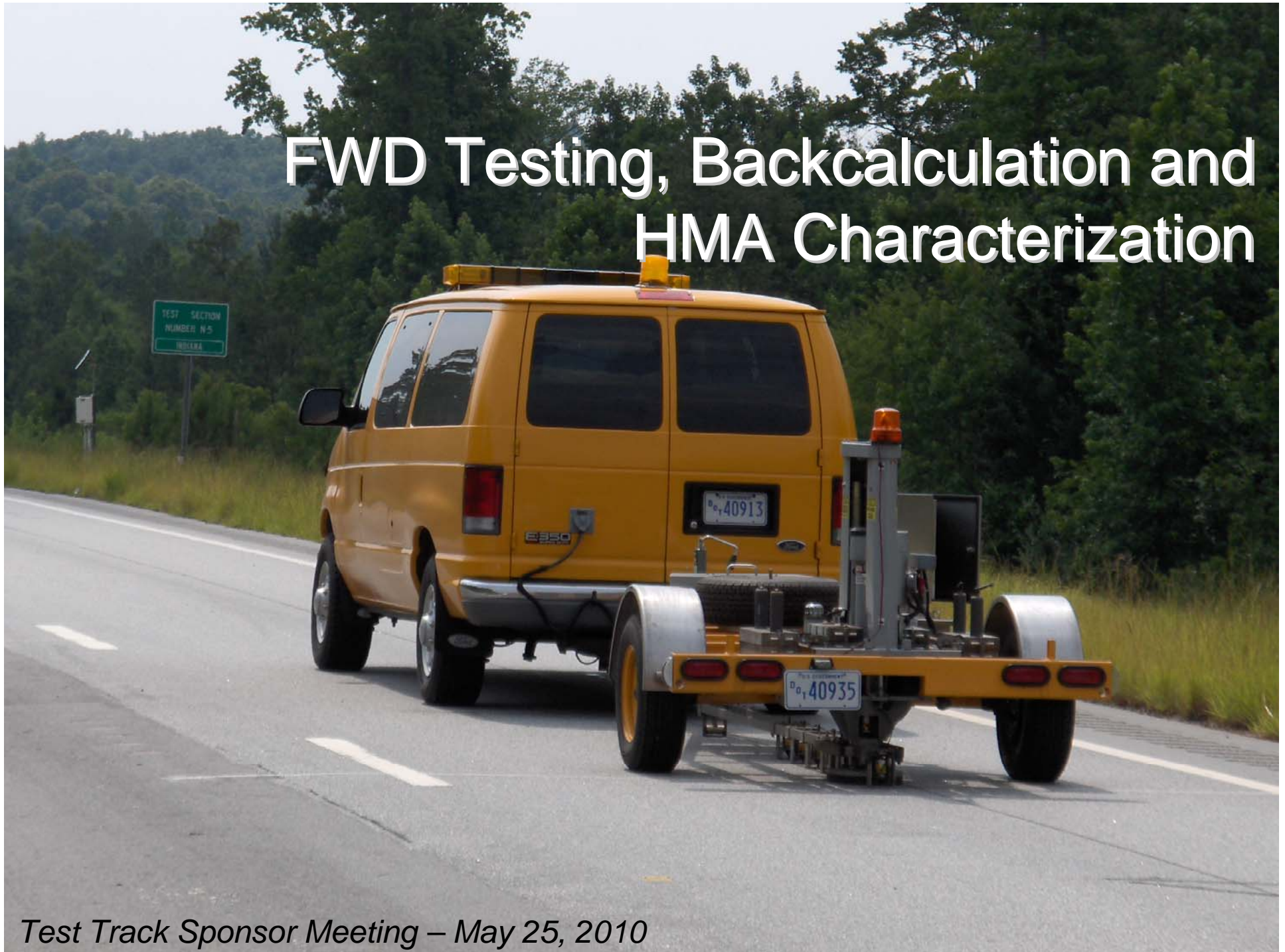


FWD Testing, Backcalculation and HMA Characterization

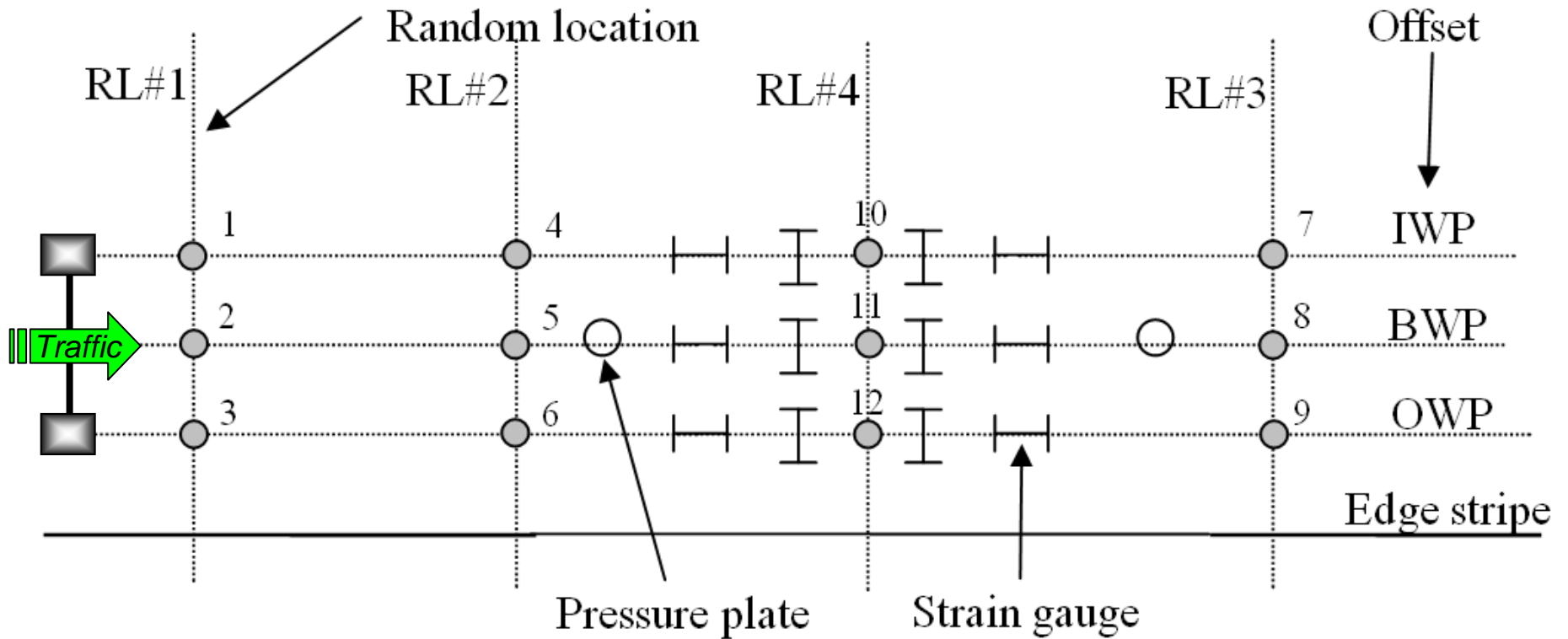


Test Track Sponsor Meeting – May 25, 2010

Background

- Modulus of materials primary input for M-E analysis and design
- Laboratory data limited
- FWD testing in field can capture...
 - Spatial variability
 - Temperature effects
 - Effects of damage
- FWD testing is the best representation of in place conditions

