FIELD TESTING AND CALIBRATION OF THE VERTICAL INSITU PERMEAMETER (VIP)

PI: Dr. Ana Mohseni

CO-PI: Dr. Raphael Crowley

Consultant: Dr. Harald Klammler

Graduate Student: Caitlin Tibbetts

GRIP August 20, 2015

OVERVIEW

- Background
  - VAHIP
  - VIP
- Project Objective
- Literature Review
- Site Identification
- VIP Testing
- Results
- Moving Forward
  - VIP
  - VAHIP 2.0

BACKGROUND

- VAHIP – Vertical and Horizontal Insitu Permeameter
  - Developed to measure vertical and horizontal permeability
    - 2 flow ports
  - Complex mechanical design
    - Rotation through stages
  - Difficult operation
  - Lengthy assembly and disassembly
    - Cleaning
- VIP – Vertical Insitu Permeameter
  - Developed to offer a simpler version of VAHIP
    - 1 flow port
    - Smaller, lighter design
  - Improvement compared to existing insitu permeability techniques

PROJECT OBJECTIVE

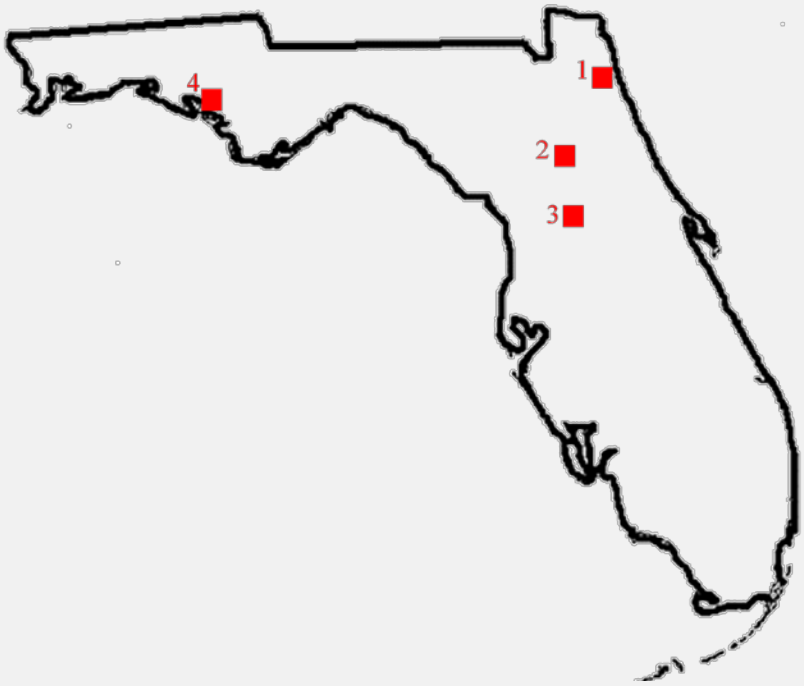
- Implement a simple field procedure
- Develop simple and theoretically consistent equations for VIP data interpretation
- Conduct field testing of VIP at multiple sites for validation
- Perform an empirical data analyses comparing VIP data with independent field permeability data
- Tasks:
  - Literature review
  - Site identification
  - VIP testing
  - Data analyses and empirical equations development
  - Draft and final reports

LITERATURE REVIEW

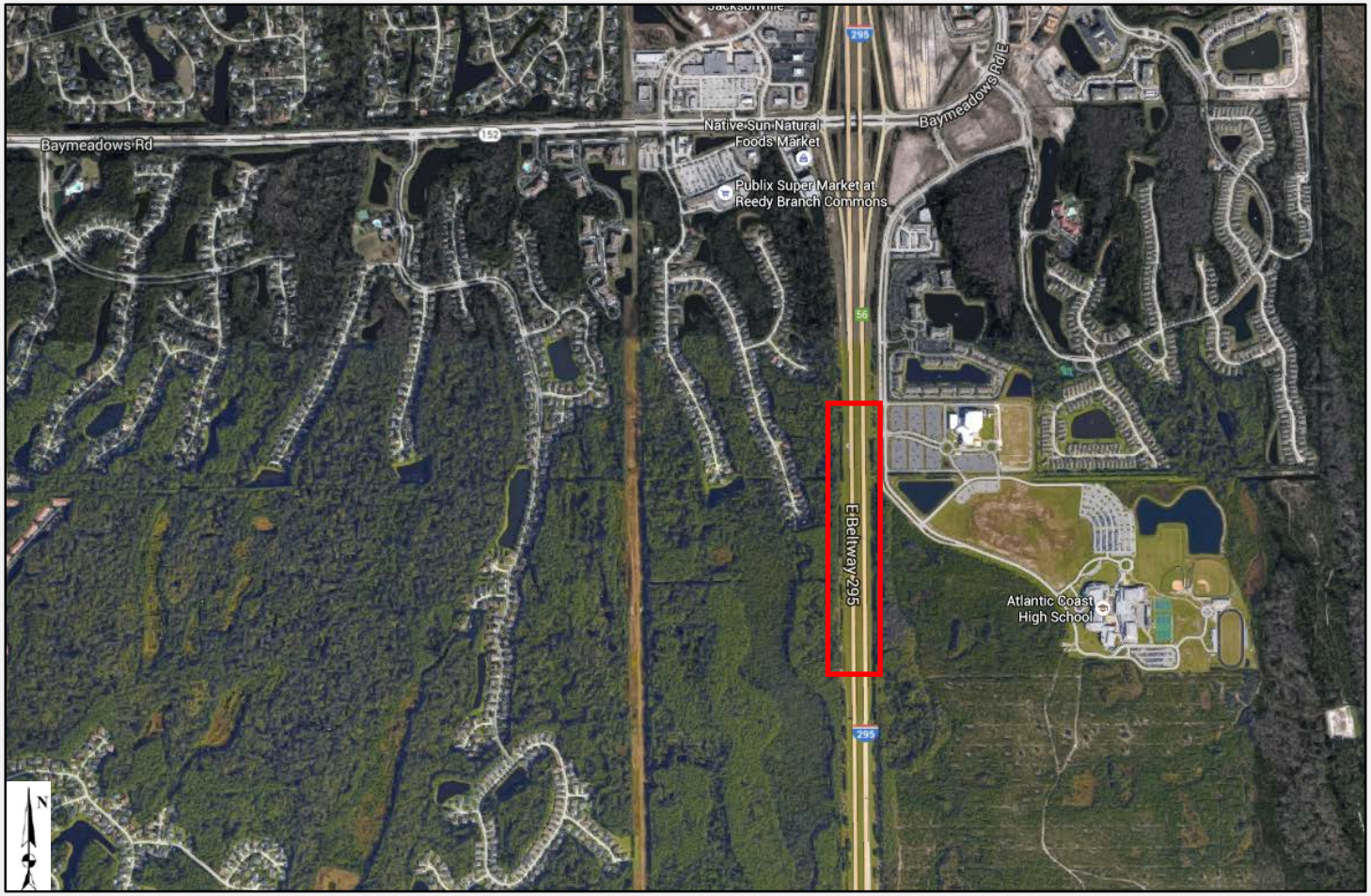
- Focus ➔ development of direct-push permeameter
  - Faster setup and testing times
  - Simplified procedure
  - Less soil disturbance
  - More detailed permeability measurement
    - Multiple depths
    - Vertical and horizontal permeability
    - More accurate
- Selection of VIP testing procedure and permeability equation
  - Falling head procedure
  - Hvorslev Case C: flush bottom in uniform soil
    - $k_m = \frac{\pi d^2}{4F(t_f - t_i)} ln \frac{H_i}{H_f}$
      - Where k_m is the mean (overall) permeability

SITE IDENTIFICATION

- Jacksonville – SR-9A
  - 4 dry retention ponds/ditches to manage stormwater runoff along SR-9A/I-295
- Hawthorne – SR-20
  - Collection of potential pond locations along SR-20 east of Hawthorne
- Lady Lake – SR-500
  - 1 dry retention pond off SR-500 (not performing to design specifications)
- Panama City
  - Small lot east of Panama City airport
    - Previous site investigation not performed



JACKSONVILLE – SR-9A



HAWTHORNE – SR-20

LADY LAKE – SR-500

PANAMA CITY


NORTHSHORE ISLANDS
NORTHSHORE
WOODRIDGE
VENETIAN VILLA
VENETIAN VILLAS
390
BELAIRE ESTATES
77
RAVENWOOD
WOODRUN
385
STATE PALMS
FOREST RIDGE
A. Crawford
Hig
FLORIDIAN PLACE
Jenks Ave
77
385
W Baldwin Rd
E Baldwin Rd
KING'S RANCH
HUNTINGDON ESTATES
BALDWIN HEIGHTS
TIMBERWOLF ESTATES REPLAT
KING ESTATES
TUPELO COURT
FOREST HILLS
FOREST PARK EAST
Harrison Ave
77
retty Bayou
390
Stanford Rd
THE WOODS
327
NORTHGATE
THE WOODS

