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

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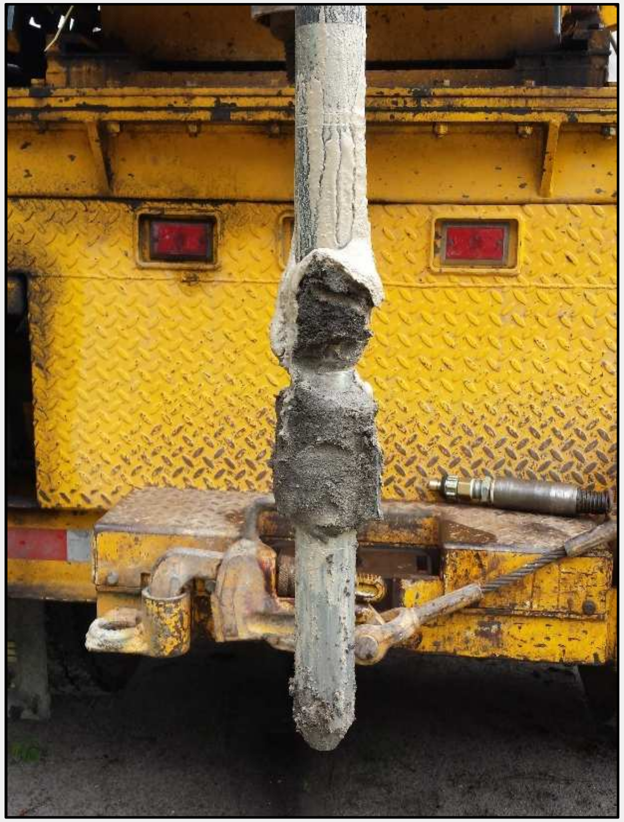
VIP PROJECT

- **Objective**
  - Implement a simple field procedure for measuring hydraulic conductivity
- **VIP has been successfully field demonstrated** and validated at four DOT sites
  - FDOT Test Method FM 5-614
- **Areas for improvement**
  - Delivers an "average" conductivity rather than independent values of k_v and k_h
  - Difficulty driving the probe in certain soils