Testing Locations



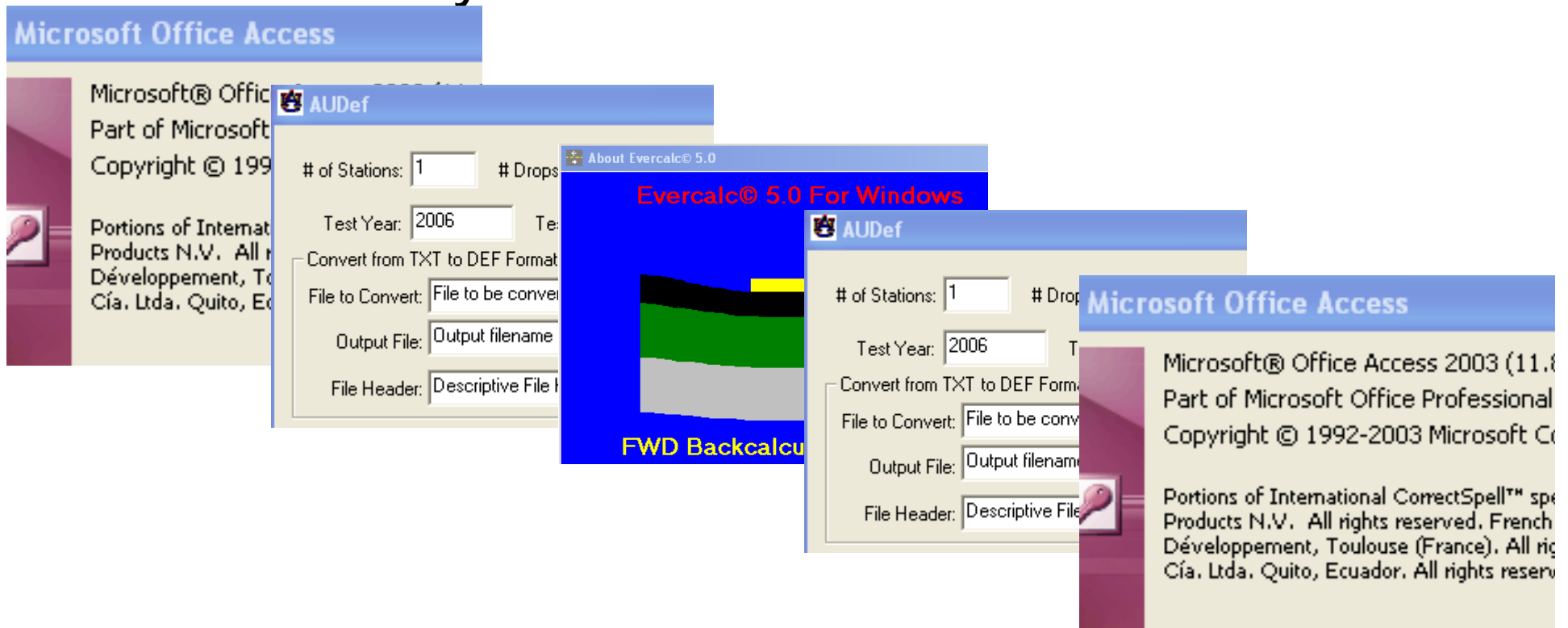
Test Parameters

- Testing done 3 times/month
 - Off day is for relative calibration of sensors
- Dynatest 8000
- 9 sensors
 - 0, 8, 12, 18, 24, 36, 48, 60 and 72”
- 5.91” radius split plate
- 4 drop heights
 - 6, 9, 12 and 16 kip
 - 3 replicates at each height
- Temps recorded at time of test

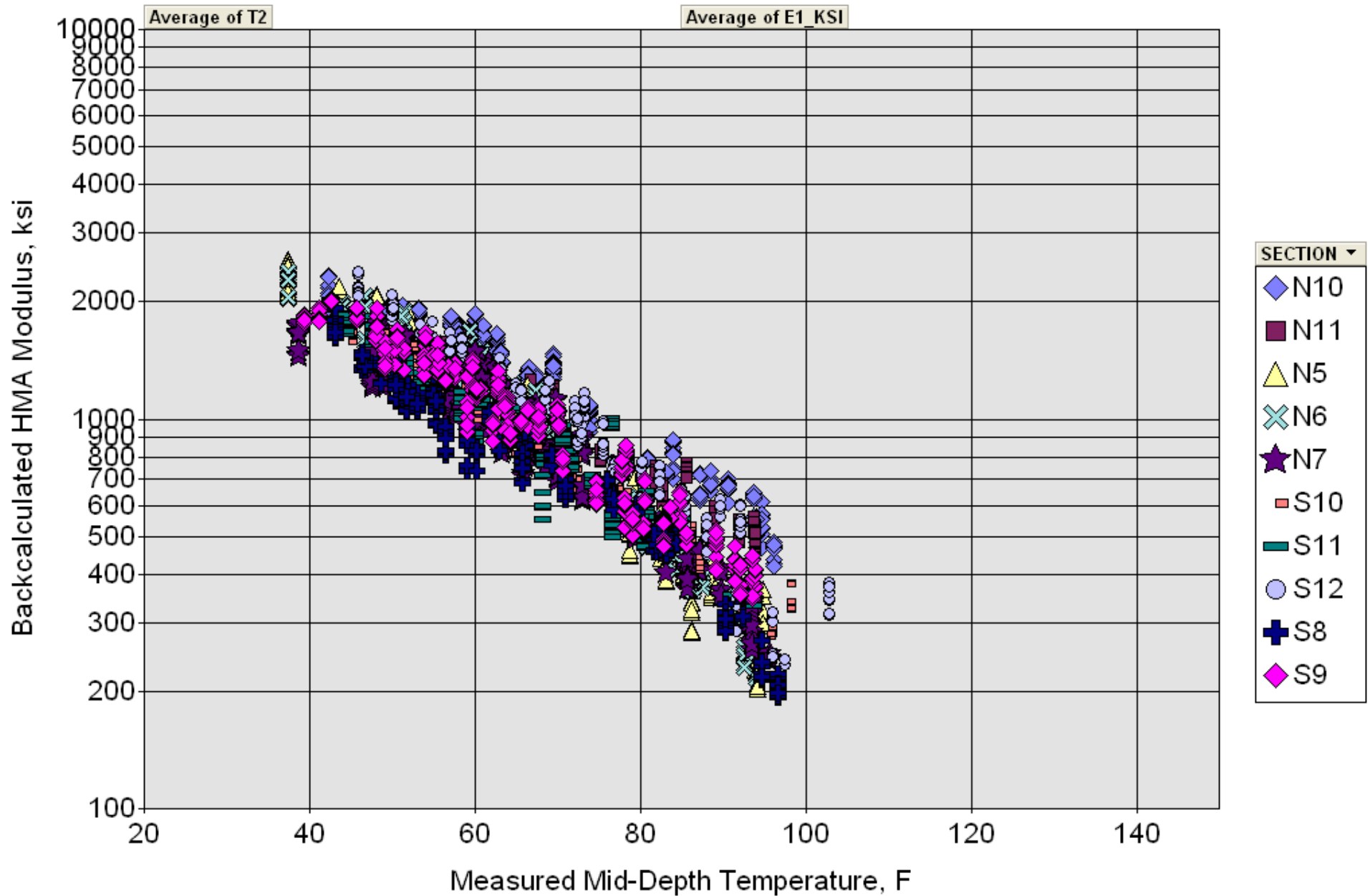


Backcalculation and Data Management

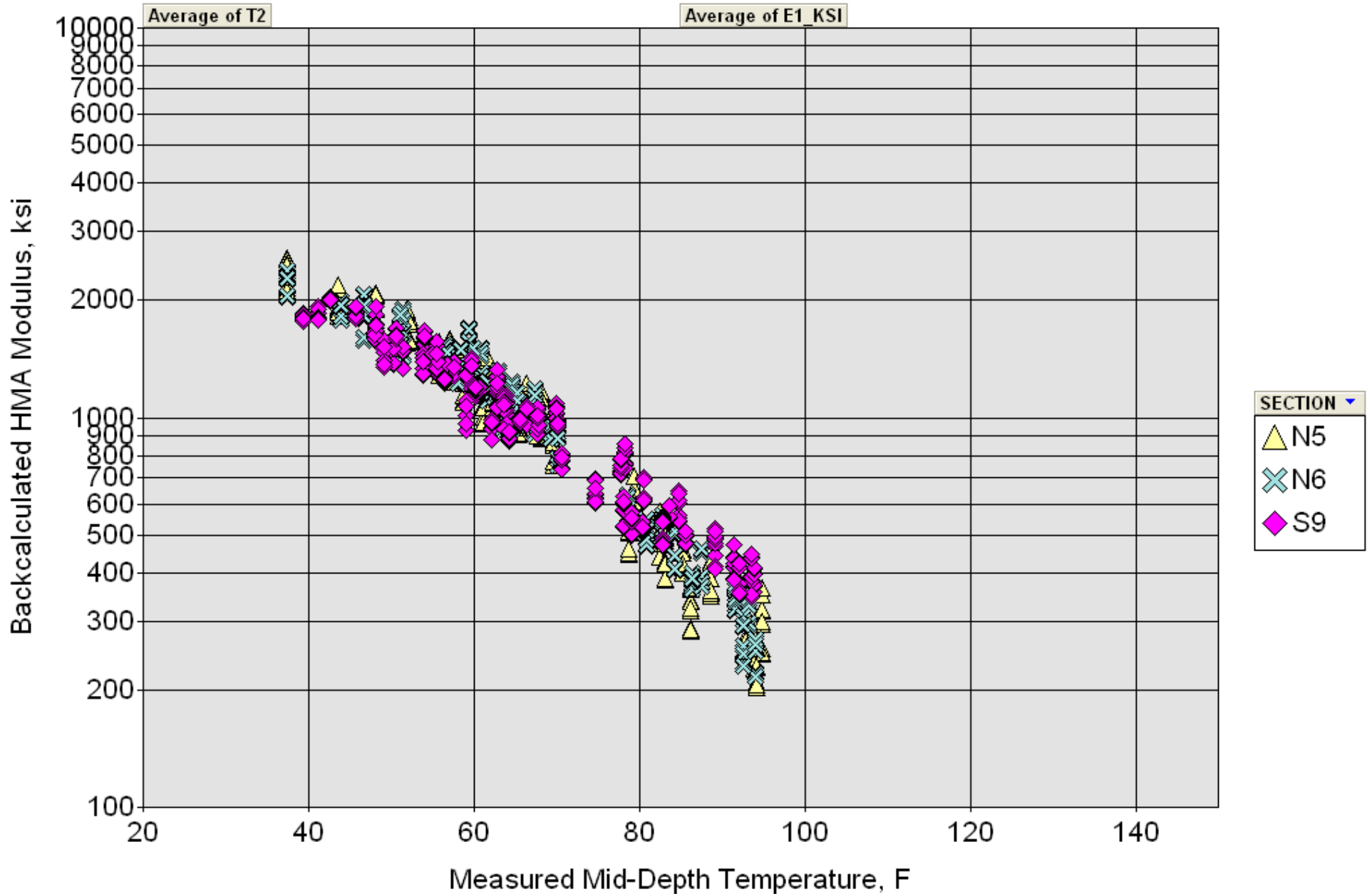
- EVERCALC 5.0
 - 3 Layer structures
 - HMA / Agg Base / Subgrade
 - No rigid layer
 - Limit analyses to $RMSE < 3\%$



