Implementation of Validated Intelligent Compaction for Real-Time Mapping of Pavement Foundation Modulus

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USER ROLES | PROJECTS | VIC MAPS | SITE VISION | REPORTS | ANALYSIS | CONFIGURABLE | MOBILE

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Acknowledgements

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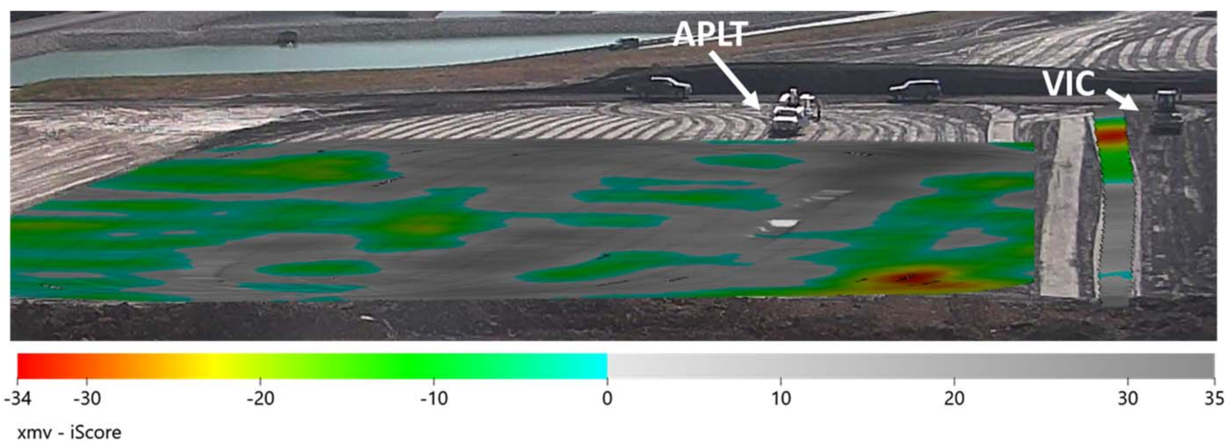
Outline

- I-25 Project Introduction
- Mechanistic Design & Verification
- Validated Intelligent Compaction (VIC)
- I-25 Project Application and Results



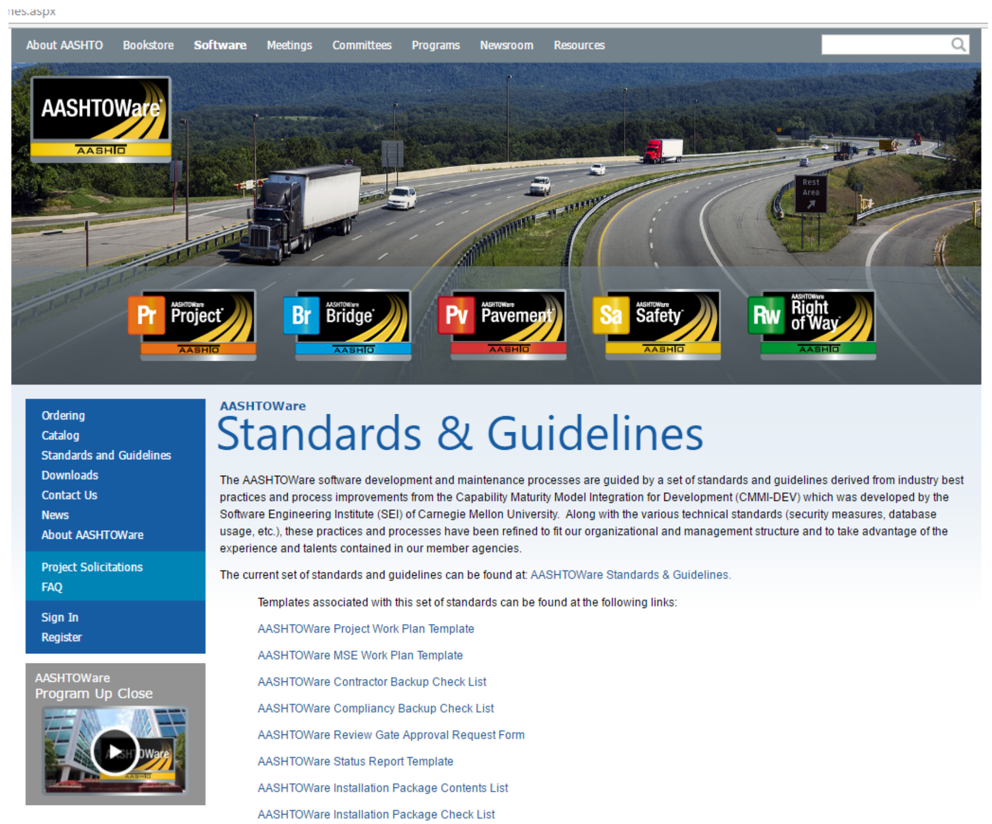
I-25 North Express Lanes Project

- ~15-mile long roadway rehabilitation / reconstruction project (Johnstown to Fort Collins, CO).
- Pavement design optimization using ME design method.
- QA requirements include cyclic plate load testing to verify design Resilient Modulus, M_r.
- Calibrated Validated Intelligent Compaction (VIC) utilized as demonstration for full area M_r verification.

Mechanistic Construction Testing & Design Verification

"*Pavement ME Design represents a quantum leap forward from previous processes*," (http://www.aashtoware.org)

- Mechanistic Design used to Optimize Pavement System
  - *Strength, Modulus, and Deformation Testing*
  - *Uniformity and Modulus Mapping (Intelligent Compaction)*
- Supports Performance-Based Materials Selection



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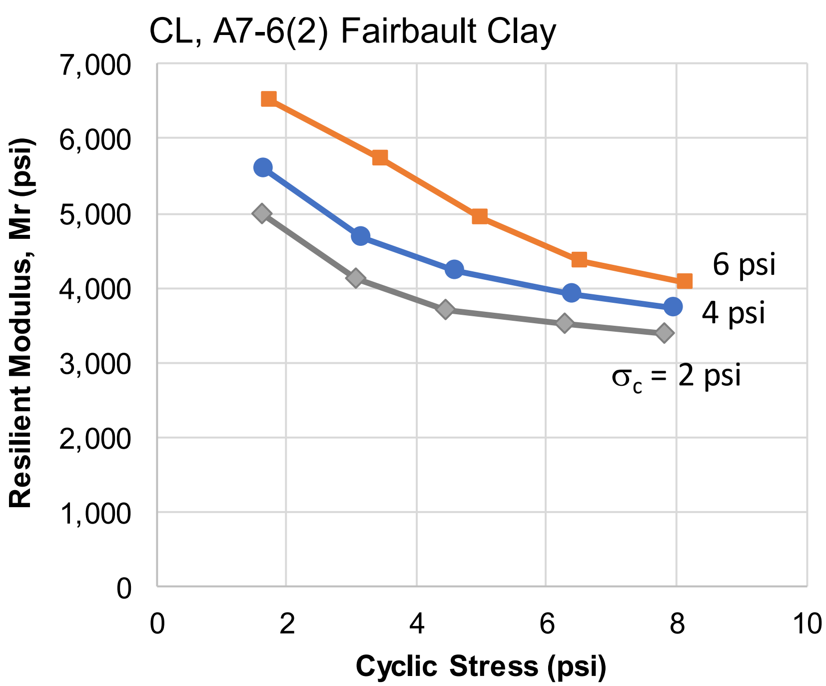
Mechanistic parameters are: Stress-Dependent

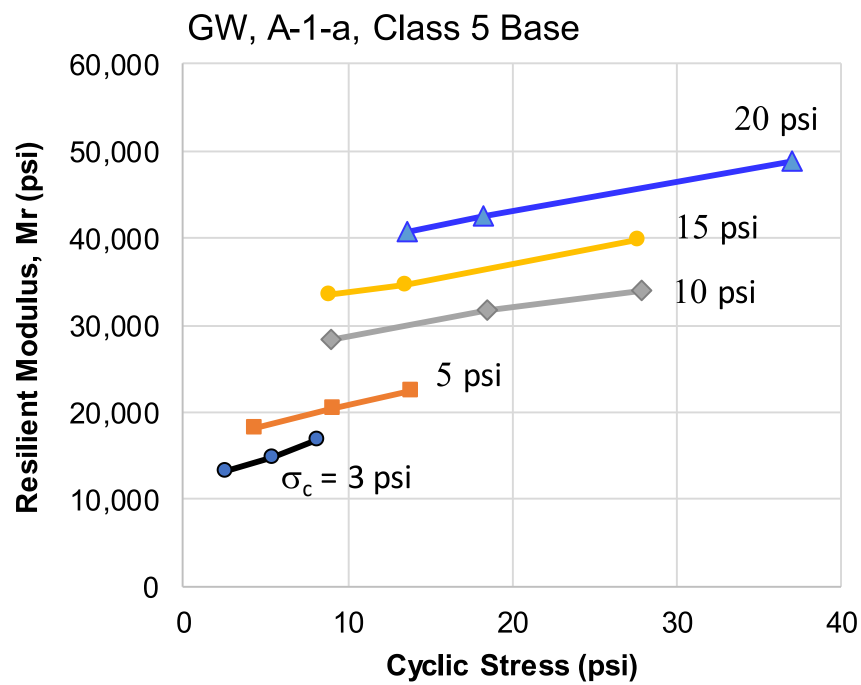
$$M_r = k_1^* P_a \left(\frac{\theta}{P_a}\right)^{k_2} \left(\frac{\tau_{oct}}{P_a} + 1\right)^{k_3}$$

AASHTO (2015) Universal Model

Fine-grained materials exhibit stress-softening behavior

Coarse-grained materials exhibit stress-hardening behavior

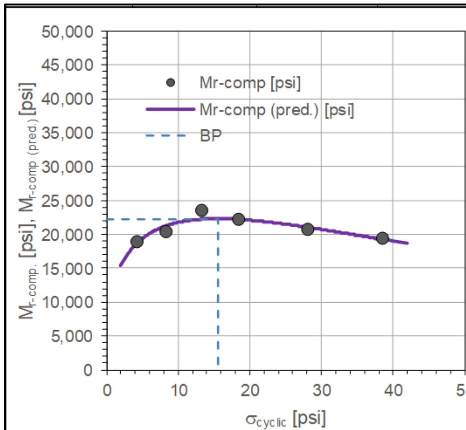


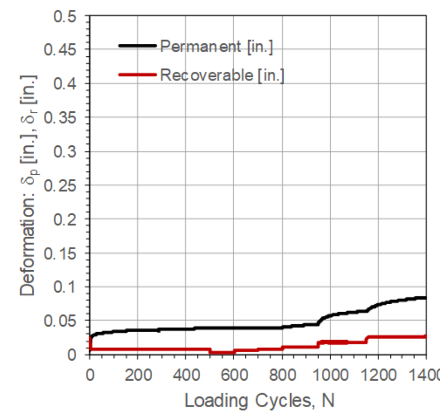


In situ Cyclic APLTs performed to determine Universal model parameters and verify design at spot locations

$$M_r = k_1^* P_a \left(\frac{\theta}{P_a}\right)^{k_2} \left(\frac{\tau_{oct}}{P_a} + 1\right)^{k_3}$$

