

Effectiveness and Guidance of Aggressive Rehabilitation of Gravel Roads

Final Report
November 2025



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**Final Report
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Principal Investigator

Jeramy C. Ashlock, Professor and James M. Hoover Chair in Geotechnical Engineering
Department of Civil, Construction, and Environmental Engineering
Iowa State University

Research Assistant

Godfred Akwaa

Authors

Godfred Akwaa and Jeramy C. Ashlock

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A report from

Institute for Transportation

Iowa State University

2711 South Loop Drive, Suite 4700

Ames, IA 50010-8664

Phone: 515-294-8103 / Fax: 515-294-0467

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EXECUTIVE SUMMARY

This study assessed the long-term performance of four aggressively rehabilitated gravel road test sections whose roadway cross-sectional profiles were rebuilt by recovering material from the ditches to restore the proper widths, elevations, and slopes of the roadways and the proper profiles of the drainage ditches. Two of the rehabilitated test sections were constructed with an enzymatic chemical soil stabilizer, while the other two were not. For each pair of test sections, one was constructed using smooth-tired compaction, while the other was constructed using sheepfoot compaction. A fifth control section was also studied to establish a baseline that was representative of the surrounding roads in the project area.

Among the four aggressively rehabilitated sections, the two treated with enzymatic stabilizer showed improvements in strength and stiffness in the first year, as evaluated by dynamic cone penetrometer tests, lightweight deflectometer tests, and intelligent compaction mapping. By the end of the two-year study, the differences in strength and stiffness between the sections had decreased, but the enzyme-treated rehabilitated sections had California Bearing Ratio (CBR) strength values that remained 2.5 times higher (for smooth-tired compaction) and 4.5 times higher (for sheepfoot compaction) than the CBR values of the corresponding sections without stabilizer. The stabilizer provided a significant strength increase in the surface course that lasted through heavy vehicle loading and at least two winter-spring freeze-thaw seasons. The enzyme-stabilized sections also generally maintained higher subgrade CBR values than the two sections without stabilizer.

Among the four aggressively rehabilitated test sections, sheepfoot compaction generally produced better results for the enzyme-stabilized sections, while smooth-tired compaction produced better results for the untreated sections.

The relative breakage measured using gyratory compaction testing was found to have strong linear correlations to the initial gravel content of the rehabilitated test sections, as well as to their field-measured average CBR values. Laboratory gyratory compaction testing could therefore be used as an efficient method to predict which materials or blends of materials will give the best performance under actual traffic loading.

The particle size distribution (PSD) curves of samples collected from the test section surfaces over time showed that most of the particle breakage occurred in the first several months following construction, after which the rate of breakage greatly decreased. Overall, no consistent difference was found between the breakage values of the enzyme-treated and untreated rehabilitated sections over the full project duration.

According to the visual condition surveys, the enzyme-stabilized sections experienced the least surface deterioration, with only minor evidence of rutting or corrugation. The rehabilitated but unstabilized sections showed the most visible signs of deterioration in the form of rutting and depressions along the wheel paths and migration of material to the shoulders. The control section also exhibited minor rutting and showed noticeable migration of material to the shoulders.

Particle size distributions determined by image analysis using the Iowa Department of Transportation's (Iowa DOT's) Camsizer device (but limited to material coarser than the No. 10 sieve) were found to produce results consistent with traditional sieve analysis.

The intelligent compaction mapping indicated that the four rehabilitated sections experienced an initial decrease in stiffness and modulus after construction in 2023 but then recovered in 2024, with the enzyme-stabilized sections exceeding the stiffness and modulus of the control section by spring 2024. By the end of the project in spring 2025, the stiffness and modulus values for all sections decreased and converged to similar ranges.

Overall, this study demonstrated the effectiveness of aggressively rehabilitating gravel roads that had been lowered, widened, and flattened by decades of heavy traffic. Rebuilding the roadway cross sections improved the drainage capacity of the test sections relative to the much flatter control section. The enzymatic soil stabilizer showed measurable benefits in terms of strength and stiffness. The benefits were greatest in the first year after construction but then decreased somewhat by the end of the second year. With additional field testing and observation, it could be determined whether the latter decrease was a temporary trend or whether the rehabilitation and stabilization will produce continued benefits over time.

Based on the findings of this study, it is recommended that the strong correlation between field-measured CBR values and relative breakage as measured by gyratory compaction tests be studied further to help develop stronger predictive capabilities of field performance. It is also recommended that Camsizer testing with smaller particle sizes be pursued to track changes in PSD curves from which particle breakage can be determined more efficiently than traditional sieve analysis. Additional field testing and sampling at the project site is recommended to quantify the longer-term benefits of both the aggressive rehabilitation and the enzymatic stabilizer. Finally, the benefits of enzymatic stabilization should be studied in other Iowa counties, as the extremely strong and stiff subgrade soils encountered at the Camp Dodge site are not representative of typical Iowa gravel roads.

CHAPTER 1 INTRODUCTION

1.1 Problem Statement

The goal of this project was to study the effectiveness of the aggressive rehabilitation of granular-surfaced (gravel) roads by extensively rebuilding the cross-sectional profiles of roadway test sections and drainage ditches using two different compaction methods and optional chemical stabilization of the surface and subgrade. To ensure widespread usefulness and implementability of the results, the construction was performed using types of equipment that are typically available to county engineers. The project also helped establish a cooperative relationship between Iowa State University, the Iowa Department of Transportation (Iowa DOT), the Iowa County Engineers Association Service Bureau, and the Iowa Army National Guard for mutually beneficial research projects on the long-term performance of granular-surfaced roads.

1.2 Goal and Objectives of the Research

The Camp Dodge Iowa Army National Guard base in Johnston, Iowa, offered a unique opportunity to study the relative effectiveness of the aggressive rehabilitation of granular roads using two different compaction methods and the option of chemical stabilization. The site encompasses over 5 mi of heavily loaded granular-surfaced roads exhibiting various forms of distress, such as frost boils, rutting, washboarding, loss of crown, filling of drainage ditches, excessive widening, and flooding in low-lying areas. The present study quantified the performance of a control section at this site and four rehabilitated test sections whose cross-sections were rebuilt and narrowed using sheepfoot compaction in half of the rebuilt sections and smooth-tired compaction in the others, with chemical stabilization of the near-surface subgrade in half of the rebuilt sections using a liquid enzymatic soil stabilizer.

The project had the following objectives:

- **Objective 1:** Construct test sections by rebuilding and narrowing the flattened and widened roads to their original widths and cross-sectional profiles. Construct sections using two methods of subgrade compaction (smooth-tired roller or sheepfoot roller), with and without a liquid chemical enzymatic stabilizer incorporated into the top 6 in. of a mixture of the subgrade and previous surfacing materials.
- **Objective 2:** Perform laboratory and field tests on the test sections over a period of two years.
- **Objective 3:** Analyze the relative performance of the test sections through two winter-spring freeze-thaw seasons.

1.3 Site Selection

The test sections were constructed at the Camp Dodge military base next to Saylorville Lake in Johnston, Iowa, about 30 mi southwest of Ames. Figure 1 shows the location of the project in relation to the other Iowa counties.

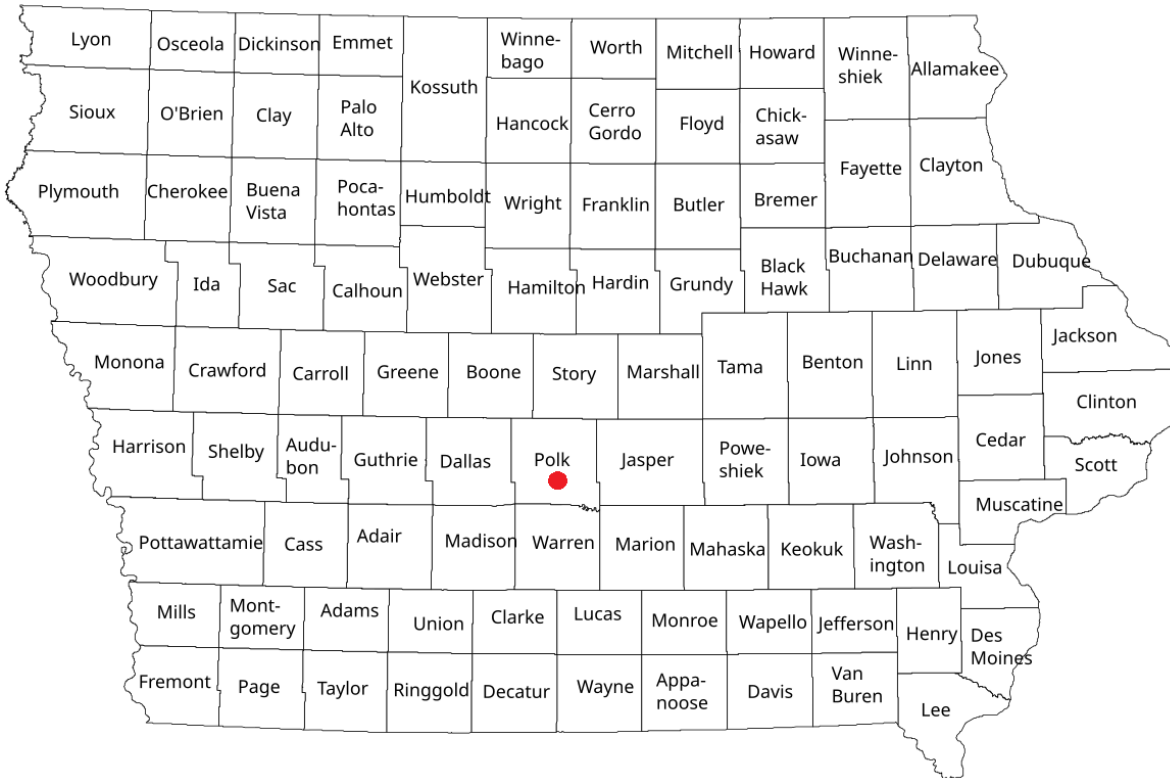


Figure 1. Location of the project

The base encompasses an extensive network of granular-surfaced roads exhibiting various forms of deterioration, as described previously. The Iowa Army National Guard assisted with access, test section construction, and logistical coordination. The road segments selected for test section construction had been significantly widened due to long-term heavy traffic loading, causing reduced drainage capacity that often resulted in standing water on the road surface after precipitation events.

1.4 Significance of the Research

The purpose of this research was to evaluate the effectiveness of aggressive rehabilitation as well as the practical applicability and potential use of enzymatic chemical stabilizers to improve the performance of granular-surfaced roads over two freeze-thaw cycles. By constructing the test sections without specialized equipment, the procedures detailed in this study are likely to be implementable by county engineer offices using equipment that they have on hand or can easily rent.

1.5 Organization of the Report

This report is organized into the following seven chapters and four appendices:

- Chapter 1 (Introduction) outlines the problem statement, research goal and objectives, site selection, and the significance of the research.
- Chapter 2 (Background) provides additional background information related to the performance, maintenance, and rehabilitation of granular-surfaced roads.
- Chapter 3 (Test Methods) describes the laboratory and field tests that were conducted in this project.
- Chapter 4 (Materials) describes the geomaterials and summarizes the laboratory test results for the construction materials, including particle size analysis, index properties, and abrasion performance.
- Chapter 5 (Design and Construction of Test Sections) describes the project site, test sections, and the construction and maintenance procedures.
- Chapter 6 (Results and Discussion) provides the results of the field and laboratory tests performed over the two-year project duration, including key results and comparisons with intelligent compaction mapping data presented in Appendix D.
- Chapter 7 (Conclusions and Recommendations) summarizes the key findings of the project and provides recommendations for future research based on the results.
- Appendix A contains the complete particle size distribution (PSD) results for all samples collected in spring 2024, fall 2024, and spring 2025. Results for other testing periods are presented in Chapter 6.
- Appendix B contains the complete automated dynamic cone penetrometer (ADCP) test results for the post-construction testing periods of fall 2023, spring 2024, fall 2024, and spring 2025.
- Appendix C contains the particle breakage results for fall 2024 and spring 2025 determined from the PSD curves of field samples taken from the surface courses. Results for earlier testing periods are presented in Chapter 6.
- Appendix D contains the complete intelligent compaction mapping report from Ingios Geotechnics.

CHAPTER 2 BACKGROUND

Over the long-term service life of a granular-surfaced roadway, the cumulative effects of traffic loads and maintenance operations can gradually move the road surface and subgrade materials downward and outward, which increases the roadway width, reduces the crown, and fills up the drainage ditches. The reduced crown and shallower ditches decrease the drainage effectiveness of the roadway, leading to further degradation, moisture-related damage, and overall reduced performance and sustainability. These factors increase annual maintenance costs for the roadway due to the materials, equipment, and labor needed for resurfacing and regrading. Roads that experience problems such as these constitute a significant financial and safety burden to local agencies as well as the traveling public.

Major rebuilding or regrading of such granular-surfaced roads by bringing in material from the ditches to reestablish the design roadway width and restore the crown and ditch drainage capacity can improve sustainability and performance by reducing maintenance demands for secondary roads departments. Granular-surfaced roads in Iowa are typically 24 to 28 ft wide but can reach up to 40 ft in some counties. The methods to perform rebuilding of such roads vary across the state due to differences in soil types, available manpower and equipment, and even public opinion. However, it is widely accepted that a proper width and cross-sectional profile are essential to maintain the proper drainage and long-term performance of granular-surfaced roads.

Beyond Iowa, a significant percentage of the nation's transportation infrastructure is comprised of granular-surfaced roads, particularly in low-traffic and rural regions. Specifically, granular-surfaced roads constitute around 54% of the 4.1 million miles of public roads in the United States (Ibrahim et al. 2019). The rate and severity of granular road deterioration is strongly influenced by the volume and type of traffic loads, the engineering properties of the surface course materials, and the strength and drainage properties of the underlying subgrade (Jones and Paige-Green 2015). Because of their unbound wearing surfaces, granular-surfaced roads usually require more frequent maintenance than paved roads. The combined effects of traffic, aggregate deterioration, weathering, erosion, and maintenance operations progressively displace surface and subgrade materials laterally and vertically (FHWA 2015). Even with regular maintenance, such displacements can cause widening of the roadway, loss of crown, and accumulation of sediment in the drainage ditches. These factors compound to reduce the drainage capacity of the surface, further exacerbating the problem of moisture retention and accelerating the structural degradation of the roadway profile. These drainage issues reduce the overall sustainability of such roads.

The most common maintenance operations for granular roads are blading at regular intervals or after the appearance of surface distress, and the spreading of new aggregates when necessary (FHWA 2015). However, this approach can be insufficient for roads with high traffic counts or underlying subgrade problems. Frequent blading can also contribute to a loss of fine particles (Skorseth and Selim 2005), which are needed to help maintain surface stability and durability by binding larger particles together. Gravel road rehabilitation goes beyond regular maintenance and typically involves loosening a large amount of surface and subgrade material to rebuild the road geometry, including the foreslopes, drainage ditches, and crown (FHWA 2015). The aggressive

rehabilitation examined in the present study refers to a complete rebuilding of the roadway cross-section profile by bringing in material from the ditches and increasing the road elevation to restore the proper crown and drainage capacity while also reducing the roadway width to its former value.

Beyond conventional maintenance and rehabilitation techniques, chemical stabilization can improve the performance and longevity of roadway surfaces and subgrades, thereby reducing maintenance frequency (e.g., Tan et al. 2020, Xue et al. 2022). For example, Puppala (2016) observed an 80% increase in unconfined compressive strength accompanied by a 300% increase in California Bearing Ratio (CBR) for a soil sample after stabilization by lime. In a two-year field study, Monlux and Mitchell (2007) determined that a chloride-treated surface with proper maintenance could achieve a service life of up to 10 years. The extended service life was primarily attributed to significant reductions in raveling and surface corrugation. Although many studies have been conducted on various strategies to extend the service lives of granular roads, relatively few have investigated aggressive rehabilitation, let alone the combination of aggressive rehabilitation and chemical stabilization examined in the present study.

CHAPTER 3 TEST METHODS

This chapter describes the methods used in this study to evaluate the performance of the field test sections, including both laboratory and field investigations. Field tests were performed to measure the in situ stiffness and strength of the surface and subgrade layers, while laboratory tests were conducted to determine soil classifications and index properties and to quantify the aggregate breakage and compaction behavior of the surface and subgrade materials.

3.1 Field Tests

To evaluate the relative performance of the rehabilitated and control test sections under field conditions, lightweight deflectometer (LWD) and ADCP tests were conducted over two years of winter-spring freeze-thaw cycles, in fall and spring of both years. A limited number of ADCP tests were also conducted prior to construction. The equipment and procedures as well as the data interpretation for these tests are presented in the following sections.

3.1.1 Lightweight Deflectometer Test

The LWD test provides a rapid assessment of the composite elastic modulus of a roadway's surface and subgrade layers. It involves application of an impulse load to the ground through a loading plate. The resulting plate deflection is recorded by an internal transducer, and surface stiffness is computed. For this project, the Zorn ZFG 3000 LWD device shown in Figure 2 was used, with the specifications summarized in Table 1. The test was performed in accordance with ASTM E2835-11.



Figure 2. Zorn ZFG 3000 LWD device

Table 1. Properties of Zorn ZFG 3000 LWD device

Parameter	Value
Falling Weight	22.05 lb
Drop Height	27.95 in.
Maximum Applied Force	1,589 lb
Total Load Pulse	18±2 ms
Measuring Range	0.0079 to 1.18 in.
Plate Diameter	11.8 in.
Plate Thickness	0.79 in.
Type of Buffer	Steel spring
Buffer Stiffness	24,832 lb/ft
Deflection Transducer	Accelerometer in plate

The Zorn ZFG 3000 LWD features a drop weight of 22.05 lb (10 kg), a drop height of 27.95 in. (710 mm), and a base plate diameter of 11.81 in. (300 mm). The magnitude of the force pulse can be calculated as

$$F = \sqrt{2mghC} \quad (1)$$

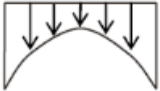
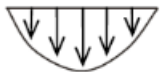
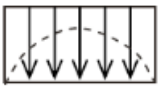
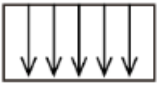
where m is the mass of the falling weight, g is acceleration due to gravity, h is the drop height and C is the buffer stiffness constant.

The composite elastic modulus (E_{LWD}) was calculated based on Boussinesq's solution from elastic theory, using equation 2:

$$E_{LWD} = \frac{(1-\nu^2)\sigma_o a}{d_o} f \quad (2)$$

where σ_o is the applied stress (MPa); a is the radius of the plate (mm); ν is the Poisson's ratio, which was assumed in this study to be 0.4; d_o is the deflection of the loading plate (mm) averaged over three consecutive drops; and f is a shape factor that depends on stress distribution. A summary of shape factors corresponding to different assumed contact stress distributions is provided in Table 2. For this study, a shape factor of 2 was assumed because the depth of influence (approximately one plate diameter, 1 ft) consists of 2 to 4 in. of surfacing aggregates bound by fines, followed by 8 to 10 in. of clayey subgrade.

Table 2. Summary of shape factors for elastic modulus estimation from lightweight deflectometer tests

Plate Type	Soil Type	Stress Distribution (Shape)	Shape Factor (f)
Rigid	Clay (elastic material)	Inverse parabolic 	$\pi/2$
Rigid	Cohesionless sand	Parabolic 	$8/3$
Rigid	Material with intermediate characteristics	Inverse parabolic to uniform 	$\pi/2$ to 2
Flexible	Clay (elastic material)	Uniform 	2
Flexible	Cohesionless sand	Parabolic 	$8/3$

Source: Fang 1991, after Terzaghi and Peck 1967

3.1.2 Automated Dynamic Cone Penetrometer Test

To evaluate the in situ shear strength profiles of the aggregate and soil layers, ADCP tests were conducted in accordance with ASTM D6951/D6951M-18. The dynamic cone penetrometer (DCP) test involves applying a dynamic load with a drop hammer weighing 17.6 lb (8 kg) from a height of 22.6 in. (574 mm) to drive a conical tip into the soil. The resulting penetration depth and number of blows are recorded, from which the CBR value is calculated using correlations developed by the U.S. Army Corps of Engineers and provided in ASTM D6951/D6951M-18. The Sapper Automatic DCP device from Kessler Soils Engineering was used, as shown in Figure 3.



Figure 3. KSE Sapper Automatic DCP device

ASTM D6951/D6951M-18 provides the following correlations for estimating the CBR values of different soil types defined by the Unified Soil Classification System (USCS):

For all soils except CH soils and CL soils with $CBR < 10$:

$$DCP-CBR = 292 / (DCPI \times 25.4)^{1.12} \quad (3)$$

For CL soils with $CBR < 10$:

$$DCP-CBR = 1 / (0.432283 \times DCPI)^2 \quad (4)$$

For CH soils:

$$DCP-CBR = 1 / (0.072923 \times DCPI) \quad (5)$$

In the above equations, DCPI is the dynamic cone penetrometer index in units of inches per blow, which was obtained by dividing the increase in penetration depth between two readings by the corresponding number of blows.

To analyze the ADCP data, each test section was evaluated as a two-layer system consisting of the surface course and the subgrade. The interface between the two layers was identified graphically as the point of the minimum radius of curvature in the plot of cumulative blows versus depth, as shown in Figure 4. In cases for which this plot does not show a clear transition point, the interface was instead identified as the point of initial drastic change in the value of the CBR versus depth plot. For many tests in this study, the latter was found to be a better indicator

of interface depth. To compare results between different tests, a common subgrade layer thickness of 40 in. below the interface layer was used.

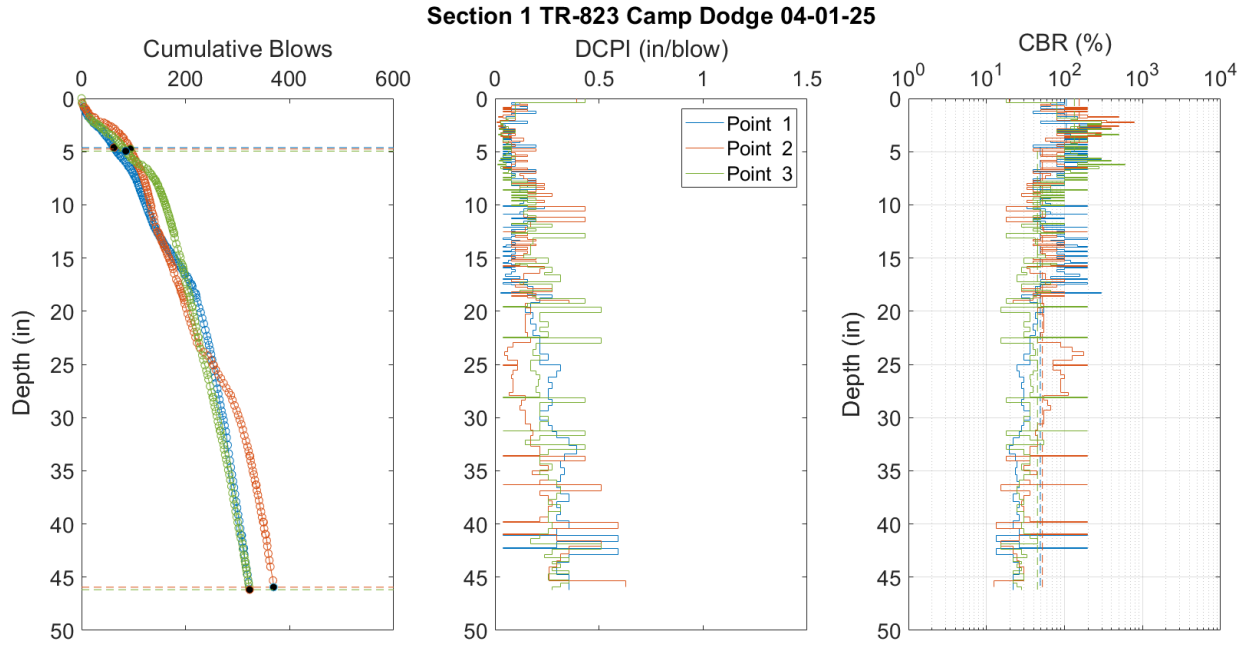


Figure 4. Example of DCP depth profiles: (a) cumulative blows, (b) DCPI, (c) DCP-CBR

For each test, the weighted average DCP-CBR values for the surface and subgrade layers were then calculated using equation (5):

$$DCP-CBR_{AVG} = \frac{(CBR_i \times H_i) + (CBR_{i+1} \times H_{i+1}) \dots (CBR_n \times H_n)}{\sum_i^n H_i} \quad (6)$$

where H_i is the depth increment for the i^{th} CBR value and n is the number of depth increments within the layer. The resulting weighted average DCP-CBR value for the surface aggregate layer is denoted as $DCP-CBR_{AGG}$, and the weighted average value for the subgrade layer is denoted as $DCP-CBR_{SG}$.

3.1.3 Intelligent Compaction Mapping

To assess the relative uniformity and stiffness of the different test sections, intelligent compaction mapping was performed by Ingios Geotechnics using a CS56B vibratory smooth drum roller equipped with the company's COMP-Score RT system. The system featured pre-calibrated models to measure composite resilient modulus (M_r) in units of pounds per square inch (psi) and modulus of subgrade reaction (k) values in units of psi/in. The valid range of calibrated parameters for the COMP-Score RT models used in the intelligent compaction mapping of gravel roads was 2,000 to 20,000 psi for M_r and 60 to 550 psi/in. for k .

Mapping was performed using two roller passes with 100% coverage over each test section prior to construction and again in each fall and spring close to the dates of the other field tests. In each test, the first pass was performed to reduce surface roughness, and the second pass was used for intelligent compaction mapping measurements. The resulting data quantified the structural support capacity in terms of color-coded maps of the M_r and k values. For each round of tests, e-Compaction reports were provided that included maps and tables summarizing the following data:

- Quality analysis metrics for the resilient modulus and k values indicating the percentage of area passing a selected target value, along with several key statistical measures.
- Spatial data including the total mapped area in square feet for each section as well as minimum, maximum, and average elevations.
- The minimum, maximum, and average velocity of the intelligent compaction roller during mapping.
- Maps of the M_r and k values over each test section.
- Maps showing delta engineering parameter values (measured minus target values) for M_r and k . The target values for these engineering parameters were selected as 3,600 psi for M_r and 100 psi/in. for k .
- Additional maps showing i-Score values (not relevant for this study), blob analysis showing areas larger than 500 ft² having poor support for which measured values are less than the target (none existed for this study), pass counts (equal to 1 for this study), elevation above mean sea level, and materials (not relevant for this study).
- A photo of the test section at the time of mapping.
- Box and whisker plots and summary statistics for the M_r and k values.

3.1.4 Visual Condition Surveys

As part of the field investigations, visual condition surveys were conducted and digital photographs were taken to document the surface condition of each test section. Photographs of the visual surveys can be found in Section 6.2.4.

3.2 Laboratory Tests

To evaluate the engineering properties of the surface course and subgrade materials of the various test sections, a series of laboratory tests were conducted. These tests included particle size distribution (sieve analysis), Atterberg limits tests, and gyratory compaction tests. The results provided critical insight into the gradation, plasticity, and degradation of the materials under traffic loads.

3.2.1 Soil Index Property Tests

Soil index tests were carried out to help identify and classify the surface course and subgrade materials from the test sections. The tests included sieve analysis, hydrometer tests, and Atterberg limits tests. Based on the results, soil samples were classified using the USCS.

3.2.1.1 Particle Size Analysis

Particle size analysis was conducted in accordance with ASTM D422, using sieve analysis for particles retained on the No. 200 sieve and a hydrometer test for finer fractions. Sieve sizes ranged from 3 in. (75 mm) to No. 200 (75 μ m). Hydrometer tests were performed on air-dried samples that passed the No. 10 (2 mm) sieve. A riffle splitter was used to prepare representative test specimens from the geomaterial samples collected in the field. The sieve and hydrometer test setups used for the analysis are shown in Figure 5 and Figure 6, respectively.

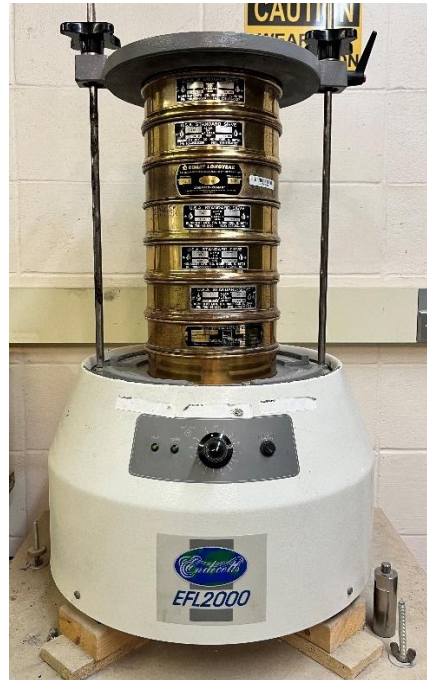


Figure 5. Shaker for sieve analysis



Figure 6. Hydrometer test equipment

3.2.1.2 Atterberg Limits Tests

Atterberg limits (liquid limit, plastic limit, and plasticity index) were determined per ASTM D4318 on both surface aggregate and subgrade materials. Samples that passed the No. 40 (425 μm) sieve were used for the tests. The plastic limit was measured using a plastic limit rolling device as per ASTM standard, and the liquid limit was assessed by the fall cone method. The plastic limit rolling and fall cone devices are shown in Figure 7.



Figure 7. Fall cone test device and plastic limit rolling device

3.2.1.3 Soil Classification

The results from the particle size analysis combined with the Atterberg limits were used to classify the materials in accordance with ASTM D2487-10. The soil classification was performed using the USCS with GEOSYS software.

3.2.2 Gyratory Compaction Tests

Granular surface materials used in unpaved roads are constantly exposed to traffic loads, which apply both vertical and shear stresses. Over time, these stresses cause the particles to shift, break down, and compact. While traditional tests like the Los Angeles (LA) abrasion and Micro-Deval tests are useful for measuring how well aggregates resist wear, they do not fully represent the effects of real traffic loads, especially the combined vertical and shearing forces that occur under

moving tires. To better simulate these field conditions, this study used the gyratory compaction test.

3.2.2.1 Gyratory Compaction

The gyratory compaction test was originally developed to evaluate the compaction behavior of asphalt mixes and has recently been successfully adapted for granular materials (Li et al. 2017). The device enables measurement of key properties such as dry unit weight, shear resistance, void ratio, and compaction energy across a controlled number of gyrations of a constant vertical load. This is especially important for coarse and well-graded aggregates used in unpaved roads, where particle shape and packing influence how well the material performs under traffic loading (Bozorgzad 2017, Ghasemi et al. 2016, Ghasemi et al. 2018). The test was generally performed in accordance with ASTM D6925, which is the standard procedure for preparing and measuring the density of hot-mix asphalt specimens using a gyratory compactor. Although this standard is designed for asphalt, it was adapted here to test unbound granular aggregate. The aggregate test samples were prepared using a riffle splitter and then separated into two test specimens of approximately 4,500 g each. The tests were performed using a Brovold Gyratory Compactor from Pine Instrument Co. and a Troxler pressure distribution analyzer (PDA), as shown in Figure 8.



Figure 8. Gyrator compactor (left) and pressure distribution analyzer (right)

During the tests, the gyratory compactor was set to a vertical pressure of 600 kPa (the same value used for Superpave specifications) and an angle of gyration of 1.25° and was operated at 30 revolutions per minute (rpm). These parameters simulate the kneading effect of traffic on road surfaces, as the gyratory head on top rotates while applying a constant vertical pressure to the specimen. The specimen height was recorded to the nearest 0.1 mm after each gyration by the

system's internal displacement transducer. The PDA was placed on top of the specimen to record the applied load and its angle of gyration during compaction. Each specimen was compacted with a total of 500 gyrations, with continuous recording of the specimen height and PDA data enabling calculation of the dry unit weight, shear resistance, void ratio, and compaction energy throughout the test. Since the device has a limitation of applying a maximum of 299 gyrations at a time, the test was completed in two series of 250 gyrations each, with two dwell gyrations performed before each series to square the specimen. Table 3 summarizes the operational parameters used for the gyratory compaction tests.

Table 3. Operational parameters of gyratory compaction device

Parameter	Value
Vertical pressure	$600 \pm 10\text{kPa}$
Gyration angle	$1.25 \pm 0.02^\circ$
Number of gyrations	500
Gyration rate	$30 \pm 0.5\text{rpm}$
Number of dwell gyrations	2

The PDA data were used to determine the shear resistance of each specimen during compaction. The device consists of three load cells, which are used to determine the resultant vertical load (R) and eccentricity (e_R) of the load relative to the center during the test. The resultant vertical load is the summation of the forces recorded by the three load cells (P_1 , P_2 , and P_3) at any sampling time. The eccentricity of the load was calculated using moment equilibrium equations along two perpendicular axes. In this study, the distance between each pair of load cells was 100 mm. With reference to the variables defined in Figure 9, the following equations were used to determine the eccentricities and shear resistance:

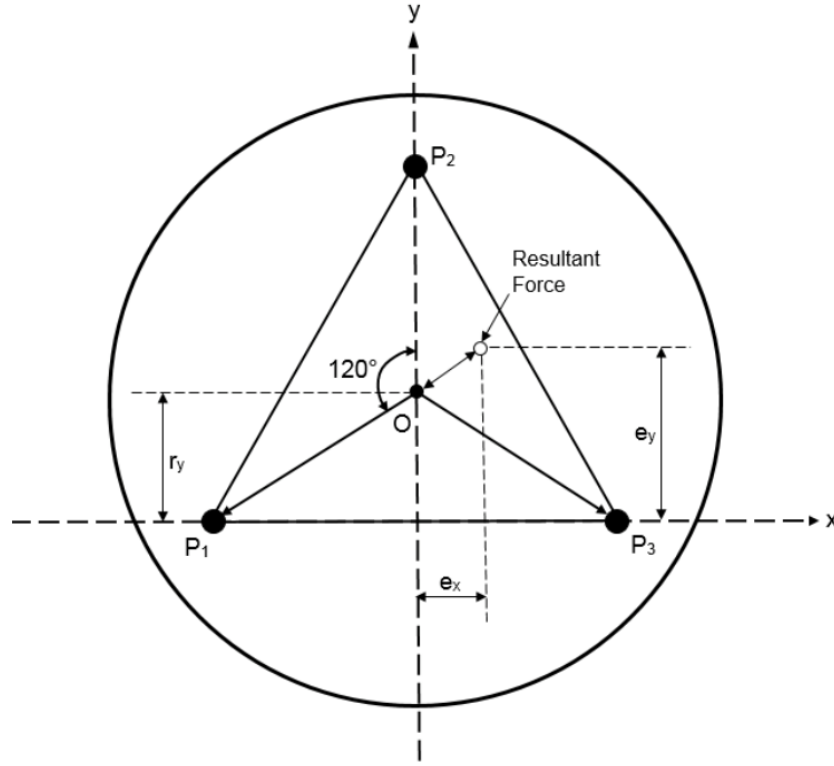
$$\sum M_y = 0 \rightarrow e_x(R) = P_3 \left(\frac{100\text{mm}}{2} \right) - P_1 \left(\frac{100\text{mm}}{2} \right) \quad (7)$$

$$\sum M_x = 0 \rightarrow e_y(R) = P_2(100 \cdot \cos 30^\circ) \quad (8)$$

$$e_R = \sqrt{e_x^2 + (r_y - e_y)^2} \quad (9)$$

$$\tau_G = \frac{R_i e_i}{A H_i} \quad (10)$$

where e_x and e_y are the eccentricities of the resultant force in the x and y directions, e_R is the eccentricity of the resultant load, e_r is the eccentricity of the center point from the x axis, τ_G is the bulk frictional shear resistance of the specimen, A is the cross-sectional area of the compaction mold, R_i is the resultant vertical load for each gyration, e_i is the eccentricity of the resultant load for each gyration, and H_i is the sample height at each gyration.



Guler et al. 2000

Figure 9. Definition of variables used to calculate angle of gyration for PDA device

The PDA data were also used to determine the amount of compaction energy applied to the specimen. The total compaction energy is calculated as the work done per unit volume due to the resultant force moving a distance equal to the specimen's change in height, plus the work per unit volume due to the moment caused by the eccentricity of the resultant load. It can be calculated as follows (Li 2013):

$$\text{Energy}_{\text{gyratory}} = \frac{\sigma_{\text{vertical}} A(H_0 - H_N) + 4\theta \sum_{i=0}^n (\tau_{G_i} V_i)}{V_i} \quad (11)$$

where σ_{vertical} is the vertical pressure applied, H_0 is the initial specimen height (m), H_N is the height after compaction (m), θ is the gyration angle (radians), V_i is the specimen volume after each gyration (m^3), and τ_{G_i} is the corresponding shear resistance of the specimen after each gyration (kPa).

3.2.2.2 Image Analysis

Image analysis was conducted on the coarse fraction of the gyratory compaction samples (material retained on the No. 10 sieve, washed and oven dried) both before and after compaction using the Iowa DOT's Camsizer P4 device (Figure 10). This device uses advanced image processing technology to measure particle size and shape for particles ranging from 0.02 mm to

30.0 mm in diameter (Dawson 2021). This procedure was performed in accordance with AASHTO T 381-181.



Figure 10. Iowa DOT Camsizer device

CHAPTER 4 MATERIALS

As introduced in Chapter 1, a total of four aggressively rehabilitated test sections were constructed, and a fifth control section was designated. This chapter presents the results of sieve analysis, Atterberg limits, and gyratory abrasion tests performed on the geomaterials collected from the test sections before and during construction in August 2023.

4.1 Geomaterial Samples from Test Sections During Construction

Subgrade samples were collected at the start of construction, and samples of the final aggregate surfaces were obtained during final blading at the end of construction. Within each test section, the samples were collected from three different points and mixed to obtain representative specimens. For the rehabilitated Sections 1 through 4, the surface was constructed using Class A roadstone from the Schildberg Construction Monarch Quarry (Source Code A61036 in Iowa DOT Materials IM T203). The roadstone was stockpiled in a gravel parking lot ahead of time, then loaded into dump trucks at the time of construction using a front end loader. The collected samples were analyzed to determine their particle size distributions, index properties (including Atterberg limits), and soil classifications. Photos of smaller representative subsamples of the surface aggregate and subgrade materials from each test section are shown in Figure 11 and Figure 12, respectively.

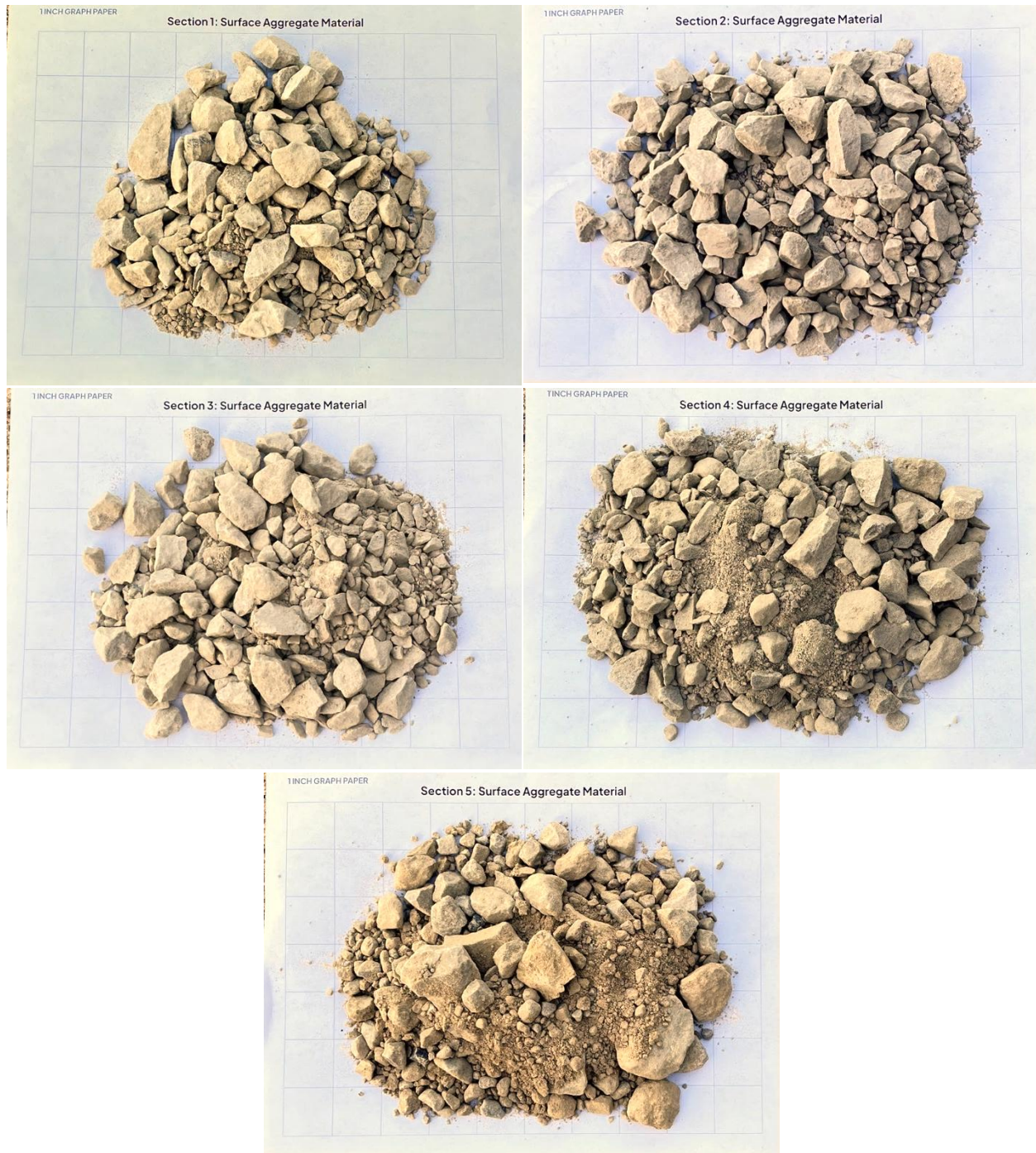


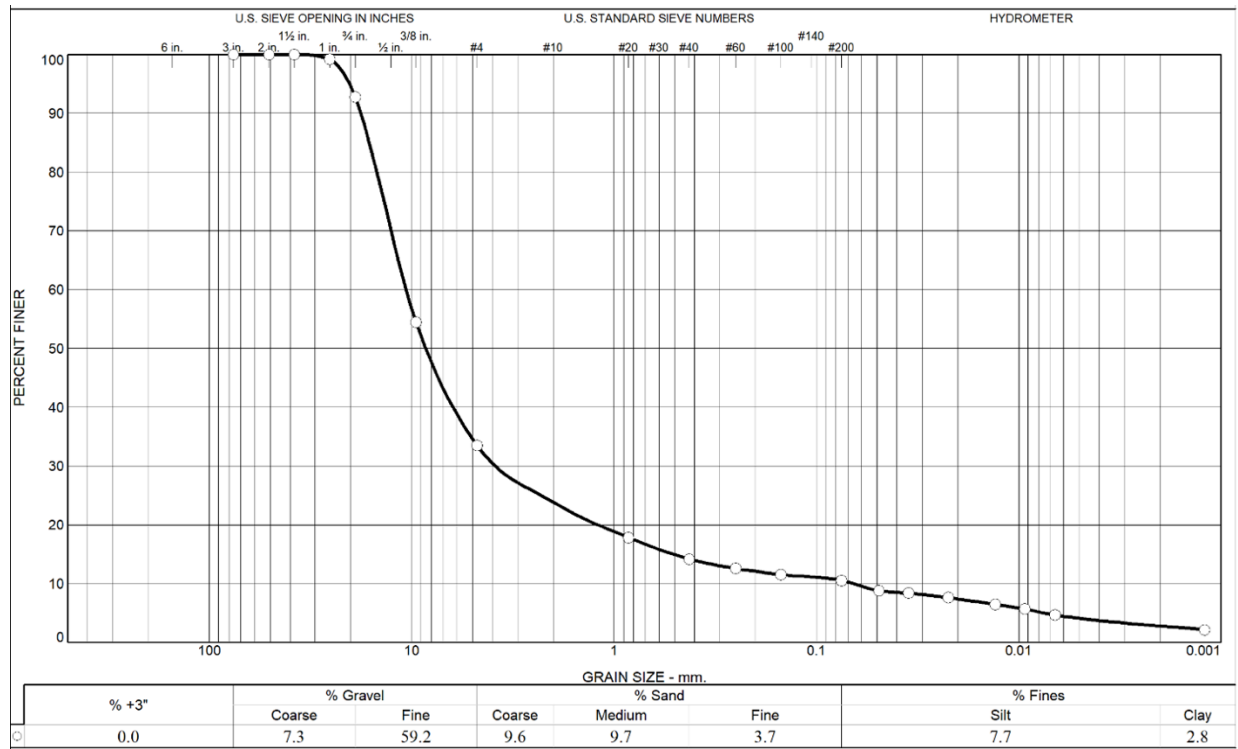
Figure 11. Surface aggregate samples collected from each test section during construction



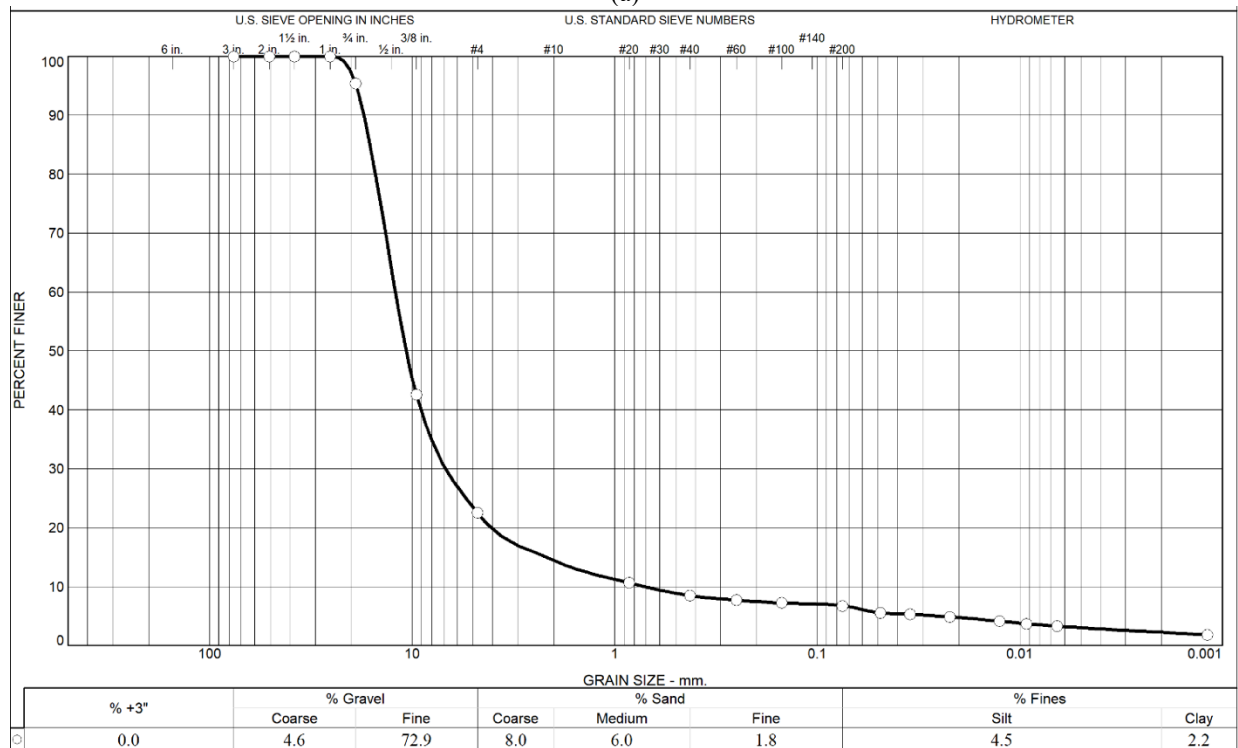
Figure 12. Subgrade samples collected from each test section during construction

4.2 Gradation

The PSD curves of the surface aggregate materials collected during construction in August 2023 are shown in Figure 13 through Figure 15. A summary of the classification results is provided in Table 4.

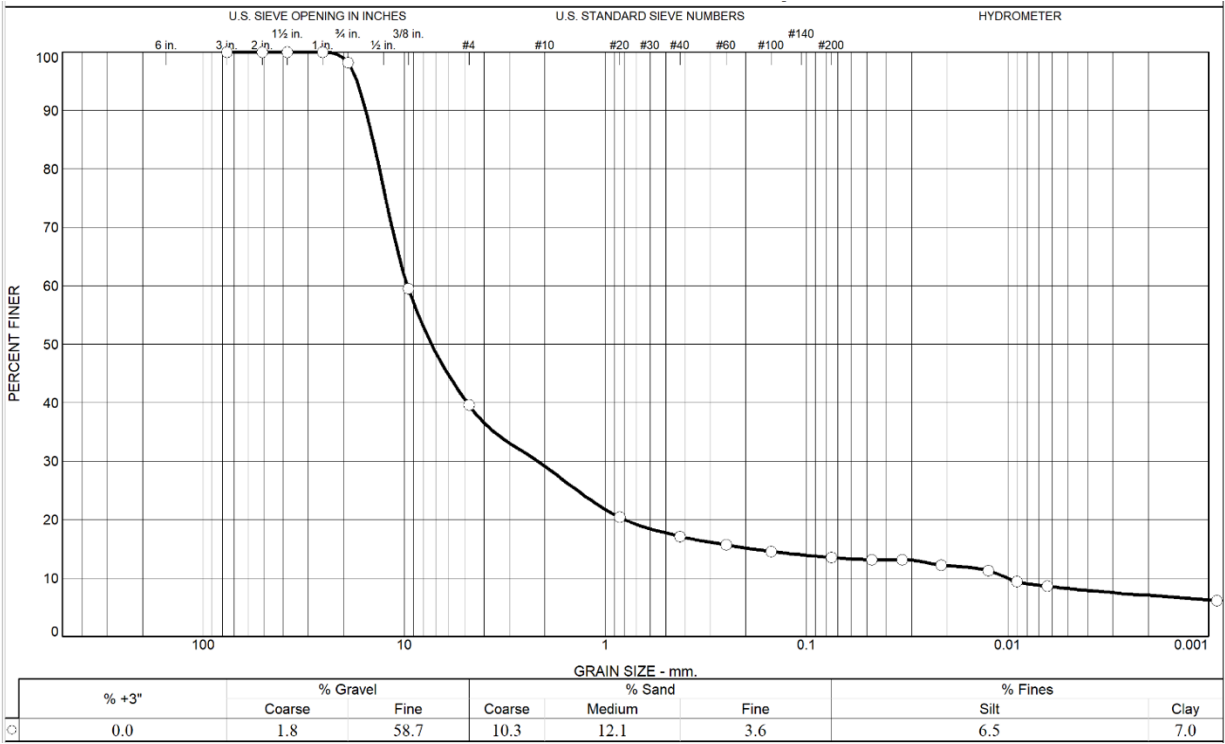


(a)

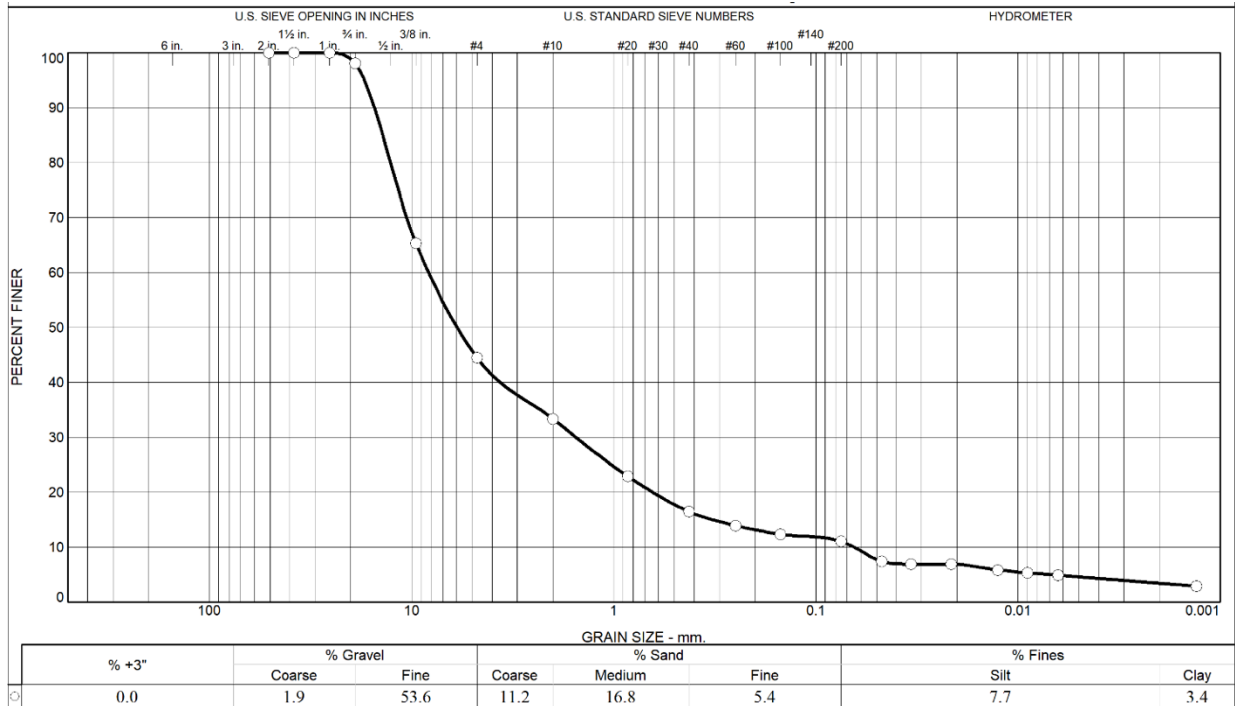


(b)

Figure 13. PSD curves of surface aggregate material collected during construction in August 2023 from (a) Section 1 and (b) Section 2



(a)



(b)

Figure 14. PSD curves of surface aggregate material collected during construction in August 2023 from (a) Section 3 and (b) Section 4

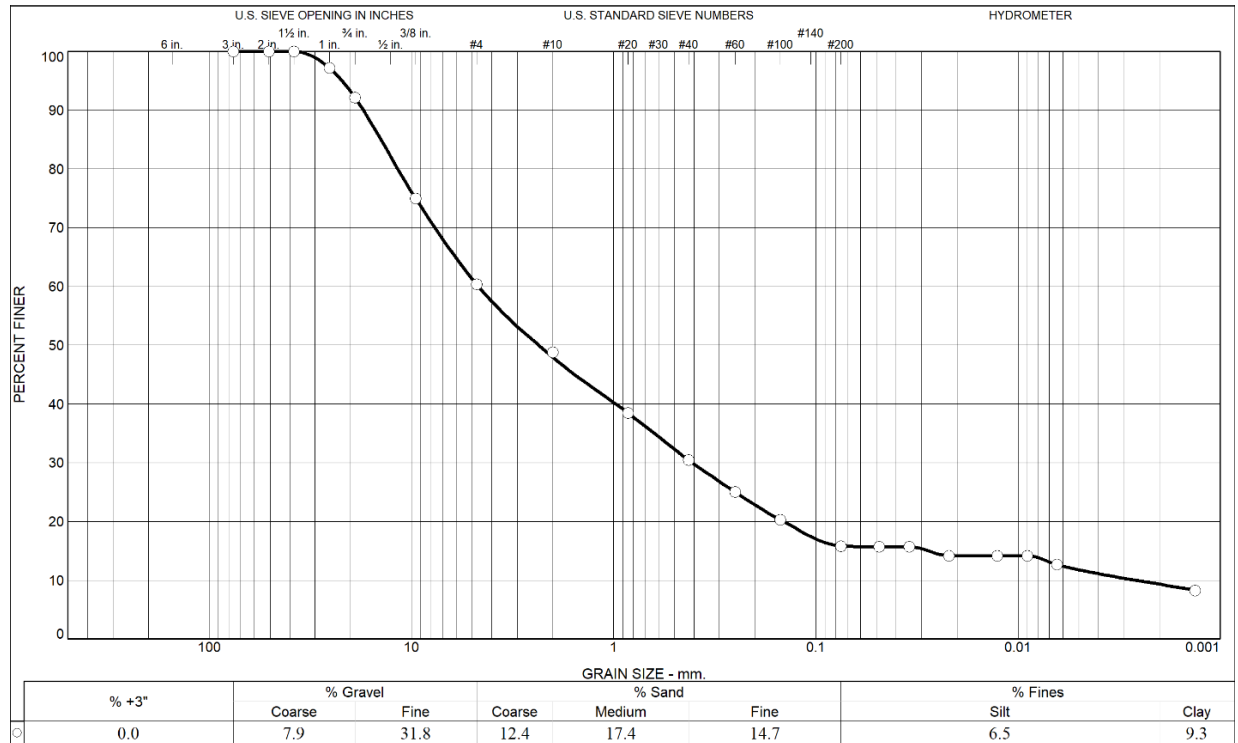


Figure 15. PSD curves of surface aggregate material collected during construction in August 2023 from Section 5

Table 4. Index properties of surface aggregate materials from test sections

Parameter	Section 1	Section 2	Section 3	Section 4	Section 5
Particle-size analysis (ASTM D422-03)					
Gravel content (%) (>4.75 mm)	66.5	77.5	60.5	55.5	39.7
Sand content (%) (4.75 mm-75 μm)	23.0	15.8	26.0	33.4	44.5
Silt content (%) (75 μm-2 μm)	7.7	4.5	6.5	7.7	6.5
Clay content (%) (<2 μm)	2.8	2.2	7.0	3.4	9.3
D ₁₀ (mm)	0.0653	0.7134	0.0100	0.0646	0.0026
D ₃₀ (mm)	3.8717	6.8276	2.1663	1.5383	0.4075
D ₆₀ (mm)	10.6714	12.1015	9.6364	8.2328	4.6643
Coefficient of uniformity, C _u	163.3	17.0	962.7	127.4	1,784.5
Coefficient of curvature, C _c	21.5	5.4	48.7	4.5	13.6
Atterberg limits (ASTM D4318-10e1)					
Liquid limit (%)	22	24	25	23	NP*
Plastic limit (%)	17	17	19	14	NP*
Plasticity index (%)	5	7	6	9	NP*
AASHTO and USCS soil classifications (AASHTO M 145-91 and ASTM D2487-11)					
AASHTO Classification	A-1-a(0)	A-2-4(0)	A-1-a(0)	A-2-4(0)	A-1-b(0)
USCS group symbol	GC-GM	GC-GM	GC-GM	GP-GC	SM
USCS group name	Silty clayey gravel with sand	Silty clayey gravel with sand	Silty clayey gravel with sand	Poorly graded gravel with clay and sand	Silty sand with gravel

*NP = Non-plastic

4.2.1 Surface Course Properties

According to the results shown in Table 4, the initial gravel content after construction was notably high across all of the rehabilitated Sections 1 through 4, ranging from 55.5% to 77.5%, indicating that the surface aggregates were predominantly coarse grained. Section 2 contained the highest gravel fraction (77.5%), followed closely by Section 1 (66.5%). Among the rehabilitated surfaces, Section 4 had the lowest gravel content at 55.5%, while Section 3 showed a moderate value of 60.5%. The high gravel content across these sections is consistent with the intended design of using durable, load-bearing aggregate materials for surface construction. Ideally, all of Sections 1 through 4 should have had similar gradations, since the same Class A roadstone was used to construct them. The observed differences could be due to the inherent variability of the material, segregation in the stockpile, variations in construction, or sampling error. In contrast, the surface of the untouched control Section 5 had already been in place and subjected to weathering and traffic loading for some time, so it had a lower gravel content of 39.7% and was classified as a silty sand with gravel.

