Field Implementation of the Vertical In situ Permeameter (VIP) BDV31-977-88

FDOT GRIP Meeting

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Outline

- Introduction
- Project Background
- Project Objectives
- Calibration and preliminary testing analysis
- Remaining Tasks

Introduction

- Measuring hydraulic conductivity in soil can be challenging
- Grain size, grain orientation, density, degree of saturation, and soil type all effect hydraulic conductivity
- Soil disturbance can lead to skewed results
- Several methods have been developed to measure hydraulic conductivity
  - Includes laboratory and field methods

Introduction

- Laboratory methods are often questionable
  - Inherent sample disturbance induced during extraction and transport
- Field methods induce less disturbance
  - Provides better insight for in situ conditions
- Field testing is often preferred
  - Traditional field testing includes cased and uncased borehole methods
  - Disturbance is still induced during drilling to test depth
    - Creates more variability in hydraulic conductivity measurements
- Traditional field testing is more expensive and time consuming
  - Makes the approach less ideal

Project Background

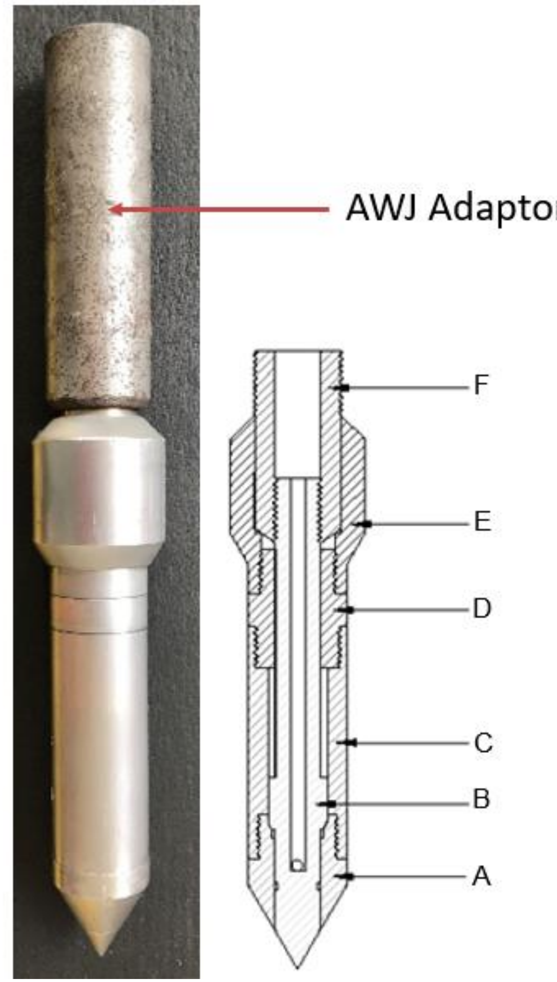
- Recently UF and FDOT developed a new permeability probe, the Vertical In situ Permeameter (VIP)
  - Includes an inner rod/outer casing design with a retractable tip that produces a circular injection surface
  - Retractable tip injects flow in the vertical direction
- Does not utilize a well screen with horizontal injection
  - Typical drive point probe flow injection
- Channeling effects are eliminated by VIP design
  - No fluid injection necessary during advancement
- Smearing and/or siltation effects are minimized by the VIP's unique design.
  - Probe is closed off from debris intrusion during advancement
- Vertical injection eliminates misleading results caused by the well screen positioned between two different soil layers.

Original VIP Probe Design

A. Probe head
B. Inner rod
C. Main chamber
D. Connector
E. Friction reducer
F. AWJ adaptor connection

*AWJ adaptor depicted

**3 set screws not depicted



VIP Probe Testing Observations

- VIP measurements were in good agreement with results obtained from various conventional methods
  - Cased constant head
  - Cased falling head
  - Uncased constant head
- VIP requires far less test time than conventional methods
  - Greatly improves efficiency
  - More data can be collected with less effort
- Based on the success, a new Florida Method of Test was developed for the probe
  - FM 5-614
- Additional testing is recommended to validate the success of the preliminary trials

Research Primary Objectives

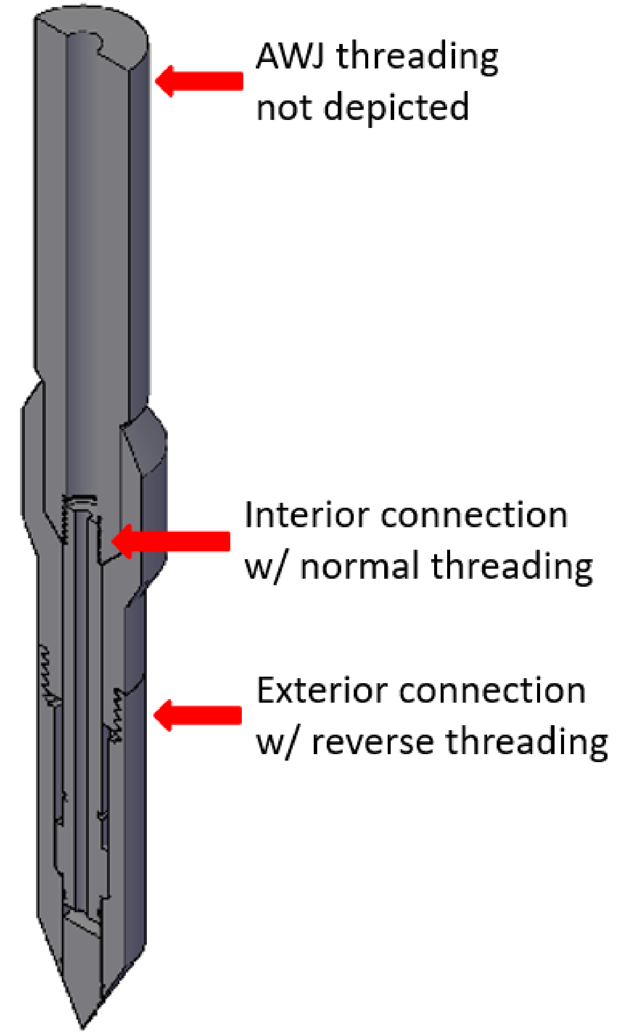
- The primary objective of the current research effort is to implement VIP testing throughout Florida
  – Validation testing
  – Introduce the new test method to each FDOT district
    - On-site training provided by UF research team
- 8 locations will be tested
  – 7 FDOT districts and along the turnpike
  – 2 sites per location
- Variable soil and field conditions will be encountered
  – Provide a better understanding of the probe's capabilities and constraints

