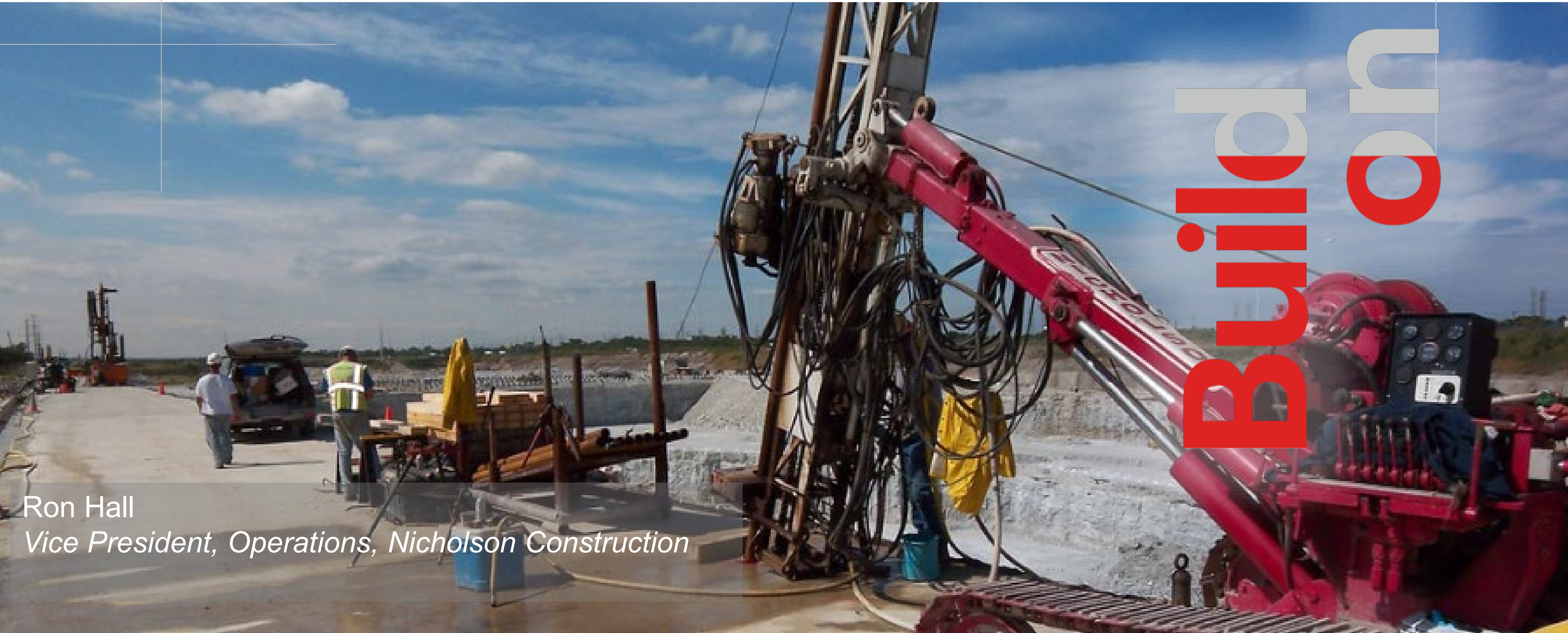
A Driller’s Perspective:
Techniques, Problem Resolution, and Common Issues with Specs and Work Plans



Ron Hall
Vice President, Operations, Nicholson Construction

1 Introduction

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Drilling Method vs. Geology

- Overburden / Embankment Drilling Methods
- Rock Drilling Methods
- Other Methods

Unforeseen Conditions

- Proper Planning
- Drilling Method Selection
- Work Plans

Contract Specifications & QC

- Team approach to understanding specifications with clear acceptance requirements
- Realtime Monitoring

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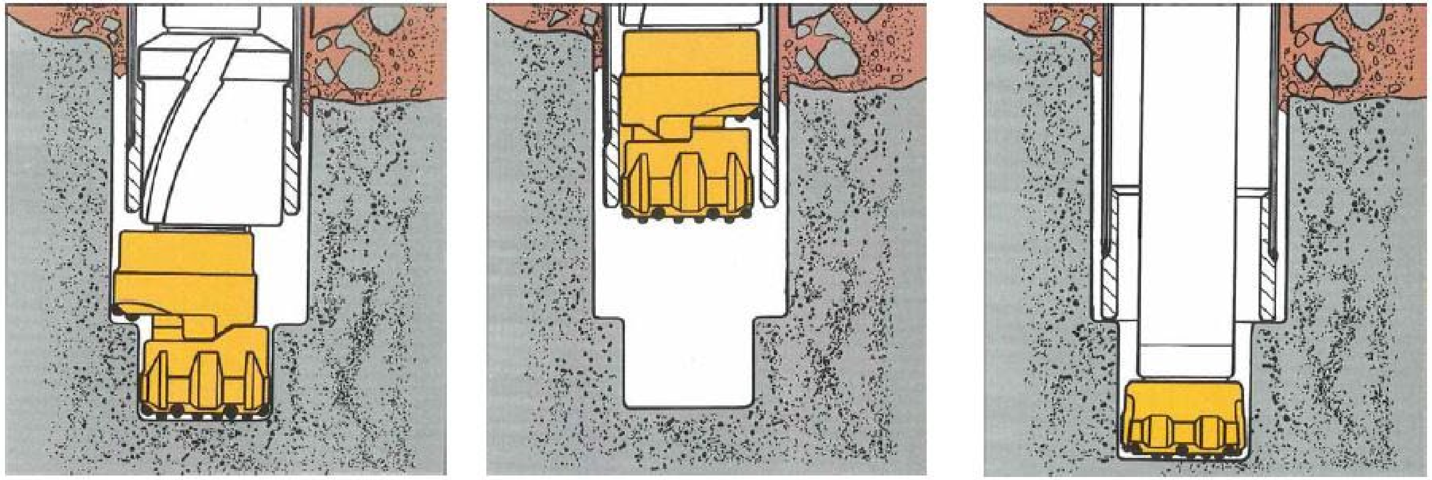
2 Drilling Method: Overview

