DELVE underground

Geotechnical Considerations for Pipeline Projects

Northern California Pipe Users Group

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Our History

Delve Underground, originally Jacobs Associates, was founded by Don Jacobs in 1954.

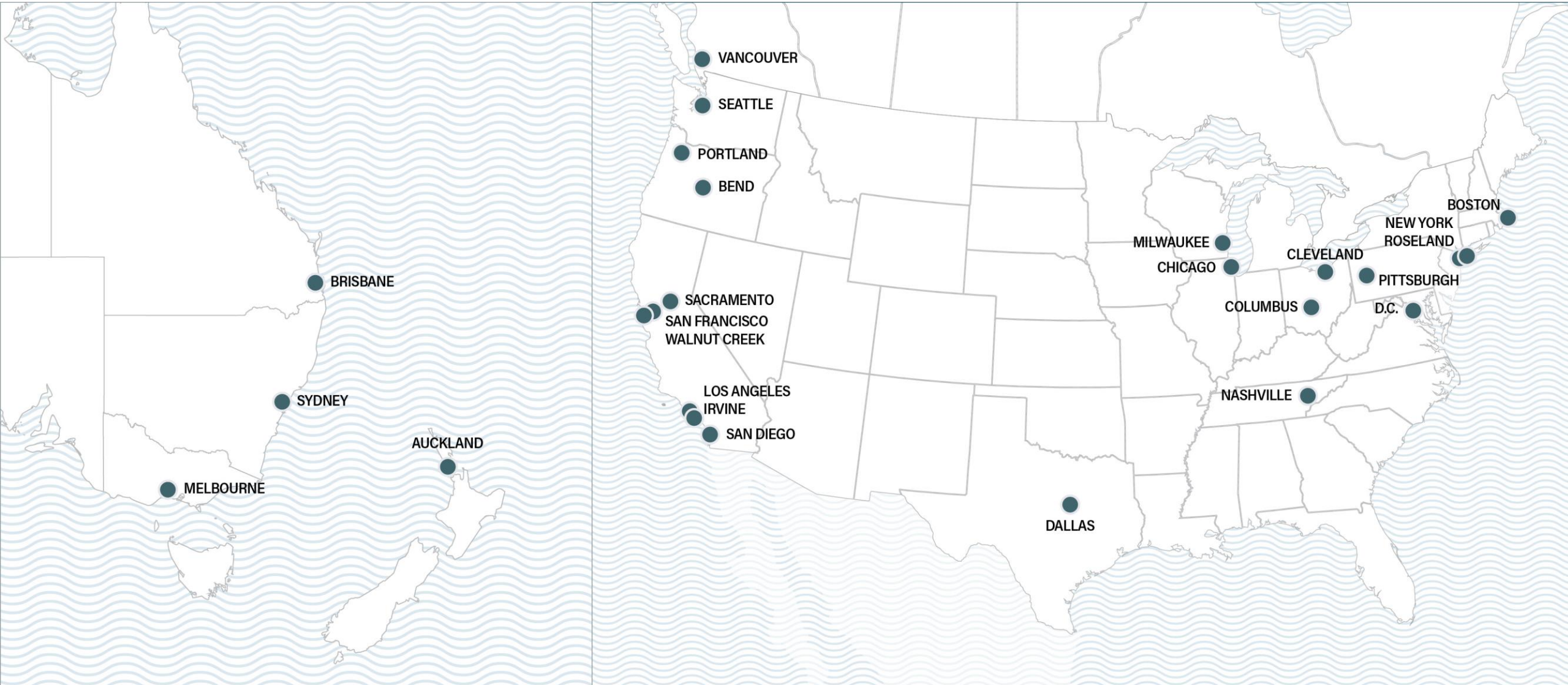
The firm began as “contractor’s engineer” on heavy civil underground projects.

It expanded into design & consulting for owners as market changed.

Snowy Mountains Hydro Scheme, Australia | First project for Delve Underground

Office Locations

350 personnel globally in **25** offices



Overview of Services

- **Tunnels & Underground Engineering**
- **Trenchless Engineering**
- **Tunnel Inspection & Rehabilitation**
- **Engineering Consulting**
  - Geotechnical Engineering
  - Structural Engineering
  - Soil Structure Interaction Modeling
  - Pipeline Engineering
  - Design Technology/ Digital Engineering
  - Civil & Architectural Design
  - Sustainable Design & Construction
  - Risk Assessment & Mitigation
  - Geotechnical Instrumentation
- **Advisory Consulting**
- **Construction Management**
- **Construction Claims Services**

Important geotechnial aspects for pipeline and trenchless design:

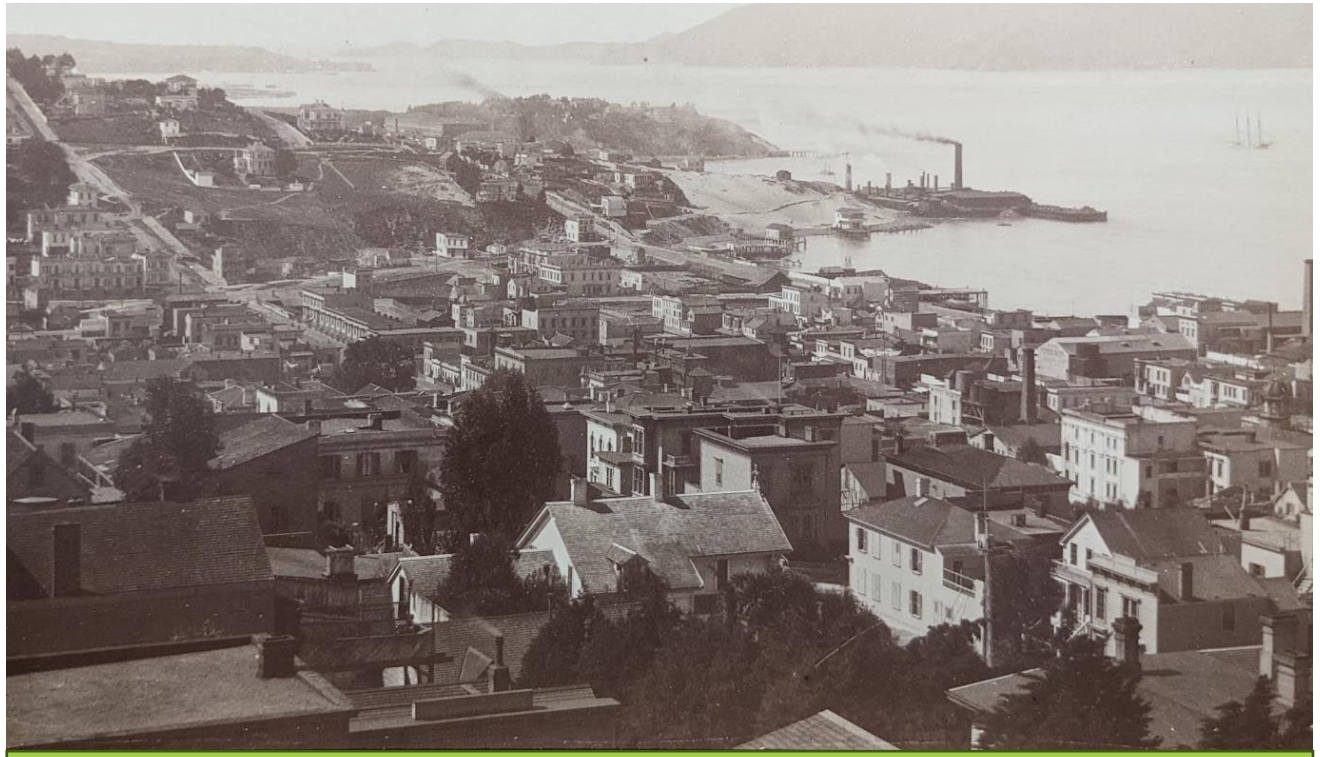
- **Geohazards**
- **Data collection**
- **Design requirements**
- **Construction issues**
- **Geotechnical Instrumentation/Monitoring**

DELVE
underground

Publicly-Available resources

The Desktop Study and Field Reconnaissance

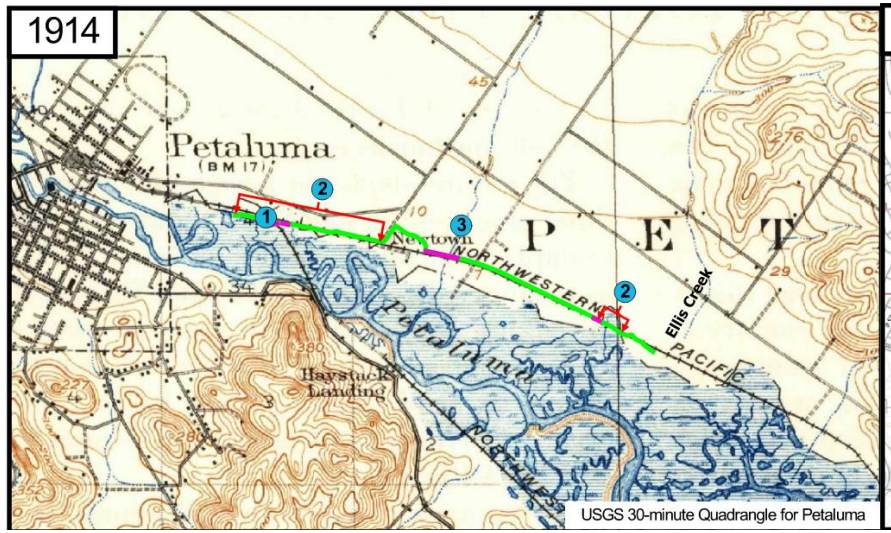
1) **Review historical topographic & geologic maps**
2) **Review historical air photos**
3) **Review groundwater information**
    1) Groundwater depth
    2) Hazardous material concerns?
4) **Other "local" resources**
    1) Historical creek maps
    2) Reference borings
5) **Field Reconnaissance**