Research Secondary Objectives

- Investigate and update VIP probe design provided in FM 5-614
  - More robust internal design for percussive driving
  - Simplify design for easier assembly and disassembly
- Fabricate 8 probes and falling head vessels
  - Distribute amongst the FDOT districts
- Develop an instructional video
  - VIP training purposes
  - Promote the newly developed test method

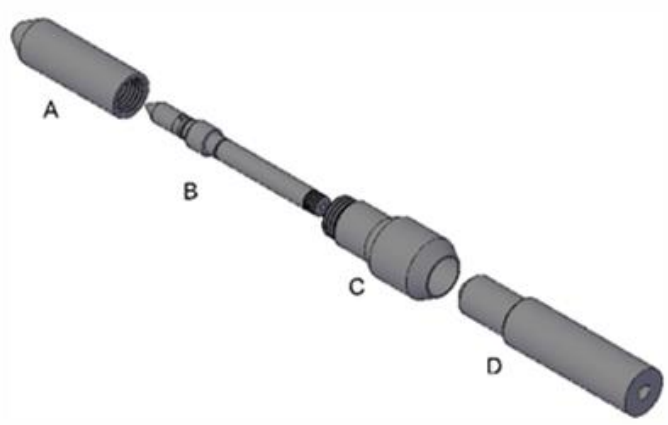
New VIP Design

- Simplified probe design
  - 4 individual probe components
  - Combined original VIP probe components:
    - Probe head and main chamber
    - Connector and friction reducer
    - AWJ adaptor connection and AWJ adaptor
- One interior and one exterior threaded connection
  - Reverse threading used on exterior connection
    - Eliminates unthreading when adding AWJ rods without using set screws
- Additional attributes:
  - Robust threading
  - Increased wall thickness
  - 2” stroke length
  - Upper chamber O-ring ensures water only flows through injection port at probe tip
  - Assembly in less than 30 seconds
  - Easier to fabricate concentric probe pieces
  - Easier to fabricate proper internal alignment
  - 20% reduction in fabrication cost