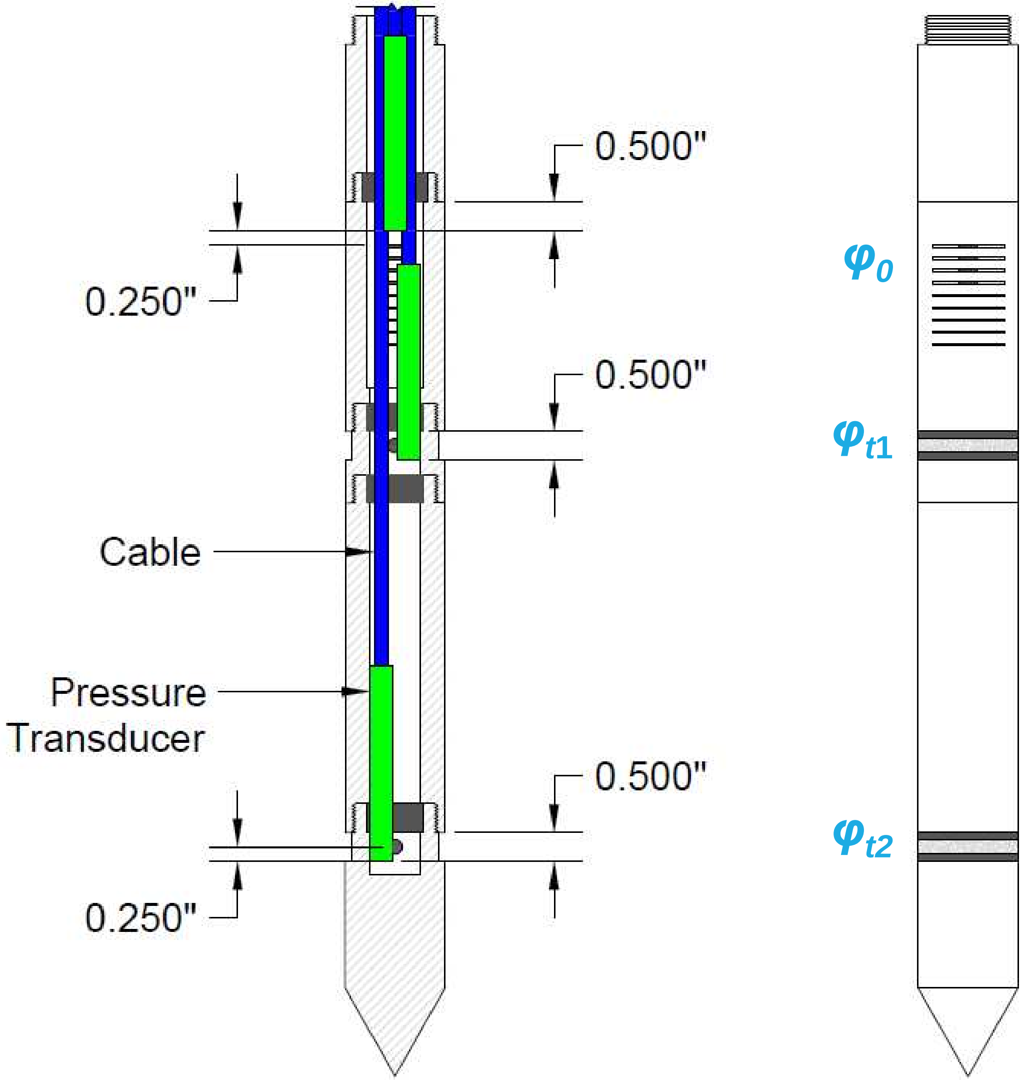
ADDITIONAL TASKS

1. Identification of an appropriate pressure measurement system
2. Development of computer-aided drawings (CAD) for the proposed probe
3. Fabrication of a PVC-prototype and possible adjustments of injection system
4. Testing of PVC-prototype at the DOT test pit
5. Fabrication of a steel probe
6. Final report

IMPROVED VAHIP

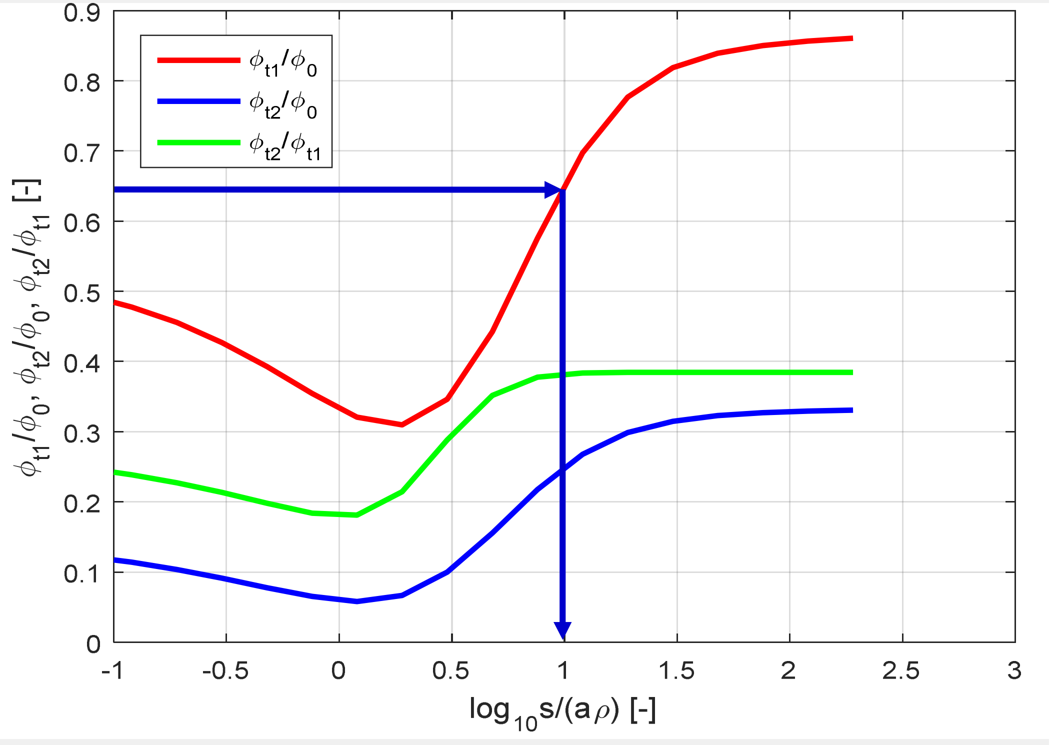
- Advances in flow theory provide potential for **estimating vertical and horizontal permeability k_v and k_h under saturated conditions**
- **Simple** mechanical design (no moving parts)
- **Automated** data acquisition using pressure transducers (no hand readings)
- Potentially capable of reaching **greater depths** (reduced probe diameter)
- Potentially **insensitive to smearing and compaction** near probe surface

PROBE DESIGN



ASSESMENT OF HORIZONTAL AND VERTICAL PERMEABILITY

- The head ratios only depend on:
  - Probe radius a
  - Screen length s
  - Anisotropy ratio $\rho^2 = \frac{k_v}{k_h}$