AASHTO (2015) Universal Model





Model: AASHTO (2015)

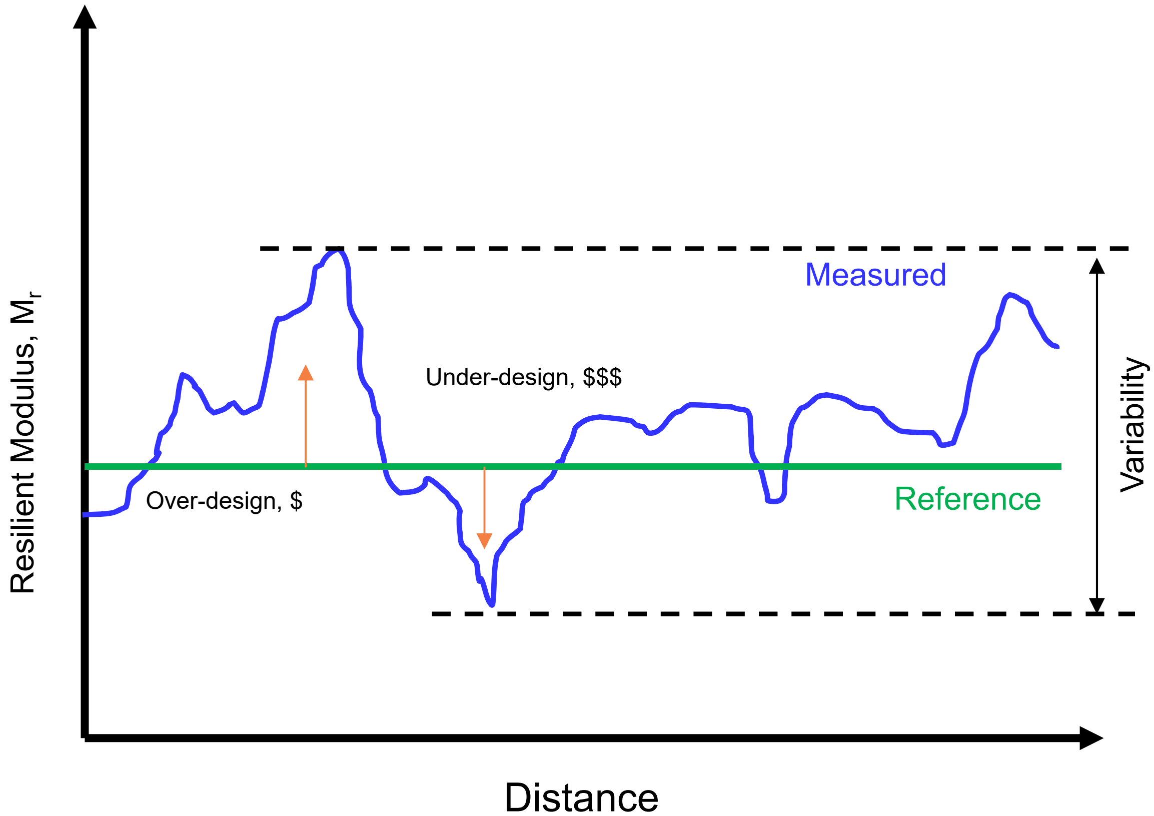
$$M_{r-comp} = k_1^* P_a \left(\frac{\theta}{P_a}\right)^{k_2^*} \left(1 + \frac{\tau_{oct}}{P_a}\right)^{k_3^*}$$

Parameter	Value	P-Value
k^*_1	1,612.4	6.67E-07
k^*_2	0.337	3.44E-02
k^*_3	-2.371	3.63E-02
Adj. R^2	0.762	
Std. Error [psi]	731	

$M_{r\text{-comp (pred.)-BP}}$ [psi]		22,311
	$\sigma_{cyclic\text{-BP}}$ [psi]	15.5

Full Area Quality Assurance and Design Verification

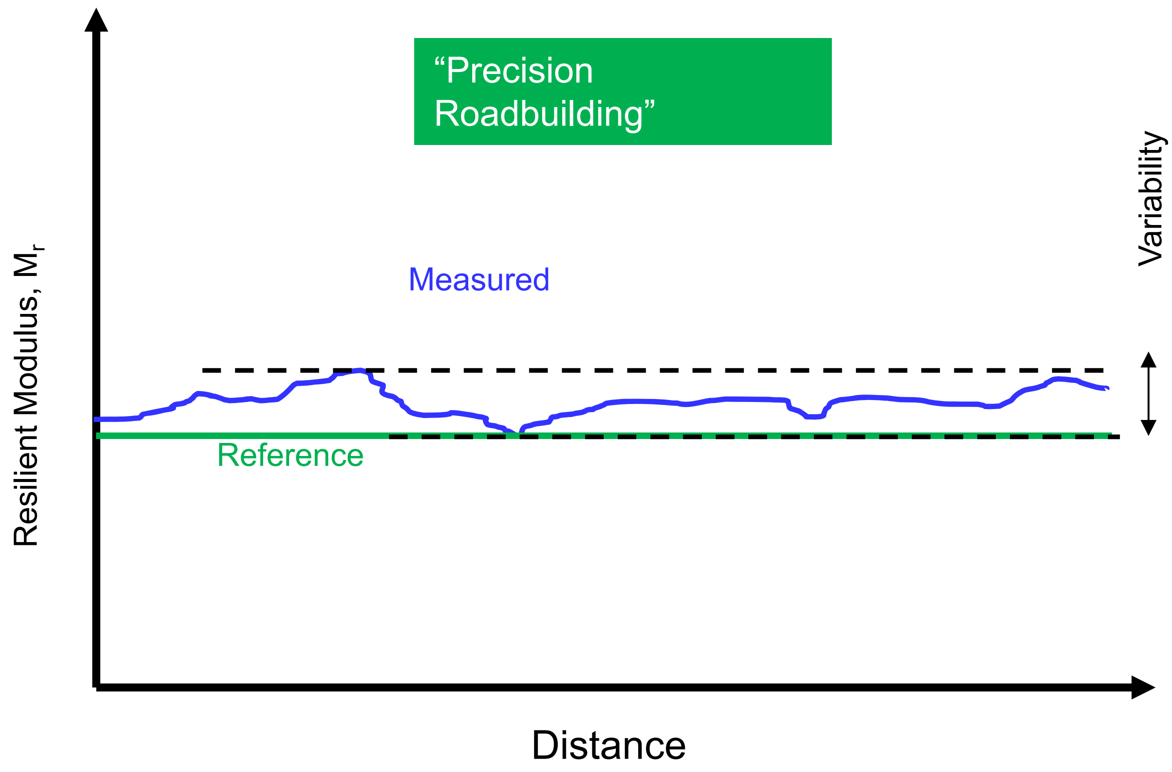
This is the current world we live in…



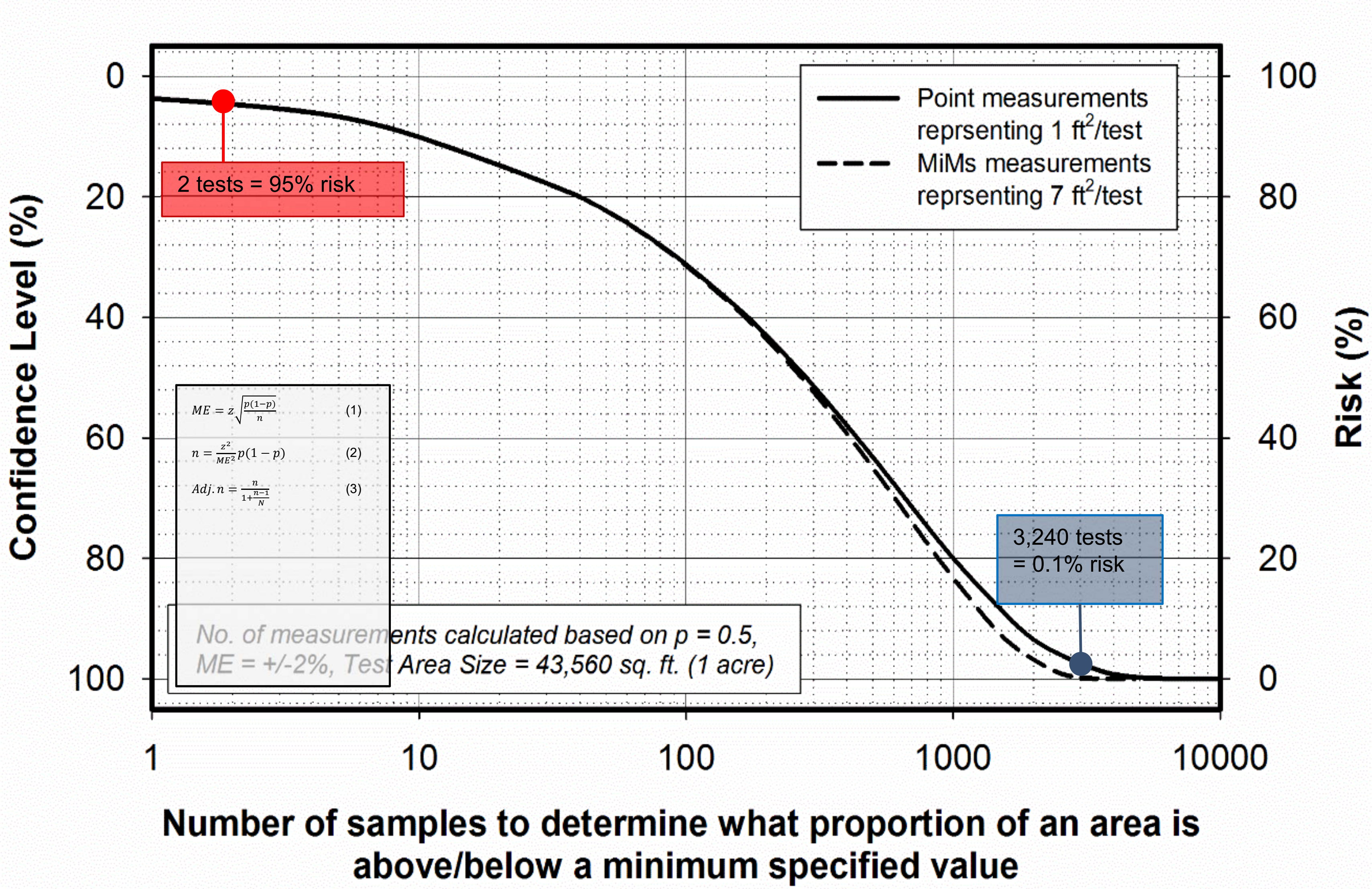
What value would you pick for design??

Full Area Quality Assurance and Design Verification

Better question: How do we build things to meet the design?