Overburden / Embankment Drilling Methods for Casing Advancement

- Eccentric Reamer
- Symmetrix Casing Advancer
- Dual Head Percussion
- Sonic
- Auger

Eccentric Reamer



Pilot Bit and Eccentric Reamer

Reamer enlarges borehole to allow casing to advance.

Upon reaching bedrock, the drill string is rotated in opposite direction to "fold in" reamer.

After seating the casing, the drilling system is switched to conventional DTH and drilling resumes.

Image Source: SANDVICK ROCK TOOLS

Advantages

- Advancement of casing through cobbles, boulders and glacial tills or other unconsolidated formations

Disadvantages

- Requires a medium (water or air) to operate hammer for advancing casing which may cause formation damage in engineered fills

Symmetrix Casing Advancement

Advantages

- Advancement of casing through soft and medium ground conditions
- Reduced or limited water/fracture exposure during borehole advancement
- Can be used with either rotary water flush methods or air/water hammer

Disadvantages

- Advancement is limited to soft and medium ground conditions
- Increased $/LF due to reduced production rate

Dual Head Percussion

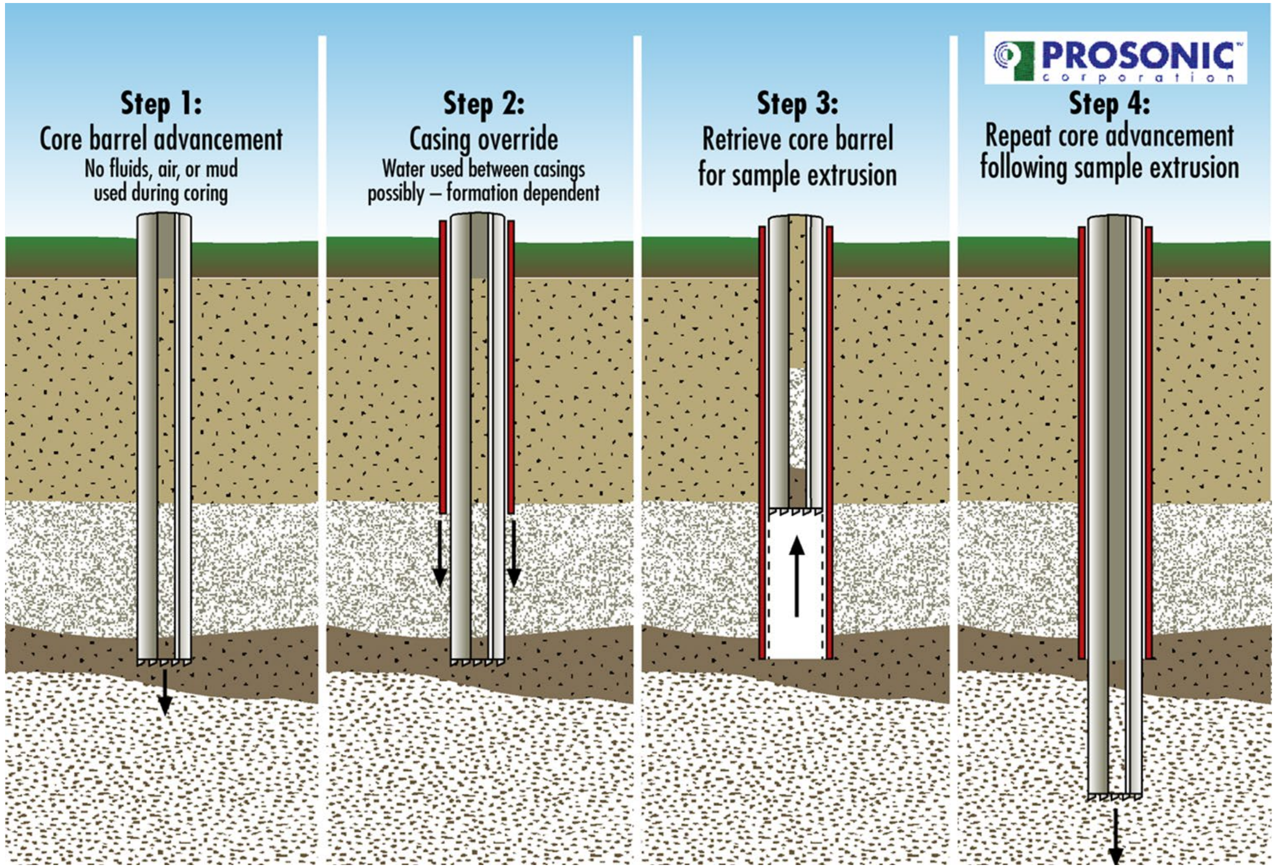
Advantages

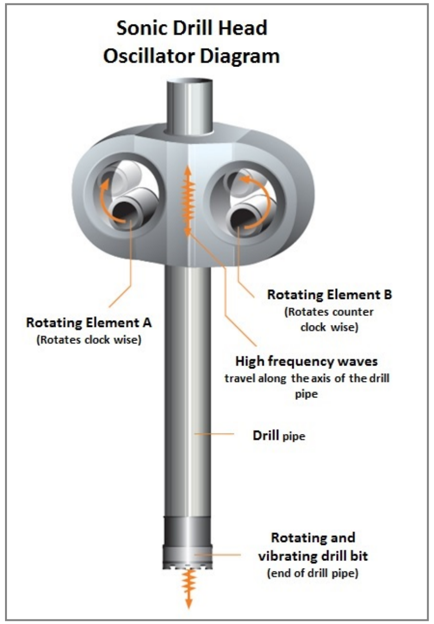
- Advance casing through most types of ground conditions
- Accommodates various bit types to adept to formations (soft ground, cobbles)
- Consistent and high production rates
- Dual string is very rigid and conducive to straight hole or maintaining positive alignment

Disadvantages

- Specialized equipment with costly initial purchase of equipment and tooling
- Requires fluid (water or air) to advance casing

Sonic Drilling (Courtesy of Cascade Drilling)





Typically Resonates at **50-150 Hz** (Cycles per Second)

Sonic Drilling

Advantages

- 2 to 3 times faster than conventional overburden drilling methods in many soil types
- Minimal or no requirement for water during drilling process
- Completely cased borehole for isolation or installation
- Verticality of <2% deviation
- Provides high quality continuous cores
- Waste reduction of up to 80% relative to conventional methods
- Can meet strict engineering requirements

Disadvantages

- Limited advancement in large cobbles and boulder fields