VIP TESTING

- Testing Procedure
  - Equipment
  - Field testing materials
- Preliminary Testing
  - SMO
- Field Testing
  - Jacksonville – SR-9A
    - 30 tests over 8 borings
  - Hawthorne – SR-20
    - 50 tests over 12 borings
  - Lady Lake – SR-500
    - 15 tests over 4 borings
  - Panama City
    - 9 tests over 3 borings

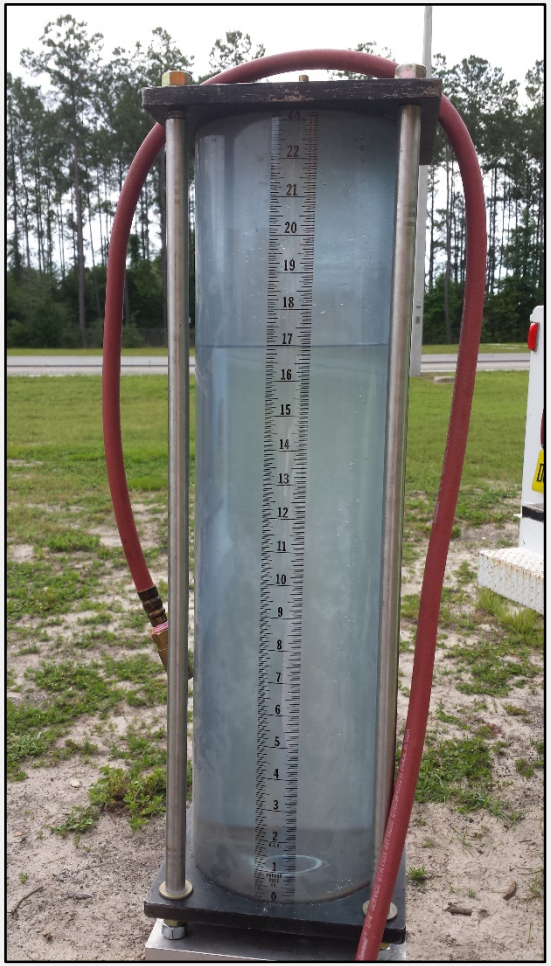
TESTING PROCEDURE

- Setup
  - Attach probe to SPT rig
    - Advance to testing depth
  - Level support stand for water tank
  - Place water tank on support stand
    - Attach water hoses
    - Fill water tank
    - Measure height from ground to base of water tank
  - Setup compressed air for flushing
  - Fill in data sheet
    - General information
    - Dry eraser marker for water tank

- Testing
  - Lift ~2 inches to open probe
    - Use hook to hold in place
    - Mark rod with chalk to monitor
  - Attach AWJ water connection
  - Attach water hose
  - Saturate soil for 15 min.
    - Refill water tank as necessary
  - Begin test
    - Use stopwatch for time increments
    - Take readings of water level in tank
  - Stop test
  - Attach air hose to top of water tank
    - Flush probe
  - Push down ~2 inches to close probe
  - Disconnect hoses

TESTING SETUP

TESTING SETUP



Equipment Checklist

VIP ASSEMBLY:

Item	Inspection	In	Out
Probe	- Clean with wire brush - Threading - O-ring - Tighten set screws		
Probe Maintenance Set	- Wire brush - Allen keys (7/64 & 1/8) - Extra set screws - Extra O-rings		
AWJ Connection			
AWJ Water Connections	- One stays connected to AWJ rod and other is if rods are disconnected		
Water Vessel w/Cap	- Cap (top of water tank) - Nuts to secure to stand		
Support Stand			
Water Hose – Probe/Tank Connection	- Quick connections		
Portable Air Compressor w/Tank	- Pressure		
Air Hose	- Quick connections		
Tape Measure			
Stopwatch			
Temperature Gun	- Measure temperature of test water		
Clipboard			
Data Sheet w/Pen	- Extra - Thin dry eraser marker for water tank		

SPT RIG:

Item	Inspection	In	Out
AWJ Rods	- Multiple lengths		
Grease Sealant			
Water Source	- 3 gallon water tank * # of tests		
Water Hose	- Connects rig water supply to water tank		
Air Compressor	- Pressure - Instead of portable		
Electrical Source (for rig w/o comp. air)	- 450 W		
Chalk			
Water Level Indicator & Hand Auger	- If pre-drilling is not required (no hole)		

SETUP:

Task	Description
Probe	▪ Assemble probe and attach AWJ connector – Ensure internal connections are tight ▪ Attach probe to SPT rig, use grease sealant between the connections
Water Supply	▪ Setup support stand and secure water tank – Place stand on level ground where it will not hinder the SPT rig operation • Hanging cap will be in center if level – Ensure water hose for probe will reach – Ensure water hose to fill tank will reach ▪ Attach water hose to base of water tank – Place end of hose on top of water tank to prevent flow ▪ Fill water tank
Air Supply	▪ If using air compressor on SPT rig ➔ adjust air pressure to proper level (Table 1) – Attach air hose and place near water tank ▪ If using portable air compressor ➔ attach to electrical source and fill air tank – Adjust air pressure to proper level (Table 1) – Attach air hose and place near water tank
Misc.	▪ Have data sheets and pen attached to clipboard – Multiples – Thin dry eraser marker for water tank ▪ Check stopwatch ▪ Have tape measure and chalk ready

BREAKDOWN:

Task	Description
Probe	▪ Remove AWJ water connection ▪ Pull probe out of soil – Disconnect AWJ rods ▪ Clean probe with water and air if necessary – Check set screws and connections – Open/close probe to ensure smooth transitions
Water Supply	▪ Drain water tank away from pathways – Ensure cap is tight ▪ Disconnect water hose from base of water tank – Coil ▪ Remove water tank from support stand ▪ Breakdown support stand
Air Supply	▪ Disconnect air hose from air compressor – Coil ▪ Turn off air compressor
Misc.	▪ Make sure all data sheets/pen are together and attached to clipboard – Ensure data sheet is filled out completely • Date, time, weather conditions, etc. ▪ Collect stopwatch, tape measure, and chalk ▪ Use checklist to ensure all equipment is packed for next location

Procedure for Operating Vertical Insitu Permeameter (VIP)

1. Advance probe to desired test depth using SPT rig's direct-push technique*
    a. Place grease between rod connections
2. Lift ~1.6 inches to open the probe (Use tape measure or Figure 1)
    a. Mark base of rod at ground level to track
3. Attach AWJ water connection
4. Attach water hose from water tank to AWJ water connection
    a. Kink the hose to quick connect
    b. Ensure spring guard is in place at AWJ connection
5. Let water drain for 15 minutes to ensure soil is saturated
    a. Add additional water to water tank if necessary
    b. Get data sheets/pen and stopwatch ready for testing
6. Begin test
    a. Start stopwatch when water level is at readable mark
    b. See Table 1 for recording time and total length of test
7. Test is complete
8. Attach air hose to top of water tank
    a. Ensure cap is tight on water tank
    b. Ensure air pressure is at proper level (Table 1)
9. Flush water through probe to clean (Table 1)
10. While system is flushing, push down ~1.6 inches to close the probe (Use tape measure or Figure 1)
    a. Previous mark should now be at ground level again
11. Disconnect air hose from water tank
12. Disconnect water hose from AWJ water connection
    a. Kink hose to remove and place end on top of water tank to prevent flow
13. Refill water tank
14. Probe is now ready to be pushed to next test depth
15. Repeat

Probe Stages | Rig Advancement | Adjustments | Test

*Pre-drilling (when direct-push is not viable):

- Stop drill minimum of 1 foot prior to final testing depth
    - Reduces soil disturbance
    - Allows probe to be pushed to final depth
    - Borehole of lesser diameter than probe may be drilled for last foot if material is very stiff
- Ensure probe is closed before advancement
- Continue with normal procedure

Supplemental Information

Table 1: Air Pressure and Testing Times Based on Soil Type*

Soil Type	Air Pressure	Recording Increment	Total Length of Test	Flush Time
Coarse Sand	10 – 20 psi	30 sec	5 min	10 sec
Fine Sand	15 – 25 psi	30 sec – 1 min	5 – 10 min	10 – 30 sec
Silty Sand	20 – 30 psi	30 sec – 1 min	5 – 10 min	10 – 30 sec
Sandy Silt	25 – 35 psi	1 – 5 min	10 – 50 min	10 – 30 sec
Clay	30 – 50 psi	5 – 10 min	50 min	30 sec – 1 min

*Numbers in this table are general approximations and will vary based on actual soil type and field conditions. Proper discretion should be used when selecting values. Initial saturation can be used to estimate appropriate values for the air pressure and time increments. Water tank is rated for 90 psi.

