Review & Discussion of Integrated Site Characterization Approach

[Questions to ask in reviewing work as it is planned, executed, and documented]

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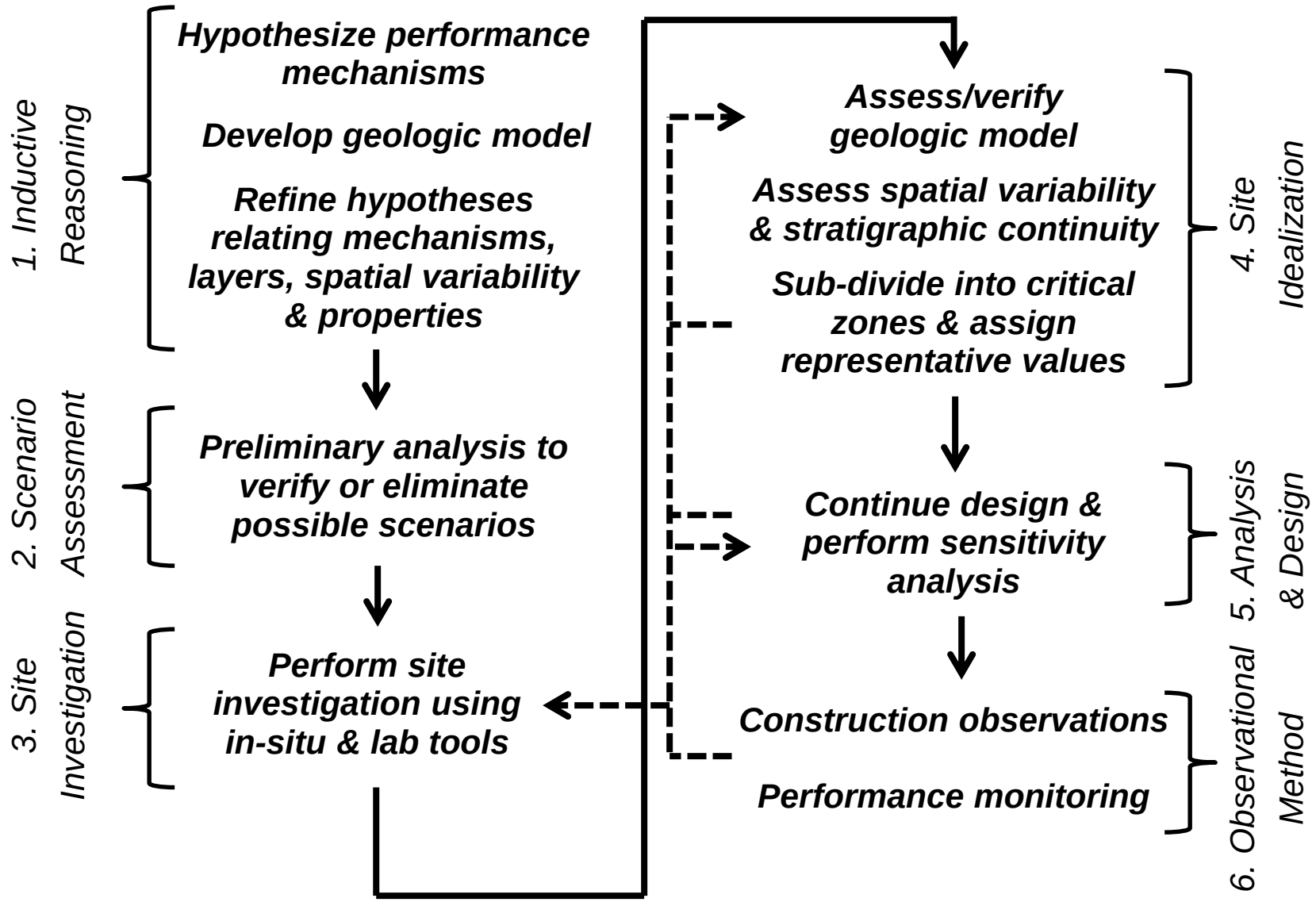
Site Characterization Process



