2015 International Petroleum Environmental Conference

SOIL SAMPLING UTILIZING HORIZONTAL/DIRECTIONAL DRILLING METHODS

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Directional Control

- The bit is navigated along a prescribed path
- The bore path need not be horizontal or straight
- Bore path is design is based on
  - Allowable bending radius of drill pipe
  - Geology
  - Sample location
  - Surface constraints

Directional Control/Steering

- The drill string is steered by pushing the drill pipe against an asymmetric bit with a hydraulic jet; “duck bill” or bent sub
- The force against the bit or sub forces the drill pipe in direction of the bit orientation
- When the entire assembly is rotated, the drill string goes straight
- A sensor behind the bit sends the direction/orientation of the bit to the surface

Directional Control/Steering

Locating Technologies

- **Several Options Available**
  - **Walkover/Radio Beacon**
  - **Wireline**
    - **Oil Field Technology**
    - **Short Steering Tool (SST)**
  - **Gyroscopic**
- **Selection based on bore path, interference risk, depth and cost**
- **All methods have ± 0.5 – 2% depth accuracy**

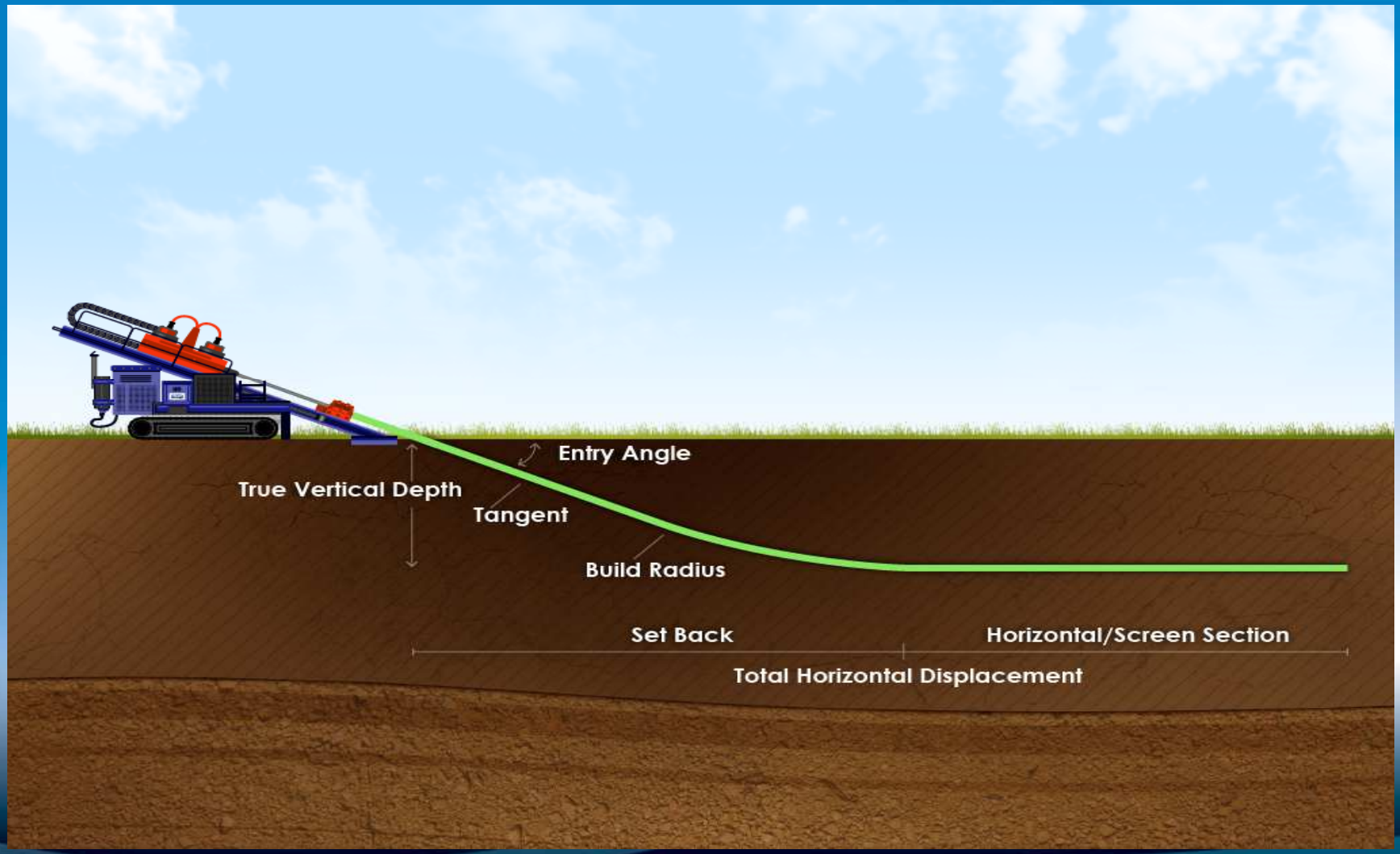
Drilling Fluids are Required

- **Maintain hole stability**
- **Remove cuttings**
- **Limit drilling fluid loss to the formation**
- **Cool bit and steering tools**

Bore Path Geometry

- **Terminology**
  - Entry angle
  - Tangent
  - Radius of curvature (build radius)
  - Horizontal section
  - True vertical depth
  - Measured depth/pipe length
  - Set back – determined by combination of the above

Bore Path Geometry



Drilling Equipment

- **Drill rig**
- **Fluid cleaning/recycling system**
- **Pipe trailer**
- **Support vehicles**
  - **Water truck**
  - **Crew truck**