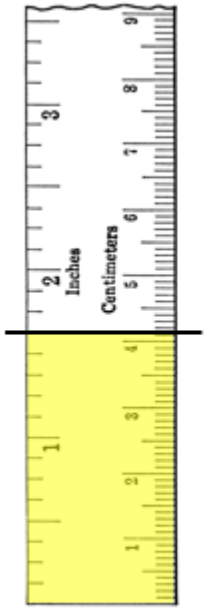


Figure 1: Open/Close Distance for Probe

DATA SHEET

Site Information:

Date	
Project Location	
Tested By	
Weather/Notes	

Boring Hole Information:

Hole No.		Drill Depth (ft) – for pre-drilled hole	
Station – Offset			
Test No.		Hole Diameter (in)	
Hole Depth (ft)		Water Temperature (°C or °F) – circle	
Water Table (ft)			
Distance to Base of Water Tank (in) – measured from ground surface			

Test Information:

Reading No.	Time (min)	Height in Water Tank (in)
1	0	
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

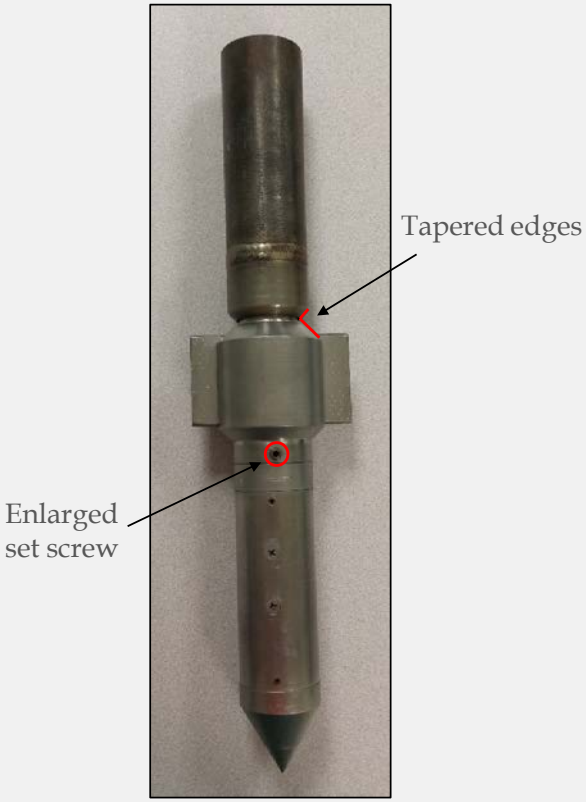
Other:

Height Drop during Saturation (in/min)				
Rig Pressure during Advancement (psi)				
Air Pressure for Flushing Probe (psi)				
Soil Description (not classification)				

PRELIMINARY TESTING AT SMO

VIP MODIFICATIONS

- Tapered friction sleeve and AWJ connection adapter
  - Prevent soil buildup between connections
- Enlarged set screw on friction sleeve
  - More resistance to torque
- Removed internal pin
  - Locking mechanism
- Added O-ring to inner rod
  - Keeps outer casing in place during advancement
- Removed wings on friction sleeve
  - Less resistance during advancement
    - Rotation through "stages" no longer necessary



FIELD TESTING

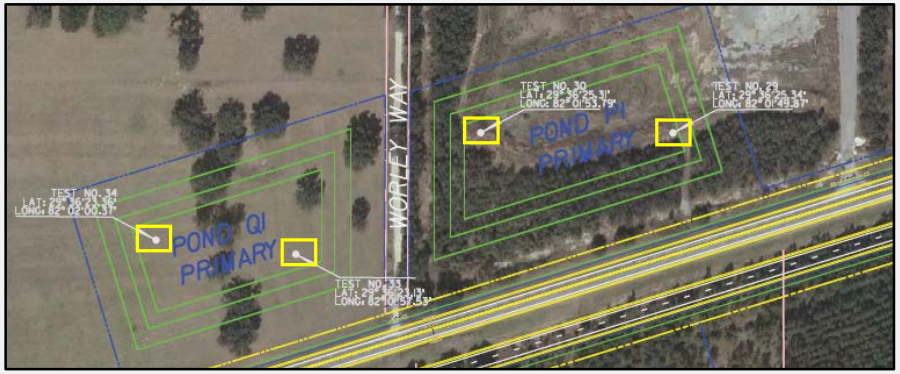
JACKSONVILLE – SR-9A

- Soil Type
  - Fairly uniform soil type
    - Fine sand to slightly silty fine sand (SP/A-3)
- Location
  - 8 borings
    - Ponds: 140R and 150R
  - 4 – 8.4 ft testing depths
    - No pre-drilling required
- Permeability
  - 30 tests
  - Range: no flow – 8.8 x 10^{-3} cm/s
  - Average: 1.8 x 10^{-3} cm/s
  - CV of site: 1.26
    - Spatial variability

HAWTHORNE – SR-20

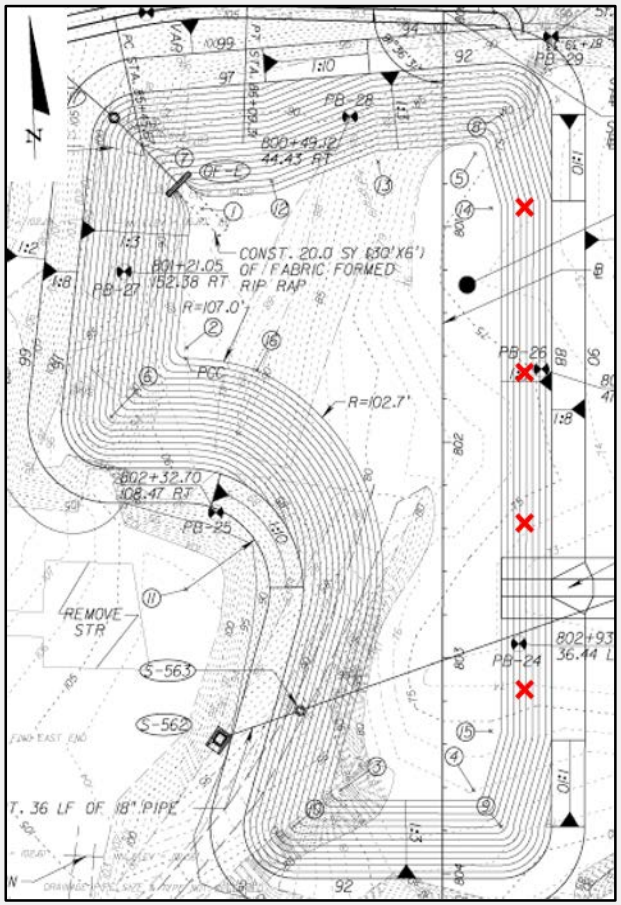
- Soil Type
  - Wide range of soil types encountered
    - Sand (SP/A-3)
    - Clayey sand (SC/A-2-4/A-2-6)
- Location
  - 12 borings
    - Ponds: P1, Q1, D4, Basin 1 Alt 2, 300, and 900a
  - 5 – 15 ft testing depths
    - Pre-drilling required for some depths
- Permeability
  - 50 tests
  - Range: no flow – 2.3×10^{-2} cm/s
  - Average: 4.1×10^{-3} cm/s
  - CV of site: 1.42
    - Spatial variability

HAWTHORNE – SR-20



LADY LAKE – SR-500

- Soil Type
  - Ranged from fine sand to clay
    - Silty and/or clayey fine sand (A-2) → majority
- Location
  - 4 borings
    - Berm along east side of pond
  - 5 – 15 ft testing depths
    - Pre-drilling required for 2nd depth (10 ft)
- Permeability
  - 15 tests
  - Range: no flow – 1.1 x 10^{-2} cm/s
  - Average: 1.5 x 10^{-3} cm/s
  - CV of site: 1.77
    - Spatial variability