- Requires large footprint for equipment setup
- Specialized equipment with costly initial purchase of equipment and tooling

Auger Drilling (HSA)

Image Source:
http://geotech.ecs.umass.edu/spkelley/researchpics/gwcontamfigure11.jpg

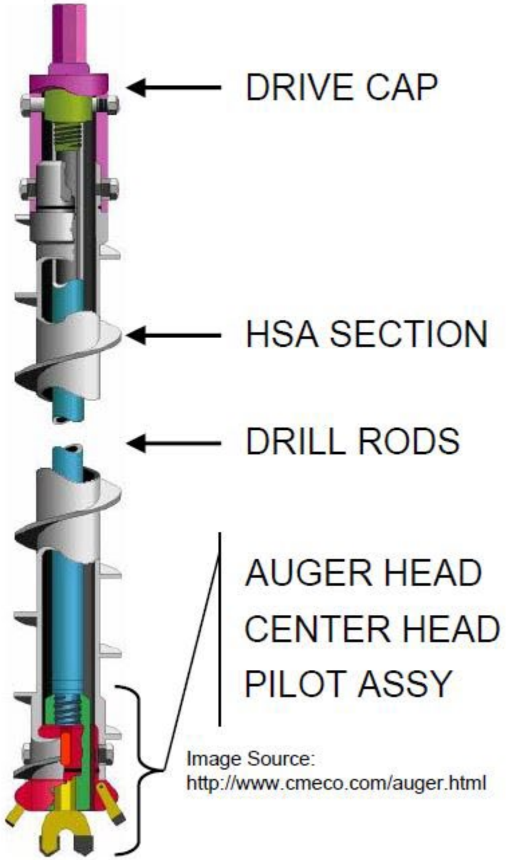


Image Source:
http://www.cmeco.com/auger.html

Advantages

- No requirement for drilling fluids
- Equipment is readily available
- Small footprint for equipment setup

Disadvantages

- Limited drilling depth
- Limited or no capability in drilling cobbles and bedrock
- Angle limitations

Auger Drilling

Conventional Auger Drilling

- A helical or spiral tool form is used to move material from the subsurface to the surface
- A bit at the bottom cuts into the subsurface material
- Spiral augers on outside convey the material to the surface while spinning

Hollow-Stem Auger

- Center of auger is hollow like a straw when the inner drive rods and plug are removed
- During drilling or formation cutting, the center is filled with rods connected to a plug at the bottom bit
- Once the desired drilling depth is reached, the center plug and rods can be pulled out, leaving the hollow augers in place
- The hollow augers hold the borehole open for sediment sampling and well installation

Rock Drilling Methods

- Top Drive Percussion
  - Air & Water
- Down the hole water hammer
- Coring

Top Drive Percussion Drilling

Advantages

- High rates of production
- Lower $/LF
- Equipment and tooling are readily available

Disadvantages

- Hole alignment typically has higher deviation than other drilling methods
- Depth limitations
- Environmental issues with noise and dust control

D-T-H Water Hammer

Image Source: www.wassara.com

Advantages

- Clean hole and minimal impact to formation
- Alignment control
- Minimal amount of oil and dust in air with low noise
- Little to no contamination with tooling oil
- Water bearing zones – does not influence water level
- Reduced energy consumption and wear on drill steel
- Automated drilling capabilities available

Disadvantages

- Large reservoir of water required to operate hammer
- Water filtration required for longevity of system
- Water treatment – discharge water may be problematic
- Costly setup due to specialized equipment requirements