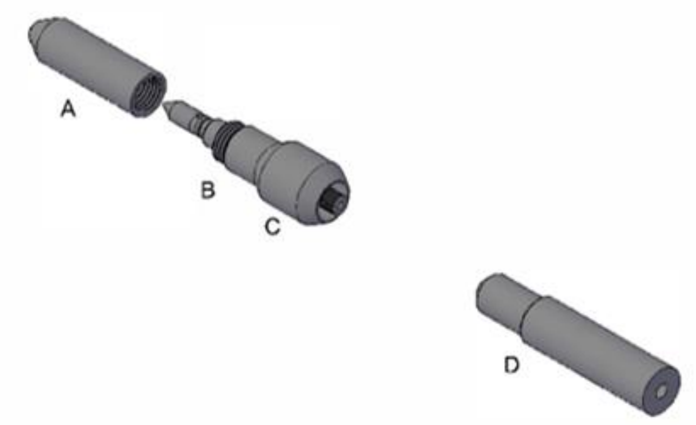


Simplified Assembly

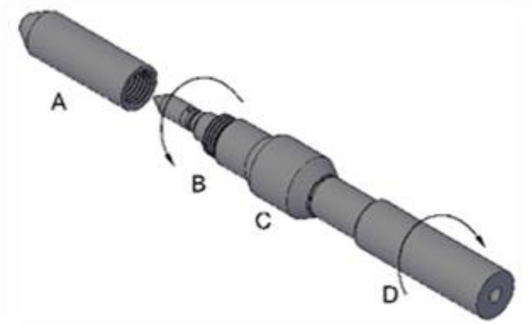
1.) Arrange parts A - D



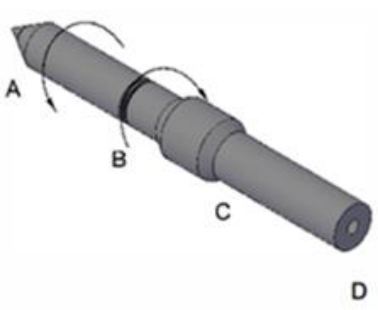
2.) Slide C onto B



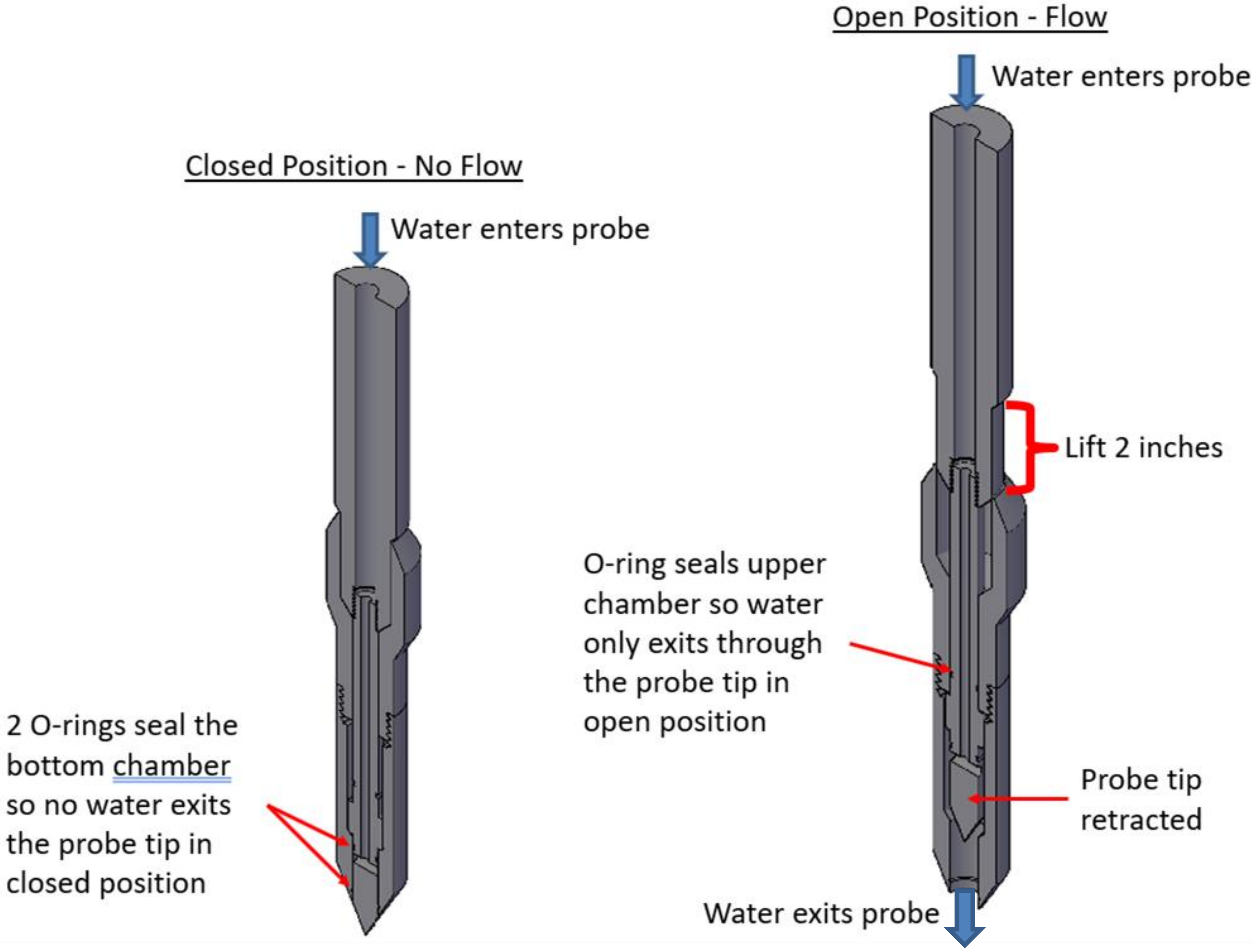
3.) Slide D into C and thread onto B (CW)



4.) Thread A onto C (CCW)



Probe Mechanics



VIP Testing Equipment

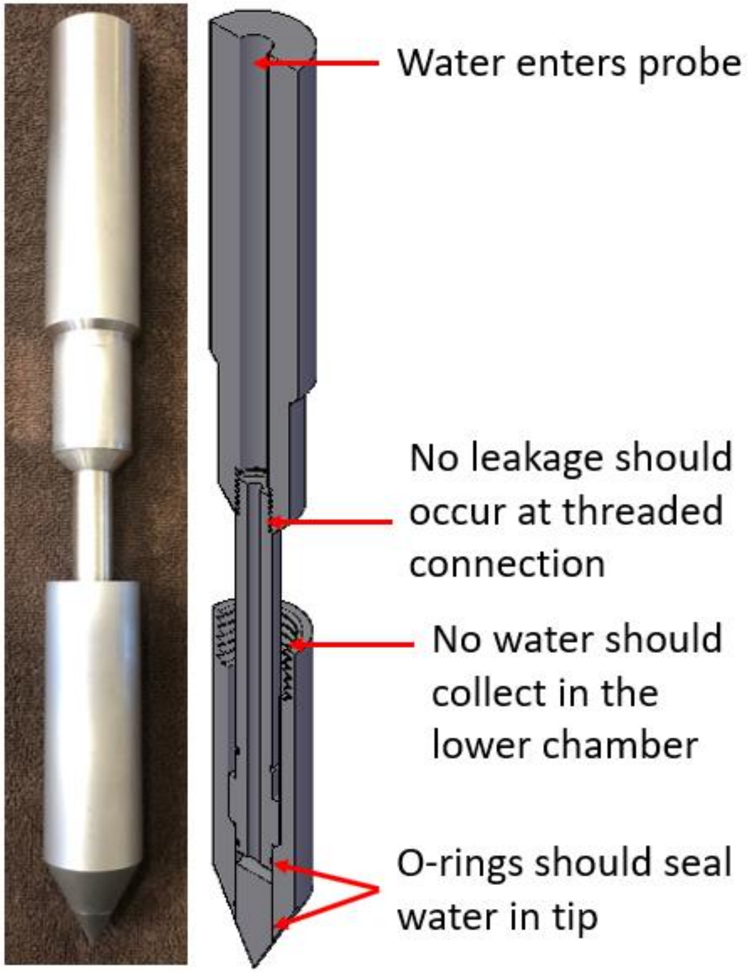
- Each district will receive:
  - VIP Probe
  - Falling Head Vessel
  - AWJ attachment
- On-site training will be provided within each FDOT district
- YouTube VIP instructional video will also be available