PANAMA CITY

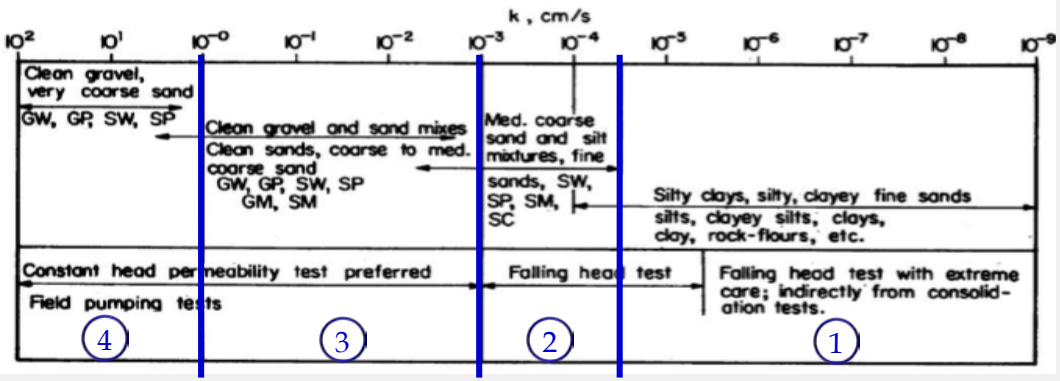
- Soil Type
  - Fairly uniform
    - Dark brown coarse sand (some fines and wood)
- Location
  - 3 borings
  - 5 – 15 ft testing depths
    - Pre-drilling required for some depths
- Permeability
  - 9 tests
  - Range: 1.5×10^{-3} – 1.0×10^{-2} cm/s
  - Average: 4.5×10^{-3} cm/s
  - CV of site: 0.71
    - Spatial variability

RESULTS

- Classification
  - Saturation
  - Soil type
- Overall Results
  - By soil type:
    - Average
    - Minimum and maximum
    - Standard deviation
    - Coefficient of variation
    - Number of tests
- Results by Location
- Final Results

SATURATION AND SOIL TYPE

- Saturation
  - Saturated – 43%
  - Unsaturated – 57%
- Soil Type
  - Based on Bowles as cited in FDOT Soils and Foundations Handbook



Soil Type	Soil Description	Permeability Range (cm/s)
1	Silt/clay	No flow – 5×10^{-5}
2	Fine sand	5×10^{-5} – 1×10^{-3}
3	Coarse clean sand	1×10^{-3} – 1
4	Clean gravel	1 – 100

OVERALL RESULTS

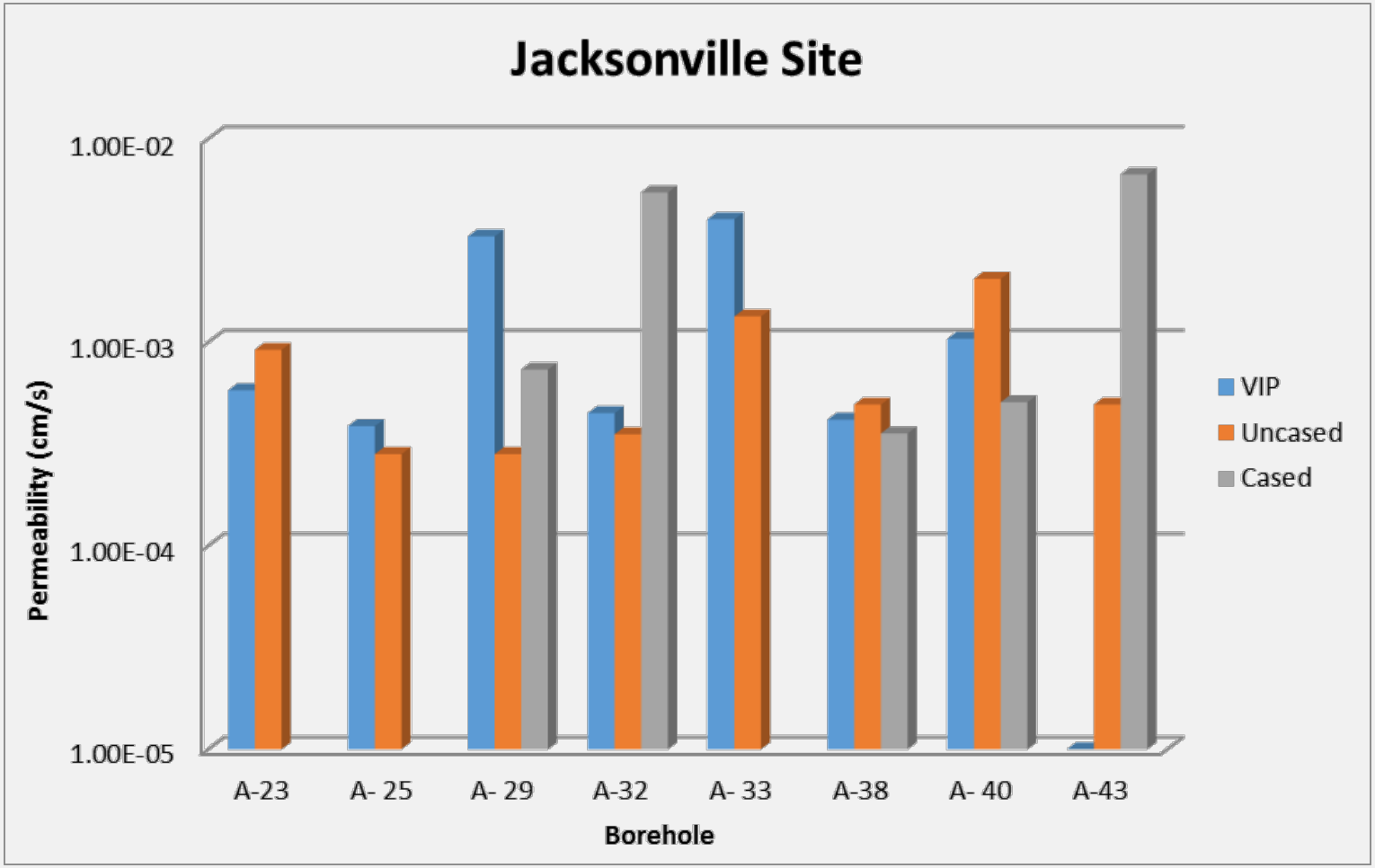
- VIP Data

Soil Type	Average (cm/s)	Min. (cm/s)	Max. (cm/s)	Std. Dev. (cm/s)	CV	# of Tests	% of Tests
1	6.6×10^{-6}	0	2.4×10^{-5}	9.6×10^{-6}	1.45	24	33%
2	3.1×10^{-4}	5.7×10^{-5}	9.5×10^{-4}	2.5×10^{-4}	0.79	18	25%
3	6.1×10^{-3}	1.0×10^{-3}	2.3×10^{-2}	5.4×10^{-3}	0.90	30	42%