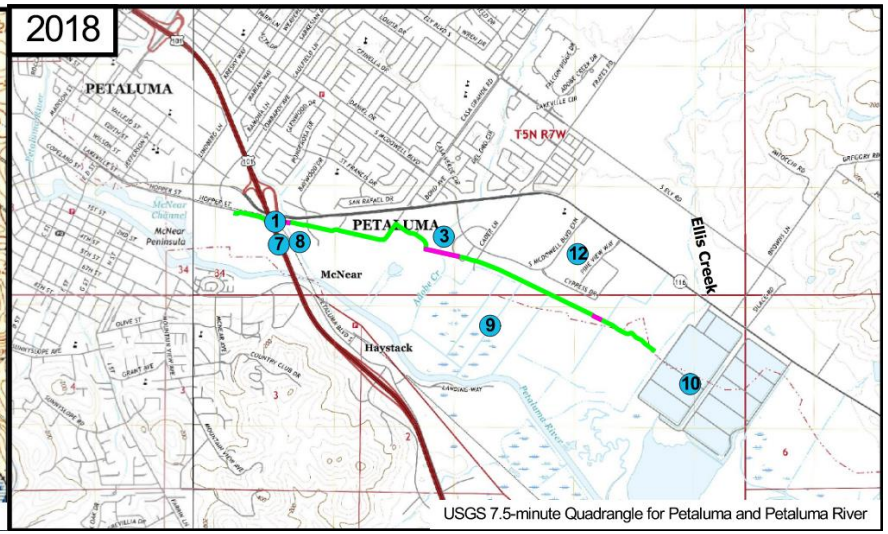


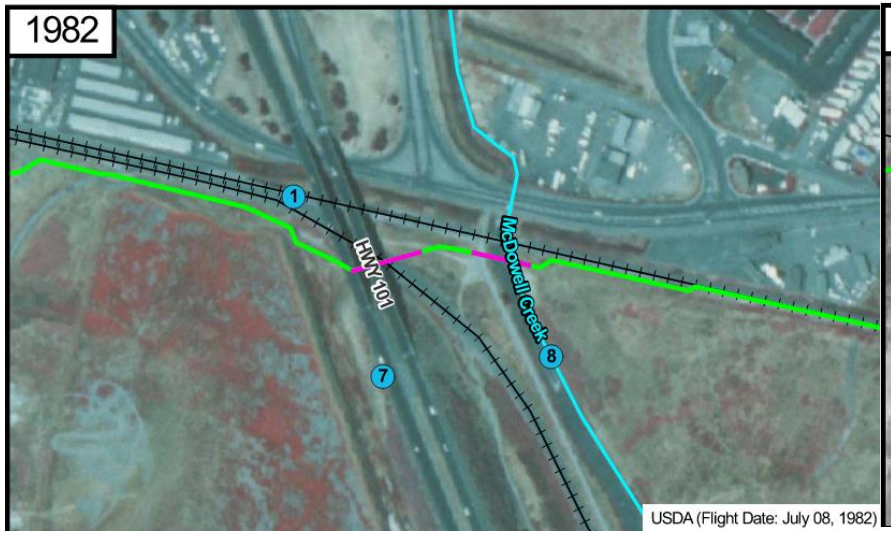
Published Maps

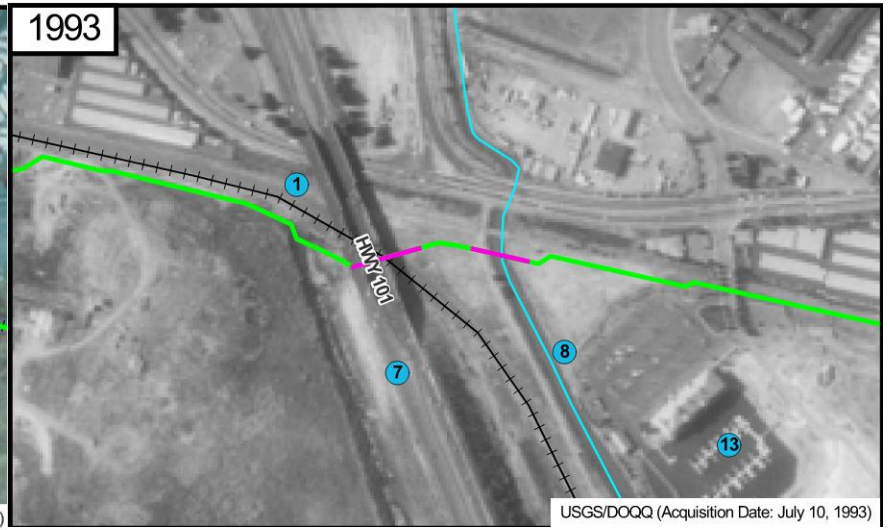
Historical Topographic Maps and Air Photos

- Marsh land
- Drainageways
- Railroad
- Roadways
- Site developments



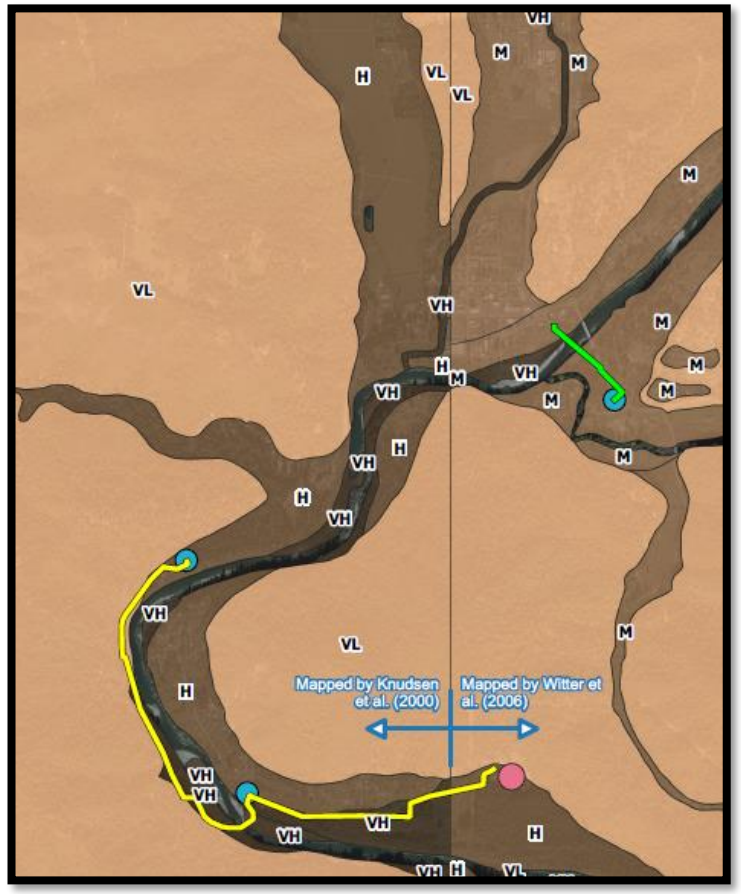


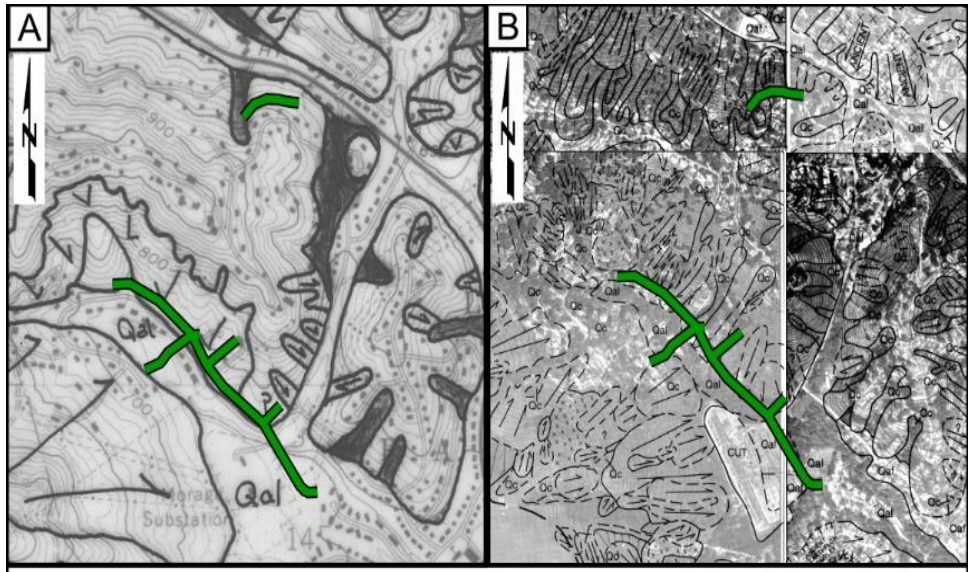




Published Maps

Geologic Map and Geohazard Maps





LEGEND:

- Project alignment

Landslide deposit and direction of movement (queried or dashed where uncertain), and "X" where ancient or indistinct.Debris composed of fresh and weathered rock fragment, sediment, colluvial material and artificial fill.

Qal **Alluvial Deposit** - Irregularly stratified, poorly consolidated deposits of mud, silt, sand, gravel, cobble, and boulder deposited in stream and river beds and on adjoining flood plains.

Qc **Colluvial and/or Alluvial Fan Deposits** - unstratified or poorly stratified, unconsolidated to poorly consolidated deposits composed of fresh and weathered rock fragments, soil, sediment, or irregular mixtures of these materials, that accumulate near the foot of a slope or cliff by slow downslope movement of surficial material predominantly by the action of gravity, but assisted by running water that is not concentrated into channels.

Qaf **Artifical Fill** - Loose to very well consolidated gravel, sand silt, clay, rock fragments, organic matter and debris.

**Interpreted from historic arial photography between 1928 and 1991 and plotted on a 9 March 1991 photograph using National Geodetic Vertical Datum of 1929.*

Maps and descriptions modified from Nilsen 1975 (Map A) and Rogers/Pacific 1991 (Map B)

LEGEND:

- Project alignment

Qa **Surficial sediments** - Alluvial gravel, sand and clay, includes all alluvial fan gravel near foothills.

Qls **Landslide rubble**

Tor **Orinda Formation (Late Miocene)** - Nonmarine, distinctly to indistinctly bedded, gray to greenish gray pebble to boulder conglomerate sandstone, siltstone and claystone; includes basaltic volcanics in some areas.

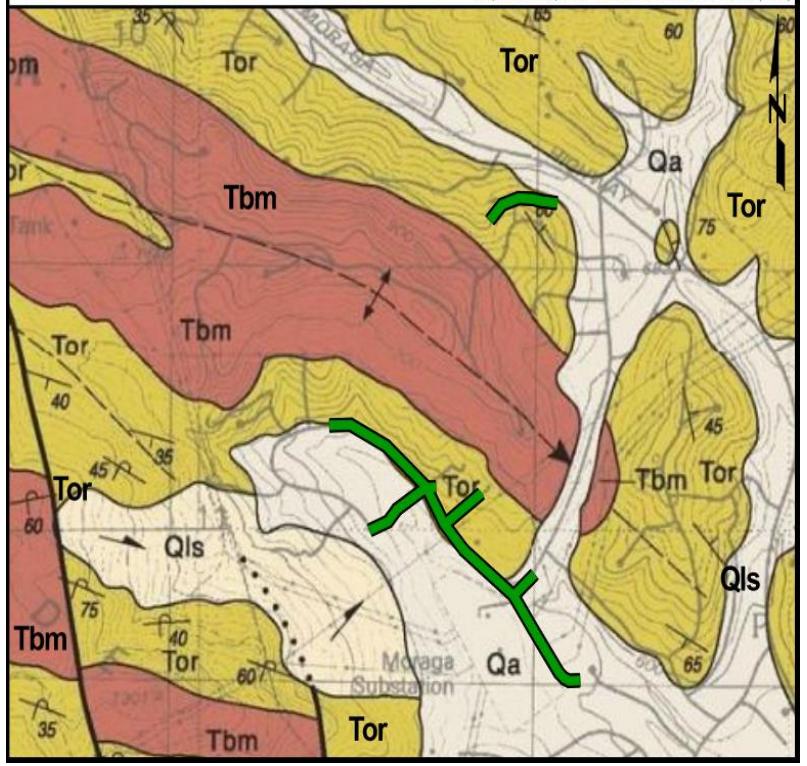
Tbm **Moraga Basalt (Late Miocene)** - Black, fine grained, massive, locally vesicular.

30 Strike and dip of bedding mapped by cited reference.

Fold Axis (Anticline and Syncline as labeled)

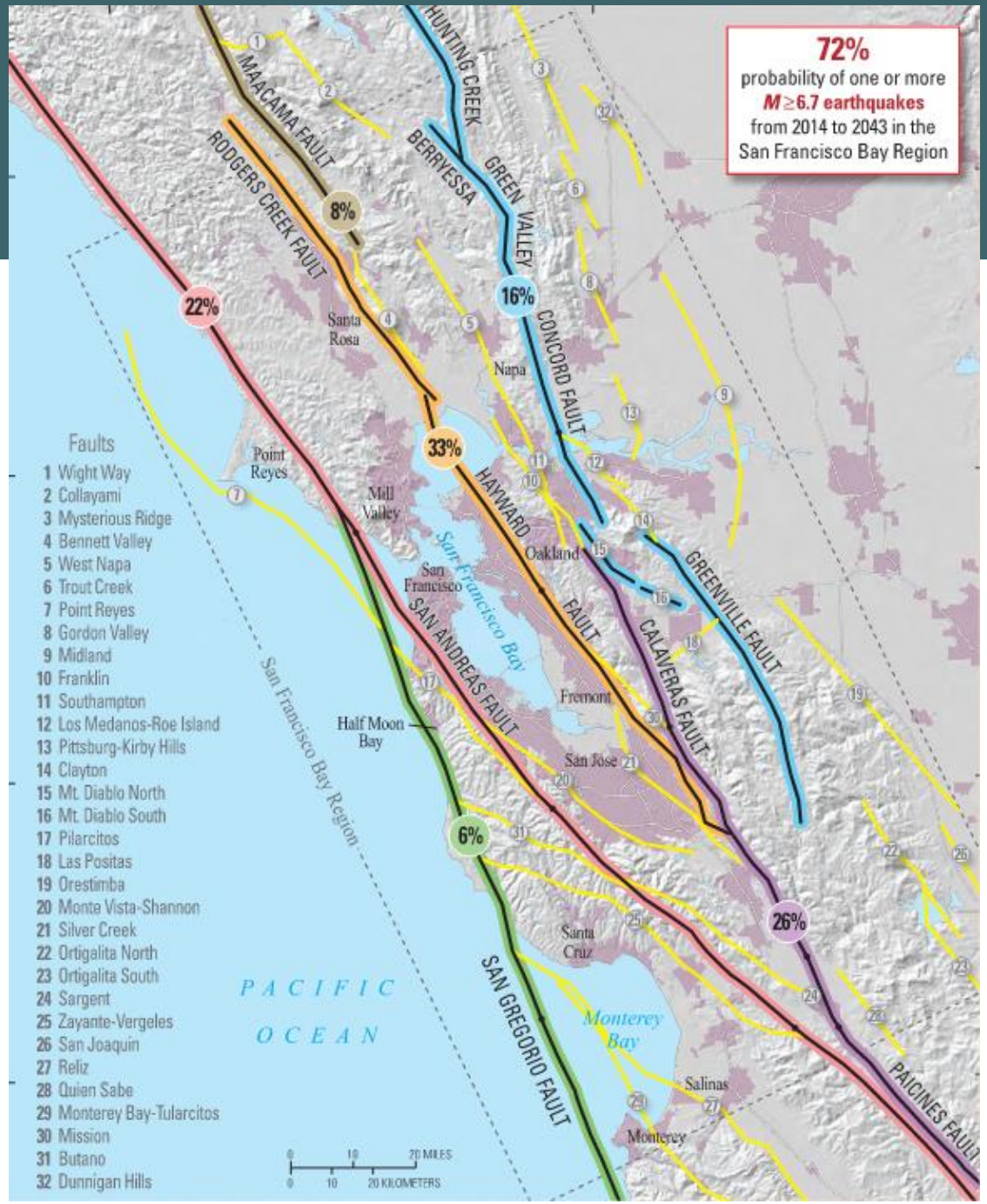
0 850' 1700'