VIP Calibration

- Calibration was completed to ensure the probes and accompanying equipment function properly before distribution
- Required a standard calibration procedure to be developed
  - Check O-ring compression
  - Determine permeability limits of the probe
- The previously developed shape factor (F) is also be investigated
  - Currently, F = 3D
  - Could range from 2.5D to 3.1D based on the literature

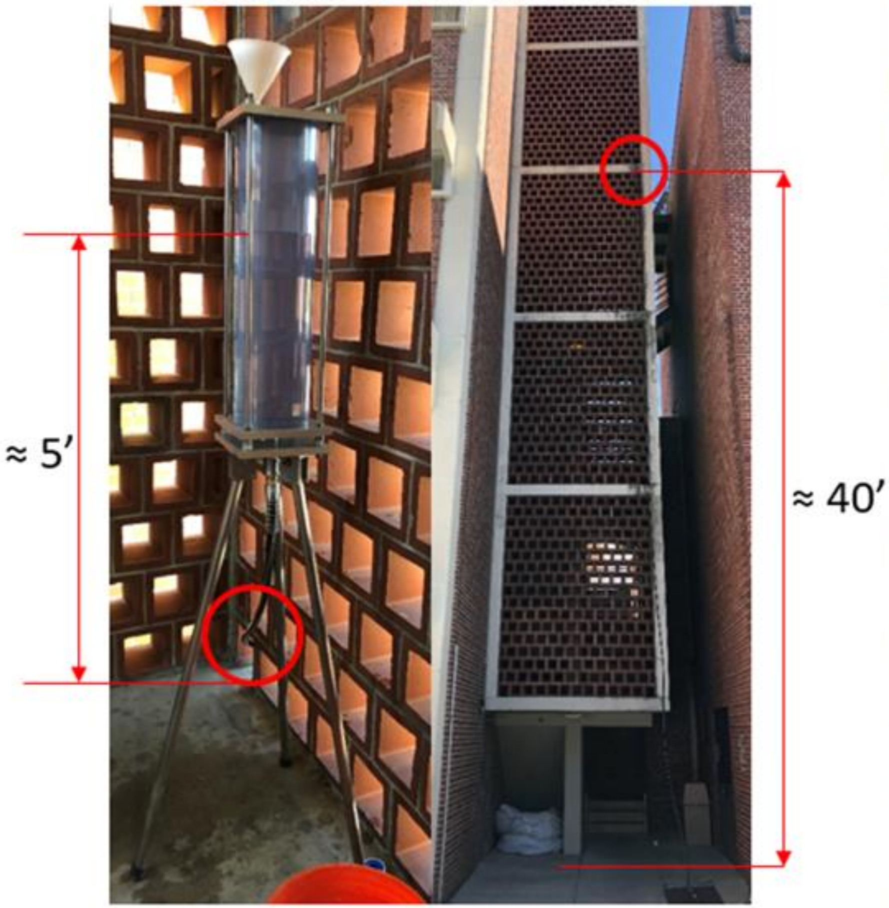
O-ring Watertight Seal Testing

- Friction reducer is removed
  - Can observe internal components for leakage
- Water is introduced to probe at various elevation heads
- Investigated locations for leakage
  - O-ring seals near tip
    - Ensures water is contained until the probe tip is retracted to inject water for testing
  - Internal threaded connection
    - Ensures water only exits through the inner rod flow ports