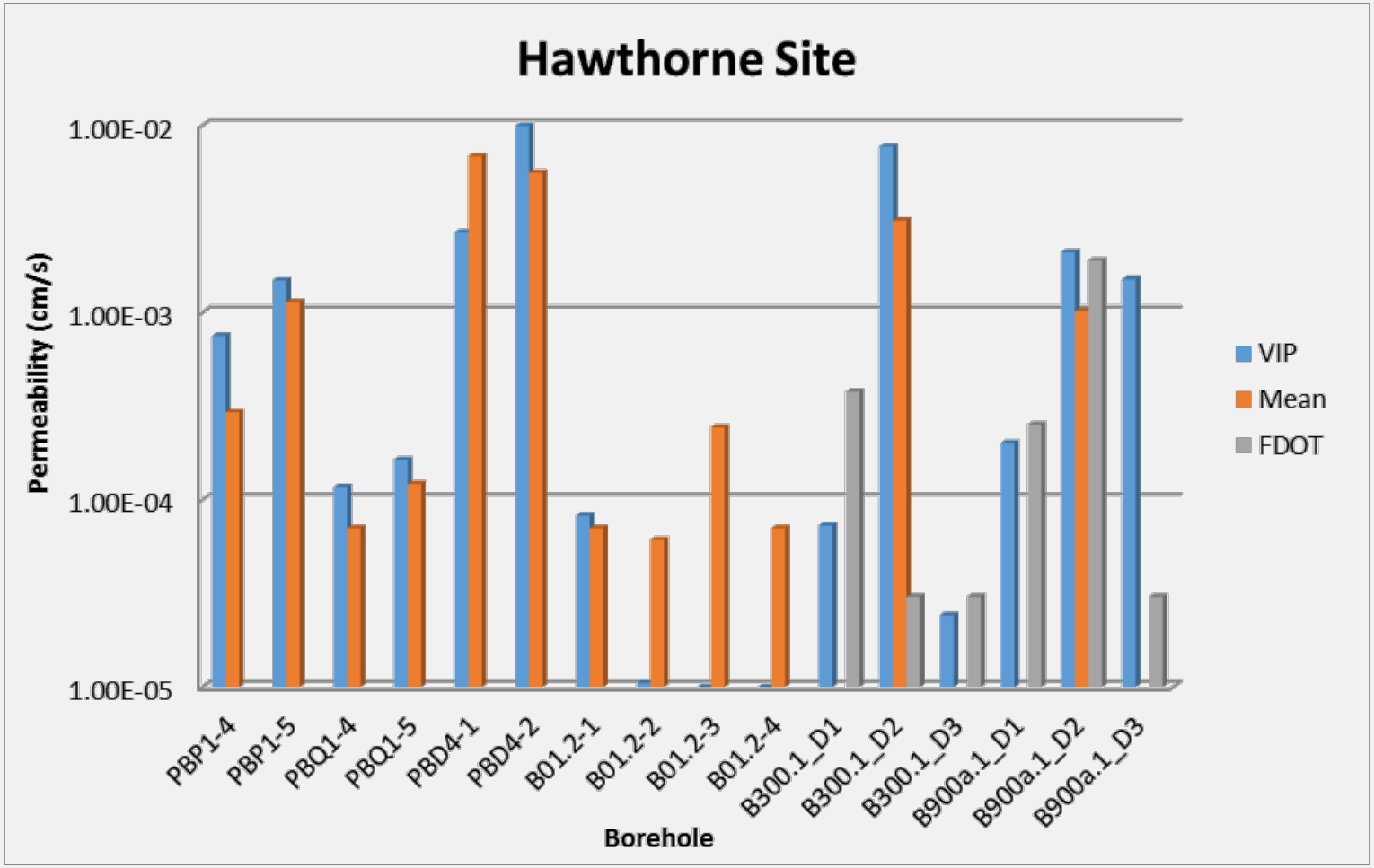
- Consultant/FDOT Data

Soil Type	Average (cm/s)	Min. (cm/s)	Max. (cm/s)	Std. Dev. (cm/s)	CV	# of Tests	% of Tests
1	7.5×10^{-6}	0	4.5×10^{-5}	1.6×10^{-6}	2.16	10	21%
2	3.1×10^{-4}	6.1×10^{-5}	9.2×10^{-4}	2.2×10^{-4}	0.71	23	49%
3	3.5×10^{-3}	1.0×10^{-3}	8.2×10^{-3}	2.5×10^{-3}	0.72	14	30%