Small Rig Set Up Area

- **7,000 lb. capacity rig**
- **30’ x 50’ area**

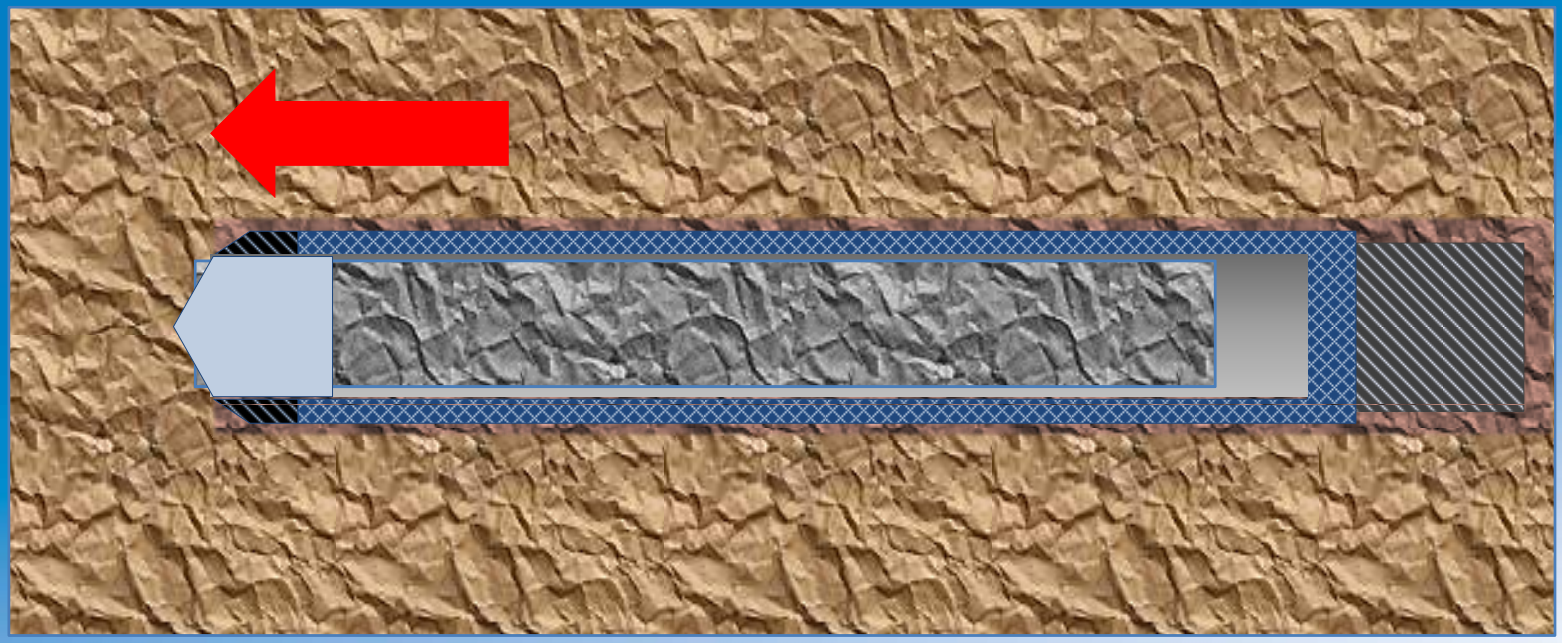
Soil Sampling

- **Goals**
  - **Obtain representative samples at a predetermined target**
  - **Challenges**
    - **Sample location**
    - **Avoid "scraping" sample from side wall or bottom of borehole**
    - **Exclude drilling fluids**
    - **Retain unconsolidated material**
    - **Quick visual identification**

Tooling

- **Two types of samplers**
  - **Set screw/bullet nose**

DTD “Bullet” Sampler



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Tooling

- **Two types of samplers**
  - **Piston**

Tooling

- **Sample recovery**
  - **2” diameter up to 18” long**
  - **Standard acetate sleeves allows for visual inspection**

Soil Sampling

- **Methodology**
  - **Drill/steer to sampling point**
  - **Remove drill rod**
  - **Push sampler to end of bore**
  - **Obtain sample**
  - **Pull sampling tool**
  - **Repeat**