Decreasing Risk With Full Coverage Testing



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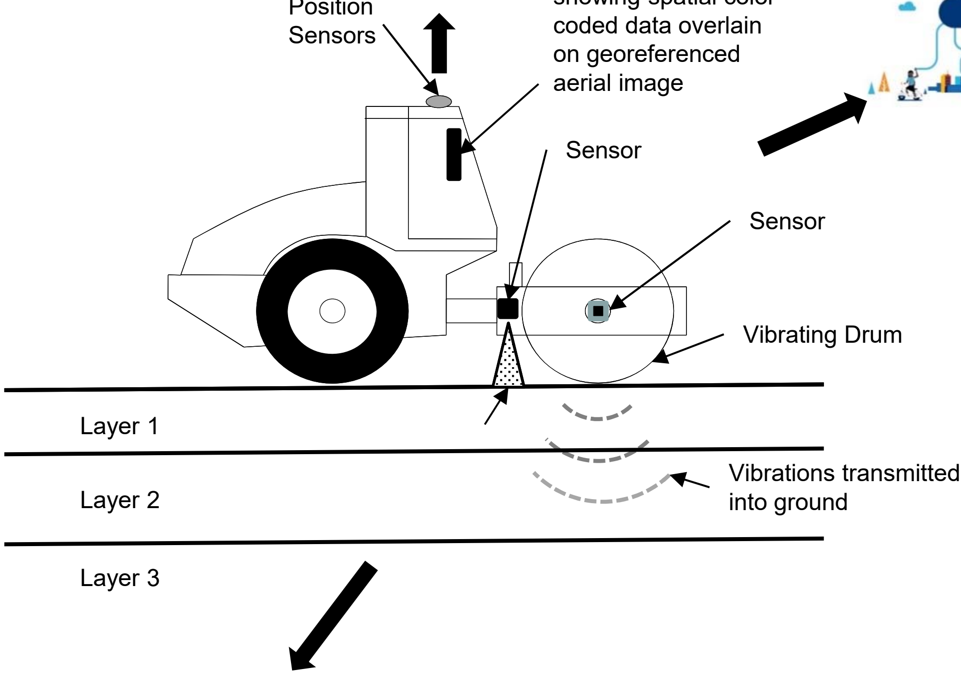
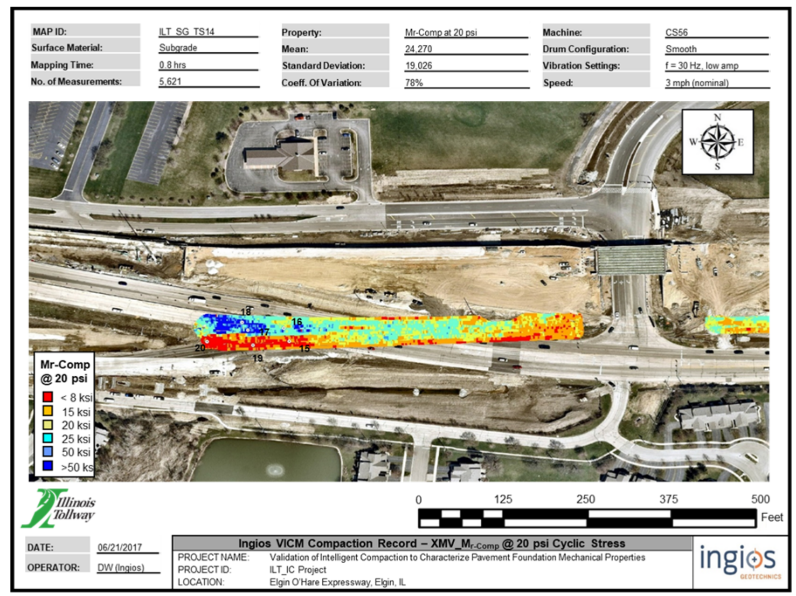
VIC & COMP-Score Connect

Options for GNSS:
SBAS (WAAS), OmniSTAR, D-GPS, RTK-GPS, dual antenna, IMUs



Outputs:
- Real-Time Monitoring
- Engineering Reports
- Email Alert Messages
- Control charts
- Calibration Verification
- WebCam and Pictures
- QC/QA Records
- Asset Mapping
- QC/QA Test Locations
- Compaction Cost Analyzer

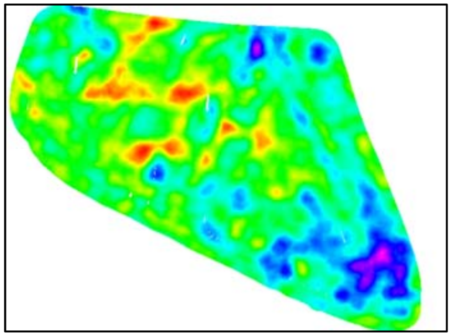
Customizable solutions for each machine, each site, and each customer.



Options for Engineering Outputs:
M_r, E_s, k-value, CBR, γ_d*, w%*, Material type

How VIC Works

- Integrate sensor package into machine (options for stress-dependent modulus, 40+ different material outputs, and material/moisture vision system)
- Display real-time results to operator and via real-time CID dashboard system
- VIC is field calibrated using APLT for site conditions
- Auto-generate compaction reports and alert messages to team, including function for P.E. review
- Use advanced desktop software to analysis multi-layer properties and identify areas for QA/QC testing
- Identify areas for improvement (not compaction)
- Improve compaction efficiency and **reduce risk of poor-quality**

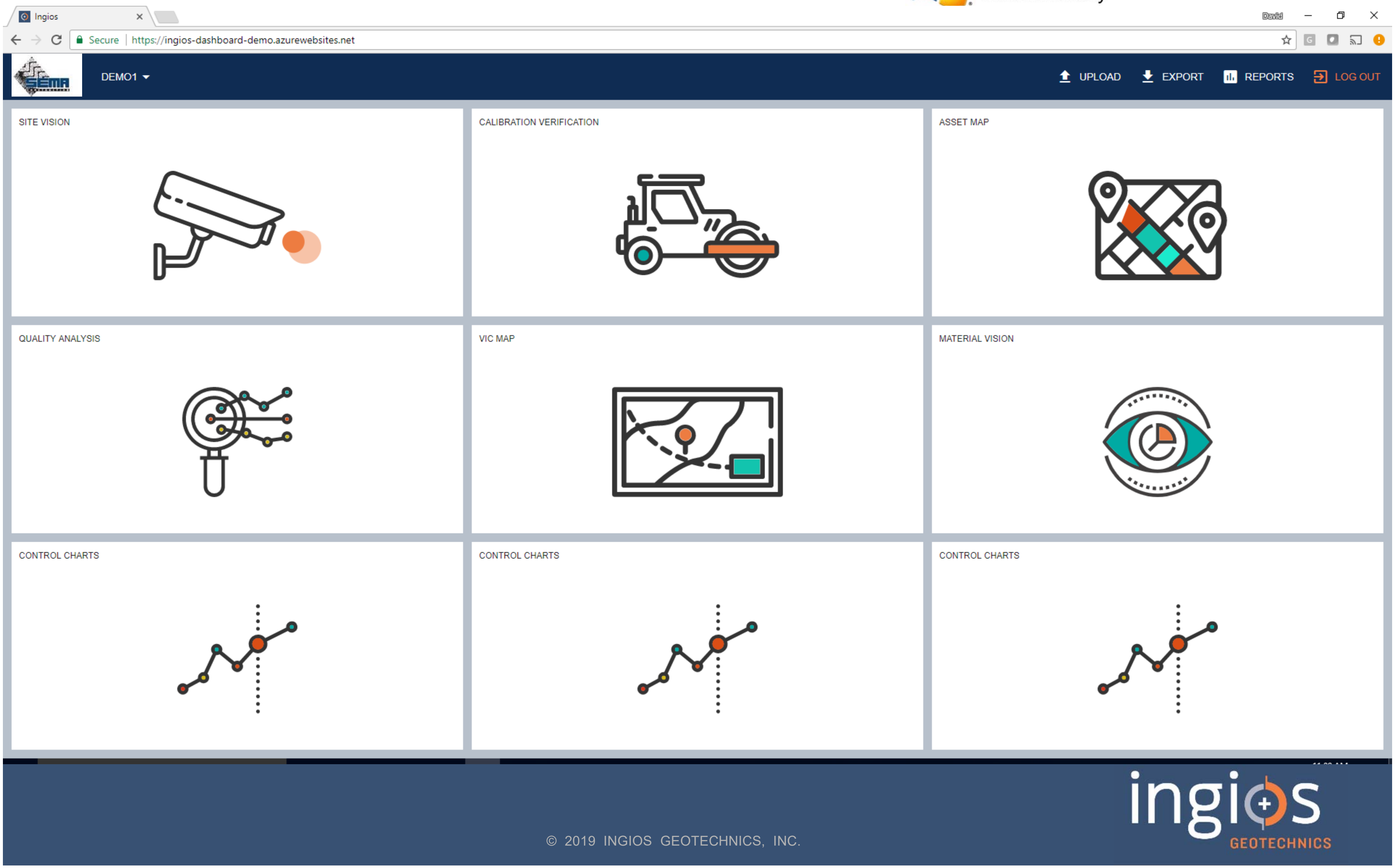


Operator Display

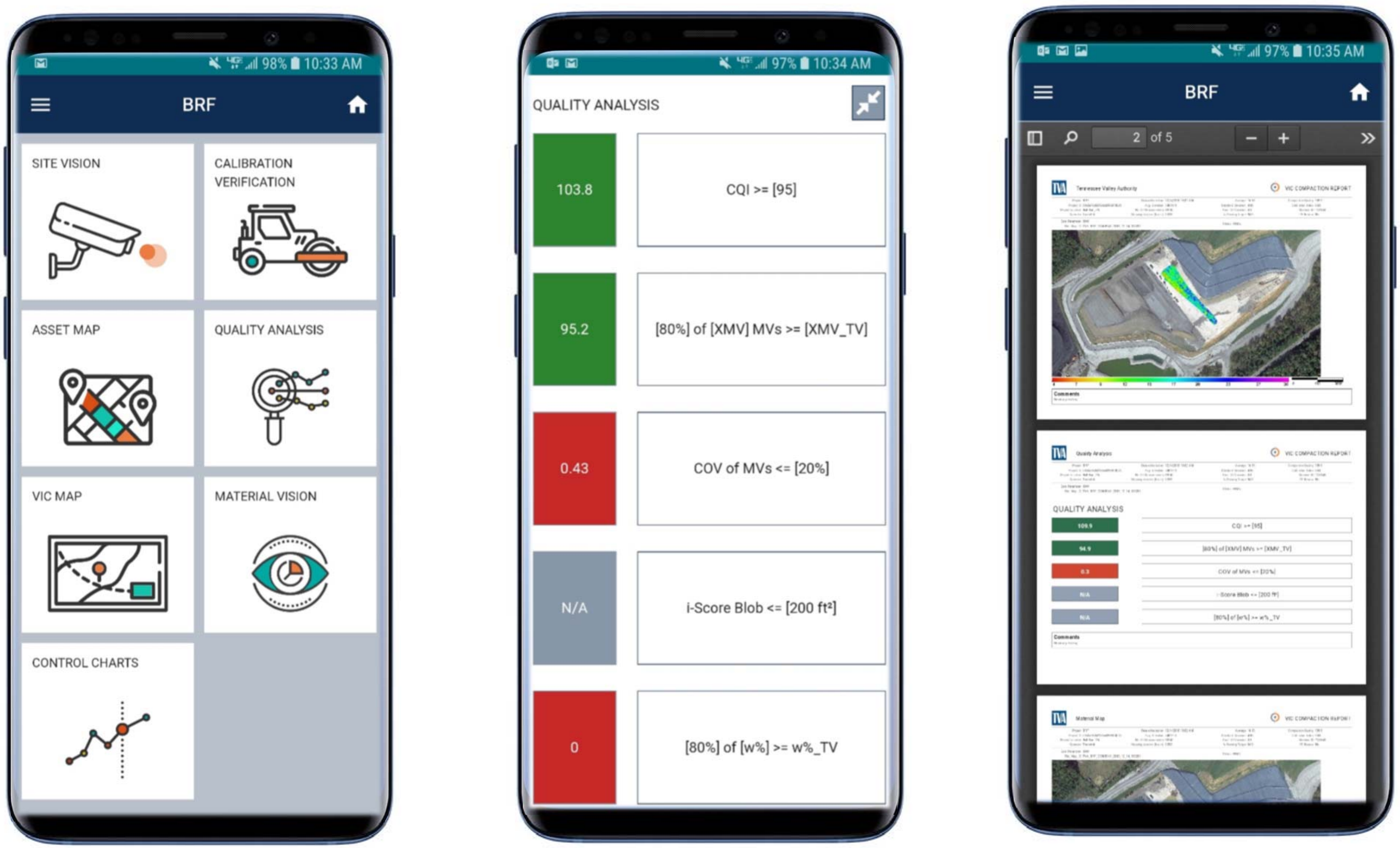
COMP-Score Connect: Cloud-based data management tool