Core Drilling

Advantages

- Core recovery process allow inspection and testing of formation samples
- In situ orientation of geological features and fractures with special scribe shoe
- Alignment Control w/ ability to drill straight holes

Disadvantages

- Slower production due to core retrieval and managing core samples
- Higher $/LF due to slower production and high cost of tooling

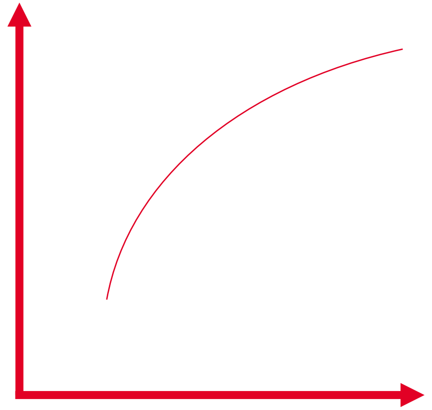
Other Drilling Methods

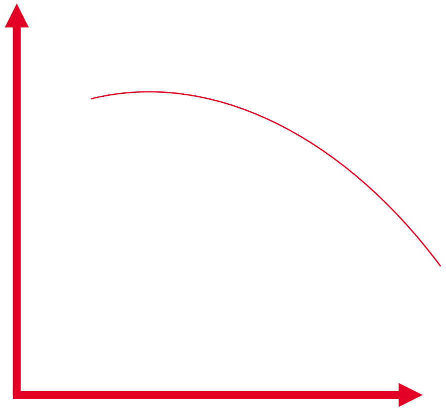
- Reverse Circulation
- D-T-H Air Hammer
- Top Drive Air
- Directional Drilling (HDD)
- Circuit Drilling (Grouting)

Drilling Summary

- Many ways to drill
  - Combination of methods can be used on single holes
- Selected drilling method needs to address:
  - Cost
  - Production
  - Design performance
- Stable holes produce the best technical performance
  - Some marginally stable holes can be corrected with post grouting
- Drill method should be left up to the contractor with understanding of the clients' concerns

Drilling Cost vs. Performance & Production





3 Unforeseen Conditions

Unforeseen Conditions – Can be reduced by planning

- Drilling method selection
- Drilling risks
- Work Plan

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Drilling Method Selection

Why are we drilling?

- Investigation
- Monitoring
- Remediation
    - Grouting
    - Stabilization
    - Instrumentation
- Other

Drilling Method Selection

Upper Stillwater Dam

- Original Concept to crack repair
  - Large Diameter Shafts w/ horizontal cross holes for wire rope concrete cutting
  - Safety Concerns

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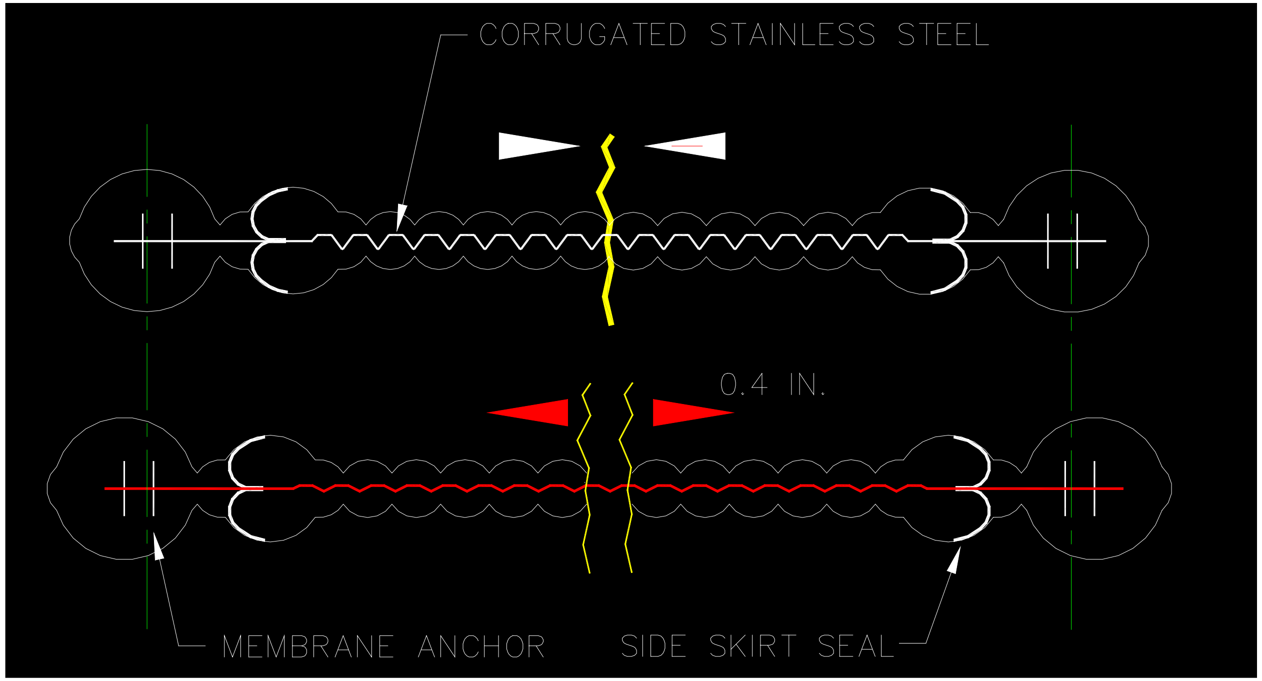
Drilling Method Selection