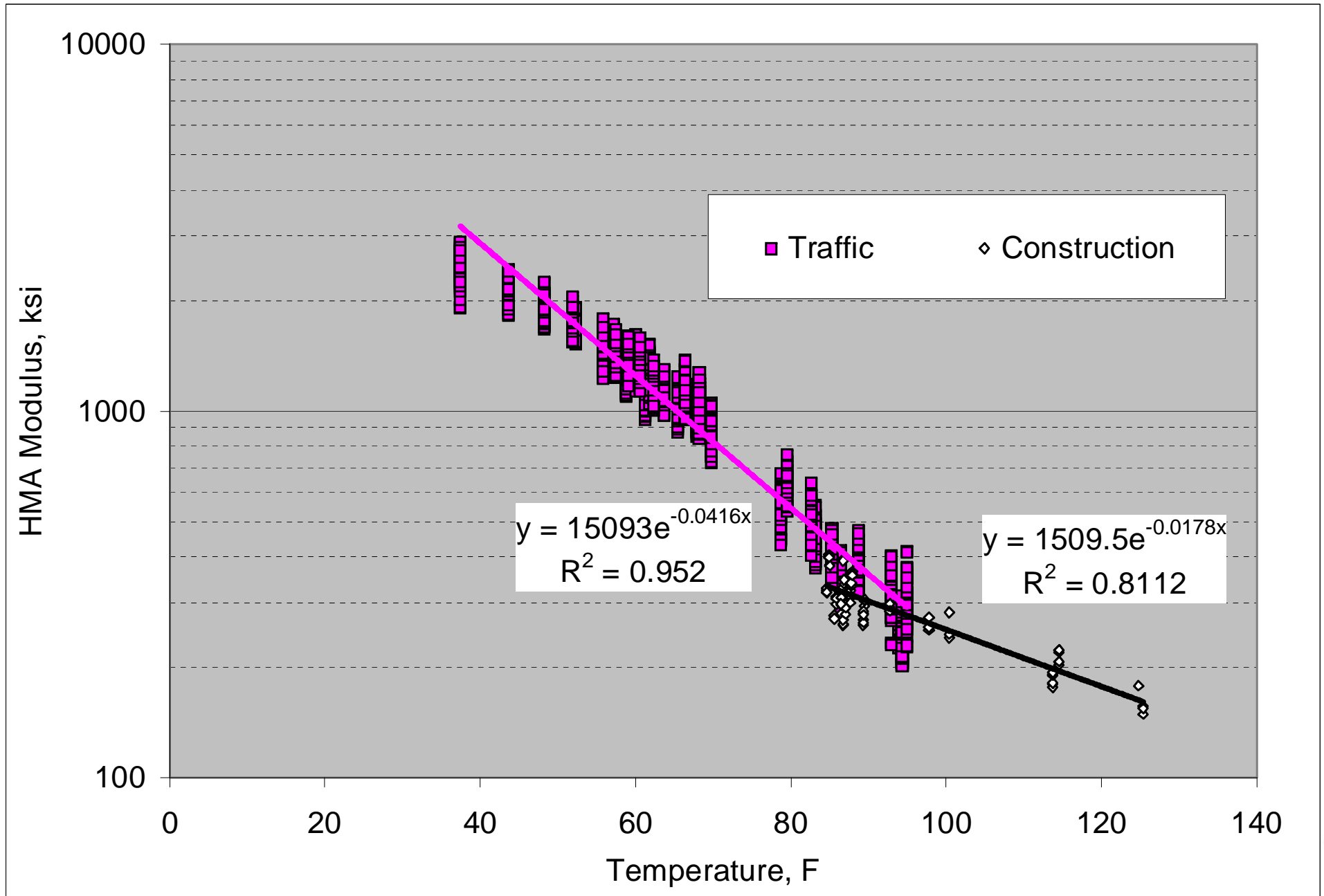
All New Sections – E vs T



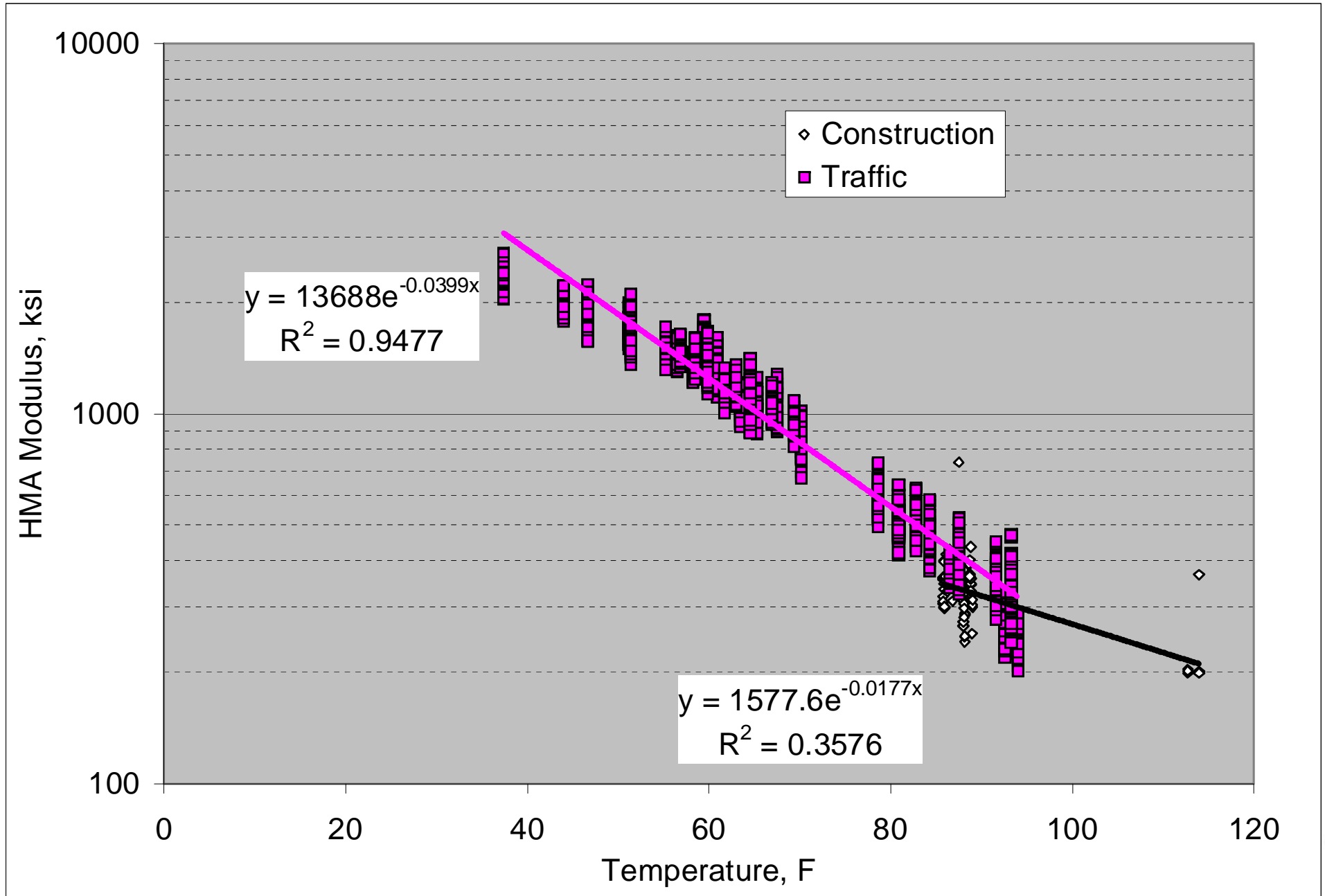
Thiopave vs Control



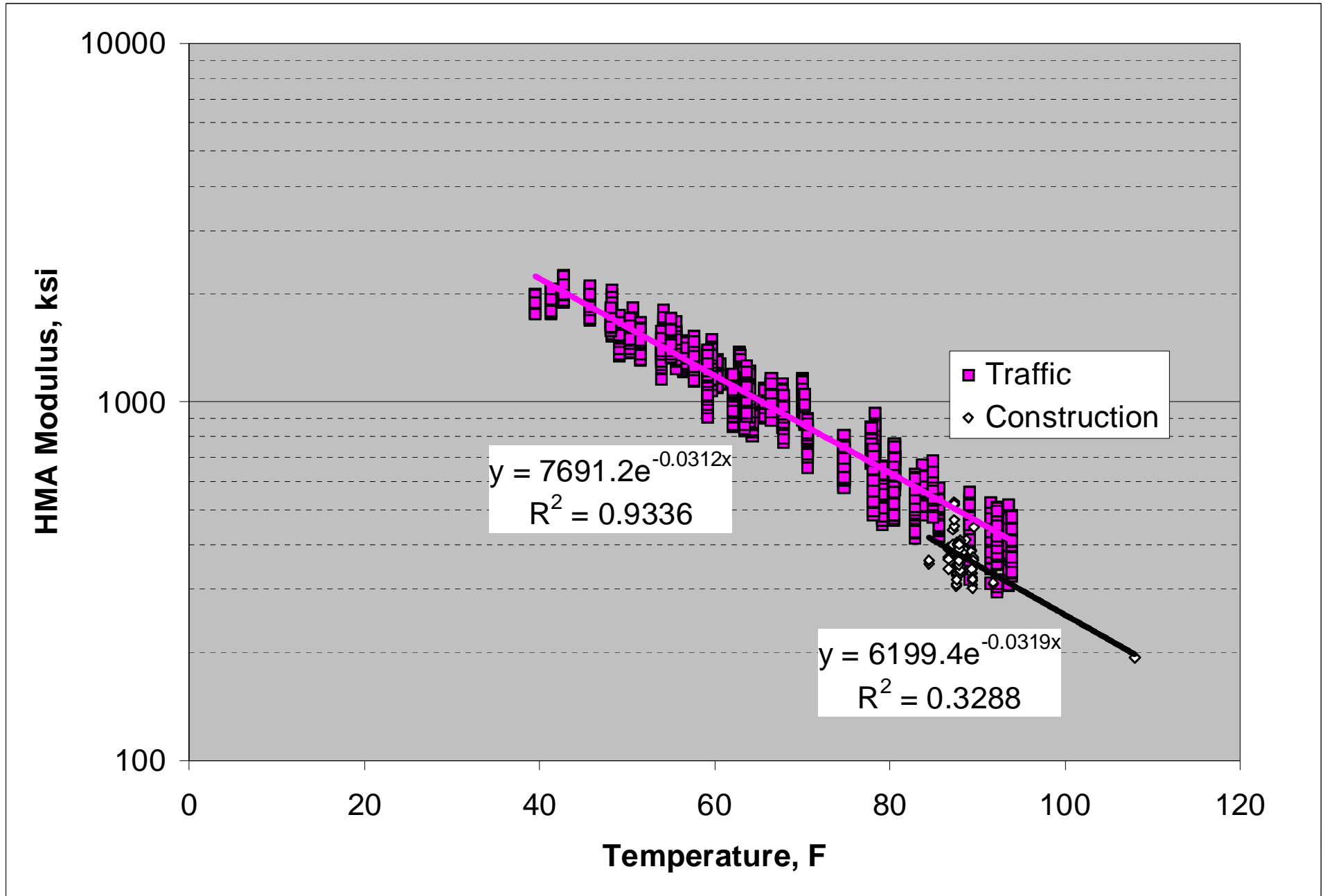
N5 – Before and After Traffic