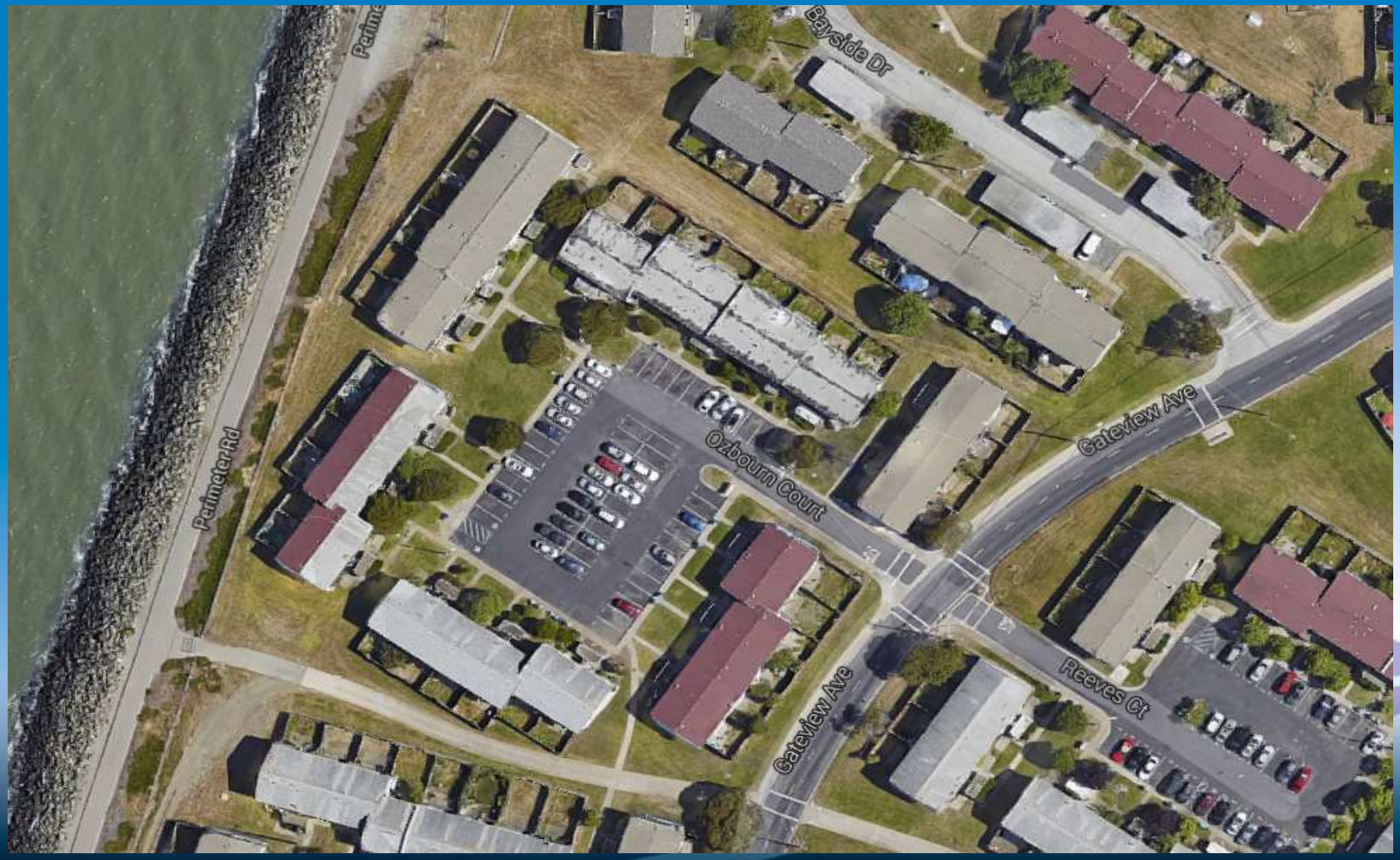
Project Sites

- **Past Projects**
  - **DOE Site, OH/building slab**
  - **Belle Chase, LA/1,000,000 gallon tank**
  - **Pasco, WA/unlined landfill**
  - **Belle Chase, LA/concrete revetment**
  - **Urban Site, CA/occupied housing**
  - **Industrial Facility, IL/under pond**

Soil Sampling Case Study

- **Urban location**