The sand fraction in Sections 1 through 4 ranged from 15.8% (Section 2) to 33.4% (Section 4) and was highest in the control section at 44.5%. The silt content was relatively low and uniform, ranging from 4.5% to 7.7%, and the clay content ranged from 2.2% to 9.3%, with the highest value occurring in the control section. These low fines (silt+clay) contents, ranging from 6.7% (Section 2) to 15.8% (control Section 5) are desirable for surface aggregate, as they provide some binding of the larger particles while helping to reduce moisture retention, limit dust generation, and minimize plastic behavior under loading.

The Atterberg limits results confirmed the low plasticity of the surface materials, which is ideal for aggregate surfacing. The liquid limit values were non-plastic (NP) for the control section and ranged from 23% to 25% for Sections 1 through 4, for which the plasticity index (PI) values were uniformly low, ranging from 5% to 9%. These results suggest that the surface materials are predominantly non-cohesive and are unlikely to exhibit significant plastic deformation under traffic loads or changes in moisture. Based on the USCS (ASTM D2487-11), the surface aggregates from Sections 1, 2 and 3 were categorized as silty clayey gravel with sand (GC-GM), while Section 4 was poorly graded gravel with clay and sand (GP-GC) due to its slightly higher PI. Section 5, which had a moderate amount of non-plastic fines, was classified as silty sand with gravel (SM), as it consisted of crushed limestone surfacing aggregates that had been broken down into the range of sand and fines by vehicle loads.

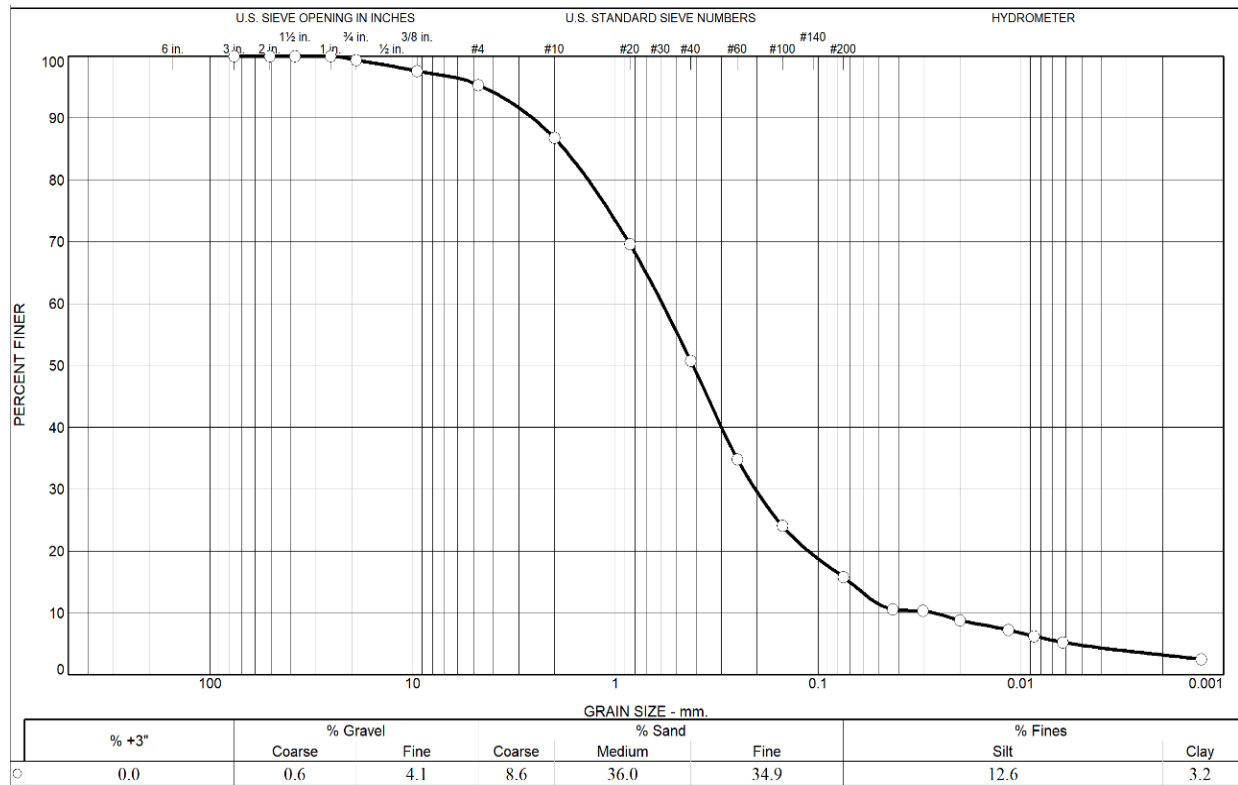
4.2.2 Subgrade Properties

The PSD curves of the subgrade materials are shown in Figure 16 through Figure 18, with a summary of the classification results presented in Table 5. The gravel content of the subgrade material ranged from 2.4% to 13.3% across the rehabilitated test Sections 1 through 4, indicating moderate variation in the coarse fraction. Section 5, the control section, contained the highest gravel content of 25.5%, consistent with the significant amount of large, buried debris in the subgrade, while the chemically stabilized Sections 1 and 2 had significantly lower gravel

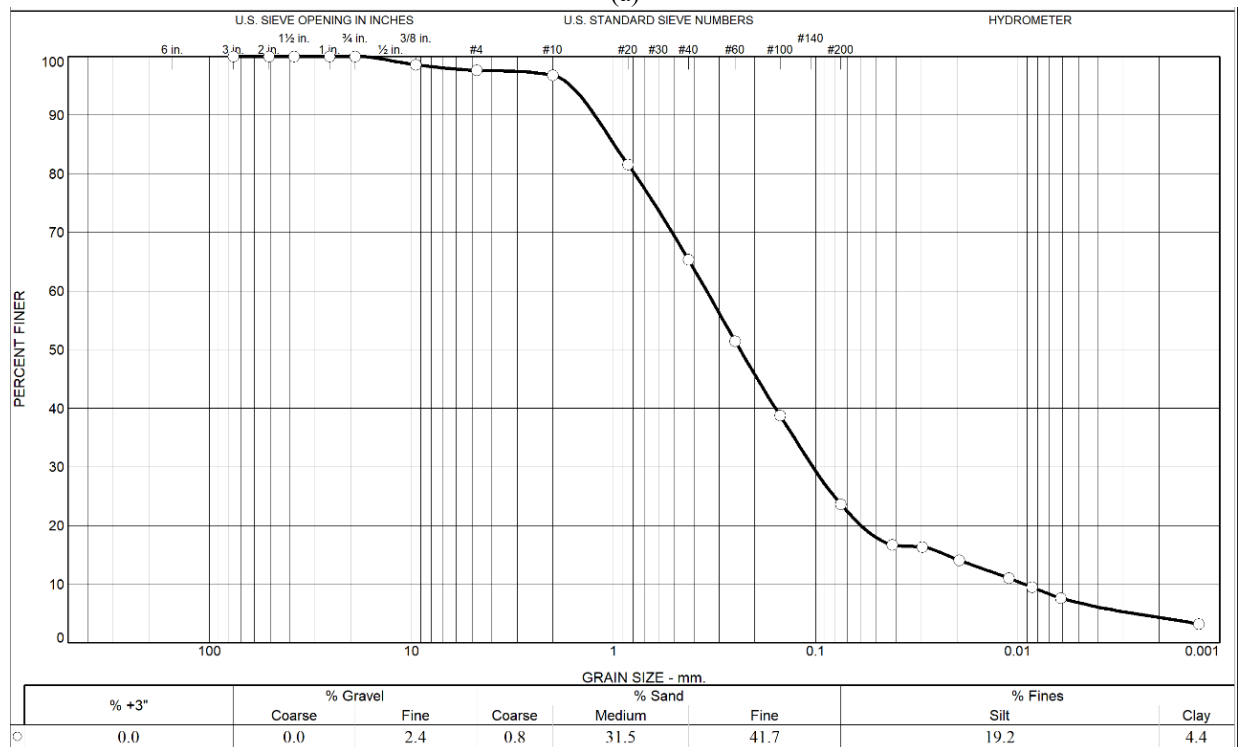
contents of 4.7% and 2.4%, respectively. Sections 3 and 4, without chemical stabilization, had moderate gravel contents of 13.3% and 7.4%, respectively.

The sand fraction was the predominant subgrade component across all sections, ranging from 61.0% to 81.9%, indicating that the subgrade material across all sections is primarily sand with some fines and gravel. The clay content was relatively low across all sections, ranging from 0.8% to 4.4%, suggesting low plasticity behavior, which was later confirmed by Atterberg limit results.

The liquid limits for Sections 1 to 4 were relatively consistent at around 30%. Section 5 showed the highest value at 39%. The PI showed more variation; Sections 4 and 5 had the highest PI values of 18% and 19%, indicating a greater amount of plastic fines toward the north end of the test sections. Section 1 also had a relatively high PI of 16%, while the PI values for Sections 2 and 3 were lower, at 10% and 9%, respectively. Based on the USCS, the subgrade materials in Sections 1, 2, and 4, were all classified as clayey sand (SC), while Section 3 was classified as poorly graded sand (SP) due to its lower fines content and lower coefficient of uniformity. The control Section 5 was classified as clayey sand with gravel (SC) due to its much higher gravel content.

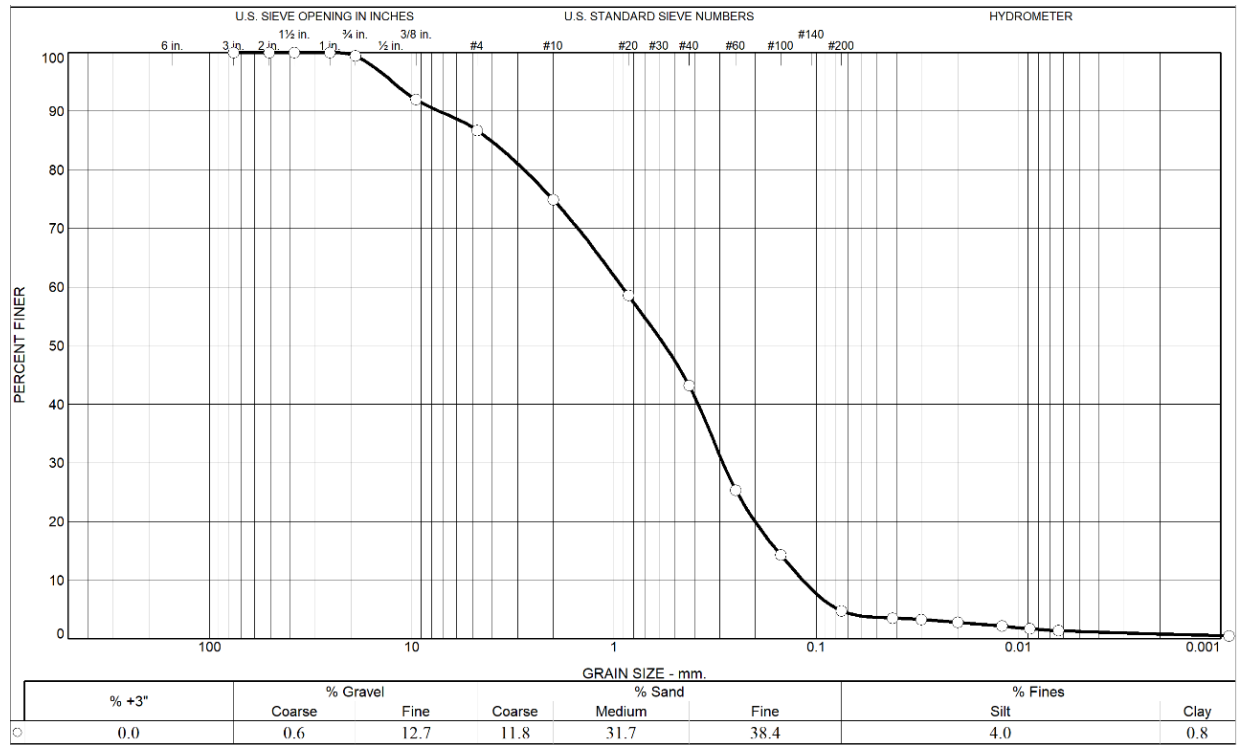


(a)

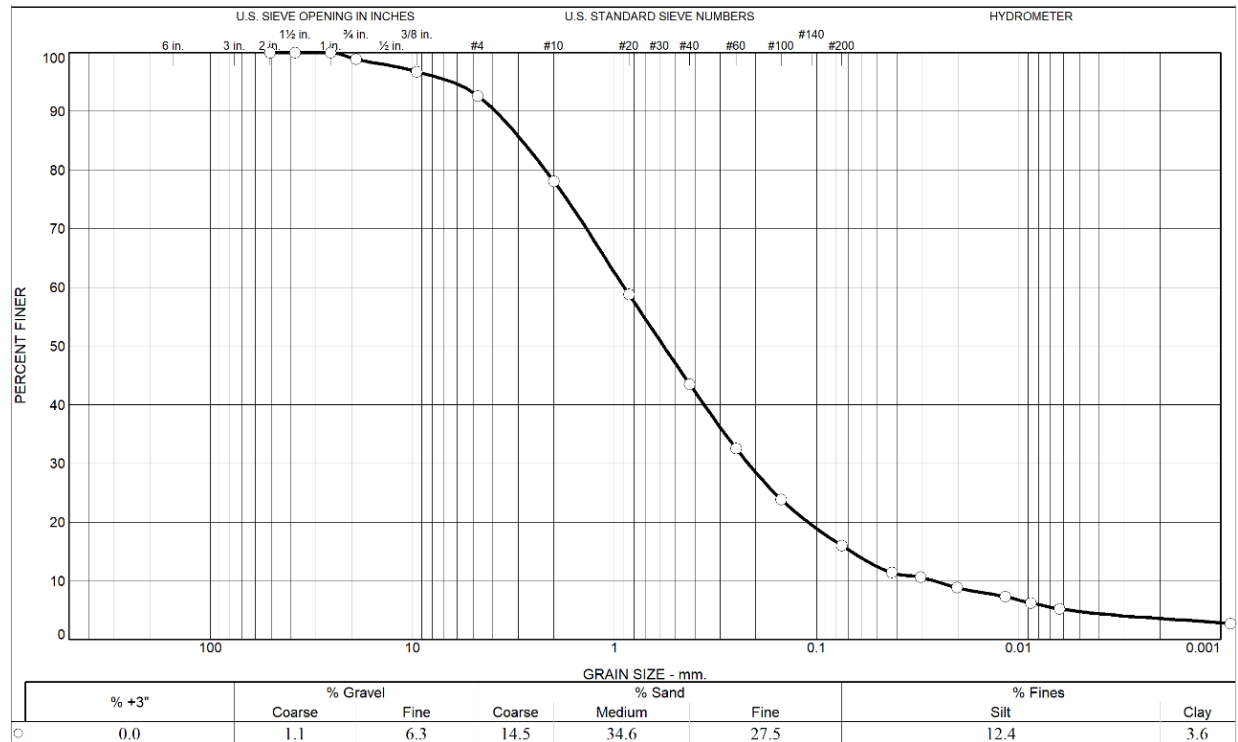


(b)

Figure 16. PSD curves of subgrade material collected during construction in August 2023 from (a) Section 1 and (b) Section 2



(a)



(b)

Figure 17. PSD curves of subgrade material collected during construction in August 2023 from (a) Section 3 and (b) Section 4

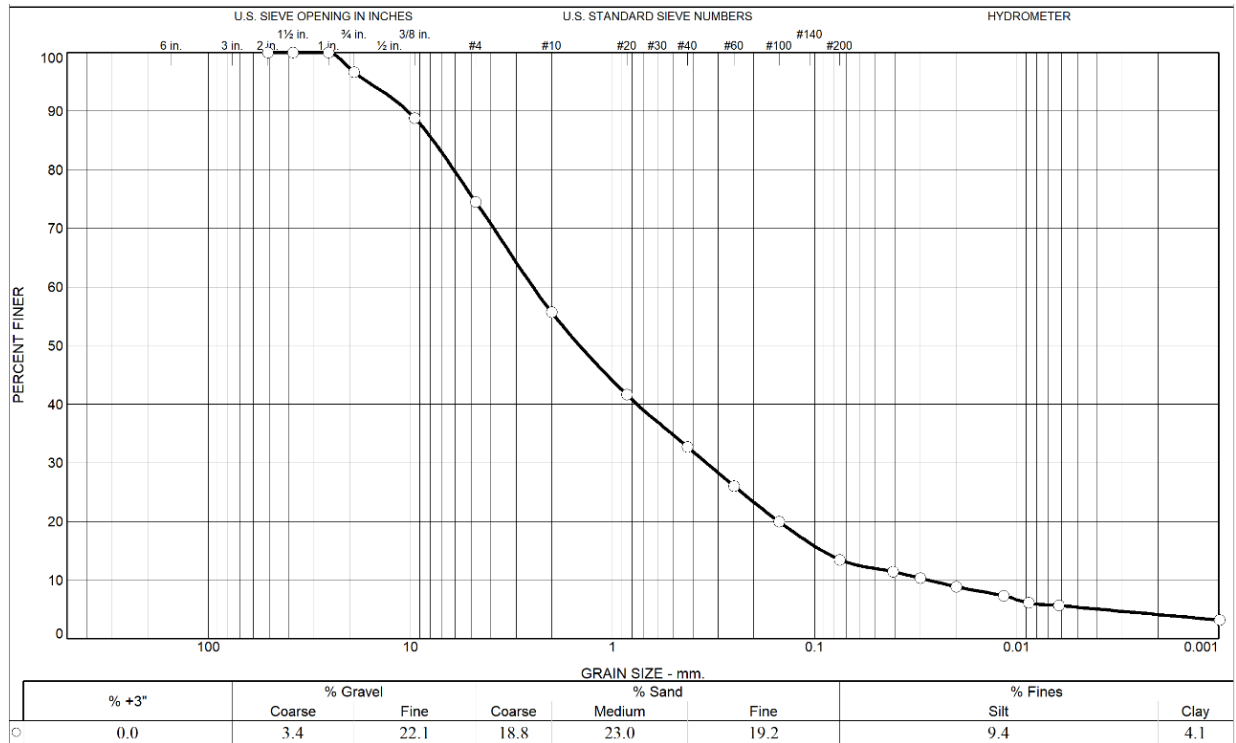


Figure 18. PSD curves of subgrade material collected during construction in August 2023 from Section 5

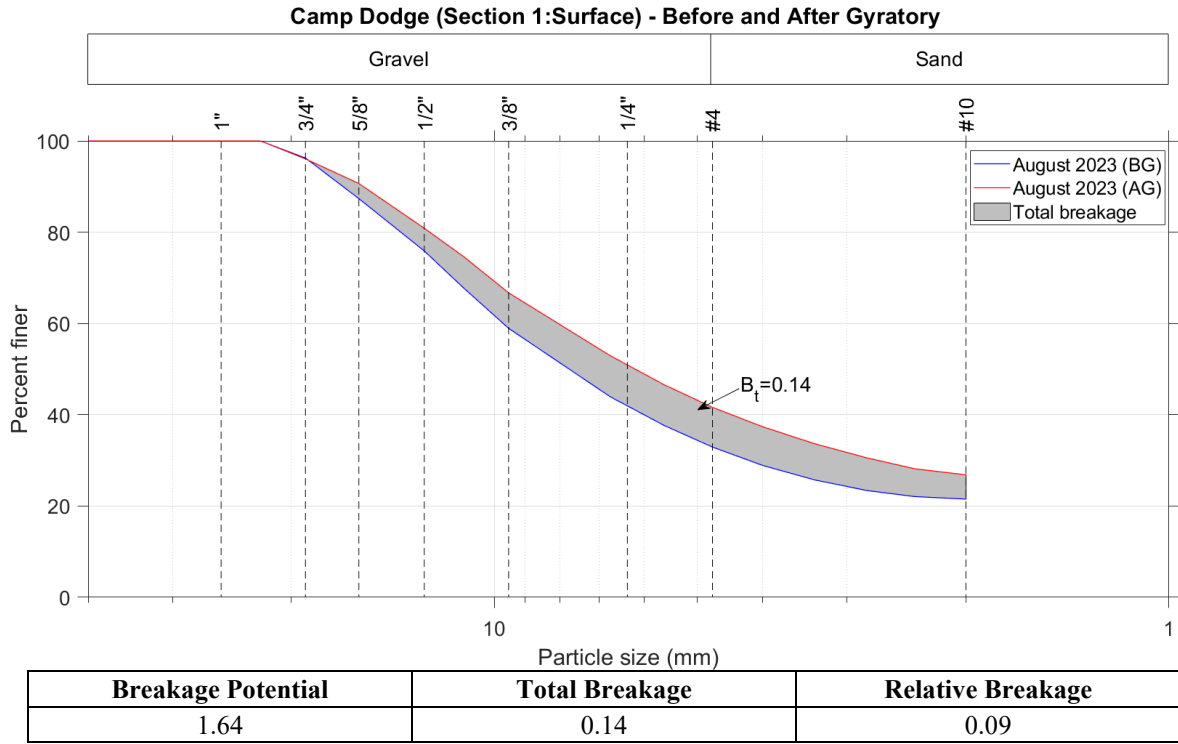
Table 5. Index properties of subgrade materials from test sections

Parameter	Section 1	Section 2	Section 3	Section 4	Section 5
Particle-size analysis (ASTM D422-03)					
Gravel content (%) (>4.75 mm)	4.7	2.4	13.3	7.4	25.5
Sand content (%) (4.75 mm-75 µm)	79.5	74.0	81.9	76.6	61.0
Silt content (%) (75 µm-2 µm)	12.6	19.2	4.0	12.4	9.4
Clay content (%) (<2 µm)	3.2	4.4	0.8	3.6	4.1
D ₁₀ (mm)	0.0267	0.0092	0.1165	0.0263	0.0272
D ₃₀ (mm)	0.2042	0.1031	0.2896	0.2178	0.3434
D ₆₀ (mm)	0.5880	0.3461	0.9115	0.8968	2.4753
Coefficient of uniformity, C _u	22.01	37.47	7.82	34.16	91.02
Coefficient of curvature, C _c	2.65	3.33	0.79	2.02	1.75
Atterberg limits (ASTM D4318-10e1)					
Liquid limit (%)	30	30	30	31	39
Plastic limit (%)	14	20	21	13	20
Plasticity index	16	10	9	18	19
AASHTO and USCS soil classifications (AASHTO M 145-91 and ASTM D2487-11)					
AASHTO Classification	A-2-6(0)	A-2-4(0)	A-2-4(0)	A-2-6(0)	A-2-6(0)
USCS group symbol	SC	SC	SP	SC	SC
USCS group name	Clayey sand	Clayey sand	Poorly graded sand	Clayey sand	Clayey sand with gravel

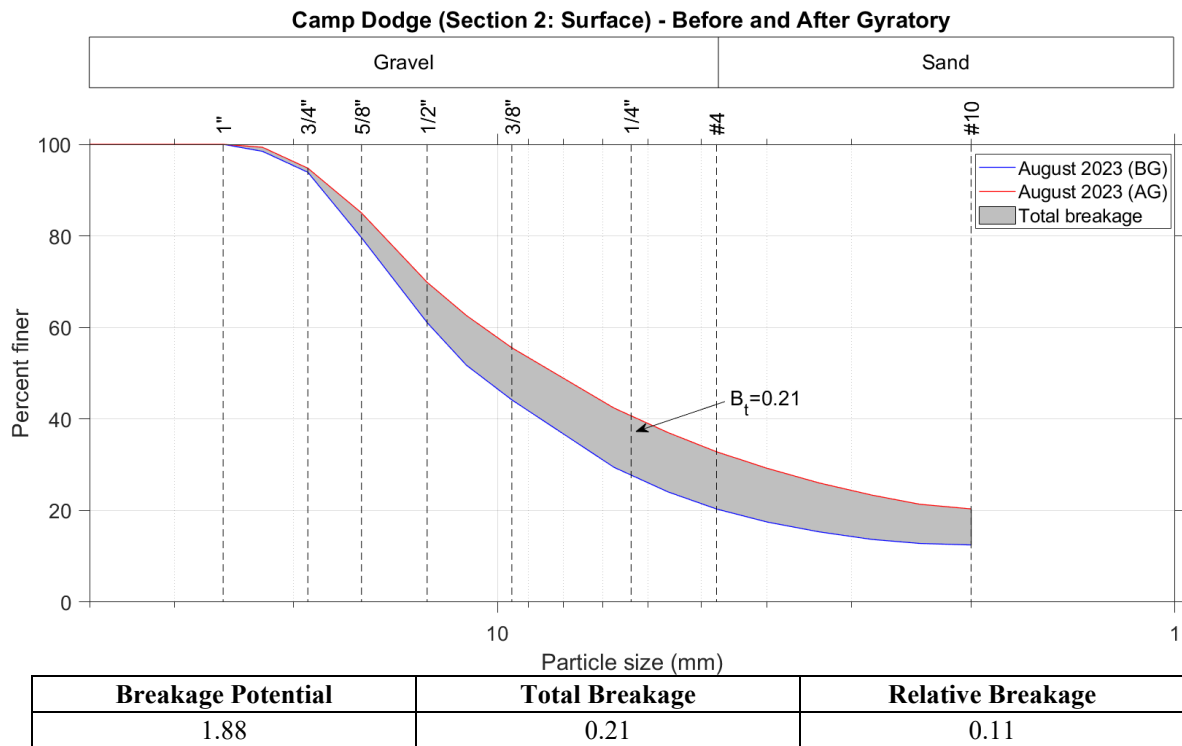
4.3 Gyratory Compaction Test Results

Gyratory compaction tests were performed on the surface aggregate samples collected from each of the five test sections during construction to assess their compaction behavior and mechanical stability. The primary focus of these tests was to evaluate changes in breakage, dry unit weight (γ_{dry}), and shear resistance (τ_G) under simulated traffic loading conditions. These parameters provide insight into a material's ability to resist deformation and maintain structural integrity during its service life. Because the same surfacing materials were used to construct Sections 1 through 4, their samples were expected to exhibit similar breakage values in gyratory compaction tests. Over time, the different stabilization and compaction methods and differences in subgrade support conditions were anticipated to result in different amounts of aggregate breakage under actual traffic loading. The results of gyratory compaction tests performed on samples collected each fall and spring throughout the project are presented in Chapter 6.

The PSD curves before and after gyratory compaction of the samples collected during construction in August 2023 are shown in Figure 19 through Figure 21. The total breakage, calculated as the shaded area between the curves produced before gyratory compaction (BG) and after gyratory compaction (AG), is also indicated in the figures. Table 6 summarizes the breakage results from these figures, including the total breakage, breakage potential, and relative breakage. As shown in the figures and table, Sections 1 and 2 exhibited the highest levels of aggregate breakage during gyratory compaction, with total breakage values of 0.14 and 0.21 corresponding to relative breakage values of 9% and 11%, respectively. The slightly higher breakage for these sections might be attributed to the cementing effect of the enzymatic stabilizer, which likely increased aggregate bonding, interlocking, and brittleness as the bonds broke down under compactive effort. Although the stabilizer was mixed into the subgrade during construction of Sections 1 and 2, it was also present in the surface course samples. The untreated Sections 3 and 4 demonstrated intermediate total breakage values of 0.11 and 0.10, respectively, both corresponding to a relative breakage of 7%. In contrast, the control Section 5 had the lowest breakage value of 0.01 with a relative breakage of 1%. This minimal breakage is likely due to the prolonged exposure of this section to heavy traffic before sampling, which had already broken down the surface aggregate into a more stable, sandy gradation.

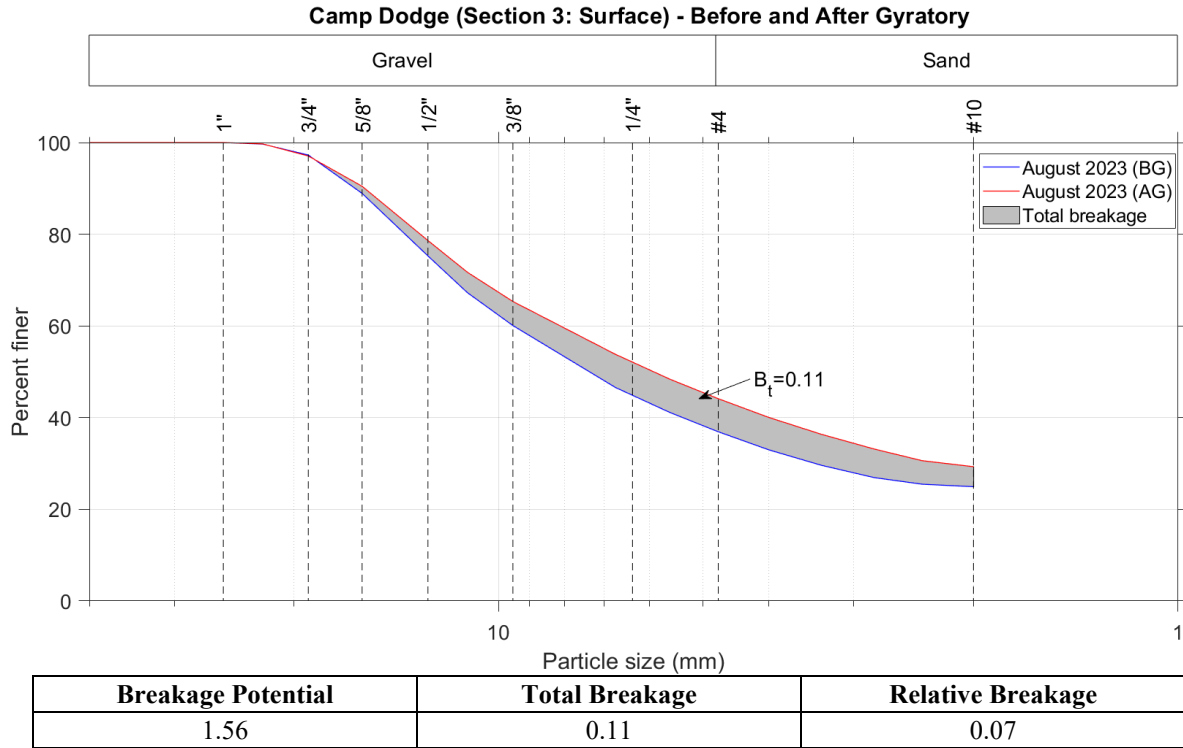


(a)

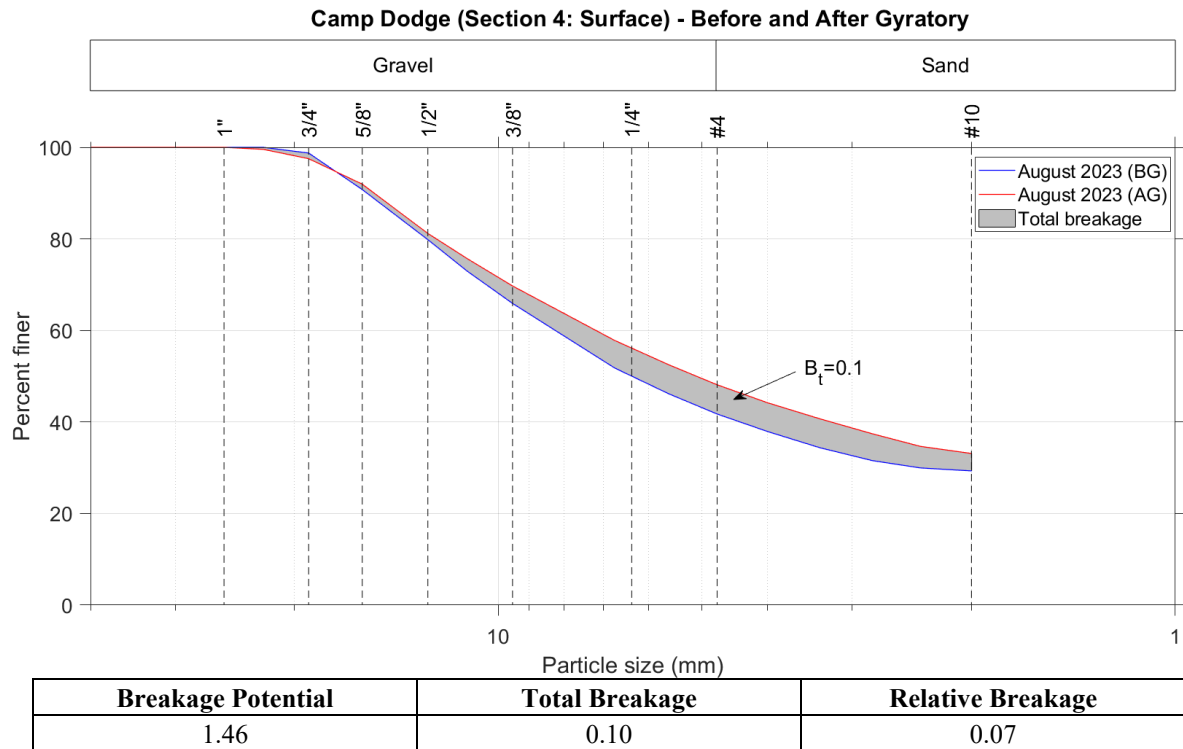


(b)

Figure 19. Gyratory breakage characteristics of surface aggregate from (a) Section 1 and (b) Section 2



(a)



(b)

Figure 20. Gyratory breakage characteristics of surface aggregate from (a) Section 3 and (b) Section 4

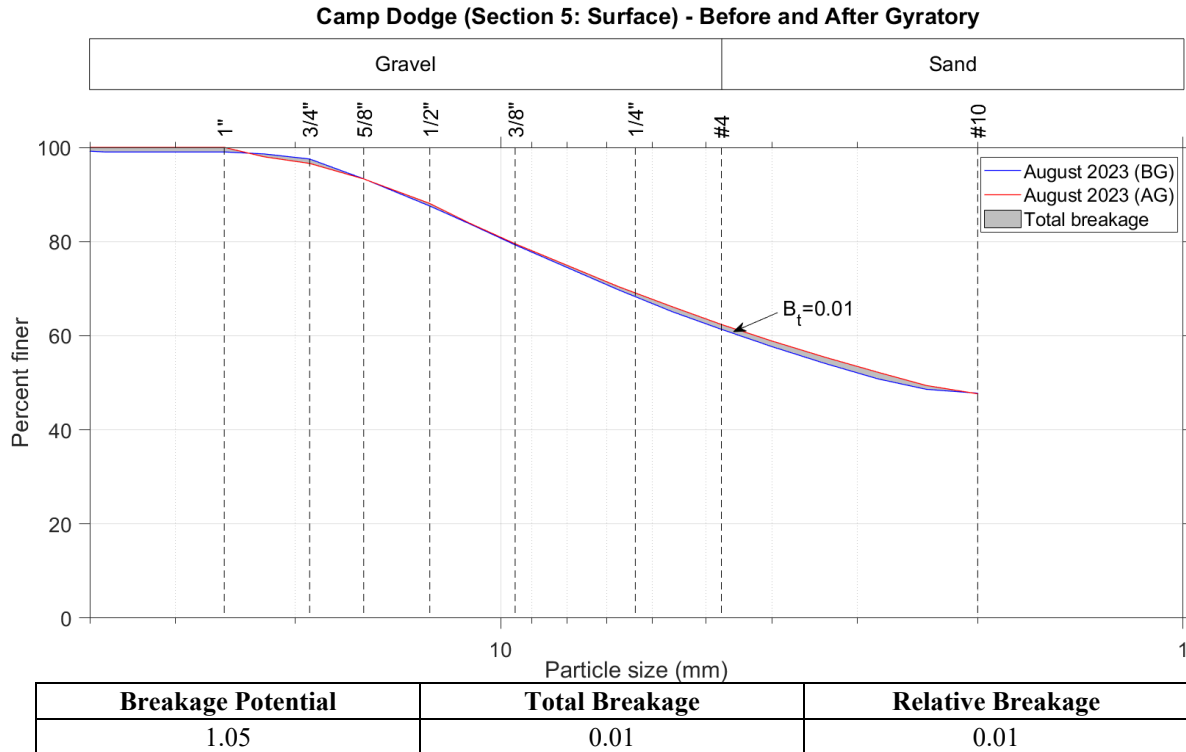


Figure 21. Gyratory breakage characteristics of surface aggregate from Section 5

Table 6. Breakage of surface course materials determined from gyratory compaction

Section	Breakage Potential	Total Breakage	Relative Breakage
1	1.64	0.14	0.09
2	1.88	0.21	0.11
3	1.56	0.11	0.07
4	1.46	0.10	0.07
5	1.05	0.01	0.01

The changes in specimen heights during the 500 gyrations are shown in Figure 22. The sample from Section 5 exhibited the smallest height change during testing, measuring 0.89 in. As explained previously, this material had already been compacted by traffic for some time and therefore exhibited little breakage during the test, indicating that the height change came mostly from particle reorientations in the reconstituted laboratory test specimen. In contrast, specimens of the fresh roadstone from the other sections, which exhibited greater breakage, also showed greater height changes ranging from 1.18 to 1.64 in., with the sample from Section 2 producing the maximum height change of 1.64 in.

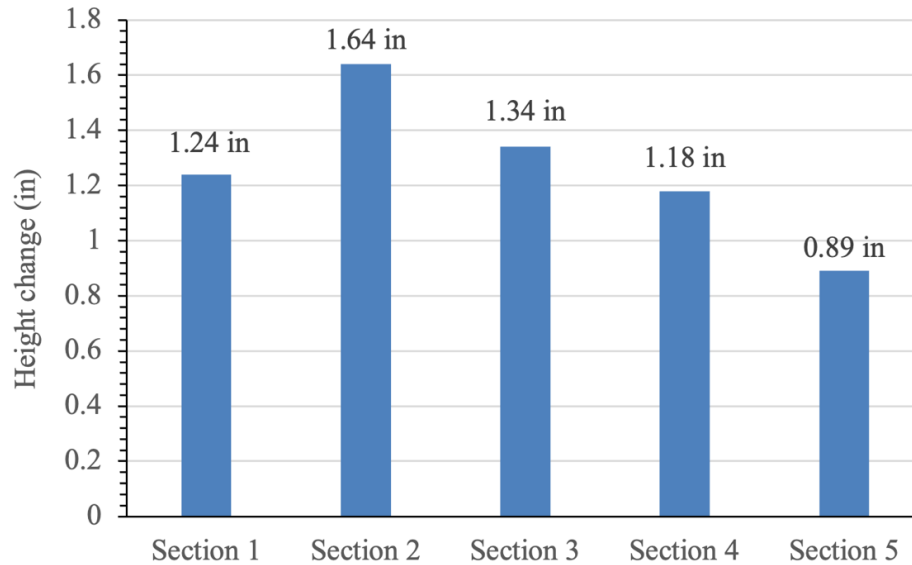
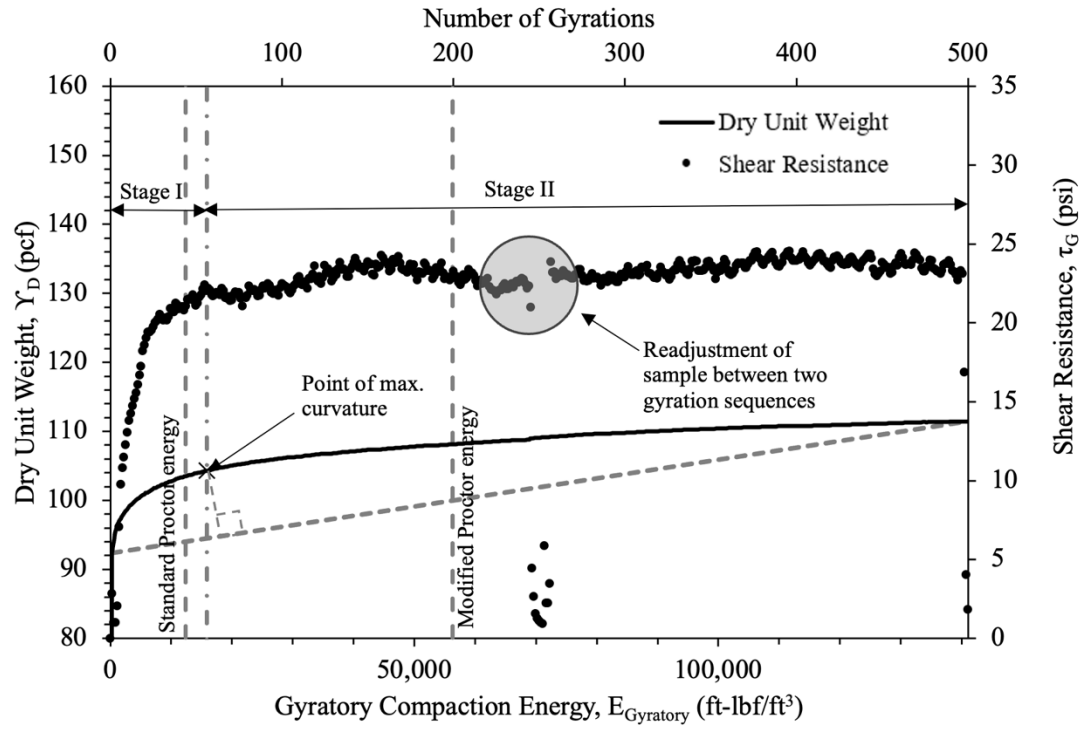
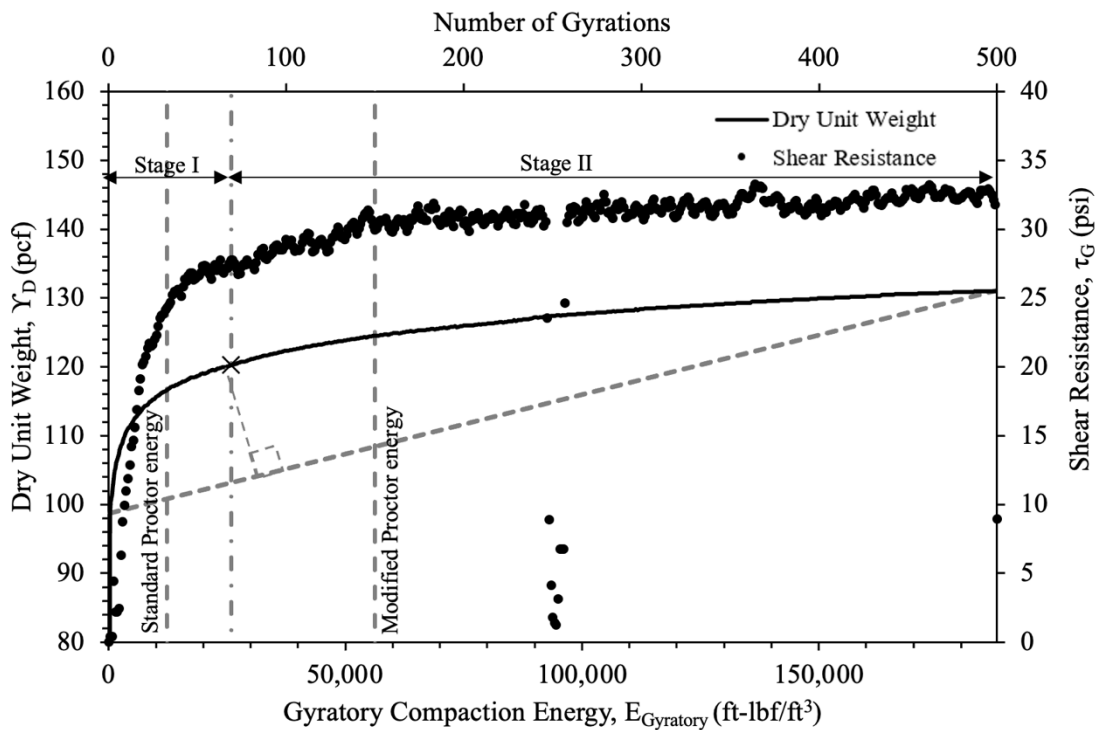


Figure 22. Change in specimen height after 500 gyrations

The relationships between dry unit weight, shear resistance, and compaction energy for the gyratory compaction tests of the surface course materials sampled during construction are shown in Figure 23 through Figure 25. A summary of the final dry unit weight and shear resistance values at the end of the tests is provided in Table 7 along with the initial and final void ratios. The results show that the dry unit weight values varied somewhat across the test sections, reflecting differences in material gradation, density, particle breakage, and stiffness during compaction. The surface materials for Section 2 reached the highest dry unit weight of 131.0 pcf, followed by the previously compacted in-service control Section 5 materials at 124.9 pcf and the Section 3 materials at 122.5 pcf. The lowest dry unit weights were recorded in Section 1 and Section 4 at 111.5 pcf and 109.5 pcf, respectively, indicating relatively lower compaction of these materials achieved under the same gyratory effort. The virgin construction materials from Sections 1 through 4 exhibited similar decreases in void ratio ranging from 0.30 to 0.43, whereas the previously compacted materials from Section 5 had the smallest void ratio decrease of 0.23.

