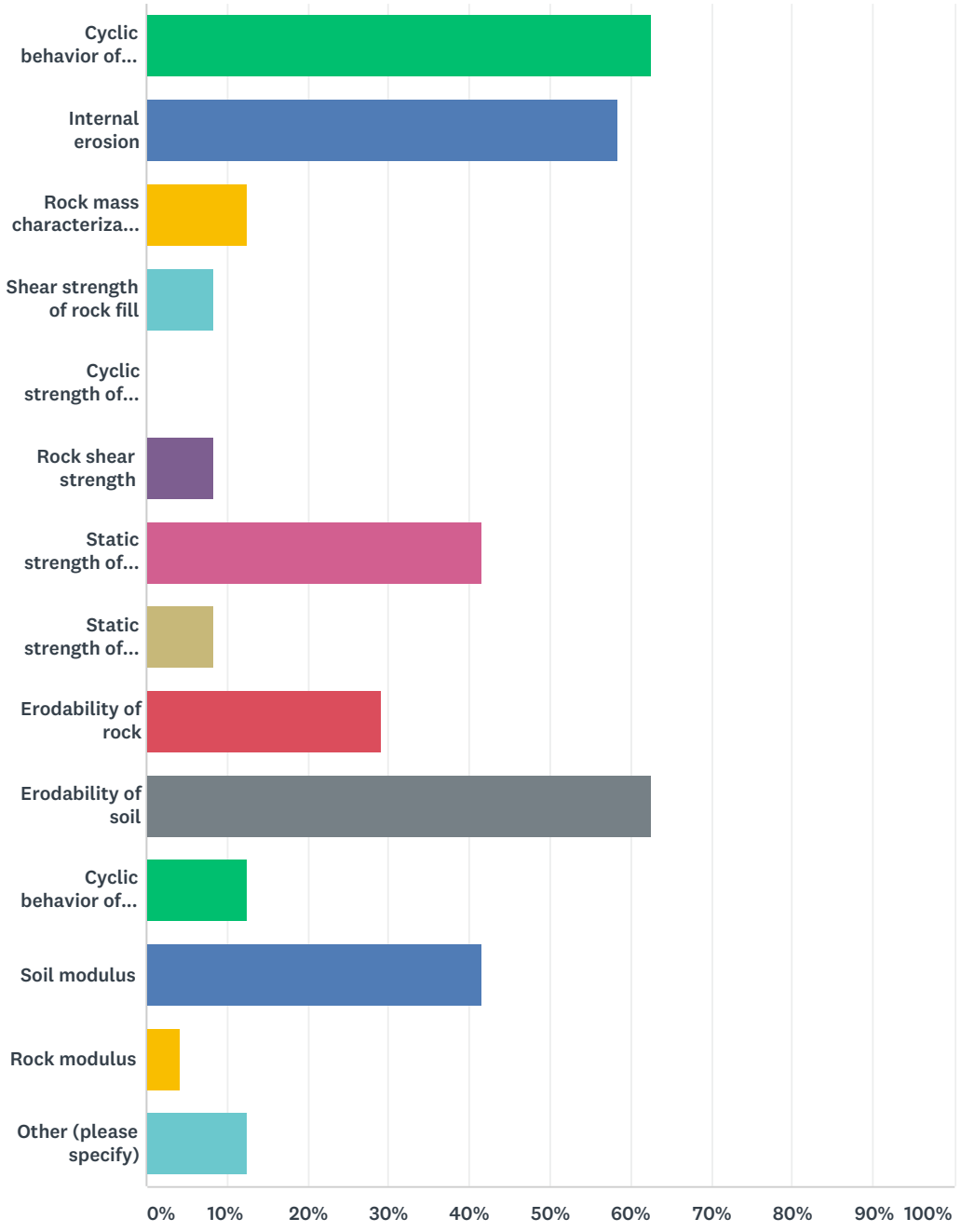



| ANSWER CHOICES | RESPONSES | |
|---|---|---|
| Riprap | 29.17% | 7 |
| Filter sand | 45.83% | 11 |
| Canal lining | 33.33% | 8 |
| Dewatering | 45.83% | 11 |
| Other (please specify) | 20.83% | 5 |
| Total Respondents: 24 | | |