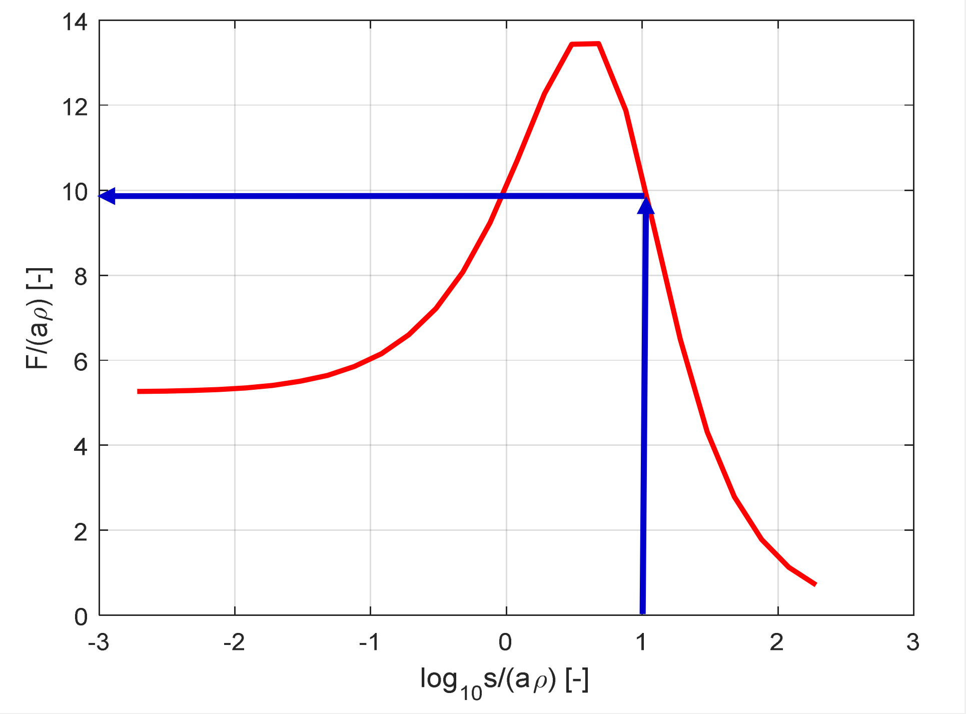
ASSESMENT OF HORIZONTAL AND VERTICAL PERMEABILITY