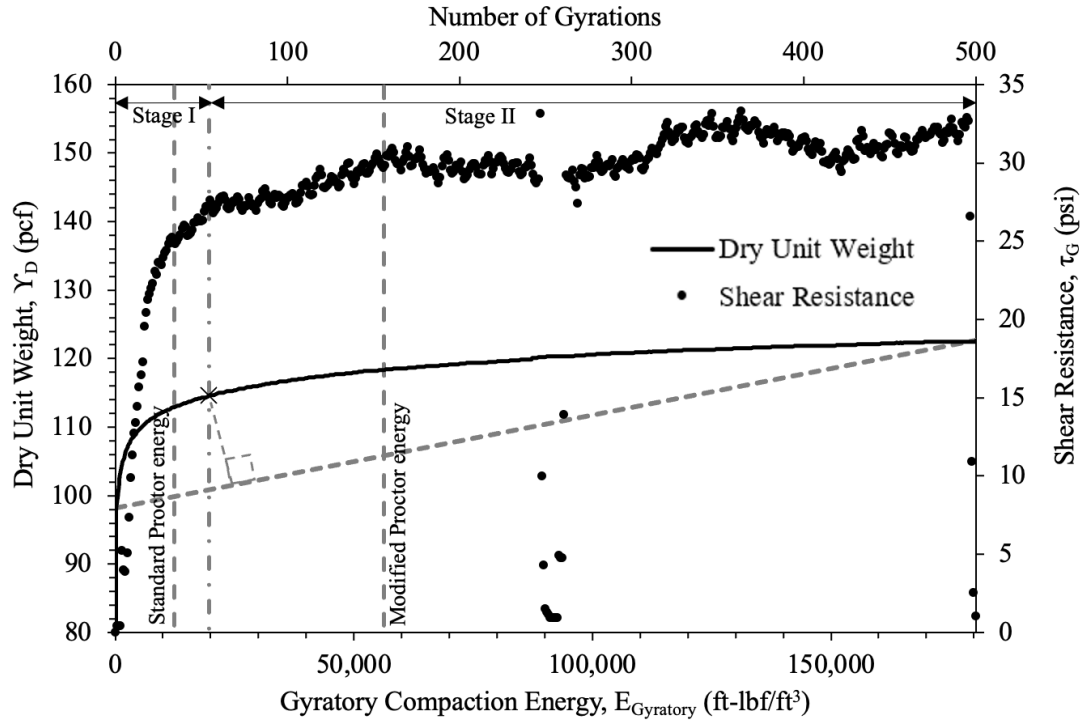


(a)

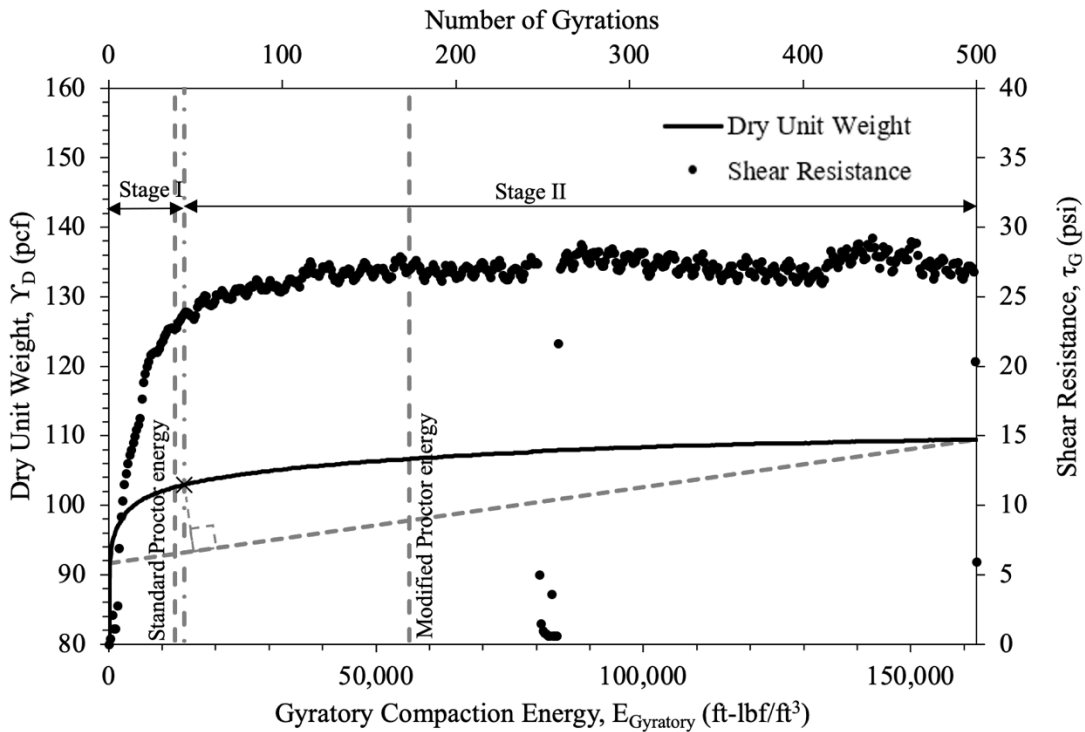


(b)

Figure 23. Unit weight and shear resistance as functions of compaction energy for samples from (a) Section 1 and (b) Section 2



(a)



(b)

Figure 24. Unit weight and shear resistance as functions of compaction energy for samples from (a) Section 3 and (b) Section 4

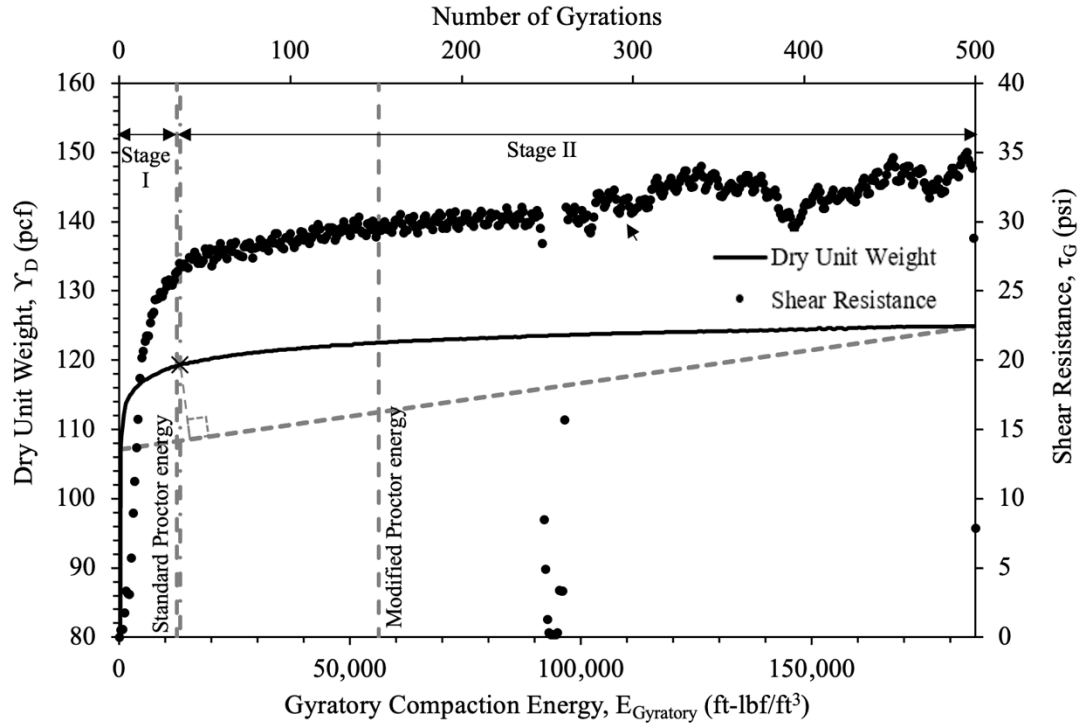


Figure 25. Unit weight and shear resistance as functions of compaction energy for samples from Section 5

Table 7. Final values of dry unit weight and shear resistance from gyrotory compaction tests for surface materials sampled during construction

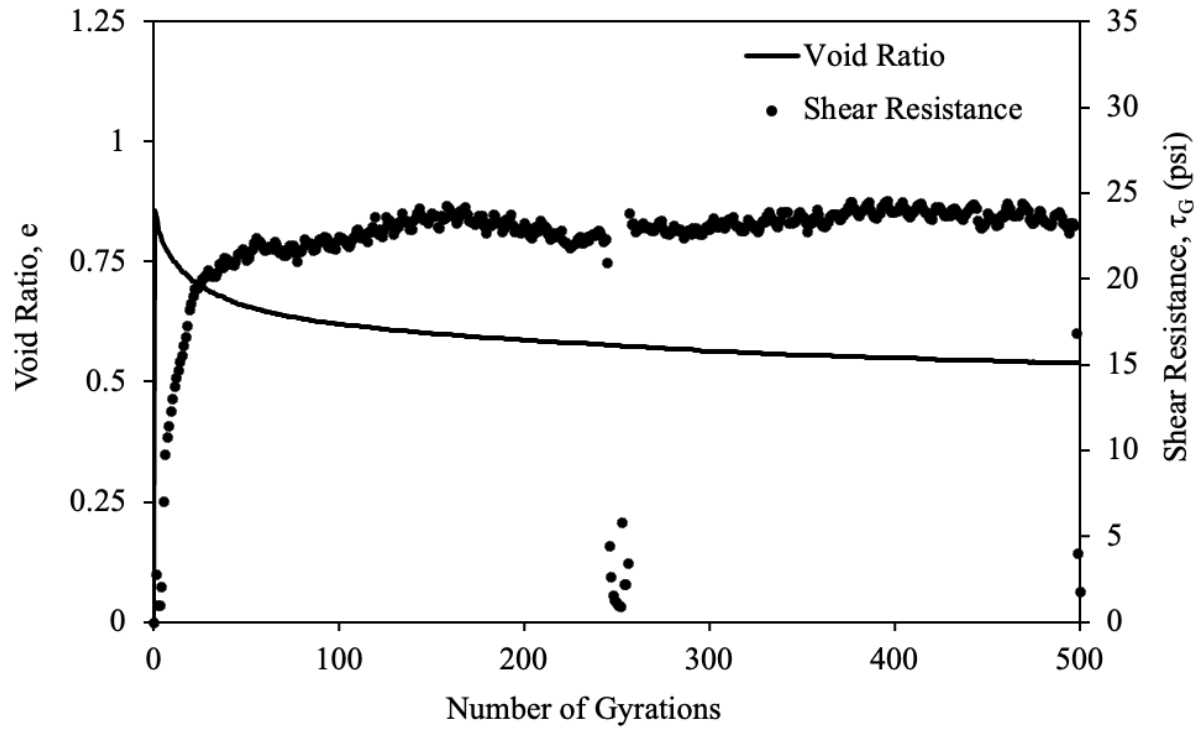
Section	Dry unit weight, Y_D (pcf)	Shear resistance, τ_G (psi)	Initial void ratio	Final void ratio	Decrease in void ratio
1	111.45	23.10	0.86	0.54	0.32
2	131.00	31.77	0.74	0.31	0.43
3	122.51	32.26	0.75	0.40	0.35
4	109.46	26.81	0.87	0.57	0.30
5	124.9	33.84	0.60	0.37	0.23

In Figure 23 through Figure 25, a straight line is drawn between the starting and ending dry unit weight values, and the longest perpendicular line extending to the dry unit weight curve is used to determine an approximate point of maximum curvature. This point defines the number of gyrations beyond which additional compaction energy produces diminishing returns, dividing the test results into two stages. The boundary line between these two stages would therefore make a good target value for field compaction. This boundary line lies near or slightly above the Standard Proctor compaction energy for all specimens, and in all cases it was well below Modified Proctor compaction energy.

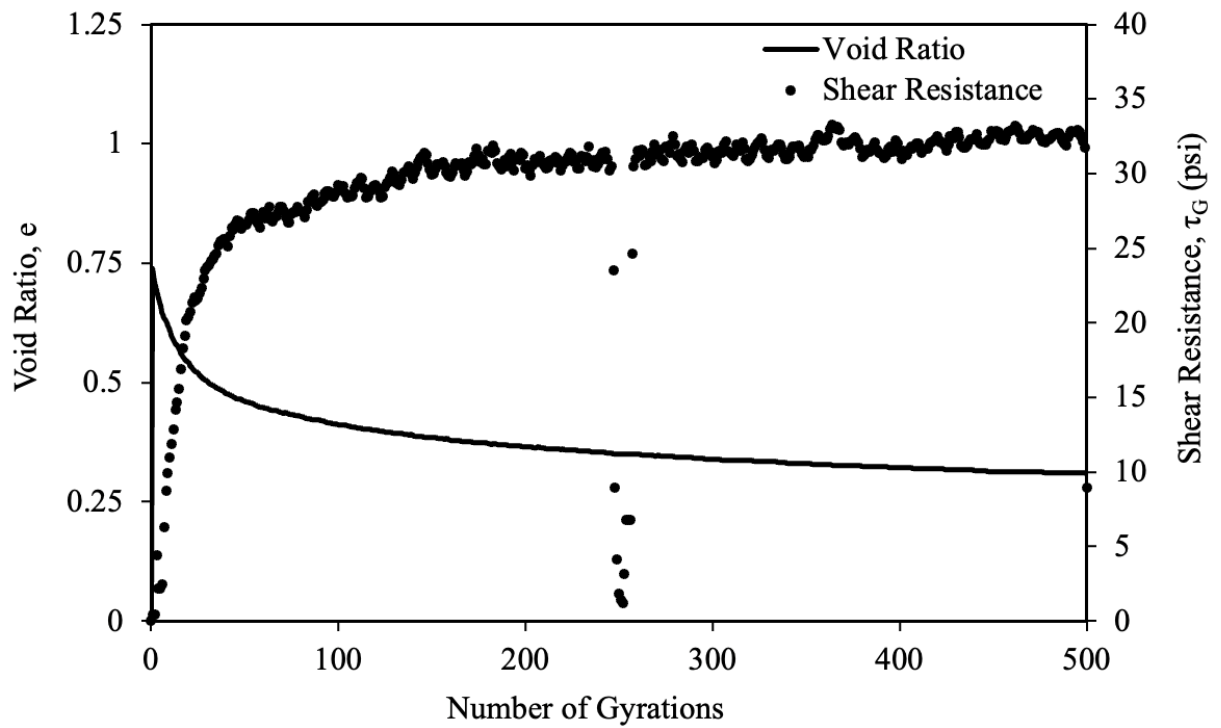
The shear resistance values, which reflect the internal strength of the compacted material, ranged from 23.10 to 33.84 psi. The control Section 5 exhibited the highest shear resistance, suggesting

a well-graded and mechanically stable aggregate matrix for the previously compacted in-service materials. Sections 2 and 3 also showed high shear strength values of 31.77 psi and 32.26 psi, respectively, while Sections 1 and 4 exhibited comparatively lower resistance values of 23.10 psi and 26.81 psi, respectively, possibly due to differences in aggregate interlock or particle degradation during gyratory compaction. It is important to note that all samples were subjected to the same compactive effort in these laboratory tests, with energy levels surpassing both the Standard and Modified Proctor methods, as indicated by the vertical lines in Figure 23 through Figure 25.

The changes in void ratio during gyratory compaction are plotted along with shear resistance in Figure 26 through Figure 28. The results show a clear relationship between void ratio and shear resistance across all test specimens. The void ratio showed a smooth decrease during the test, while the shear resistance fluctuated somewhat but generally followed an increasing trend. In general, both variables changed quickly at the start of the test, then exhibited more gradual changes, indicating a slower rate of compaction as the number of gyrations increased. This variation is mainly due to the kneading and shearing action of the gyratory compactor, which causes the aggregate particles to constantly shift, rotate, and initiate or break contact with each other as the test progresses. These changes in particle arrangement affect how the load is distributed, leading to observed fluctuations in shear resistance (Li et al. 2017). A notable change occurred around 250 gyrations, at which point each test was briefly paused and restarted due to the equipment's limitation of a maximum of 299 gyrations. Although the void ratio changed very little at that point, there was a significant momentary decrease in shear resistance as the vertical stress was removed and reapplied before another 250 gyrations were conducted. This highlights how sensitive shear resistance is to the material's internal structure, especially as the material becomes more compact and the number of contacts between particles increases.



(a)



(b)

Figure 26. Changes in void ratio and shear resistance during gyratory compaction tests of surface aggregate material from (a) Section 1 and (b) Section 2

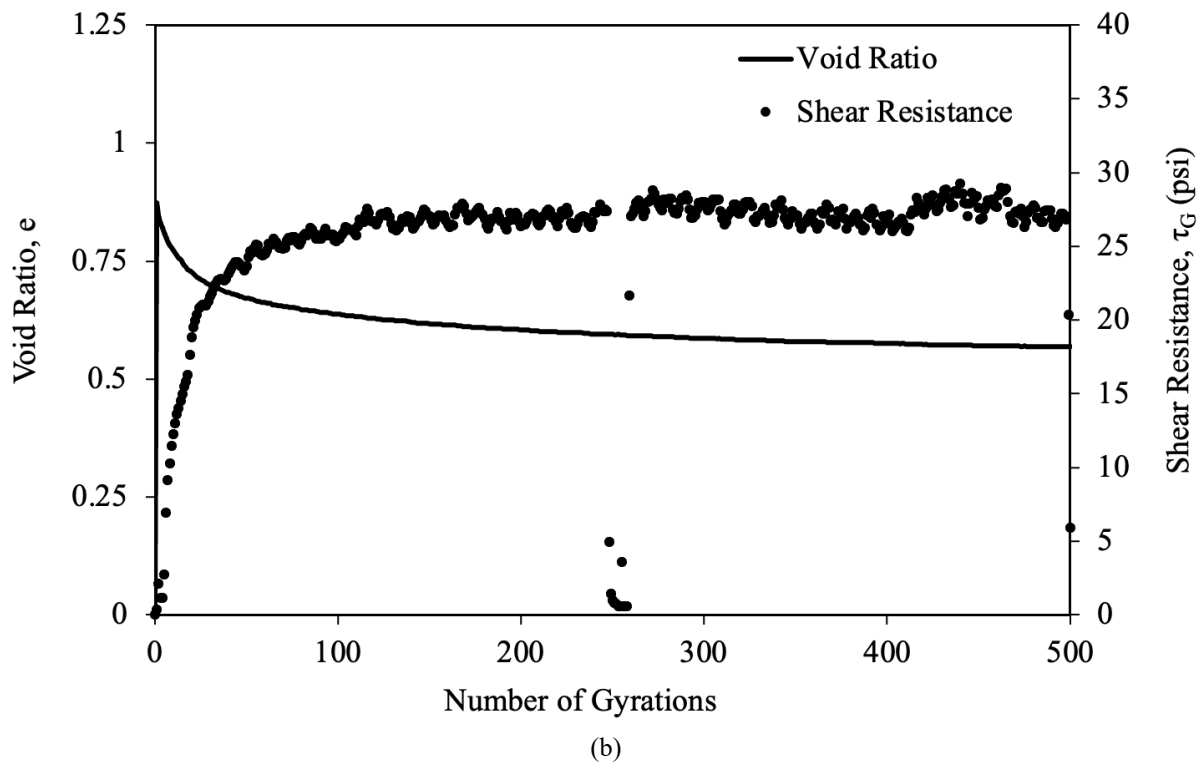
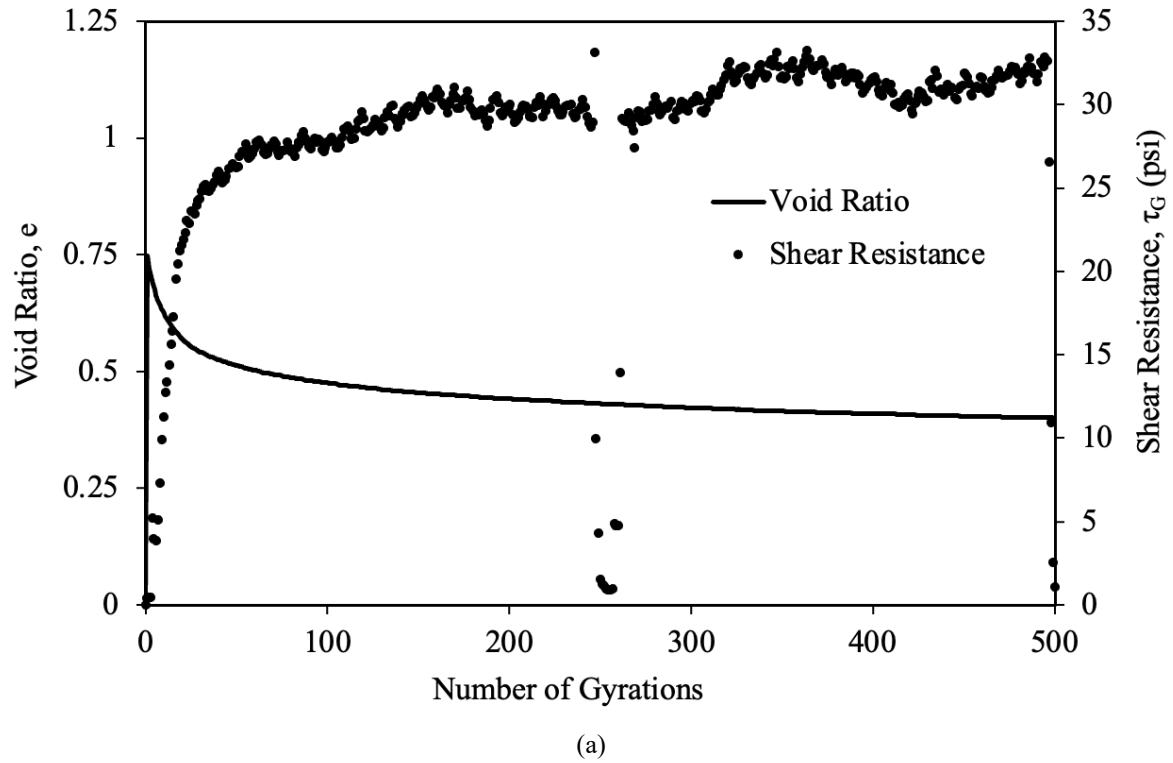


Figure 27. Changes in void ratio and shear resistance during gyratory compaction tests of surface aggregate material from (a) Section 3 and (b) Section 4

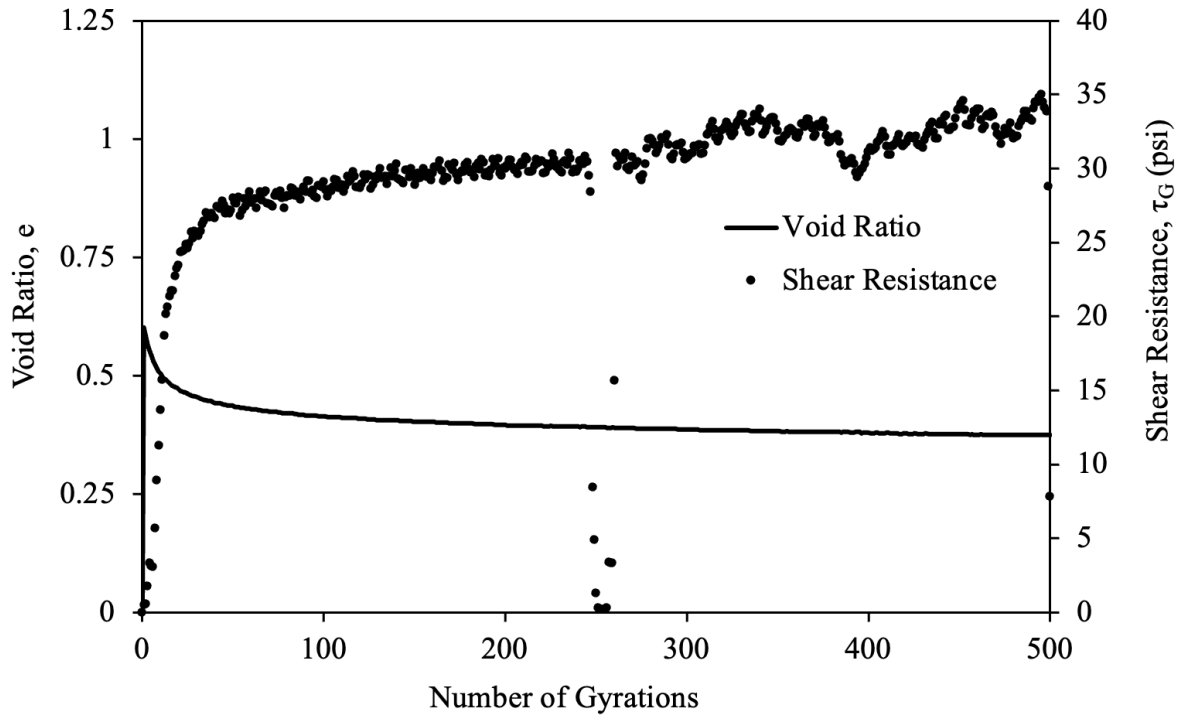


Figure 28. Changes in void ratio and shear resistance during gyratory compaction tests of surface aggregate material from Section 5

For the materials tested in this study, a strong linear relationship was observed between the initial gravel content of the specimens and their relative breakage (B_R) during gyratory compaction tests. This correlation is illustrated in Figure 29, which shows an increase in relative breakage with pre-test gravel content. However, it is important to recognize that gravel content alone does not fully determine breakage behavior. The mechanical degradation of granular materials is also influenced by factors such as gradation, particle shape (morphology), void ratio, and applied loading conditions. These factors collectively affect the way particles rearrange, interlock, and fracture during compaction and under traffic loads in the field.

Further analysis revealed an additional correlation between the initial gravel content and field-measured average CBR values of the granular surface course (Figure 30). This relationship was developed using CBR data collected during fall 2023, which closely corresponds to the timeframe in which the surface aggregate samples for the gyratory tests were collected. Section 5 was excluded from the correlation because it did not receive new surfacing aggregates, and all ADCP tests for this section in fall 2023 gave refusal around a depth of 2 in., resulting in very high CBR values because of the impenetrable subgrade. As a result, Section 5 was treated as an outlier to preserve the accuracy of the correlation. As shown in Figure 30, the data suggest that field CBR values tend to increase with an increase in the relative breakage observed during gyratory compaction. Together, these findings imply that field CBR values could potentially be estimated from the initial gravel content of a gyratory compaction test specimen. It is important to note that this observation has not yet been validated, and further field and laboratory investigation is needed to confirm the reliability of this relationship.

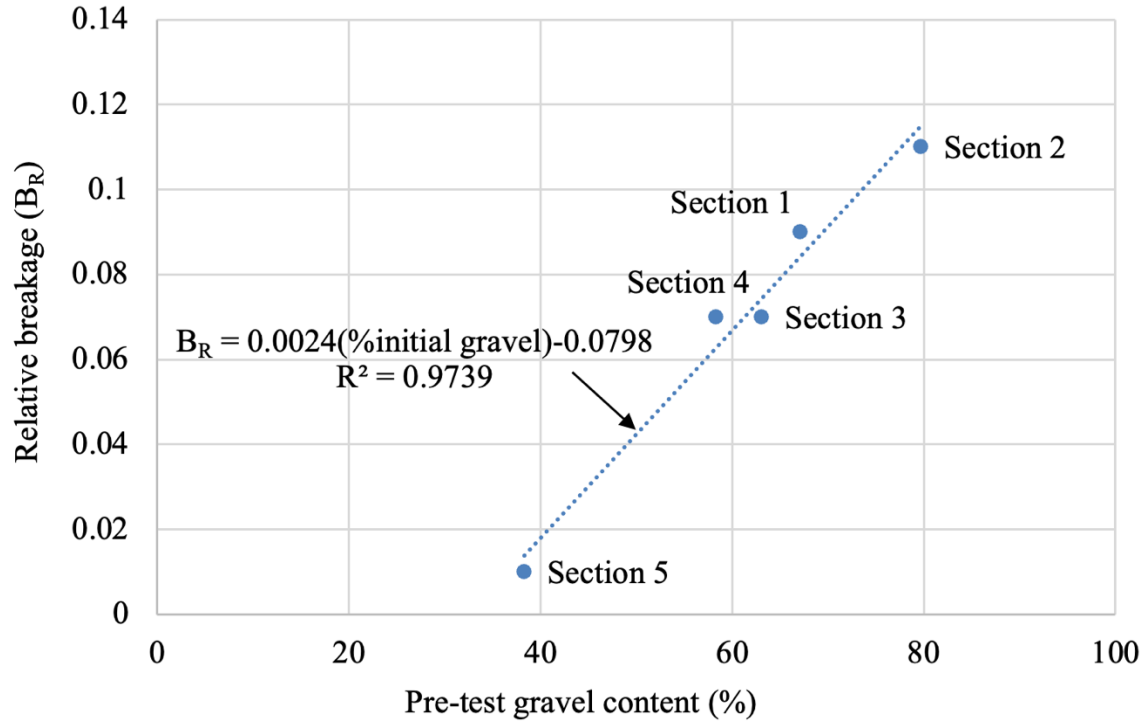


Figure 29. Relationship between initial gravel content of specimens measured by image analysis and relative breakage during gyratory compaction tests

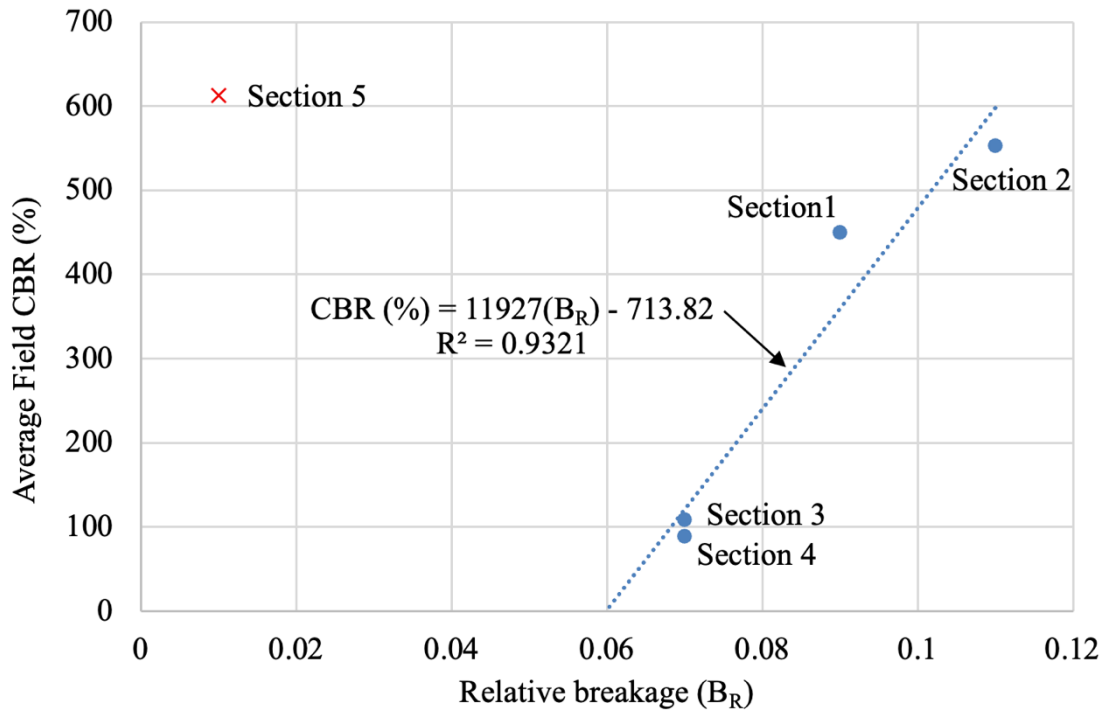


Figure 30. Relationship between relative breakage of specimens during gyratory compaction tests and average field CBR value

CHAPTER 5 DESIGN AND CONSTRUCTION OF TEST SECTIONS

This chapter presents the design approach and construction procedures adopted for the aggressively rehabilitated test sections with and without chemical stabilization. It also details the equipment and techniques utilized. Five test sections were designed in collaboration with the project's technical advisory committee (TAC). The locations of the test sections are illustrated in Figure 1. Experienced motor grader operators were supplied by Dallas, Decatur, Humbolt, Keokuk, and Wright Counties to perform construction, and a Maintenance Superintendent from Dallas County oversaw the construction operations.

5.1 Design of Test Sections

The following test sections were designated for the project, as shown in Figure 31:

- Section 1: Enzymatic stabilization with smooth-tired compaction (1,500 ft)
- Section 2: Enzymatic stabilization with sheepsfoot compaction (1,500 ft)
- Section 3: Smooth-tired compaction only (660 ft)
- Section 4: Sheepsfoot compaction only (660 ft)
- Section 5: Control section with no stabilization or compaction (1,320 ft)



Figure 31. Project test section layout

Sections 1 and 2 each spanned 1,500 ft and were treated with Perma-Zyme, an enzymatic liquid chemical stabilizer. After material from the ditches and from the previous granular surface, which consisted of a few inches of deteriorated crushed limestone aggregates, was incorporated into the rebuilt roadway profile, the stabilizer was blended into the upper 6 in. of the resulting blend of materials. The most important requirement for soil to be compatible with Perma-Zyme is that it possess some organic content, which is usually achieved in the form of clay (Substrata 2022). Therefore, soil having some degree of plasticity should be compatible, but a range of particle sizes is also essential for the soil to bind with the stabilizer. For design with Perma-Zyme, the manufacturer recommends performing a sieve analysis and verifying that the soil possesses at least 20% fines passing the No. 200 sieve, along with a range of particle sizes for proper binding. Proctor compaction tests are recommended to determine the soil's optimum moisture content, along with Atterberg limits tests to assess the soil's plasticity and thus compatibility with the stabilizer.

To ensure that the stabilizer would be effective for the soil conditions at the site, two soil samples were collected from the subgrade next to Section 1 and sent to the manufacturer several months before construction. As shown in Figure 32, the two samples had 34% to 37% fines, and the stabilizer effectively cemented the loose, silty soils into a hardened, brick-like material expected to enhance field performance. Previous applications of Perma-Zyme by various Iowa counties have also yielded favorable results.



Figure 32. Soil samples from project site treated with Perma-Zyme stabilizer

To assess the impact of different compaction techniques on aggressively rehabilitated roads, a smooth-tired pneumatic roller was used for Section 1, while a sheepfoot compactor was employed for Section 2. Sections 3 and 4, each 660 ft long, were constructed without stabilizer but with the same compaction approaches used in Sections 1 and 2, respectively. This design isolated the effect of mechanical compaction alone. Section 5, which is a 1,320 ft control section,

was untouched during construction. No additional surfacing materials were added, and no compaction or stabilization was applied.

This experimental design enabled a comparative evaluation of the field performance of various compaction methods used to construct aggressively rehabilitated roadway profiles, both with and without the addition of enzymatic stabilizer. As detailed in Chapter 6, data from field and laboratory tests conducted on the five test sections before construction and over the two-year project duration were used to assess the sections' relative strength, stiffness, and durability.

5.2 Construction of Test Sections

The construction procedures are illustrated in the form of a flow chart in Figure 33, which provides a clear overview of the major activities involved in rehabilitating and constructing the test sections. Details of the construction steps are provided in the following pages.

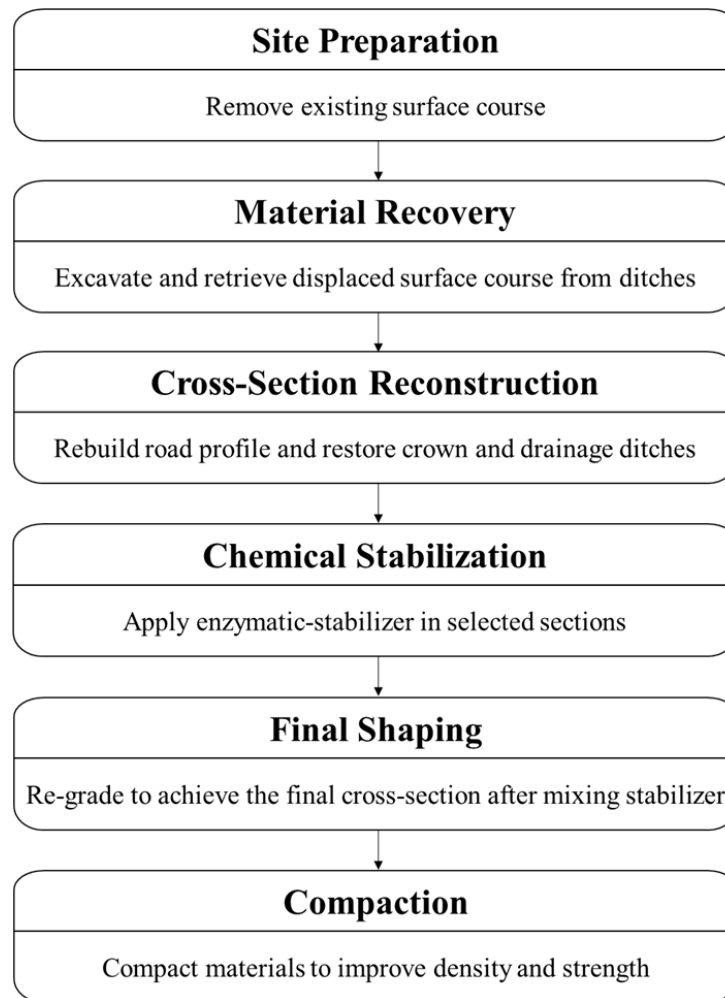


Figure 33. Flowchart of steps in test section construction

On Day 1 of construction (August 14, 2023), the existing roadway surfaces of Sections 1 through 4 were ripped using teeth attached behind a dozer (Figure 34). For typical gravel roads, ripping can usually be achieved with a scarifier or ripper attachment on a motor grader. However, the roadway in this study had been constructed with very large construction debris up to 10 in. or more in width (Figure 35), for which the larger dozer teeth were more effective. The road was then aggressively rehabilitated by excavating subgrade material from the ditches (Figure 36), bringing in the excavated ditch material to build up the central profile elevation (Figure 37), and spraying with water and mixing with motor graders (Figure 38) while also compacting with either the smooth-tired (Figure 39) or sheepfoot compactor (Figure 40). A new corrugated culvert drainage pipe was also installed on Day 1 to replace a smaller one on the north edge of the intersection of Sections 1 and 3 (Figure 41).



Figure 34. Ripping existing roadway materials



Figure 35. Example of construction debris encountered in existing roadbed materials



Figure 36. Initial excavation of ditch material in Section 1



Figure 37. Incorporation of material from both ditches to build up road elevation



Figure 38. Application of water and compaction during reconstruction of roadway profile



Figure 39. Smooth-tired compactor used for test section construction



(a)



(b)

**Figure 40. Sheepfoot compaction equipment used for test section construction:
(a) sheepfoot dozer and (b) tow-behind sheepfoot compactor**



Figure 41. Removal of old corrugated culvert pipe for replacement

These procedures rebuilt the road's cross-sectional shape while increasing the surface elevation, narrowing the width, and re-establishing the crown and side ditches to improve drainage. The combined reclaimed and in-place materials were compacted throughout the construction process to improve density and stability. After the cross-sections were rebuilt, the rehabilitated width of Sections 1 and 2 was 28 ft, whereas the width of all other sections was 22 ft. Rebuilding the aggressively rehabilitated profiles of Sections 1 through 4 required all of Day 1 (August 14, 2023) and half of Day 2 (August 15, 2023, shown in Figure 42). In the afternoon of Day 2, Sections 3 and 4 were completed by spreading Class A roadstone on the rebuilt surface, followed by spraying water and compacting (Figure 43 and Figure 44).



Figure 42. Continued shaping and compaction of reconstructed road profile on Day 2



Figure 43. Spreading Class A roadstone on surface of Section 3 on Day 2 (August 15, 2023)



Figure 44. Spreading Class A roadstone on surface of Section 4 on Day 2 (August 15, 2023)

On the morning of Day 3 (August 16, 2023), water was sprayed on the surface of Sections 1 and 2, and the top 6 in. of material was scarified in preparation for applying the stabilizer (Figure 45). The stabilizer was incorporated into the top 6 in. of Sections 1 and 2 at the manufacturer's recommended rate of 1 gal per 160 yd³ of soil. For the 28 ft width of these two sections, incorporating the stabilizer over their combined length of 3,000 ft to a depth of 6 in. resulted in the following calculated amount of stabilizer:

$$\left(\frac{3,000 \text{ ft} \times 28 \text{ ft} \times 0.5 \text{ ft}}{27 \frac{\text{ft}^3}{\text{yd}^3}} \right) \times \left(\frac{1 \text{ gal}}{160 \text{ yd}^3} \right) = 9.7 \text{ gal} \quad (12)$$

A total of 10 gal of stabilizer was therefore used, which allowed for 3% loss due to handling and runoff.



Figure 45. Spraying water on surfaces of Sections 1 and 2 on Day 3 prior to spraying stabilizer

To incorporate the stabilizer, small windrows were first formed to help reduce runoff, then the liquid stabilizer was poured into the tank of a nearly full 2,200 gal water truck (Figure 46) and sprayed over the surface of Sections 1 and 2 (Figure 47 and Figure 48). Motor graders were then used to bring the windrows in while mixing the applied stabilizer into the top 6 in. of the subgrade material (Figure 49, Figure 50, and Figure 51). After the stabilizer was incorporated and the surface was shaped, additional compaction passes were applied to the stabilized subgrade over the course of a few hours (Figure 52).



Figure 46. Adding liquid stabilizer to nearly full 2,200 gal water truck



Figure 47. Spraying liquid stabilizer on Section 1



Figure 48. Surface of Section 2 during spraying of stabilizer



Figure 49. Mixing stabilizer into top 6 in. of subgrade in Sections 1 and 2



Figure 50. Mixing stabilizer into top 6 in. of subgrade in Sections 1 and 2



Figure 51. Mixing stabilizer into top 6 in. of subgrade in Sections 1 and 2



Figure 52. Perma-Zyme treated subgrade in Section 1 before (left) and after (right) first compaction pass of smooth-tired roller

The manufacturer's recommended construction procedure is to form the soil into windrows and pre-wet them with water, then let them sit overnight before unfolding the windrows and applying the stabilizer. After stabilization, it is also recommended to wait for the treated soil to fully cure and gain strength prior to applying a gravel surface, which could require several days. However, for this project it was decided to apply the stabilizer and mix and compact for three hours, then spread a light cover of roadstone the same day and leave the road overnight (Figure 53). This construction procedure was adopted because it is the road rehabilitation scenario that Iowa county engineers would likely use. Then on Day 4, the majority of the Class A roadstone was spread (Figure 54), and additional water was applied for compaction of the final surface by a few passes of the smooth-tired roller (Figure 55). Construction was completed by noon on Day 4. The finished surfaces of Sections 1 through 4 and the untouched control Section 5 are shown in Figure 56 through Figure 60.

By the end of construction, a total of 1,315.7 tons of Class A roadstone had been uniformly spread over the rehabilitated Sections 1 through 4. On average, this equates to a thickness of 2.2 in., comprising 488.8 tons of roadstone on each of Sections 1 and 2 and 169.0 tons on each of Sections 3 and 4. These application rates equate to 1,721 tons per mile (TPM) for the 28 ft wide Sections 1 and 2 and 1,352 TPM for the 22 ft wide Sections 3 and 4, with the differences in TPM attributed only to the different widths.



Figure 53. Spreading of light roadstone cover to leave on road overnight



Figure 54. Start of spreading of surfacing aggregate on Sections 1 and 2 on Day 4 (August 17, 2023)



Figure 55. Additional water being sprayed for compaction of Class A roadstone surface



Figure 56. Surface of Section 1 at end of construction



Figure 57. Surface of Section 2 at end of construction



Figure 58. Surface of Section 3 at end of construction



Figure 59. Surface of Section 4 at end of construction



Figure 60. Surface of the untouched control Section 5 at end of construction

CHAPTER 6 RESULTS AND DISCUSSION

This chapter presents the results and analysis of field and laboratory tests performed before construction and over two fall-spring cycles. The field tests and sampling procedures were performed in the following timeframes: (1) before construction in summer 2023, (2) after construction in fall 2023, (3) after thawing in spring 2024, (4) in fall 2024, and (5) after thawing in spring 2025.

6.1 Field Tests Before Construction

Prior to construction of the test sections, a series of field tests were conducted on August 7, 2023, to evaluate the properties of the existing surface and subgrade materials at the project site. Field ADCP and LWD tests were performed to measure the strength and stiffness of the test sections.

6.1.1 Results of ADCP Tests Before Construction

Two pre-construction ADCP tests per section were performed as shown in Figure 61. Several of the tests encountered refusal due to the presence of large cobbles, boulders, and buried construction debris within the subgrade, some examples of which are shown in Figure 62. The pre-construction ADCP test results are shown in Figure 63 through Figure 67, which contain plots of the cumulative blows, DCP index, and correlated CBR values versus penetration depth. In any test, refusal was identified as 20 blows producing no advancement of the DCP rod. This limit was chosen because it was found that multiple blows with zero penetration could damage the DCP cone tip adapter at the bottom or the rod clamp at the top, requiring their replacement and possibly making extraction of the driving rod difficult when the tip deformed around the rod adapter, preventing its easy release. Refusal can be identified in the DCP plots by curves that terminate within the upper 12 in. of depth. In Section 1, two additional test points (appended with “b”) were attempted within a few feet of Points 1 and 3 after they gave refusal. Point 1b was successful, but Point 3b also resulted in refusal. In Section 5, all tests resulted in refusal, and complete soil profiles could not be obtained.

The surface layer thicknesses, indicated by horizontal dashed lines in the plots, were estimated by picking intersection points in the slopes of the cumulative blows versus depth plots. In cases where no clear break point could be determined, the surface layer thickness was instead estimated from the depth of a sudden change in the CBR value. For the pre-construction ADCP tests, the thickness of the existing surface ranged from 2.3 to 6 in., with an average value of 4.0 in. The average CBR values in the aggregate surface course and the subgrade layer were calculated as described in Chapter 3 and are also shown in the CBR plots as vertical dashed lines.



Figure 61. ADCP tests in August 2023 prior to construction



Figure 62. Examples of cobbles, boulders, and construction debris leading to ADCP refusal

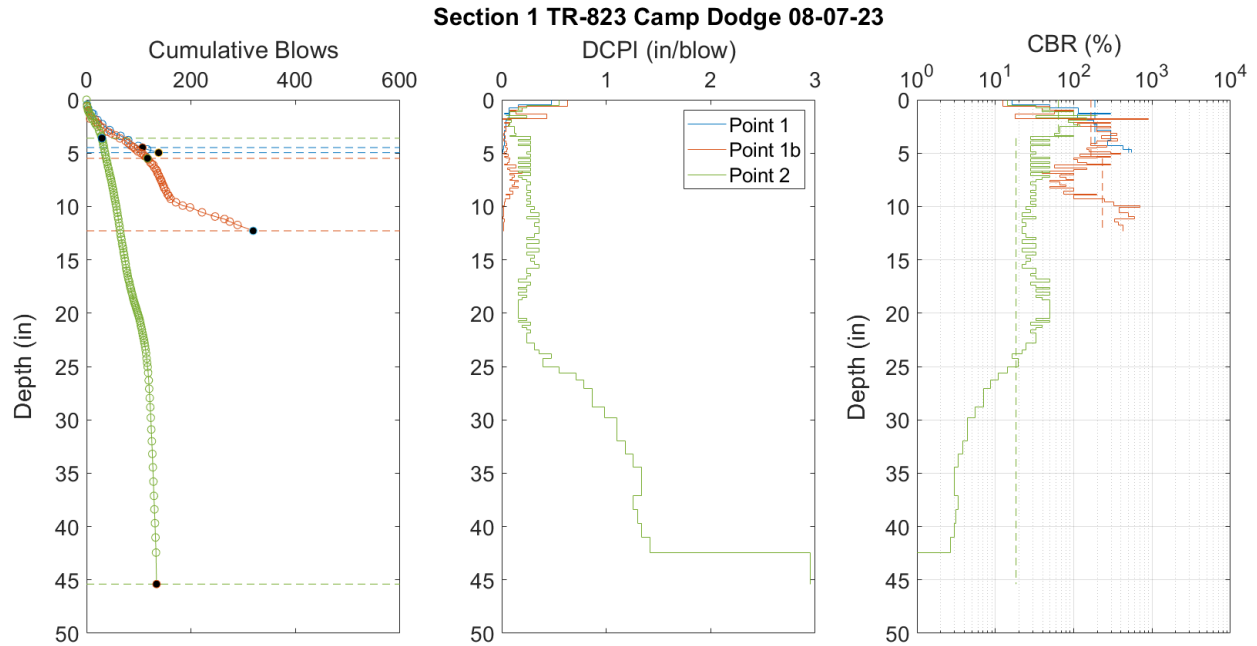


Figure 63. Pre-construction ADCP results for Section 1: (a) cumulative blows, (b) DCPI, and (c) DCP-CBR

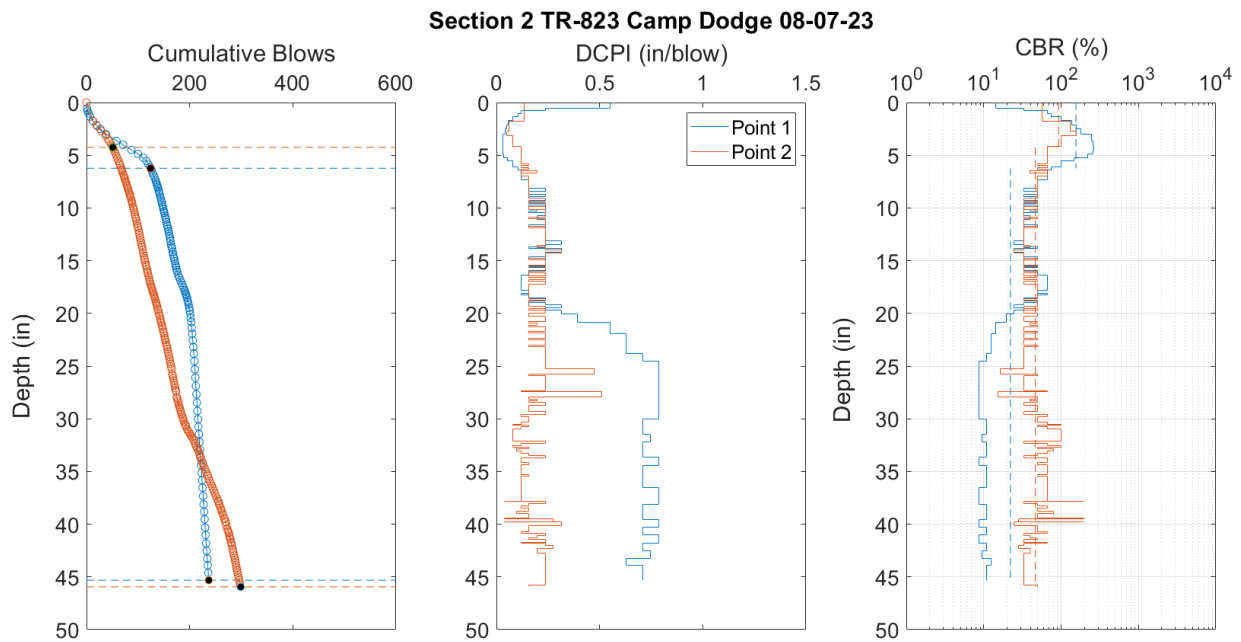


Figure 64. Pre-construction ADCP results for Section 2: (a) cumulative blows, (b) DCPI, and (c) DCP-CBR

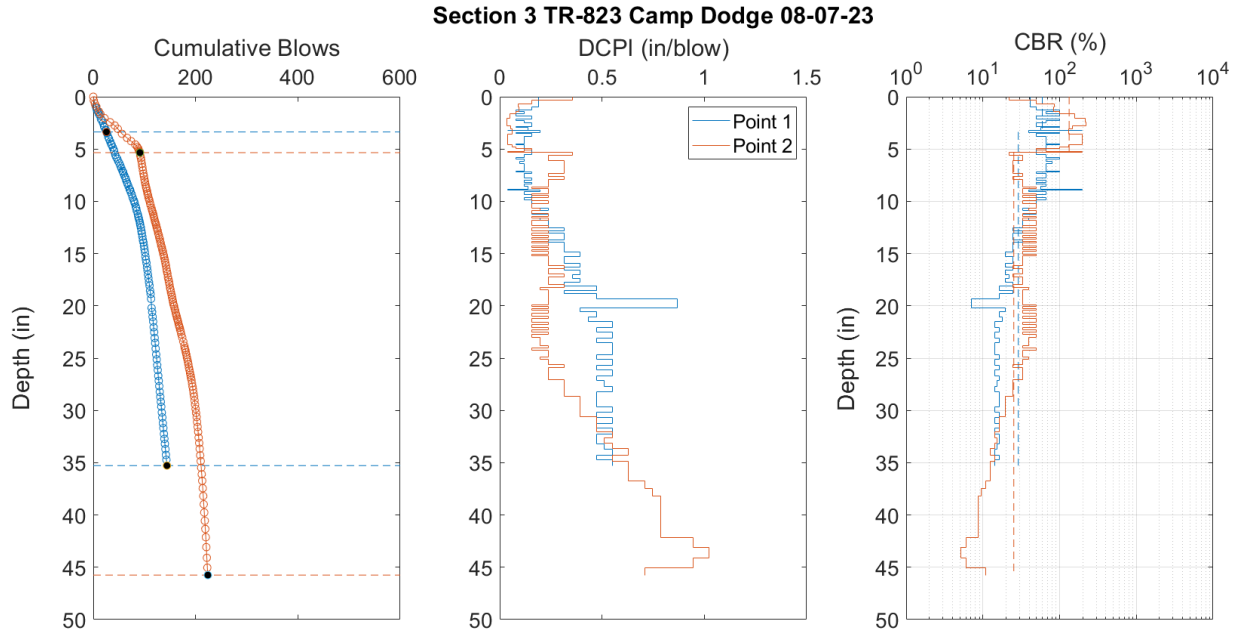


Figure 65. Pre-construction ADCP results for Section 3: (a) cumulative blows, (b) DCPI, and (c) DCP-CBR

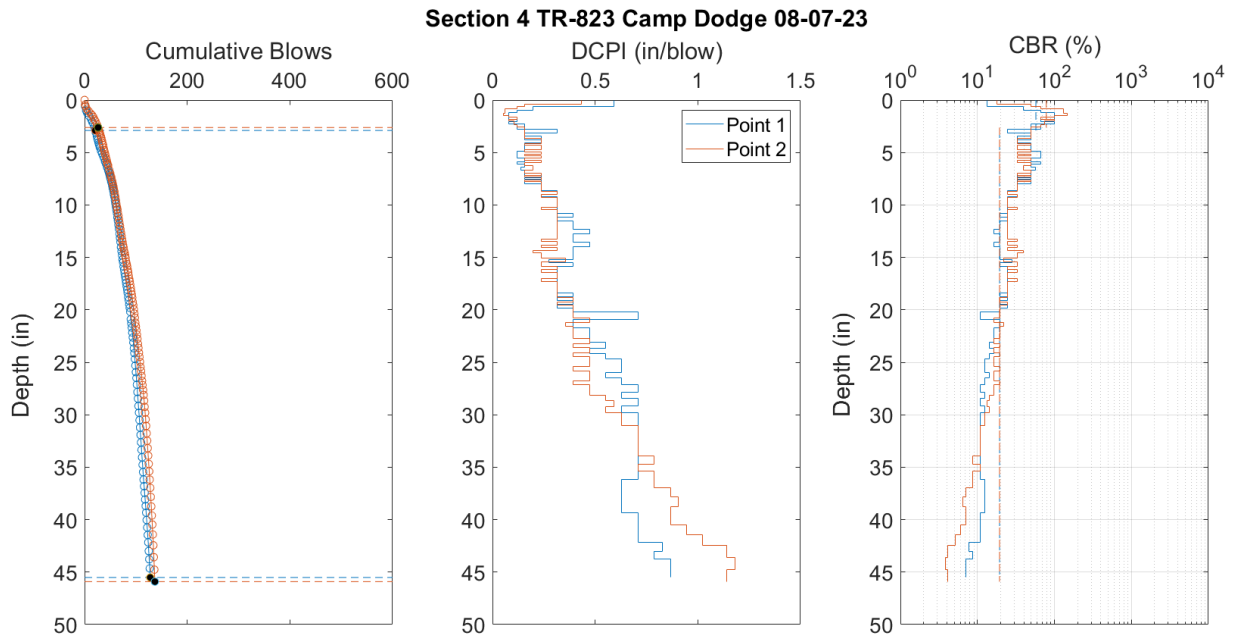


Figure 66. Pre-construction ADCP results for Section 4: (a) cumulative blows, (b) DCPI, and (c) DCP-CBR

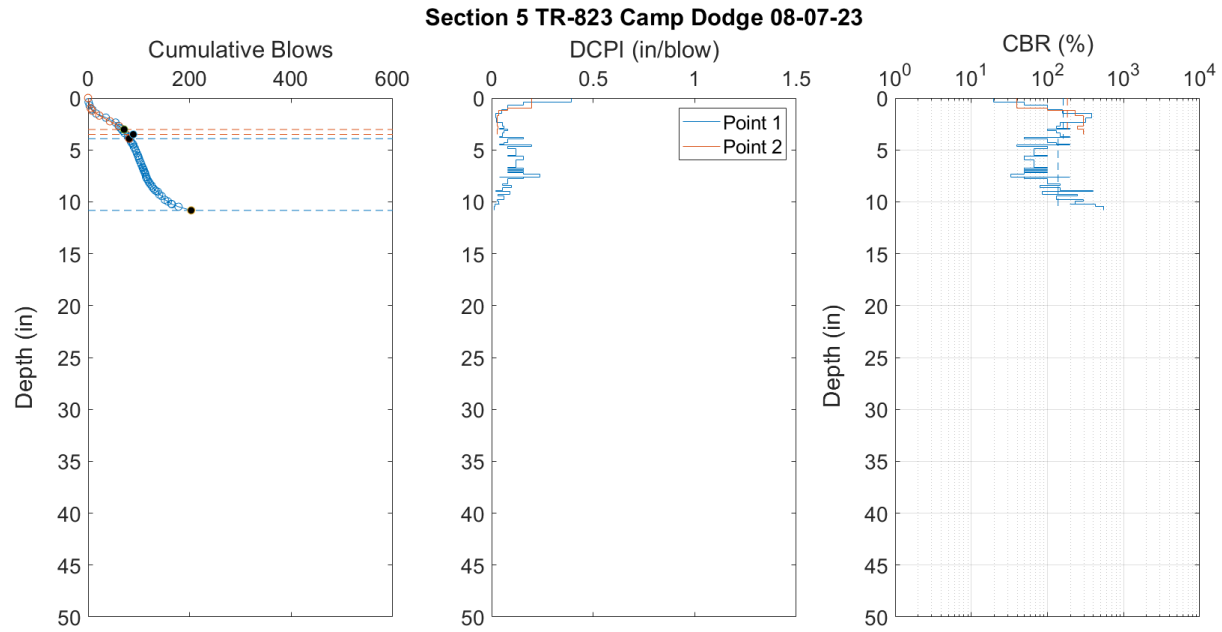


Figure 67. Pre-construction ADCP results for Section 5: (a) cumulative blows, (b) DCPI, and (c) DCP-CBR

To classify the condition of the surface and subgrade layers using their measured average CBR values, the relative strength rating system from the Iowa Statewide Urban Design and Specifications (SUDAS) *Design Manual* was applied. The SUDAS rating criteria are presented in Table 8. The pre-construction ADCP test results and corresponding SUDAS strength ratings for all five test sections are summarized in Table 9.