| # | OTHER (PLEASE SPECIFY) | DATE |
|---|---|---|
| 1 | Large-strain shear strength of silts and clays. | 8/19/2019 8:18 AM |
| 2 | Please see my past responses about dewatering; TSC designers are currently revamping how the dewatering design process was done previously. Dovetail past performance evaluations with them. | 8/7/2019 2:31 AM |
| 3 | see above | 8/7/2019 1:39 AM |
| 4 | Impact of gravel on liquefaction | 8/6/2019 9:27 AM |
| 5 | Various types of levees and their evaluation/design for performance. | 8/6/2019 9:08 AM |

# Q22 What are the four most important laboratory-scale geotechnical research topics?

Answered: 24 Skipped: 46



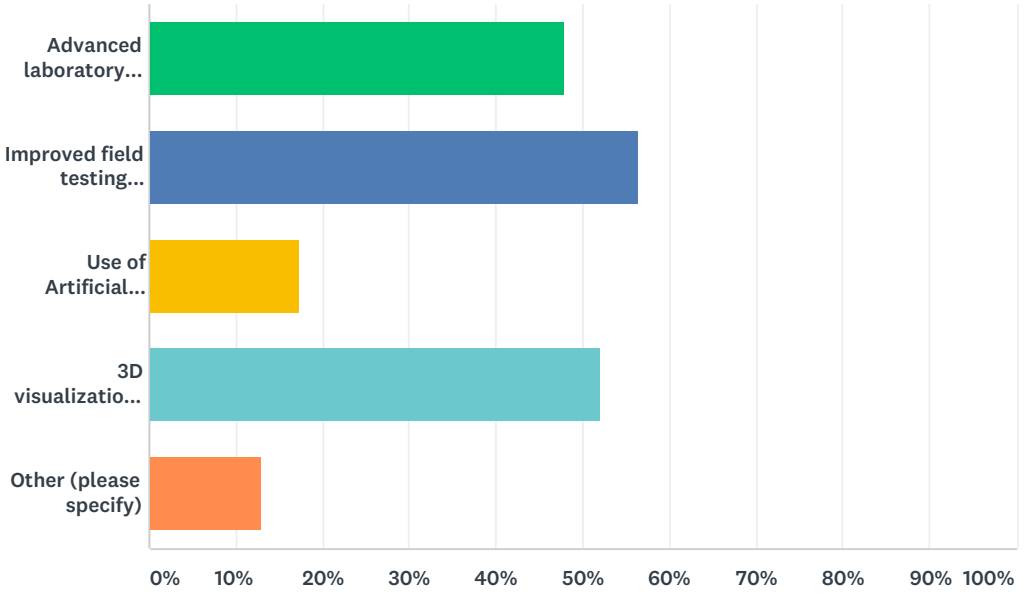

| ANSWER CHOICES | RESPONSES | |
|---|---|---|
| Cyclic behavior of soil | 62.50% | 15 |
| Internal erosion | 58.33% | 14 |
| Rock mass characterization | 12.50% | 3 |
| Shear strength of rock fill | 8.33% | 2 |

| | | |
|---|---|---|
| Cyclic strength of rock fill | 0.00% | 0 |
| Rock shear strength | 8.33% | 2 |
| Static strength of soil | 41.67% | 10 |
| Static strength of rock | 8.33% | 2 |
| Erodability of rock | 29.17% | 7 |
| Erodability of soil | 62.50% | 15 |
| Cyclic behavior of rock | 12.50% | 3 |
| Soil modulus | 41.67% | 10 |
| Rock modulus | 4.17% | 1 |
| Other (please specify) | 12.50% | 3 |
| Total Respondents: 24 | | |

| # | OTHER (PLEASE SPECIFY) | DATE |
|---|---|---|
| 1 | Our problem is too much lab work, with not enough geologic data to characterize the site and interpret the lab results | 8/12/2019 5:00 AM |
| 2 | Better field classification to laboratory results consistency | 8/6/2019 9:08 AM |
| 3 | The influence of K-alpha on liquefaction triggering analysis in sandy-silty soils | 8/6/2019 8:25 AM |