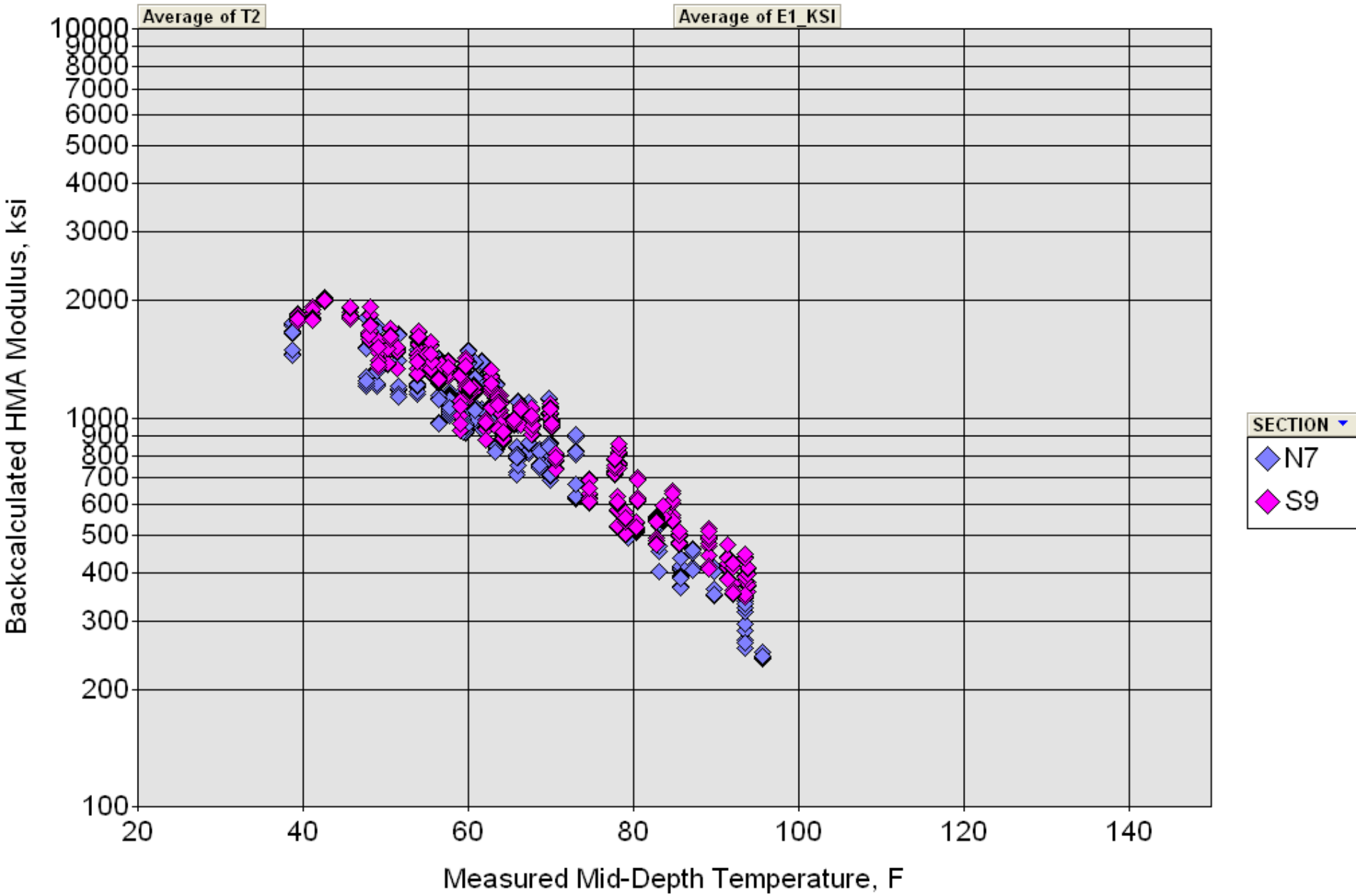
N6 – Before and After Traffic



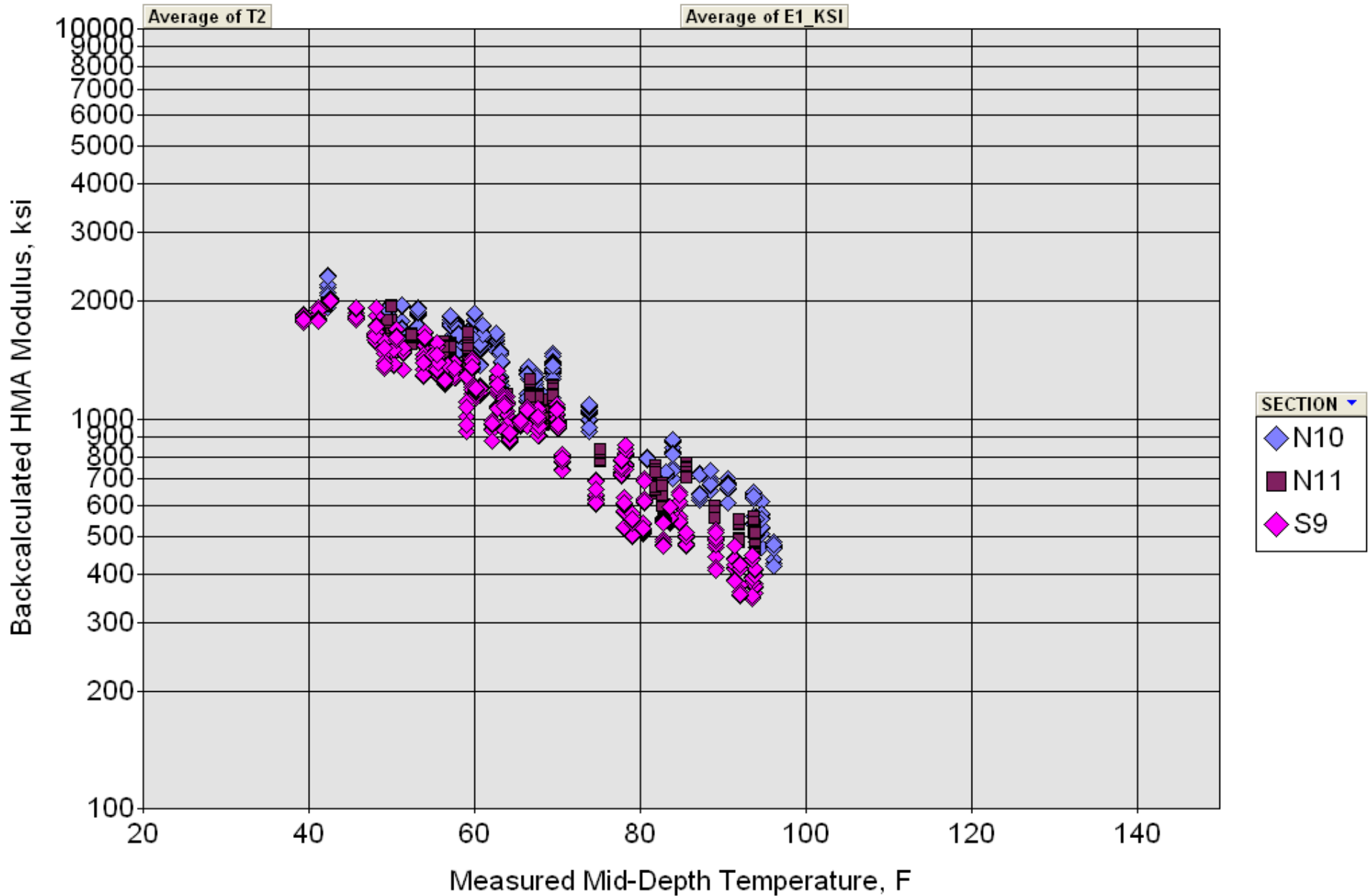
S9 Before and After Traffic



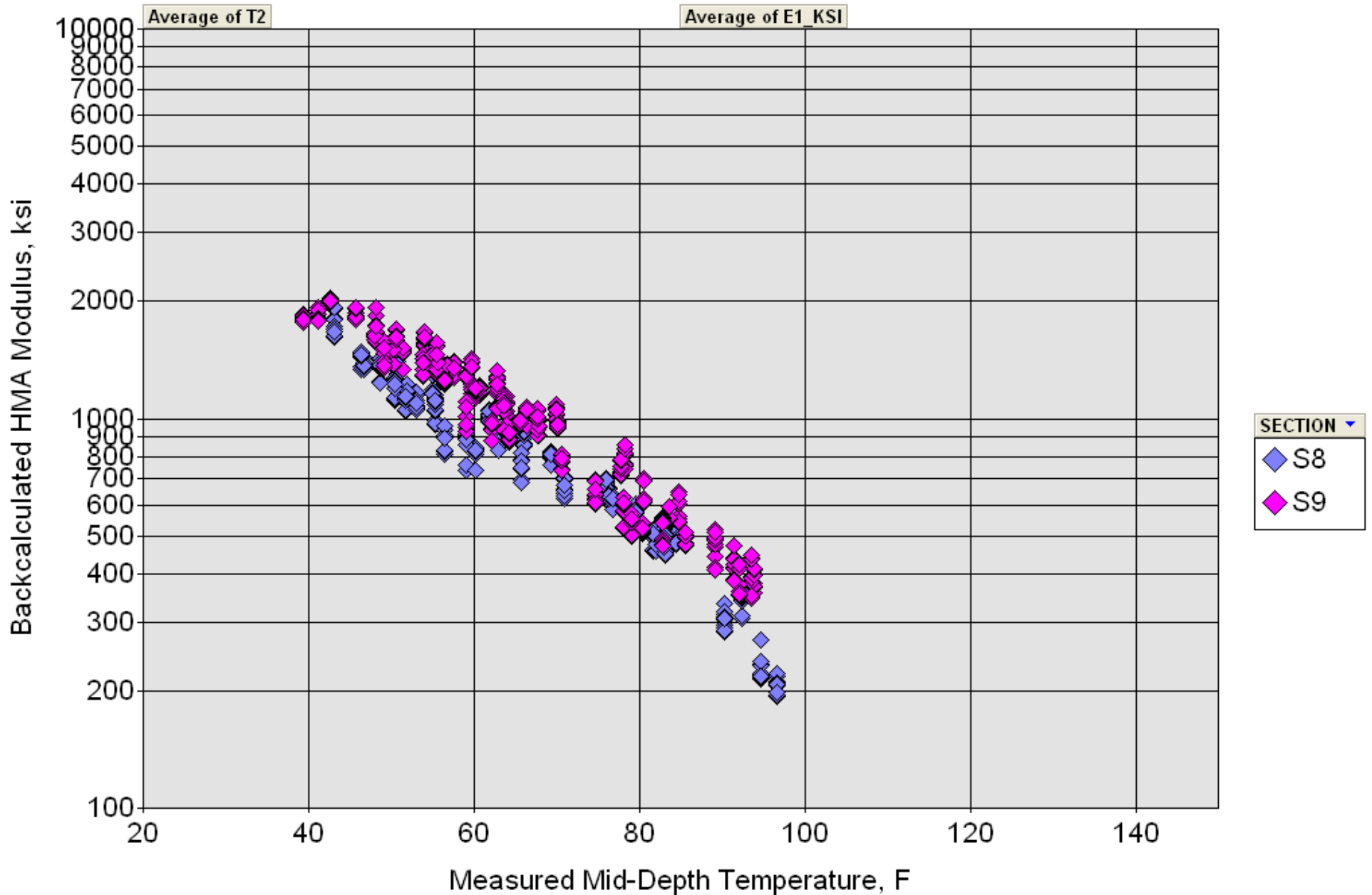
Kraton vs Control