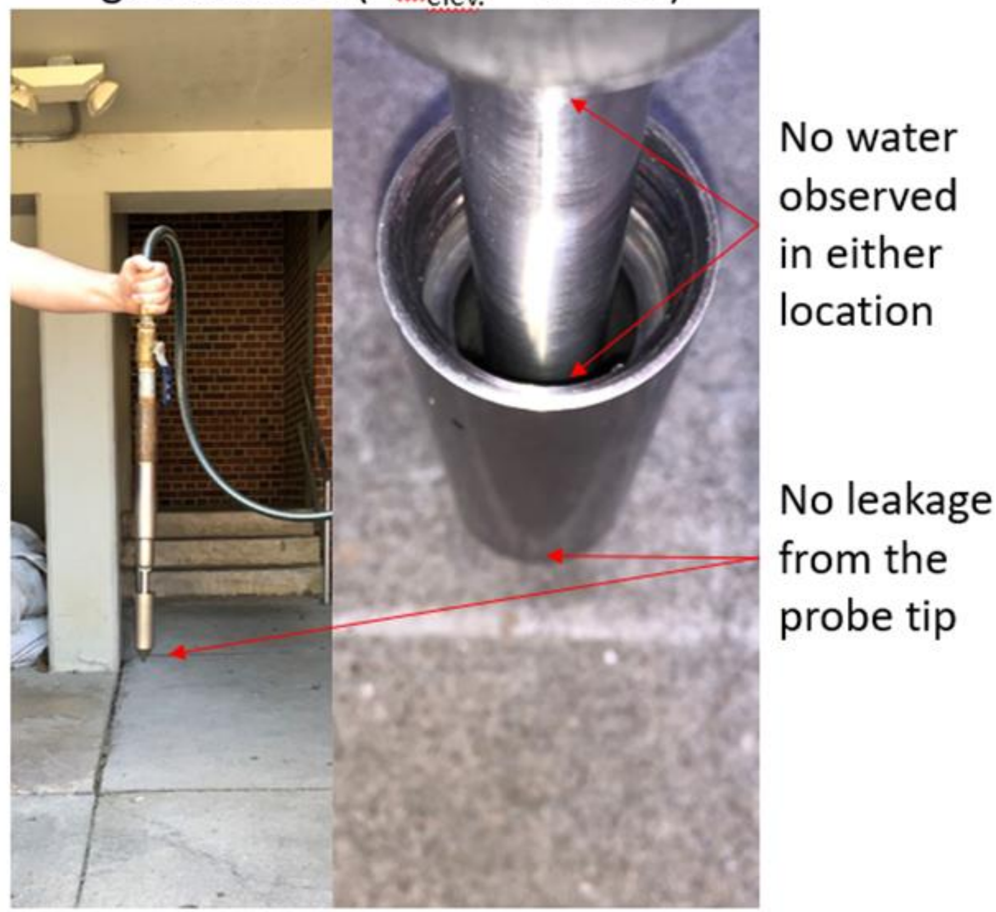


Watertight Seal Controlled Testing

Falling head vessel placed on the fifth floor of stairwell



Probe inspected for leakage at ground level ($\Delta H_{elev.} \approx 45$ feet)



Watertight Seal Testing Analysis

- Tested at 45 feet of head in controlled setting
  - Maximum estimated field test depth = 25 feet
  - Factor of safety ≈ 2 based on controlled testing

- PTFE (plumbers) tape recommended at threaded connections
  - PTFE tape is commonly used to prevent leaks in threaded pipe connections containing water under pressure
  - Some leakage observed without PTFE tape
  - No leakage observed when PTFE tape was applied at the inner rod threaded connection (internal connection)

- No leakage observed at probe tip O-ring locations
  - Confirming O-ring seal at the tip confirms upper O-ring seal
    - Same O-ring seal is provided in both locations
  - Ensures water only exits through flow ports during testing
  - Provides more accurate measurements of hydraulic conductivity

Permeability Limits

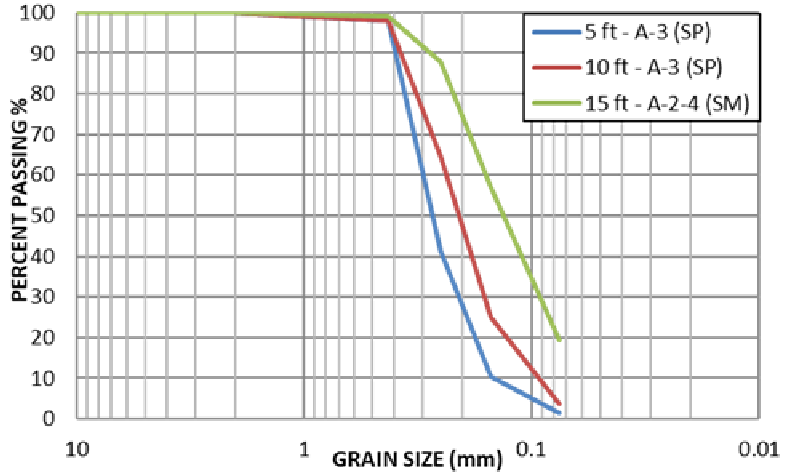
- Tests were performed in which the probe was left to drain freely into the air
  - Determines upper permeability limit
  - Procedure provided in FM 5-614
- Upper permeability was increased with new VIP design compared to original VIP design
  - $k_{max} = 1.07 \times 10^{-1}$ cm/s > $k_{max} = 7.48 \times 10^{-2}$ cm/s
- Lower permeability limit will be determined after all testing is complete
  - Lowest permeability recorded to date with new VIP design is $k_m = 3.45 \times 10^{-6}$ cm/s
    - Lowest permeability recorded with any VIP probe
    - CR 349 in District 2 → Soil Type A-7-6 (CH)