  - **Obtain soil samples under occupied residences**
    - **Unconsolidated formation**
    - **Sample locations up to 50’ from entry location and 3’ - 4’ sub slab**
    - **Drilling fluid containment critical**

Case Study - Urban



Case Study – Urban

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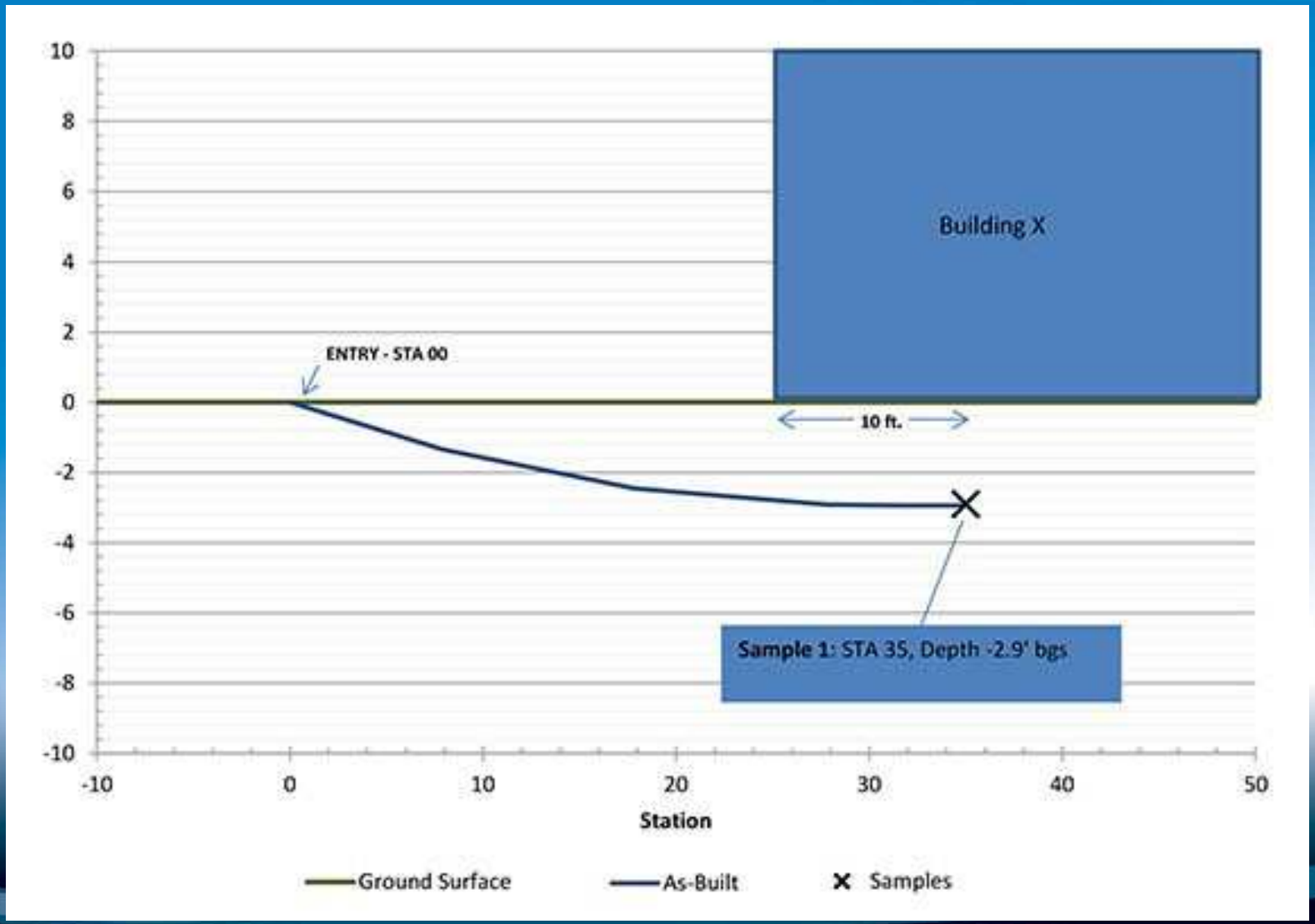