- By knowing
  - Shape Factor F
  - Injection Head φ_0
  - Injection Flow rate Q

- Horizontal conductivity can be estimated followed by the vertical component

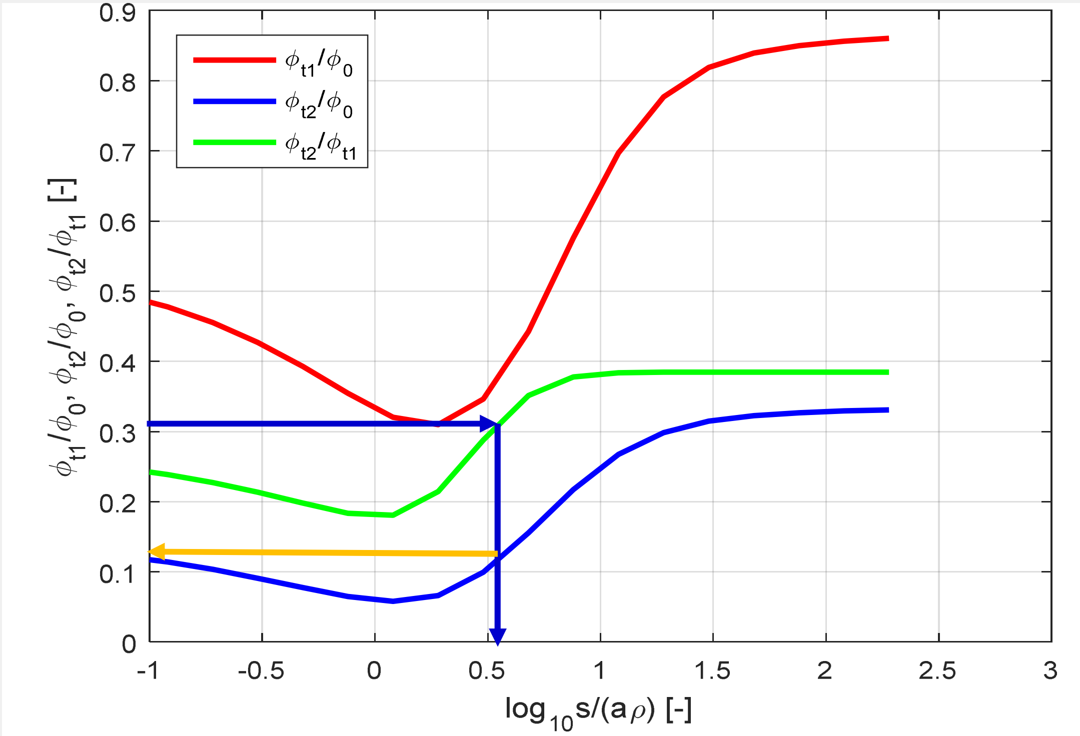
$$k_h = \frac{Q}{\varphi_0 F}$$

$$k_v = k_h \rho^2$$



ASSESMENT OF HORIZONTAL AND VERTICAL PERMEABILITY

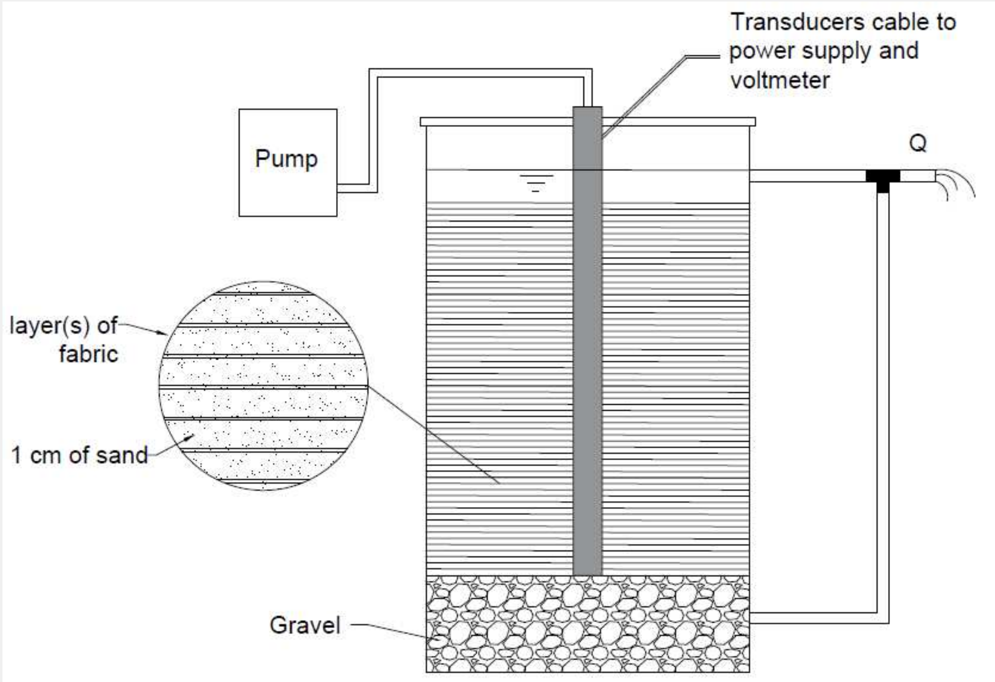
- The ratio of two head observations along the probe is **independent of possible clogging at the injection screen**
- Observation heads and ρ can be used to estimate effective injection head (after screen losses)
- As before, knowing ρ, Q and φ_{eff} are used to estimate k_h and subsequently k_v