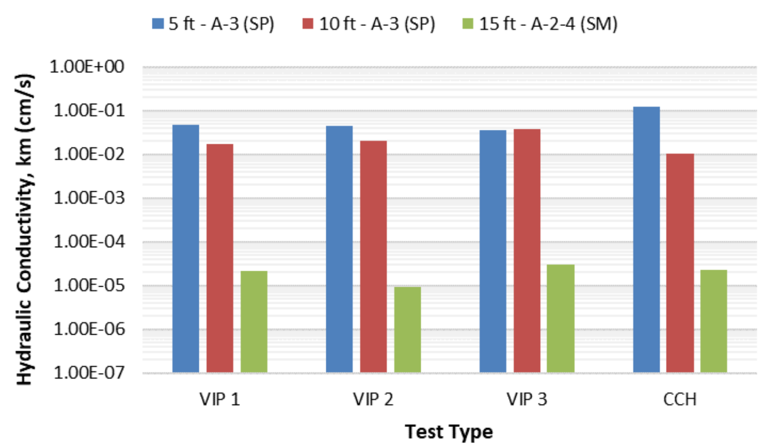
VIP Field Testing

- Field testing will be conducted at 16 different sites throughout Florida
  - 7 FDOT districts and along the turnpike (2 sites/location)
  - Districts 2 and 3 have been completed
- Additional testing will also be conducted at each site
  - Comparative conventional testing
    - Cased and uncased borehole methods
  - Soil classification
  - VIP push tests to quantify soil density effects on hydraulic conductivity
- Data will be reduced and analyzed after each site is completed
- Upon completion of all sites, a final analysis will be conducted, and conclusions will be drawn
  - Cost comparisons to conventional methods
  - Commentary on any regional/geological variability effects

D2 – Trenton – Location 1

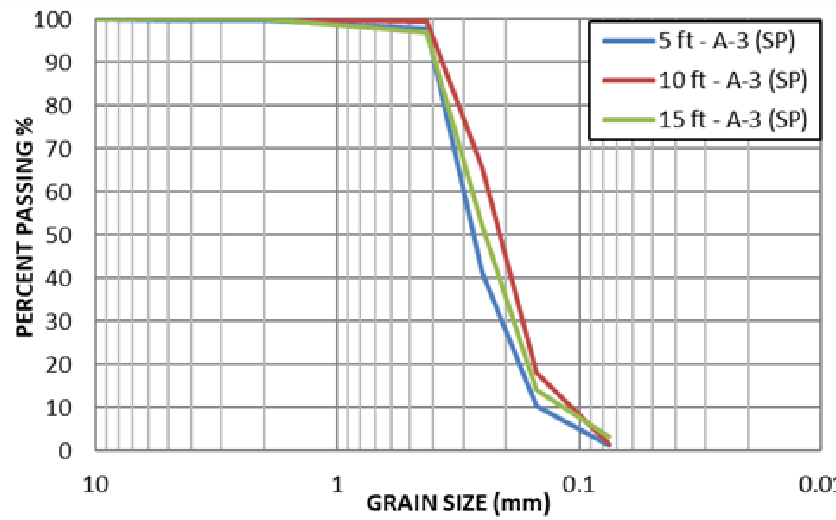
- VIP and cased constant head (CCH) test performed at 3 depths
  - Depths = 5', 10', 15'
- Sieve Analysis indicated changing soil type at 15'
  - A-3 (SP) → A-2-4 (SM)
  - 20% passing No. 200 at 15'
    - < 5% at 5' and 10'
  - Nearby boring indicated sand with red clay at 15'
- VIP and CCH both indicated changes in hydraulic conductivity (k_m) at 15'
  - $1x10^{-2}$ cm/s → $1x10^{-5}$ cm/s

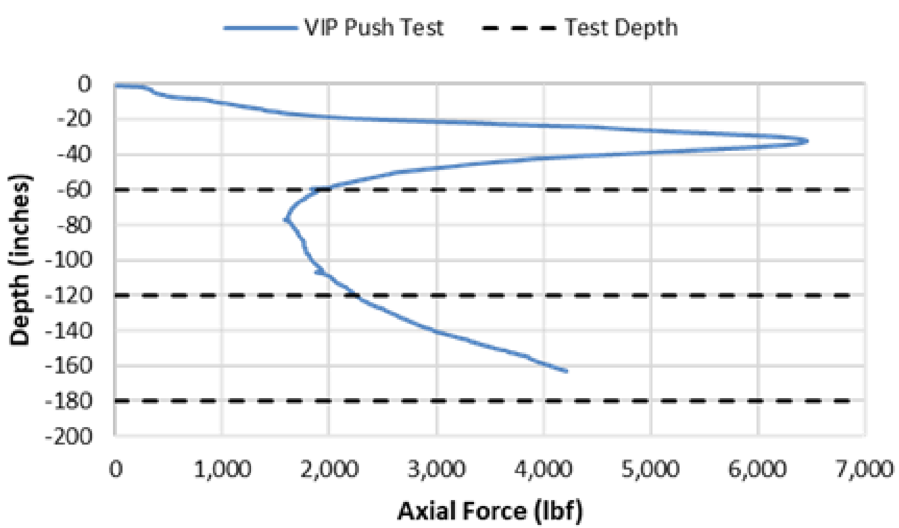


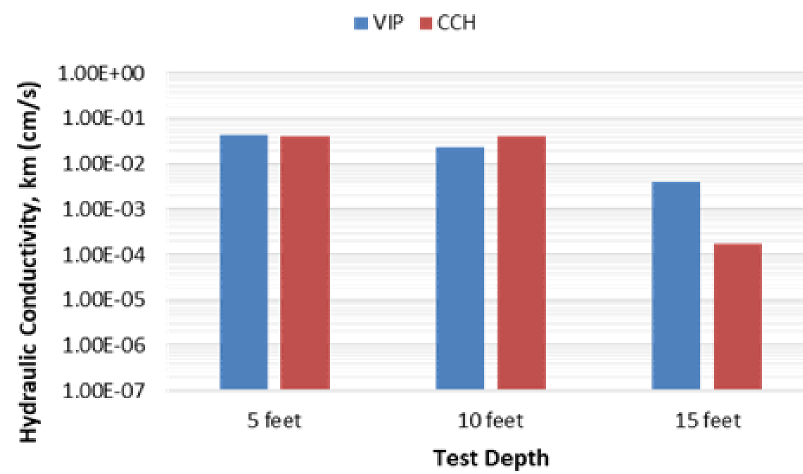


D2 – Trenton – Location 2

- Same soil type at each depth
  - A-3 (SP) at 5', 10', and 15'
- Push test indicated soil density increasing with depth
  - Based on measured axial force
- VIP and CCH tests both indicated k_m decreasing with increasing soil density