Table 8. Rating criteria of subbase and subgrade layers based on CBR values

Material	CBR (%)	Rating
Subbase	> 80	E (excellent)
	50–80	VG (very good)
	30–50	G (good)
Subgrade	20–30	VG (very good)
	10–20	F-G (fair–good)
	5–10	P-G (poor–fair)
	< 5	VP (very poor)

Source: SUDAS 2015

Table 9. Summary of pre-construction ADCP results for the five test sections

Section	Test Point	Thickness of Surface Course (in.)	Avg. DCP-CBR _{AGG} (%)	Rating	Avg. DCP- CBR _{SG} (%)	Rating
Section 1	1	4.7	305	E	Refusal at 5.0 in	-
	1b	6.2	243	E	Refusal at 12.3 in	-
	2	3.5	86	E	22	VG
	Avg.	4.8	211.3	E	22	VG
	COV	28.2%	53.4%		-	
Section 2	1	6.3	225	E	26	VG
	2	4.2	128	E	59	VG
	Avg.	5.3	176.5	E	42.5	VG
	COV	28.3%	38.9%		54.9%	
Section 3	1	3.5	78	VG	34	VG
	2	5.3	191	E	36	VG
	Avg.	4.4	134.5	E	35	VG
	COV	28.9%	59.4%		4.0%	
Section 4	1	2.9	75	VG	22	VG
	2	2.6	106	E	23	VG
	Avg.	2.8	90.5	E	22.5	VG
	COV	7.7%	24.2%		3.1%	
Section 5	1	3.8	245	E	Refusal at 10.9 in	-
	2	3.2	280	E	Refusal at 3.1 in	-
	Avg.	3.5	262.5	E	-	
	COV	12.1%	9.4%		-	

E = excellent, VG = very good, Avg. = average, COV = Coefficient of variation

The results from Table 9 show that at the time of the pre-construction tests, the average Iowa SUDAS support ratings for the surface courses were excellent for all five test sections. For the subgrades, the average Iowa SUDAS relative support ratings were Very Good in Sections 1 through 4. A subgrade rating could not be determined for Section 5 due to the ADCP test refusals, but the very high blow counts mean that it would classify as the maximum subgrade rating of Very Good. The average DCP-CBR values for the surface course and subgrade layers for the five test sections are also plotted in Figure 68 and Figure 69, which show that the surface course DCP-CBR values were erratic while the subgrade values were lower but more uniform.

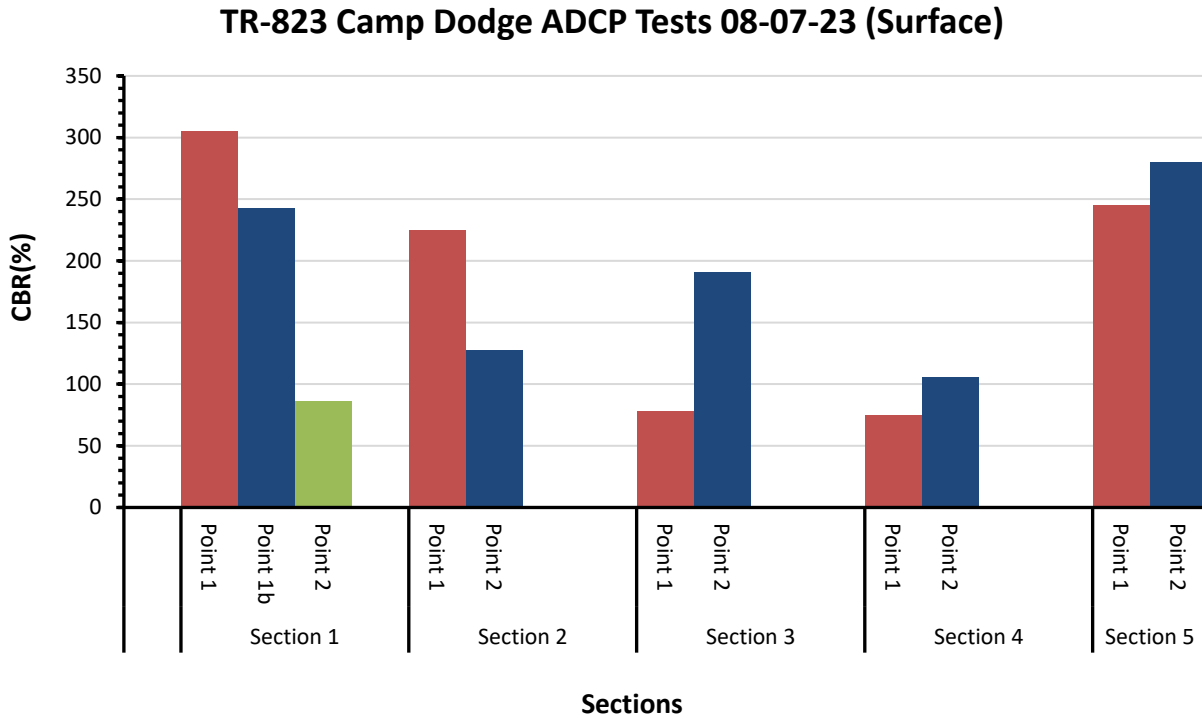


Figure 68. Pre-construction surface ADCP results for the five test sections

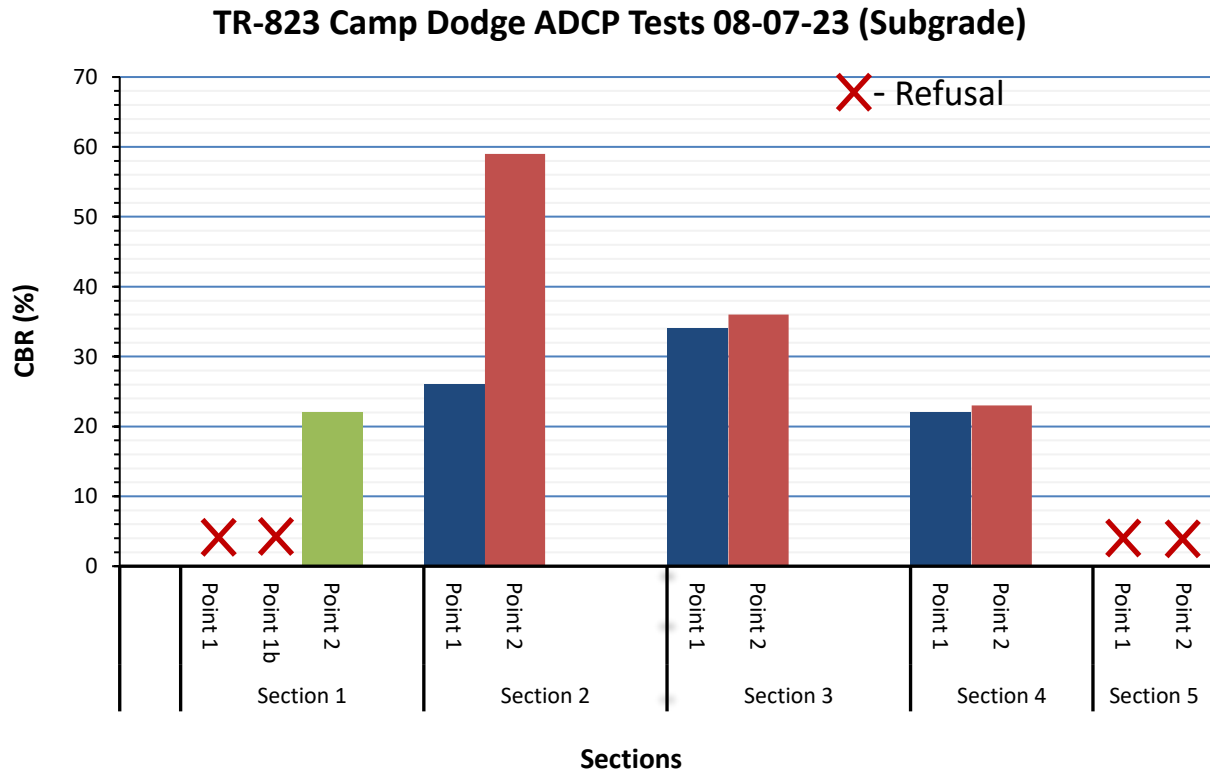


Figure 69. Pre-construction subgrade ADCP results for the five test sections

6.1.2 Results of LWD Tests Before Construction

To obtain a rough understanding of the composite elastic modulus of each test section prior to construction, two LWD tests were performed per section. For Sections 1 and 2, tests were conducted at distances of 500 ft and 1,000 ft from the start of the test sections. For Sections 3, and 4, test locations were set at 220 ft and 440 ft from the start, while for Section 5 they were set at 440 ft and 880 ft from the start. The pre-construction LWD results are shown in Figure 70, with a summary provided in Table 10 in terms of the average value and coefficient of variation (COV). The small sample size of only two test points per section precludes the use of more detailed statistical descriptors. The results showed considerable variability, with Section 3 having the highest average E_{LWD} value (16.3 ksi) and the most consistent results (COV 10.2%). Section 4 had the lowest stiffness (10.8 ksi) with moderate variability (COV 15.2%). Sections 1 had a low stiffness (11.9 ksi) and the highest variability (COV 28.6%), suggesting uneven compaction or mixed materials. Sections 2 and 5 showed similar moderate stiffness values (13.1 and 13.9 ksi) but quite different COVs of 22.4% and 10.8%, respectively.

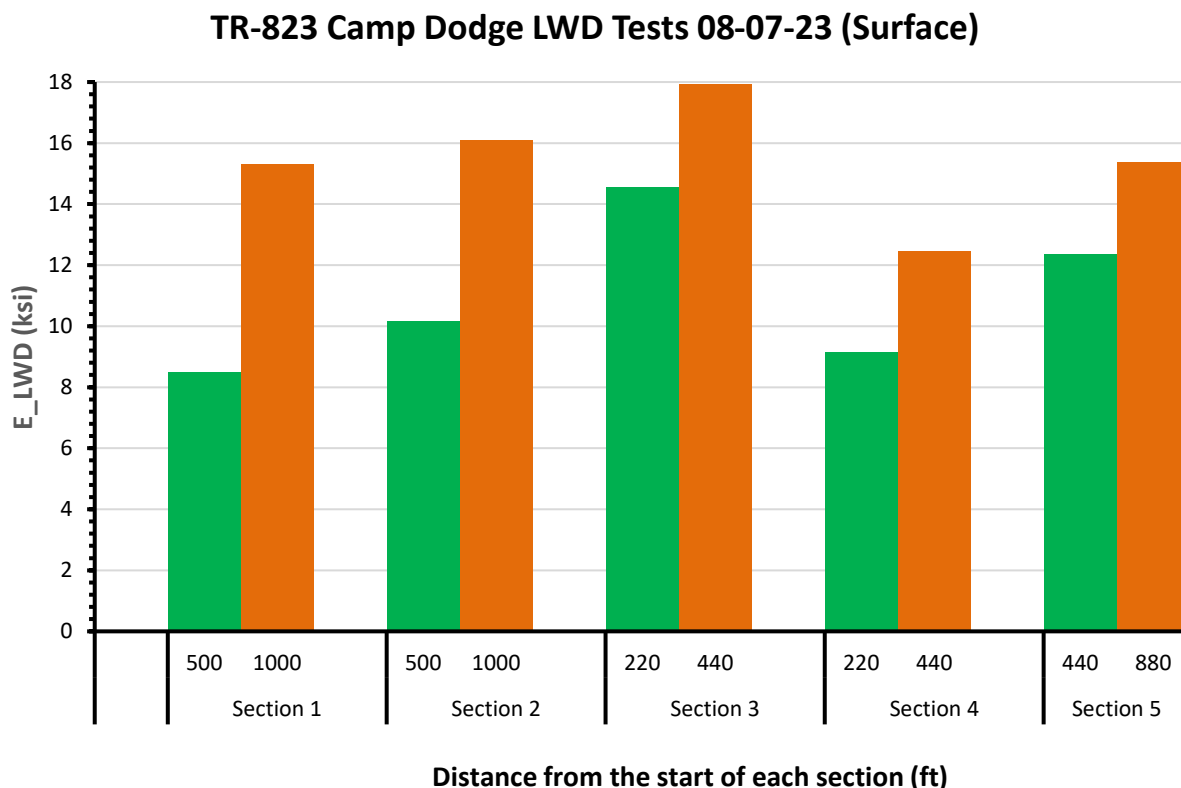


Figure 70. Pre-construction LWD results for the five test sections

Table 10. Summary of pre-construction LWD test results

Result	Section 1	Section 2	Section 3	Section 4	Section 5
Average E_{LWD} (ksi)	11.9	13.1	16.3	10.8	13.9
COV	28.6%	22.4%	10.2%	15.2%	10.8%

6.2 Field and Laboratory Tests After Construction

After construction, several series of field and laboratory tests were conducted over two fall-spring cycles to evaluate the relative performance of the test sections through changes in their subgrade and surface properties after the sections were subjected to freezing and thawing conditions. The field tests included ADCP and LWD tests to measure the strength and stiffness of the test sections. Samples of the top 4 in. of the roadway surface were also collected during each round of testing by using a hammer drill with a flat chisel bit to loosen the crust. The laboratory tests performed on the surface aggregate samples included sieve analysis, hydrometer tests, and Atterberg limits tests to evaluate changes in particle size distributions, particle breakage, and soil index properties over time.

6.2.1 Results of ADCP Tests After Construction

ADCP tests were performed to monitor changes in the strength of the aggregate surface layer and the subgrade. Selected results from these tests are presented in this section, and the entire data set of ADCP results from all testing periods after construction is provided in Appendix B.

The ADCP data were analyzed using the equations described in Chapter 3 to calculate the DCP index and estimate the field CBR values through empirical correlations. The Iowa SUDAS ratings shown in Table 8 were also computed for the surface and subgrade layers based on the CBR values. A summary of the results is provided in Table 11 through Table 14, with corresponding graphical plots of the data in Figure 71 through Figure 79.

Table 11. Summary of fall 2023 ADCP tests

Section	Test Point	Thickness of Surface Course (in.)	Avg. DCP-CBR_{AGG} (%)	Rating	Avg. DCP-CBR_{SG} (%)	Rating
Section 1	1	3.4	165	E	Refusal at 8.0 in	-
	1b	3.7	117	E	121	VG
	2	3.7	430	E	68	VG
	3	4.4	711.2	E	Refusal at 5.1 in	-
	3b	3.3	831.6	E	Refusal at 3.7 in	-
	Avg.	3.7	451.0	E	94.5	VG
Section 2	1	3.2	571	E	Refusal at 6.8 in	-
	2	3.8	706	E	Refusal at 3.9 in	-
	3	5.3	382	E	136	VG
	Avg.	4.1	553	E	136	VG
Section 3	1	3.7	143	E	35	VG
	2	3.7	90	E	Refusal at 8.0	-
	2b	5.7	93	E	Refusal at 8.0	-
	3	3.5	107	E	68	VG
	Avg.	4.2	108.3	E	51.5	VG
Section 4	1	2.6	87	E	48	VG
	2	2.7	96	E	Refusal at 12.9 in	VG
	2b	3.0	84	E	39	VG
	3	2.8	88	E	36	VG
	Avg.	2.8	88.8	E	41	VG
Section 5	1	Refusal	-	-	-	-
	1b	Refusal	-	-	-	-
	2	3.7	670	E	Refusal at 3.7 in	-
	3	Refusal	-	-	-	-
	3b	2.3	556	E	Refusal at 2.3 in	-
	Avg.	3.0	613	E	-	-

E = excellent, VG = very good

Table 12. Summary of spring 2024 ADCP tests

Section	Test Point	Thickness of Surface Course (in.)	Avg. DCP-CBR_{AGG} (%)	Rating	Avg. DCP-CBR_{SG} (%)	Rating
Section 1	1	3.9	590	E	Refusal at 15.5 in	-
	1b	3.9	704	E	87	VG
	2	3.9	533	E	171	VG
	3	4.0	726	E	80	VG
	Avg.	3.9	638.3	E	112.7	VG
Section 2	1	3.8	918	E	Refusal at 4.9 in	-
	2	3.1	453	E	Refusal at 7.1 in	-
	2b	5.2	328	E	Refusal at 7.1 in	-
	3	4.1	200	E	38	VG
	Avg.	4.1	474.8	E	38	VG
Section 3	1	3.6	93	E	72	VG
	2	4.1	87	E	88	-
	3	3.7	186	E	Refusal at 10.2	-
	3b	3.8	128	E	Refusal at 9.9	VG
	Avg.	3.8	123.5	E	80	VG
Section 4	1	3.8	99	E	45	VG
	2	4.2	79	VG	Refusal at 8.2 in	-
	2b	4.2	88	E	Refusal at 8.4 in	-
	3	4.9	107	E	32	VG
	Avg.	4.3	93.3	E	38.5	VG
Section 5	1	3.9	1140	E	Refusal at 3.9 in	-
	2	3.9	855	E	Refusal at 3.9 in	-
	3	Refusal	-	-	-	-
	3b	4.6	382	E	Refusal at 4.6 in	-
	Avg.	4.1	792.3	E	-	-

E = excellent, VG = very good

Table 13. Summary of fall 2024 ADCP tests

Section	Test Point	Thickness of Surface Course (in.)	Avg. DCP-CBR_{AGG} (%)	Rating	Avg. DCP-CBR_{SG} (%)	Rating
Section 1	1	5.3	122	E	Refusal at 16.4 in	-
	2	3.7	176	E	72	VG
	3	3.9	154	E	41	VG
	Avg.	4.3	150.7	E	56.5	VG
Section 2	1	3.7	328	E	Refusal at 6.4 in	-
	2	3.2	136	E	Refusal at 5.5 in	-
	3	3.2	240	E	Refusal at 5.4 in	-
	Avg.	3.4	234.7	E	-	VG
Section 3	1	3.9	61	E	29	VG
	2	3.6	67	E	Refusal at 7.4	-
	3	3.9	82	E	82	VG
	Avg.	3.8	70.0	E	55.5	VG
Section 4	1	4.5	64	VG	62	VG
	2	4.0	54	VG	Refusal at 9.1 in	-
	3	4.4	54	VG	52	VG
	Avg.	4.3	57.3	E	57.0	VG
Section 5	1	Refusal	-	-	-	-
	2	3.8	622	E	Refusal at 4.9 in	-
	3	2.3	290	E	Refusal at 3.7 in	-
	Avg.	3.1	456.0	E	-	-

E = excellent, VG = very good

Table 14. Summary of spring 2025 ADCP tests

Section	Test Point	Thickness of Surface Course (in.)	Avg. DCP-CBR_{AGG} (%)	Rating	Avg. DCP-CBR_{SG} (%)	Rating
Section 1	1	6.7	157	E	57	VG
	2	6.7	193	E	65	VG
	3	6.6	217	E	48	VG
	Avg.	6.7	189.0	E	56.7	VG
Section 2	1	4.1	123	E	Refusal at 6.9 in	-
	2	4.2	91	E	Refusal at 5.0 in	-
	3	4.3	433	E	Refusal at 4.4 in	-
	3b	3.9	414	E	Refusal at 5.4 in	-
	Avg.	4.1	265.3	E	-	VG
Section 3	1	5.8	82	E	Refusal at 7.4	-
	2	6.1	45	G	41	VG
	3	6.4	98	E	29	VG
	Avg.	6.1	75.0	E	35	VG
Section 4	1	5.1	61	VG	Refusal at 7.5 in	-
	2	5.4	53	VG	Refusal at 8.4 in	-
	2b	5.8	72	VG	38	VG
	3	4.3	48	VG	Refusal at 6.2 in	-
	Avg.	5.2	58.5	VG	38.0	VG
Section 5	1	5.6	330	E	27	VG
	2	5.5	288	E	74	VG
	3	3.2	376	E	Refusal at 3.4 in	-
	Avg.	4.8	331.3	E	50.5	-

E = excellent, G = good, VG = very good

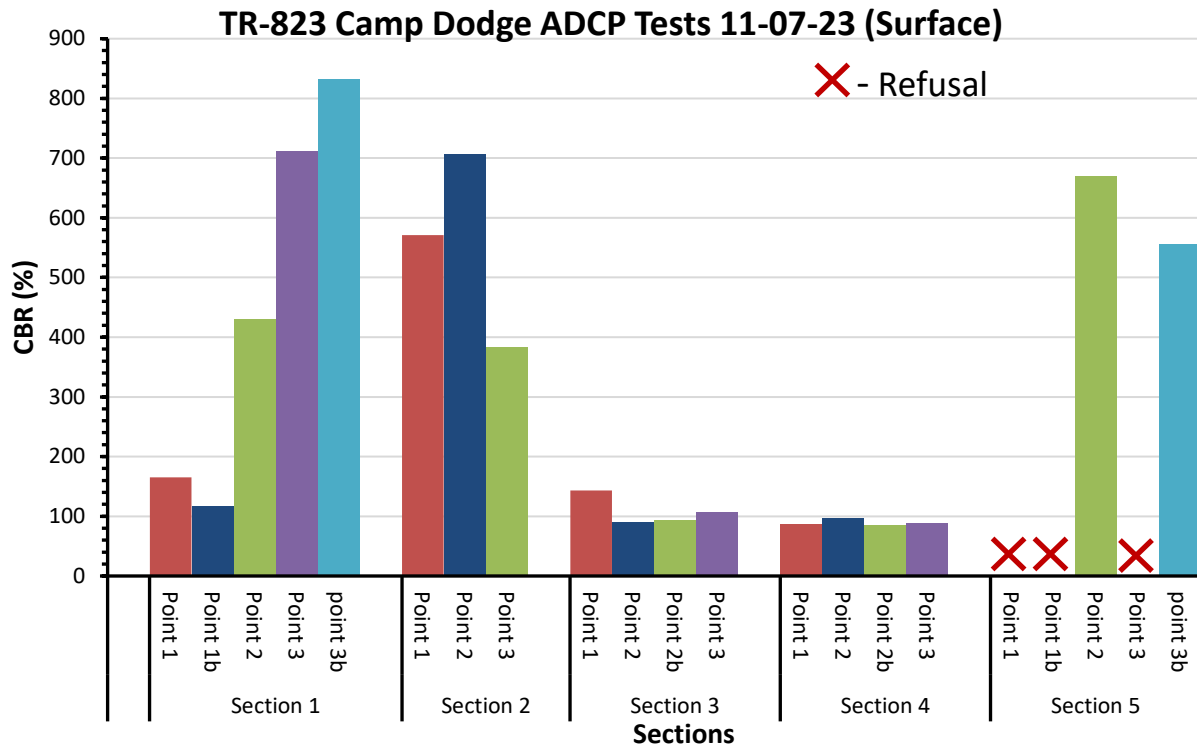


Figure 71. Surface ADCP results for fall 2023

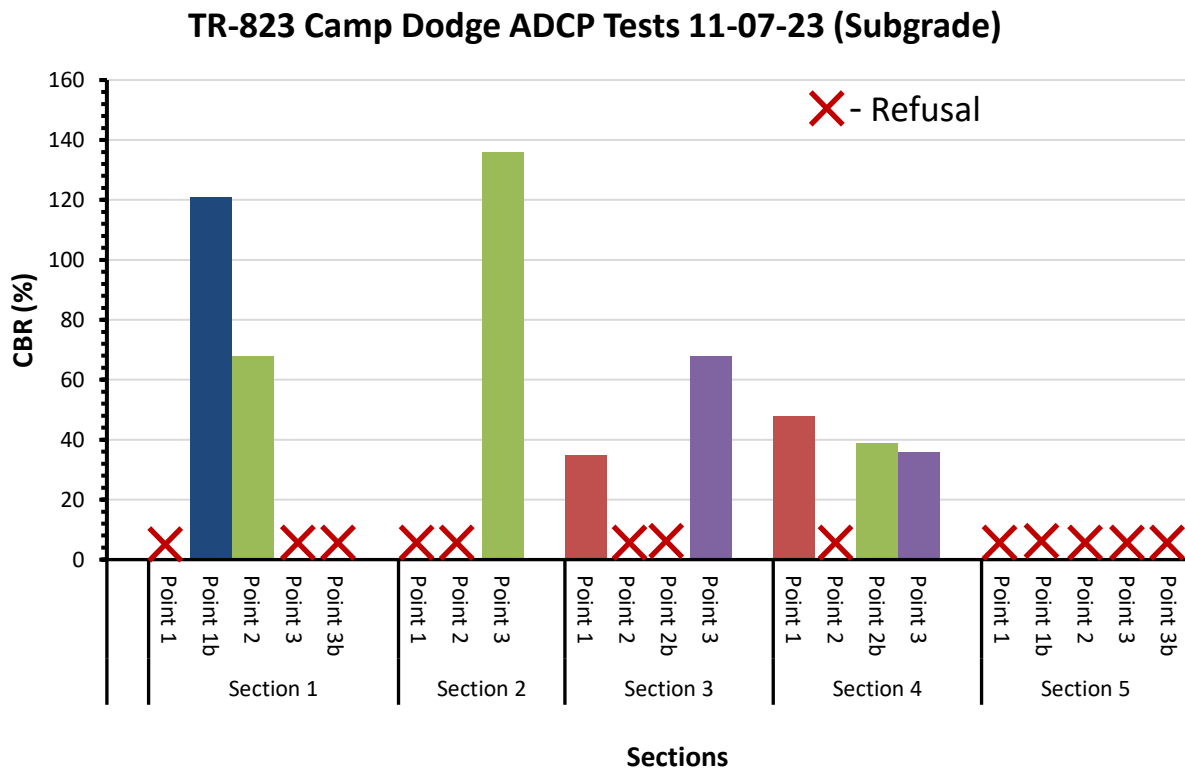


Figure 72. Subgrade ADCP results for fall 2023

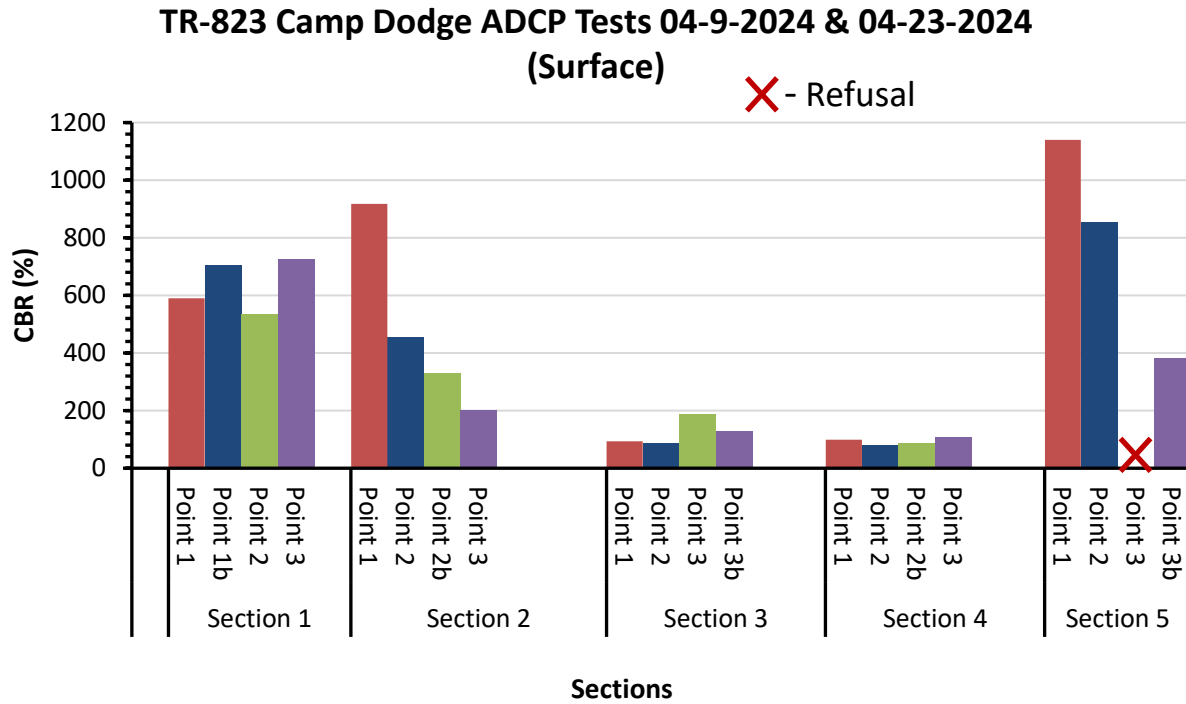


Figure 73. Surface ADCP results for spring 2024

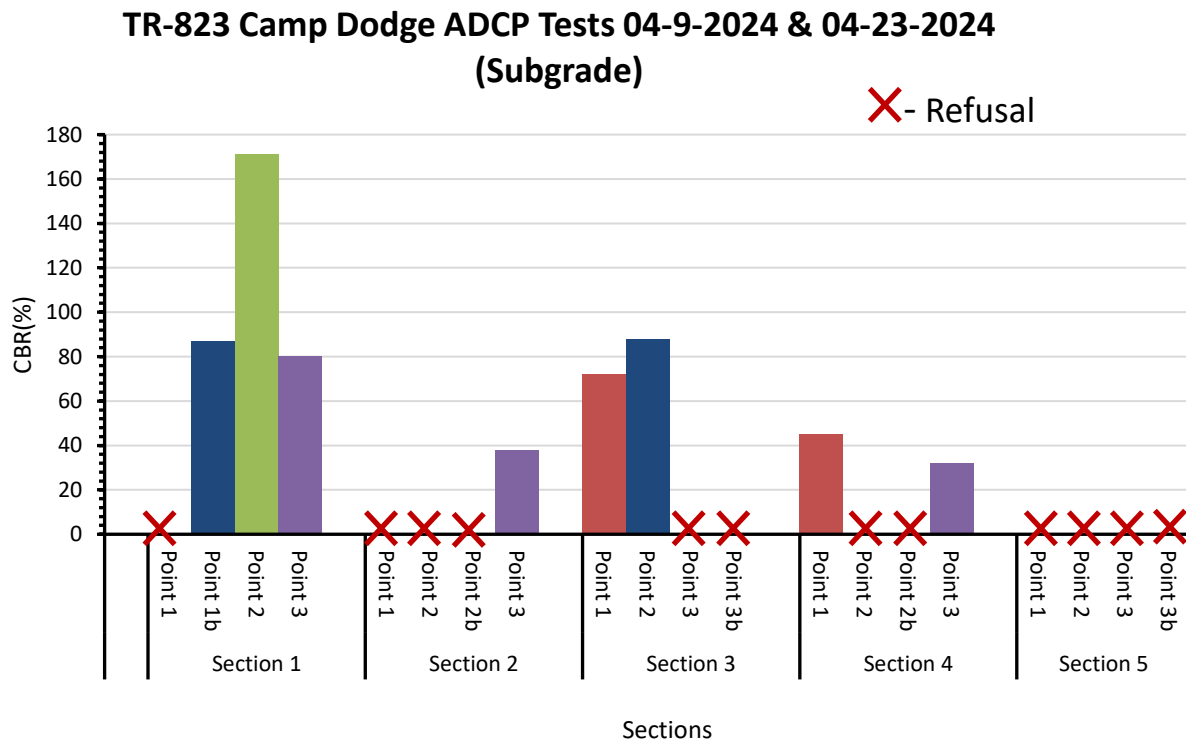


Figure 74. Subgrade ADCP results for spring 2024

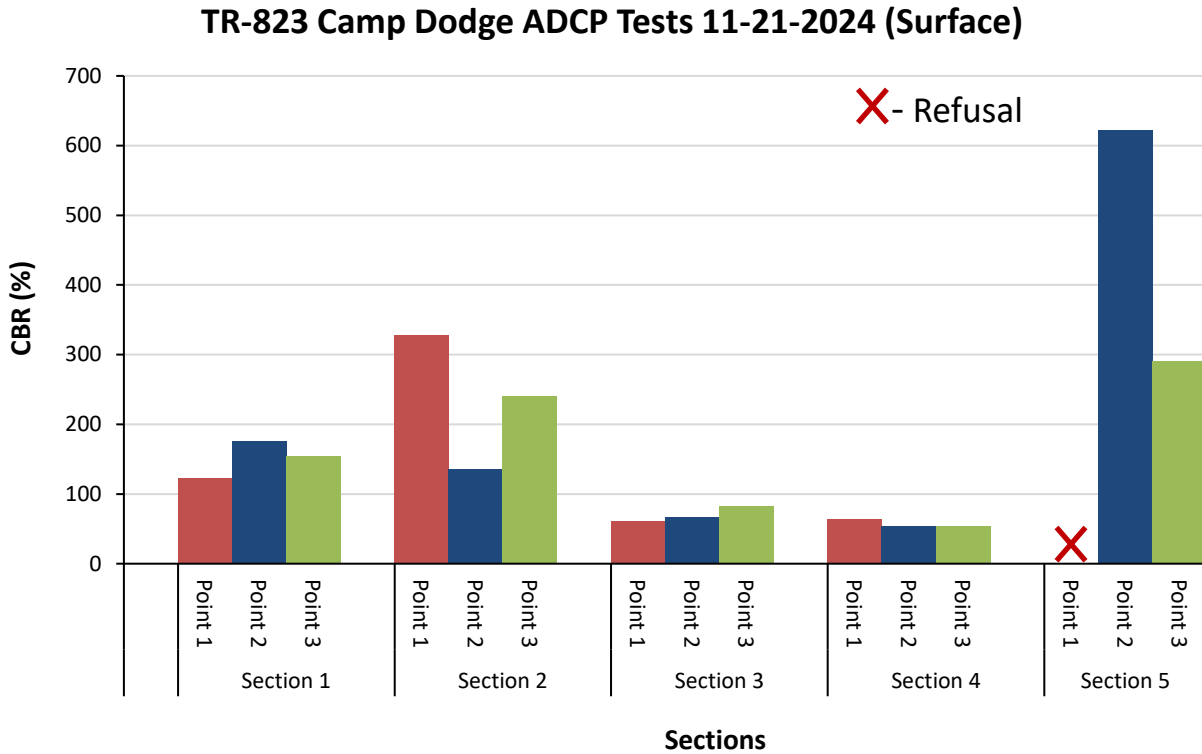


Figure 75. Surface ADCP results for fall 2024

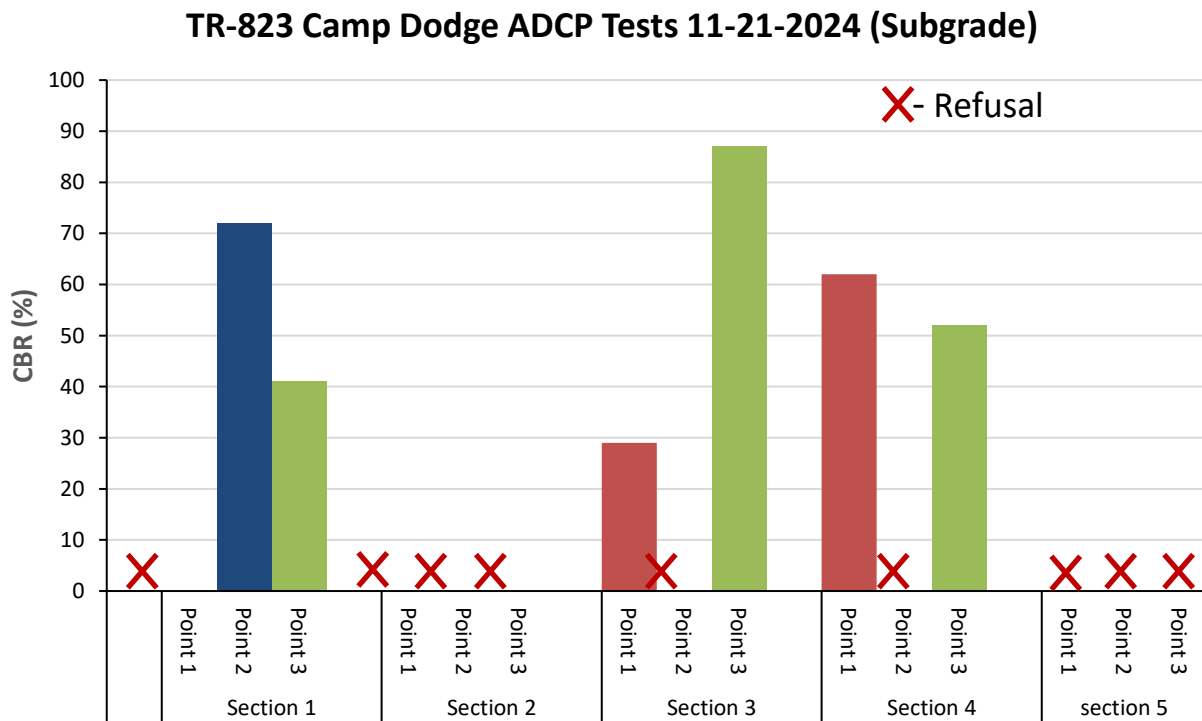


Figure 76. Subgrade ADCP results for fall 2024

**TR-823 Camp Dodge ADCP Tests 04-1-2025 & 04-8-2025
(Surface)**

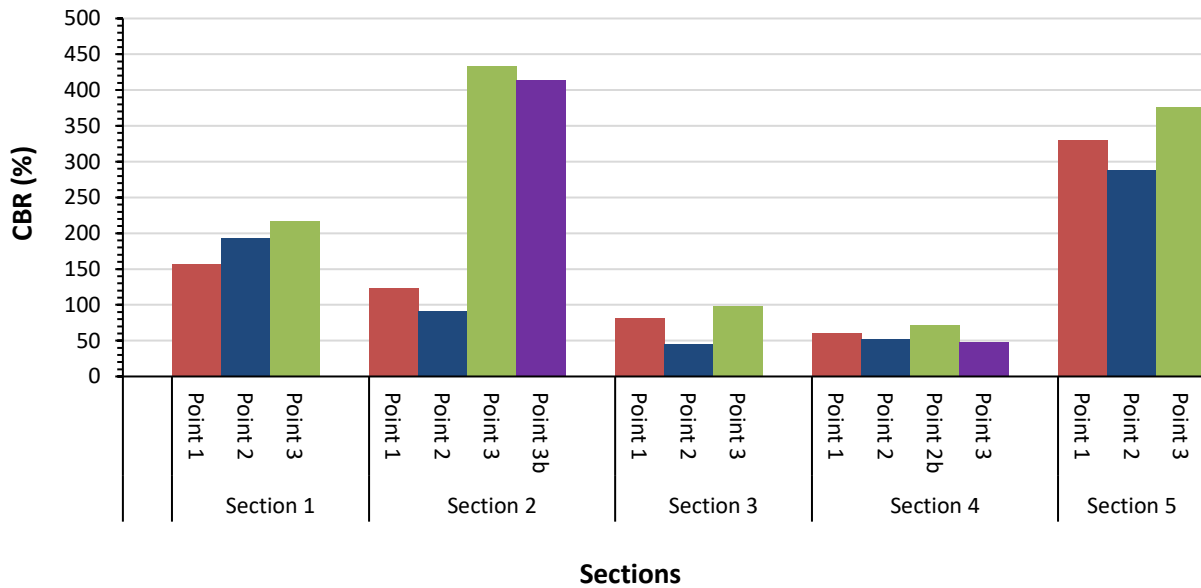


Figure 77. Surface ADCP results for spring 2025

**TR-823 Camp Dodge ADCP Tests 4-01-2024 & 04-08-2025
(SUBGRADE)**

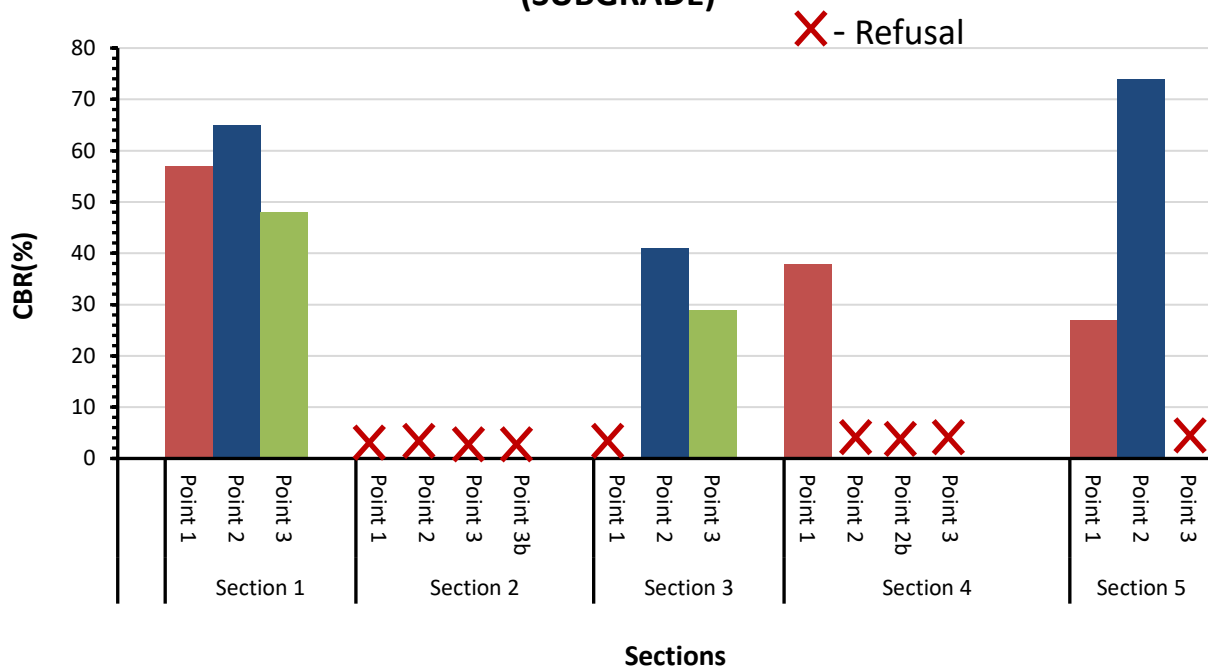
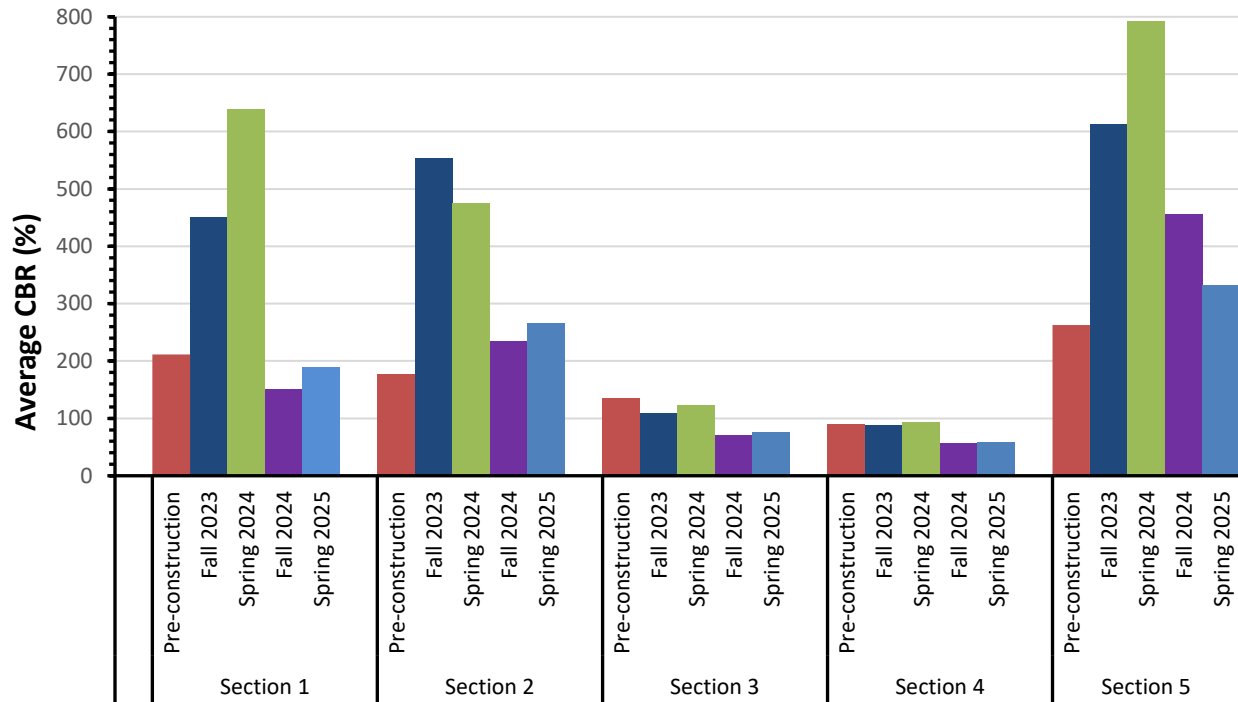
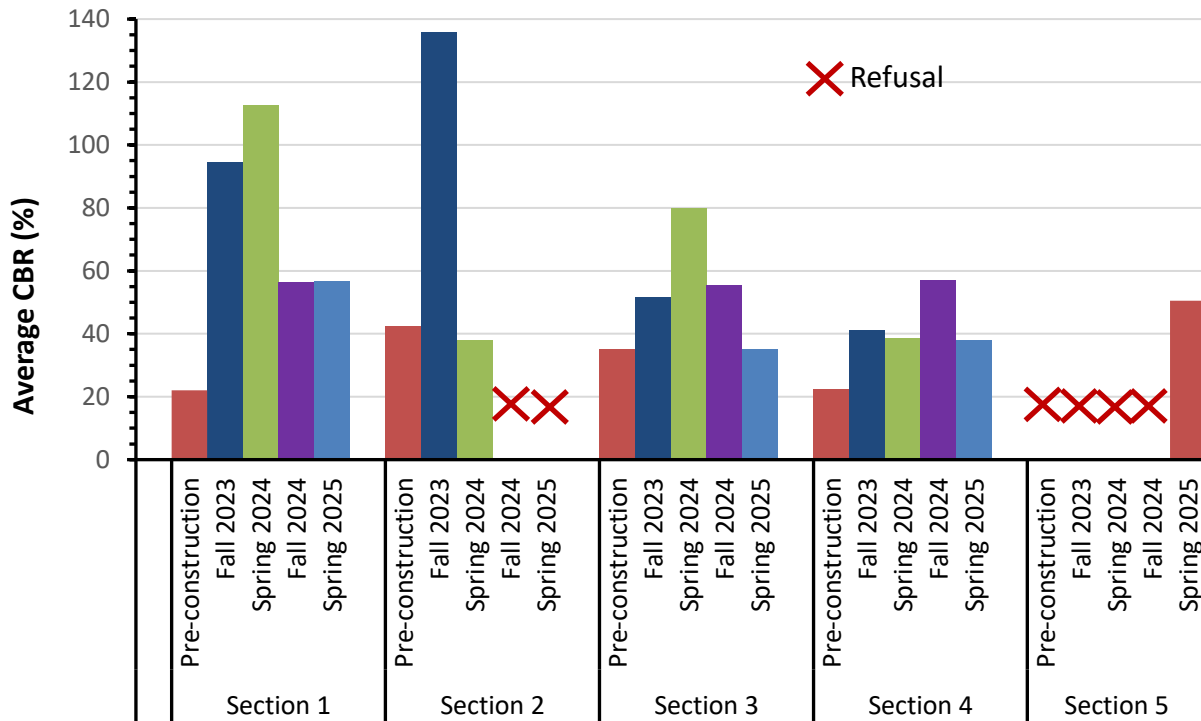


Figure 78. Subgrade ADCP results for spring 2025



(a)



(b)

Figure 79. Variation of CBR of test sections over time: (a) surface layer, (b) subgrade layer

For the rehabilitated Sections 1 through 4, the average field CBR of the surface course showed a general increase after construction by fall 2023, with the exception of Section 3 (Figure 79a). This increase reflects the initial improvement in surface strength following reconstruction and compaction. From fall 2023 to spring 2024, the average surface CBR of Section 1 increased significantly again by 42%, while that of Section 2 decreased by 14%. Over the same timeframe, Sections 3 and 4 showed slight increases of 14% and 5%, respectively. However, between spring 2024 and fall 2024, these four sections experienced significant decreases in field CBR values, which can likely be attributed to high precipitation during that period, leading to increased moisture content and reduced surface stiffness. By spring 2025, the surface CBR began to recover slightly across Sections 1 through 4, though not to the levels observed immediately after construction.

Section 5, the control section, consistently exhibited the highest surface CBR values throughout the monitoring period. This is due to the long-term effects of repeated heavy military traffic, which resulted in an extremely dense, well-compacted subgrade and a hardened surface layer that was not excavated and recompacted like in Sections 1 through 4. The heaviest vehicle on these roads is an 8x8 Heavy Expanded Mobility Tactical Truck (HEMTT) fueler having a gross weight of 64,000 lb and only 8 tires, giving a load per tire 1.8 times that of a fully loaded 80,000 lb tractor trailer with 18 tires. It is important to note that the goal of the rehabilitation in Sections 1 through 4 was not to exceed the strength of the control section, as ripping and rebuilding the profiles of Sections 1 through 4 involved less compaction than decades of traffic over Section 5 by the heavy military vehicles. Instead, the primary goal was to restore the proper road profile and drainage functionality, which are essential for long-term performance and resilience. The surface of Section 5 remained flat with virtually no ditches and therefore poor drainage capacity.

Among the rehabilitated sections, Sections 1 and 2, which had been treated with enzymatic stabilizer, consistently exhibited higher surface CBR values than Sections 3 and 4, which had been constructed without the stabilizer (Figure 79a). In all test periods except for spring 2024, Section 2, which used sheepsfoot compaction, achieved slightly higher field CBR values than Section 1, which was compacted with a smooth-tired roller. The unstabilized Sections 3 and 4 exhibited only minor differences in field CBR between the two compaction methods, with slightly higher values consistently observed in Section 3, which had been constructed with smooth-tired compaction.

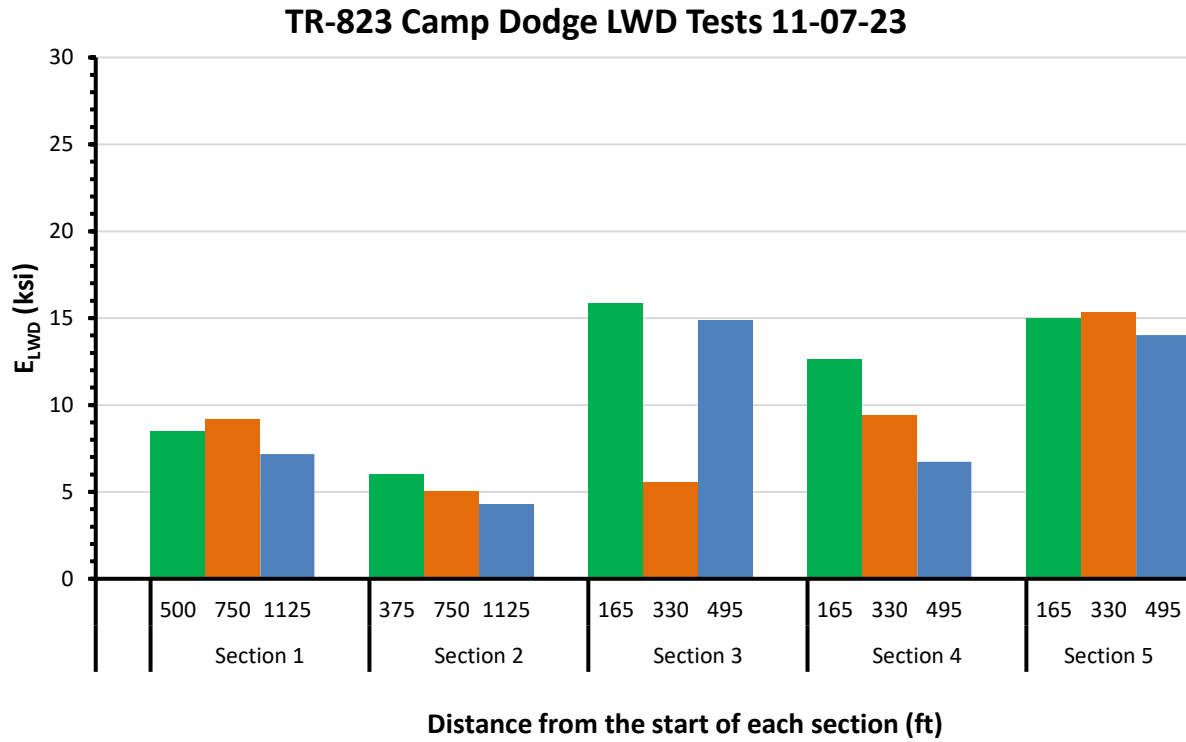
Subgrade CBR values followed similar trends to those of the surface layers, with an initial improvement after construction that mostly continued through spring 2024 (Figure 79b), followed by a general reduction by spring 2025. This decrease is again likely due to seasonal freeze-thaw effects and high precipitation periods. Notably, Sections 1 and 2, which included enzymatic stabilizer, generally maintained higher subgrade CBR values compared to Sections 3 and 4, which did not include stabilizer, reinforcing the benefit of stabilization in improving not only the surface but also the underlying layers.