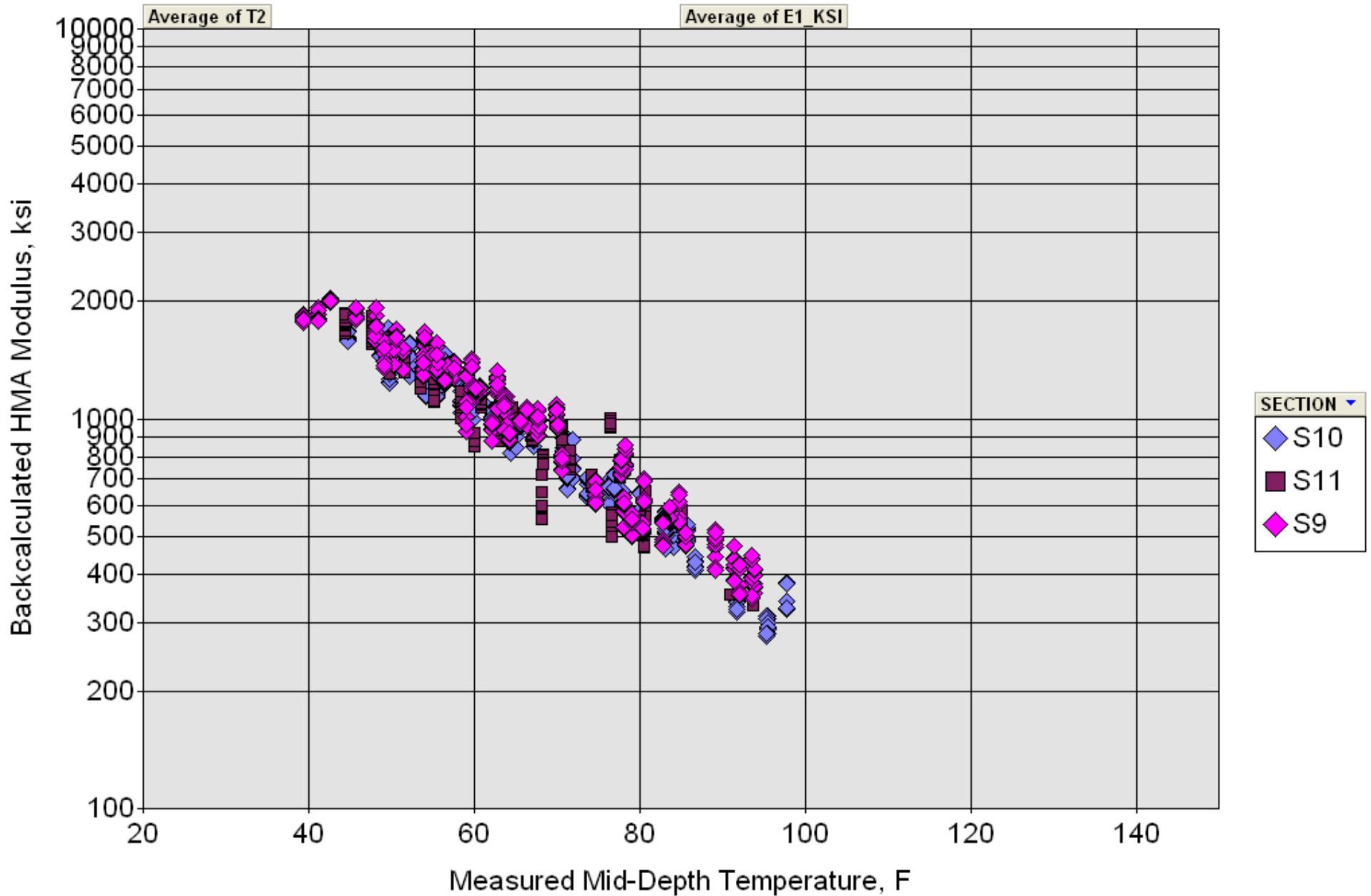
50% RAP vs Control



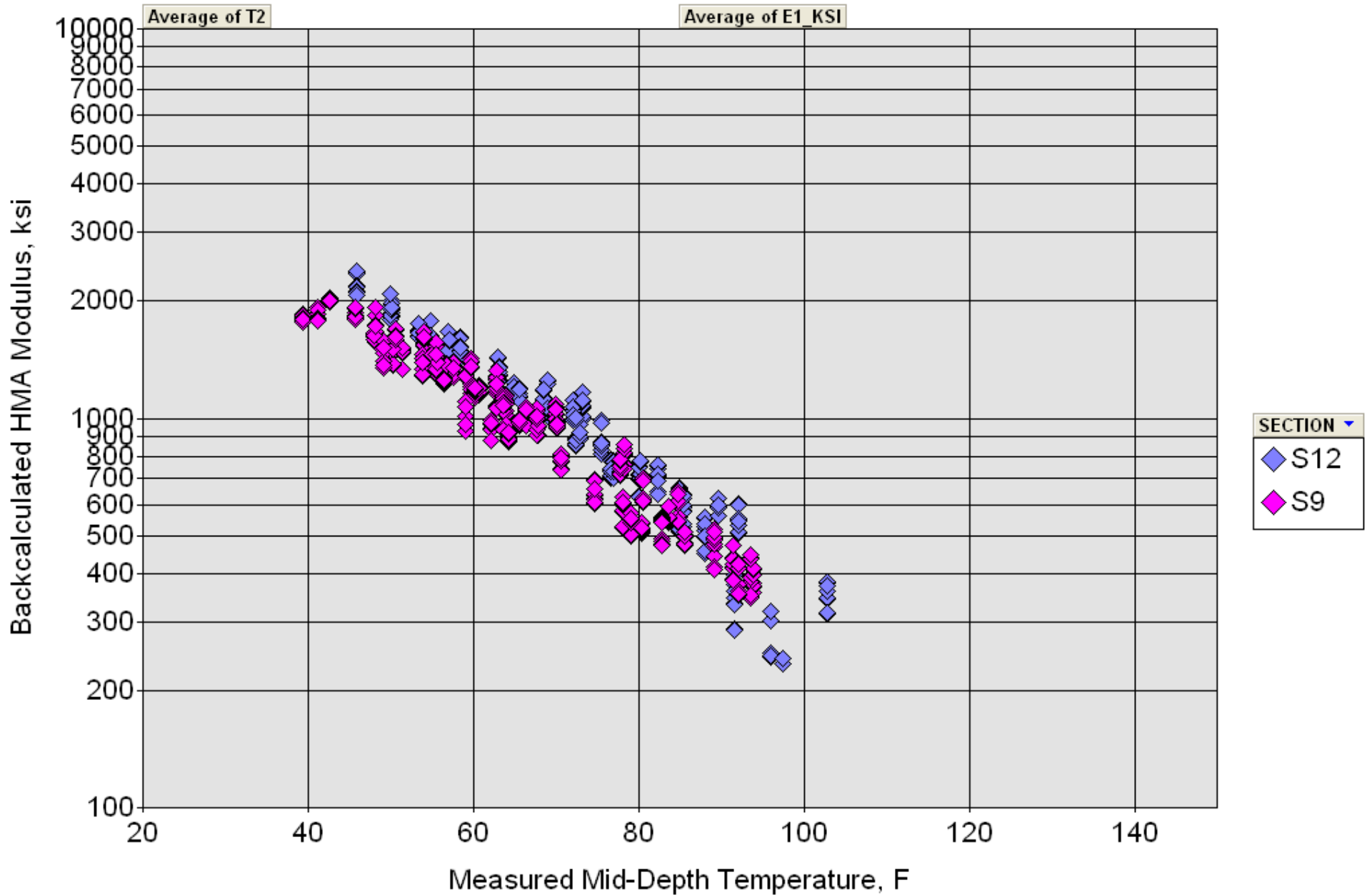
OGFC vs Control



WMA vs Control



TLA vs Control



Temperature Correction

- Fit exponential functions to each data set