Map and descriptons modified from Dibblee and Minch (2005)



Typical geohazards

- Fault Rupture
- Landslide
- Expansive Soil
- Liquefaction/Lateral Spreading
- Settlement/Subsidence
- High Groundwater
- Flood/Tsunami/SLR



Geohazards

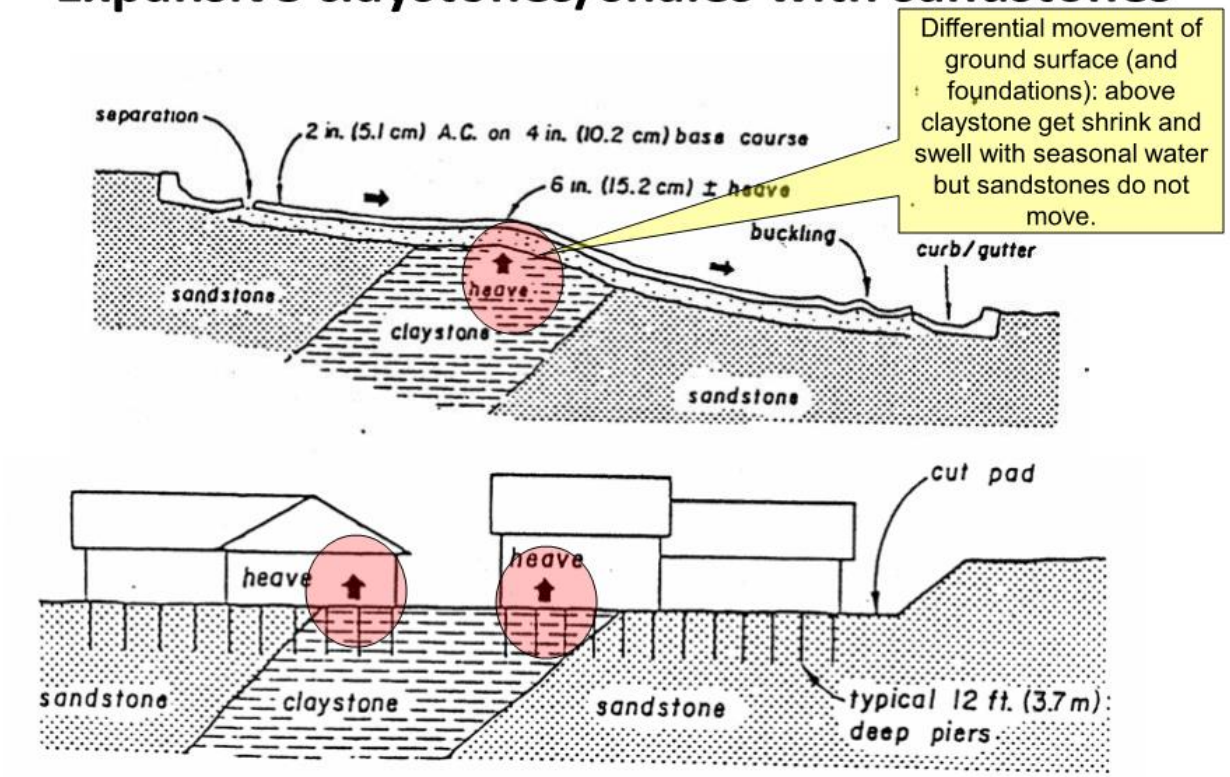
Landslides and Expansion Potential

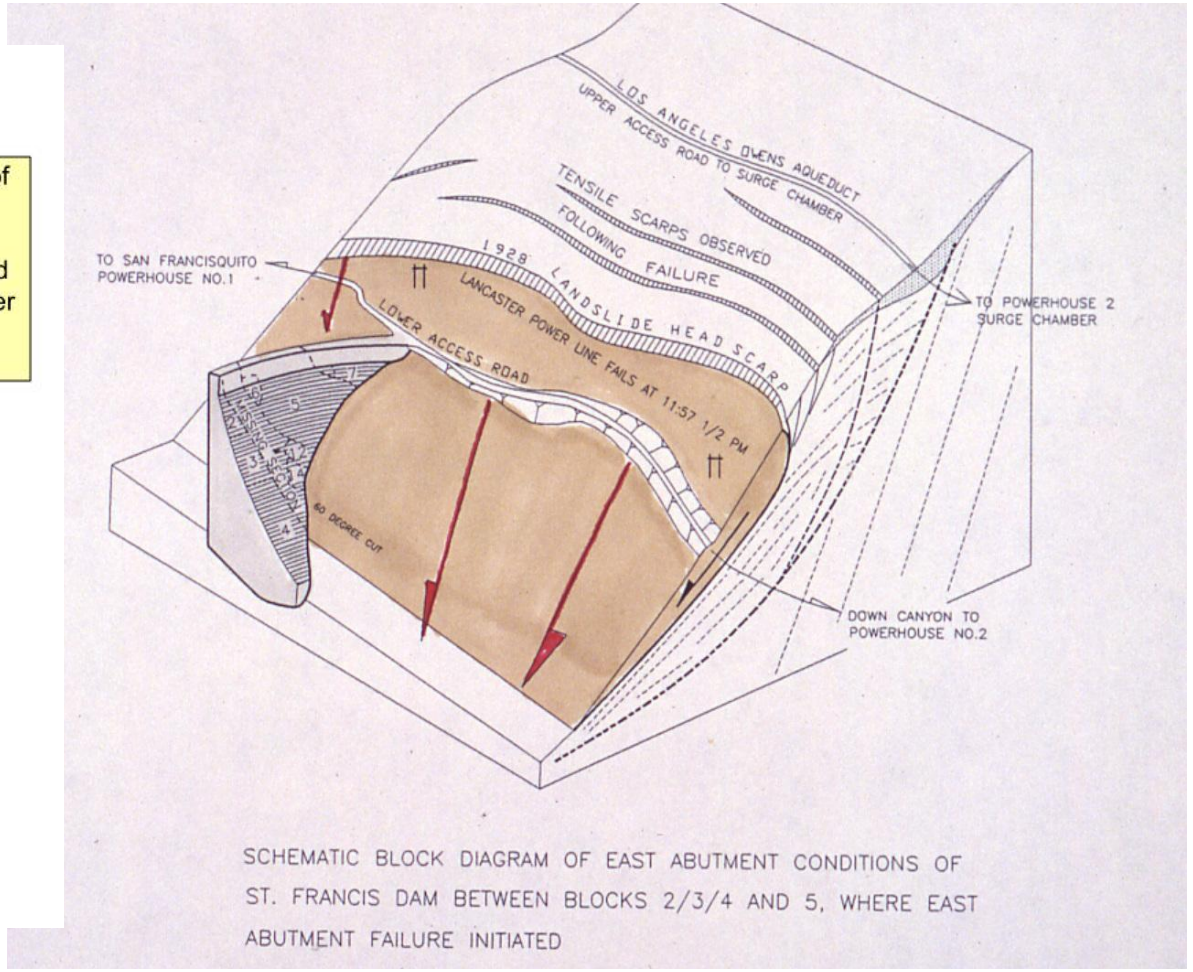
- **Weathering**
- **Swelling**
  - Function of mineralogy, surface water, pore water chemistry, biologic activity (bacteria)
- **Loss of strength**
  - Increased water content leads to loss of strength
- **Slope stability**
- **Loss of strength upon exposure to water**
- **Shrink / Swell (expansivity) potential**
- **Explosive gasses in carbonaceous rock**