Upper Stillwater Dam

- VE concept
- Stainless Steel Pliable Membrane

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Drilling Method Selection

Upper Stillwater Dam

- Specialized Tooling
- Vertical alignment a key component

Drilling Method Selection

Upper Stillwater Dam

- Vertical pliable membrane a success
- Right tooling for right job
- Engineering + Planning = Operational Success

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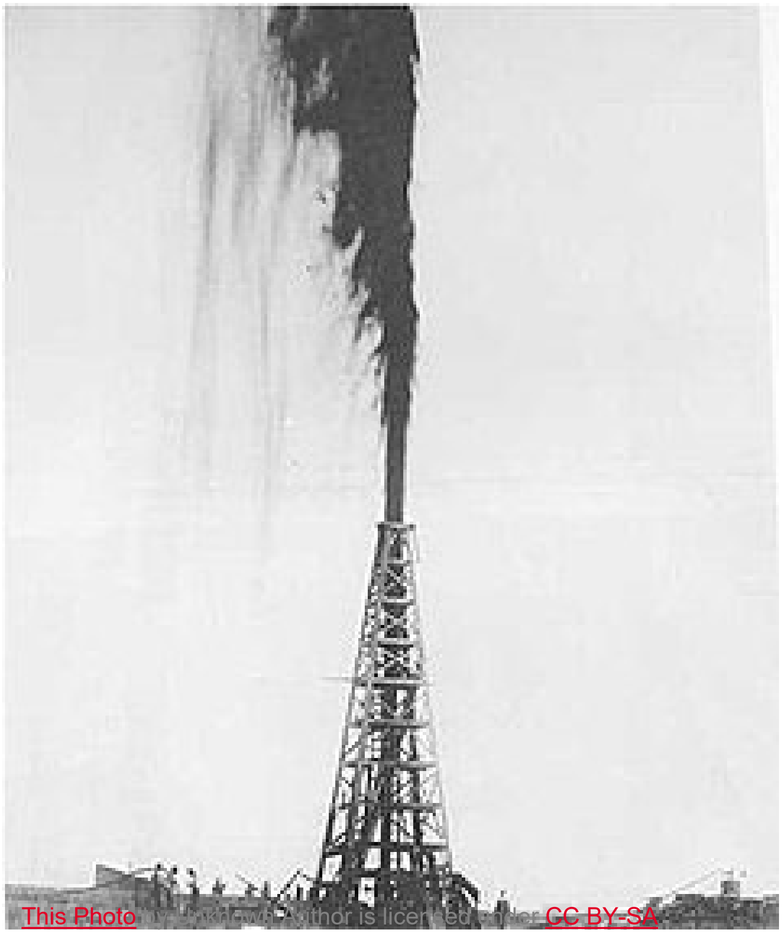
Drilling Risks



What Can Happen?

- Embankment
  - Piping
  - Heave
  - Damage
    - Fracturing
    - Sinkhole
    - Damage to core
- Rock
  - Fractures
  - Piping
  - Artesian Flow

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Work Plans

- Once we have evaluated the risk and have chosen a drilling method, a work plan should be developed
- Work plans are based on
  - Regulation requirements
  - Foreseen risks
    - Embankment conditions
    - Material to be drilled
    - Are artesian conditions a possibility?
    - other

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Work Plans

Table of Contents

- Develop a detailed work plan so everyone knows what the established goals and risks are
- Your work plan should include stop or hold points based on the risk evaluation
- Having a plan B is always a good idea

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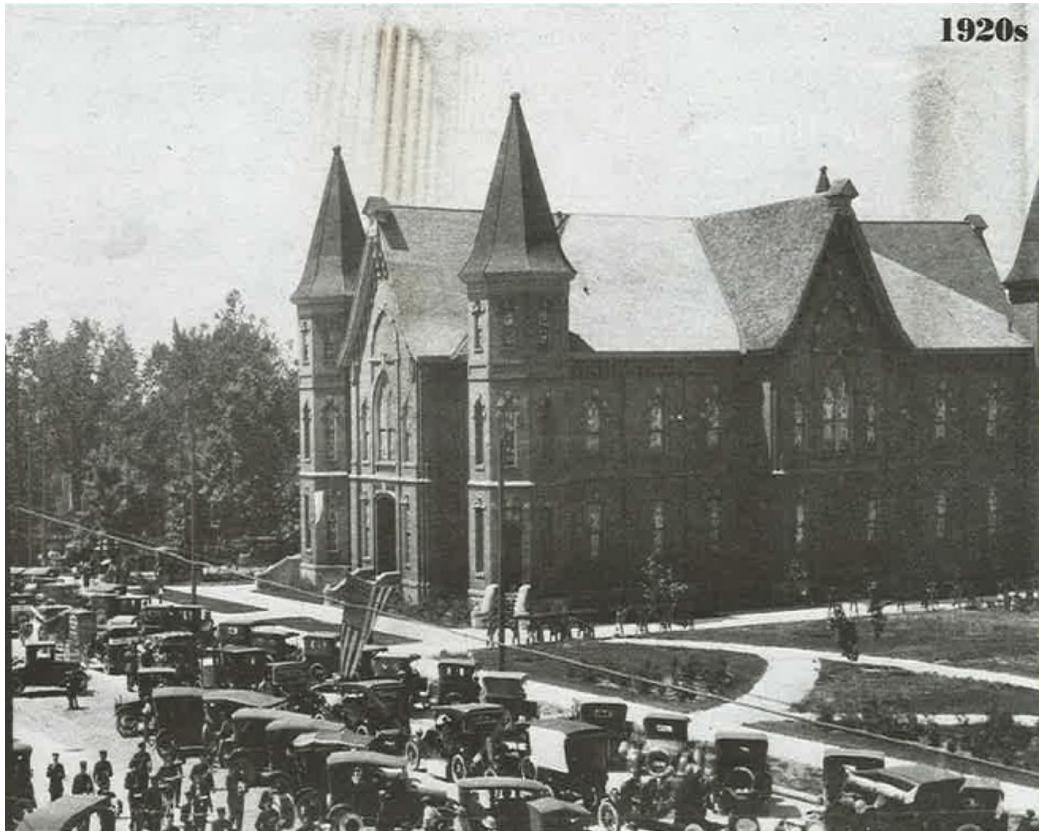
Work Plans