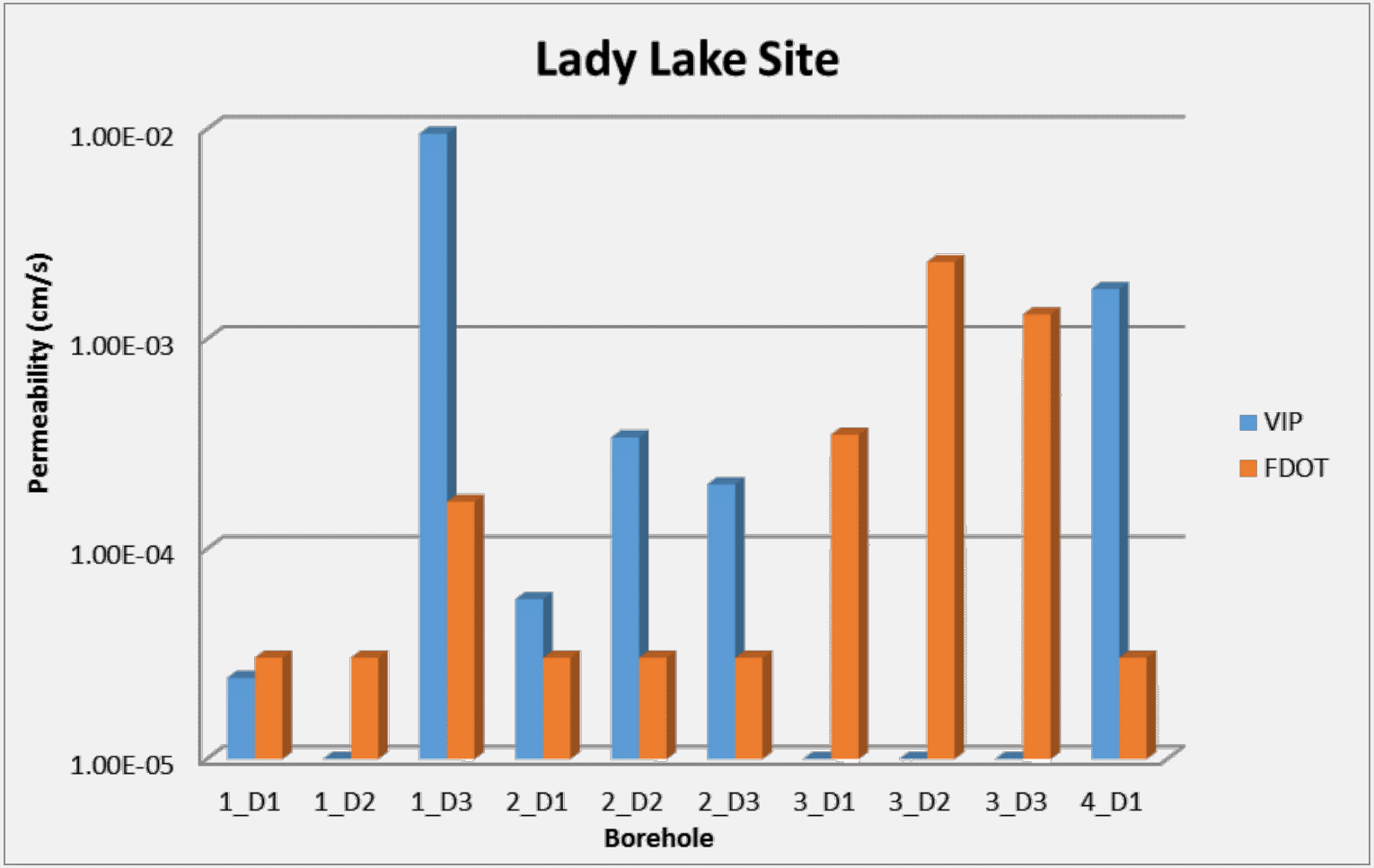
JACKSONVILLE – SR-9A



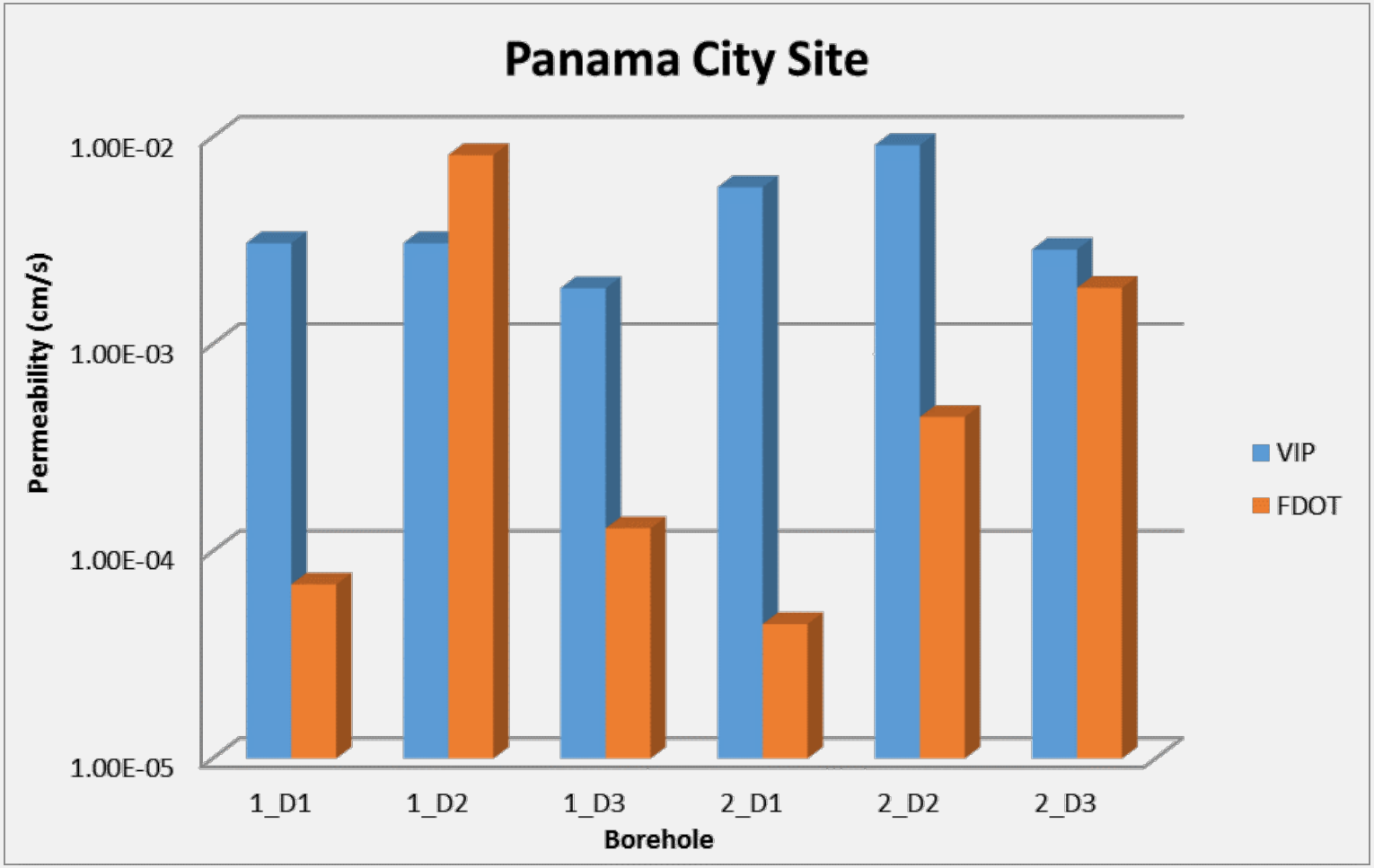
HAWTHORNE – SR-20



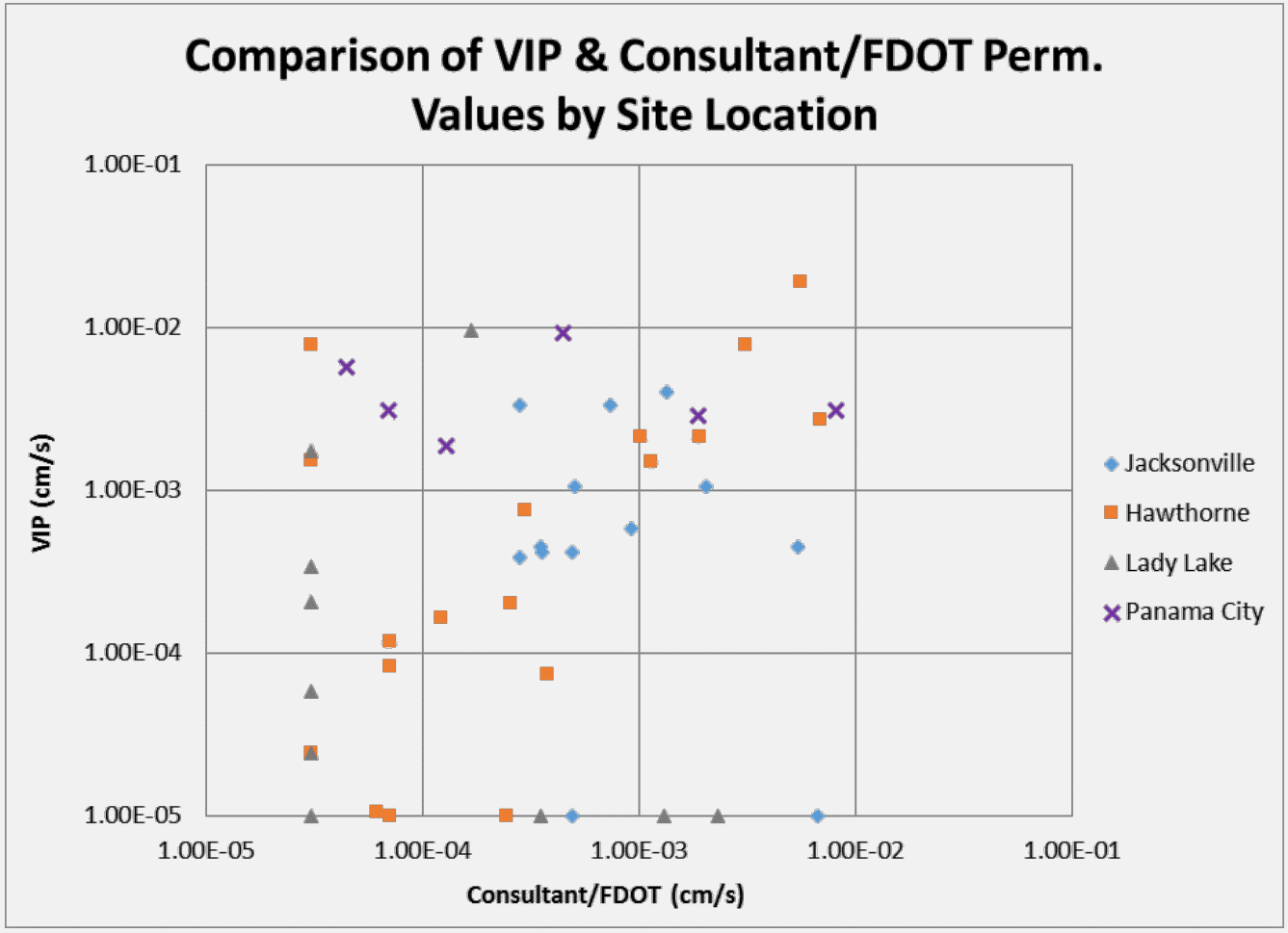
LADY LAKE – SR-500



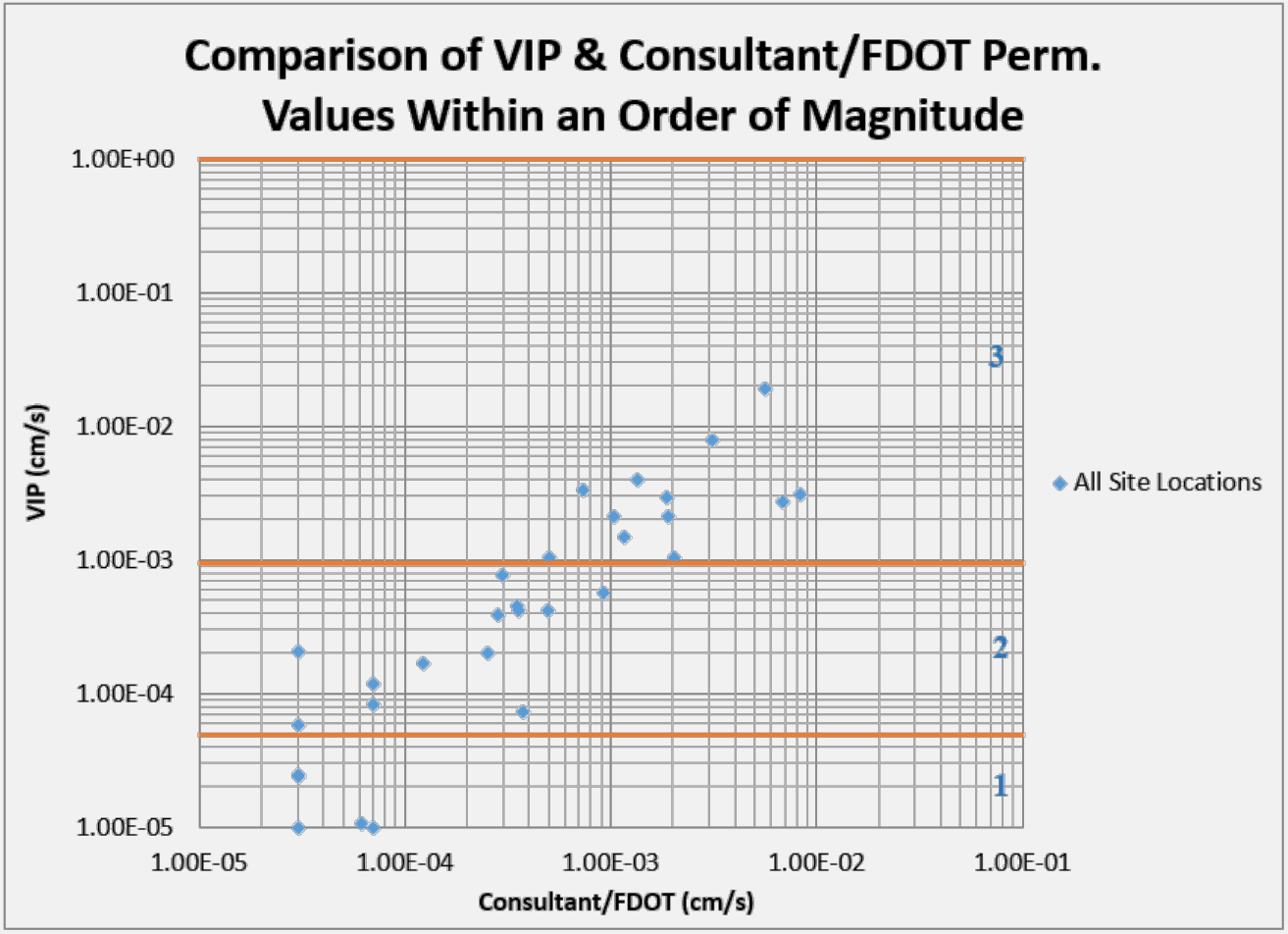
PANAMA CITY


Panama City Site
Permeability (cm/s)
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1_D1
1_D2
1_D3
2_D1
2_D2
2_D3
Borehole
VIP
FDOT