$$k_h = \frac{Q}{\varphi_{eff} F}$$

LABORATORY TESTING

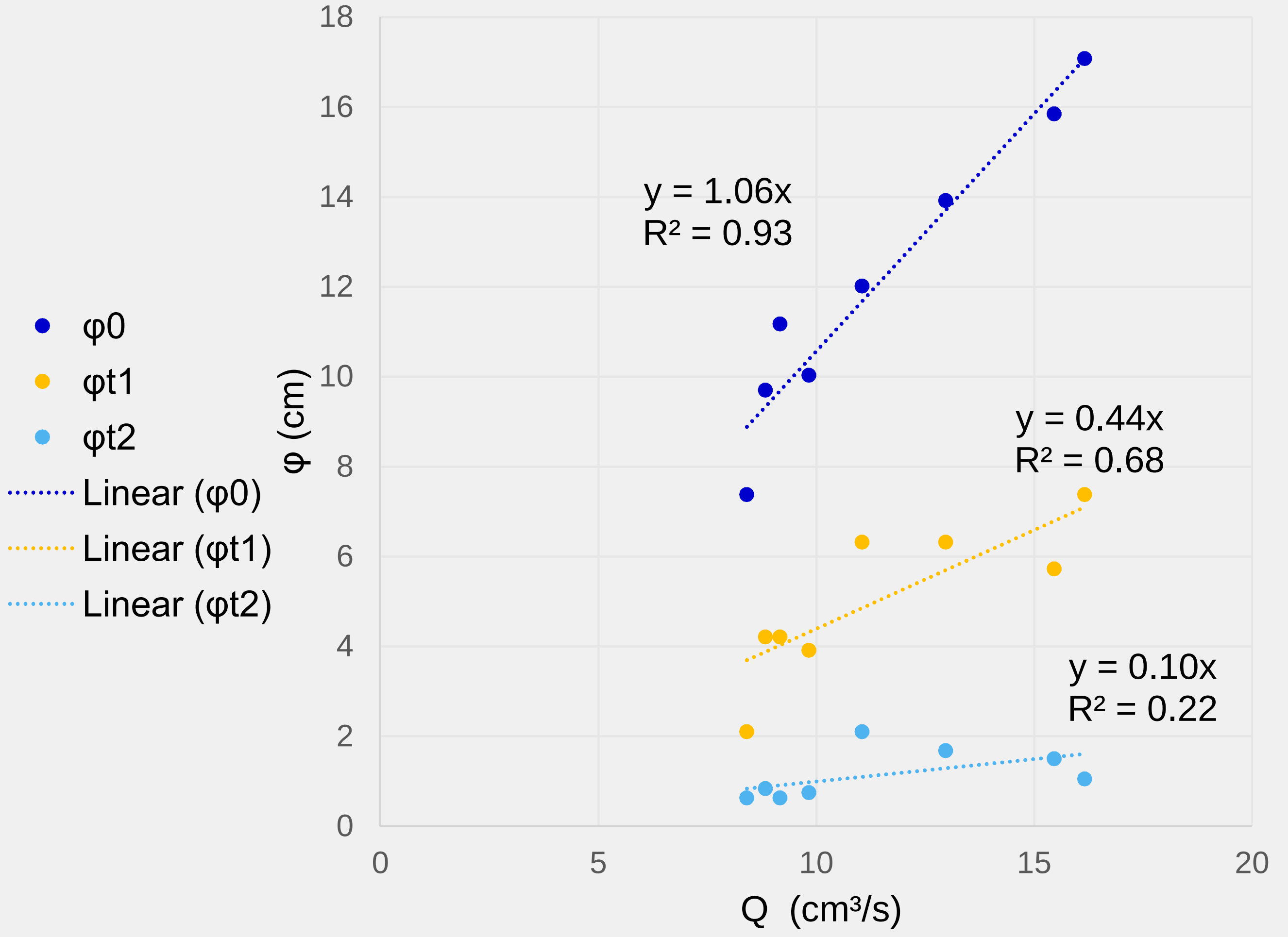
- A PVC prototype was fabricated and tested in barrels with three different anisotropy scenarios generated by alternating high and low conductivity layers
    - **Scenario 1**: coarse sand (no layering)
    - **Scenario 2**: 1 cm of sand between one layer of fabric
    - **Scenario 3**: 1 cm of sand between two layers of fabric



SCENARIO 1 RESULTS

Test	k_h (cm/s)	k_h (cm/s)	k_h (cm/s)	$k_{h\ avg}$ (cm/s)	k_v (cm/s)	k_v (cm/s)	k_v (cm/s)	$k_{v\ avg}$ (cm/s)
1	0.078	0.044	0.031	**0.051**	0.014	0.026	0.046	**0.028**
2	0.053	N/A	N/A	**0.053**	0.016	N/A	N/A	**0.016**
3	0.12	0.099	0.070	**0.096**	0.011	0.012	0.015	**0.013**
4	0.088	0.063	0.047	**0.066**	0.013	0.018	0.025	**0.019**
5	0.059	0.052	0.048	**0.053**	0.021	0.024	0.027	**0.024**
6	0.080	N/A	N/A	**0.080**	0.014	N/A	N/A	**0.014**
7	0.068	0.042	N/A	**0.055**	0.018	0.033	N/A	**0.026**
8	N/A	0.055	0.069	**0.062**	N/A	0.033	0.024	**0.028**
	0.078	**0.059**	**0.053**		**0.015**	**0.024**	**0.028**	
Average		**0.065**				**0.022**		
Avg from independent test		0.069				0.025		