Subgrade CBR data collection faced significant challenges due to the presence of large cobbles, boulders, and buried construction debris, which led to multiple ADCP refusals and damaged cone tip adapters, particularly in Sections 2 and 5. In Section 5, only one successful test was

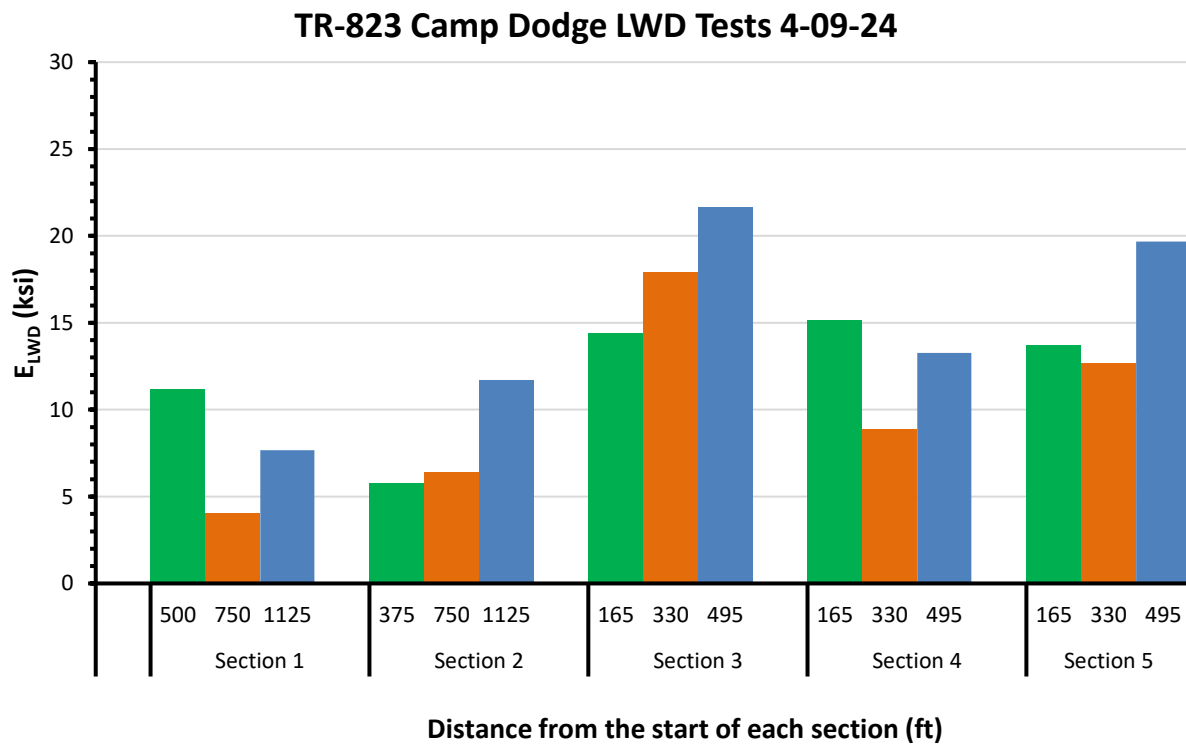
achieved out of over 15 attempts, but it yielded the highest subgrade CBR value among all sections, confirming the exceptionally high strength of the undisturbed subgrade in the vicinity of the control section. At the end of this test, the soil resistance was so high that the rod could not be extracted by the ADCP device, requiring it to be extracted by drilling several feet into the ground with a hammer drill, pouring water down the hole, and pulling up while rotating the rod to break the soil adhesion.

6.2.2 Results of LWD Tests After Construction

To evaluate and monitor changes in the composite elastic modulus (E_{LWD}) after construction, three LWD tests per section were performed in each fall and spring over the two-year project duration. The individual LWD test results from each testing period are shown in Figure 80 and Figure 81. Each section's average composite elastic modulus value over time is presented graphically in Figure 82 and summarized in Table 15. As shown in Figure 82 and Table 15, the average E_{LWD} values for the rehabilitated Sections 1 through 4 showed an initial decrease after construction by fall 2023, followed by a general increasing trend over time through spring 2025. The initial drop in stiffness likely reflects the effects of construction disturbance, increased moisture, and lack of long-term particle interlock immediately after rebuilding. Over time, the modulus values improved as consolidation and particle breakage (resulting in more well-graded distributions) took place under traffic and environmental exposure.

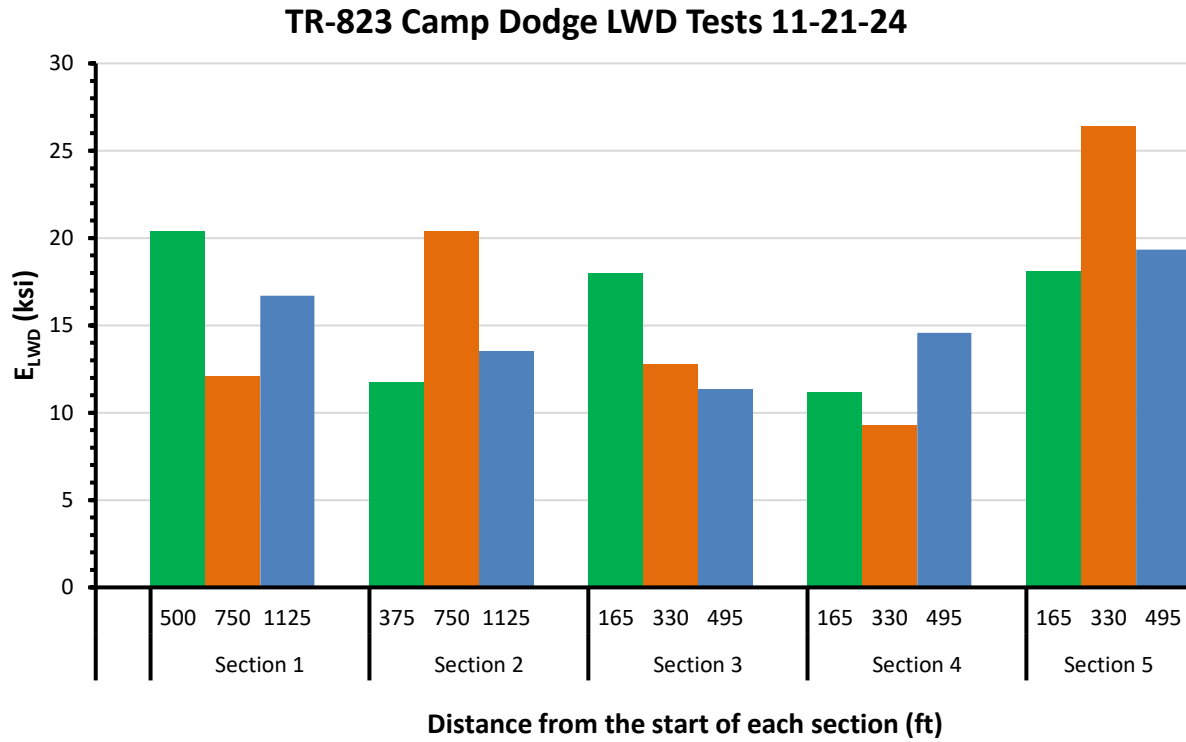


(a)

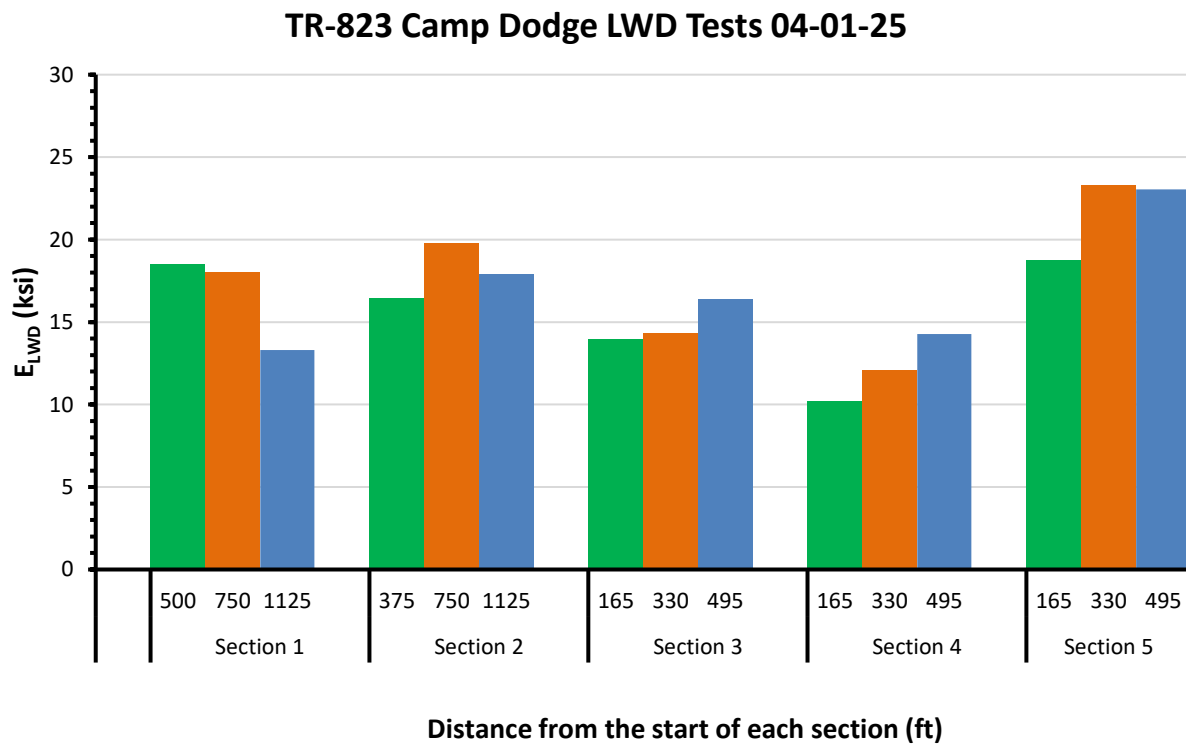


(b)

Figure 80. LWD results for (a) fall 2023 and (b) spring 2024



(a)



(b)

Figure 81. LWD results for (a) fall 2024 and (b) spring 2025

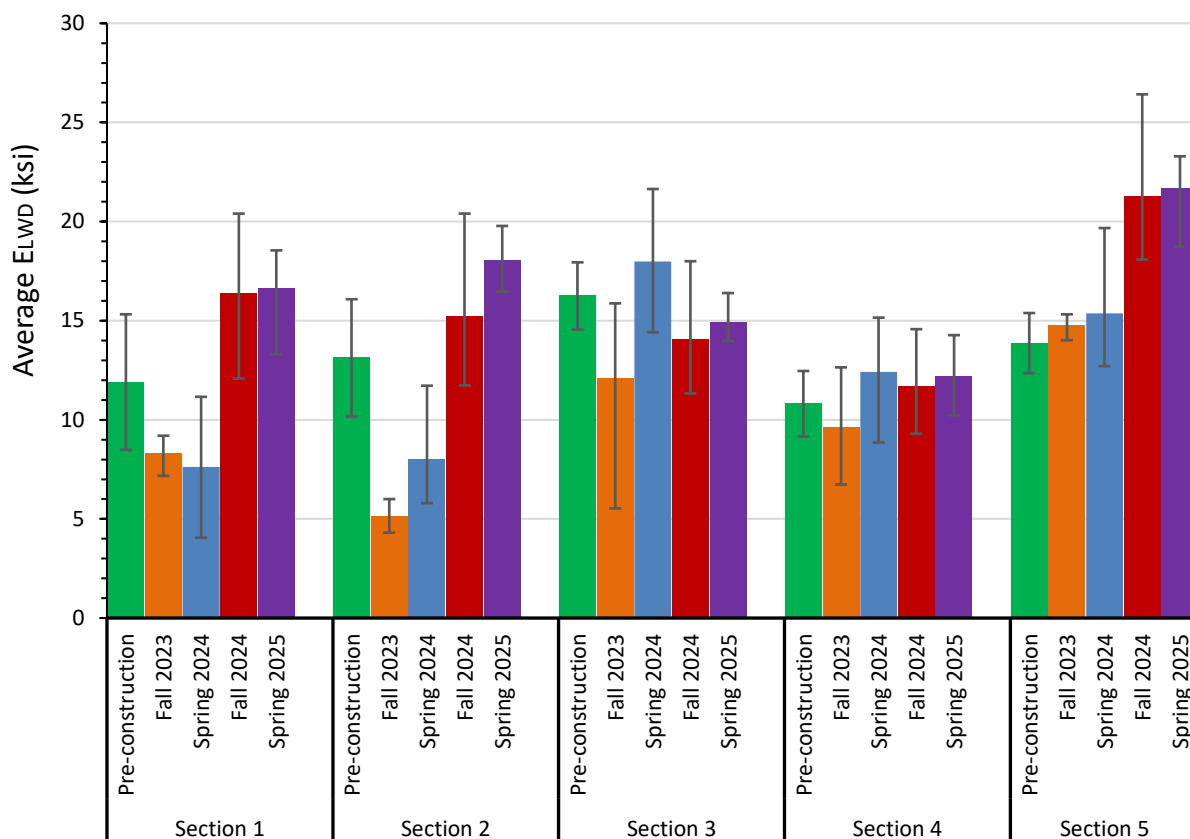


Figure 82. Average composite elastic modulus of test sections over time (bars indicate range of measured values)

Table 15. Summary of LWD test results (average ELWD [ksi]) of test sections over time

Section	Pre-construction	Fall 2023	Spring 2024	Fall 2024	Spring 2025
1	11.9	8.3	7.6	16.4	16.6
2	13.1	5.1	8.0	15.2	18.0
3	16.2	12.1	18.0	14.0	14.9
4	10.8	9.6	12.4	11.7	12.2
5	13.9	14.8	15.4	21.3	21.7

Sections 1 and 2, which were treated with enzymatic stabilizer and therefore required a significant volume of water, started with lower modulus values in fall 2023 compared to Sections 3 and 4, which were compacted without stabilizer and used less water (Figure 82). Specifically, Section 2 had the lowest initial post-construction modulus at 5.1 ksi in fall 2023, likely due to a higher moisture content temporarily softening the material. However, by fall 2024 and spring 2025, both Sections 1 and 2 showed a strong recovery by more than doubling in stiffness. Section 1 reached 16.4 ksi and 16.6 ksi in fall 2024 and spring 2025, respectively, while Section 2 reached 15.2 ksi and 18.0 ksi (Table 15). These values exceeded the final values of the untreated sections. The benefits of enzymatic stabilization were therefore observed to increase over time, likely due to continued curing providing improved bonding between particles.

Section 3, which had the highest pre-construction modulus of 16.2 ksi, showed a temporary 25% drop in fall 2023 but recovered to 18.0 ksi in spring 2024 before slightly decreasing and stabilizing around 14.0 to 14.9 ksi, indicating some initial compaction benefit but less overall long-term gain compared to the chemically stabilized sections. Section 4 followed a similar pattern to Section 3 but with lower overall values.

Section 5, the control section, consistently showed the highest modulus values across all test dates, reflecting its long-term compaction history and dense clay subgrade. This is consistent with the previously reported high field CBR values for the section. As previously stated, the purpose of the control section was to understand how the aggressive rebuilding of a roadway cross section would change the conditions of that road relative to the surrounding roads. It was anticipated that the stiffness and strength of the newly rebuilt profiles in Sections 1 through 4 would not exceed those of the very dense and compacted control section. Rather, increasing the roadway elevation and restoring the drainage ditches by rebuilding the roadway cross-sectional profile was intended to improve the drainage capacity of the rehabilitated sections relative to the control section.

Among the chemically stabilized Sections 1 and 2, no consistent long-term trend was observed between the two subgrade compaction types. Among the untreated Sections 3 and 4, the modulus was consistently 15% to 30% higher in Section 3, which had been constructed with smooth-tired compaction, than in Section 4, which had been constructed with sheepsfoot compaction. These results suggest that when enzymatic chemical stabilization is used, compaction type alone may have a limited long-term influence on stiffness. However, in the absence of enzymatic stabilization, long-term modulus improvements were more significant when using smooth-tired compaction on the subgrade.

6.2.3 Particle Size Distribution Test Results

During each round of field testing from spring 2024 onward, samples of surface materials were collected from all test sections (Figure 83). In each test section, the samples were obtained from two points in the wheel paths using a hammer drill with a chisel bit to loosen the top 4 in. of material (Figure 84). The two samples were then combined and mixed to obtain a representative sample for the section. Laboratory gradation tests were performed on the samples to track changes in PSD curves over time, from which aggregate breakage was quantified. Atterberg limits tests were also performed to determine the plasticity of the fines fractions. The resulting PSD curves are presented in Appendix A, and a summary of the corresponding particle size analysis results, Atterberg limits, and classification results are presented in Table 16 through Table 18 for spring 2024, fall 2024, and spring 2025. The corresponding results for fall 2023 after construction were previously provided in Chapter 4.



Figure 83. Sample materials collected during field testing



Figure 84. Method of collecting surface samples using hammer drill with chisel bit

Table 16. Index properties of surface materials from test sections on April 9, 2024

Parameter	Section 1	Section 2	Section 3	Section 4	Section 5
Particle-size analysis results (ASTM D422-03)					
Gravel content (%) (>4.75mm)	35.7	39.8	34.7	30.3	51.8
Sand content (%) (4.75mm-75µm)	39.3	38.3	40.5	41.7	35.6
Silt content (%) (75 µm-2µm)	19.2	16.2	16.8	20.0	9.1
Clay content (%) (< 2µm)	5.8	5.7	8.0	8.0	3.5
D ₁₀ (mm)	0.0058	0.0067	0.0038	0.0035	0.0188
D ₃₀ (mm)	0.172	0.234	0.189	0.108	1.289
D ₆₀ (mm)	3.474	4.697	3.365	2.083	7.826
Coefficient of uniformity, C _u	598.2	697.6	889.0	587.6	415.8
Coefficient of curvature, C _c	1.46	1.73	2.80	1.58	11.28
Atterberg limits (ASTM D4318-10e1)					
Liquid limit (%)	26	25	28	29	NP
Plastic limit (%)	12	12	21	26	NP
Plasticity index	14	13	7	3	NP
AASHTO and USCS soil classifications (AASHTO M 145-91 and ASTM D2487-11)					
AASHTO Classification	A-2-6(0)	A-2-6(0)	A-2-4(0)	A-2-4(0)	A-1-a
USCS group symbol	SC	GC	SC-SM	SM	GM
USCS group name	Clayey sand with gravel	Clayey gravel with sand	Silty, clayey sand with gravel	Silty sand with gravel	Silty gravel with sand

Table 17. Index properties of surface materials from test sections on November 21, 2024

Parameter	Section 1	Section 2	Section 3	Section 4	Section 5
Particle-size analysis results (ASTM D422-03)					
Gravel content (%) (>4.75mm)	40.9	36.8	33.9	27.7	57.5
Sand content (%) (4.75mm-75µm)	37.7	40.5	41.4	42.4	31.1
Silt content (%) (75 µm-2µm)	14.9	16.6	17.3	21.1	7.6
Clay content (%) (< 2µm)	6.5	6.1	7.4	8.8	3.8
D ₁₀ (mm)	0.0054	0.0045	0.0041	0.0025	0.0646
D ₃₀ (mm)	0.233	0.216	0.196	0.077	1.729
D ₆₀ (mm)	5.057	3.868	3.306	1.925	9.668
Coefficient of uniformity, C _u	929.7	862.7	815.0	772.1	149.6
Coefficient of curvature, C _c	1.97	2.69	2.86	1.22	4.78
Atterberg limits test results (ASTM D4318-10e1)					
Liquid limit (%)	26	25	26	29	NP
Plastic limit (%)	18	18	18	19	NP
Plasticity index	8	7	9	10	NP
AASHTO and USCS soil classifications (AASHTO M 145-91 and ASTM D2487-11)					
AASHTO Classification	A-2-4(0)	A-2-4(0)	A-2-4(0)	A-2-4(0)	A-1-a(0)
USCS group symbol	GC	SC-SM	SC	SC	GP-GM
USCS group name	Clayey gravel with sand	Silty, clayey sand with gravel	Clayey sand with gravel	Clayey sand with gravel	Poorly graded gravel with silt and sand

Table 18. Index properties of surface materials from test sections on April 1, 2025

Parameter	Section 1	Section 2	Section 3	Section 4	Section 5
Particle-size analysis results (ASTM D422-03)					
Gravel content (%) (>4.75mm)	32.2	38.8	36.3	26.7	54.4
Sand content (%) (4.75mm-75µm)	42.6	40.2	40.4	40.0	31.0
Silt content (%) (75 µm-2µm)	15.7	10.9	12.9	20.0	7.6
Clay content (%) (< 2µm)	9.5	10.1	10.4	13.3	7.0
D ₁₀ (mm)	0.0023	0.0020	0.0017	0.0012	0.0072
D ₃₀ (mm)	0.141	0.280	0.199	0.059	1.094
D ₆₀ (mm)	2.533	4.367	3.819	1.486	9.304
Coefficient of uniformity, Cu	1088.7	2221.3	2257.2	1239.0	1294.6
Coefficient of curvature, Cc	3.36	9.14	6.11	1.92	17.88
Atterberg limits test results (ASTM D4318-10e1)					
Liquid limit (%)	26	25	28	29	NP
Plastic limit (%)	15	15	17	19	NP
Plasticity index	9	10	11	10	NP
AASHTO and USCS soil classifications (AASHTO M 145-91 and ASTM D2487-11)					
AASHTO Classification	A-2-6(0)	A-2-4(0)	A-2-6(0)	A-2-4(0)	A-1-a(0)
USCS group symbol	SC	SC	SC	SC	GM
USCS group name	Clayey sand with gravel	Clayey sand with gravel	Clayey sand with gravel	Clayey sand with gravel	Silty gravel with sand

Together with Table 4 in Chapter 4, the test results in Table 16 through Table 18 correspond to the gradations and index properties of the surface aggregate materials sampled from the five test sections on August 15–17, 2023, April 9, 2024, November 21, 2024, and April 1, 2025. These samples reflect the in-place condition of the surface aggregates over time under the influence of traffic loading and environmental exposure, including seasonal freeze-thaw cycles.

In terms of USCS classifications, the data show that immediately after construction in 2023, Sections 1 through 3 all classified as silty clayey gravel with sand (GC-GM), while Section 4 classified as poorly graded gravel with clay and sand (GP-GC) due to its slightly higher PI, and the untouched control Section 5 classified as silty sand with gravel (SM). By the following spring of 2024, Sections 1 through 4 had undergone significant decreases in gravel content and increases in sand and fines contents due to particle breakage. In contrast, the control Section 5 experienced an increase in gravel content in the same timeframe, explained by maintenance operations performed using a gravel rake (Figure 85), which transferred gravel particles from the shoulders back into the roadway. Specifically, by spring 2024, the USCS classifications of Sections 1 through 5 had changed to clayey sand with gravel (SC), clayey gravel with sand (GC), silty clayey sand with gravel (SC-SM), silty sand with gravel (SM), and silty gravel with sand (GM), respectively.



Figure 85. Gravel rake used to retrieve coarse aggregates from shoulders

In terms of size fractions, the gravel contents of the rehabilitated Sections 1 through 4 were at their highest immediately following construction in 2023, ranging from 55.5% to 77.5%, while the gravel content of the untouched Section 5 was only 39.7% (Table 4). The corresponding initial sand contents ranged from 15.8% to 33.4% for the rehabilitated sections and 44.5% for the control section, while the fines contents were between 6.7% and 13.5% for the rehabilitated sections and 15.8% for the control section. By spring 2024, the gravel contents of Sections 1 through 4 had decreased significantly, ranging from 30.3% to 39.8% (Table 16), while that of Section 5 had increased to 51.8% because of the maintenance operations retrieving gravel from the shoulders. The sand content generally dominated the gradations of Sections 1 through 4 in spring 2024, ranging from 38.3% to 41.7%, while the control section had 35.6% sand. The fines contents had also increased significantly for Sections 1 through 4, ranging from 21.9% to 28.0%, while that of Section 5 decreased to 12.6%.

Over time, the gradation trends generally reflected a reduction in gravel-sized particles and an increase in sand and fines, suggesting progressive mechanical degradation. This trend is evident in the decreasing gravel-to-sand ratios and the moderate increases in clay-sized particles, particularly in Sections 3 and 4 (see Table 16 through Table 18). These changes are consistent with surface abrasion and breakdown of the particles under traffic loading and freeze-thaw conditions. A slight increase in gravel content was occasionally observed due to maintenance operations involving a gravel rake reclaiming larger particles from the shoulders.

By the final round of field tests in spring 2025 (Table 18), enough gravel breakage had occurred for the surfaces of all of the rehabilitated Sections 1 through 4 to classify as clayey sand with gravel (SC). The surface of Section 5 remained a silty gravel with sand (GM) because the lack of

drainage ditches and foreslopes made it easier to regularly use a gravel rake to bring in gravel-sized particles from the shoulders on this section. Sections 1 through 4 ended up with final gravel contents ranging from 26.7% to 38.8%, while that of Section 5 was 54.4%. Final sand contents were in the narrow range of 40.0% to 42.6% for Sections 1 through 4, compared to 31% for Section 5. Final fines contents were between 21.0% and 33.3% for Sections 1 through 4, compared to 14.6% for Section 5.

The durability of the granular surface course materials was also quantified using Hardin's breakage parameters (Hardin 1985), determined from the particle size curves of the samples collected over time. The post-construction gradations from August 2023 served as the initial reference curves for all breakage calculations. The total breakage (B_t) of the gravel and sand-size aggregates was determined by calculating the area between each PSD curve and its corresponding reference curve, as shown in Figure 86, with 0.075 mm used as the lower particle size limit in this study. The breakage potential (B_p) is defined as the area above the reference PSD curve up to the 100% finer line on the y-axis, which represents the theoretical maximum possible value of the total breakage (Figure 87). The relative breakage is defined as the ratio of total breakage to breakage potential and quantifies the percentage of the possible breakage that actually occurs. The breakage calculations used in this study assumed that the field samples were representative of the test sections and that no new material was added between sampling times.

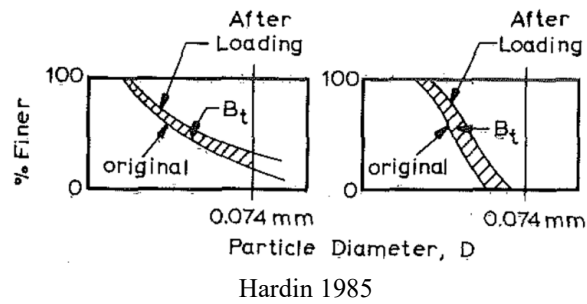


Figure 86. Definition of total breakage

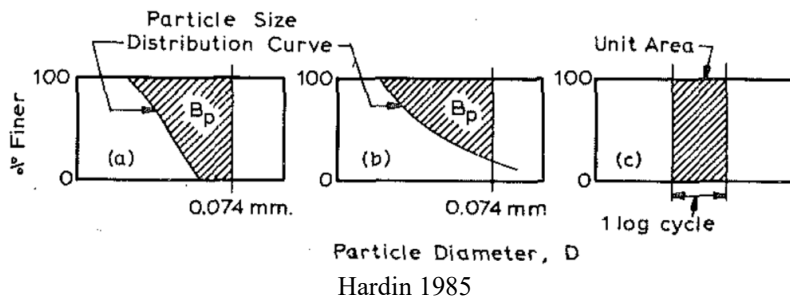
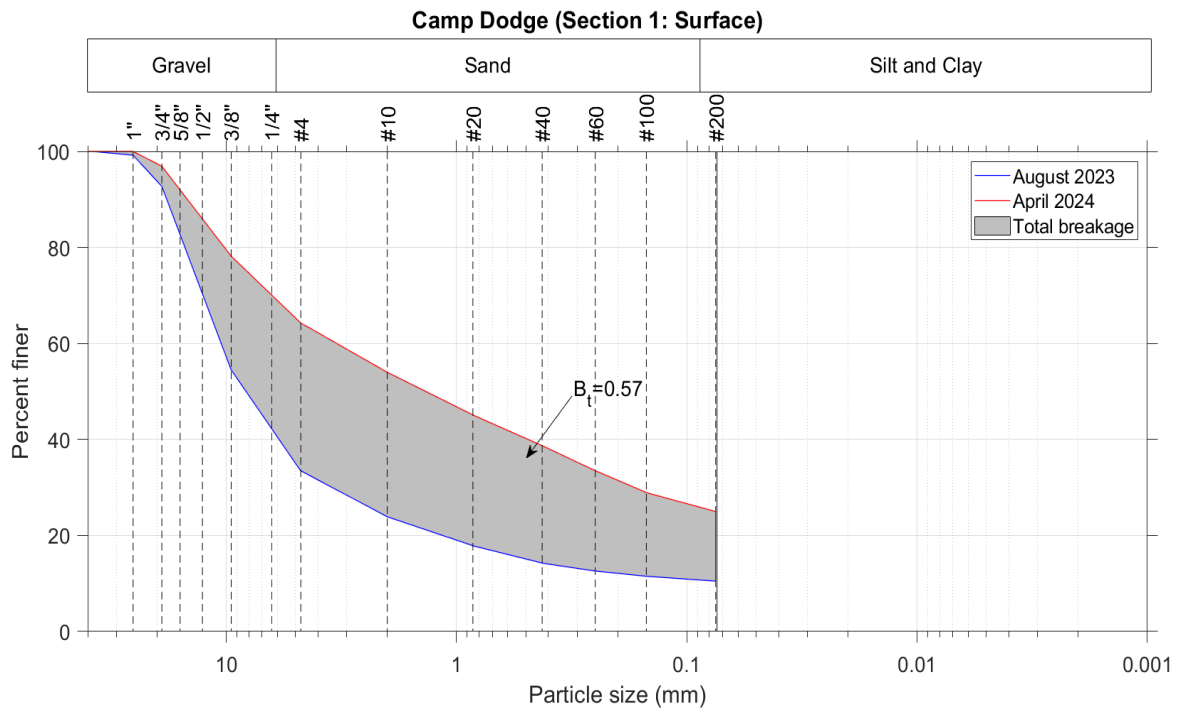


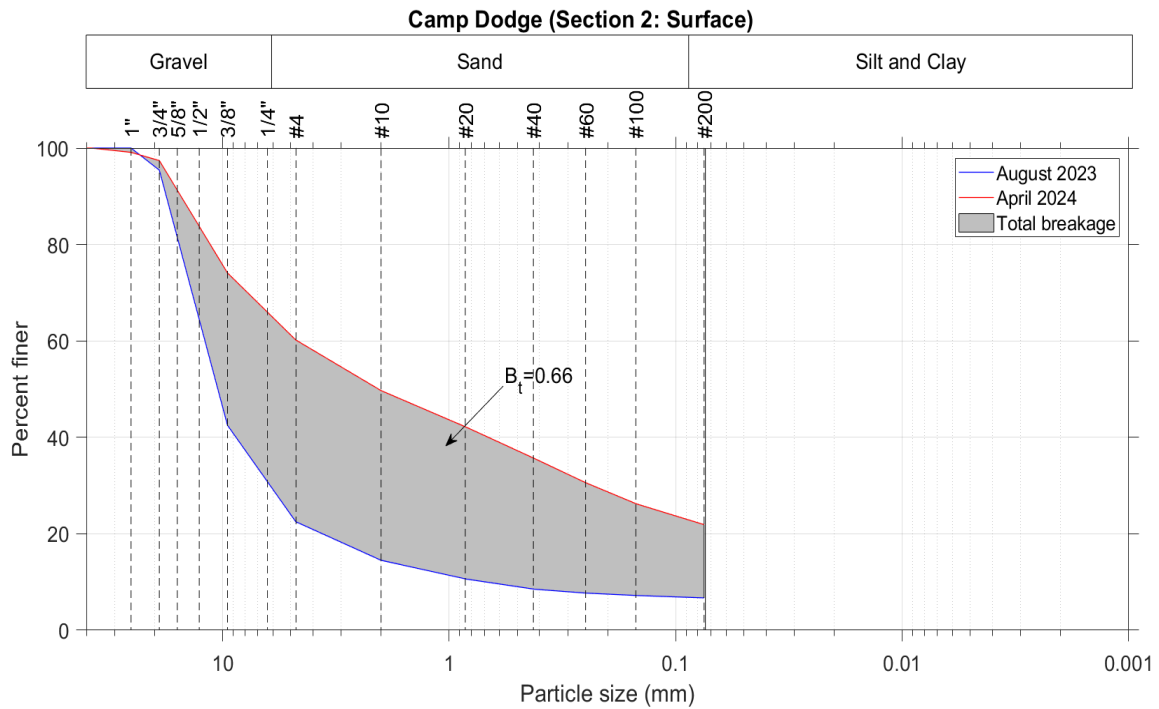
Figure 87. Definition of breakage potential

The total breakage observed in the test sections for the interval spanning the post-construction phase (summer 2023) to spring 2024 is illustrated in Figure 88 through Figure 90. The total breakage results for all other time intervals are provided in Appendix C. Table 19 provides a

summary of the total breakage, breakage potential, and relative breakage results over time for all sections.

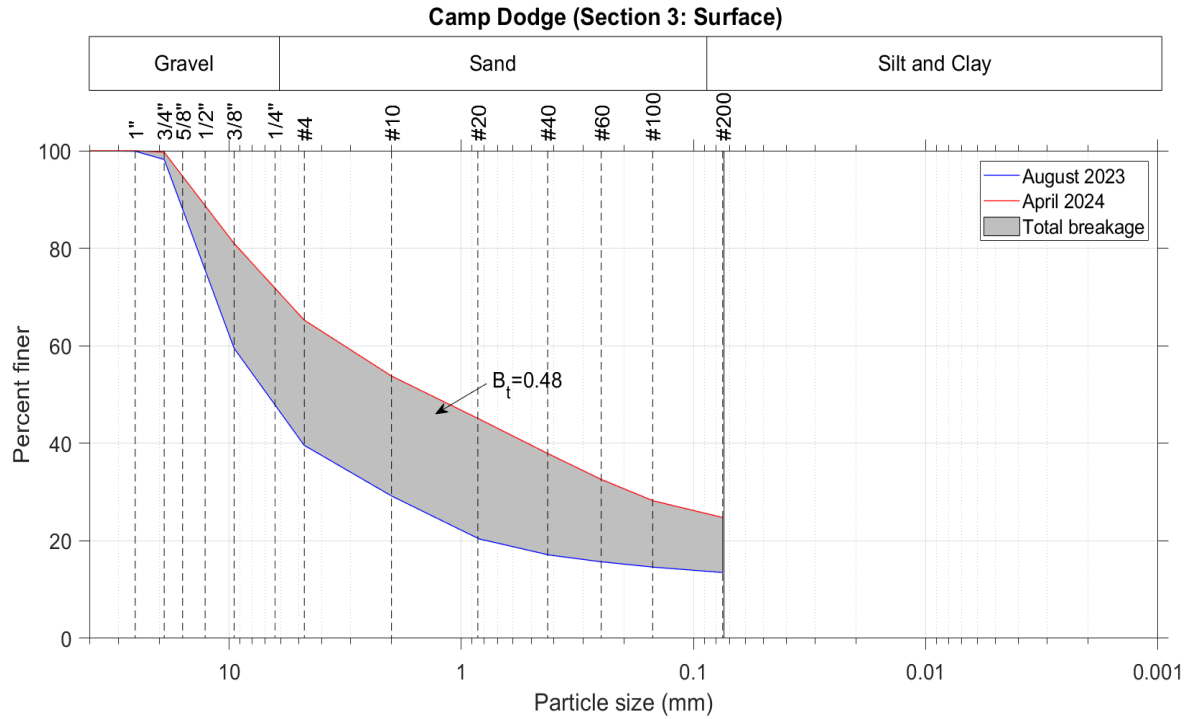


(a)

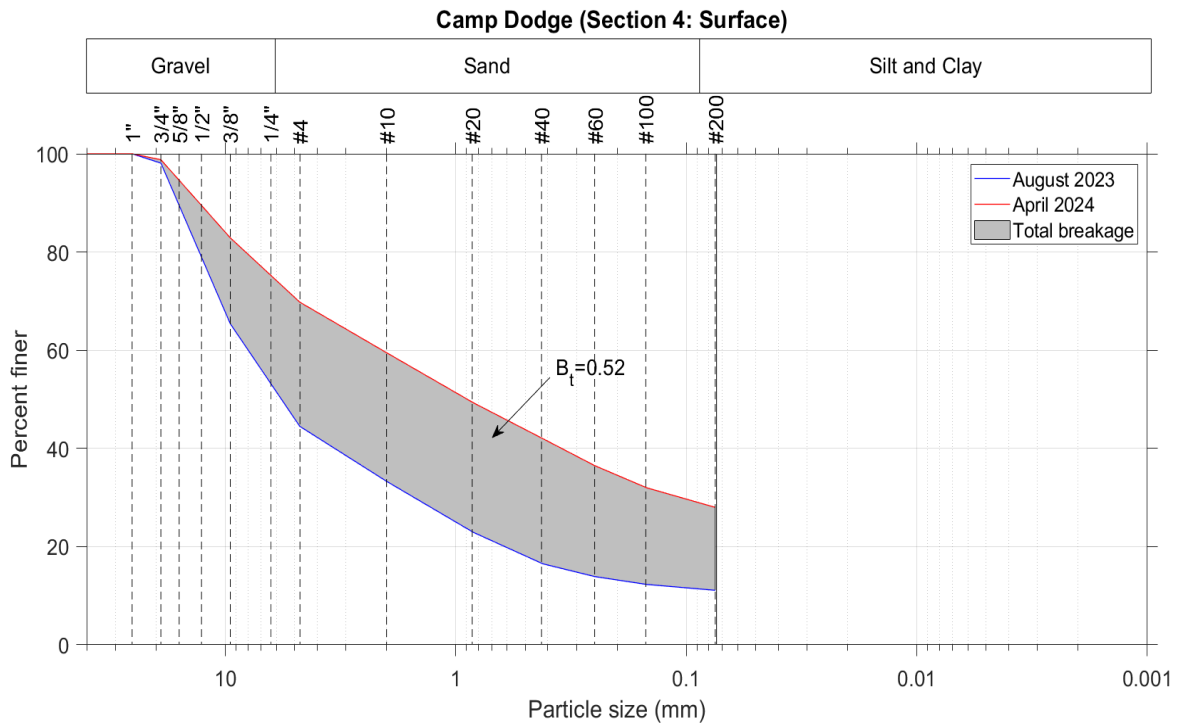


(b)

Figure 88. Determination of total breakage between summer 2023 (post construction) and spring 2024 for (a) Section 1 and (b) Section 2



(a)



(b)

Figure 89. Determination of total breakage between summer 2023 (post construction) and spring 2024 for (a) Section 3 and (b) Section 4

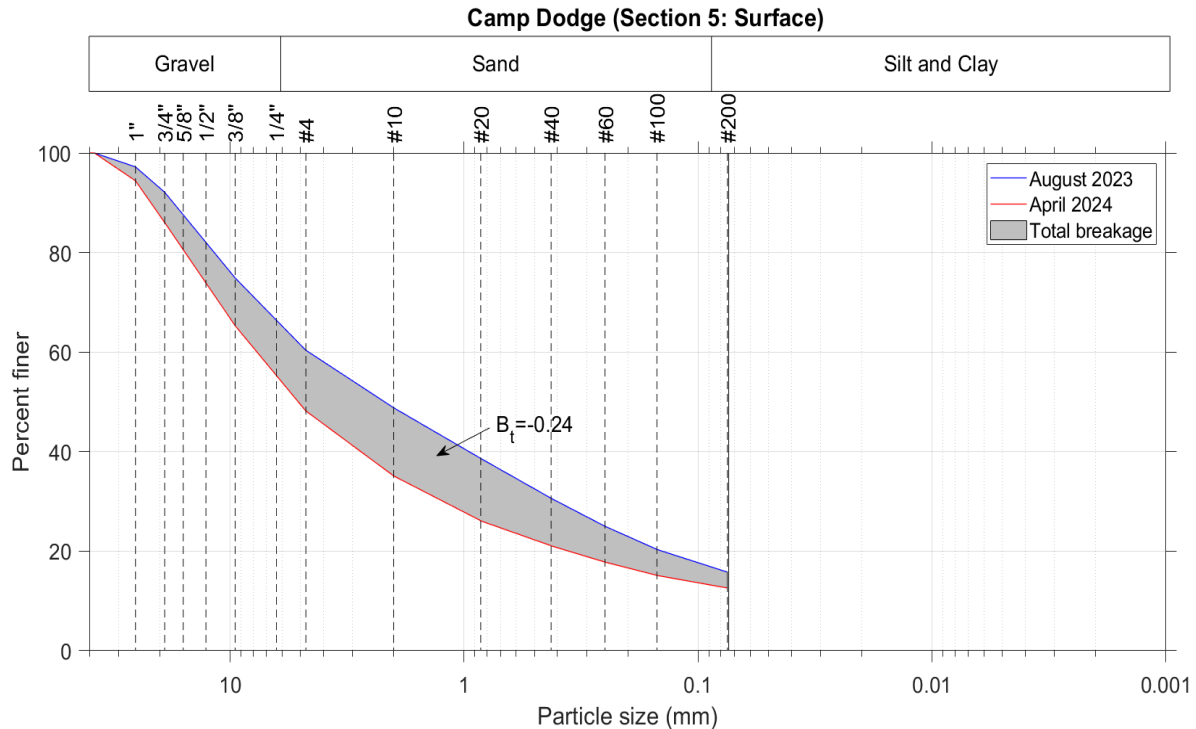


Figure 90. Determination of total breakage between summer 2023 (post construction) and spring 2024 for Section 5

Table 19. Breakage of surface course materials determined from PSD curves

Section	Reference 8/17/2023 Breakage Potential	Date Sampled					
		4/9/2024		11/21/2024		4/1/2025	
		Total Breakage	Relative Breakage	Total Breakage	Relative Breakage	Total Breakage	Relative Breakage
1	1.74	0.57	0.33	0.45	0.26	0.63	0.36
2	1.91	0.66	0.35	0.70	0.37	0.64	0.34
3	1.63	0.48	0.29	0.47	0.29	0.45	0.28
4	1.59	0.52	0.33	0.57	0.36	0.64	0.40
5	1.32	-0.24	-0.18	-0.32	-0.24	-0.26	-0.19

As detailed in Table 19, Sections 1 and 2 exhibited the greatest breakage potential, indicating that they had coarser initial gradations than the other sections. This observation aligns with expectations due to the cementing effect of the enzymatic stabilizer used in these sections, which binds finer particles together, effectively limiting their movement and increasing contact between larger particles. Such bonding can enhance the stability of the aggregate matrix but also create tighter inter-particle forces that may lead to early-stage particle fragmentation under compaction.

In comparison, Sections 3 and 4, which were compacted but not chemically treated, showed slightly lower breakage potential values. This implies a finer initial gradation, likely due to the absence of chemical bonding mechanisms that otherwise influence particle packing and contact

stress. These differences highlight the role of stabilization in shaping initial gradation characteristics.

Section 5, the untreated control, had the lowest breakage potential of all sections. This is consistent with its history, during which decades of heavy military vehicle loading had already broken down the surface course to a finer gradation, and the lack of recent resurfacing or addition of coarse aggregates. Unlike the rehabilitated sections, the control section experienced only long-term traffic-induced compaction that tended to embed the coarse material into the underlying stiff subgrade.

The breakage results over time show that most of the particle degradation occurred between August 2023 and April 2024, after which the rate of breakage was greatly reduced. This pattern reflects well-documented behavior, where most surface course degradation happens soon after construction due to initial compaction and traffic loading. During this period, Sections 1 and 2 experienced a slightly higher total breakage than Sections 3 and 4. However, their relative breakage values remained comparable, suggesting that the greater total breakage observed in Sections 1 and 2 is largely a result of their coarser initial gradations.

After April 2024, breakage values across all sections fluctuated slightly, likely reflecting sampling variability rather than true material behavior. No consistent trend in total breakage was observed when comparing treated and untreated sections over the full observation period. It is worth noting that Section 5 consistently showed negative breakage values, indicating a coarsening of the surface material over time. This was attributed to the operation of the road groomer, which redistributed coarser gravel from the shoulders and ditches back into the wheel paths, where samples were taken. Similar minor decreases in total breakage were noted in other sections during some intervals, likely for the same reason. Importantly, no new aggregate was introduced to any of the test sections during the study. As traffic continues to act on the surface, it is expected that the coarser reclaimed particles will also begin to degrade, gradually increasing the total breakage over time.

6.2.4 Visual Condition Surveys

During each round of field tests, visual condition surveys were conducted, with digital photographs taken to provide documentation of the surface conditions and reveal any signs of distress. The survey photographs for each section and testing period are provided in Figure 91 through Figure 95.



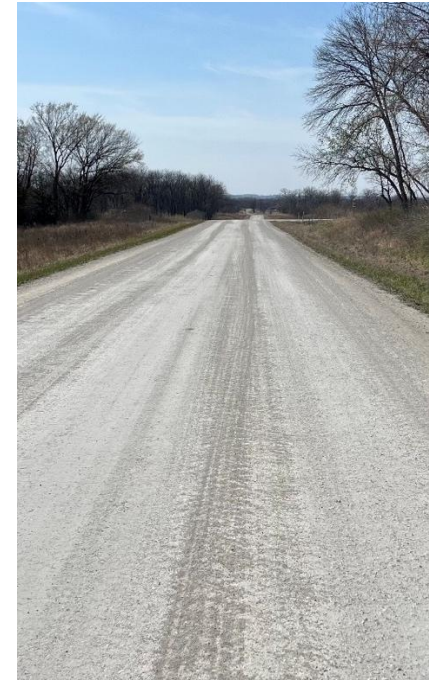
End of construction, Summer 2023



Spring 2024



Fall 2024

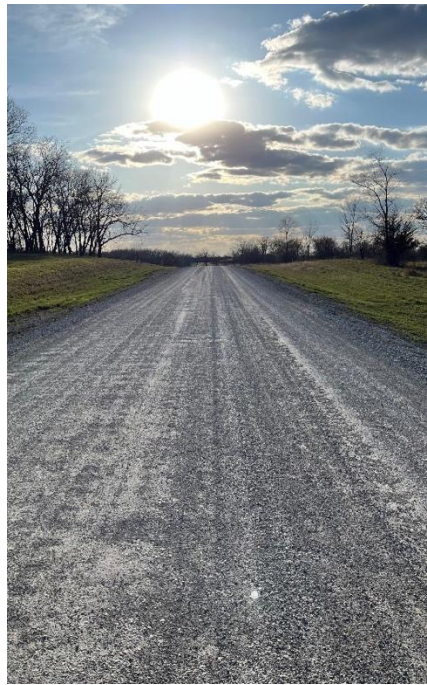


Spring 2025

Figure 91. Survey photos of Section 1 over time



End of construction, Summer 2023



Spring 2024



Fall 2024



Spring 2025

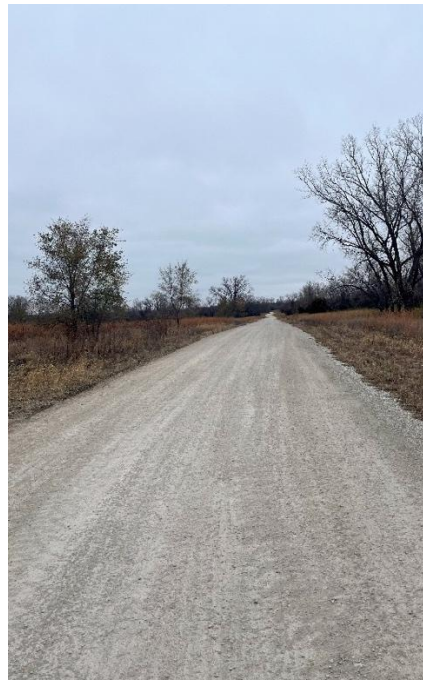
Figure 92. Survey photos of Section 2 over time



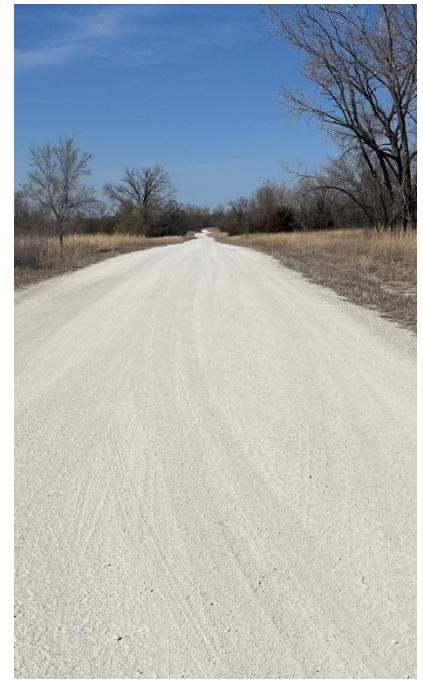
End of construction, Summer 2023



Spring 2024



Fall 2024



Spring 2025

Figure 93. Survey photos of Section 3 over time



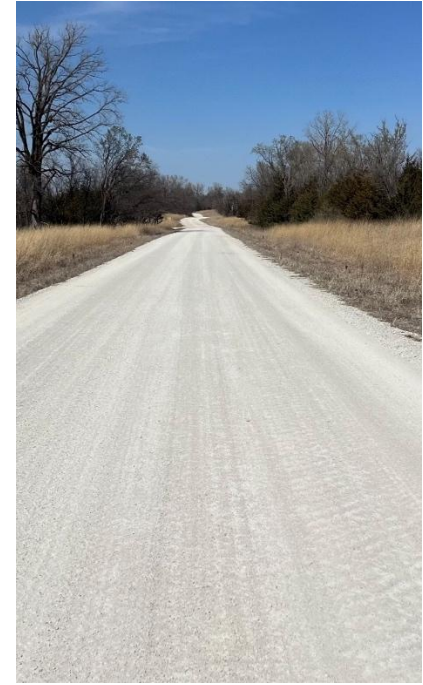
End of construction, Summer 2023



Spring 2024



Fall 2024



Spring 2025

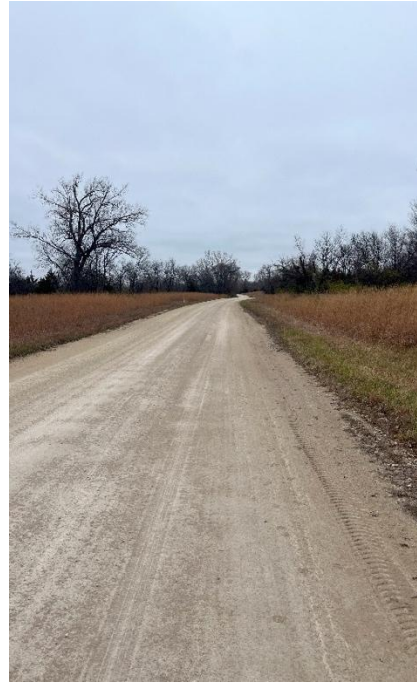
Figure 94. Survey photos of Section 4 over time



End of construction, Summer 2023



Spring 2024



Fall 2024



Spring 2025

Figure 95. Survey photos of Section 5 over time

Overall, surface conditions across the test sections showed minimal to moderate levels of distress during the observation period. Sections 3 and 4, which did not receive chemical stabilization, exhibited the most visible deterioration beginning in spring 2024, with the development of moderate rutting and depressions along the wheel paths (Figure 93 and Figure 94). By fall 2024, these untreated sections also showed signs of shoulder material migration, indicating lateral displacement of gravel under traffic.

In contrast, the stabilized Sections 1 and 2 demonstrated the least surface deterioration. Their surfaces remained relatively smooth and dry, closely resembling concrete pavement, with only minor evidence of rutting or corrugation (Figure 91 and Figure 92). Some shoulder material migration was observed in these two sections by fall 2024, similar to that seen in the untreated sections, though to a lesser extent.

Section 5 (control), which had experienced long-term traffic loading prior to the study, maintained a densely compacted and polished surface. It exhibited minor rutting but showed more noticeable surface material migration, likely due to the cumulative effects of long-term loading and the lack of rehabilitation (Figure 95).

6.2.5 Comparison of Sieve and Image Analysis Methods

The particle size distribution of the surface aggregate materials was determined using two methods: traditional sieve analysis, conducted in accordance with ASTM D422, and digital image analysis using the Iowa DOT Camsizer, performed following AASHTO T 381-181 as previously described in Chapter 3. To assess the accuracy and practical applicability of image analysis for gradation evaluation, PSD curves obtained from both methods are compared in this section.

The comparison focuses on the surface aggregate samples collected during fall 2023, as this was the only period in which image analysis was conducted both before and after gyratory compaction tests. To achieve reasonable test durations, Camsizer tests were limited to material larger than the No. 10 sieve. Figure 96 through Figure 100 compare the PSD curves from both test methods and demonstrate fairly good agreement for all samples. Based on these results, digital image analysis using the Camsizer can serve as a reliable alternative or complement to traditional sieve analysis for the coarse fractions of geomaterials. The Camsizer provides additional benefits that include greatly reduced testing time and the ability to automatically determine a wide range of particle morphology parameters such as roundness, sphericity, form factor, shape factor, roundness index, and angularity, among others (Lamba et al. 2025).