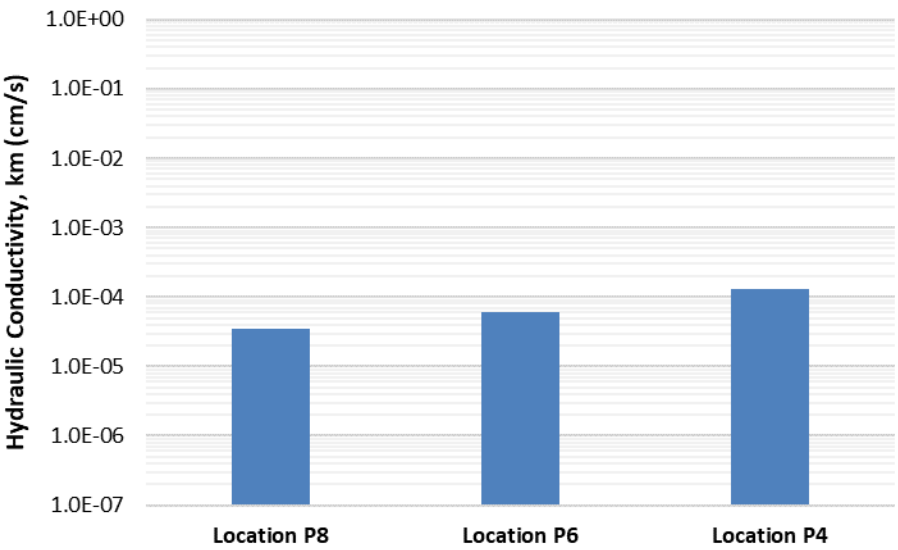






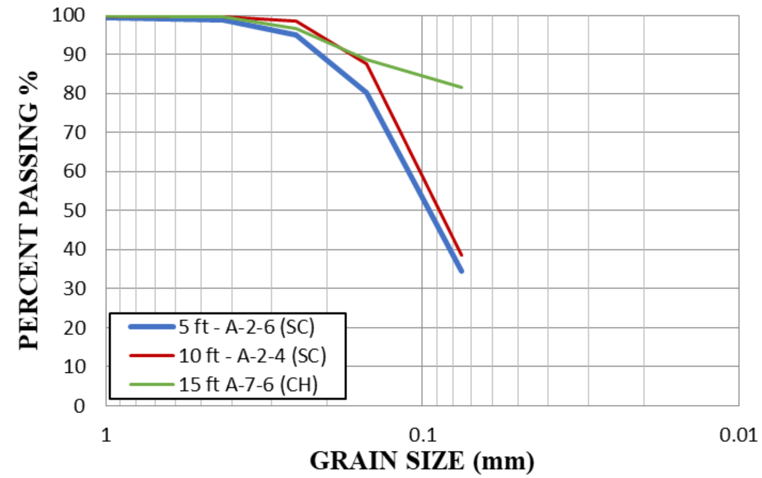
D2 – Newberry

- Investigated a potential retention pond site
  - Provided training to FDOT D2 field specialists
- Tested the hydraulic conductivity at the same elevation across the site
- Similar hydraulic conductivity across the site @ same elevation
  - Slight increase in K_m moving east to west

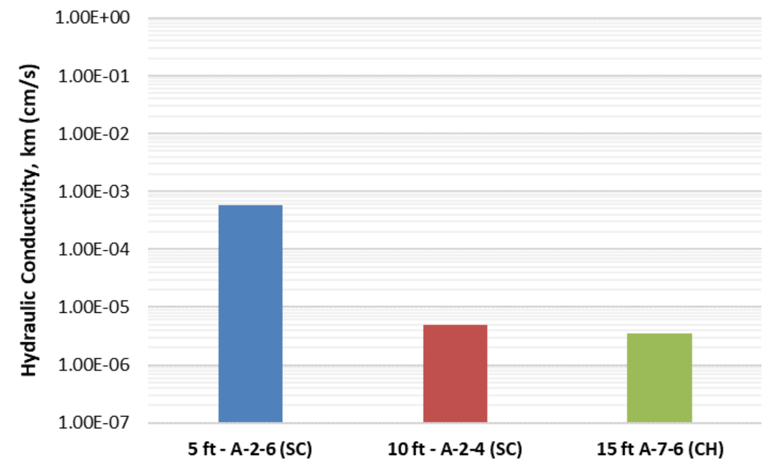


D2 – CR 349

- Provided VIP training to D2 consultants
- Observed large change in k_m moving from 5' to 10'
  - Increase in SPT blow counts
- Recorded lowest k_m to date at 15' (A-7-6 / CH)
  - K_m = 3.45 x 10^{-6} cm/s