# Q23 What do you see as the two best methods to improve Reclamation's geotechnical investigations?

Answered: 23 Skipped: 47




| ANSWER CHOICES | RESPONSES | |
|---|---|---|
| Advanced laboratory testing (i.e. bender elements, resonant column, acoustic emissions, etc.) | 47.83% | 11 |
| Improved field testing procedures | 56.52% | 13 |
| Use of Artificial Neural Networks in data analysis | 17.39% | 4 |
| 3D visualization of subsurface data | 52.17% | 12 |
| Other (please specify) | 13.04% | 3 |
| Total Respondents: 23 | | |

| # | OTHER (PLEASE SPECIFY) | DATE |
|---|---|---|
| 1 | More site characterization, less lab work | 8/12/2019 5:00 AM |
| 2 | No comment | 8/8/2019 2:50 AM |
| 3 | Allow time for permitting, performance and documentation prior to final design, develop a library of reports and documents | 8/6/2019 9:28 AM |

# Q24 What question should we have asked? What is the answer?

Answered: 7 Skipped: 63

| # | RESPONSES | DATE |
|---|---|---|
| 1 | Advancements to help with seismic design would be most beneficial (i.e. specific soil behavior to earthquake loads especially pressures on a retaining wall). Short of an LSDYNA model, Woods and M-O are the only methods we have as of now. | 8/12/2019 4:03 AM |
| 2 | N/A | 8/8/2019 2:50 AM |
| 3 | This question was answered previously | 8/7/2019 8:13 AM |
| 4 | not sure | 8/7/2019 1:47 AM |
| 5 | ? | 8/7/2019 1:39 AM |
| 6 | No recommendation | 8/7/2019 1:23 AM |
| 7 | NA | 8/6/2019 9:04 AM |

# Q27 Additional comments

Answered: 12 Skipped: 58

| # | RESPONSES | DATE |
|---|---|---|
| 1 | Hope this was helpful!!! | 8/19/2019 8:47 AM |
| 2 | I work in waterways and concrete dams group. So I'm more geared towards concrete issues. | 8/13/2019 3:28 AM |
| 3 | None | 8/8/2019 2:50 AM |
| 4 | Thank you Evan, for the opportunity to take this survey | 8/7/2019 8:14 AM |
| 5 | There seemed to be a very large emphasis on dewatering field testing. As evidenced by my responses, please coordinate dewatering field testing with the TSC dewatering team. We (Reclamation) need to make sure that the people designing dewatering systems are involved with gathering the dewatering field data. There is too much uncertainty to compartmentalize any segment of the dewatering design/data collection/construction process. | 8/7/2019 2:34 AM |
| 6 | none | 8/7/2019 1:39 AM |
| 7 | None. | 8/7/2019 1:24 AM |
| 8 | Thank you for including the operation and maintenance community in your outreach. If we can provide additional information on your road map please let us know. Geotechnical research topics are of great importance to our organization. | 8/6/2019 2:00 PM |
| 9 | I should have said I was not qualified to answer the construction questions. I didn't know what I was getting myself into. :-) | 8/6/2019 9:29 AM |
| 10 | Thank you for the opportunity to participate. | 8/6/2019 9:04 AM |
| 11 | Not sure if I was knowledgeable enough to answer questions about the construction issues, but I answered anyways. | 8/6/2019 8:26 AM |
| 12 | Thank you very much conducting such a well-run and important survey. | 8/6/2019 7:55 AM |