Geohazards

Landslides, Adverse Geology, and Expansion Potential

Expansive claystones/shales with sandstones

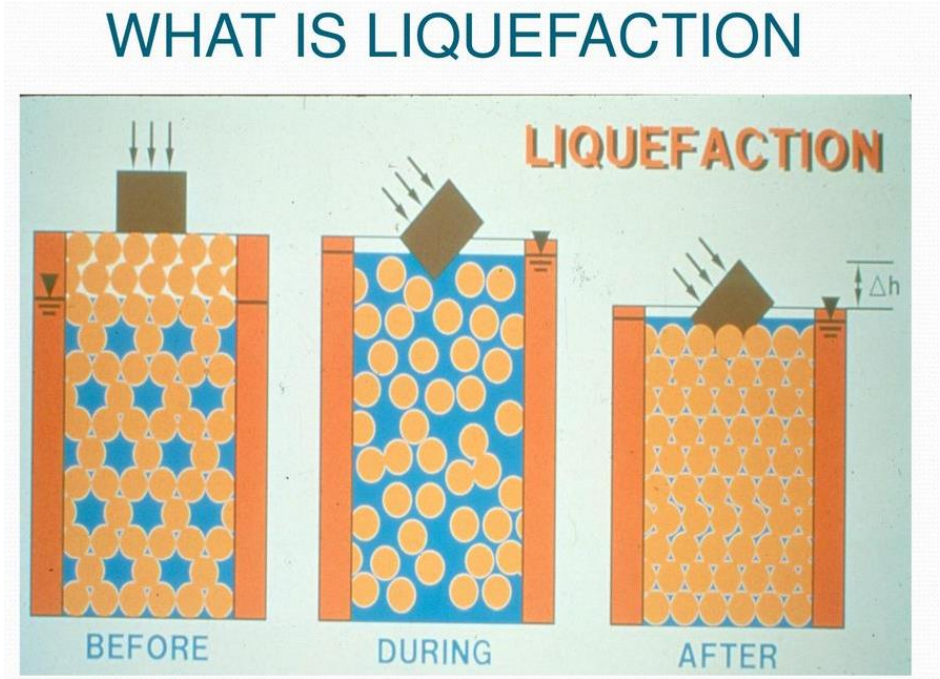




Geohazards

Liquefaction

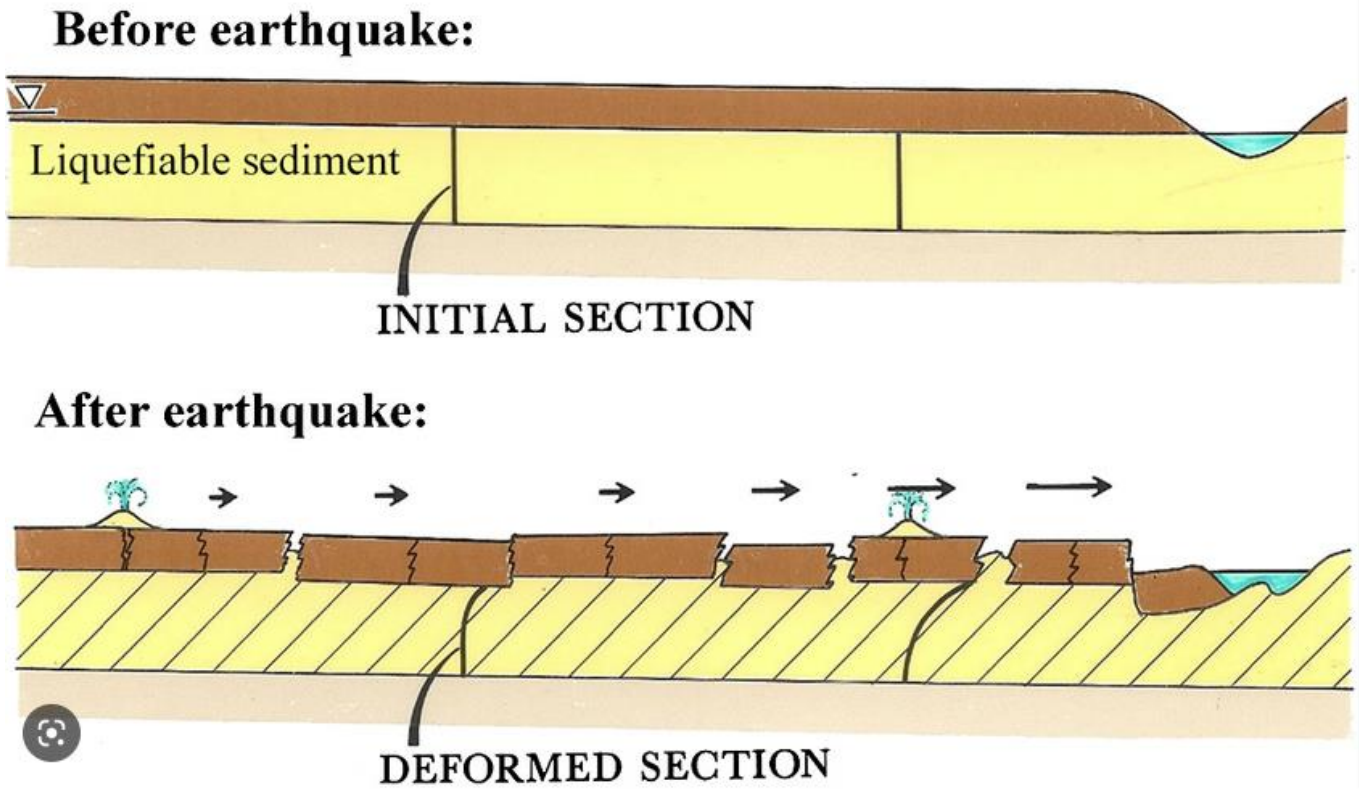
- Groundwater and Holocene deposits in the upper 50 feet
- Loose, coarser sands or poorly graded (“clean”) sands. Fines content < 10+/-%
- Also, in gravels and silts, but less common



Geohazards

Lateral Spreading

- Free-face sites: riverbank, streambank, etc
- Gently sloping sites



Field Reconnaissance

Non-Invasive

- Bedrock outcrops
- Creek bed

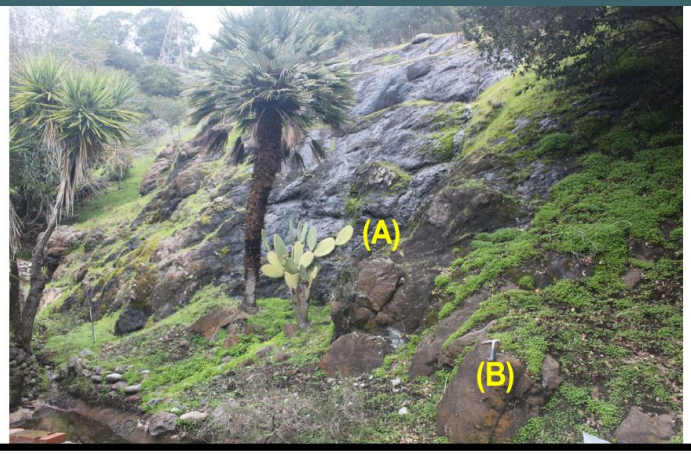


Photo 2 - Native exposures of seepage on moderately hard to hard bedrock (A) and geologist pick for scale (B).

Photo 1 - Native exposures of hard to very hard volcanic bedrock (A) and geologist pick for scale (B).

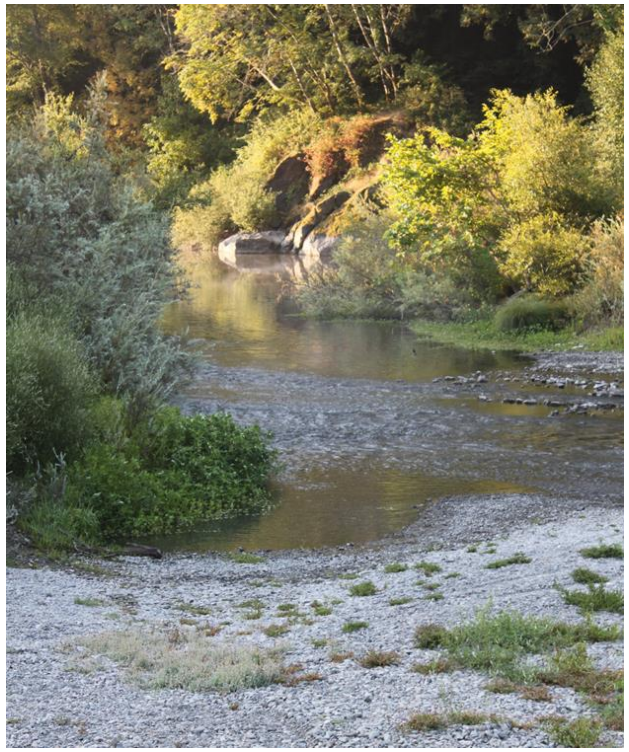


Photo 5 - Westward view along Laurel Street of the potential trenchless installation "3" of the culverted Bay Creek (A; approximated in yellow). Light-colored and relatively sedimentary soft bedrock (Purisima Formation; B) is exposed in roadcuts upslope and downslope of the crossing.

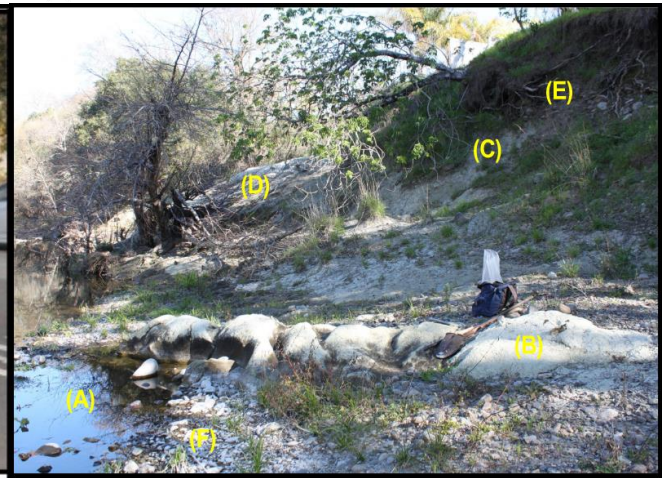


Photo 6 - Close-up view of elements visible in Photo 5, including Sonoma Creek (A), and outcrops of Glen Ellen Formation? (B, C, and D) underlying stream terrace and channel deposits of hard volcanic gravel, cobble and boulder in the creek bank (E) and on the creek floor (F). Compare with Photos 5, 7, and 8.

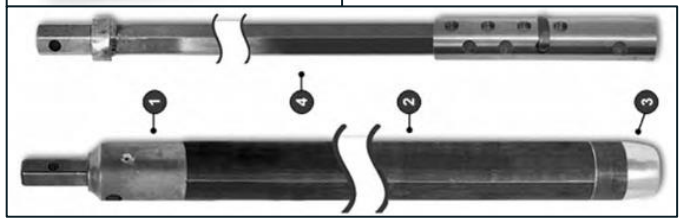
Field Investigation Planning

- **Type of field investigation**
- **Number and location of borings**
  - one boring or CPT every 1,000 feet for Open Cut
  - one boring or CPT at each trenchless shaft locations
  - one boring or CPT in the middle of trenchless segment, if possible.
- **Sampling depth**
- **Permits**
- **Existing Utilities (Private Utility Locator)**