- Establish your expectations with team goals
  - Project goal
  - Risk assessment and review
  - Schedule demands
  - Success criteria
  - Oversite requirements
  - Regulatory Requirement

Work Plans

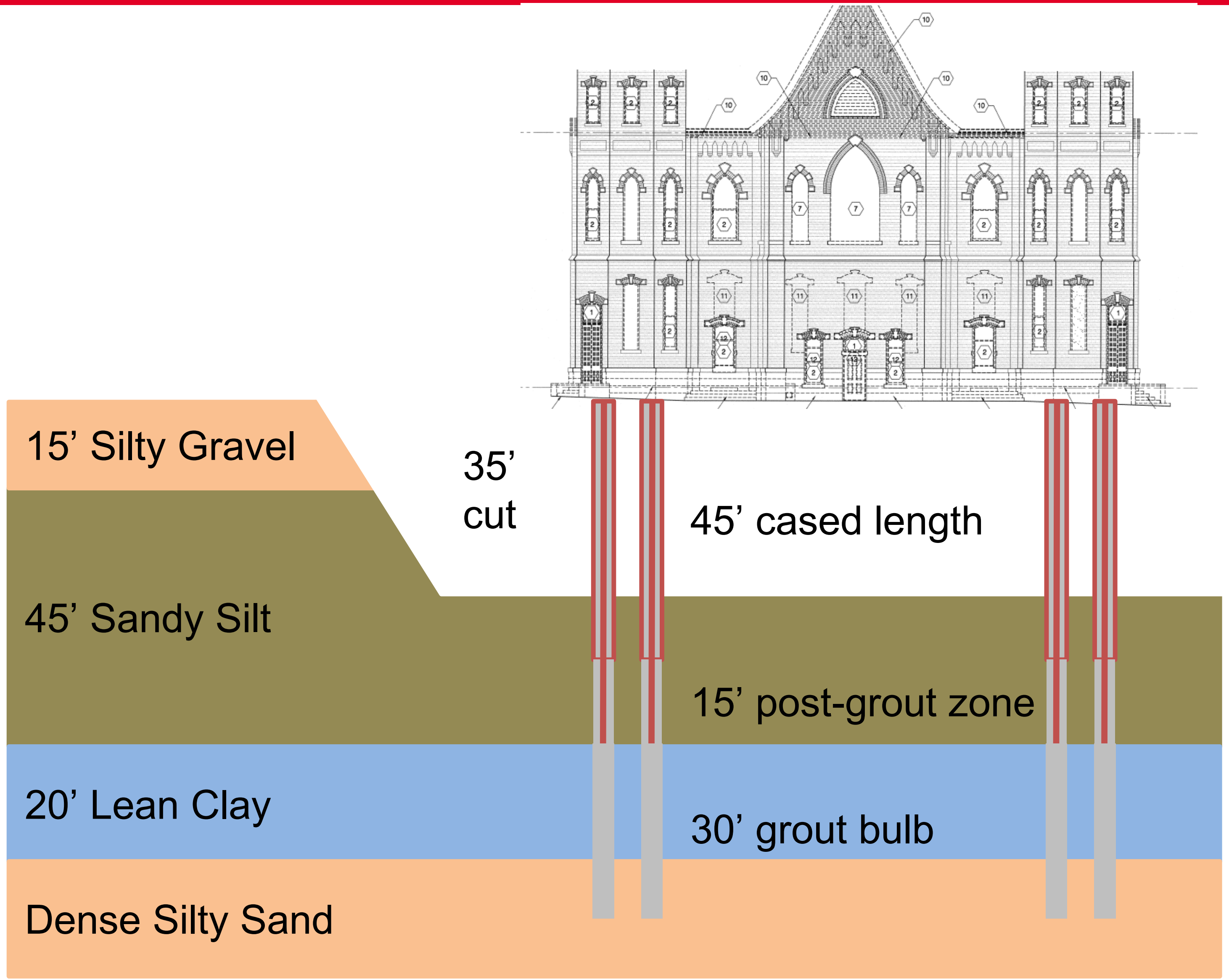
- Dec 17, 2010

Provo Temple



Work Plans

- Vision to Reality



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Work Plans

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4 Contract Specs & QC

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Specifications

- Develop specifications as a guideline
  - Subsurface work is usually unknown. Specifications can provide a starting point to understand the project goal
  - Adapt to the conditions. Do not force a requirement if it is apparent this is not the right approach
  - Utilize experience from the team to adapt to the conditions
- Provide units with quantities
  - Allows contractor to understand owners' assumptions and discuss if there is anticipated change
- Provide variation clause
  - Helps the contractor and the owner mitigate claims