Step 0: …Before You Start

- *What areas of expertise are necessary for the project, and who will fill each role?*
- *Who has expertise/experience on similar projects, and are they sufficiently engaged?*
- *What past experience/knowledge do we have in the project's geological setting (same or similar)?*
- *What analogs exist at/near the project site that indicate possible controlling mechanisms, performance issues, and design solutions?*
- *To what extent, and in what capacity, must a geologist be involved in formulating, and later revising, the geologic model?*
- *Have sufficient time and budget been allocated for stages besides the site investigation (SI) stage? If not, how must the scope of SI be reduced?*
- *After/during which stages should we perform internal/external project review?*

Step 1.1: Hypothesize Performance Mechanisms

- *What mechanisms influenced the performance of prior structures at or near the site?*
- *What mechanisms have controlled the design or performance of similar structures in the region?*
- *Given the current project design, what mechanisms likely control performance?*
- *For each potential mechanism identified:*
  - *what is the mechanism length scale?*
  - *what soil zones are engaged in the mechanism?*
  - *what are the relevant soil engineering properties?*
- *How was the likelihood of the different potential mechanisms ranked?*

Step 1.2: Develop Geologic Model

- *How has prior geologic mapping (regional and site-specific) been incorporated into the model?*
- *What information from historical documentation (site work, construction photos, post-EQ reconnaissance, aerial photos) influenced the model?*
- *For each geologic and earthwork zone:*
  - *what were the depositional and weathering processes?*
  - *what is the expected spatial variability?*
  - *what is the expected composition (grain size, plasticity)?*
  - *what is the expected anisotropy (layering, fracturing, strike/dip)?*
- *Which soft/weak/permeable layers have been problematic in the past or may be in the future?*
- *What are the groundwater conditions and how do/will they vary in time?*
- *How was seismic activity assessed, and is it a concern?*

Step 1.3: Refine Hypotheses Relating Mechanisms, Layers, Spatial Variability & Properties

- *What information was primarily relied upon in refining certain hypothesized mechanisms and excluding others?*
- *For each mechanism how did the geologic model influence the ranked likelihood of occurrence and identification of zones expected to control performance?*
- *Are there particular stratigraphic layers that will (likely) control/limit/guide multiple mechanisms?*
- *What historic/regional data was used to develop estimates of spatial variability and soil properties?*
- *What representative value of soil properties have been selected considering the length scale of the mechanism relative to the stratigraphic continuity of the controlling zone(s)?*

Step 2: Preliminary Analysis to Verify or Eliminate Possible Scenarios

- *What is the simplified, idealized project cross-section that represents the most likely site conditions?*
- *For the critical soil layers, what are the range of best-case and worst-case conditions for soil layer extent, continuity, and properties?*
- *What simplified analysis methods were used, and are the simplifying assumptions required acceptable at this stage?*
- *Based on the sensitivity analysis, reducing the uncertainty of which conditions (layer extent, continuity, properties) would provide the greatest reduction in performance uncertainty?*
- *Based on the sensitivity analysis, is understanding the spatial variability or obtaining accurate soil property measurements more important?*
- *Would it be beneficial (if possible) to perform future detailed analyses in a probabilistic manner, or is a deterministic approach sufficient given the unknowns and criticality of the structure?*
- *Are the outcomes of this stage consistent with observations at similar structures in the region?*

Step 3: Perform Site Investigation Using In-situ & Lab Tools

- *Given the expected spatial variability, what priority was given to mapping variability versus obtaining detailed engineering property characterization?*
- *What best practices for in-situ testing, drilling & sampling, and laboratory testing were used given the soil types and stratigraphic layering anticipated?*
- *Was the sequencing of field work appropriate for verifying the geologic model prior to detailed engineering property determination?*
- *Was a systematic approach used to assess spatial variability (e.g. multiple CPTs performed at varying spacings)?*
- *Did the insitu and laboratory testing focus on the characterizing the correct properties, and if so, was there redundancy in characterization methods to cross-verify property estimates?*
- *How do measurements obtained compare with historical data and standard literature values?*
- *Have data obtained been presented in a transparent format that readily allows side-by-side comparison of different types of information?*
- *What aspect of the geologic model was least characterized during SI?*