Soil Borings

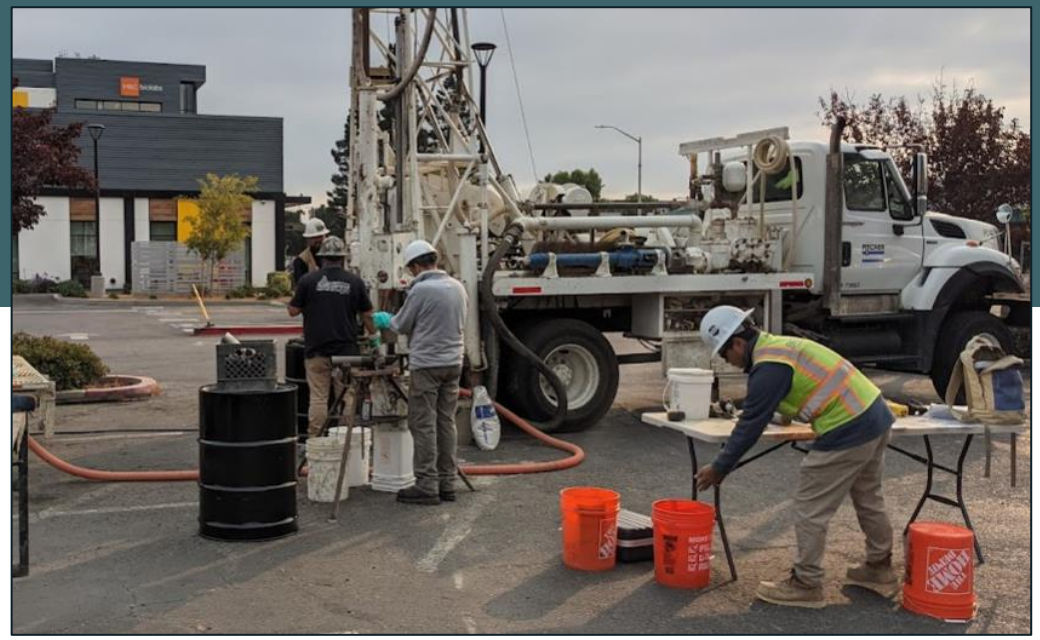
Solid Flight and Hollow Stem

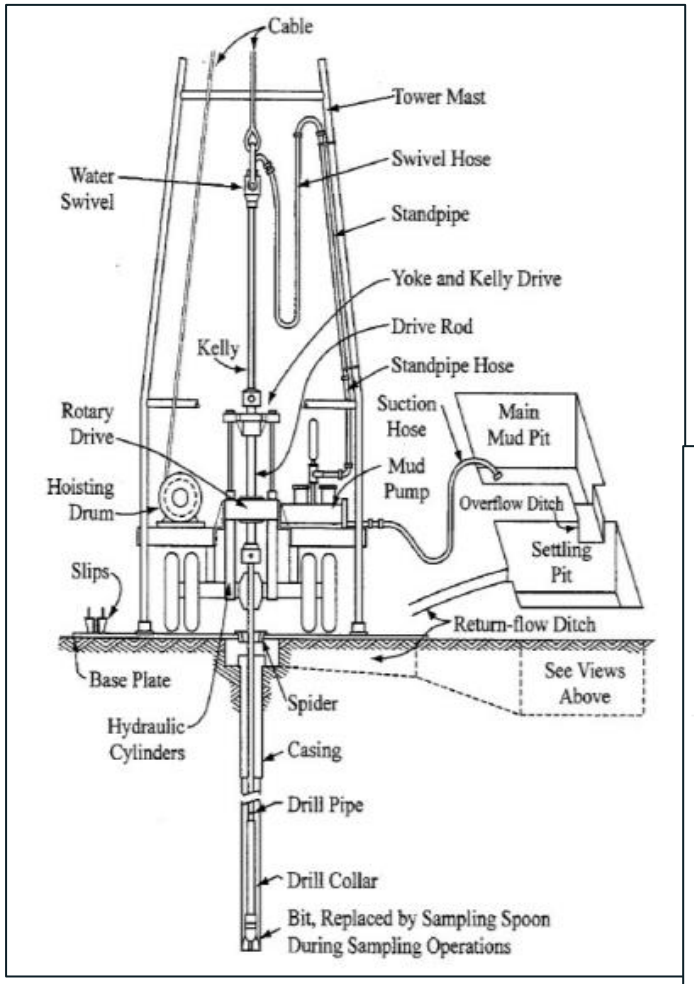
DISTURBED SAMPLES



Soil Borings

Rotary Wash





UNDISTURBED SAMPLES

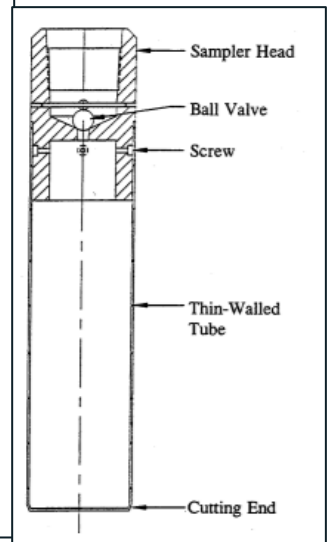
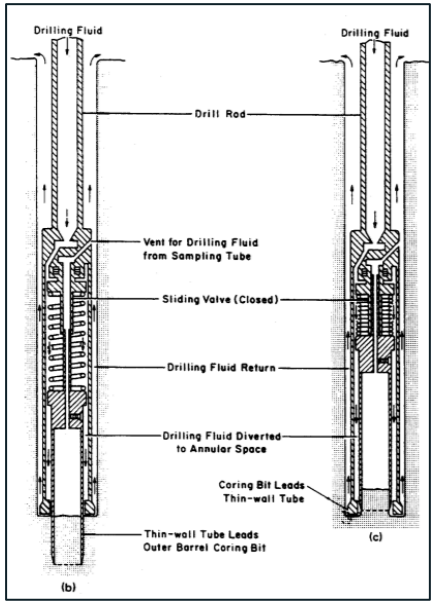
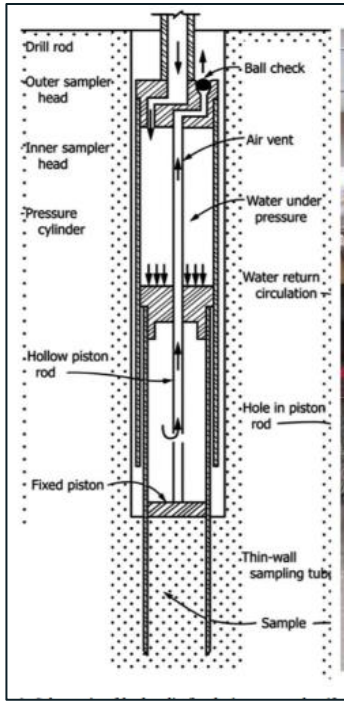


Figure 3-10. Schematic of Thin-Walled Shelby Tube (After ASTM D 4700).





Soil Borings

Rock Coring

Soil Borings

Logging on Site

ASTM D2488-17e1 ⓘ

Standard Practice for Description and Identification of Soils (Visual-Manual Procedures)

DELVE underground

Chip Trays

Sonic Coring

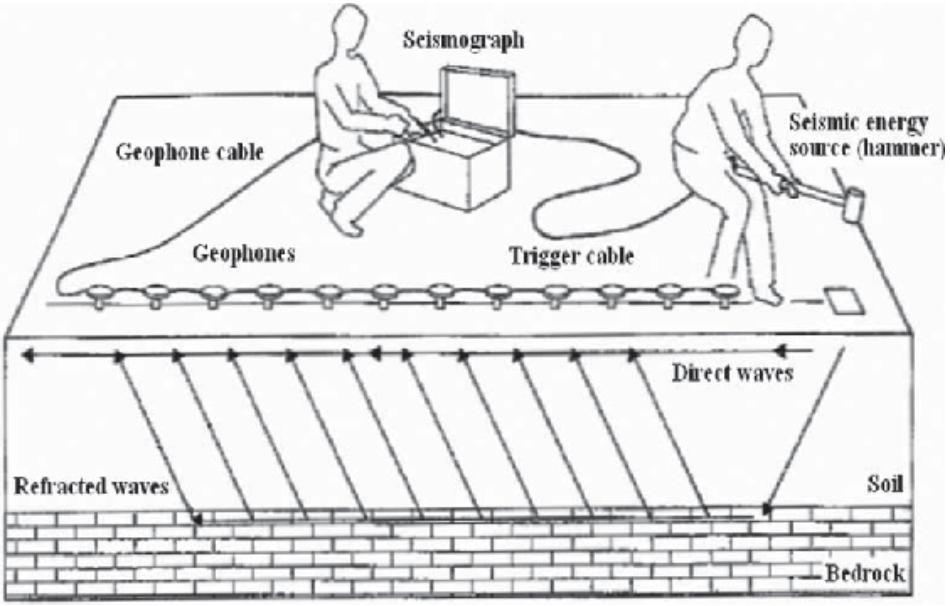
- **Continuous Sampling**
  - Subsurface stratigraphy

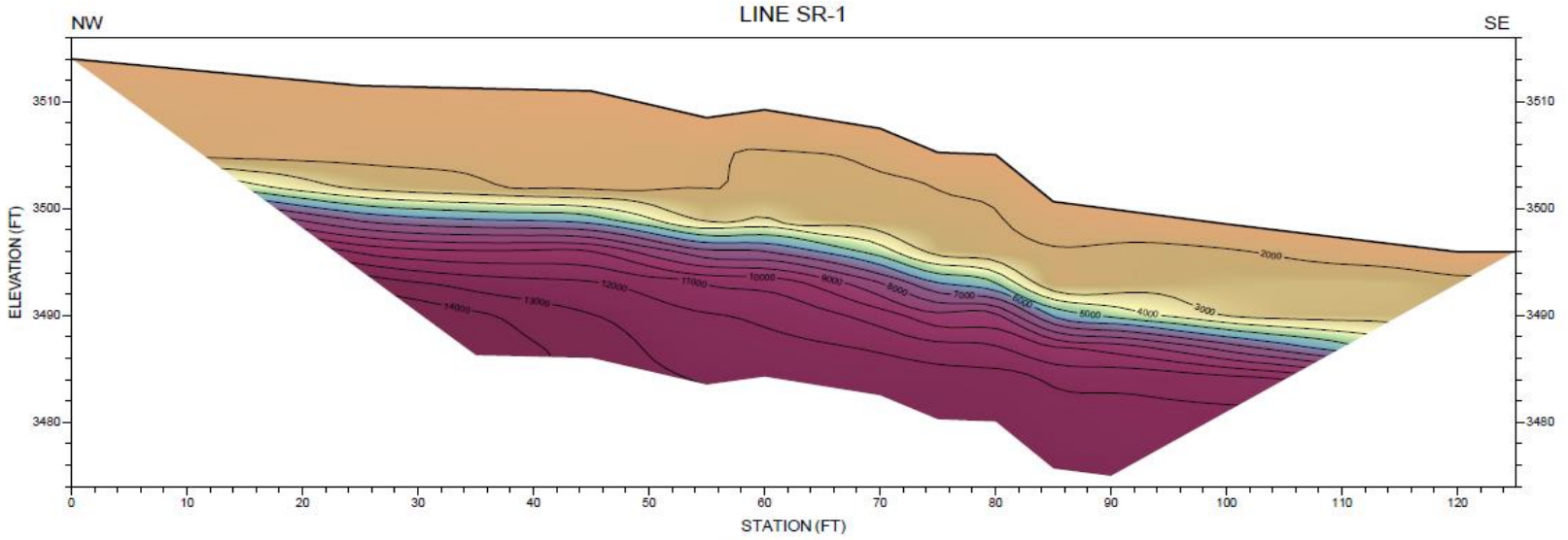
Cone Penetrometer Testing (CPT)

- **Tip resistance, Sleeve Friction, Pore Pressure**
  - Soil Behavior Type
- **Piezo Install (Push-in Piezo)**
- **Limited Soil/Water Sampling**
- **Slug Testing**

Geophysical

Seismic Refraction Survey





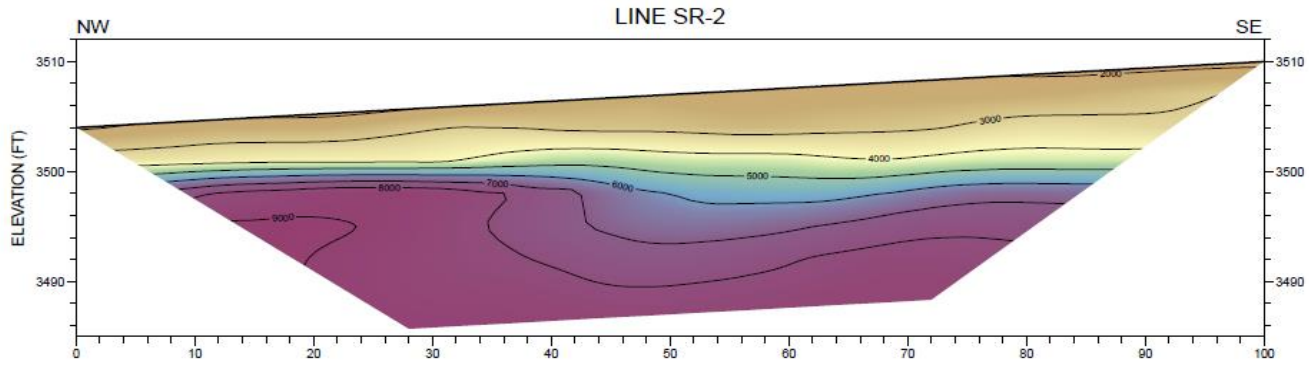


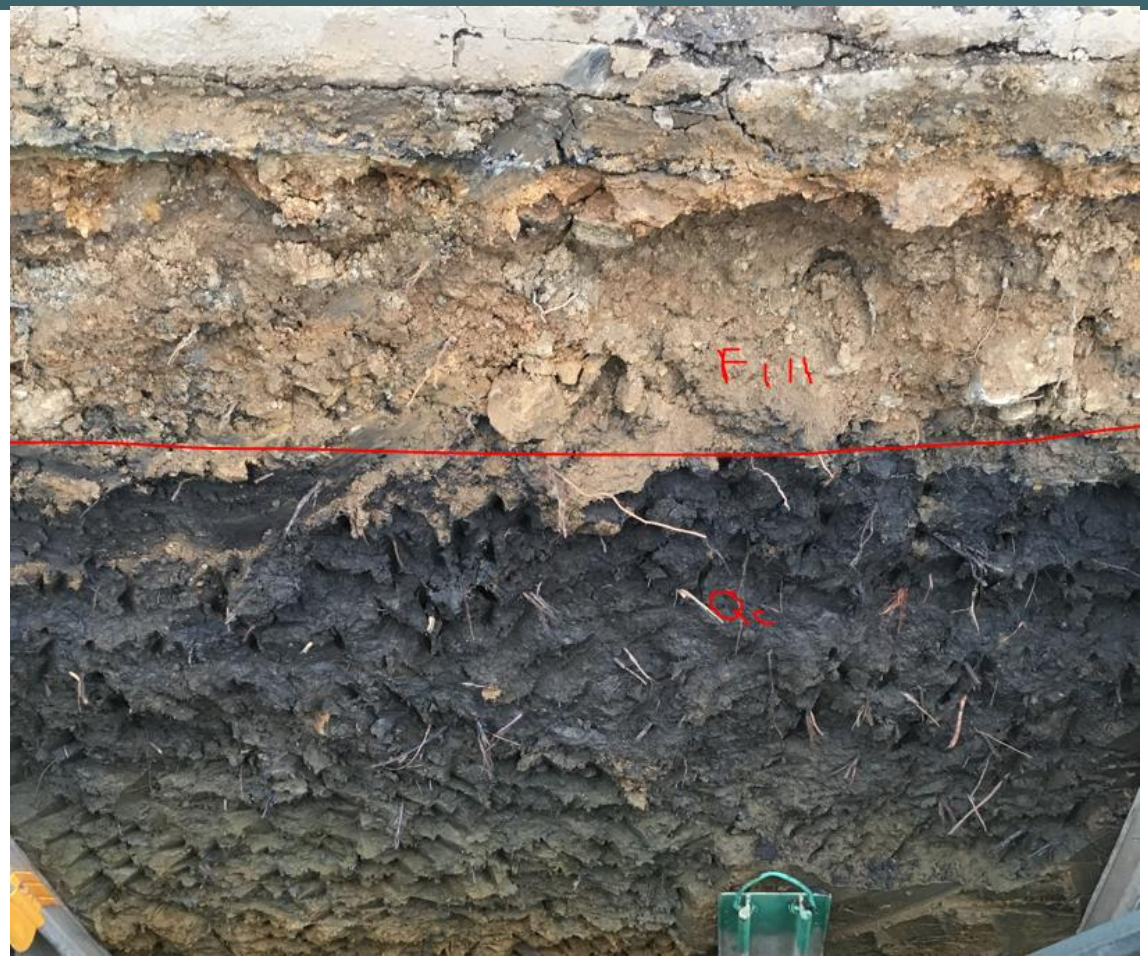
Table A. *Seismic P-Wave Velocity and General Rippability in Granitic Rock*