Microsoft Cloud

Windows Server Active Directory



Mobile Device Accessible + Real-time monitoring is available



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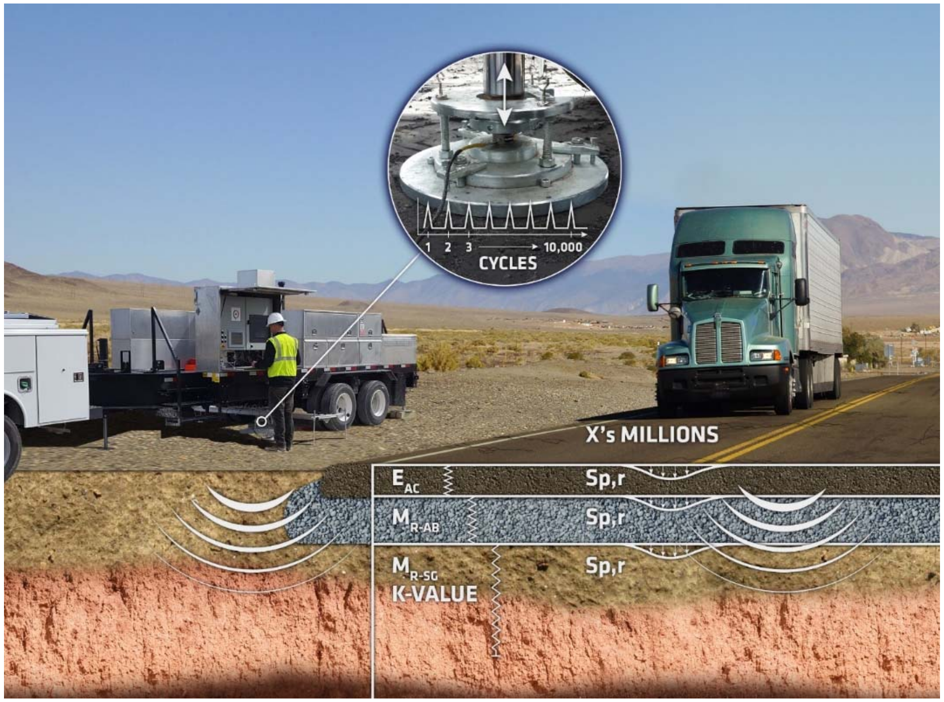
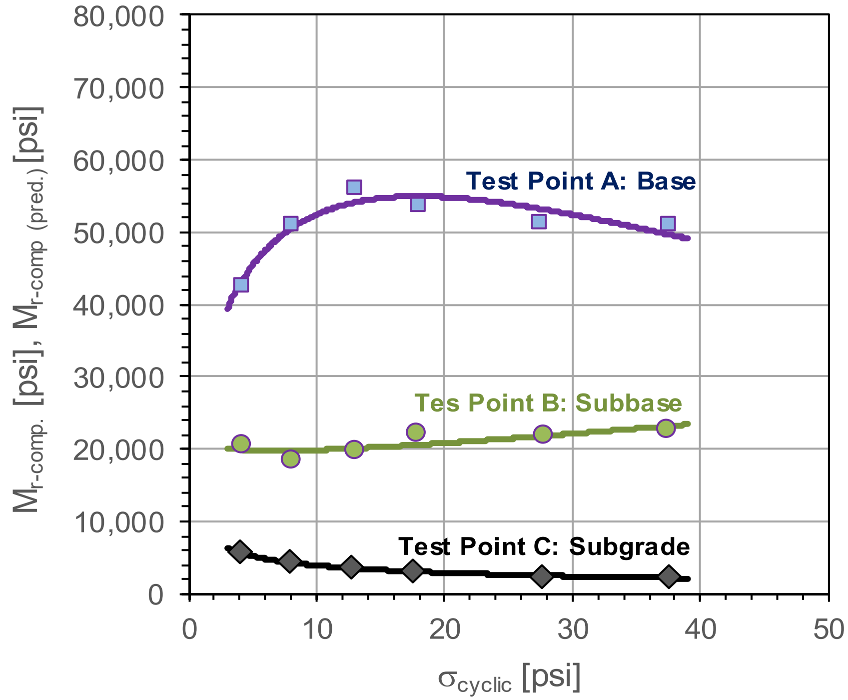
In situ Cyclic APLTs used to calibrate VIC machine

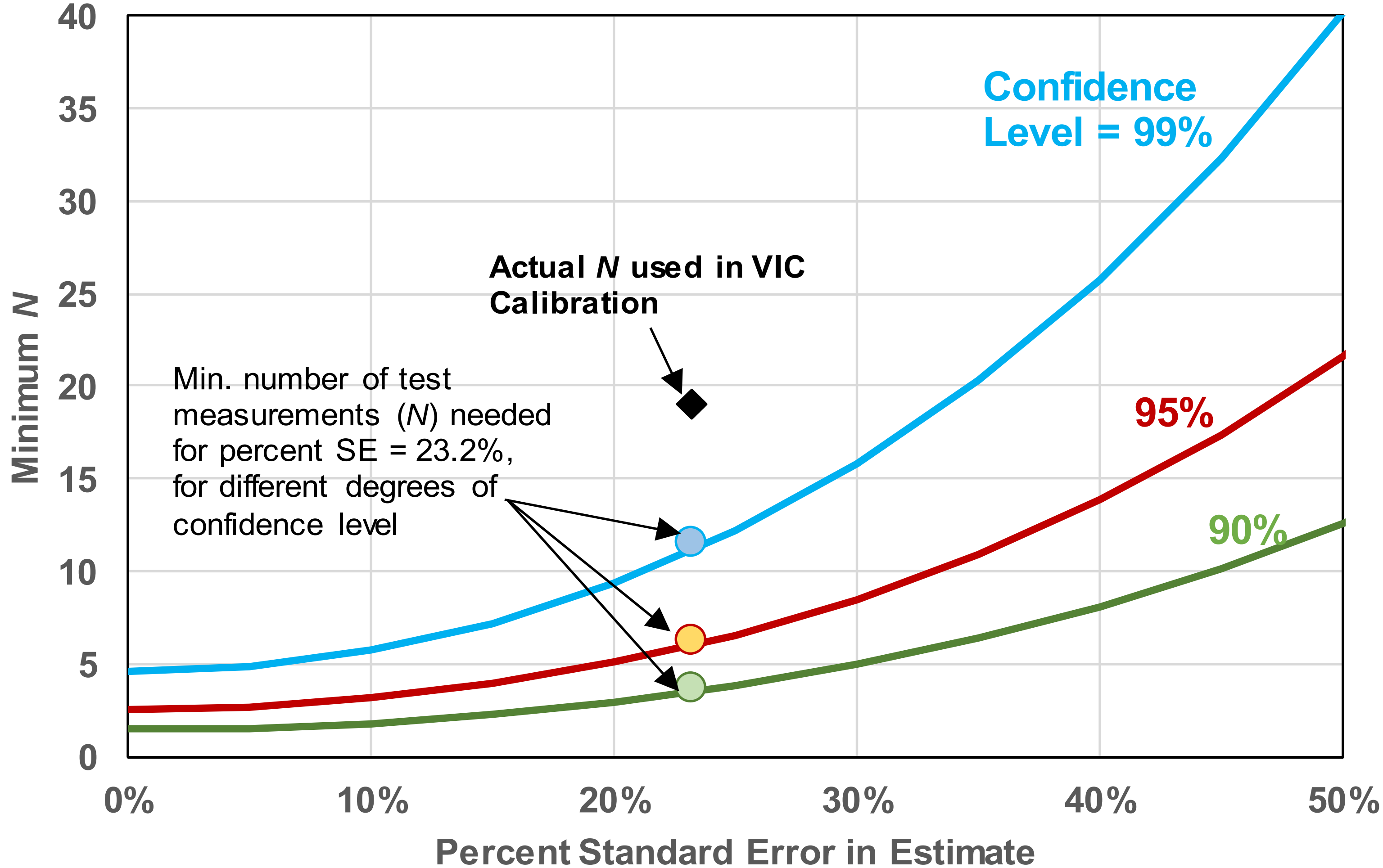
APLT connects design with QC/QA and providing stress-dependent M_r measured for VIC calibration.