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Circuit Drilling & Grouting Example

2.1 Drilling Equipment

2.1.1 Drilling equipment used for drilling grout holes or verification holes may be of either rotary or rotary-percussion type. Rotary-percussion drilling equipment, if used, shall be equipped to operate solely with water as a circulating and hole-flushing medium. No compressed air flushing shall be used. Drilling to install nipples through concrete shall be by rotary coring method only.

2.1.2 Drill bits used for grout holes shall have a diameter not less than commercial standard AX- or AW- size drill bit (approximately two inches). Side-discharge bits shall not be used if, as determined by the Company, they erode the hole and give subsequent problems in seating packers.

2.1.3 The annulus water velocity in holes being drilled shall be sufficient, without use of air, to flush all drill cuttings from the hole. Drilling equipment and techniques shall be such as to minimize erosion and caving in the hole.

2.1.4 The rotary-percussion drilling equipment shall be equipped with a relatively large-diameter guide rod or other suitable device designed to minimize deviation of the grout holes

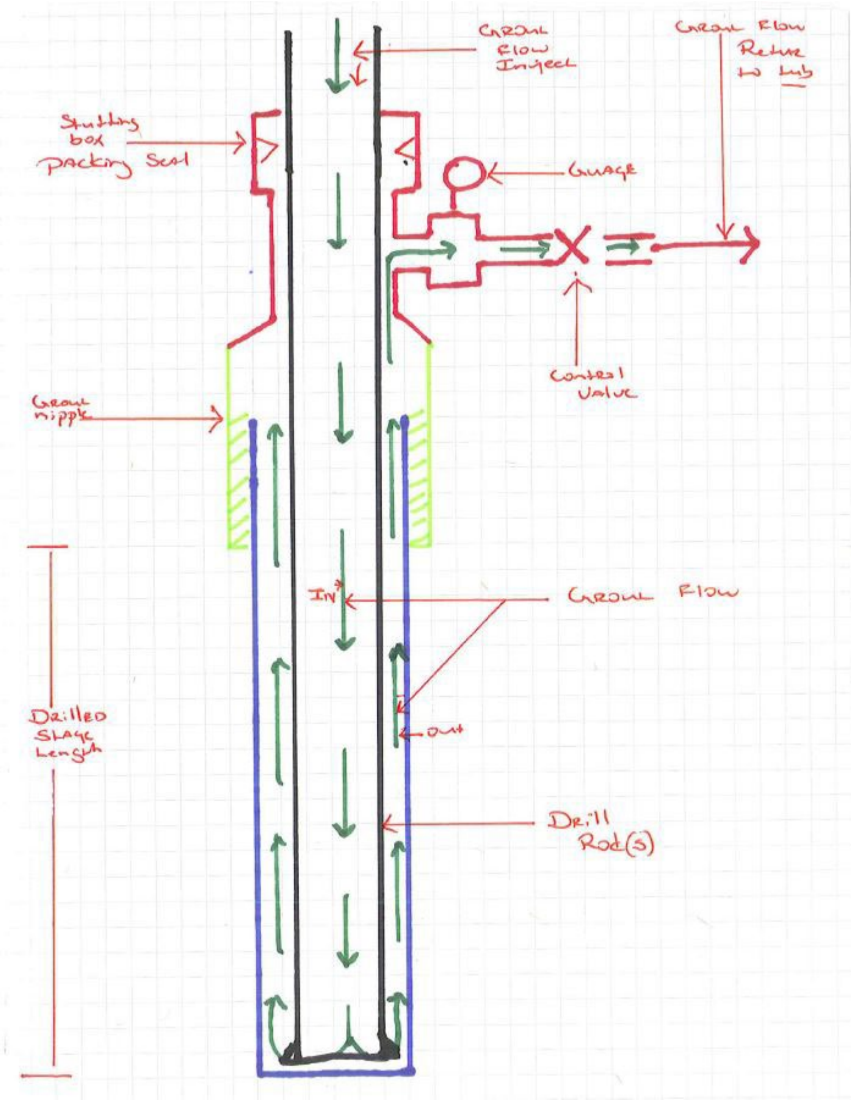
Hebgen Dam

Circuit Drilling & Grouting Example

- Worked with Owner/Engineer to adjust specs

Circuit Grouting Downstage Method-

Circuit grouting uses the drill pipe or rod(s) as the primary method of injection of grout. The basic principal is to drill to depth the desired stage using water or air, grout is then pumped thru the drill rods and circulated between the outside of the drill rods and the borehole wall. The grout nipple is fitted with a stuffing box or diverter seal that diverts grout from exiting the top of the nipple and to a control valve that will regulate both pressure and flow back to the holding tank. The theory is to produce a full circuit of grout that will see the borehole wall and to back side pressure the hole to allow proper pressure for the stage being grouted. In the ground conditions we have encountered we may have to slightly rotate the drill rods to prevent blockage of the area between the borehole wall and the drill rods. I have attached a sketch for the concept layout.