Equipment Model	Rippable Velocity (ft/sec)	Marginal Velocity (ft/sec)	Non-Rippable Velocity (ft/sec)
D8R	<5,800	5,800 to 6,800	>6,800
D9R	<6,700	6,700 to 8,000	>8,000
D10R	<7,300	7,300 to 8,500	>8,500
D11R	<8,200	8,200 to 9,600	>9,600

Caterpillar, Edition 48, June 2018

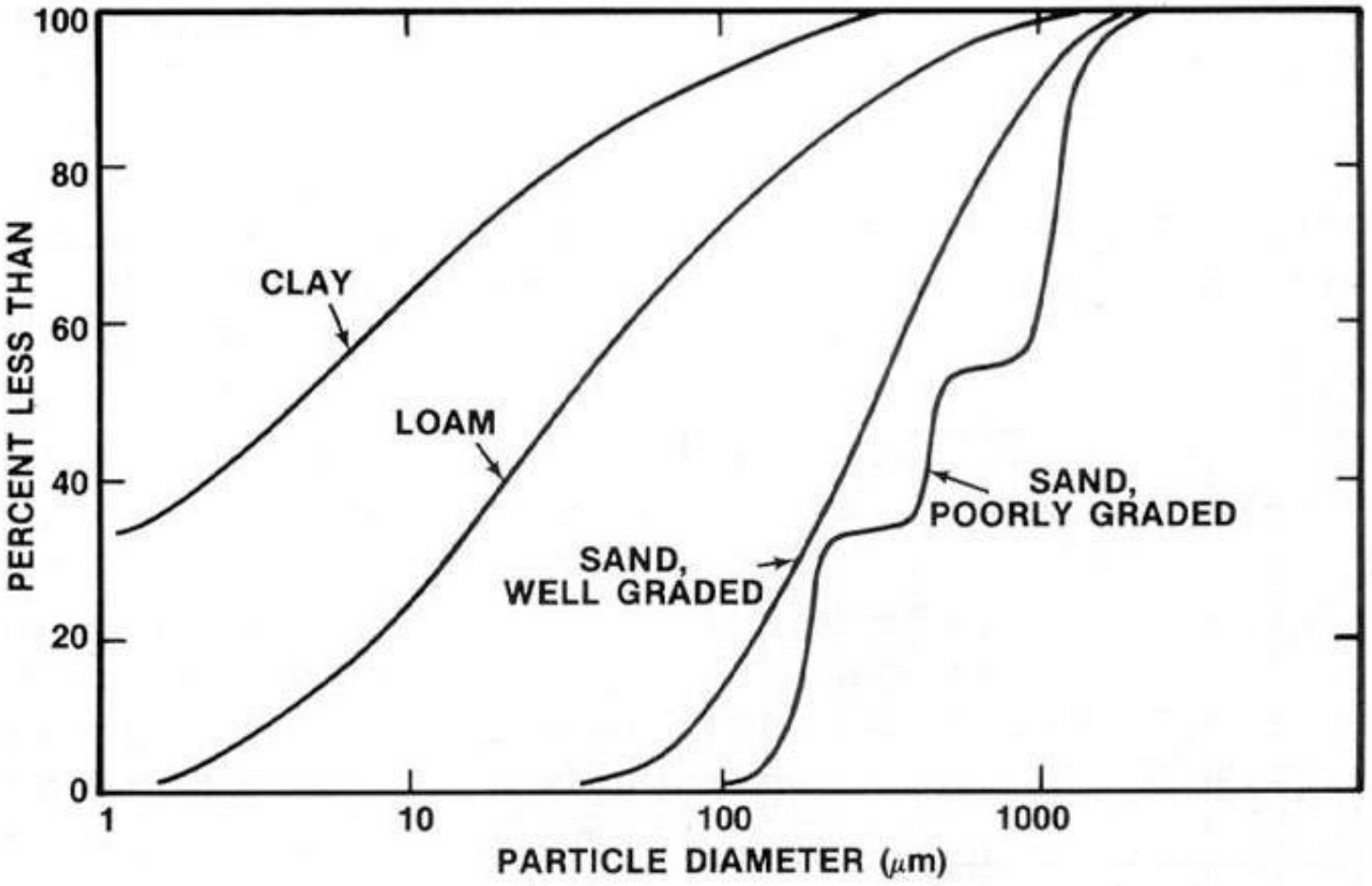
Test Pits

- Test pit excavations for existing fill characterization, soil characterization, landslide and fault exploration, bedrock depth and environmental
- With larger excavations into bedrock, you can characterize bedding and discontinuity data better
- For hillside projects, geologic hazards such as adverse bedding can be important for understanding slope stability
- Identifying and characterizing existing fill deposits is an important tool for a geologist working in geotech. Look for indicators of artificial fill such as buried grass line, construction debris, layering indicative of recent placement, soil properties that do not match the underlying soils.



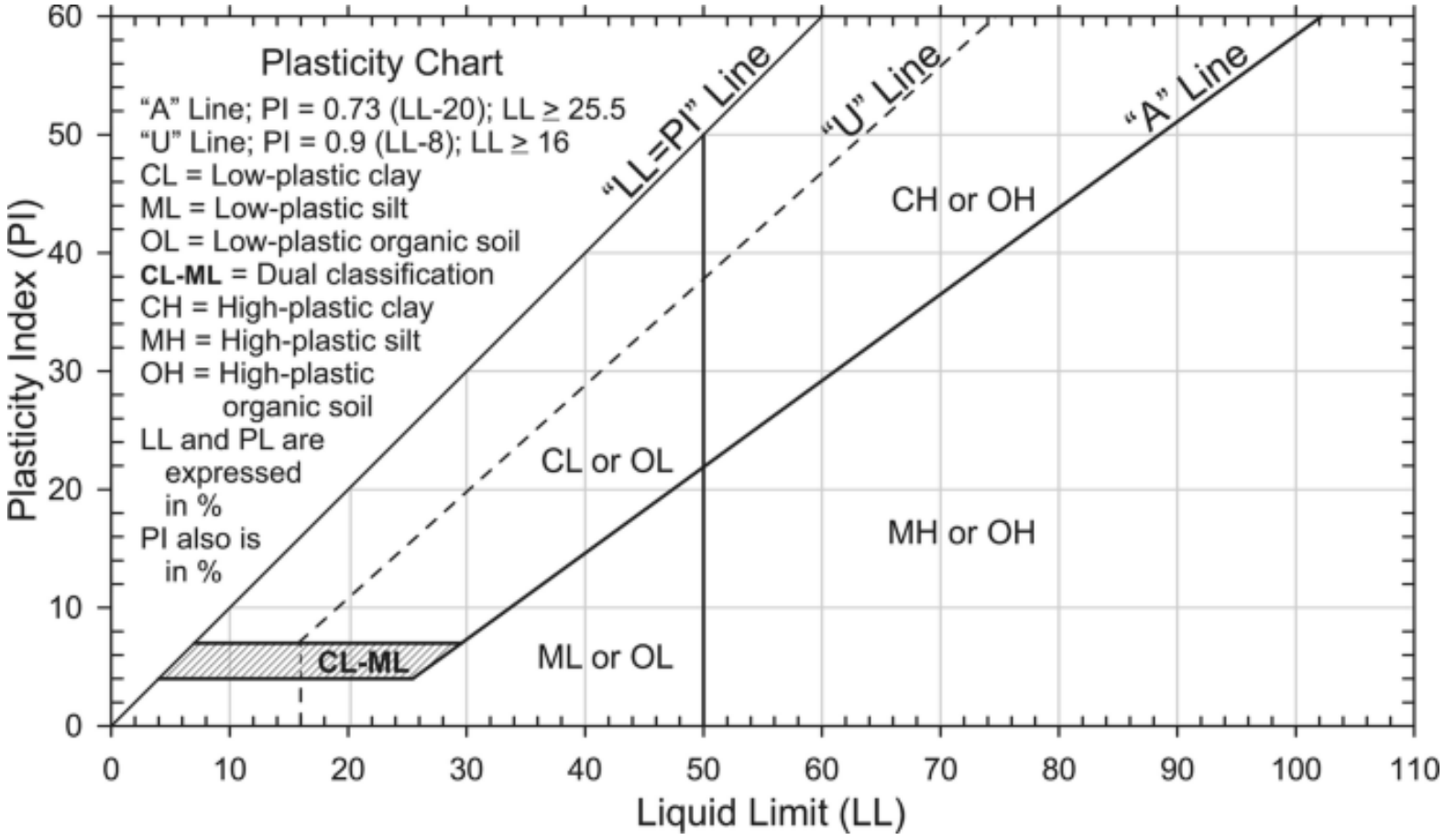
Laboratory Testing

Particle Size Distribution



Laboratory Testing

Atterberg Limits



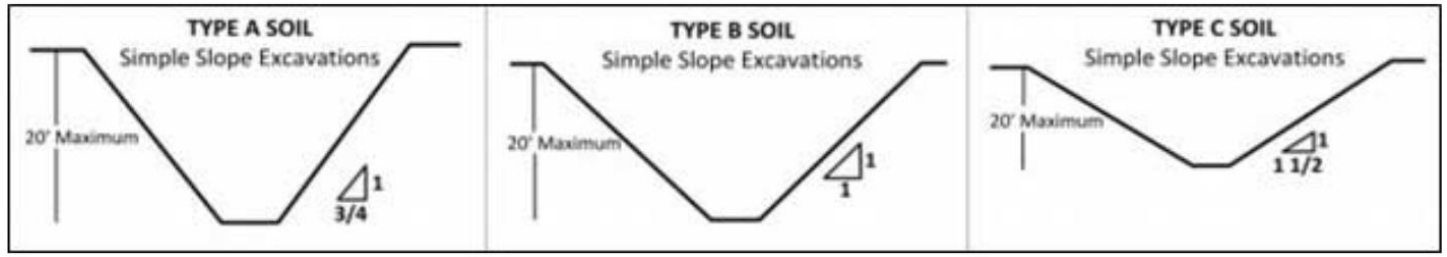
Laboratory Testing

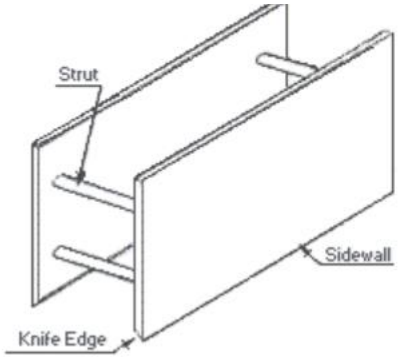
Strength and Other Tests

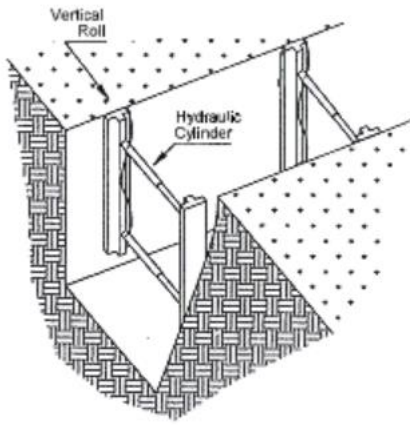
- Unconfined Compressive Strength
- Direct Shear
- Triaxial Compression
- Moisture and Density
- Consolidation
- Permeability
- Shrink/Swell
- R-value

Open Cut Method

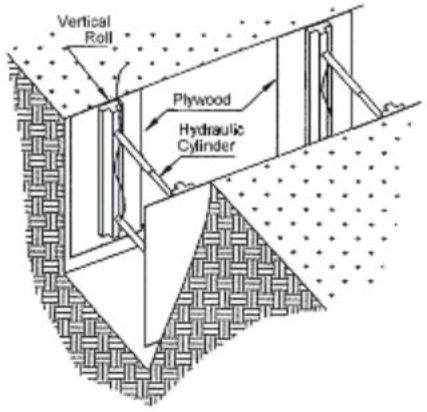
- Excavatability and ground behavior
- Cal-OSHA soil classification
- Safe temporary slopes
- Shoring guidelines
- Design groundwater
- Dewatering
- Trench backfill
- Backfill compaction
- Settlement