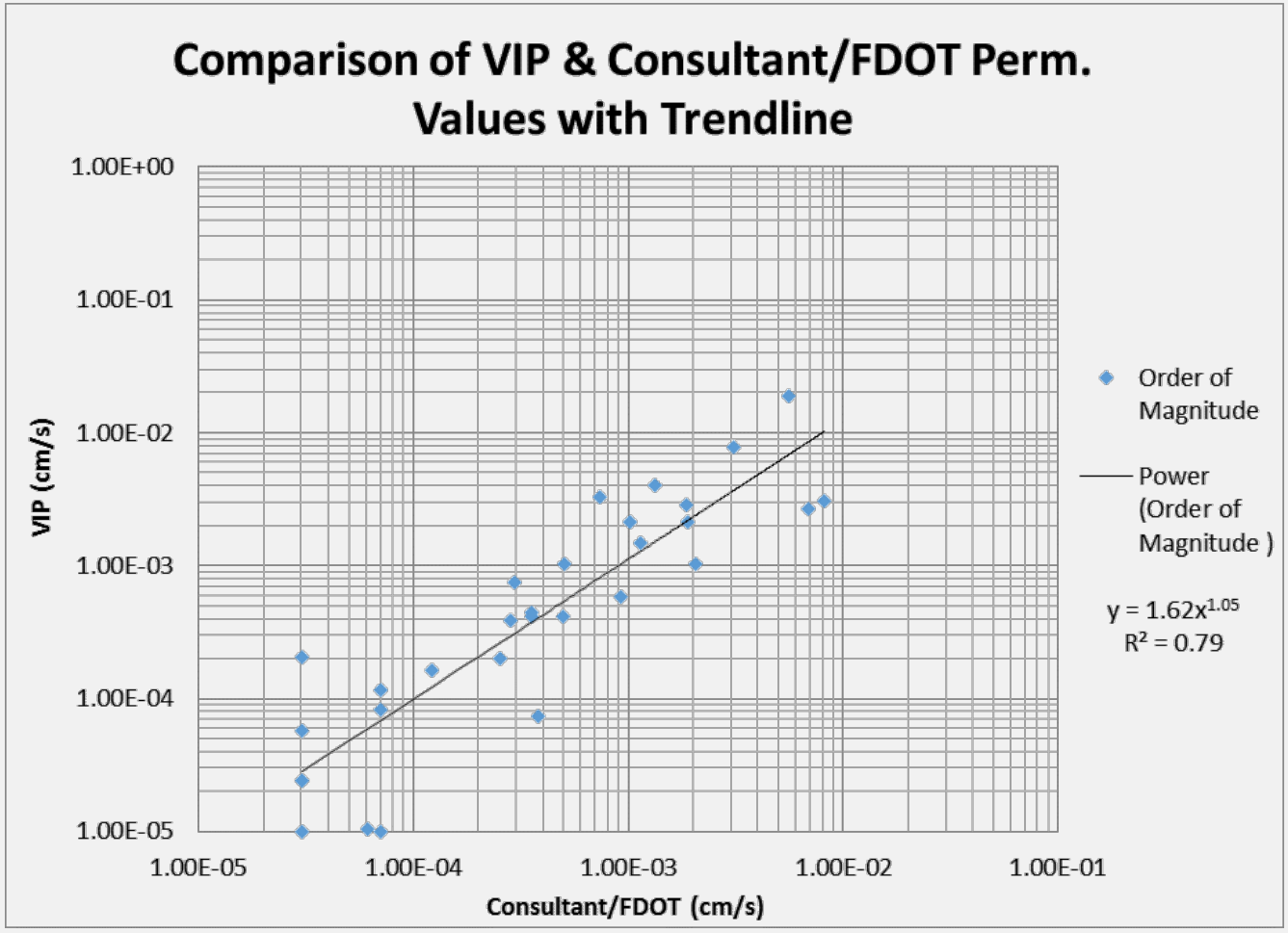
ALL DATA


Comparison of VIP & Consultant/FDOT Perm. Values by Site Location
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
VIP (cm/s)
1.00E-05
1.00E-04
1.00E-03
1.00E-02
1.00E-01
Consultant/FDOT (cm/s)
Jacksonville
Hawthorne
Lady Lake
Panama City