Case Study – Urban

- Ten samples obtained
- No impact to residents
- Drilling fluids contained
- Eleven days on site
  - Test event
  - Decon
- $10,000/sample

Case Study – WA Landfill

- Closed mixed waste facility
- Buried stacked drums
- Engineered cap, no liner
- Adjacent to active transfer station
- Challenging drilling conditions
  - Locating interference from drums
  - Soil conditions

Case Study – WA Landfill

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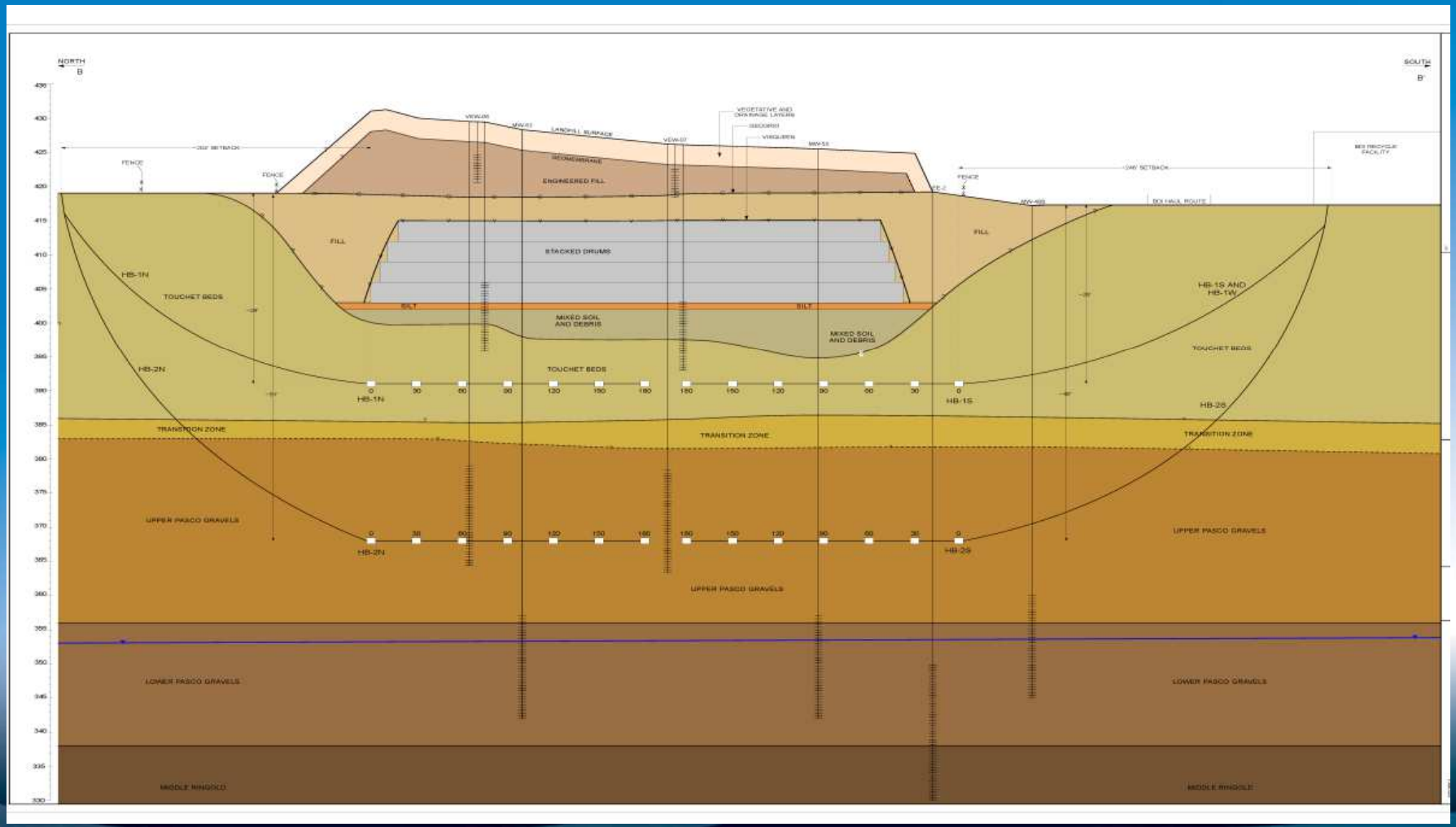