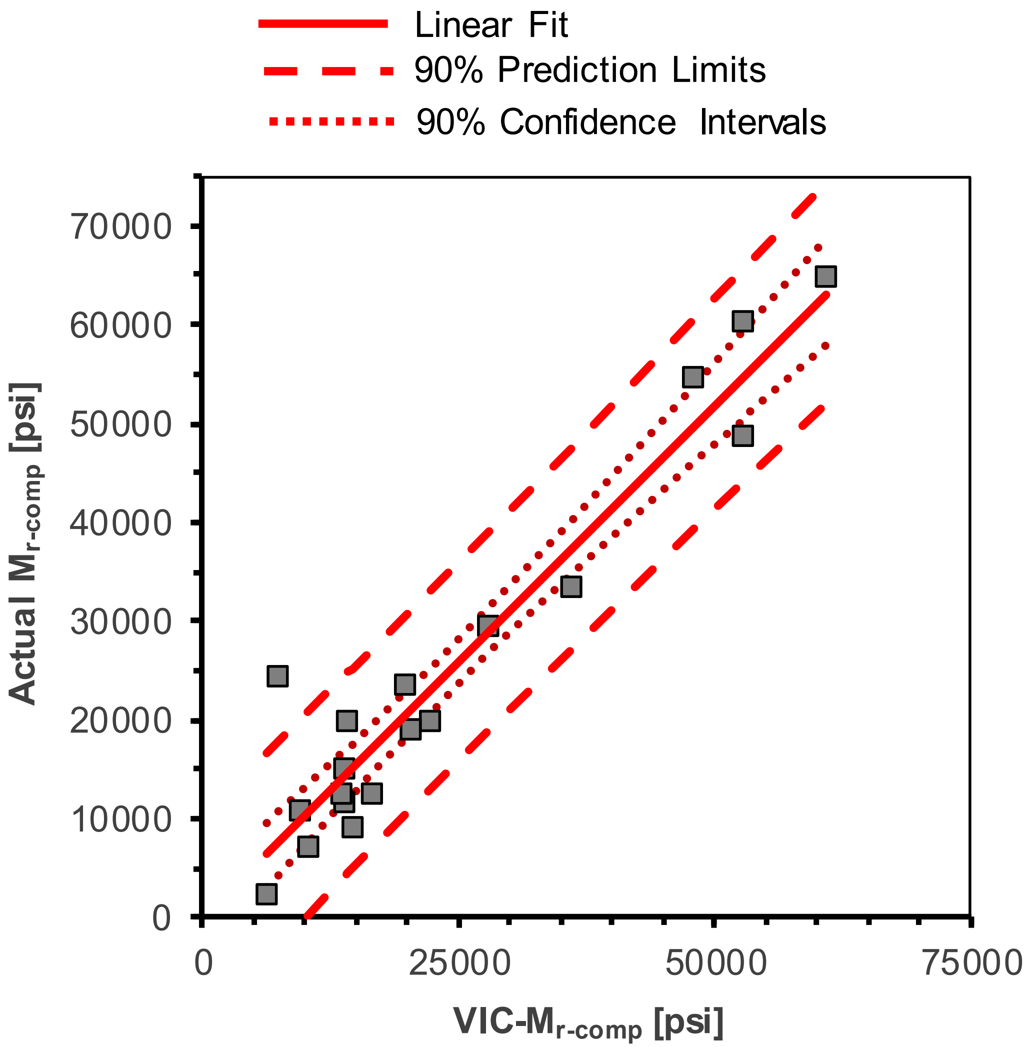


- Intent is to simulate actual stress conditions from pavement loading

How many tests should be performed for calibration testing?



VIC Calibration yielded high $R^2 > 0.9$



Regression Statistics

N	19	
R^2	0.925	
R^2(adj.)	0.904	
RMSE	5,822	psi
F-value	105.87	
p-value	<0.0001	

Measurement Statistics

Min.	2,108	psi
Max.	64,665	psi
Mean	25,096	psi
Median	19,644	psi
%SE**	23.20%	

**Percent error in prediction relative to mean

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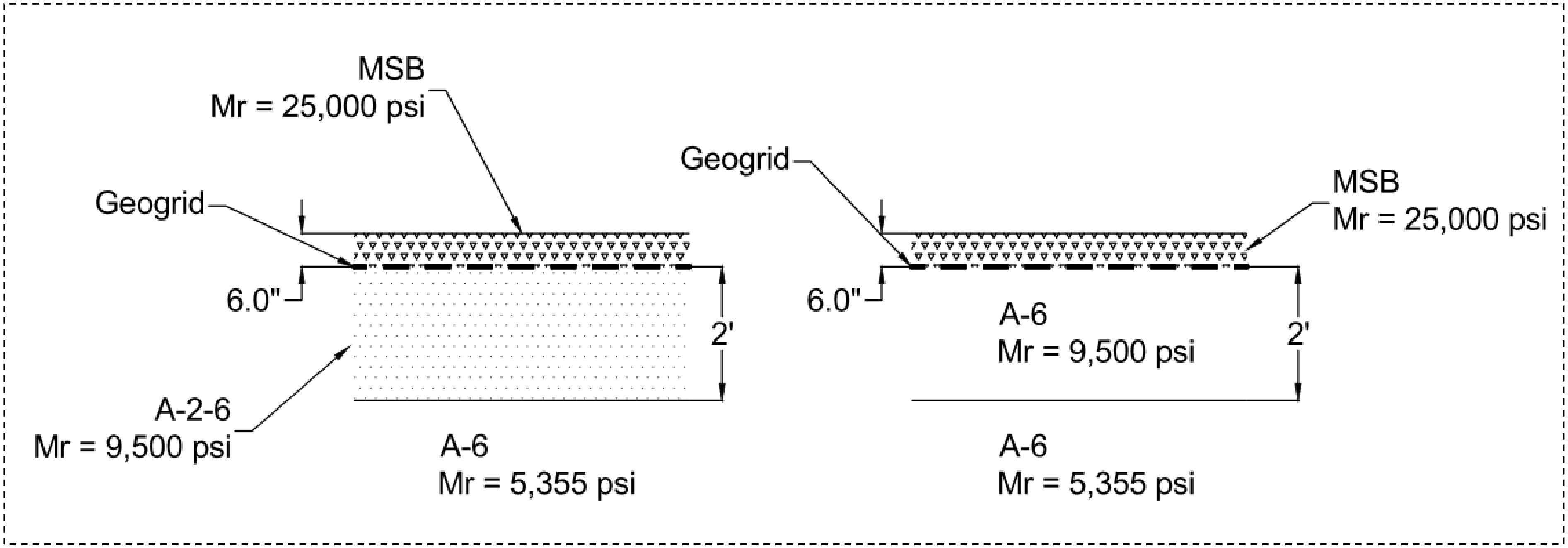
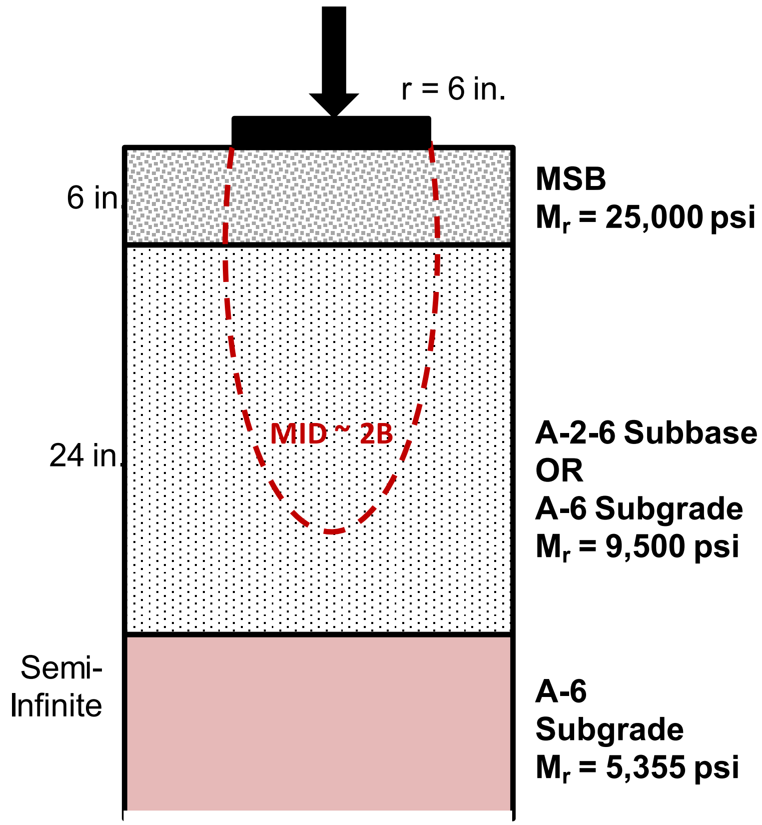
AASHTOWare ME Design based Target Values representing as-Constructed conditions were provided.



- DOT required these Mr values be field verified

In Situ Composite and Layered Mr Reference Values were determined Linking to the Design Targets



Target In Situ Composite and Two-Layered M_r values (12-inch Dia. Plate)

Combined [MSB + Subbase + Subgrade]

$M_{r\text{-}Comp}$ = 11,560 psi (30 in. + Semi-infinite)

Two Layered Analysis Options

$M_{r\text{-}MSB}$ = 25,000 psi (6 in.)

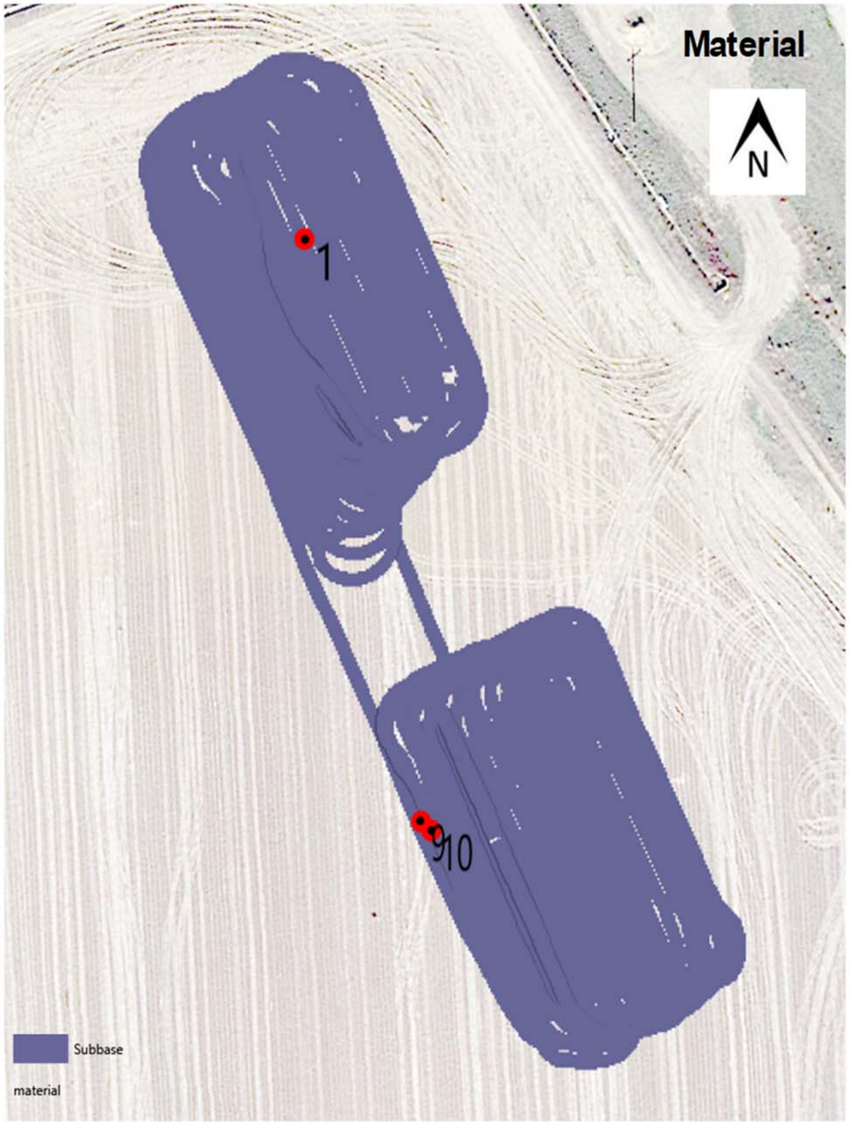
$M_{r\text{-}SB+SG}$ = 8,310 psi (24 in. + Semi-infinite)