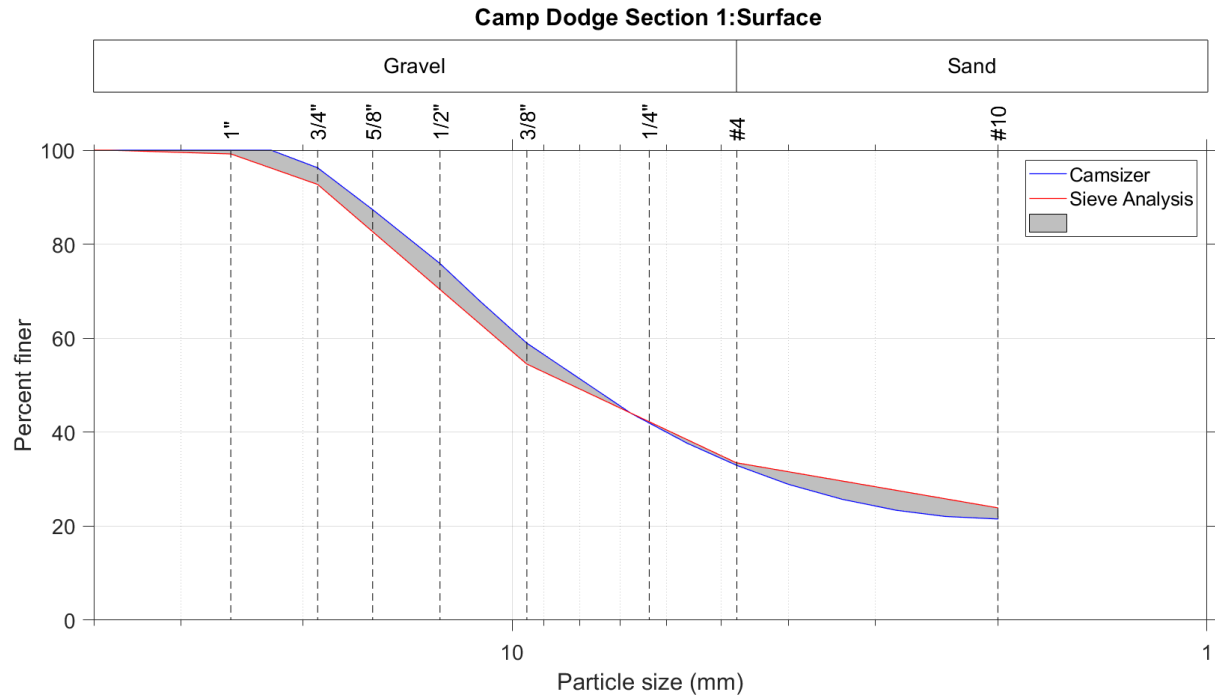


Figure 96. Comparison of PSD curves from sieve and image analysis for Section 1

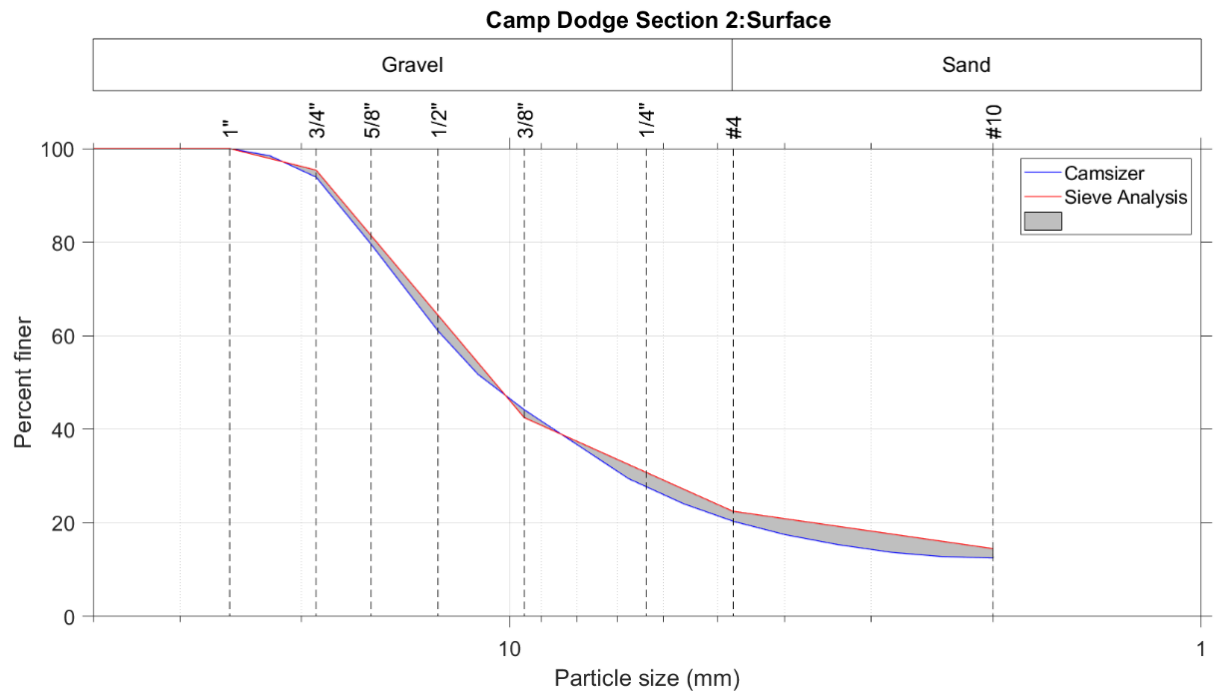


Figure 97. Comparison of PSD curves from sieve and image analysis for Section 2

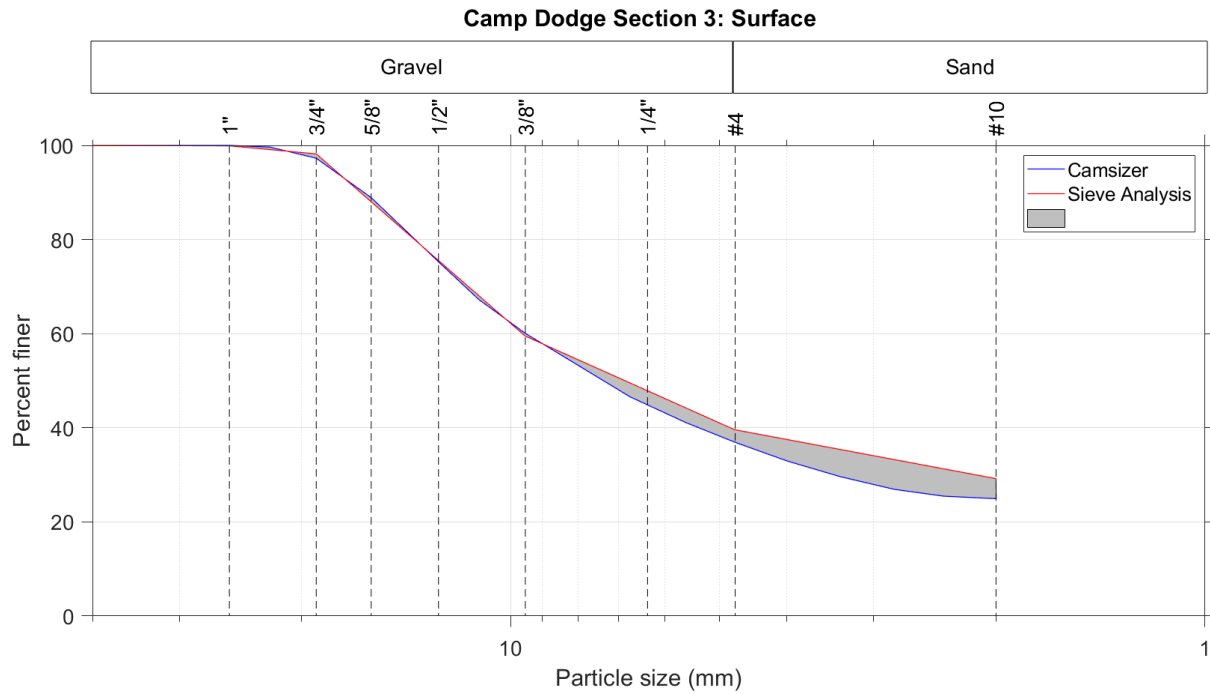


Figure 98. Comparison of PSD curves from sieve and image analysis for Section 3

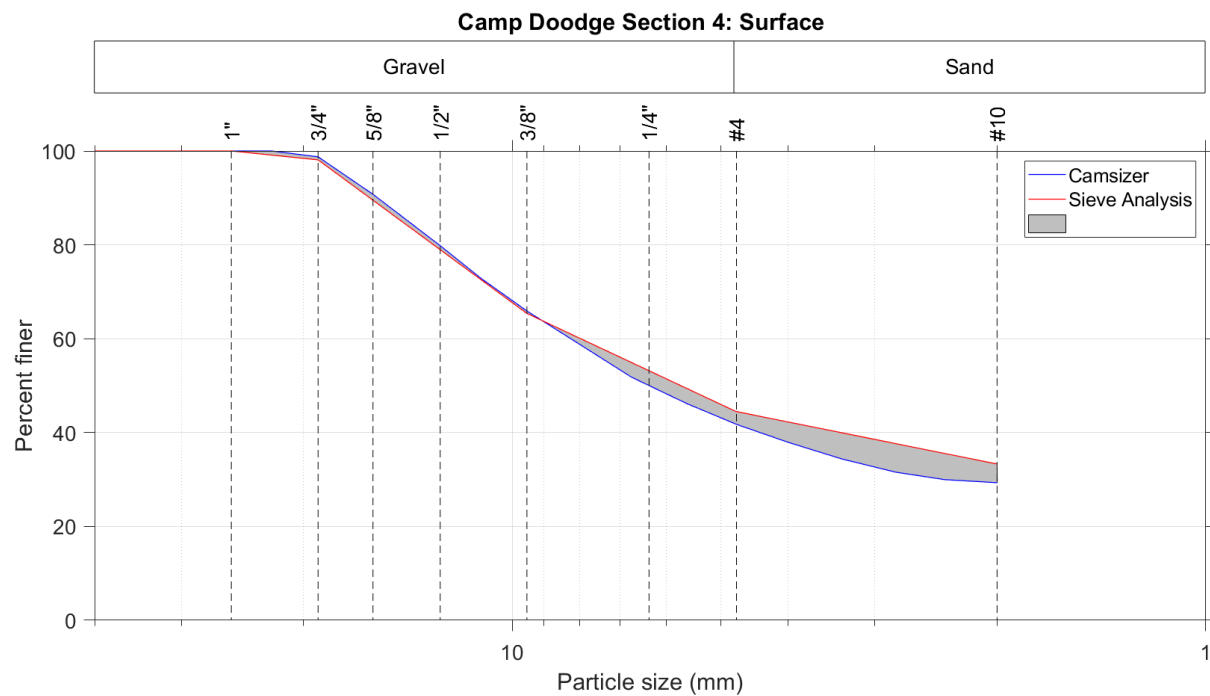


Figure 99. Comparison of PSD curves from sieve and image analysis for Section 4

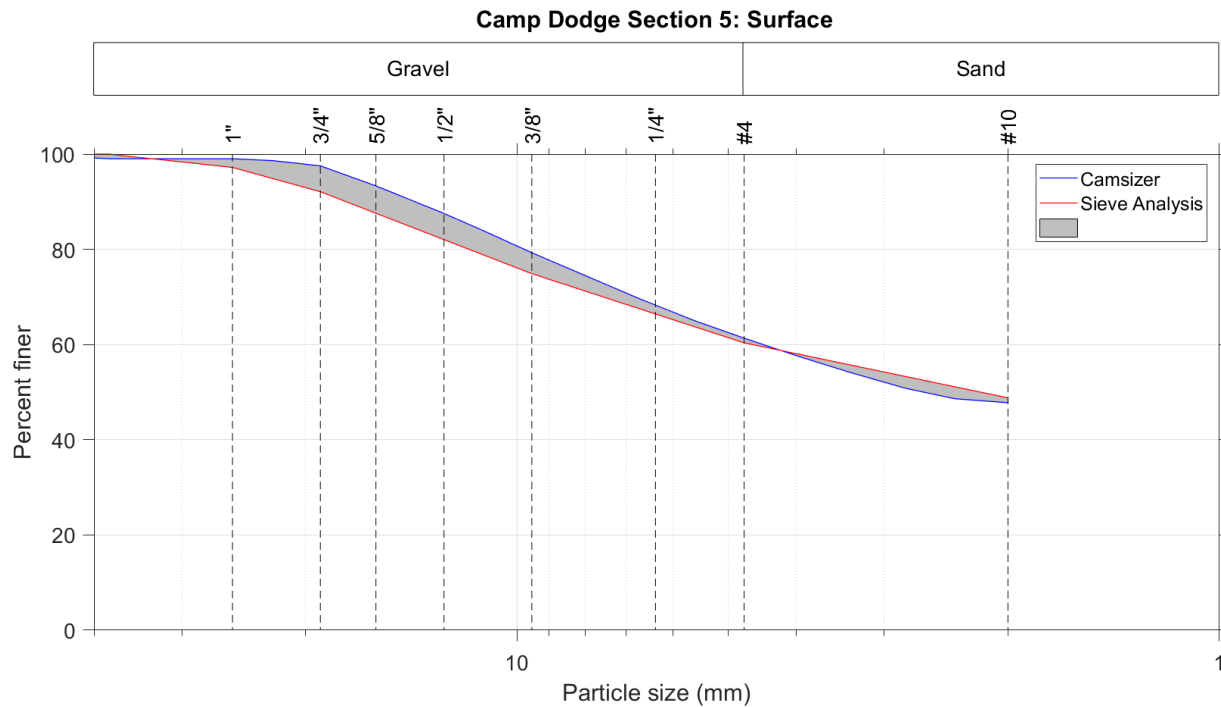


Figure 100. Comparison of PSD curves from sieve and image analysis for Section 5

6.2.6 Intelligent Compaction Mapping

To evaluate the stiffness and structural support capacity of the gravel road test sections rehabilitated using the different stabilization strategies, Ingios Geotechnics conducted intelligent compaction mapping at the test site. The five test sections were mapped with 100% coverage using a vibratory smooth drum roller equipped with Ingios' COMP-Score RT system, which was calibrated to measure the composite resilient modulus (M_r) and modulus of subgrade reaction (k). Mapping was conducted during the same timeframes as the other field tests, both before and after construction in fall 2023 and during seasonal intervals in spring 2024, fall 2024, and spring 2025, to capture the seasonal variations in performance and support capacity. The methodology included two passes per mapping session, with the first pass performed to reduce surface roughness and the second pass for intelligent compaction measurement.

The resulting data were analyzed for quality metrics such as pass coverage, spatial variability, and compliance with target stiffness thresholds. Summary statistics and visualizations of modulus values were used to assess spatial uniformity and changes over time. Key statistics and examples of representative results are presented and discussed in this section. The full Ingios report, including e-Compaction results, calibration summaries, and statistical analyses, is provided in Appendix D.

To maintain a reasonable report length, plots having zero data or that are not relevant to the current project were removed from the original Ingios intelligent compaction report, including plots of empty i-Score values, pass numbers (one pass was used), and material maps (one material was represented). Target values of k and M_r were set at 100 psi/in. and 3,600 psi,

respectively, for calculating delta values of the measured minus target values. There were no pass/fail criteria set, since the purpose of mapping was to measure spatial variations in support conditions and their differences between test sections and changes over time.

One important difference between the intelligent compaction mapping values and the previously reported LWD composite moduli are that they have very different depths of influence. The LWD test has an influence depth of approximately 1 ft and therefore gives a composite modulus of the near-surface. The intelligent compaction roller, on the other hand, has a much greater influence depth of around 6 ft and therefore characterizes the mechanical properties over a much greater depth than the LWD tests.

Color-coded maps for all five intelligent compaction testing timeframes are shown in Figure 101 through Figure 105 for k and Figure 106 through Figure 110 for M_r . Key statistical parameters for these maps are summarized in Table 20 through Table 24, including the average k and M_r values of each section as well as their COV values. Bar charts of the average k and M_r values from the Ingios report are presented in Figure 111 and Figure 112. The full Ingios report in Appendix D contains additional statistics as well as bar charts and box-and-whisker plots.

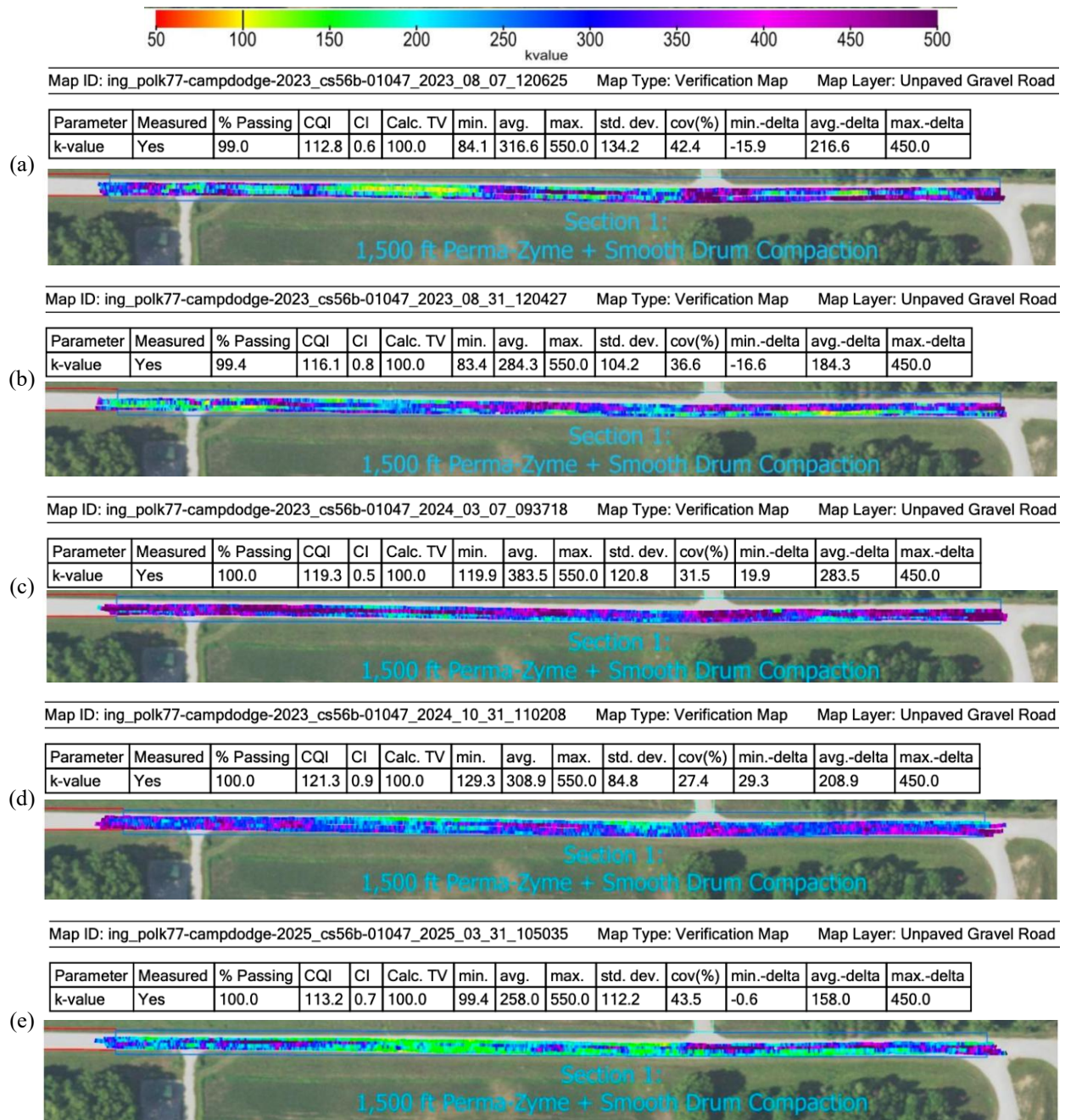


Figure 101. Section 1 modulus of subgrade reaction values from intelligent compaction mapping: (a) pre-construction, (b) fall 2023, (c) spring 2024, (d) fall 2024, (e) spring 2025

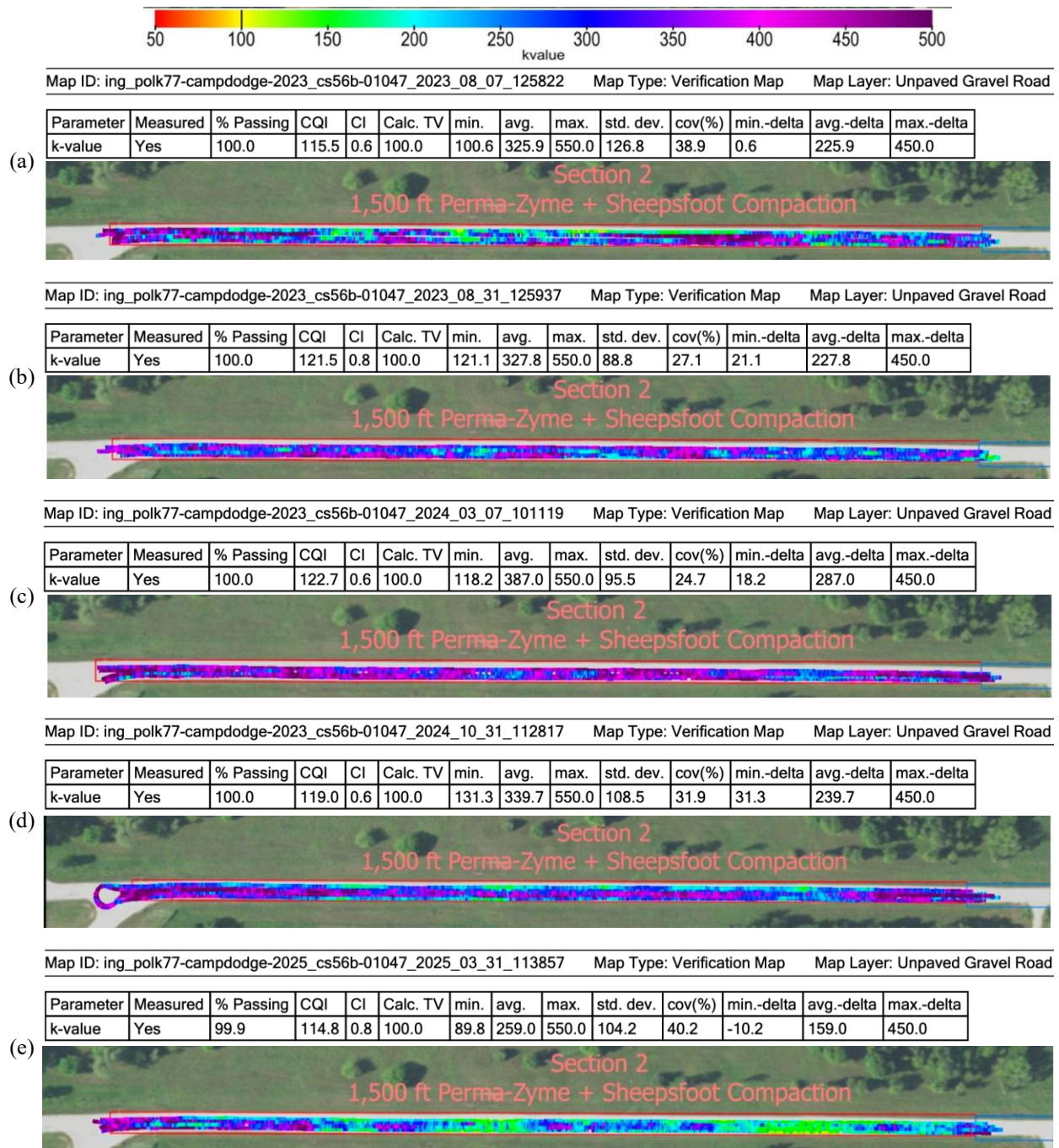


Figure 102. Section 2 modulus of subgrade reaction values from intelligent compaction mapping: (a) pre-construction, (b) fall 2023, (c) spring 2024, (d) fall 2024, (e) spring 2025

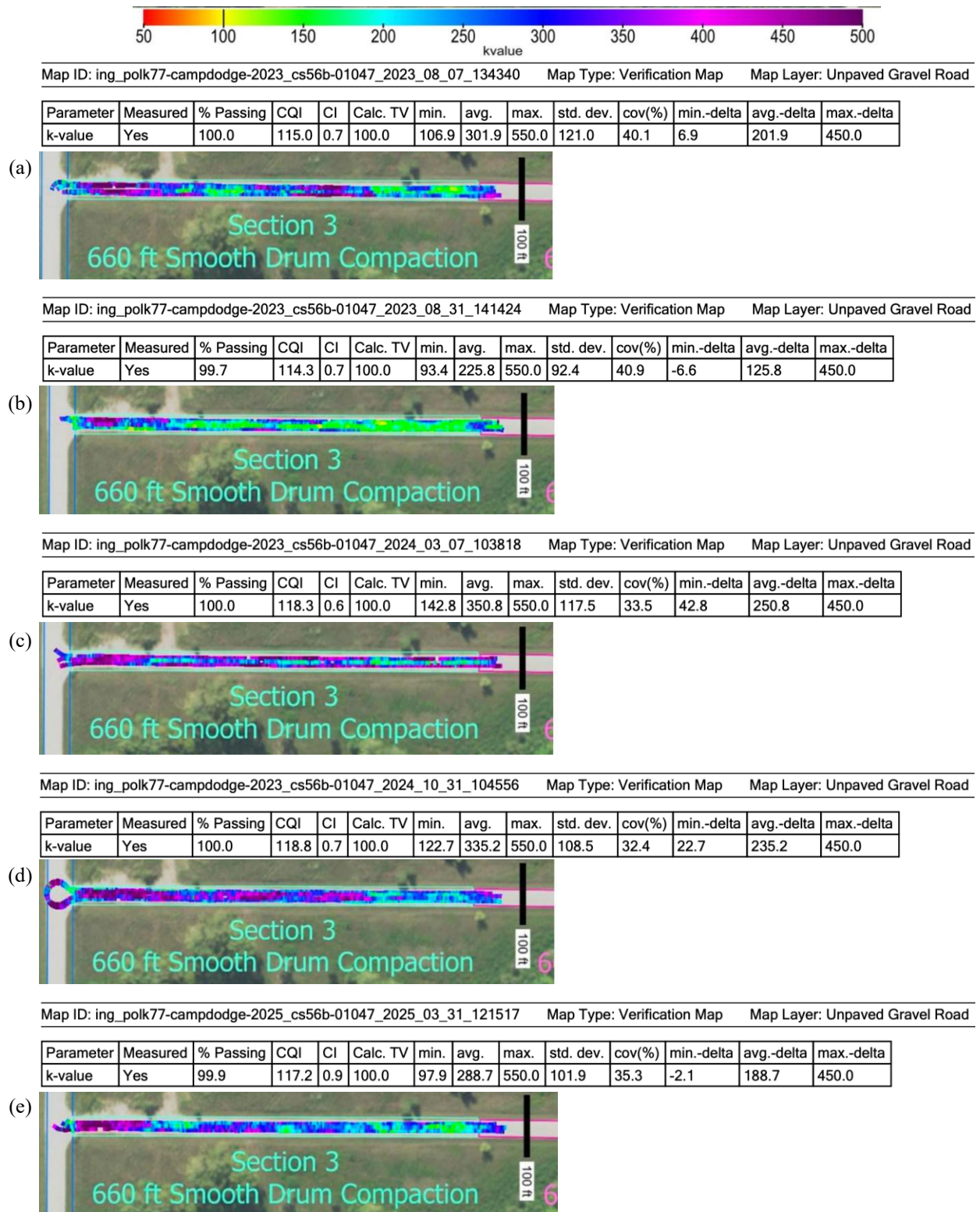


Figure 103. Section 3 modulus of subgrade reaction values from intelligent compaction mapping: (a) pre-construction, (b) fall 2023, (c) spring 2024, (d) fall 2024, (e) spring 2025

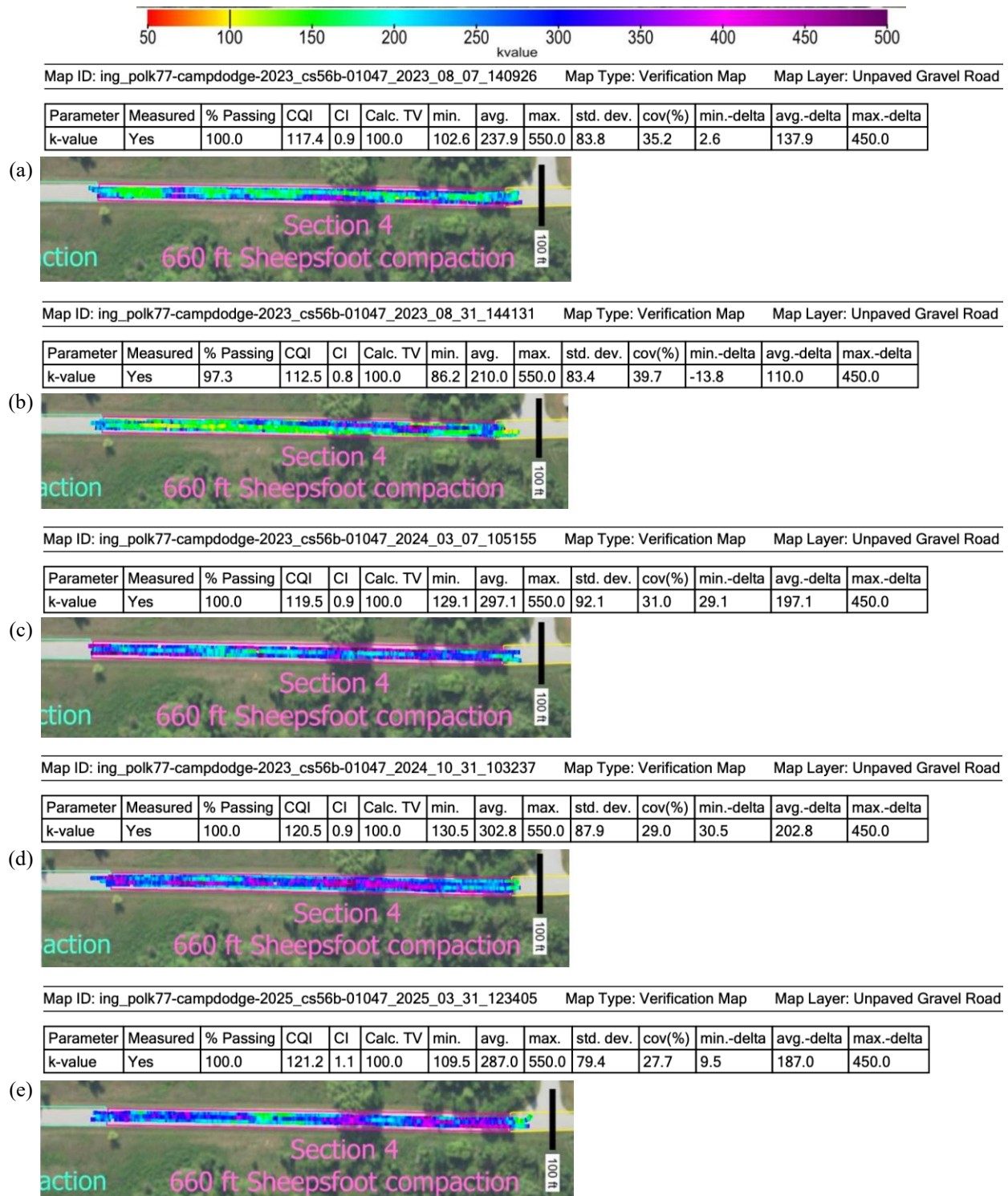


Figure 104. Section 4 modulus of subgrade reaction values from intelligent compaction mapping: (a) pre-construction, (b) fall 2023, (c) spring 2024, (d) fall 2024, (e) spring 2025

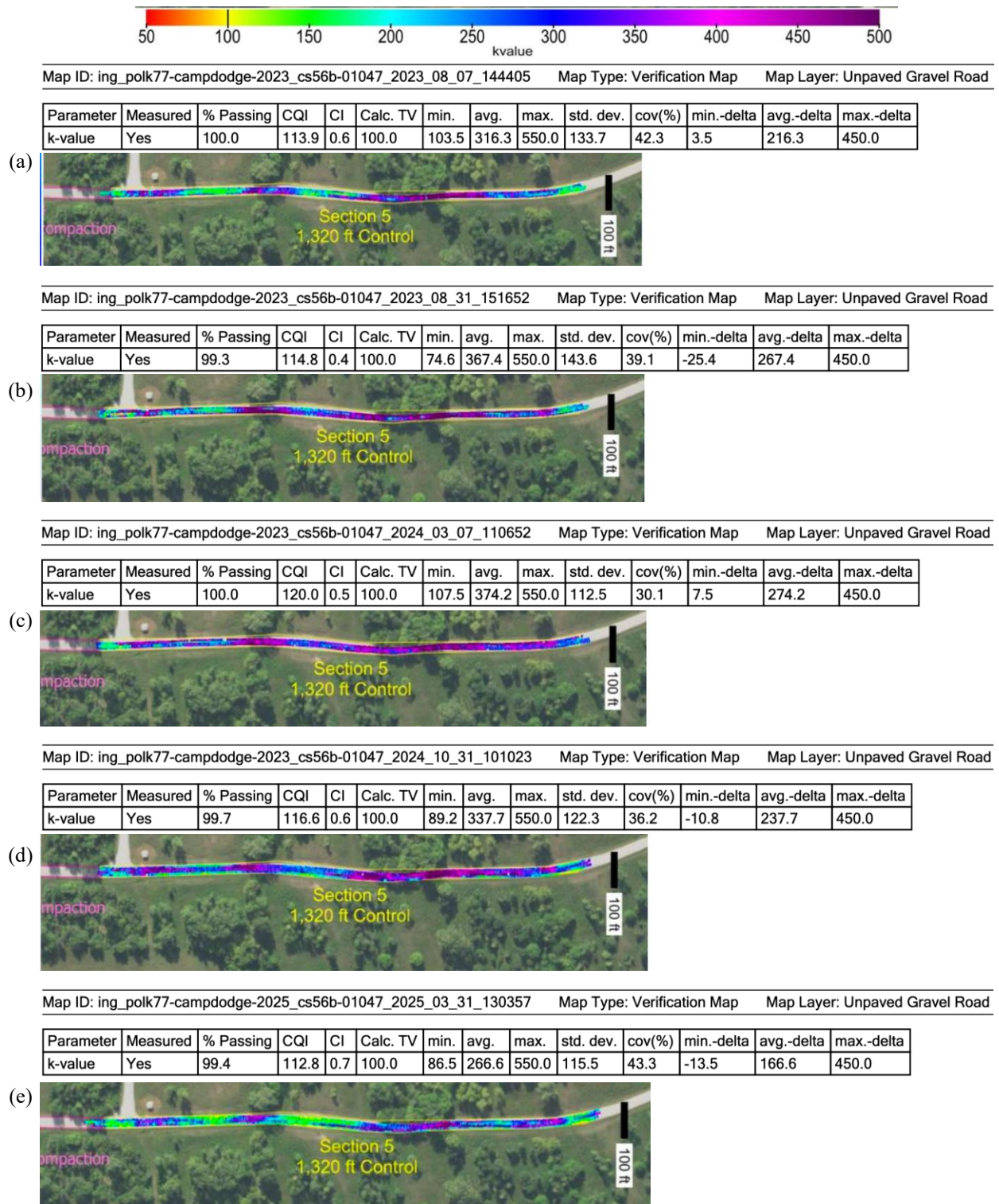


Figure 105. Section 5 modulus of subgrade reaction values from intelligent compaction mapping: (a) pre-construction, (b) fall 2023, (c) spring 2024, (d) fall 2024, (e) spring 2025

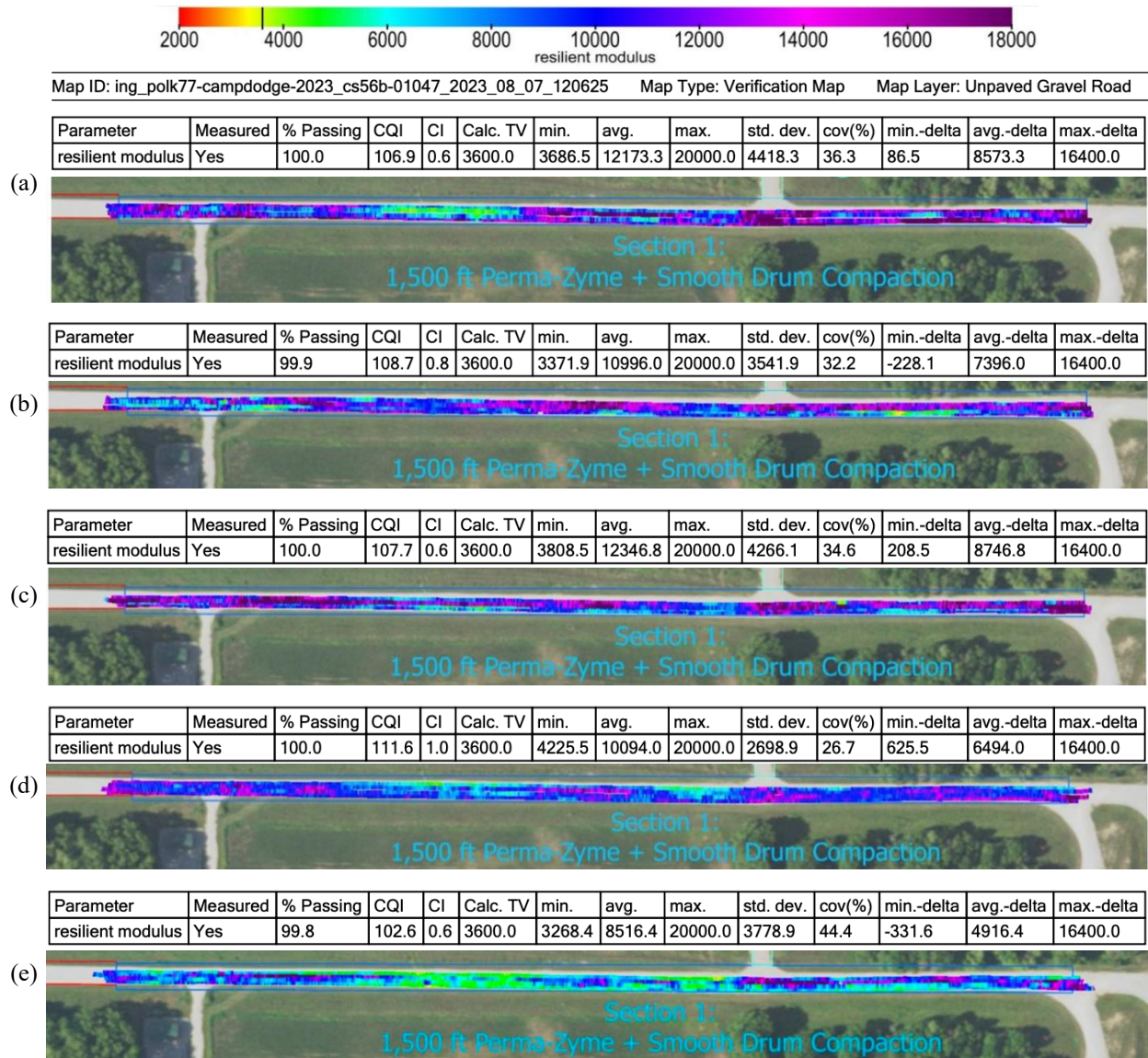


Figure 106. Section 1 resilient modulus values from intelligent compaction mapping: (a) pre-construction, (b) fall 2023, (c) spring 2024, (d) fall 2024, (e) spring 2025

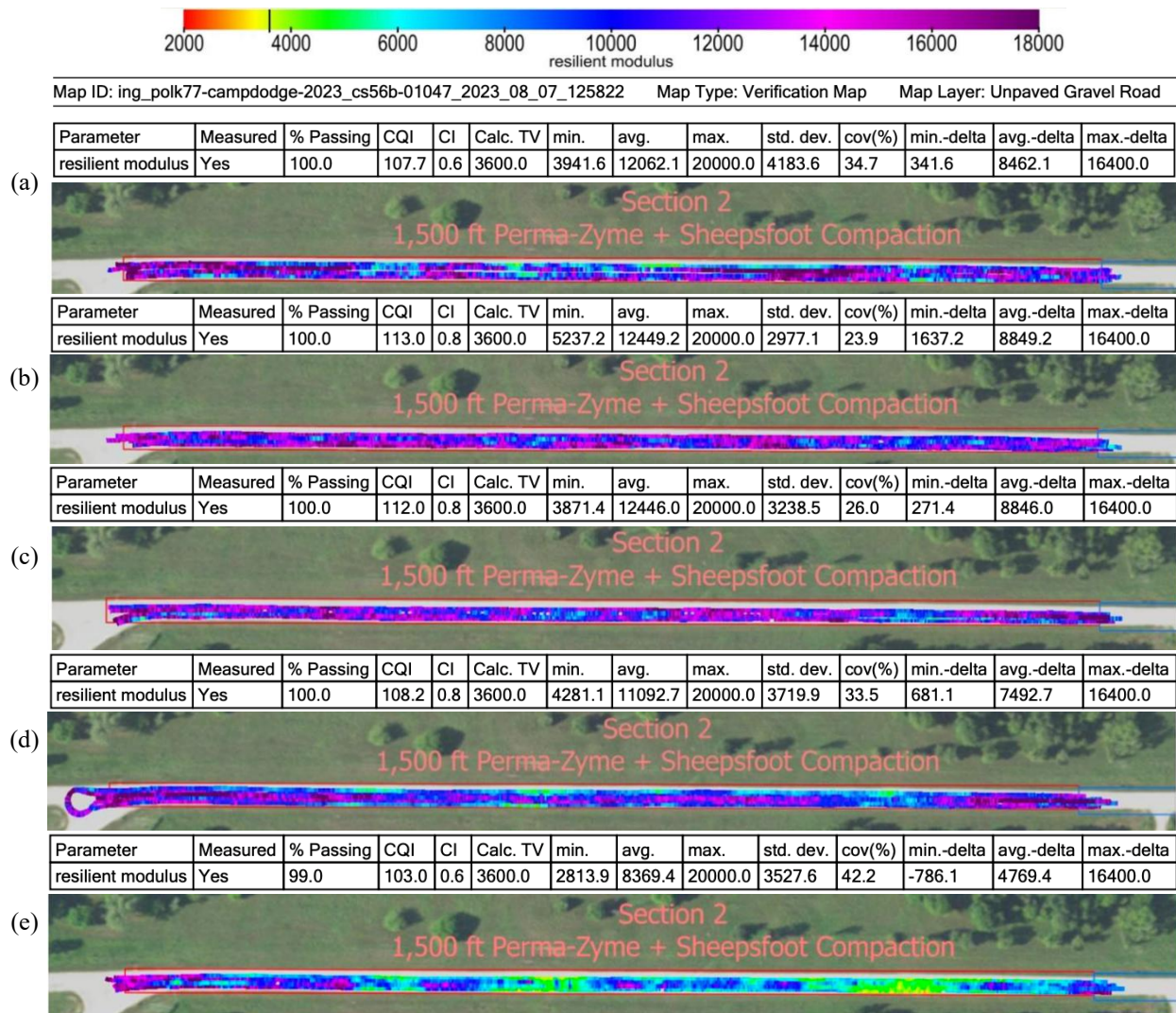


Figure 107. Section 2 resilient modulus values from intelligent compaction mapping: (a) pre-construction, (b) fall 2023, (c) spring 2024, (d) fall 2024, (e) spring 2025

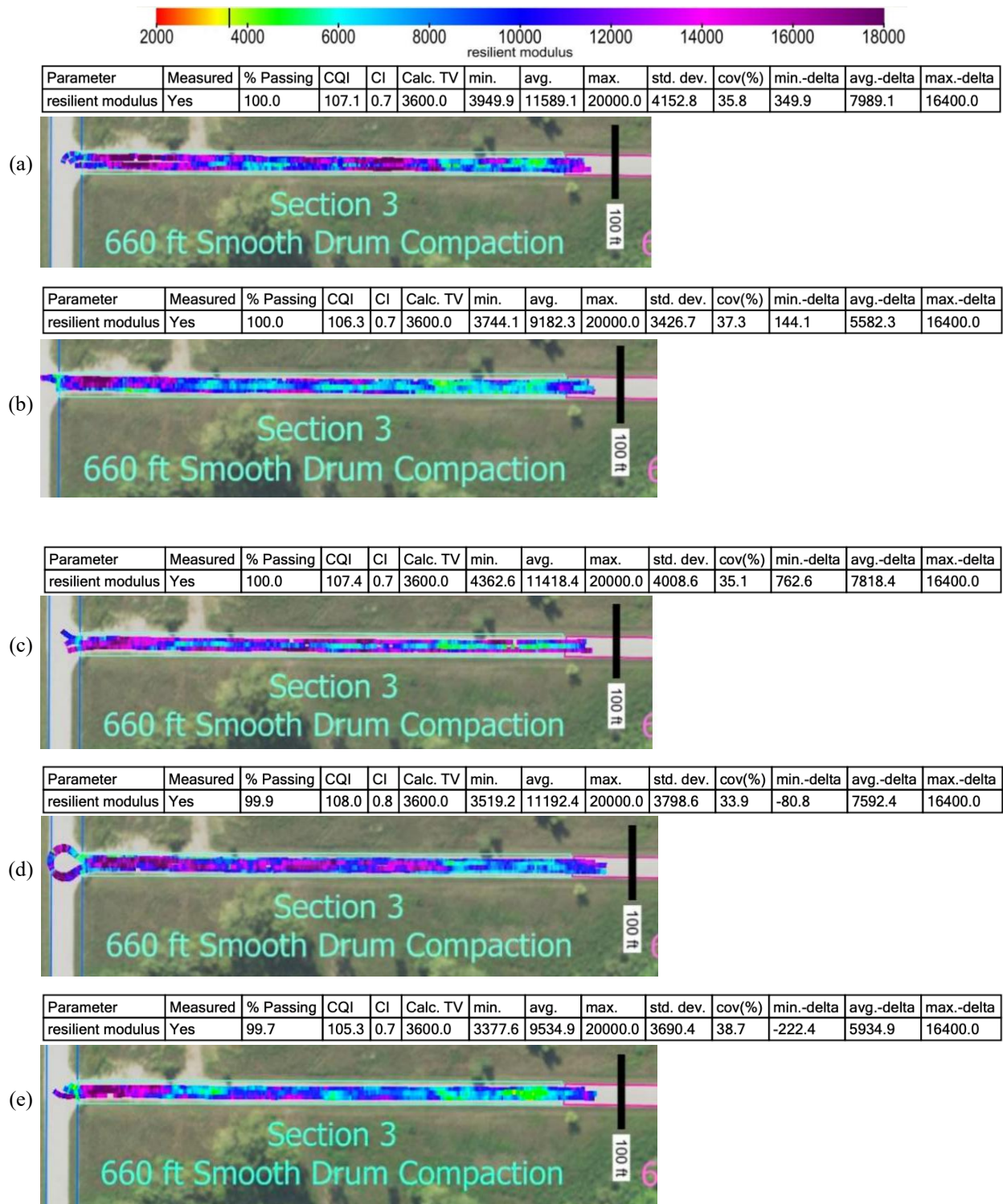


Figure 108. Section 3 resilient modulus values from intelligent compaction mapping: (a) pre-construction, (b) fall 2023, (c) spring 2024, (d) fall 2024, (e) spring 2025

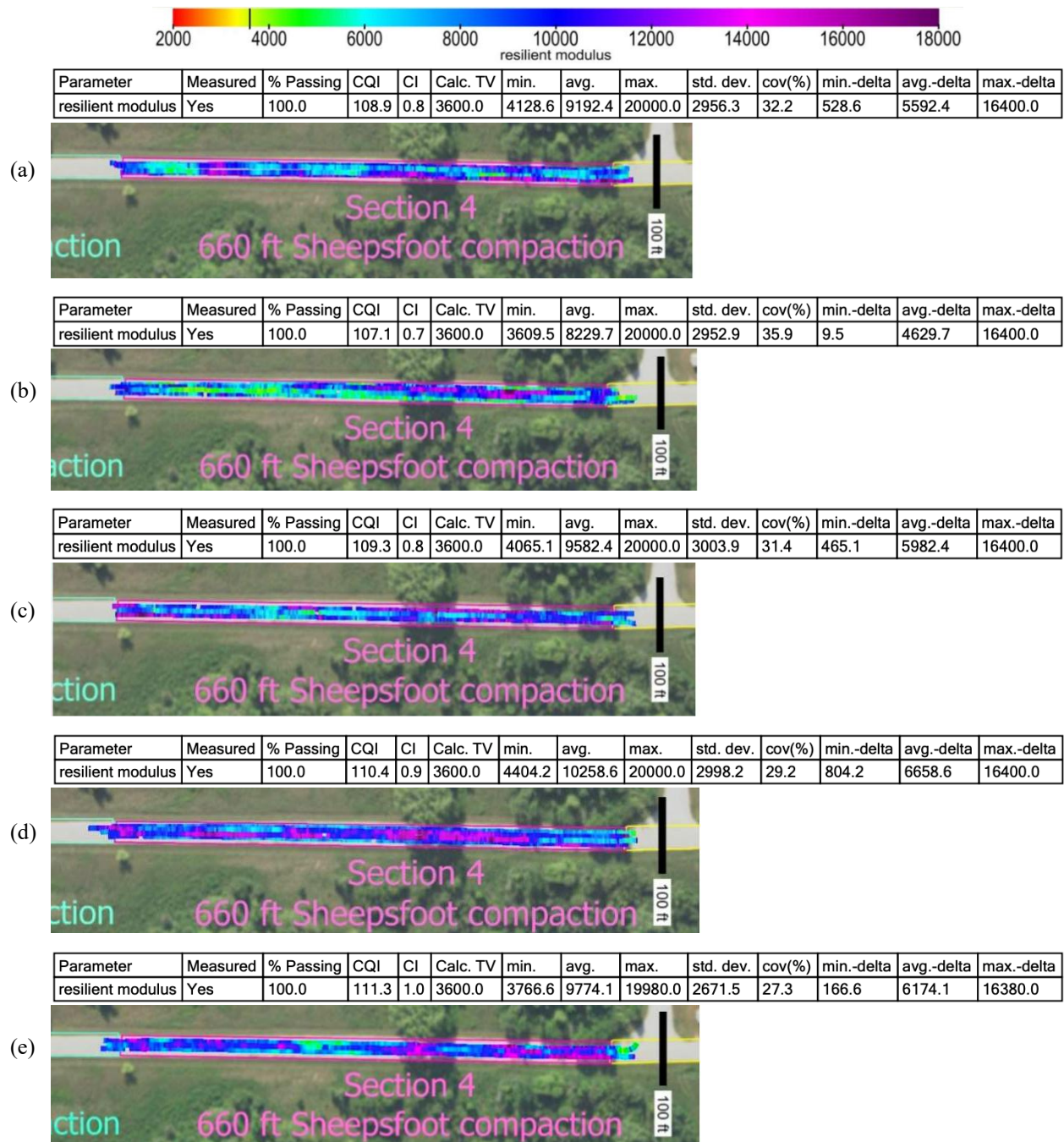


Figure 109. Section 4 resilient modulus values from intelligent compaction mapping: (a) pre-construction, (b) fall 2023, (c) spring 2024, (d) fall 2024, (e) spring 2025

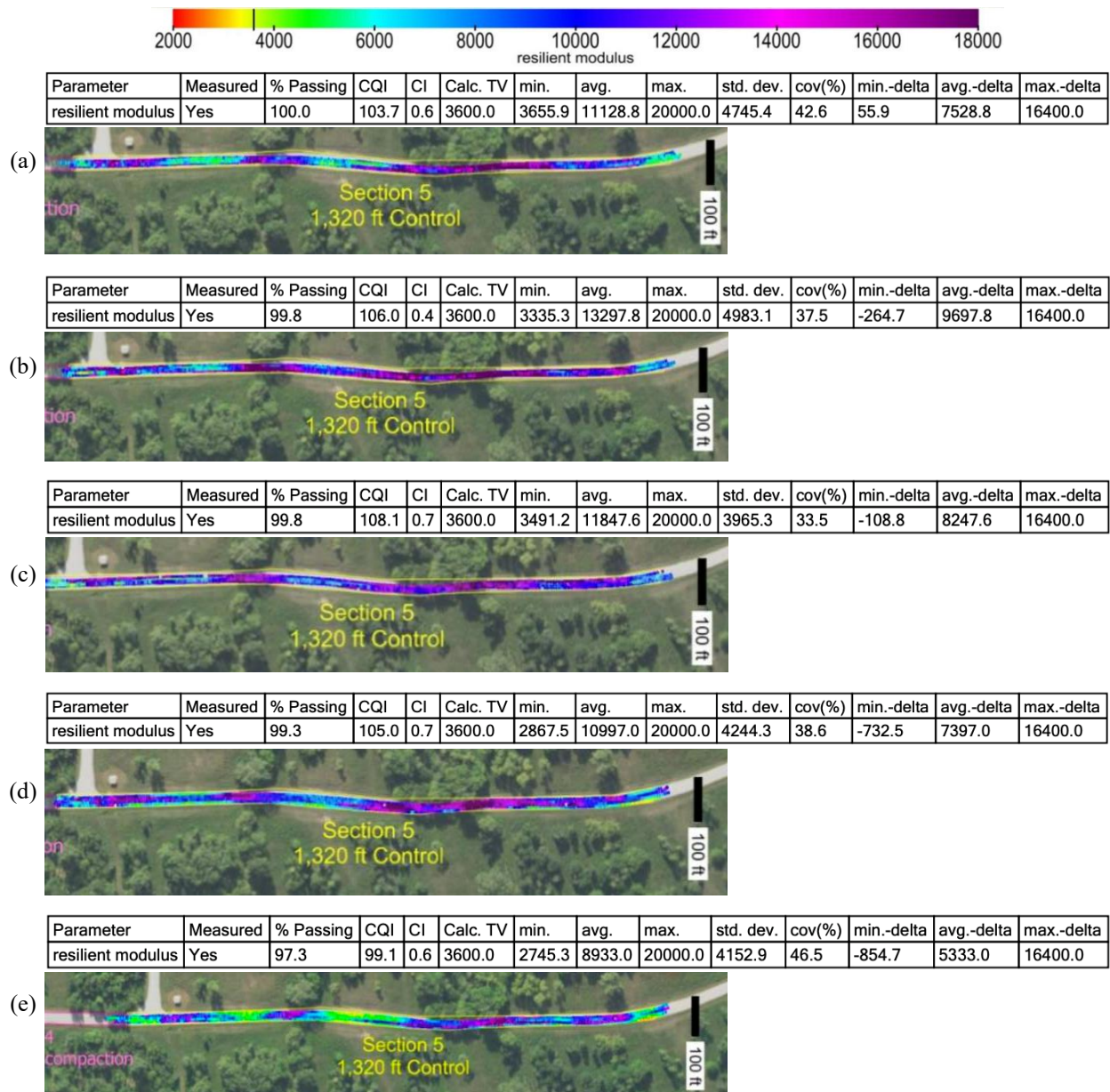


Figure 110. Section 5 resilient modulus values from intelligent compaction mapping: (a) pre-construction, (b) fall 2023, (c) spring 2024, (d) fall 2024, (e) spring 2025

Table 20. Summary of intelligent compaction mapping results for Section 1

Date	Stage	Map Area (ft ²)	k		M _r	
			Avg. (psi/in.)	COV (%)	Avg. (psi)	COV (%)
8/7/2023	Fall 2023 Pre-stabilization	33,512	317	42	12,173	36
8/31/2023	Fall 2023 Post-stabilization	32,607	284	37	10,996	32
3/7/2024	Spring 2024	29,915	383	32	12,347	35
10/31/2024	Fall 2024	38,454	309	27	10,094	27
3/31/2025	Spring 2025	33,550	258	43	8,516	44

Table 21. Summary of intelligent compaction mapping results for Section 2

Date	Stage	Map Area (ft ²)	k		M _r	
			Avg. (psi/in.)	COV (%)	Avg. (psi)	COV (%)
8/7/2023	Fall 2023 Pre-stabilization	37,049	326	39	12,062	35
8/31/2023	Fall 2023 Post-stabilization	33,781	328	27	12,449	24
3/7/2024	Spring 2024	30,766	387	25	12,446	26
10/31/2024	Fall 2024	42,261	340	32	11,093	34
3/31/2025	Spring 2025	34,154	259	40	8,369	42

Table 22. Summary of intelligent compaction mapping results for Section 3

Date	Stage	Map Area (ft ²)	k		M _r	
			Avg. (psi/in.)	COV (%)	Avg. (psi)	COV (%)
8/7/2023	Fall 2023 Pre-stabilization	13,307	302	40	11,589	36
8/31/2023	Fall 2023 Post-stabilization	13,109	226	41	9,182	37
3/7/2024	Spring 2024	12,005	351	34	11,418	35
10/31/2024	Fall 2024	15,017	335	32	11,192	34
3/31/2025	Spring 2025	12,449	289	35	9,535	39

Table 23. Summary of intelligent compaction mapping results for Section 4

Date	Stage	Map Area (ft ²)	k		M _r	
			Avg. (psi/in.)	COV (%)	Avg. (psi)	COV (%)
8/7/2023	Fall 2023 Pre-stabilization	13,425	238	35	9,192	32
8/31/2023	Fall 2023 Post-stabilization	14,481	210	40	8,230	36
3/7/2024	Spring 2024	12,028	297	31	9,582	31
10/31/2024	Fall 2024	14,656	303	29	10,259	29
3/31/2025	Spring 2025	12,569	287	28	9,774	27

Table 24. Summary of intelligent compaction mapping results for Section 5

Date	Stage	Map Area (ft ²)	k		M _r	
			Avg. (psi/in.)	COV (%)	Avg. (psi)	COV (%)
8/7/2023	Fall 2023 Pre-stabilization	23,488	316	42	11,129	43
8/31/2023	Fall 2023 Post-stabilization	23,860	367	39	13,298	37
3/7/2024	Spring 2024	24,911	374	30	11,848	33
10/31/2024	Fall 2024	32,038	338	36	10,997	39
3/31/2025	Spring 2025	30,588	267	43	8,933	46

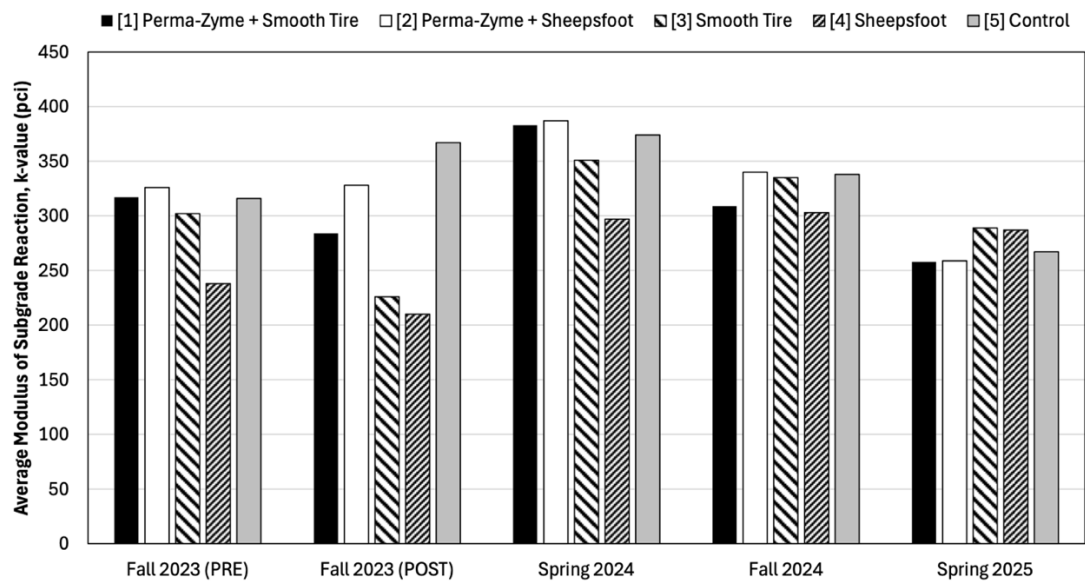


Figure 111. Average modulus of subgrade reaction values for test sections over time

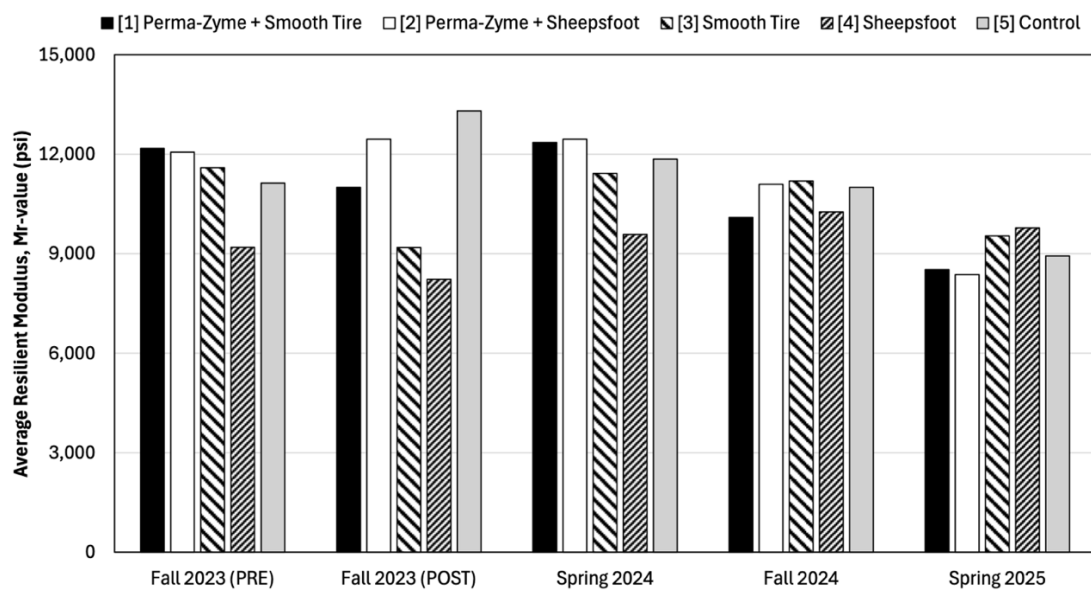


Figure 112. Average resilient modulus values for test sections over time

The results show that Sections 1, 2, 3, and 5 started out with similar average k values ranging from 302 to 326 pci before construction, whereas Section 4 had a significantly smaller pre-construction value of 238 pci (Figure 111). After construction in fall 2023, the average k values had decreased by around 11% for Sections 1 and 4, decreased by 25% for Section 3, exhibited almost no change for Section 2, and increased by 16% for Section 5. These results are consistent with the decreases observed in CBR and LWD modulus values after the cross sections were reconstructed with loosened and recompacted material brought in from the ditches.