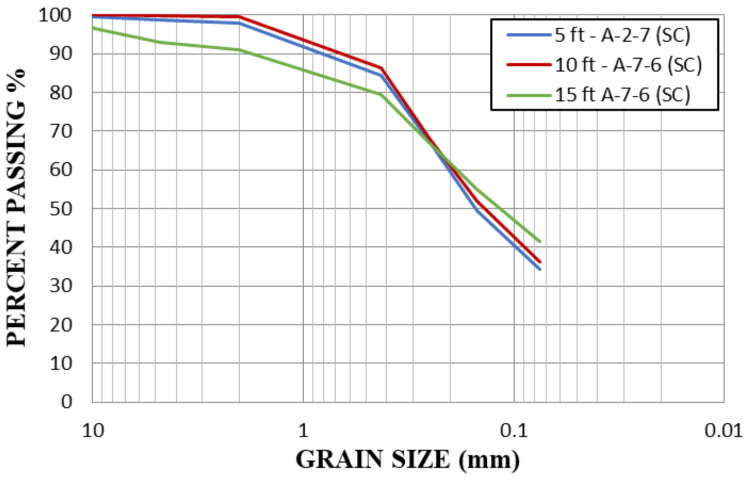


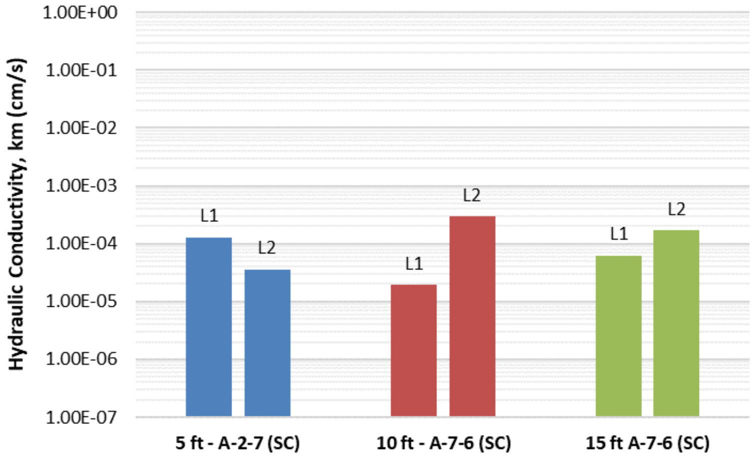
5 ft	10 ft	15 ft
SPT N = 6	SPT N = 27	SPT N = 25



D3 – Marianna

- Provided training to FDOT D3 Field Specialists
- Tested 2 locations at the site
  - 3 test depths per location
- Low k_m at all locations
- No clear trend of increasing k_m with depth
  - SPT N decreased with depth

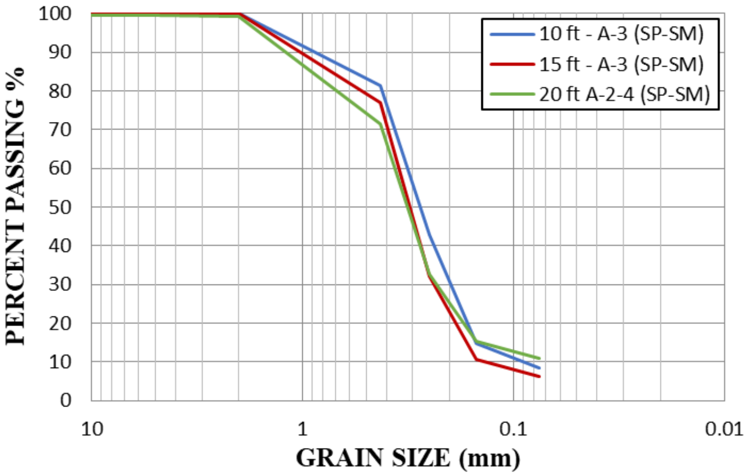


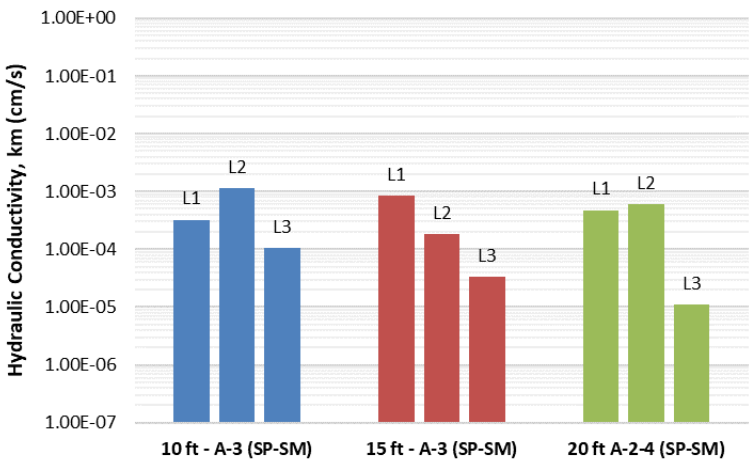


SPT N = 9 SPT N = 8 SPT N = 6

D3 – SR 231 - Cottondale

- Tested 3 locations at the site
  - 3 test depths per location
- Lower k_m at all 3 locations
- Only Location 3 indicated decreasing k_m with depth
  - SPT N variable with depth
- Often encountered dark black soil at site





SPT N = 6 SPT N = 1 SPT N = 9

Remaining Tasks

- Complete VIP testing and provide on-site training in remaining FDOT districts
  - Distribute probes and falling head vessels
- Complete instructional video
  - Filming is complete, currently editing video
- Closeout Meeting and Draft Final Report
- Final Report

Questions?