Circuit Drilling & Grouting Example

- Collaboration and a Driller’s perspective worked well on this project.

Quality Control

Alignment setup

- **Where am I?**
  - **Top of borehole**
- Where am I going?
  - Bottom of borehole (Target)
- How am I getting there?
  - Drilling method
  - **Initial setup and alignment**
  - Drilling parameters
  - Downhole survey
  - Qualified driller

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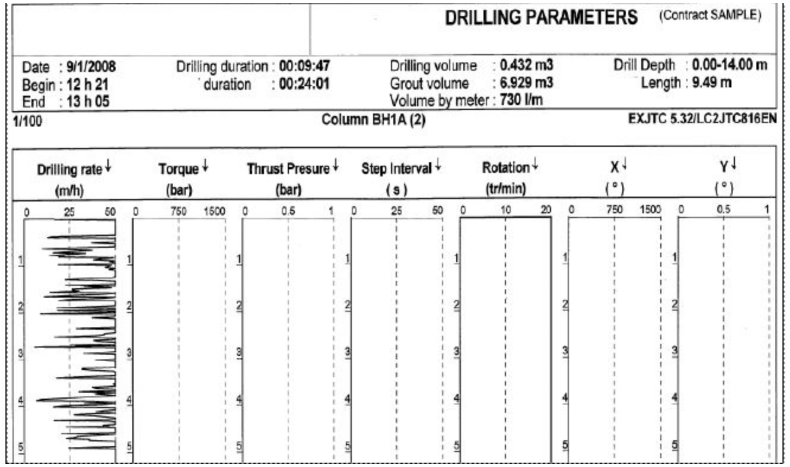
Quality Control



Drilling Parameters

- Depth
- Inclination
- Drilling Rate
- Torque
- Thrust
- Rotation Speed
- Fluid Injection Pressure

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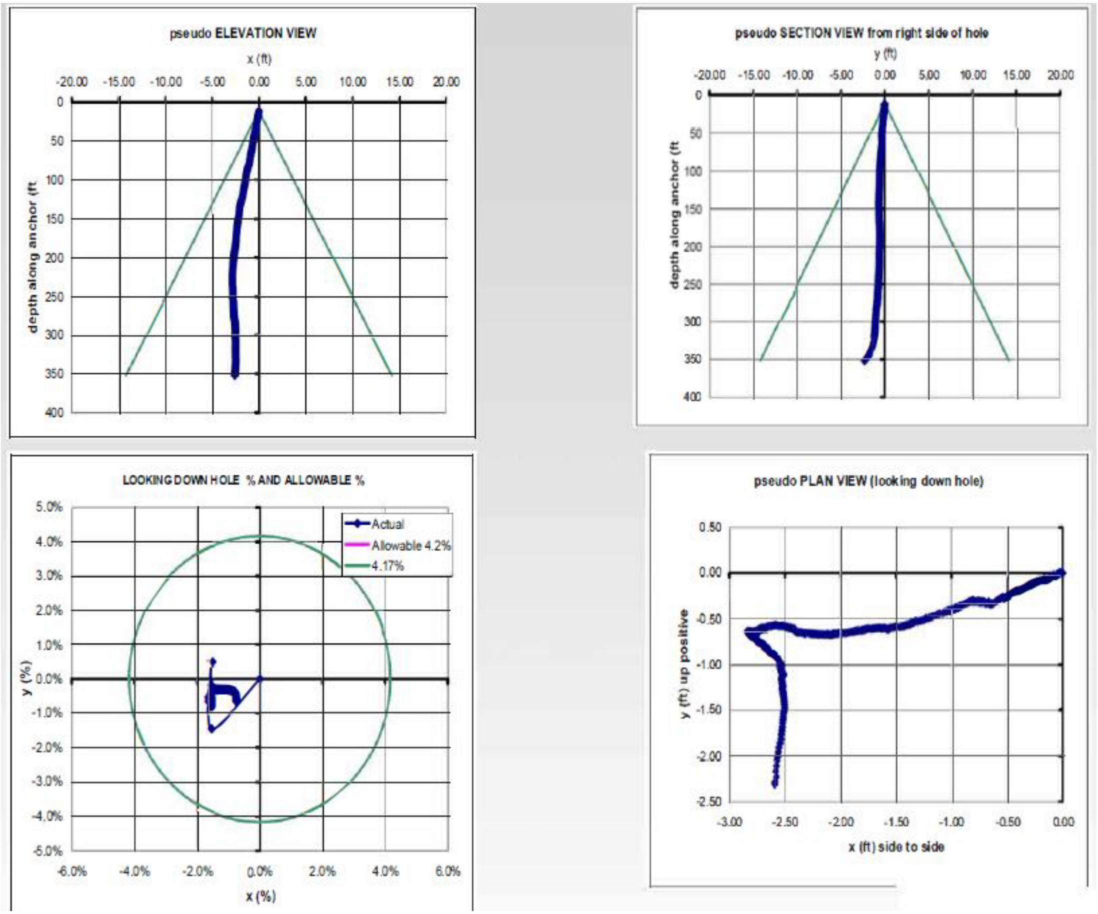
Quality Control



Downhole Survey

- Gyro
- SAA
- Koden
- OPTV
- Others

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Conclusion

- Establish Team Goals
- Work as one
- Develop
  - Communication
  - Respect
  - Honesty
  - Partnership

Questions?

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