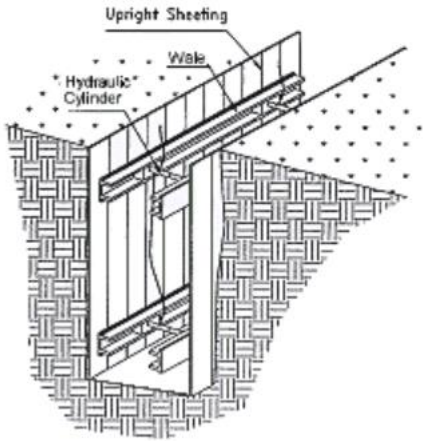




Vertical Aluminum Hydraulic Shoring (Spot Bracing)



Vertical Aluminum Hydraulic Shoring (With Plywood)

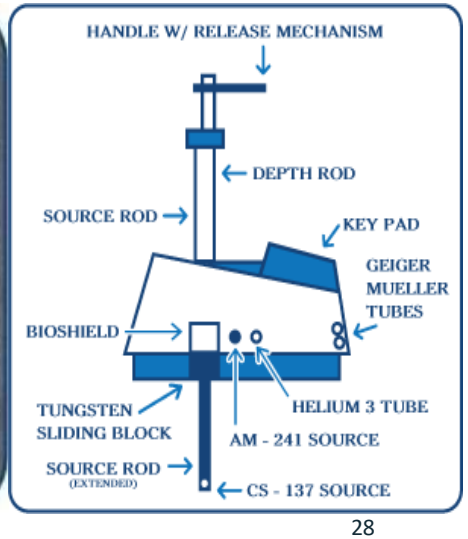


Aluminum Hydraulic Shoring Waler System (Typical)

Soil Compaction and Testing Equipment

Sand Cone

Nuclear Gauges

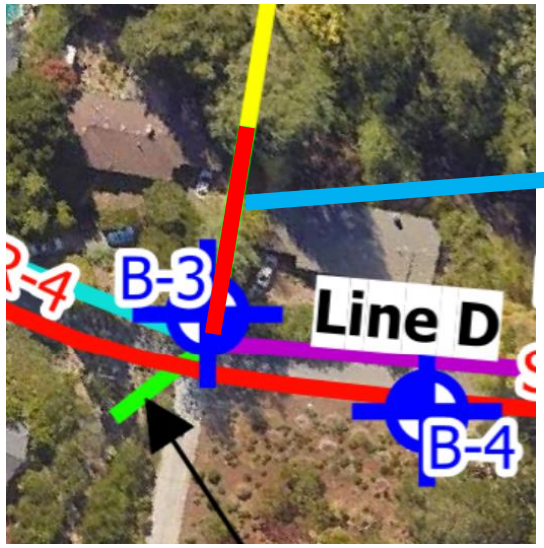


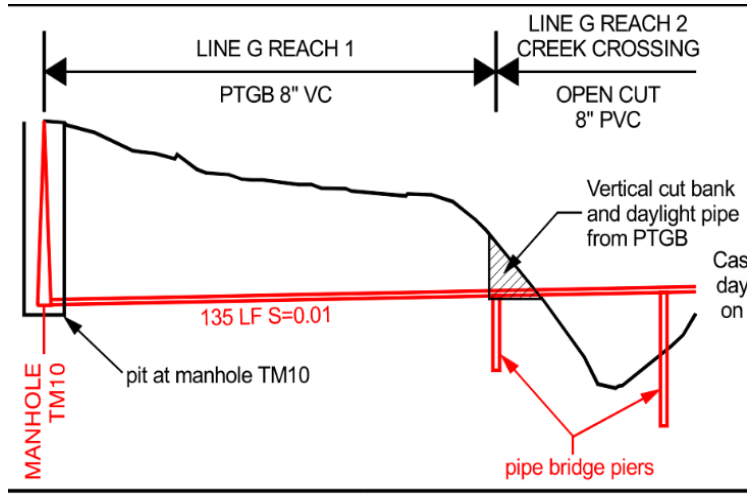
Compaction Problems:

Compaction Problems:

Trenchless Method

- **Environmentally Sensitive Areas**
  - Creek, stream, river, etc
- **Difficult Topography**
  - Deep Trench (> 25 feet)
  - Steep Slope
- **Existing Infrastructure**
  - Roadway, highway, railroad
- **Utility Conflicts**
  - Existing aqueduct
  - Large culverts
- **Community Constraint**
  - School, park, etc.





Type of Trenchless Method

- **New Installations**
  - Utility Tunneling
  - Pipe Ramming
  - Pipe Jacking
  - Auger Boring
  - Pilot Tube Guided Boring
  - Horizontal Directional Drilling
  - Direct Pipe
  - Microtunneling

- **Rehabilitation**
  - Cured-in-Place Pipe (CIPP)
  - Sliplining
  - Spray-in-Place Pipe (SIPP)
  - Pipe Bursting

Trenchless Method Selection Criteria

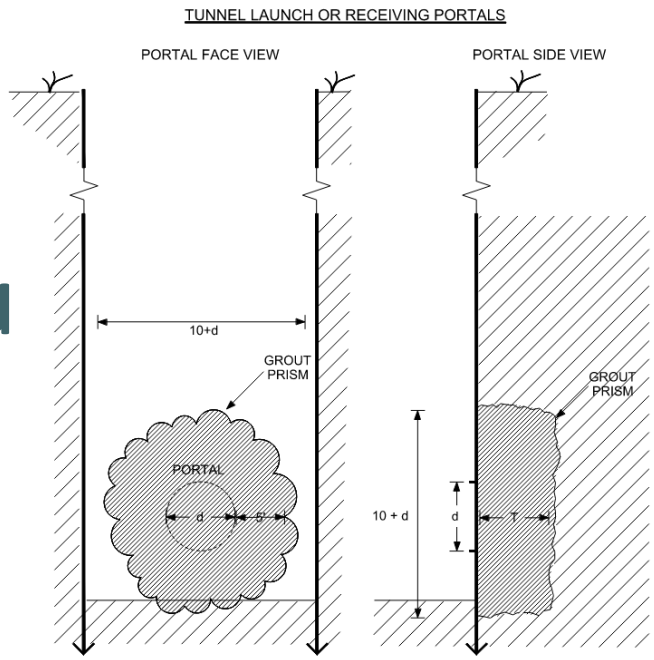
- Ground condition
- Groundwater condition
- Drive length
- Diameter
- Depth (HDD only)
- Type of pipe
- Cost
- Availability of Equipment and Team

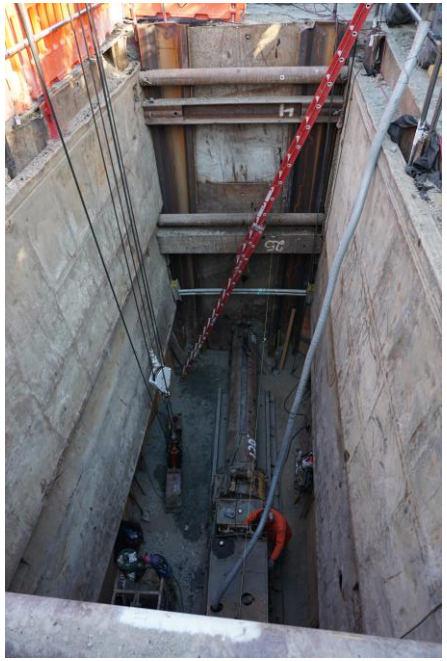
Soil Conditions	Jack and bore (Auger Boring)	Microtunneling	Horizontal Directional Drilling	Pipe Jacking
Soft to very soft clays, silts, and organic deposits	Yes	Yes	Yes	M
Medium to very stiff clays and silts	Yes	Yes	Yes	Yes
Hard clays and highly weathered shales	Yes	Yes	Yes	Yes
Very loose to loose sands above the water table	M	Yes	Yes	M
Medium to dense sands below the water table	No	Yes	Yes	No
Medium to dense sands above the water table	Yes	Yes	Yes	Yes
Gravel and cobbles with a diameter less than 2 to 4 in	Yes	Yes	M	Yes
Soils with significant cobbles, boulders, and obstructions with a diameter more than 4 to 6 in	M	M	M	M
Weathered rocks, marls, chalks, and firmly cemented soils	Yes	Yes	Yes	M
Slightly weathered to un weathered rock	Yes	M	M	No

Yes=generally used; M=possible but difficulties may occur; No= generally unsuitable.

Trenchless shafts and portals

- **Shaft selection criteria**
  - Ground condition
  - Groundwater condition
  - Depth
  - Space availability
  - Cost
- **Stabilize soil behind portal openings**
  - Dewatering
  - Pre-grouting





Geotechnical Baseline Report

When and why we need GBR?

- **Underground construction**
- **Limited investigations**
- **Variable subsurface conditions**
- **Difficulty to price uncertainty without making assumptions**
- **To minimize disputes and control costs**
- **1974 USNCTT Report, "Better Contracting for Underground Construction"**
  - "…if all bidders can base their estimates on a **well defined set of site conditions** with assurance that equitable reimbursement will be made with changed conditions are encountered, the owner will receive the **lowest reasonable bids with a minimum of contingency** for unknowns."

Geotechnical Baseline Report

What is GBR?

- **Contract Document**
- **Contractual assumptions (not always geotechnical fact)**
- **Define and allocate risk between the Owner and Contractor**
  - Conditions consistent with or less adverse than baseline allocated to the Contractor
  - Conditions more adverse allocated to the Owner
- **Will affect cost of the project**
- **Order of precedence**
- **Baseline is not a warranty**
  - That the indicated conditions will, in fact, be encountered
  - Additional compensation will be paid if conditions more adverse than the baseline are encountered

Geotechnical Baseline Report

Three Categories of Information

- **Facts**
  - Data from research and geotechnical investigations
- **Interpretations**
  - Developed from evaluations of the data
- **Judgements**
  - Informed opinions based on the data, interpretations, and professional experience

Geotechnical Baseline Report

Cost Ramifications of Baselines

- **Baselines can be set to more adverse conditions:**
  - Increase bid price
  - Allocates more risk to the Contractor
  - Possibly costs Owner more, but less risk of cost increases during construction
  - Should be justified based on the data
- **Baselines set closer to the best estimate of conditions:**
  - Decrease bid price
  - Allocate more risk to the owner
  - Potentially lower bid prices
  - Greater risk of change orders or DSC claims

Geotechnical Baseline Report

Where to set the baselines

- **ASCE, GBR Suggested Guidelines**
  - The baselines should be realistic, clear, fair to both parties, and consistent with the information contained in the GDR.
  - “Although there may be a range of reasonable baseline values, the emphasis should be on selecting baselines that the owner feels will genuinely be encountered during construction. Where the baselines are set determines the respective levels of risk allocated to the owner and contractor.”