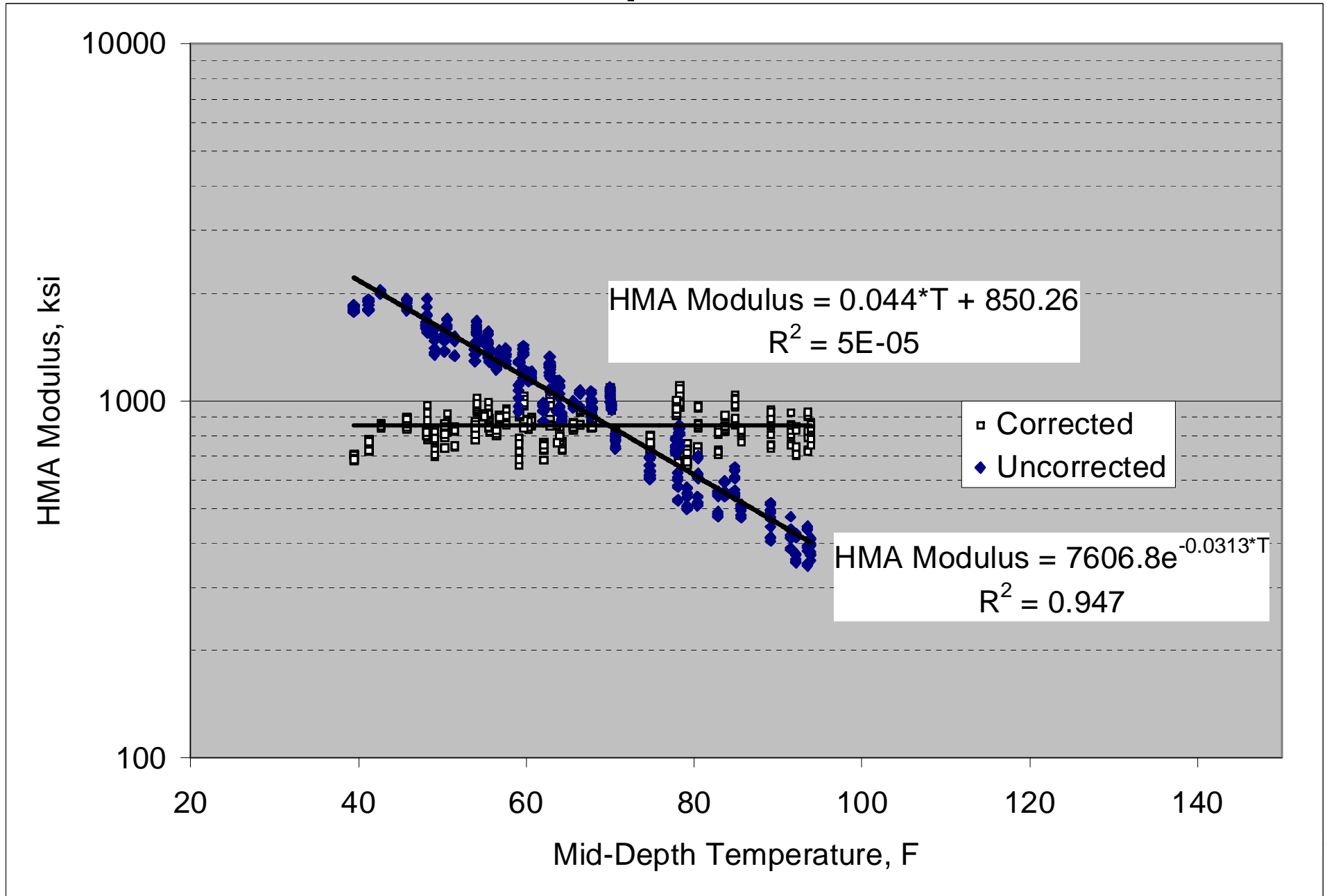
$$E = \alpha_1 e^{\alpha_2 T}$$

- Compute temperature-corrected modulus

$$\frac{E_{T_{ref}}}{E_{T_{meas}}} = \frac{\alpha_1 e^{\alpha_2 T_{ref}}}{\alpha_1 e^{\alpha_2 T_{meas}}}$$