$Mr_{\text{-}SB+SG}$ = 8,190 psi (16 in. + Semi-infinite)

$Mr_{\text{-}SB+SG}$ = 7,200 psi (8 in. + Semi-infinite)

- Composite Target Values Programmed into VIC Machine

VIC Material ID & Pass Count Map



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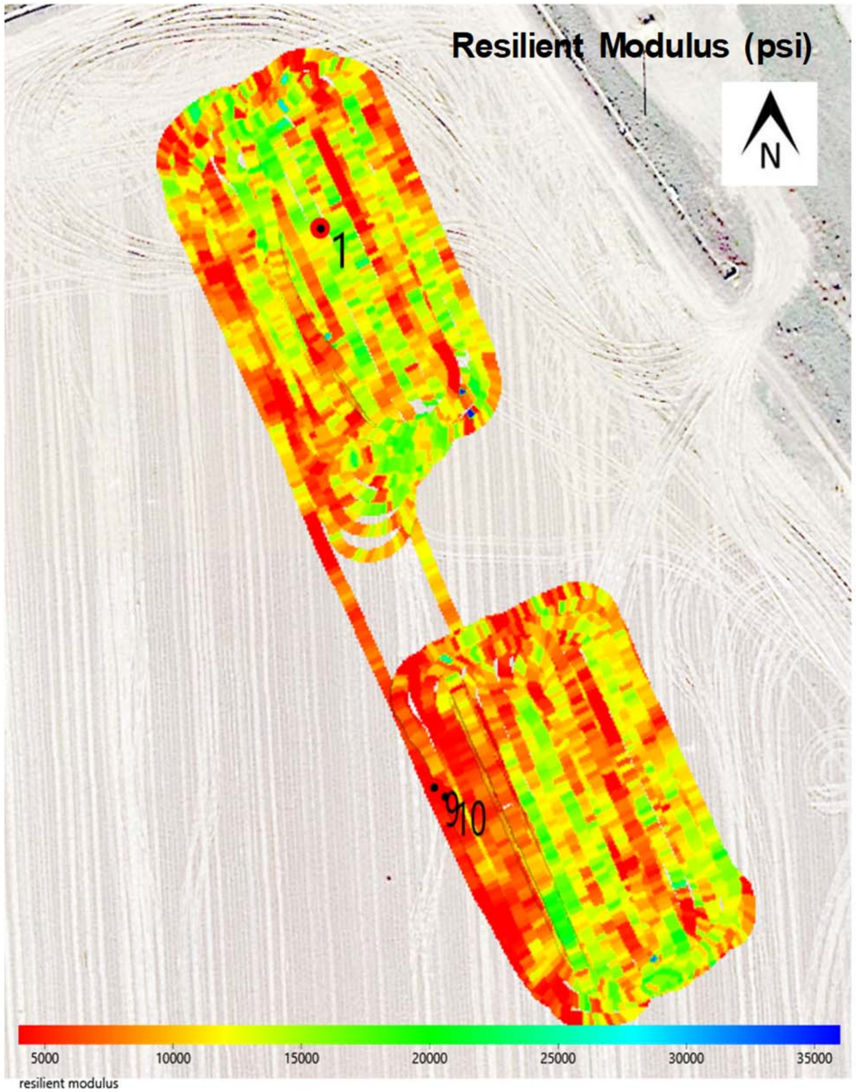
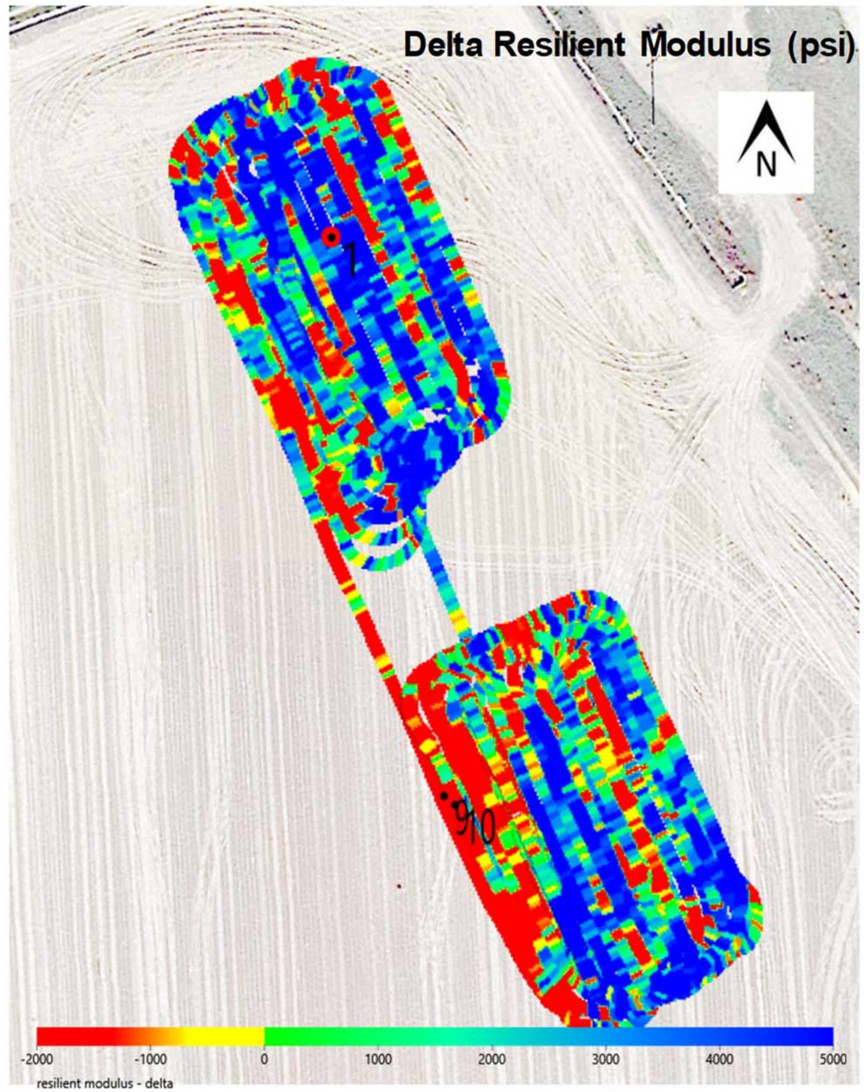
VIC M_r and ΔM_r Map (= In Situ M_r – M_r Target Value)





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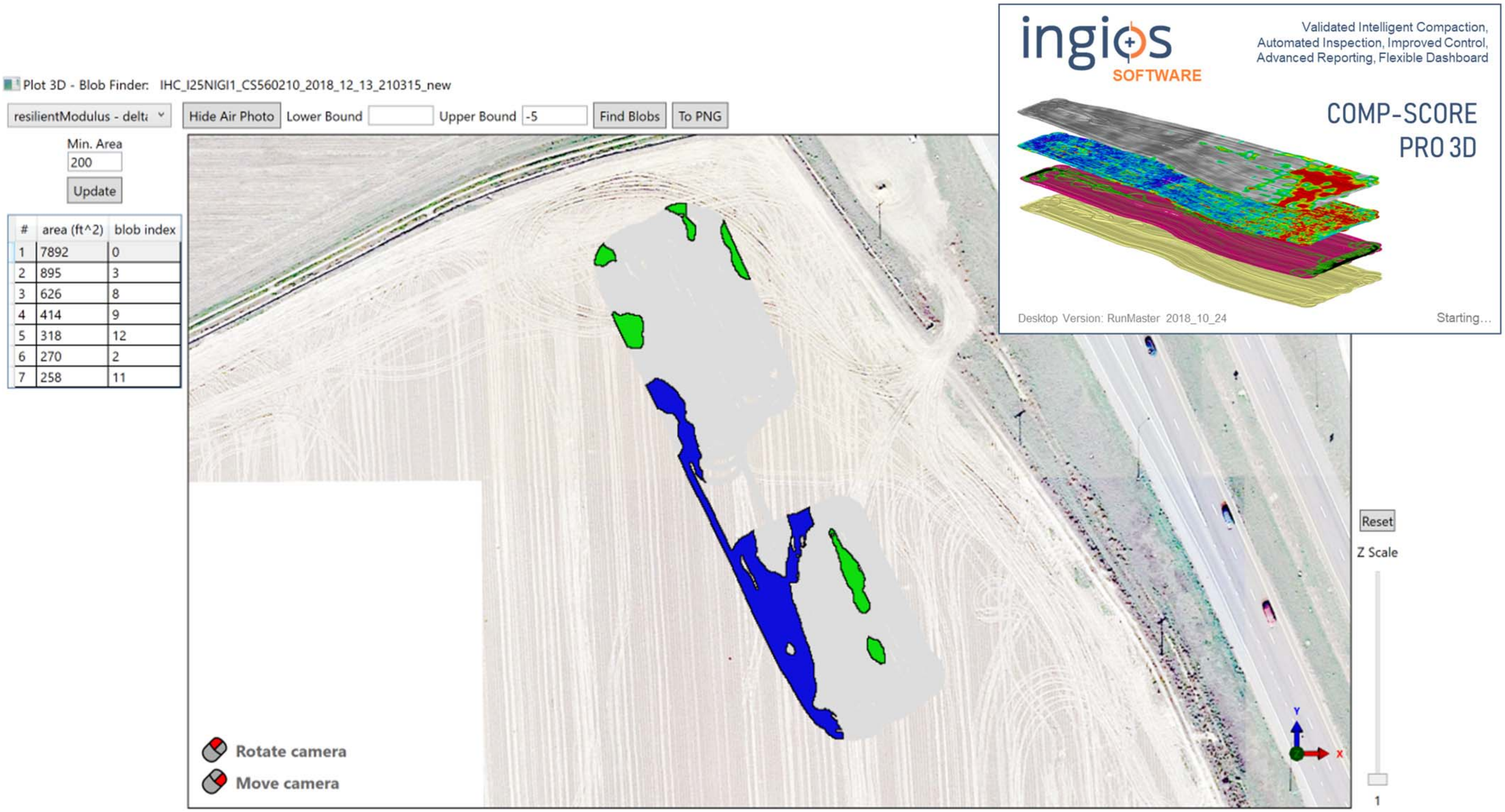
VIC CompScore *i-score* Map “Blob” Areas



Production Use of VIC on I-25 Project

- Onsite VIC Training provided to roller operators
- Contractor enabled to verify constructed M_r real-time and meet project design requirements