LINEAR REGRESSION SCENARIO 1

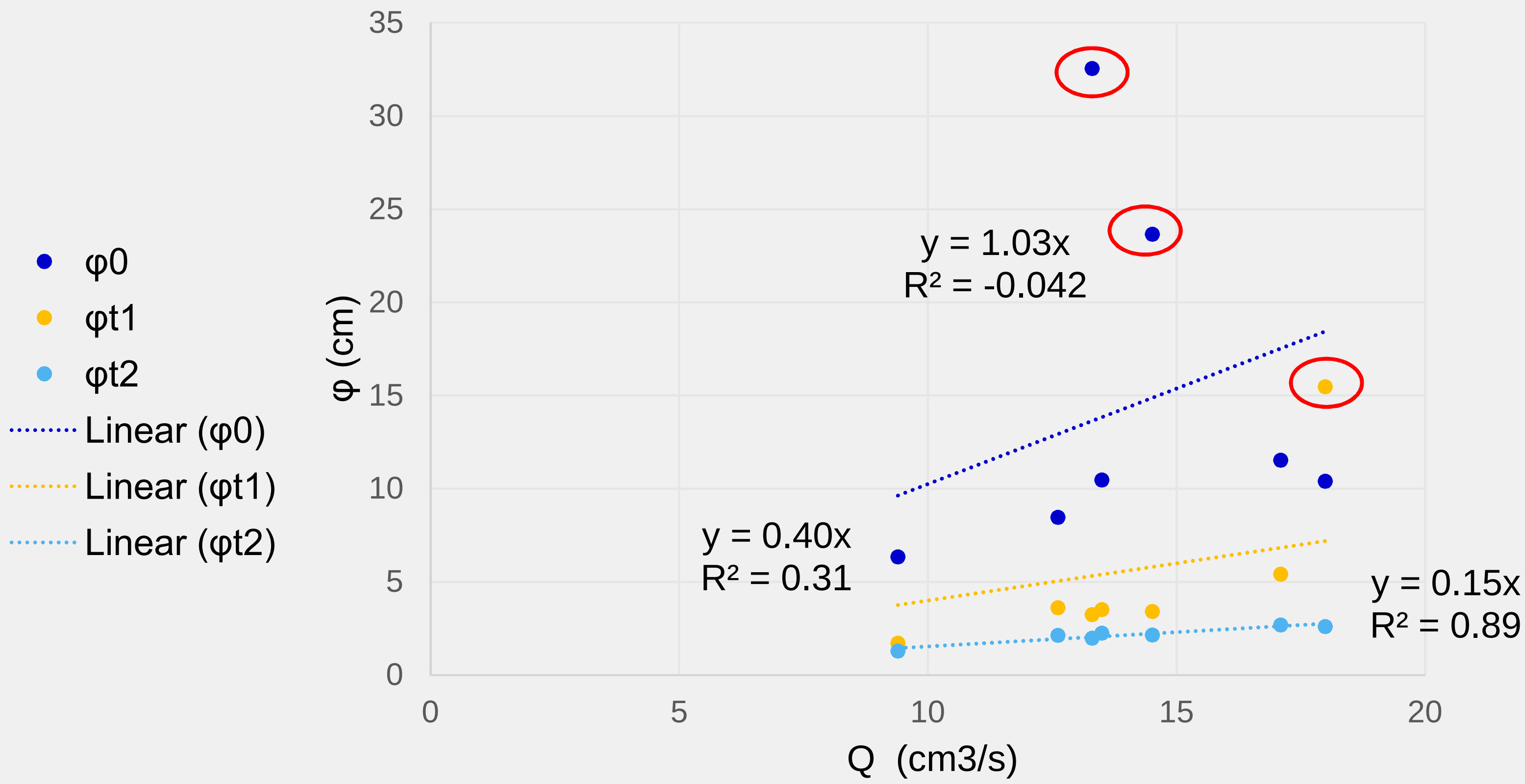


k_h (cm/s)	k_v (cm/s)
0.054	0.024
0.069	0.025

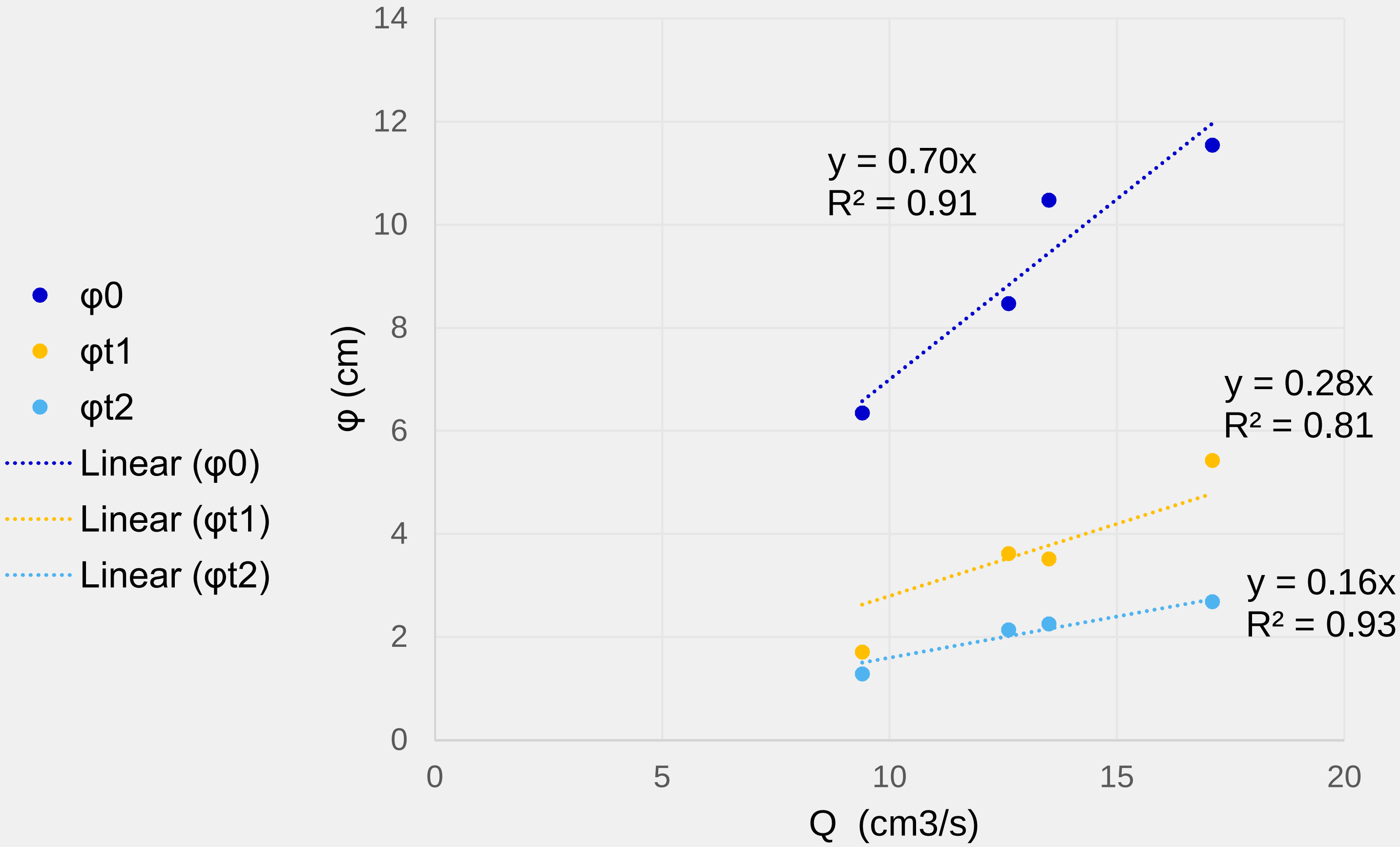
SCENARIO 2 RESULTS

Test	k_h (cm/s)	k_h (cm/s)	k_h (cm/s)	$k_{h\ avg}$ (cm/s)	k_v (cm/s)	k_v (cm/s)	k_v (cm/s)	$k_{v\ avg}$ (cm/s)
1	N/A	0.44	N/A	**0.44**	N/A	0.015	N/A	**0.015**
2	N/A	0.031	N/A	**0.031**	N/A	0.016	N/A	**0.016**
3	N/A	N/A	N/A	**N/A**	N/A	N/A	N/A	**N/A**
4	N/A	0.21	N/A	**0.21**	N/A	0.016	N/A	**0.016**
5	0.15	0.29	N/A	**0.22**	0.020	0.014	N/A	**0.017**
6	0.065	0.20	N/A	**0.13**	0.035	0.013	N/A	**0.024**
7	0.12	0.39	N/A	**0.26**	0.023	0.013	N/A	**0.018**
	0.11	**0.26**	**N/A**		**0.026**	**0.015**	**N/A**	
Average		**0.21**				**0.018**		
Avg from independent test		0.14				0.018		