From fall 2023 to spring 2024, the average k values increased between 18% and 55% for the four rehabilitated sections but increased by only 2% for the control Section 5. This indicates that the initially looser reconstructed sections recovered stiffness due to continued compaction from traffic loading, with the enzyme-treated Sections 1 and 2 having greater k values than all other sections in spring 2024. From spring 2024 to fall 2024, the k value of Section 4 increased by 2% while it decreased for all other sections by 5% to 20%, resulting in a narrow range of k values for all sections, ranging from 303 to 340 pci. From fall 2024 to spring 2025, all five sections experienced decreases in k values ranging from 5% to 24%, with the smallest percent decrease belonging to Section 4. The final k values in spring 2025 were within a narrow range of 258 to 289 pci.

Overall, the data indicate that the four rehabilitated sections experienced an initial decrease in stiffness after construction in 2023, then recovered in 2024 with the enzyme-stabilized sections exceeding the stiffness of the control section in spring 2024, after which the values for all sections decreased and converged to similar stiffnesses by spring 2025.

The M_r values (Figure 112) followed somewhat similar trends to the k values, except that Section 2 exhibited an increase in M_r in the first two testing periods after construction (i.e., fall 2023 and spring 2024). Similar to the k value trends for Section 2, the M_r values for that section in spring 2024 exceeded those of all other sections, after which time the values for all sections decreased and fell within a narrow range by fall 2024 and spring 2025.

CHAPTER 7 CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study examined the long-term performance of four aggressively rehabilitated gravel road test sections whose roadway cross-sectional profiles were rebuilt by recovering material from the ditches to restore the proper widths, elevations, and slopes of the roadways and the proper drainage ditch profiles. Test Sections 1 and 2 were treated with an enzymatic chemical stabilizer, while Sections 3 and 4 were not. Sections 1 and 3 were constructed using smooth-tired compaction, while Sections 2 and 4 were constructed using sheepfoot compaction.

Among the four aggressively rehabilitated sections, the two treated with enzymatic stabilizer had CBR strengths after construction that were over four times greater than those that underwent the same compaction method but without stabilizer. By the end of the two-year study, all sections had lower surface CBR values than they did in fall 2023 and spring 2024, but the CBR values for the enzyme-treated rehabilitated sections remained 2.5 times higher (for smooth-tired compaction) and 4.5 times higher (for sheepfoot compaction) than the CBR values for the corresponding sections without stabilizer. Within the rehabilitated sections, the stabilizer thus provided a significant strength increase in the surface course that lasted through heavy vehicle loading and at least two winter-spring freeze-thaw seasons. The enzyme-stabilized sections also generally maintained higher subgrade CBR values than the two sections without stabilizer.

Regarding the different compaction methods, for all test periods except for spring 2024, Section 2, which was treated with stabilizer and constructed using sheepfoot compaction, had slightly higher field CBR values than Section 1, which was treated with stabilizer and constructed using smooth-tired compaction. However, this trend was reversed for the unstabilized Sections 3 and 4, with slightly higher CBR values consistently observed in Section 4, which was constructed using smooth-tired compaction. Therefore, sheepfoot compaction is recommended if using the enzymatic stabilizer; otherwise smooth-tired compaction should be used.

The relative breakage measured using gyratory compaction testing was found to have strong linear correlations to the initial gravel content of the rehabilitated test sections, as well as to their field-measured average CBR values. The latter finding suggests that laboratory gyratory compaction testing could be used as an efficient method to predict the field CBR performance among different potential surfacing materials and determine which materials or blends will give the best performance under actual traffic loading.

Regarding stiffness, the average composite elastic modulus values from LWD testing on the rehabilitated Sections 1 through 4 showed an initial decrease after construction by fall 2023, followed by a general increasing trend over time through spring 2025. The two enzyme-treated sections, which required additional water during construction, initially had lower modulus values than the non-treated sections after construction. However, the modulus values of the enzyme-treated sections more than doubled in the two subsequent test periods and greatly exceeded the values of the two non-stabilized rehabilitated sections. This indicates a sustained benefit in terms of elastic modulus for the enzyme-stabilized rehabilitated sections.

The control section had been compacted by decades of extremely high traffic loads from vehicles such as military HEMTTs and remained nearly impenetrable throughout the study. This section therefore consistently exhibited the highest CBR and modulus values across all test dates. As previously described, the purpose of the control section was to understand how the aggressive rehabilitation of a roadway cross section would change the conditions of that road relative to the surrounding roads. Loosening and recompacting the roadbeds for the reconstruction of Sections 1 through 4 was not expected to result in greater strength or stiffness than the control section. Instead, increasing the roadway elevation and restoring the drainage ditches by rebuilding the roadway cross-sectional profile was intended to improve the drainage capacity and wet weather conditions of the rehabilitated sections relative to the control section. These goals were achieved, as Section 5 remained flat and nearly devoid of drainage ditches.

The PSD curves of samples collected from the test section surfaces over time showed that most of the particle breakage occurred in the first several months following construction, after which the rate of breakage greatly decreased. During the first post-construction sampling interval, the enzyme-treated Sections 1 and 2 experienced slightly higher total breakage values compared to the untreated Sections 3 and 4. However, the corresponding relative breakage values of all four rehabilitated sections were similar, suggesting that the greater total breakage observed in Sections 1 and 2 was largely a result of their coarser initial gradations after construction. No consistent difference was found between the breakage of the treated and untreated rehabilitated sections over the full project duration. The control section started with a surface that had already been broken down by traffic, so it exhibited the smallest changes in breakage over the project period. Because a road groomer was periodically used by the Iowa Army National Guard's maintenance crew to reclaim coarse gravel from the shoulders, the gradation of the control section became coarser, which translated to invalid negative breakage values.

According to the visual condition surveys, the enzyme-stabilized Sections 1 and 2 experienced the least surface deterioration, with only minor evidence of rutting or corrugation. Sections 3 and 4, which were rehabilitated using compaction without stabilizer, experienced the most visible signs of deterioration in the form of rutting and depressions along the wheel paths and migration of material to the shoulders. The control section also exhibited minor rutting and showed more noticeable migration of material to the shoulders.

A comparison of particle size distributions determined by traditional sieve analysis to those determined by image analysis using the Iowa DOT's Camsizer indicated that the Camsizer can offer a reliable alternative or complement to traditional sieve analysis. The image analysis provided by the Camsizer has the additional benefit of enabling particle morphology to be determined. However, Camsizer testing was limited to material larger than the No. 10 sieve in this study because finer material takes longer to process.

The intelligent compaction mapping indicated that the four rehabilitated sections experienced an initial decrease in stiffness and modulus after construction in 2023 but then recovered in 2024, with the enzyme-stabilized sections exceeding the stiffness and modulus of the control section by spring 2024. By the end of the project in spring 2025, the stiffness and modulus values for all sections decreased and converged to similar ranges.

Overall, this study demonstrated the effectiveness of aggressively rehabilitating gravel roads that had been lowered, widened, and flattened by decades of heavy traffic. Rebuilding the roadway cross sections improved the drainage capacity of the test sections compared to the much flatter control section. The enzymatic soil stabilizer showed measurable benefits in terms of the granular surface course strength evaluated by CBR measurements and the composite modulus/stiffness evaluated by LWD testing and intelligent compaction mapping. The benefits were greatest in the first year after construction but were observed to decrease somewhat by the end of the second year. With additional field testing and observation, it could be determined whether the latter decrease was a temporary trend or whether the rehabilitation and stabilization will produce continued benefits over time.

Recommendations for Further Study

Based on the findings of the present study, the following directions for further research are recommended:

- This study discovered a strong linear correlation between the relative breakage of surfacing aggregates as measured by gyratory compaction tests and their field-measured CBR values determined from in situ DCP tests. This relationship can be studied and developed further for different sources and blends of surfacing aggregates using new field test sections. If strong relationships between relative breakage and field CBR values can be verified with more data points that cover different materials and blends, then laboratory gyratory compaction tests could be conducted in the future to more efficiently determine which materials will have the best performance in terms of CBR values.
- The Camsizer was found to provide a reliable complement or replacement for traditional sieve analysis in this study, with the added benefit of enabling particle morphology to be determined from the images. However, Camsizer tests were limited to material coarser than the No. 10 sieve because the time needed to process samples greatly increases when finer material is included. In future studies, it is recommended that Camsizer tests, including for finer particle size ranges, be used as a more efficient and less labor-intensive replacement for sieve analysis tests to determine particle breakage of the gravel and sand fractions while tracking changes in particle morphology over time.
- The enzymatic soil stabilizer was observed to provide measurable improvements in stiffness and strength within the first year after construction. By spring 2025, however, all sections approached a relatively narrow range of stiffness and strength values. It is recommended that the project site be revisited after an additional 1 to 3 years to quantify whether the benefits of stabilization extend beyond the duration of the present project.
- The extremely dense, strong, and stiff subgrade conditions and construction debris encountered in the control section (as well as the rest of the surrounding roads) were unexpected. Although useful comparisons were obtained between the stabilized and non-stabilized rehabilitated test sections, it would be useful to construct enzyme-stabilized test sections elsewhere in Iowa to quantify their performance when supported by subgrade soil conditions more representative of typical gravel roads in Iowa.

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APPENDIX A. PARTICLE-SIZE ANALYSIS RESULTS FOR SPRING 2024 ONWARD

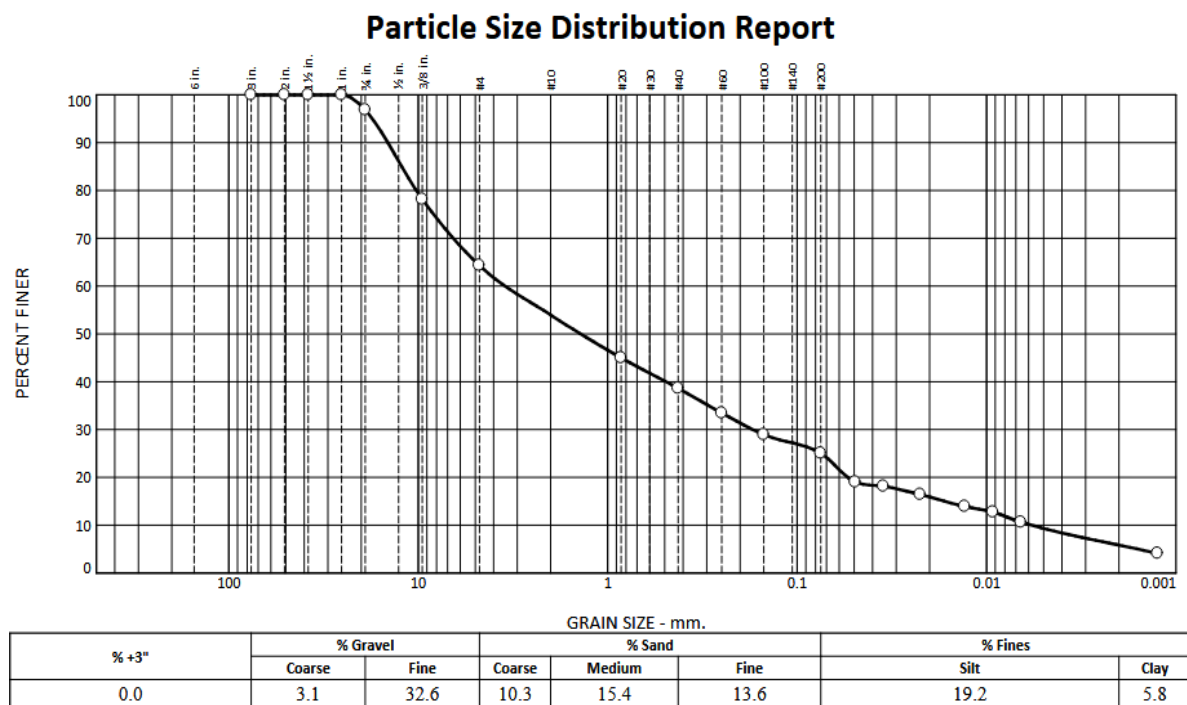


Figure A.1. PSD curve of surface aggregate material collected from Section 1 in April 2024

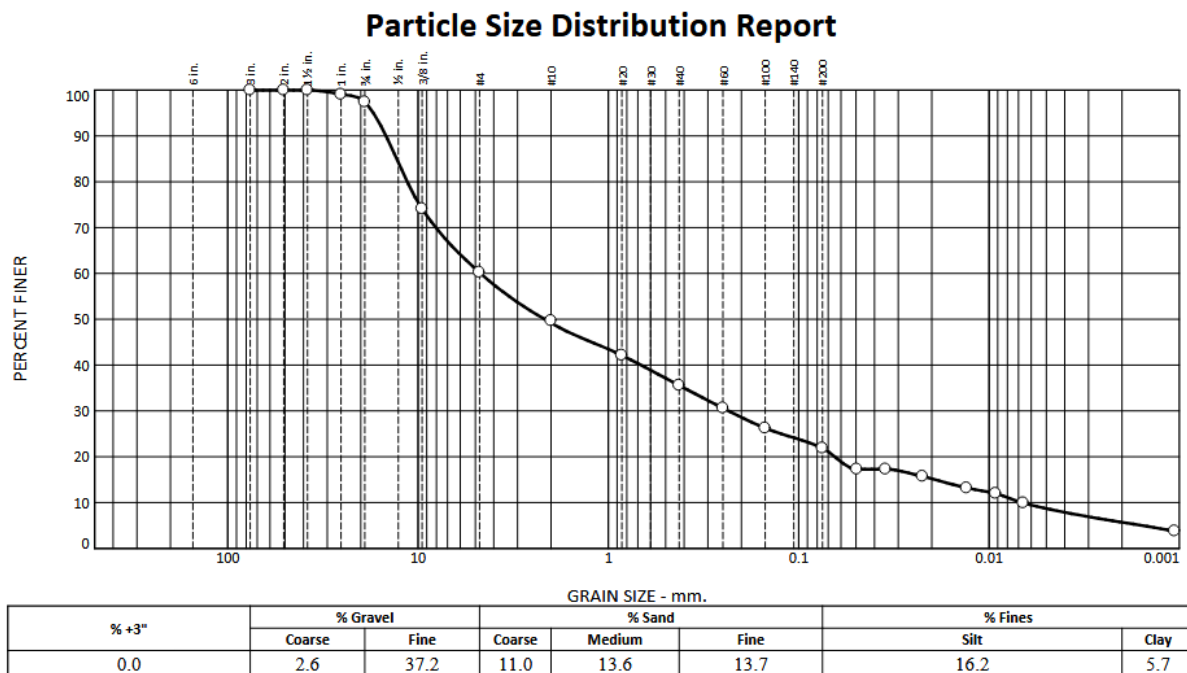


Figure A.2. PSD curve of surface aggregate material collected from Section 2 in April 2024

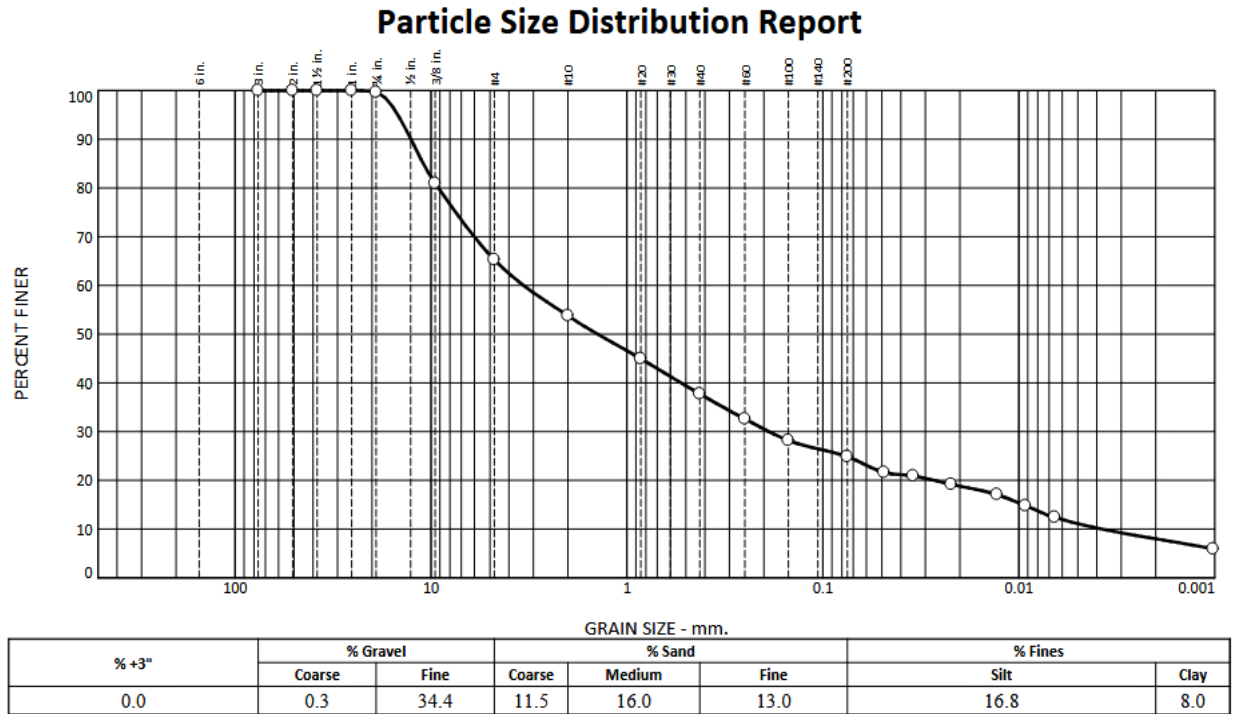


Figure A.3. PSD curve of surface aggregate material collected from Section 3 in April 2024

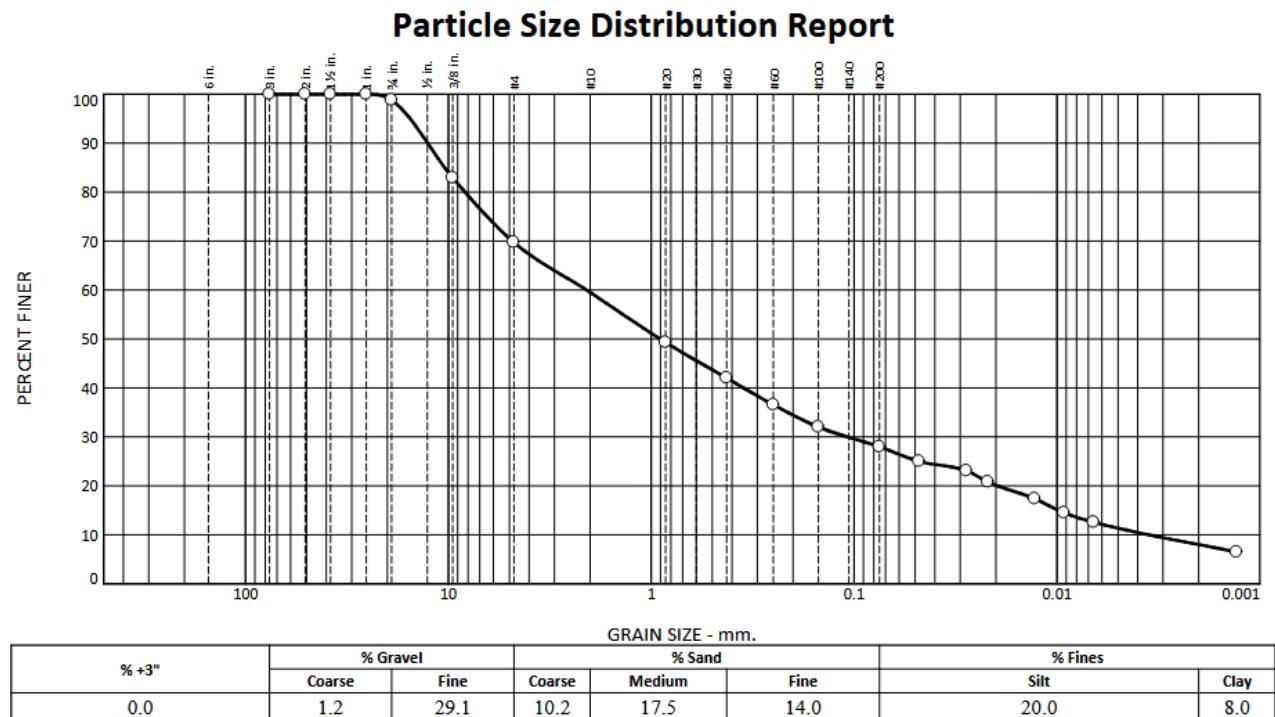


Figure A.4. PSD curve of surface aggregate material collected from Section 4 in April 2024

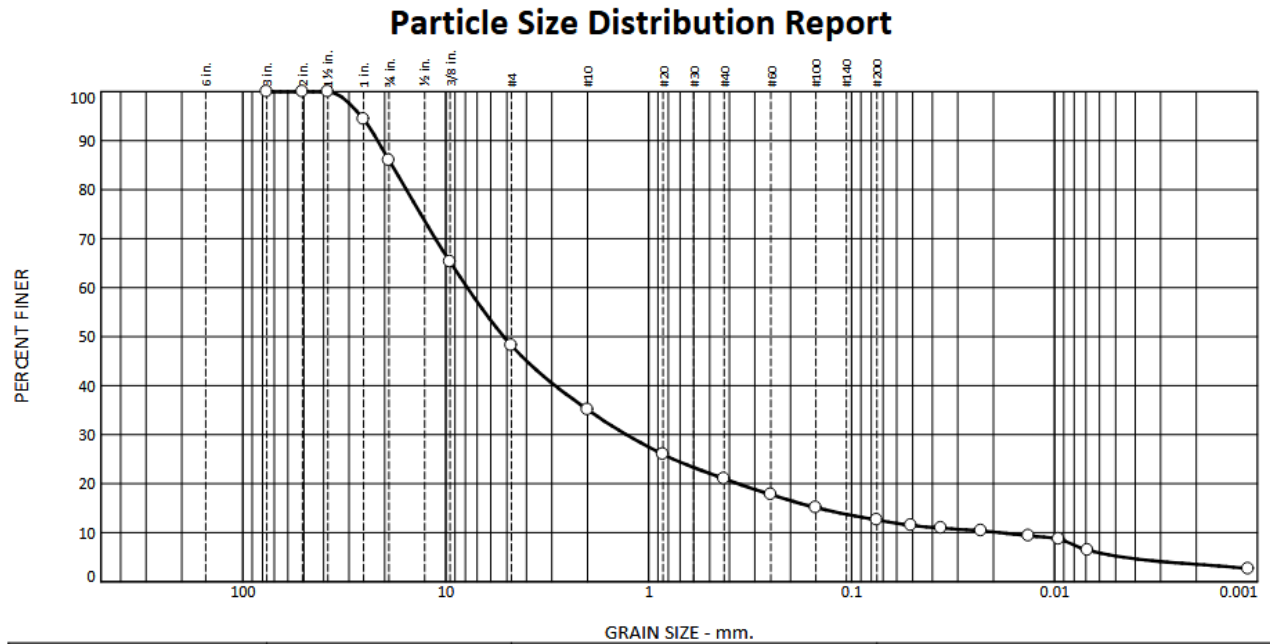


Figure A.5. PSD curve of surface aggregate material collected from Section 5 in April 2024

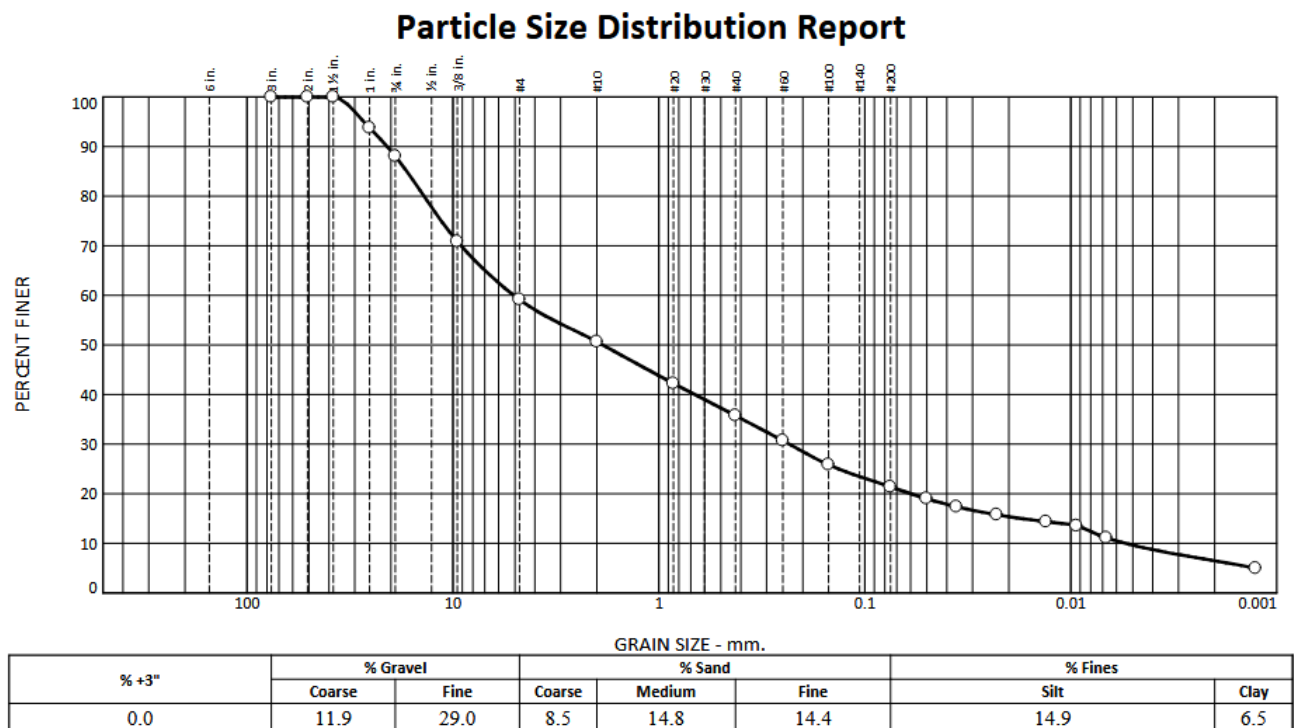


Figure A.6. PSD curve of surface aggregate material collected from Section 1 in November 2024

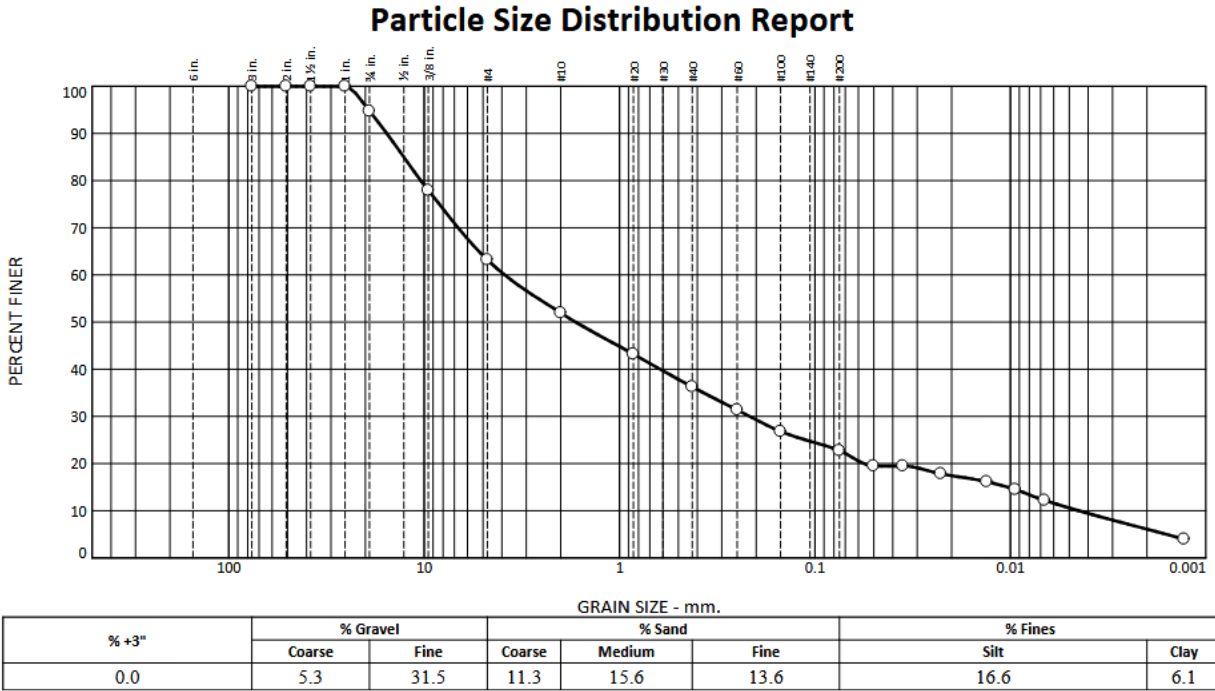


Figure A.7. PSD curve of surface aggregate material collected from Section 2 in November 2024

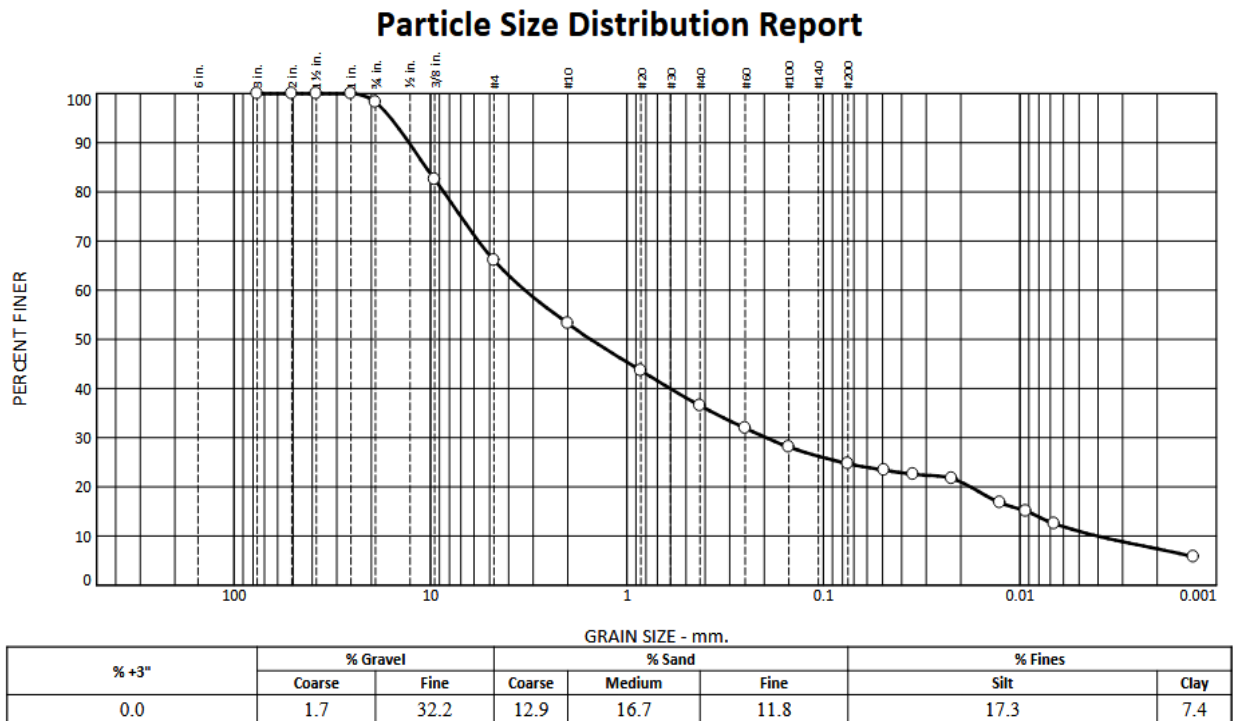


Figure A.8. PSD curve of surface aggregate material collected from Section 3 in November 2024

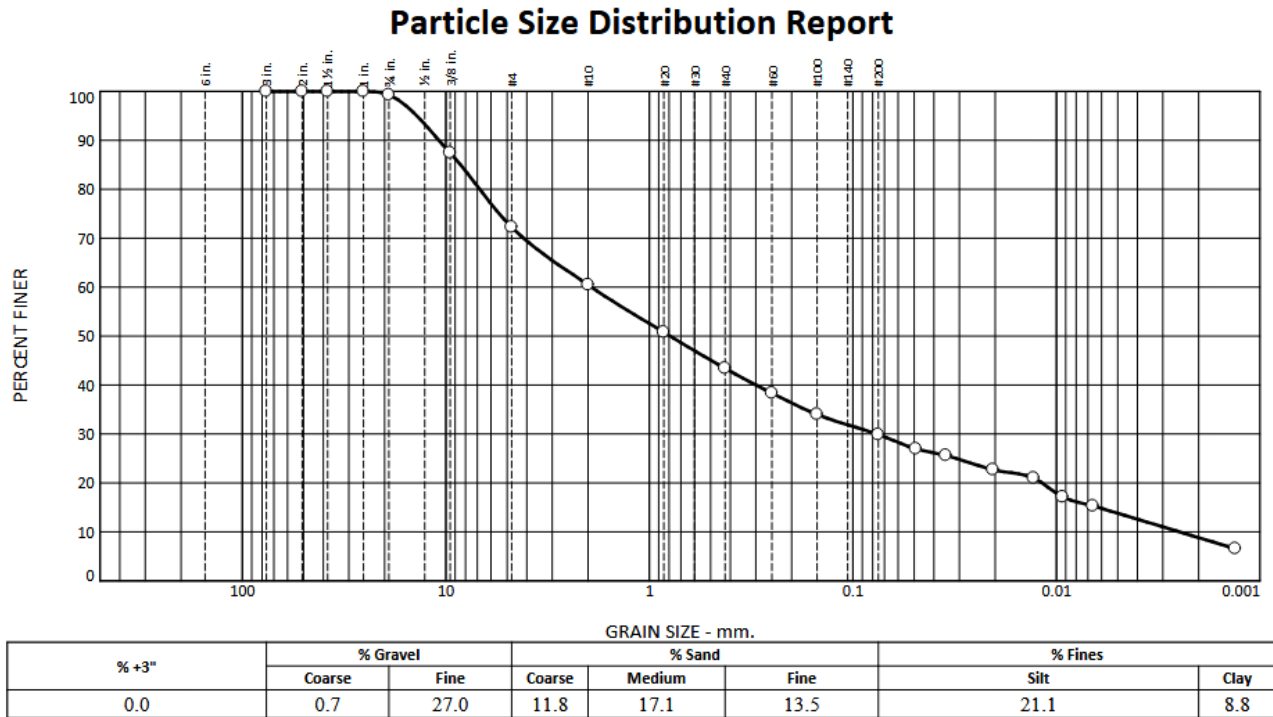


Figure A.9. PSD curve of surface aggregate material collected from Section 4 in November 2024

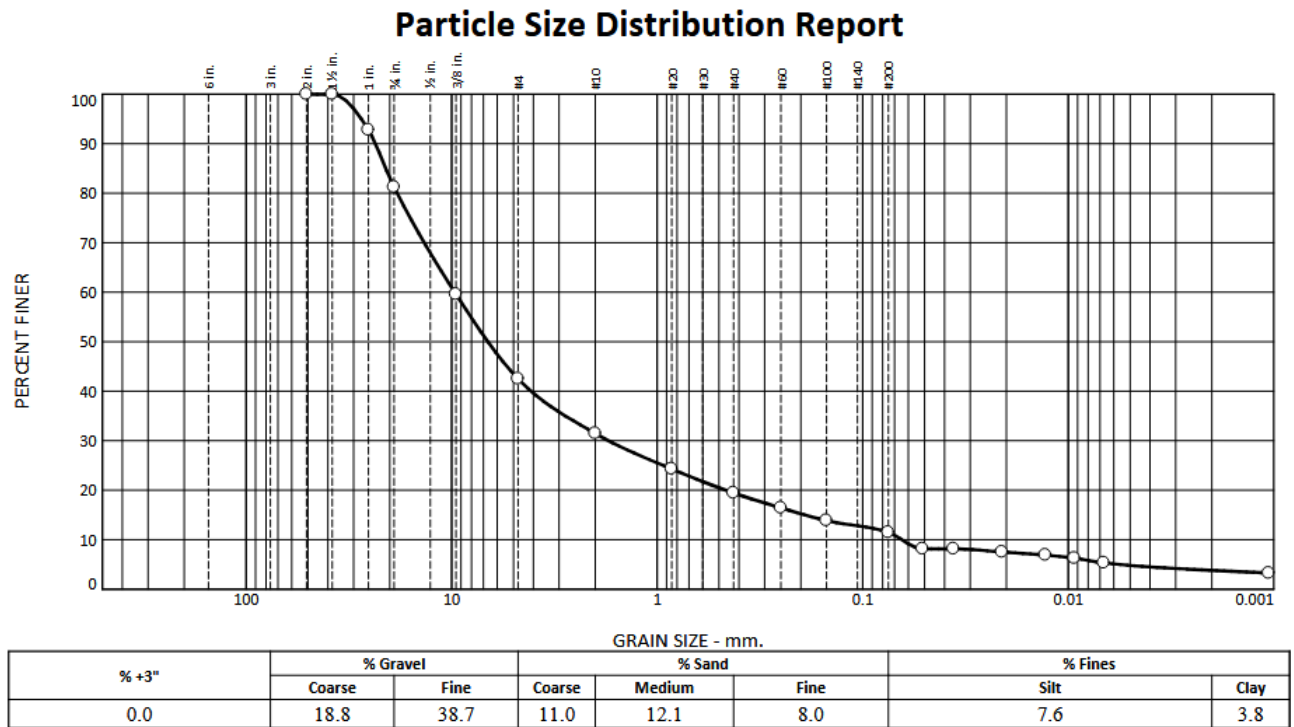


Figure A.10. PSD curve of surface aggregate material collected from Section 5 in November 2024

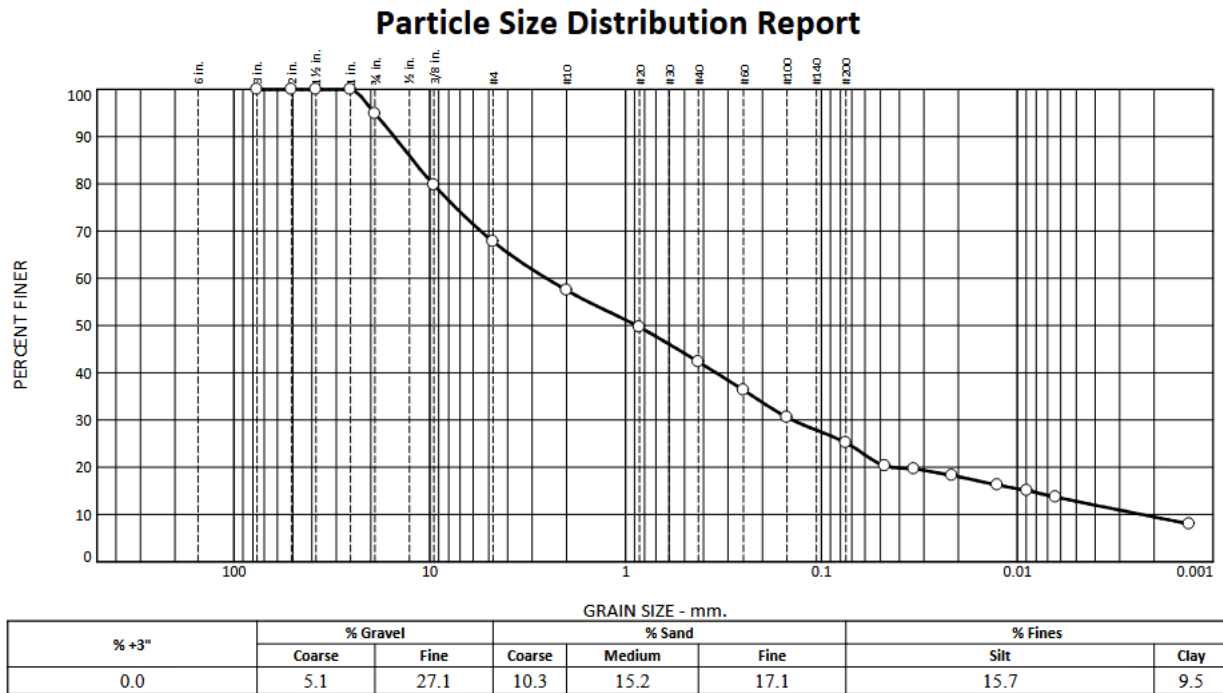


Figure A.11. PSD curve of surface aggregate material collected from Section 1 in April 2025

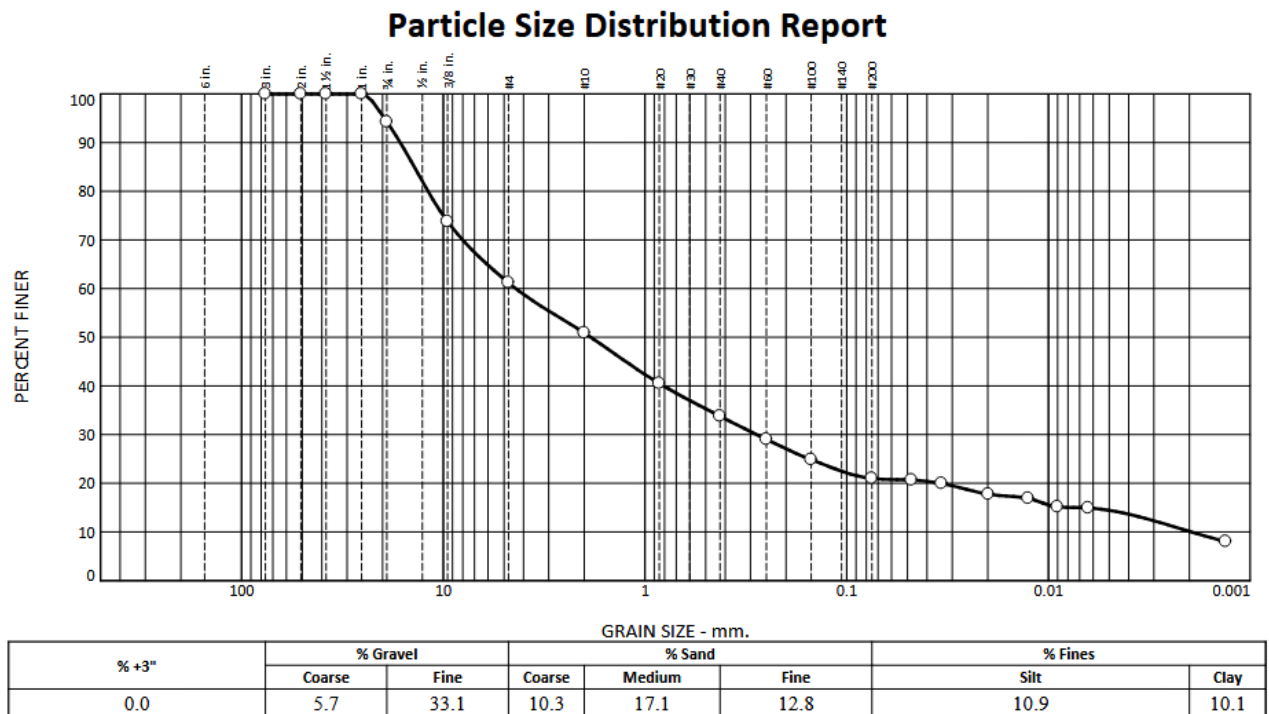


Figure A.12. PSD curve of surface aggregate material collected from Section 2 in April 2025

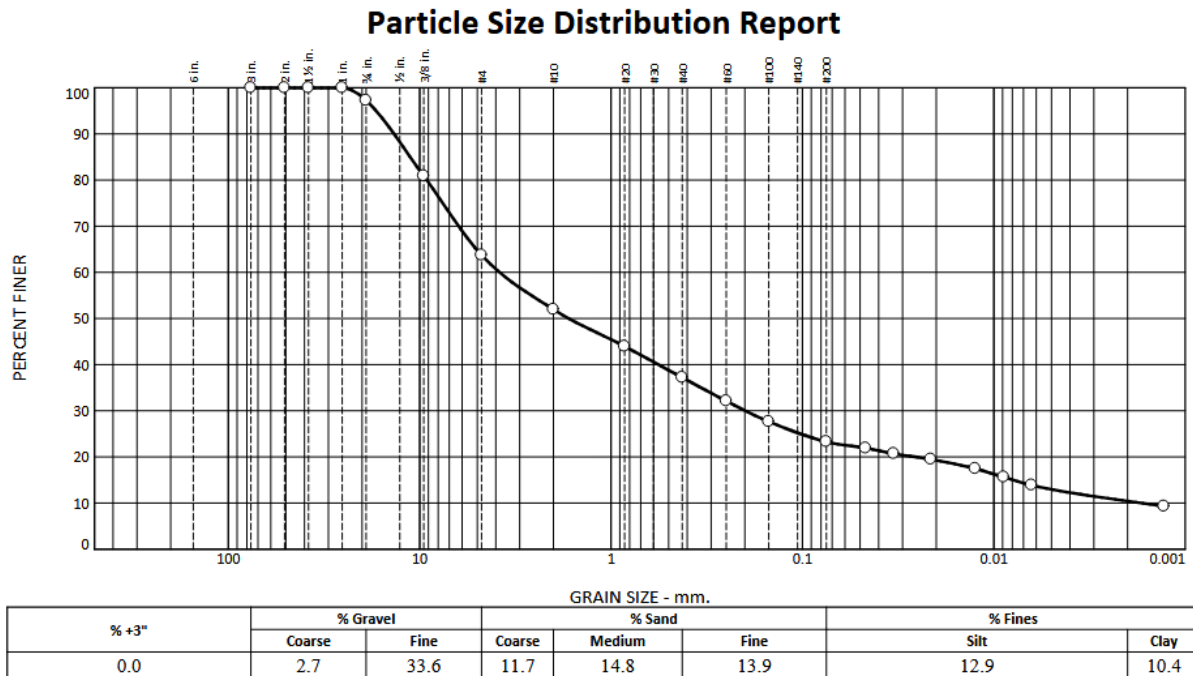


Figure A.13. PSD curve of surface aggregate material collected from Section 3 in April 2025