SEMA CONSTRUCTION

Interstate Highway Construction

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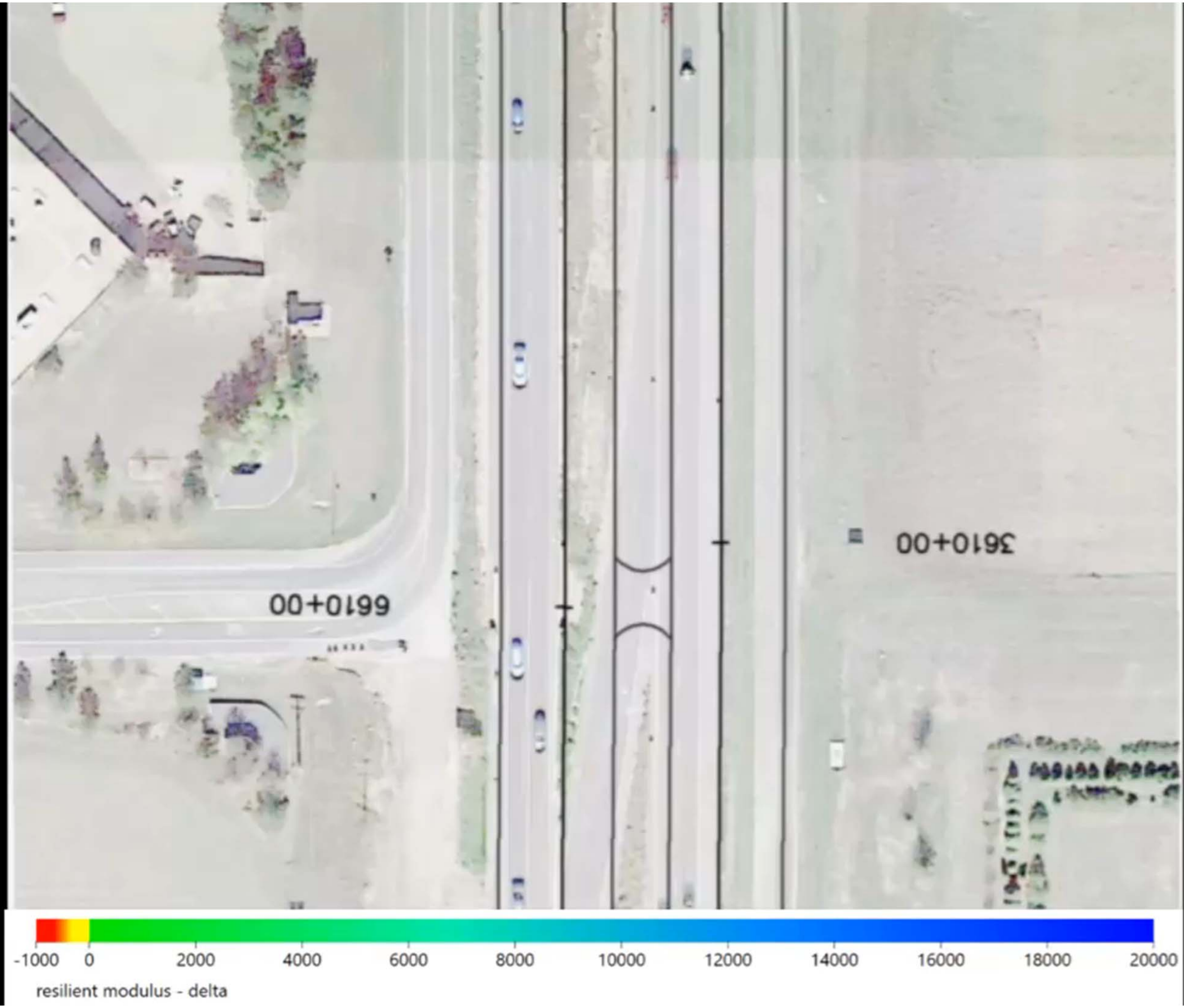
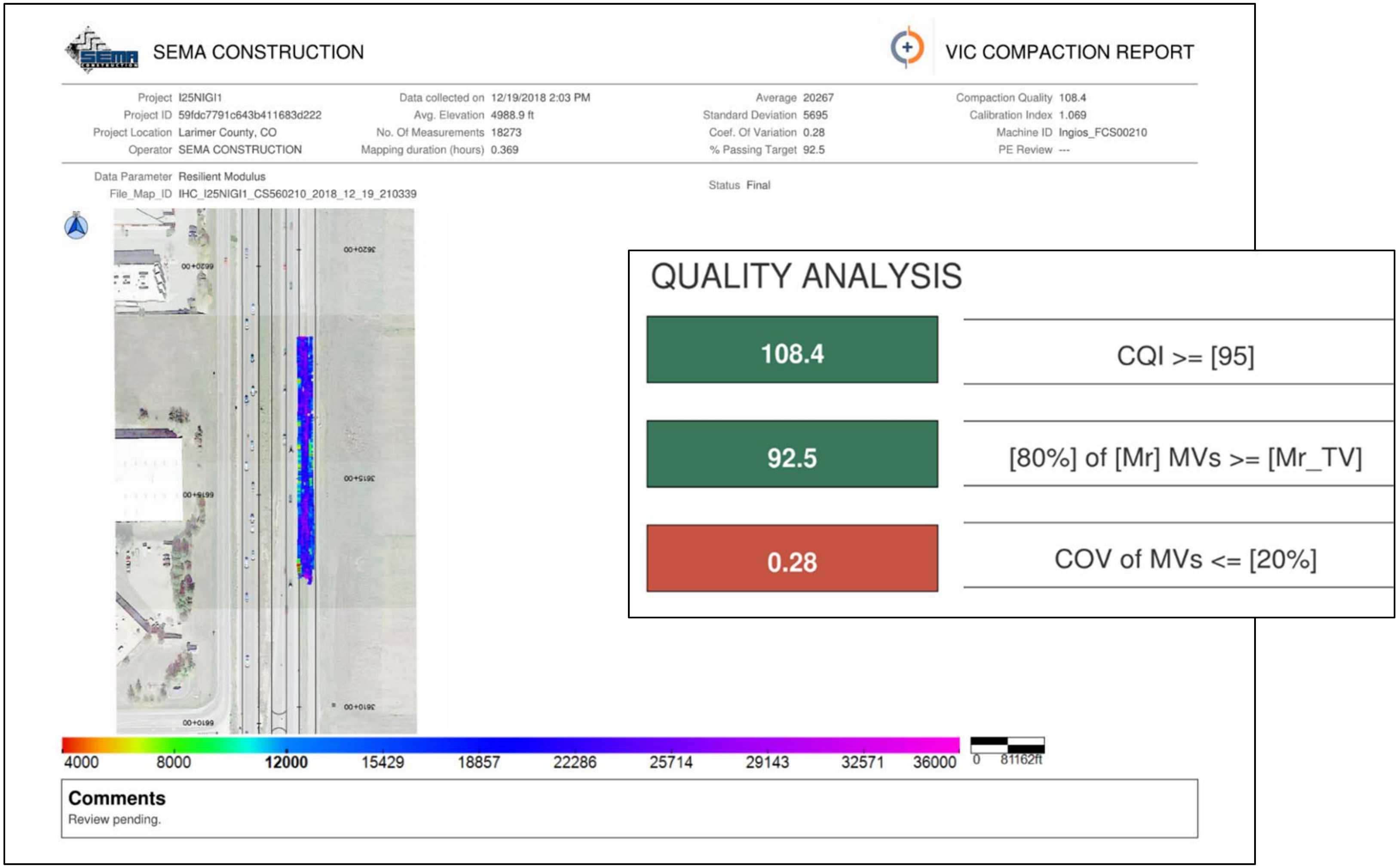
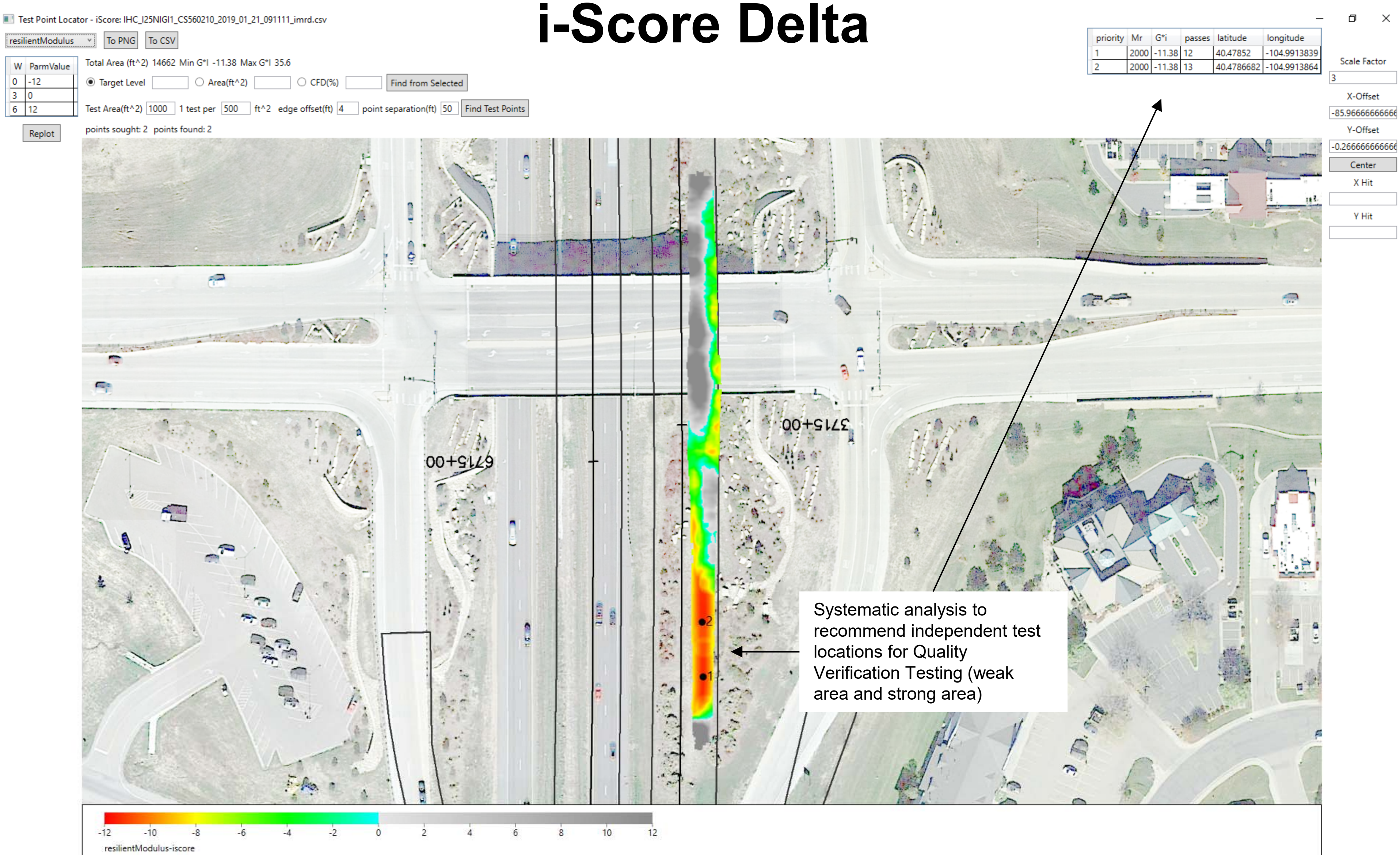


-1000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
resilient modulus - delta