Step 4.1: Assess/verify Geologic Model

- *What important changes/updates to the initial geologic model were made based on the additional information obtained during the SI?*
- *What site investigation (SI) data conflicted with the initial geologic model?*
- *Did the SI lead to changes in the understanding of the depositional and weathering mechanisms?*
- *Did the SI reveal previously unknown/unexpected zones?*
- *What SI data forced zones/layers to be redefined?*
- *Was sufficient data collected to characterize these unknown/unexpected zones?*
- *Does the geologic model reasonably explain the soil characteristics encountered on-site (e.g. gravels, clays)?*

Step 4.2: Assess Spatial Variability & Stratigraphic Continuity

- *How was the SI data used to quantitatively assess the spatial variability of critical zones?*
- *Is the distribution (COV) of relevant property (e.g. GSD, $(N_1)_{60}$) measurements in critical zones consistent with typical literature values, more uniform, or more variable?*
- *What 16%, 33%, and 50% values for critical design properties?*
- *Were soil properties and penetration resistances amenable to normalization for dependence on overburden stress?*
- *How does the spatial extent of the zones of interest compare with the length scale of the mechanism(s)?*
- *Were particular zones identified that could be critical for seepage?*
- *Were particular zones identified that may be amenable to sand-like liquefaction or clay-like strain softening during earthquake loading?*

Step 4.3: Sub-divide into Critical Zones & Assign Representative Values

- *What data led to some stratigraphic units being sub-divided based on difference in properties (e.g. gradation, strength, permeability, saturation)?*
- *Were continuous zones of weakness identified that may lead to localization of the failure mechanism, and if so, how were its properties selected?*
- *Was the length scale of the deformation mechanism comparable (or larger than) to the critical zone such that an average value is appropriate for analysis?*
- *Is the length scale of the deformation mechanism smaller than the critical zone such that a lower value is appropriate for analysis?*
- *If the mechanism intersects multiple zones, how was the interaction effects between zones handled?*
- *How was the final 'baseline' condition selected for analysis & design?*
- *How were differences in property estimates obtained by different methods resolved? (e.g. ϕ' from lab and SPT)*

Step 5: Continue Design & Perform Sensitivity Analysis

- *How does the final 'baseline' condition differ from the simplified, initial 'baseline' condition, and are the changes important to design & analysis?*
- *Were the assumptions made in the initial analysis still acceptable, or were most sophisticated analyses warranted?*
- *How were scenario variations of the 'baseline' case selected and analyzed?*
- *Did the scenarios considered include variations in stratigraphic boundaries/zones, constitutive models, EQ input motions, etc. in addition to variations in soil properties?*
- *How were differences in performance estimates obtained by different methods resolved? (e.g. liq. Triggering from SPT or CPT)*
- *What opportunities exist during construction to further evaluate the design?*

Step 6.1: Construction Observations

- *Were the priority observations to be made during construction (excavation, construction, filling) documented and disseminated to field personnel?*
- *What observations during construction enabled (or could enable) verification of the developed geologic model?*
- *What observations during construction enabled (or could enable) identification of potential seepage issues?*
- *What observations during construction enabled (or could enable) an indirect evaluation (back calculation) of key properties?*
- *What observations during construction revealed (or could reveal) unexpected/unforeseen conditions, and how did these observations influence design/construction?*

Step 6.2: Performance Monitoring

- *What measurements, in what locations and how frequently, will be obtained to monitor the initiation and progression of the controlling mechanisms?*
- *Is the instrumentation system automated, sufficiently detailed to obtain critical measurements, and yet still maintainable?*
- *Is there a long term monitoring contract in place to obtain and interpret the data collected?*
- *Has a logic action decision structure been developed and put in place to trigger decisions and actions when measurement(s) cross pre-defined threshold levels?*
- *Is there a management plan installed to review data collected and update the decision structure on a regular basis?*

Step 7: …As You Finish

- *Is the project documentation and files organized, sufficiently detailed, and archived?*
- *Has the responsibility of the continued performance monitoring plan been clearly assigned/delegated?*
- *With an additional 20% budget supplement what stages and issues would you focus on refining, and what activities would you undertake?*
- *In hindsight, which activities and expenses were excessive and not necessary? Could this of been avoidable?*
- *How should have the geologist been engaged and utilized more effectively?*
- *At what stages during the process would have peer review (internal or external) been beneficial?*
- *What lessons learned on the project would be beneficial to the office/company? How will those lessons be shared?*