$$E_{T_{ref}} = E_{T_{meas}} e^{\alpha_2 (T_{ref} - T_{meas})}$$

Example – S9



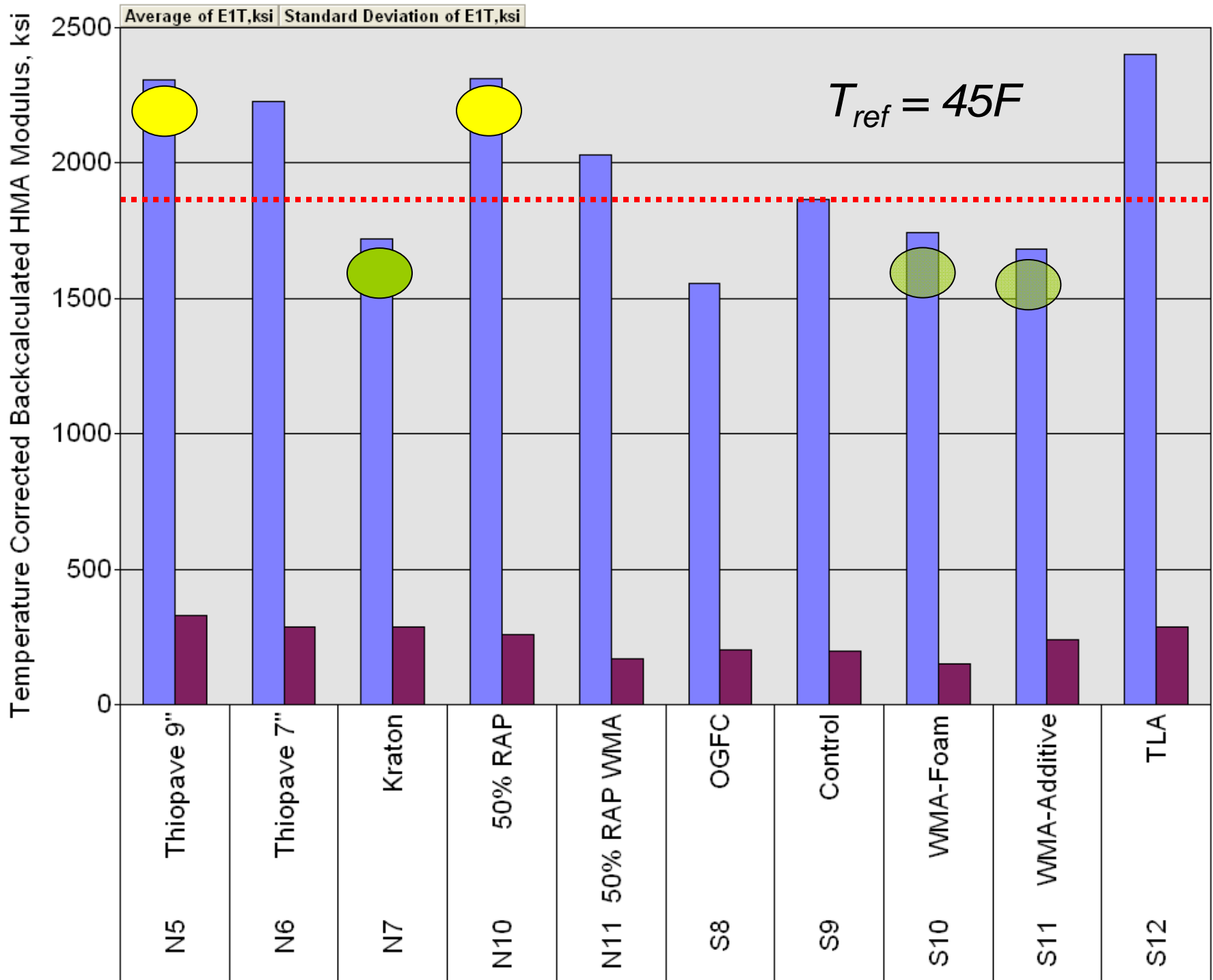
Regression Summary

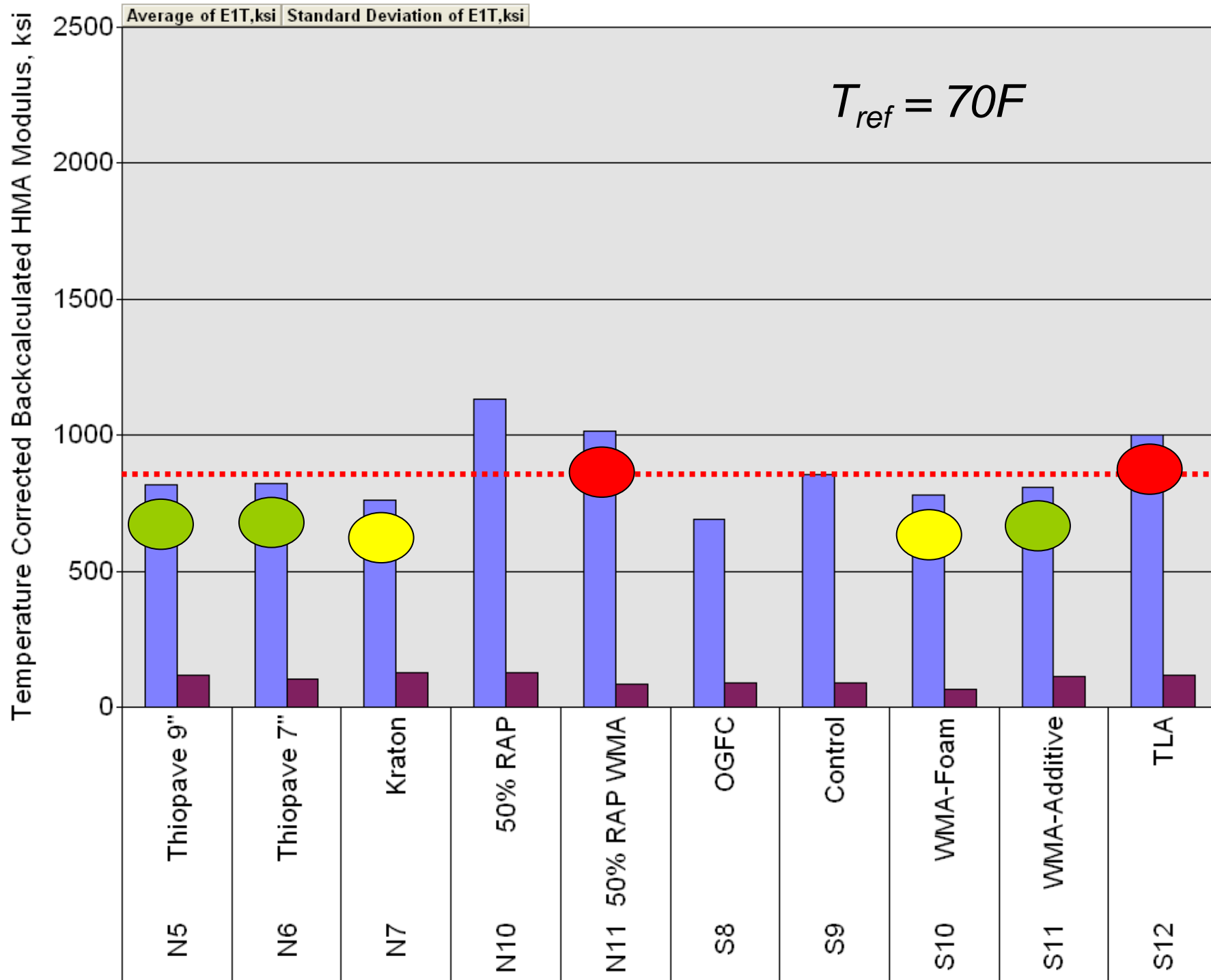
Temperature Sensitivity

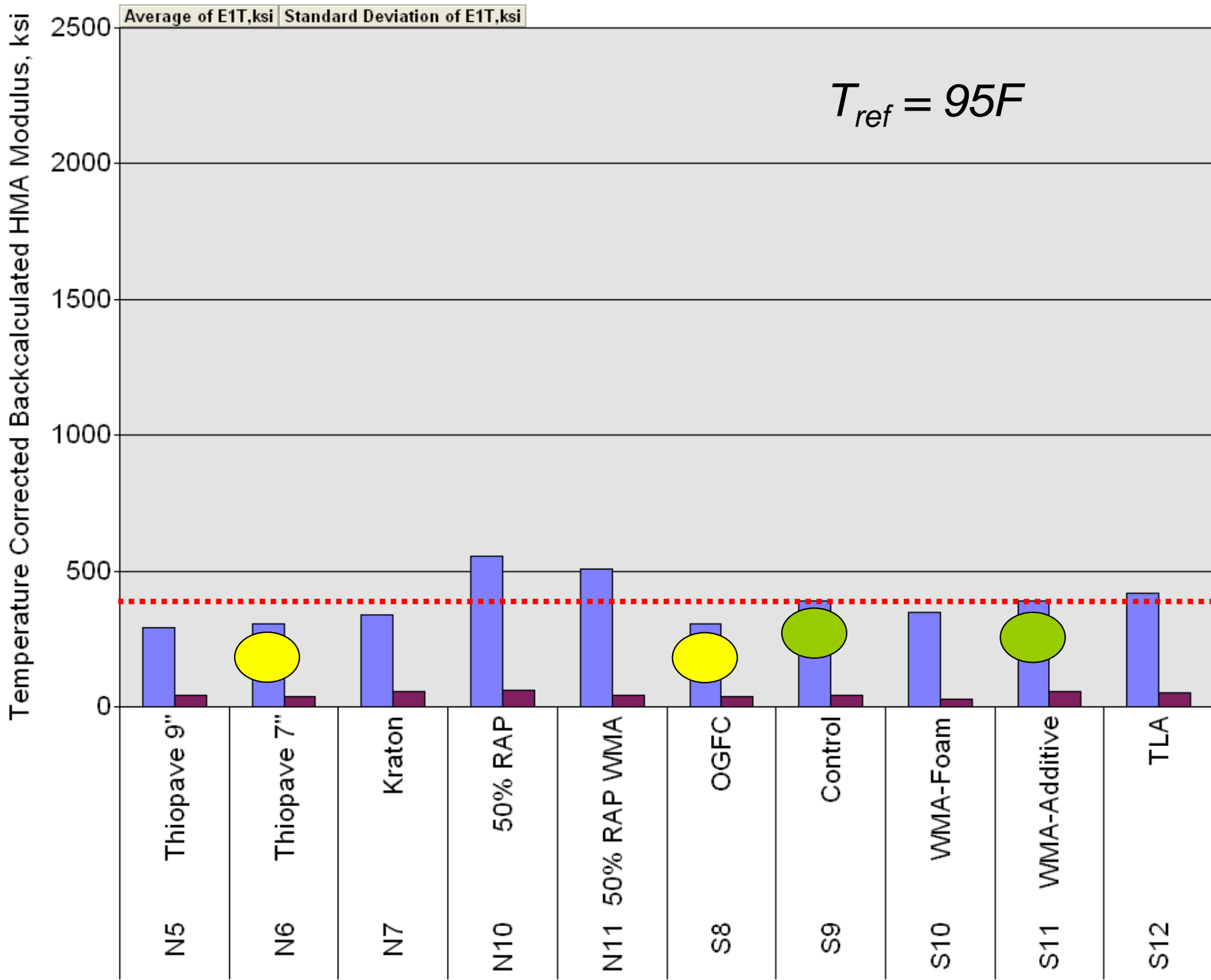
Section	α_1		α_2	R ²
N5	14792.13	Most	-0.04150	0.95
N6	13268.88	Affected	-0.03982	0.95
N7	7347.41		-0.03256	0.87
N10	8276.04	Least	-0.02850	0.93
N11	7051.97	Affected	-0.02773	0.96
S8	6668.40		-0.03256	0.94
S9	7606.82		-0.03134	0.95
S10	7366.91		-0.03213	0.97
S11	6201.97		-0.02921	0.87
S12	11439.96		-0.03488	0.94

Statistical Comparisons

- Examine Three Temperatures
 - 45, 70 and 95F
- Perform Tukey-Kramer Analysis of Variance
 - $\alpha = 0.05$ level of significance



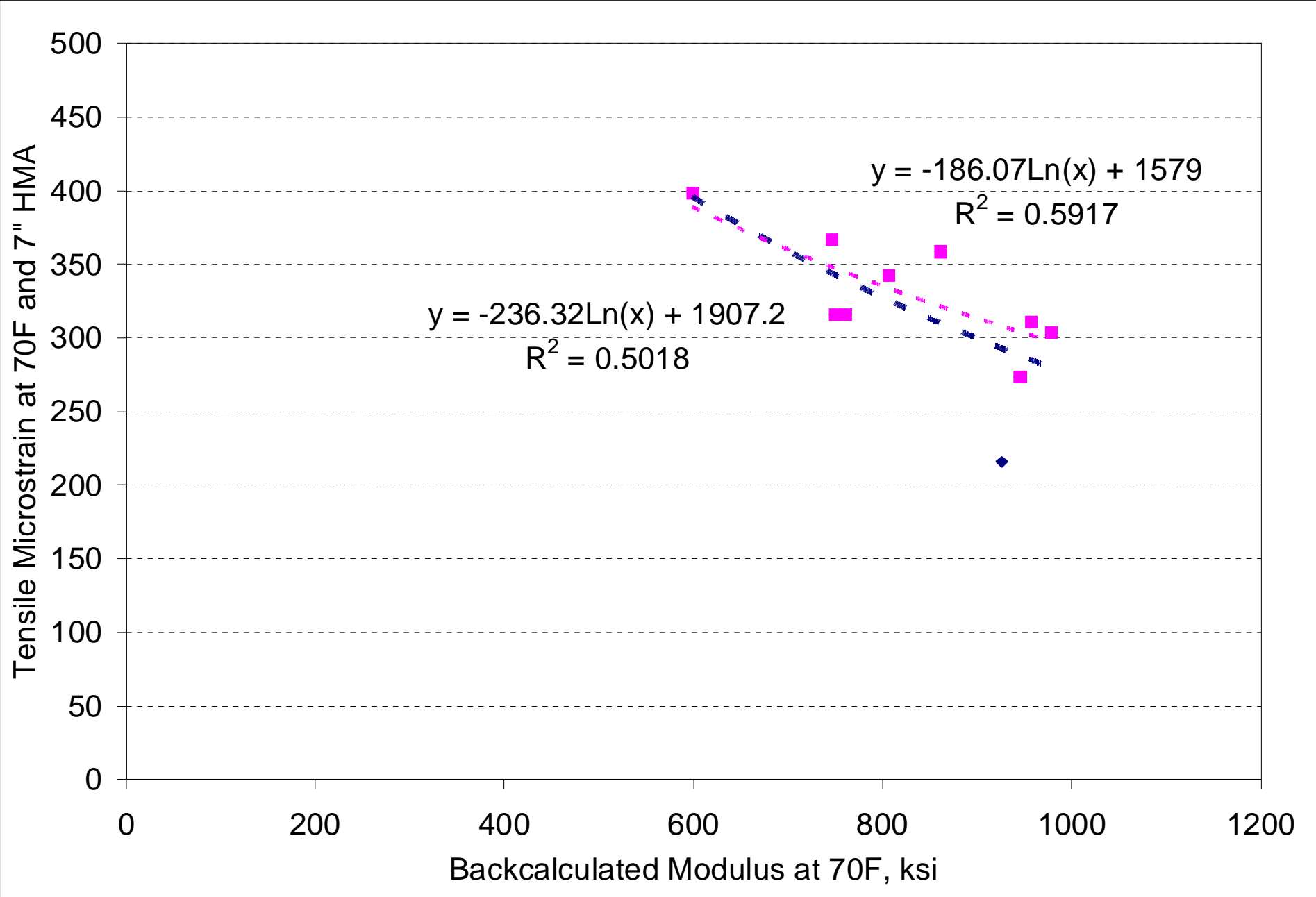




Summary of Key Findings

- All sections exhibit strong correlation between temperature and HMA modulus
- All sections have reasonably low variability (COV from 8-17%)
- Thiopave sections are most sensitive to temperature
 - Depending on temperature, may be stiffer or softer than control
 - As much as +24% and as low as -26%
 - May be aging effect?
- High RAP sections are least sensitive to temperature
 - At moderate to high temps, High RAP consistently stiffest of all materials
 - WMA RAP softer than HMA RAP (-9 to -13%)
- Kraton softer than control (-8 to -13%)
- OGFC softer than control (-17 to -22%)
- WMA – Foam softer than control (-7 to -10%)
- WMA – Additive softer at low and moderate temps (-5 to -10%)
 - Equivalent at warm temps (95F)
- TLA is stiffest of all materials at cold temps (45F)
 - Always stiffer than control (+8 to +28%)

Strain vs. Modulus (Gauge Array Only)



Further Investigations

- Backcalculate all structural sections
- Spatial analysis
 - Wheelpaths
 - Location within section
- Aging analysis
- Effects of damage as it develops
- Relationship to lab-determined moduli



Questions?