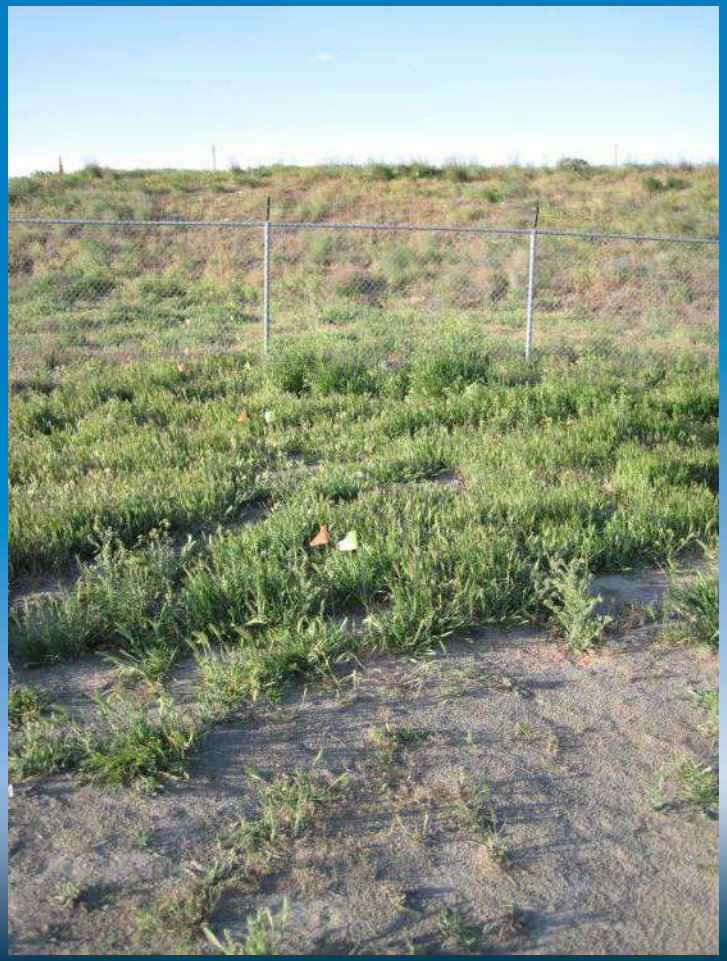


Case Study – WA Landfill

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Case Study – WA Landfill

- 70 soil samples obtained
- 2,290’ total footage drilled
- Over 91,000’ of drill pipe tripped
- $3,560/Sample

In Summary

- The technology is innovative - not experimental
- New tooling provides for sample quality
- Method is expensive and site specific
- Allows for soil samples to be obtained in areas unreachable by traditional vertical/angle drilling
- The technology is innovative – not experimental