Geotechnical Baseline Report

Risk analyses and funding buckets

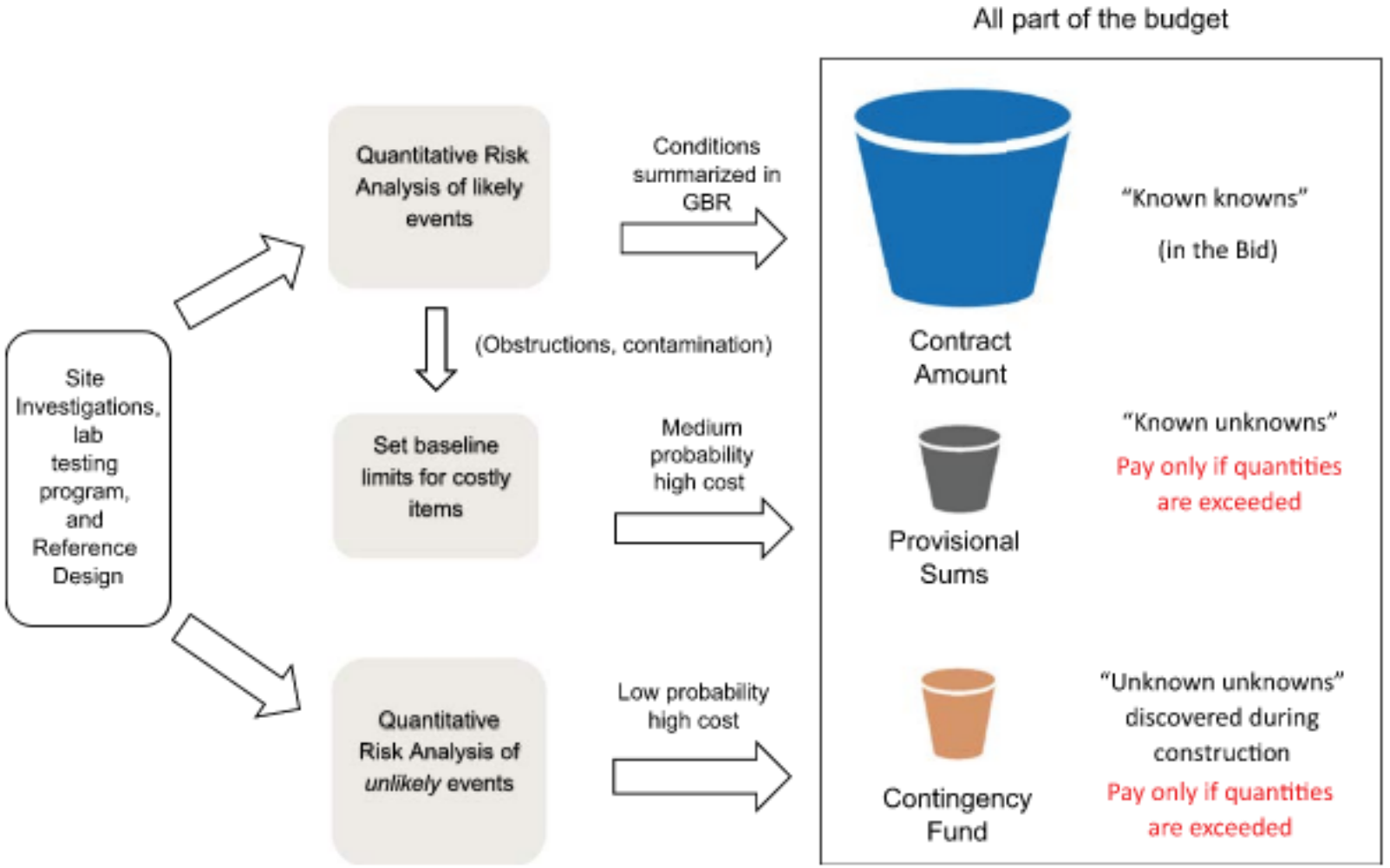
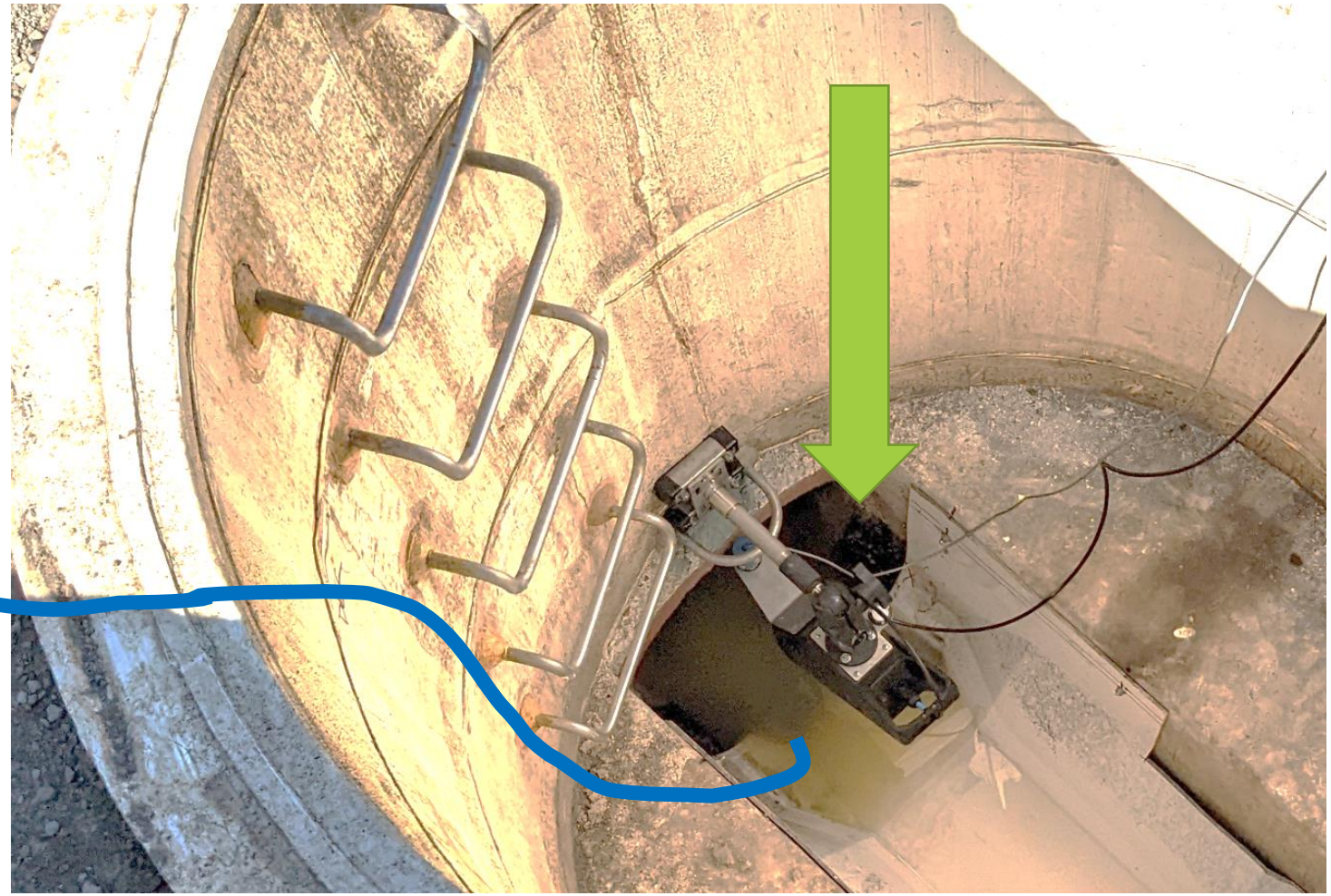


Figure 1-1. Risk analyses and funding buckets.

What kind of “geotechnical” instruments are there?

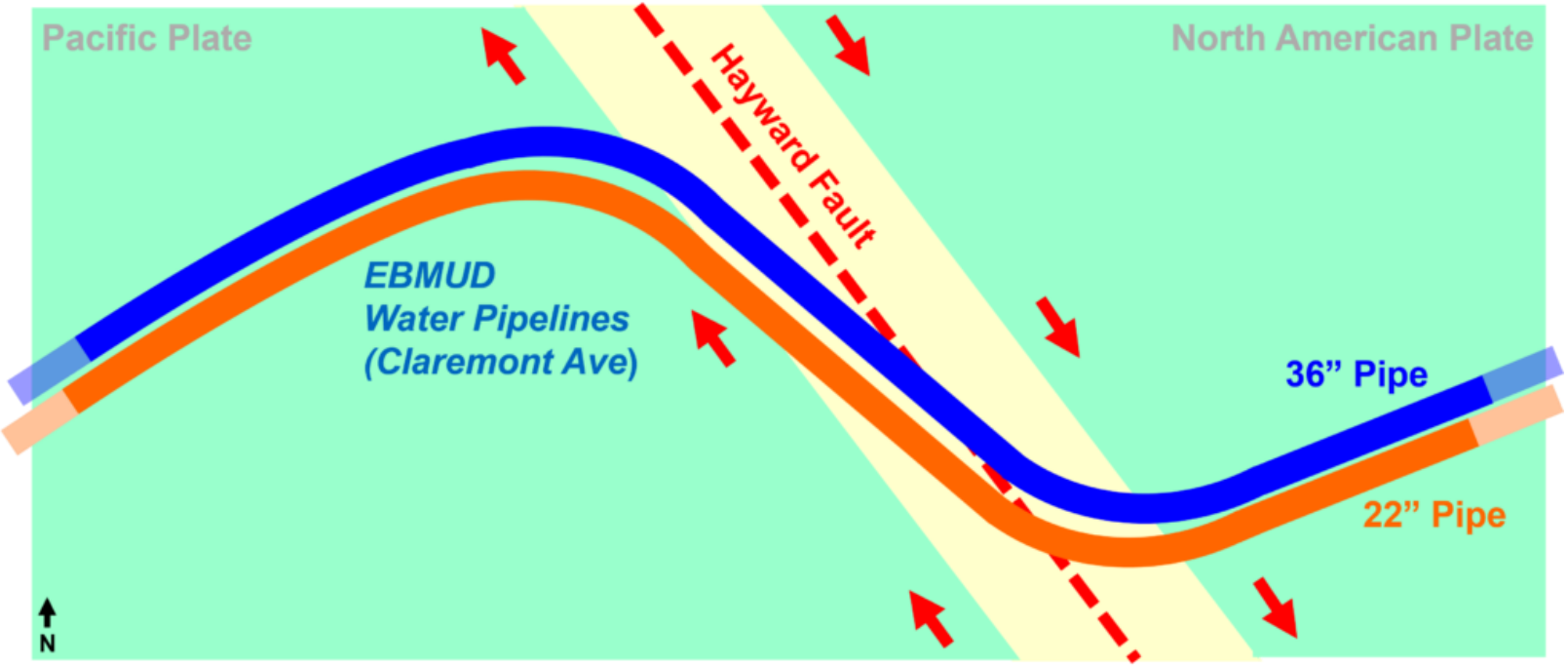
Piezometers (water)
Settlement monitors
Inclinometers (lateral movement)
Vibration monitors (construction vibrations)
Air / dust monitors (air quality)
Crack gauges
Strain gauges
Survey points

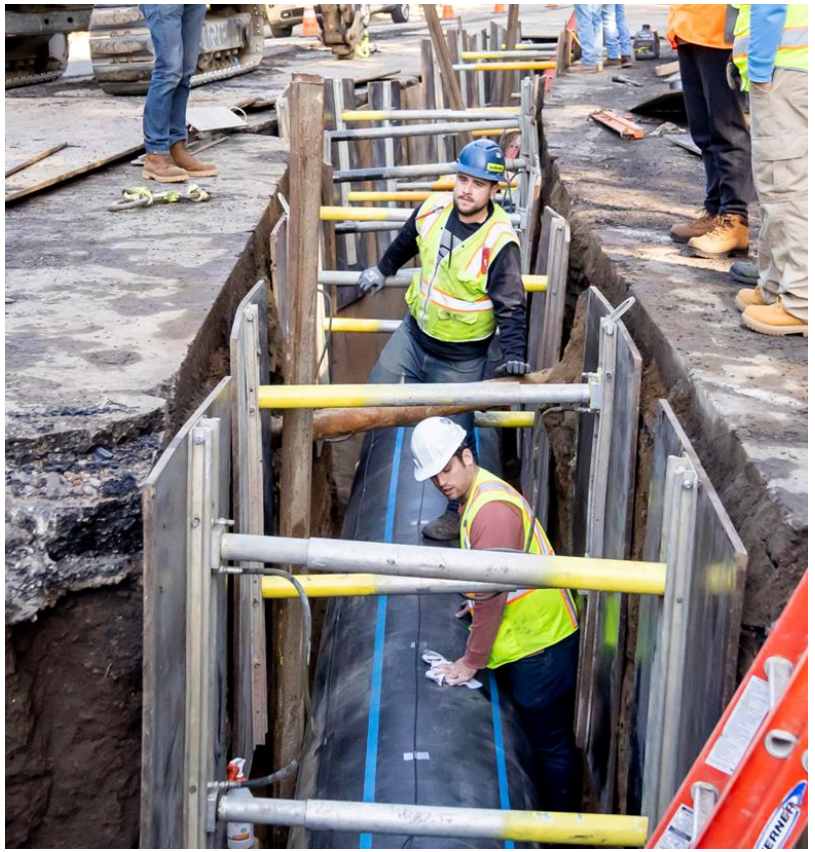
We can measure anything…
(Radar speed trap in a 24-in dia SS + water sampler)



EBMUD/UC Berkeley – Claremont Ave Pipeline

State-of-the art fiber optic sensing





Questions?