LINEAR REGRESSION SCENARIO 2



LINEAR REGRESSION
SCENARIO 2

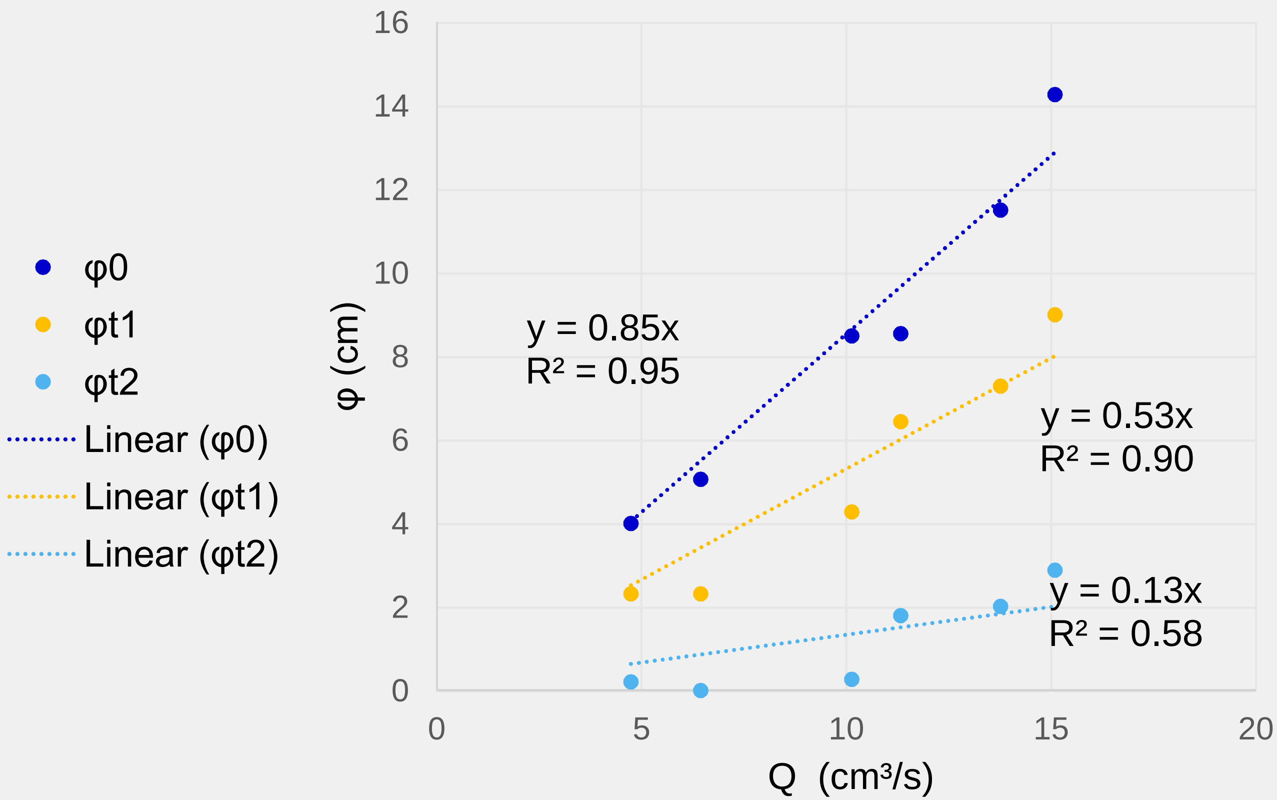


k_h (cm/s)	k_v (cm/s)
0.19	0.019
0.14	0.018

SCENARIO 3 RESULTS

Test	k_h (cm/s)	k_h (cm/s)	k_h (cm/s)	$k_{h\ avg}$ (cm/s)	k_v (cm/s)	k_v (cm/s)	k_v (cm/s)	$k_{v\ avg}$ (cm/s)
1	0.23	0.15	0.073	**0.15**	0.0097	0.012	0.020	**0.014**
2	0.27	0.13	0.063	**0.15**	0.011	0.015	0.030	**0.019**
3	0.76	0.20	0.071	**0.34**	0.010	0.014	0.033	**0.019**
4	0.12	N/A	N/A	**0.12**	0.018	N/A	N/A	**0.018**
5	0.19	N/A	N/A	**0.19**	0.012	N/A	N/A	**0.012**
6	0.14	N/A	N/A	**0.14**	0.015	N/A	N/A	**0.015**
	0.29	**0.16**	**0.069**		**0.012**	**0.014**	**0.027**	
	Average	**0.20**				**0.015**		
	Avg from independent test	**0.17**				**0.015**		

LINEAR REGRESSION
SCENARIO 3



k_h (cm/s)	k_v (cm/s)
0.17	0.014
0.17	0.015

SUMMARY

- The VAHIP provided horizontal and vertical permeability estimates under saturated conditions that are in good agreement with those obtained by independent a constant head test.
- Differences were observed between single estimates. However, in most of the cases, the single estimates were within the same order of magnitude.

- **Possible factors affecting estimates**
  - For the middle transducer only two decimals were recorded (2.1 cm resolution)
  - In order to avoid sand disturbance relatively low injection rates were used

UPCOMING TASKS

- **Test PVC prototype** and injection mechanism in DOT test pit using layers of high and low conductivity sand to emulate anisotropic conductivity
- **Manufacture steel probe (in progress)**
- **Test steel probe** in DOT test pit

THANK YOU