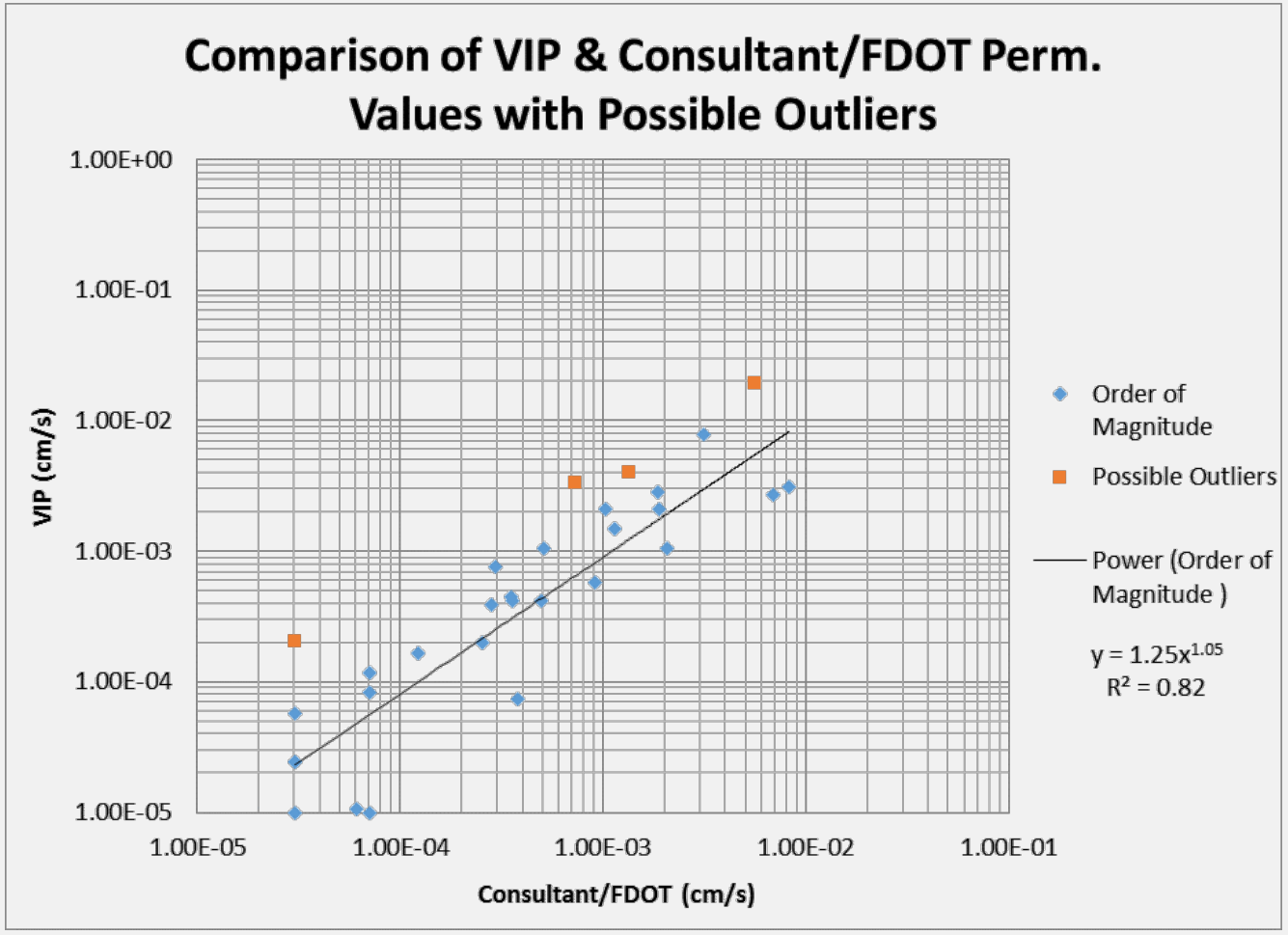
WITHIN AN ORDER OF MAGNITUDE



TRENDLINE – POWER FUNCTION



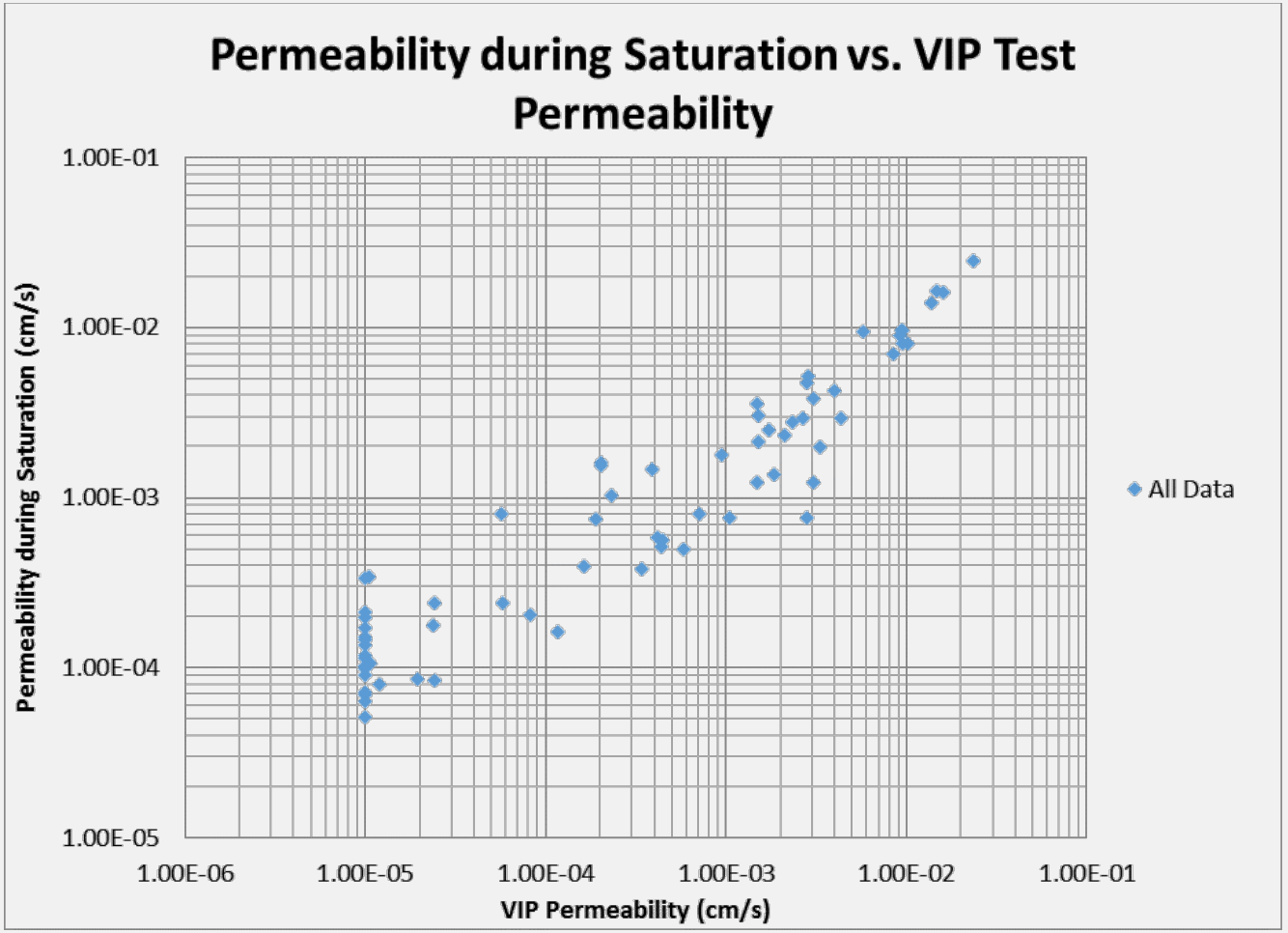
POSSIBLE OUTLIERS



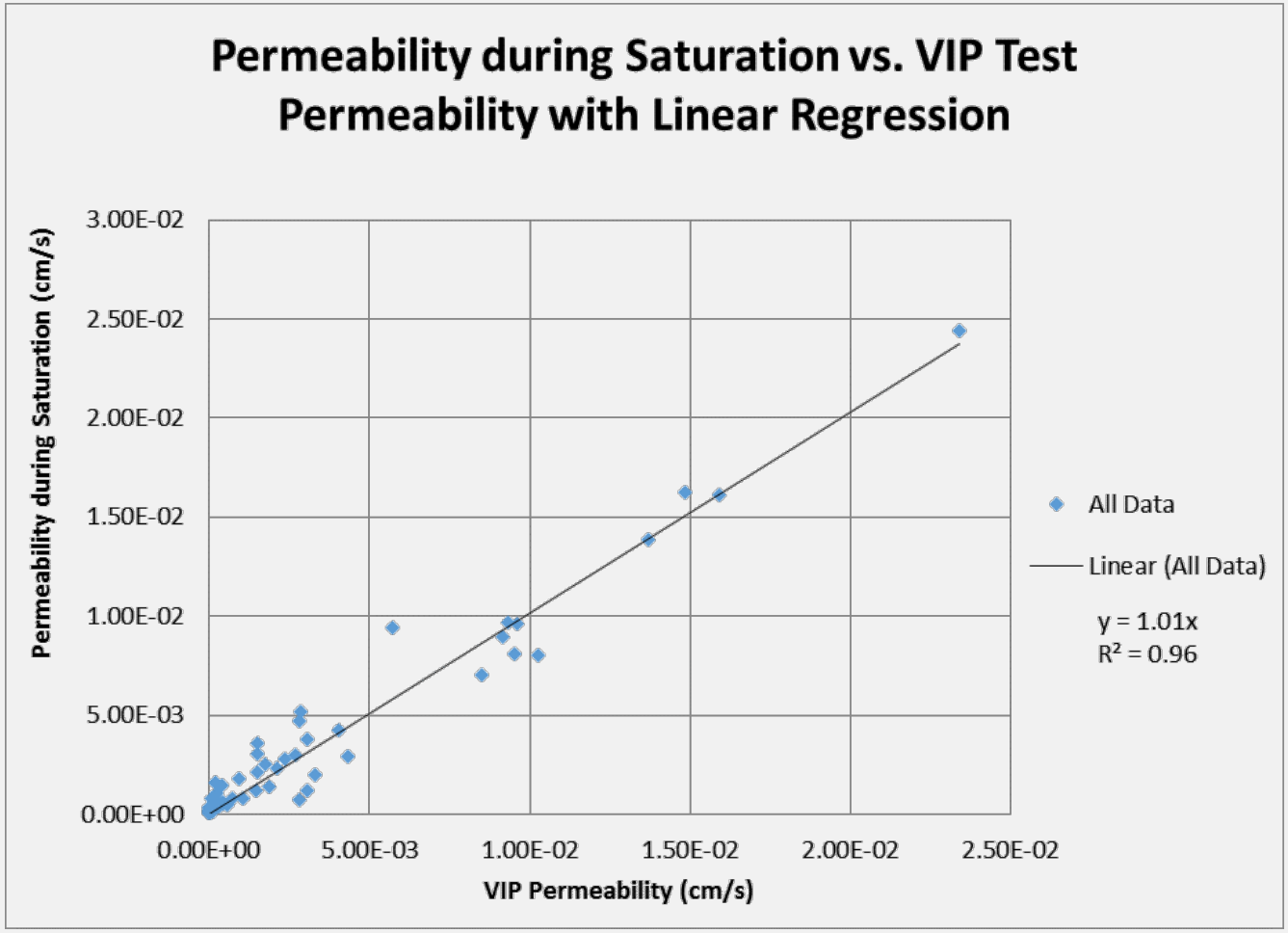
SUMMARY OF DATA

- VIP
  - 4 site locations
    - 104 tests
    - 72 depths
  - Permeability range: 1×10^{-5} – 2×10^{-2} cm/s
- Consultant/FDOT
  - Various field methods
    - Uncased/cased & constant/falling head
  - Multiple equations
- Comparison
  - 47 comparisons by depth/soil type
    - 17 outside an order of magnitude
      - 9 no flow conditions
      - 4 in Panama City
      - Remaining 4 attributed to spatial variability in soil

SATURATION DATA



SATURATION DATA



RECOMMENDATIONS

- No correction necessary for VIP permeability values
  - Hvorslev Case C equation
- Reduction of testing time
  - 15 min. saturation period
- Modification of probe design
  - Eliminate rotation through "stages"
    - Simplify internal mechanics
    - Remove friction sleeve and wings
    - Allow for smaller diameter
    - Fewer parts
- Adjustments to setup
  - Valve for water hose
  - New AWJ water connection

MOVING FORWARD

- VIP
  - Reliable mean (overall) permeability, k_m, measurement
    - $k_m = \frac{\pi d^2}{4F(t_f - t_i)} ln \frac{H_i}{H_f}$
    - 15 min. falling head test
  - Ready for field testing
    - Modifications to design to simplify
    - Adjustments to setup to increase efficiency
- VAHIP 2.0
  - Flow theory
    - Vertical and horizontal permeability, k_v and k_h
  - Design
    - Instrumented for better accuracy
    - Simple mechanical design
    - Capable of reaching greater depths

QUESTIONS?

Special thanks to the FDOT field crew – Bruce, Todd, Kyle, and Dalton – for all their hard work during field testing.