Auto-Generated VIC Compaction Reports from CompScore Connect



I^2 (weak areas) In Situ Resilient Modulus (psi): i-Score Delta



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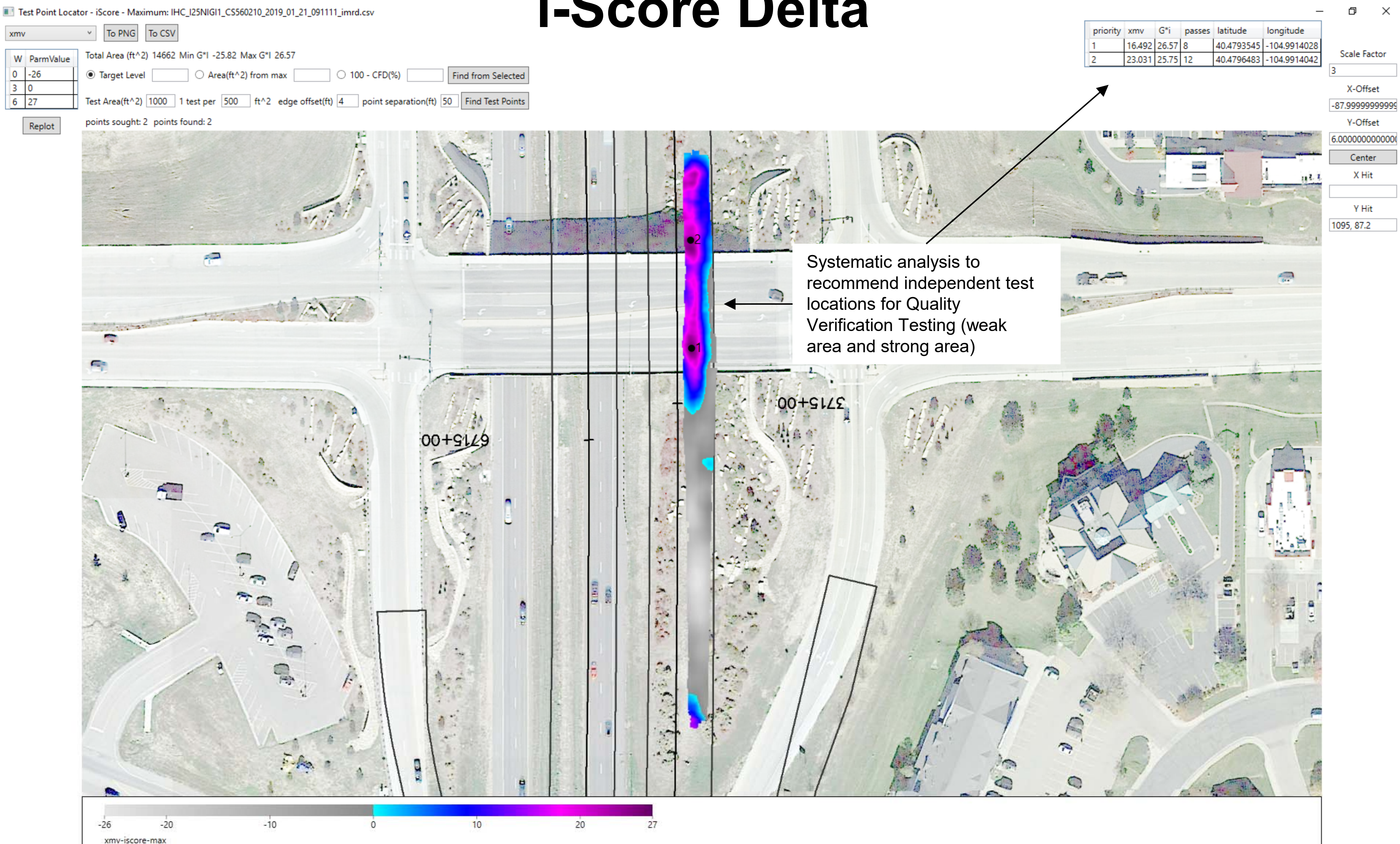
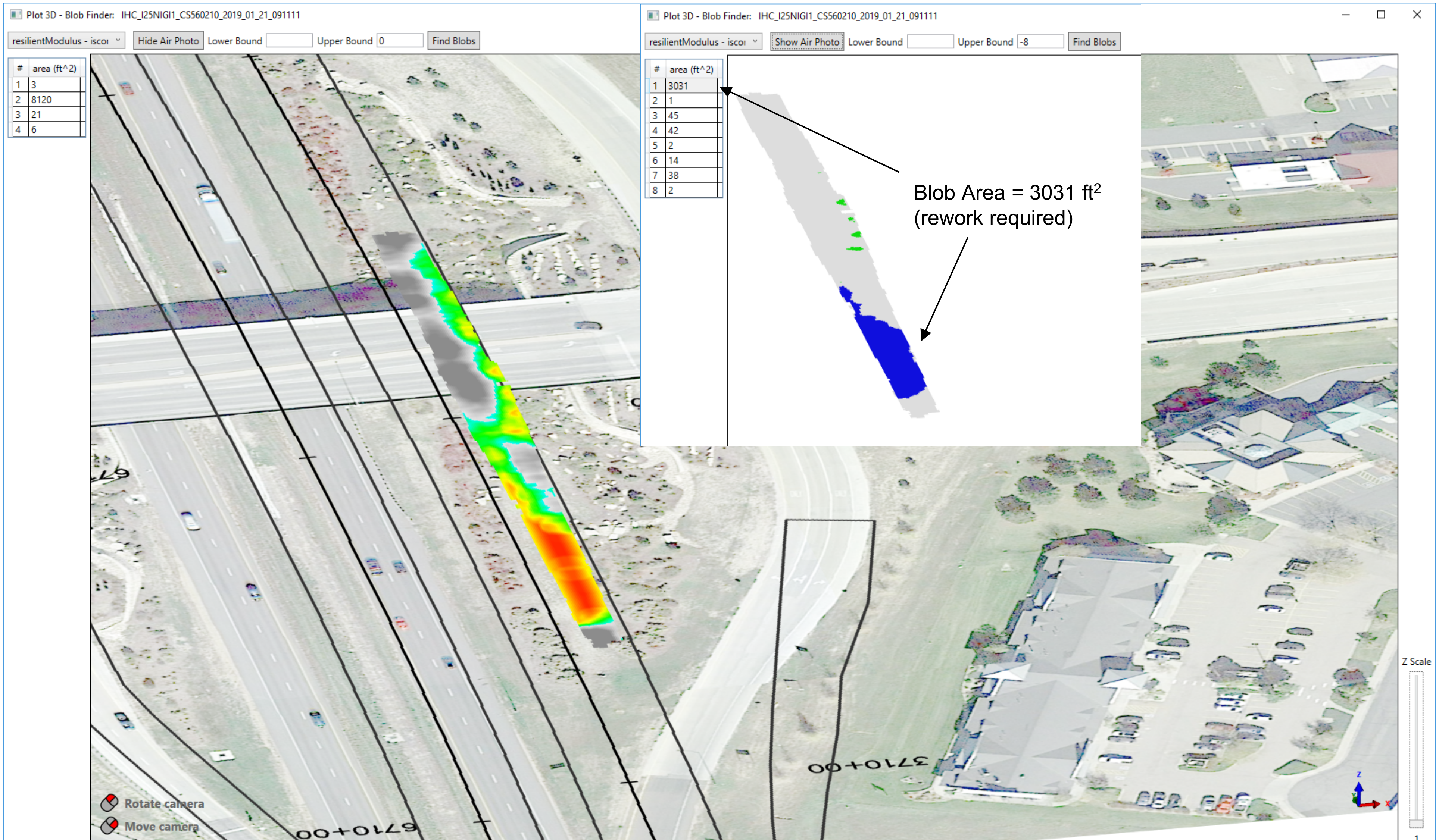
I^2 (stiff areas) In Situ Resilient Modulus (psi): i-Score Delta

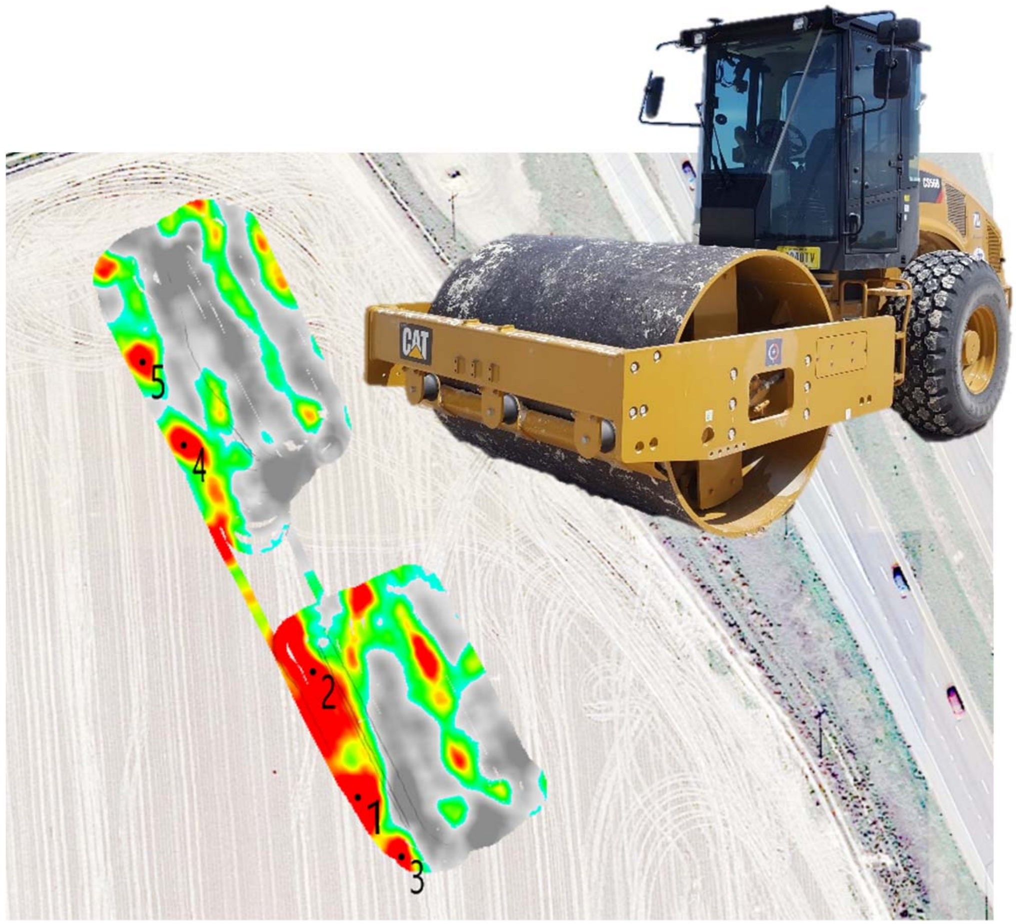


I² (rework areas) Blob Identifier



Wrap-up!

- Robust / Accurate Mr measurement from VIC machine ($R^2 > 0.9$).
- Full Coverage QA testing for design verification (> 250,000 test points).
- Real-time Mr mapping and cloud-based data management to increase contractor efficiency.
- Intelligent Inspection (I^2) for targeted testing/rework areas



Thank You!