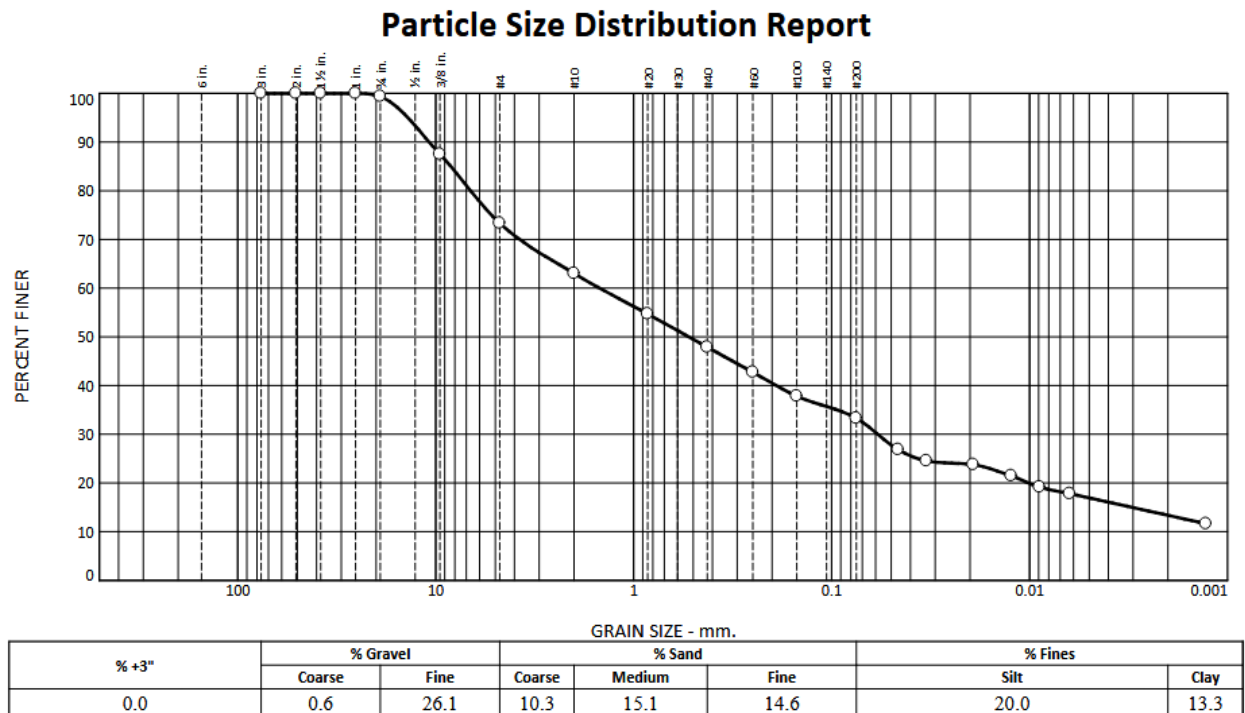


Figure A.14. PSD curve of surface aggregate material collected from Section 4 in April 2025

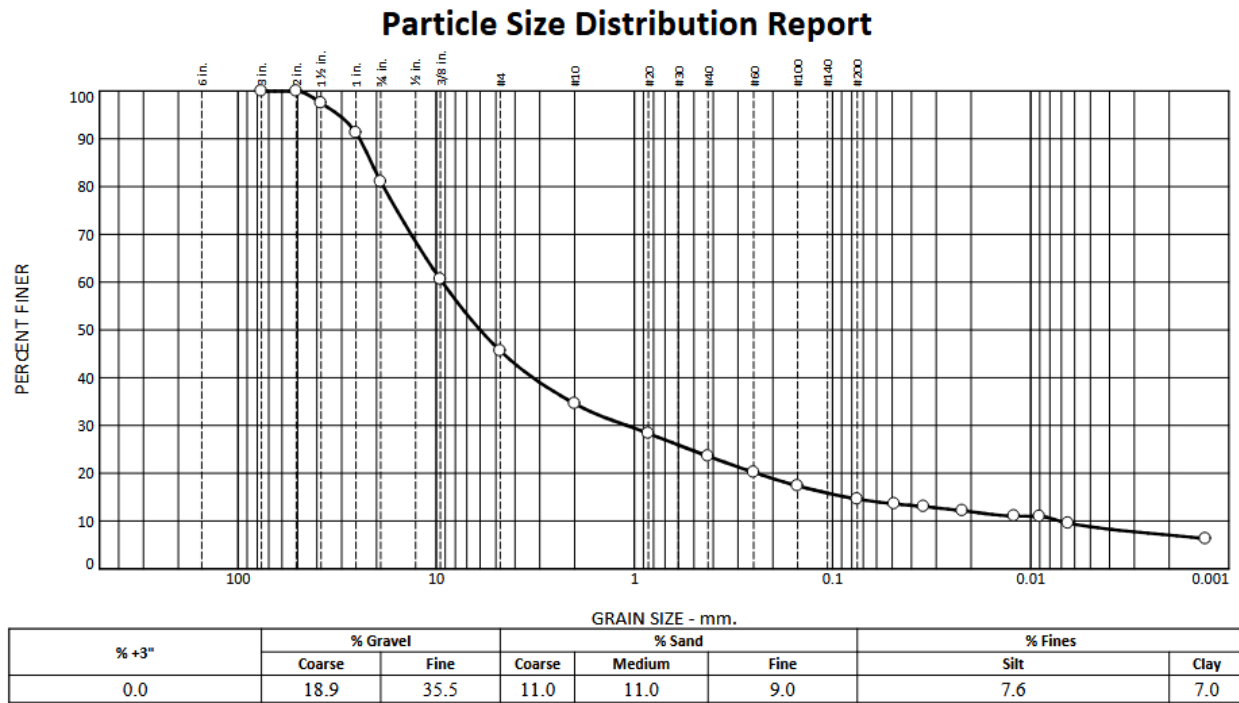


Figure A.15. PSD curve of surface aggregate material collected from Section 5 in April 2025

APPENDIX B. ADCP TEST RESULTS

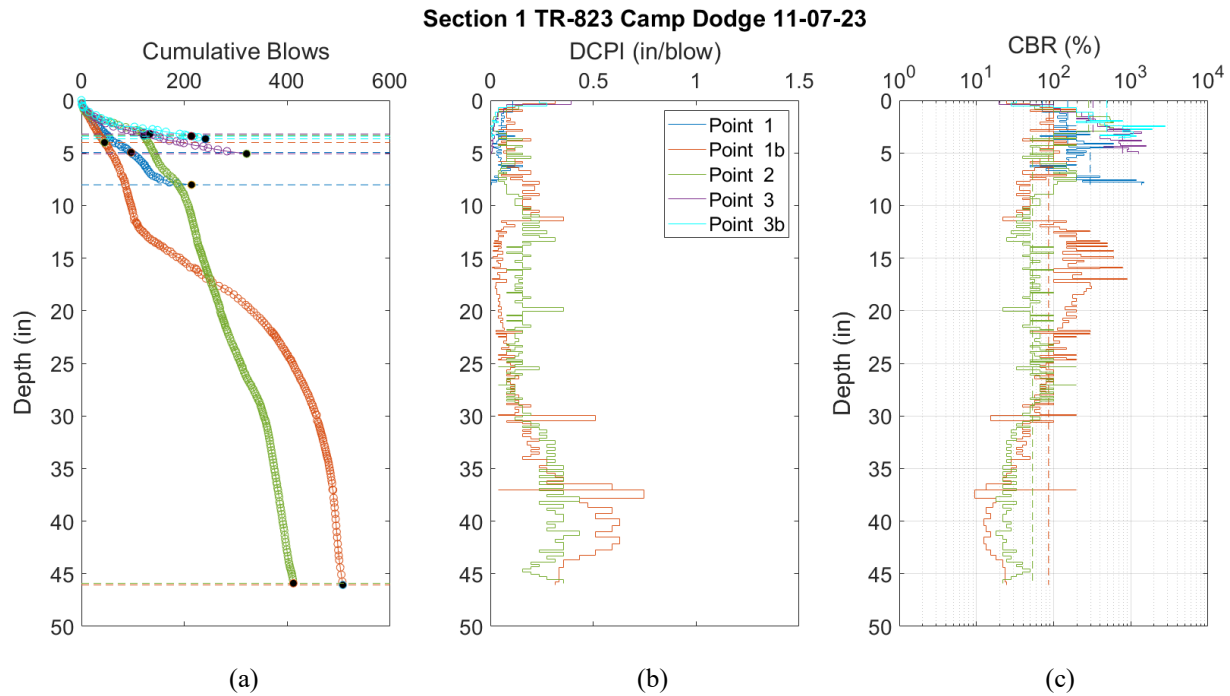


Figure B.1. ADCP results for Section 1 in fall 2023. (a) cumulative blows, (b) DCPI, and (c) DCP-CBR

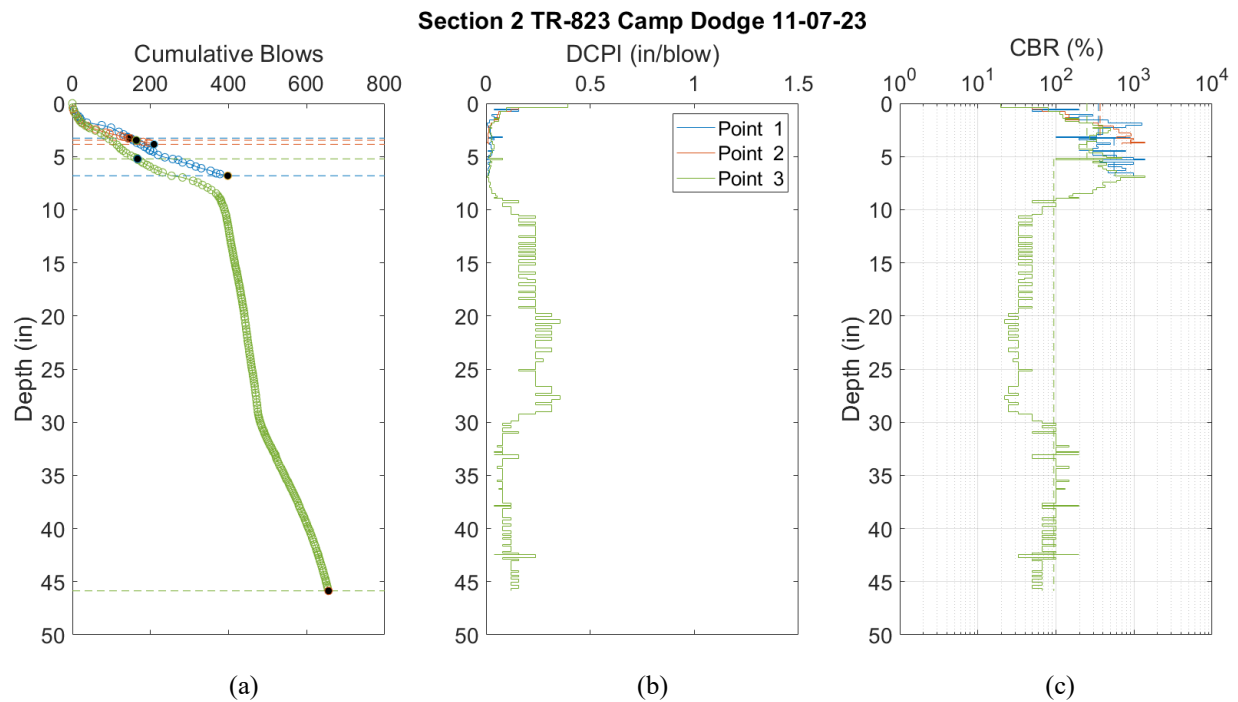


Figure B.2. ADCP results for Section 2 in fall 2023. (a) cumulative blows, (b) DCPI, and (c) DCP-CBR

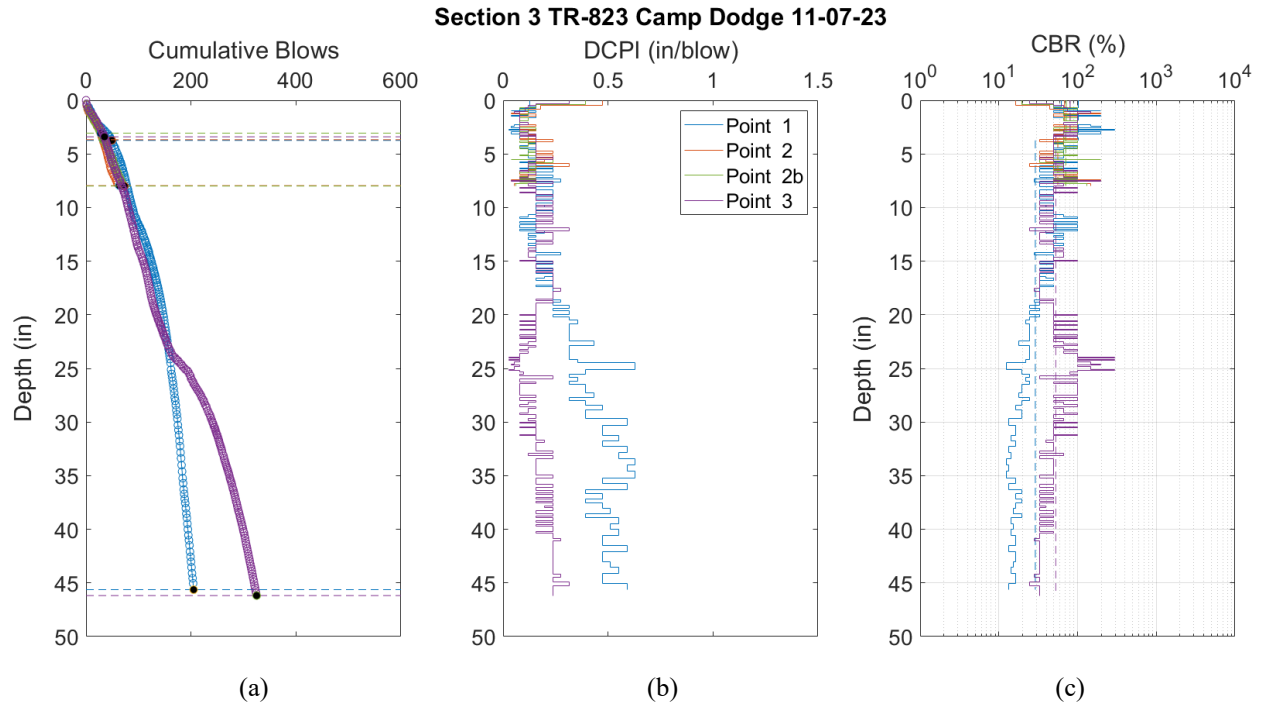


Figure B.3. ADCP results for Section 3 in fall 2023. (a) cumulative blows, (b) DCPI, and (c) DCP-CBR

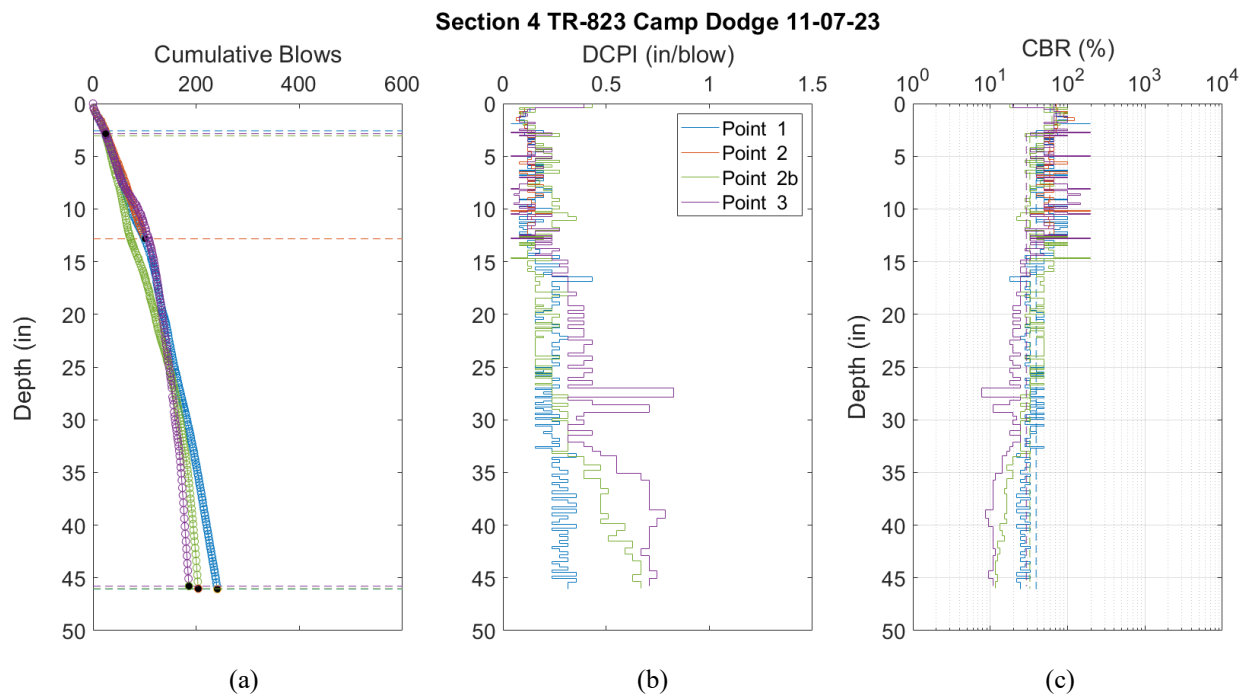


Figure B.4. ADCP results for Section 4 in fall 2023. (a) cumulative blows, (b) DCPI, and (c) DCP-CBR

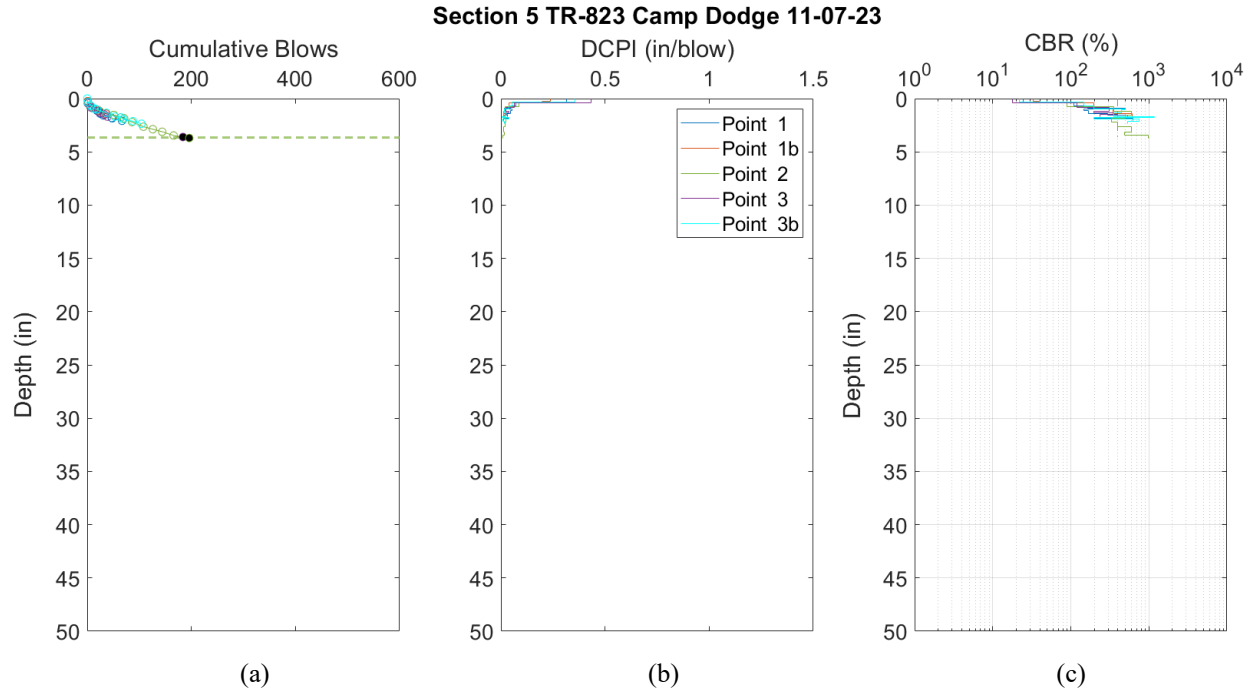


Figure B.5. ADCP results for Section 5 in fall 2023. (a) cumulative blows, (b) DCPI, and (c) DCP-CBR

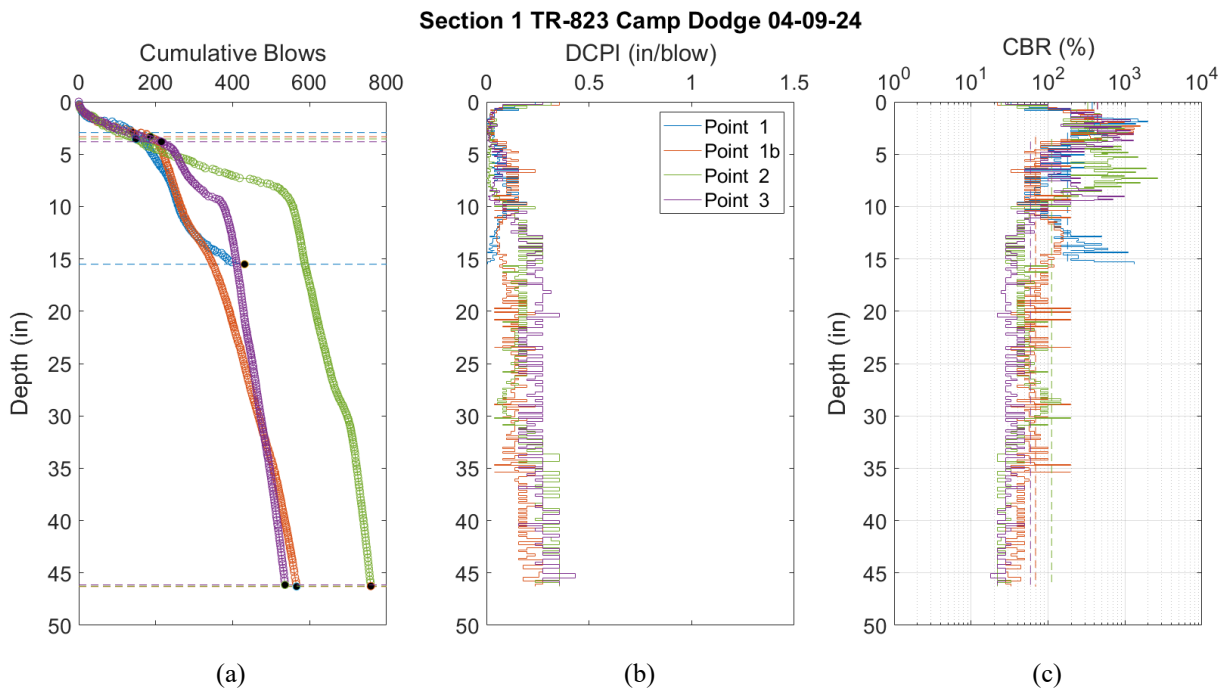


Figure B.6. ADCP results for Section 1 in spring 2024. (a) cumulative blows, (b) DCPI, and (c) DCP-CBR

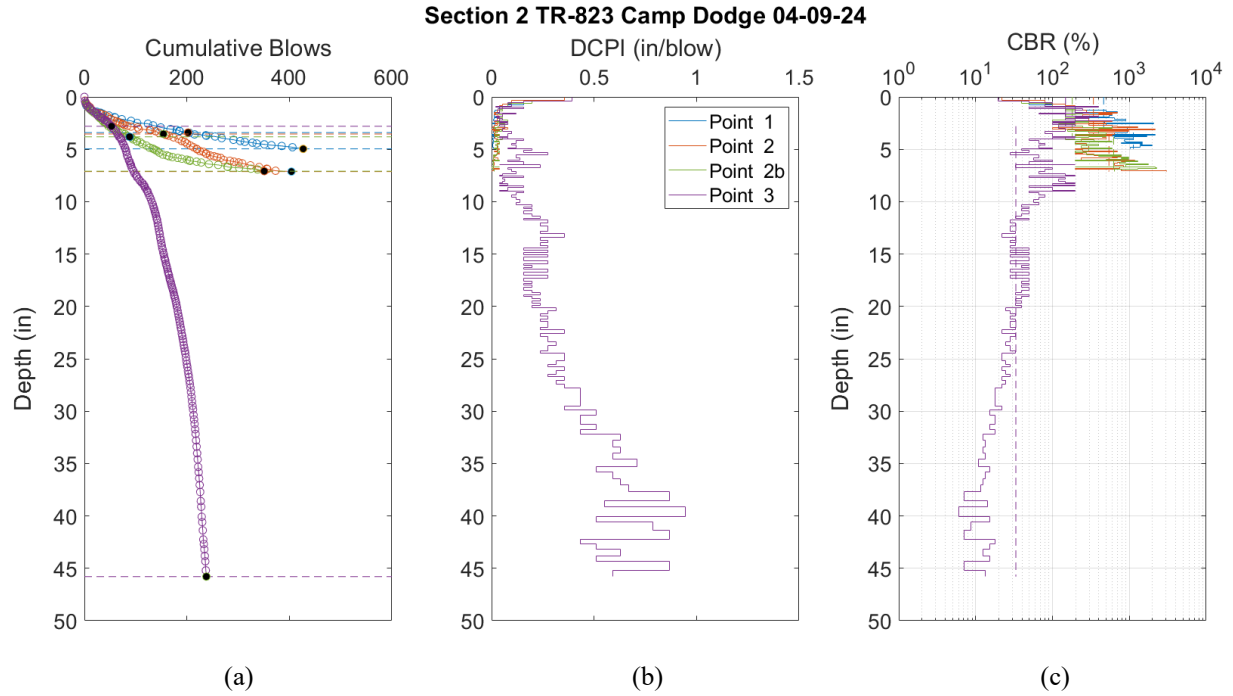


Figure B.7. ADCP results for Section 2 in spring 2024. (a) cumulative blows, (b) DCPI, and (c) DCP-CBR

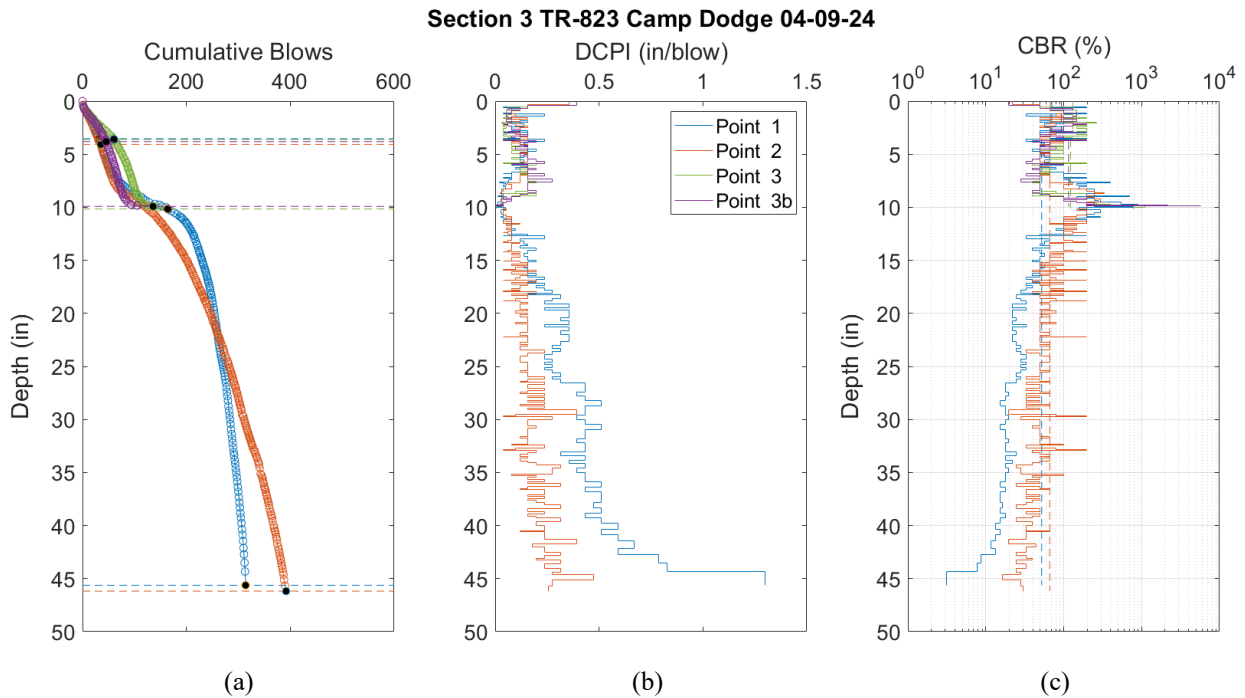


Figure B.8. ADCP results for Section 3 in spring 2024. (a) cumulative blows, (b) DCPI, and (c) DCP-CBR

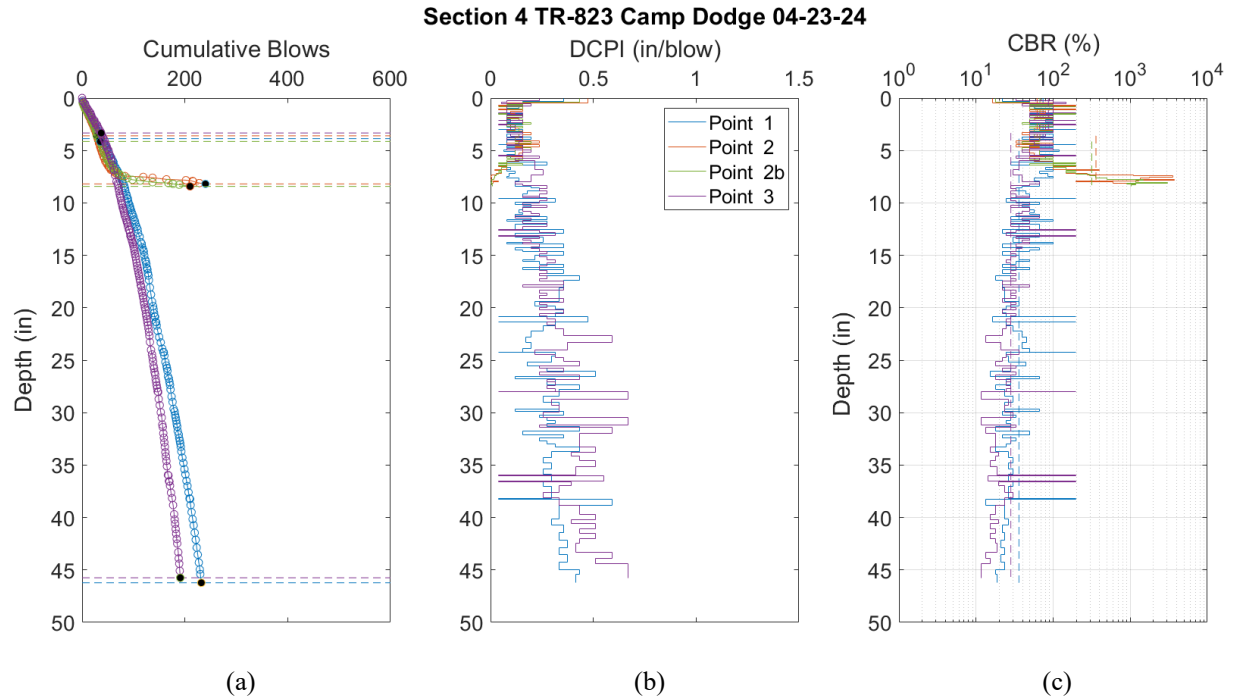


Figure B.9. ADCP results for Section 4 in spring 2024. (a) cumulative blows, (b) DCPI, and (c) DCP-CBR

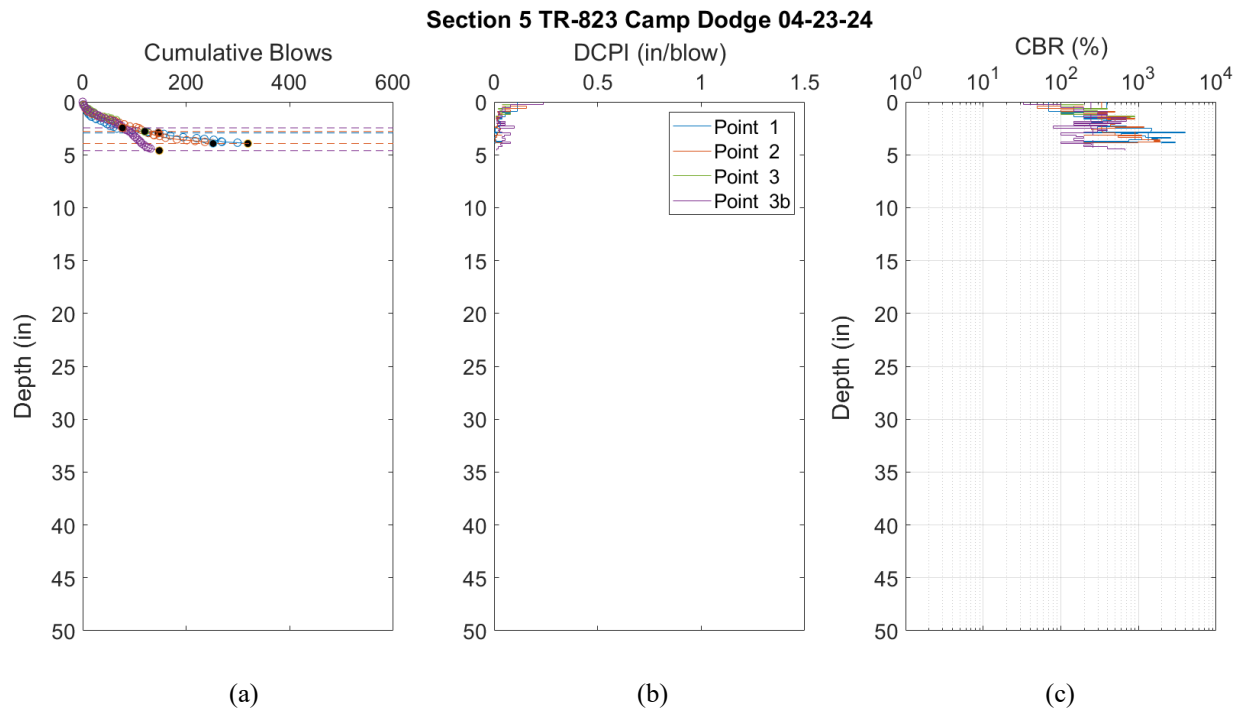


Figure B.10. ADCP results for Section 5 in spring 2024. (a) cumulative blows, (b) DCPI, and (c) DCP-CBR

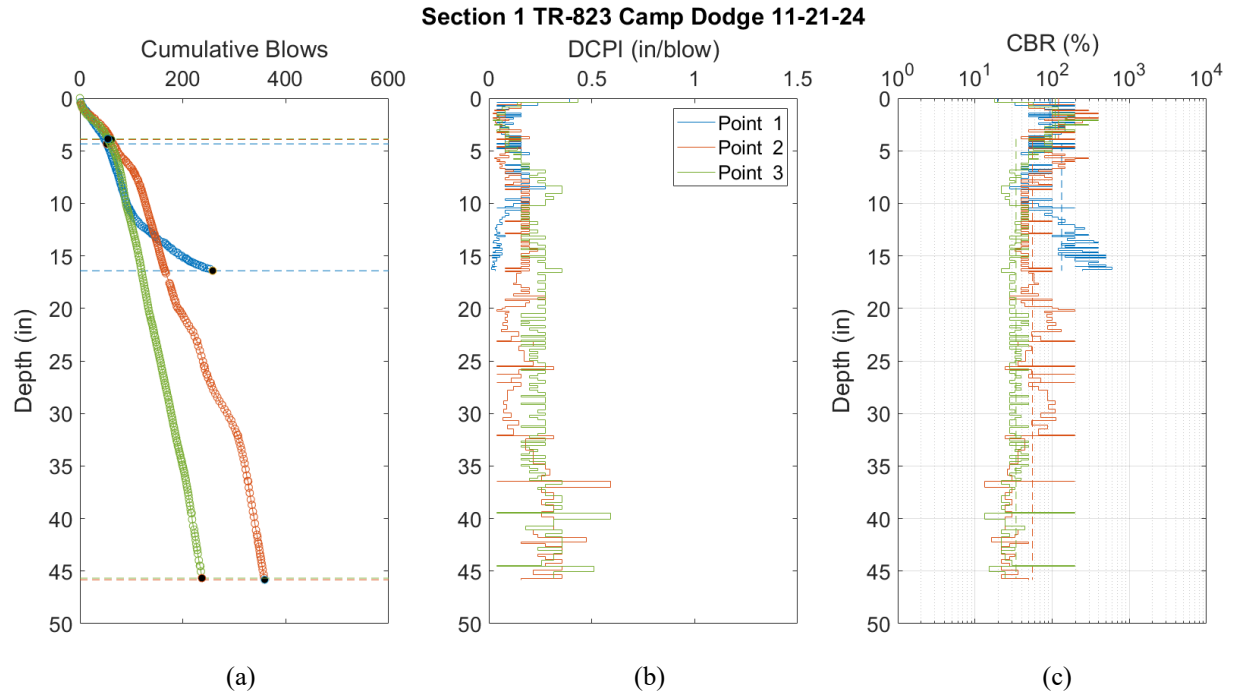


Figure B.11. ADCP results for Section 1 in fall 2024. (a) cumulative blows, (b) DCPI, and (c) DCP-CBR

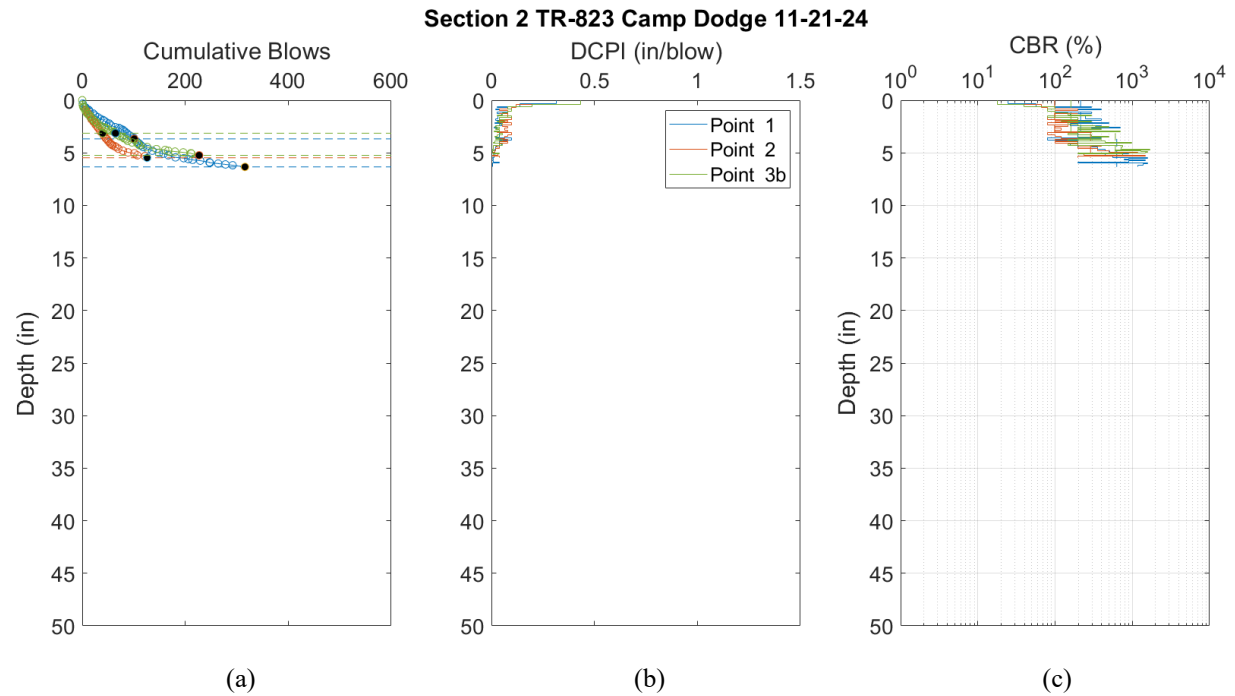


Figure B.12. ADCP results for Section 2 in fall 2024. (a) cumulative blows, (b) DCPI, and (c) DCP-CBR

Section 3 TR-823 Camp Dodge 11-21-24

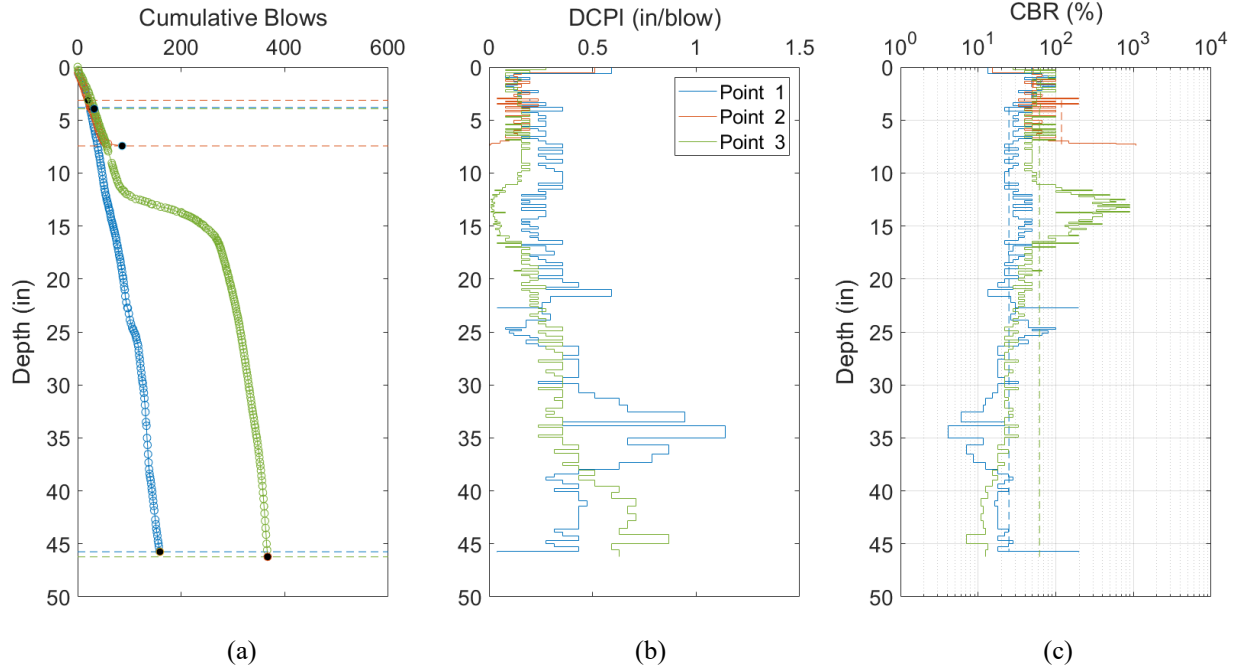


Figure B.13. ADCP results for Section 3 in fall 2024. (a) cumulative blows, (b) DCPI, and (c) DCP-CBR

Section 4 TR-823 Camp Dodge 11-21-24

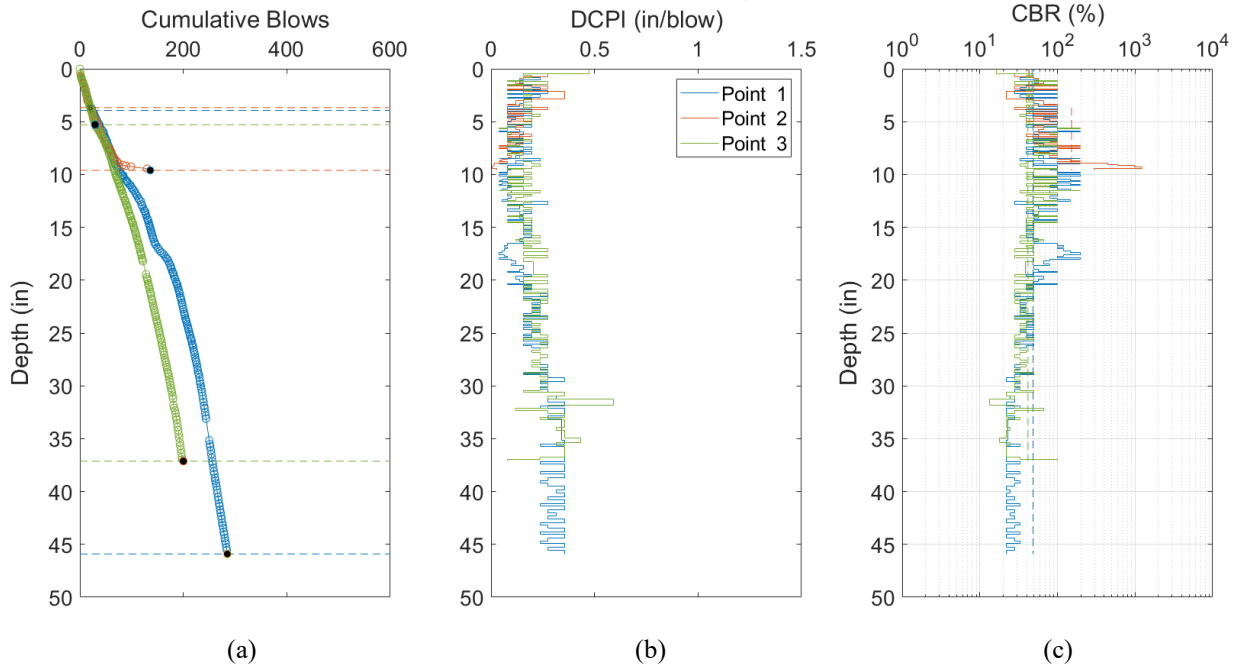


Figure B.14. ADCP results for Section 4 in fall 2024. (a) cumulative blows, (b) DCPI, and (c) DCP-CBR

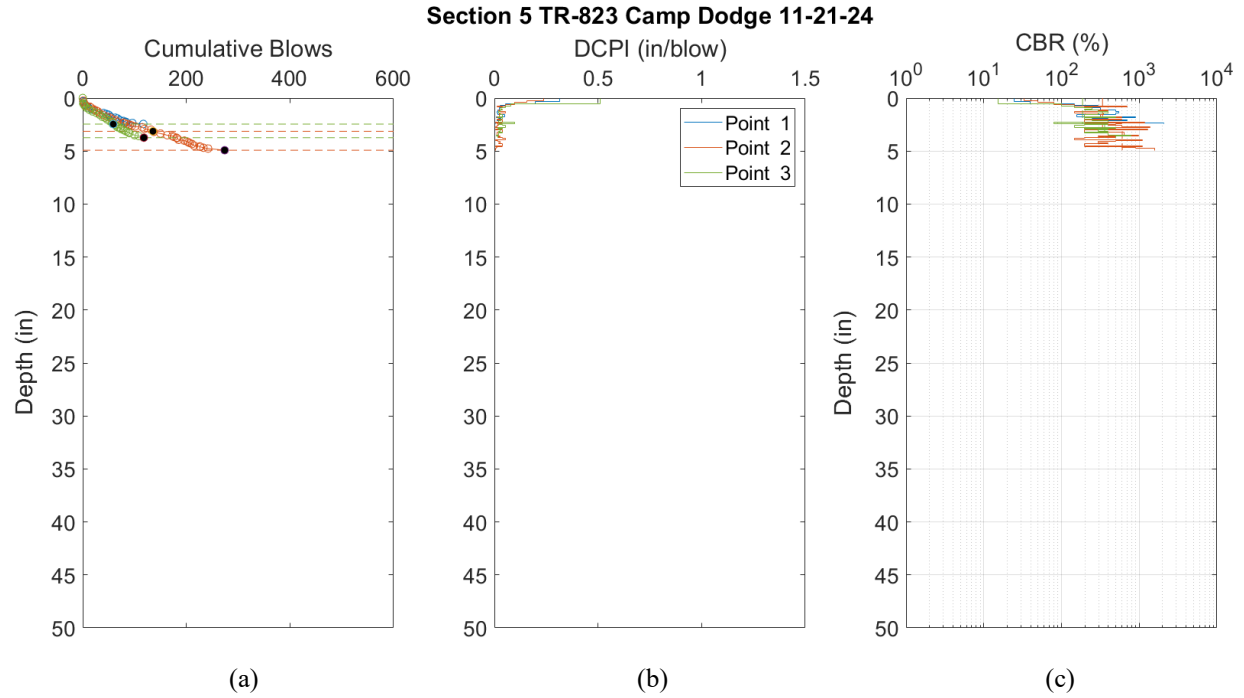


Figure B.15. ADCP results for Section 5 in fall 2024. (a) cumulative blows, (b) DCPI, and (c) DCP-CBR

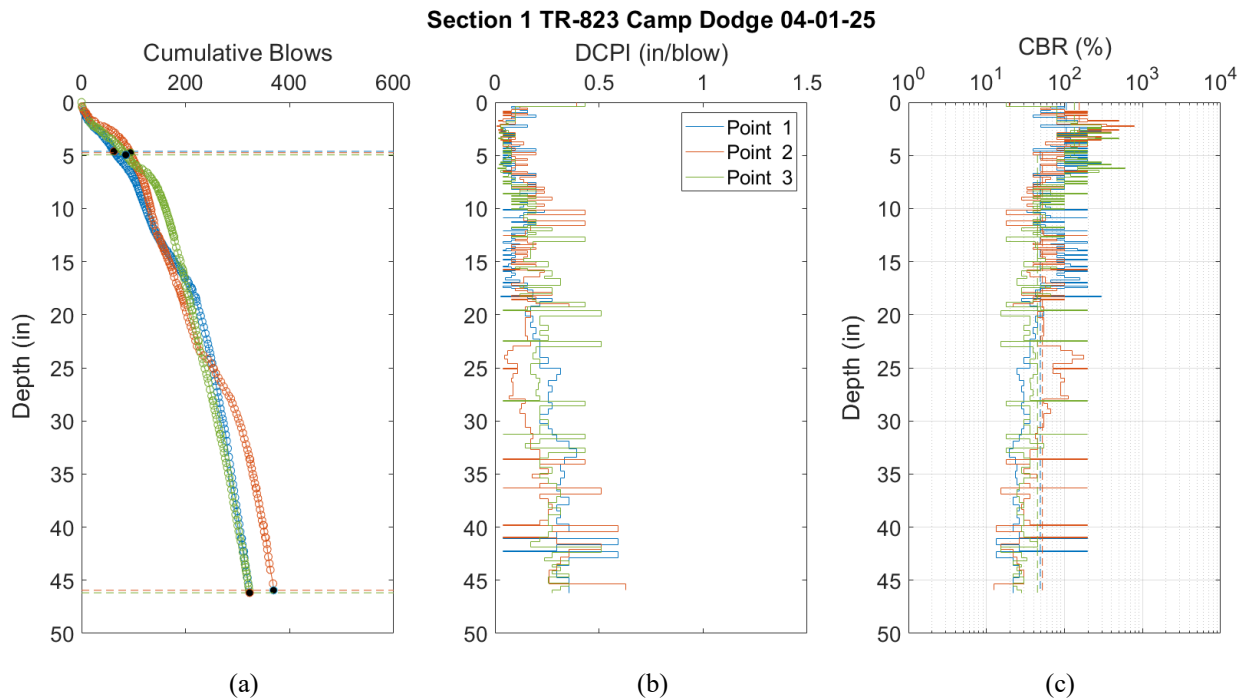


Figure B.16. ADCP results for Section 1 in spring 2025. (a) cumulative blows, (b) DCPI, and (c) DCP-CBR

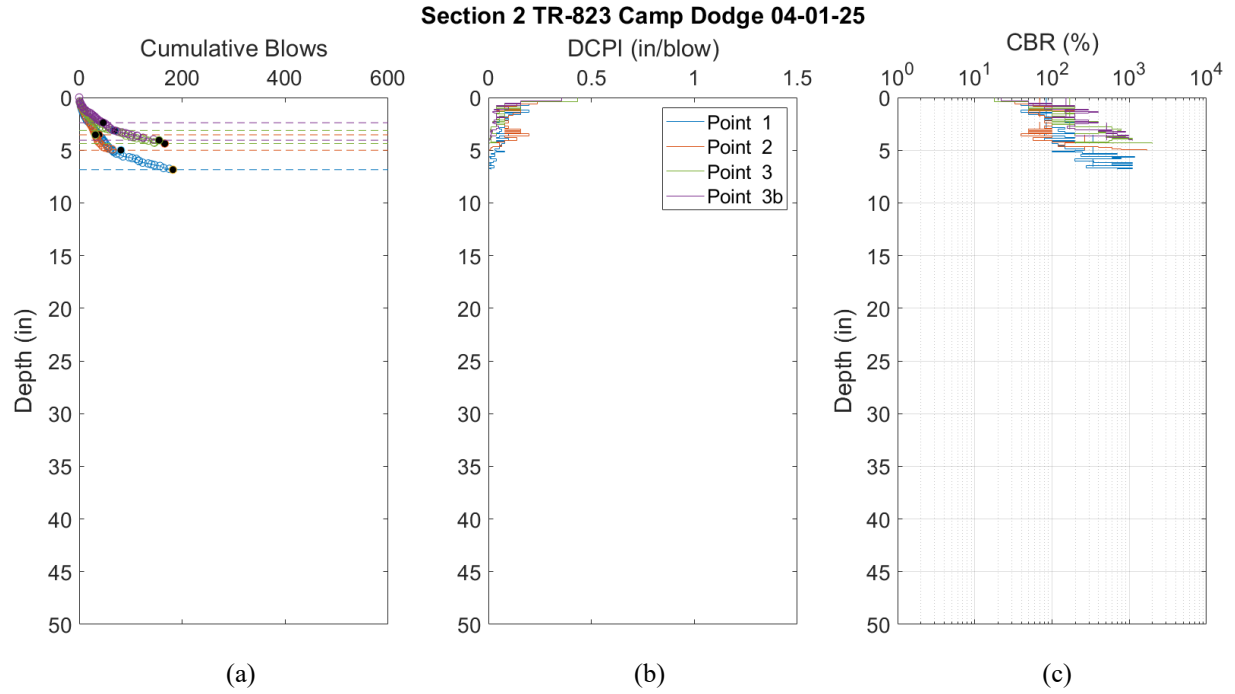


Figure B.17. ADCP results for Section 2 in spring 2025. (a) cumulative blows, (b) DCPI, and (c) DCP-CBR

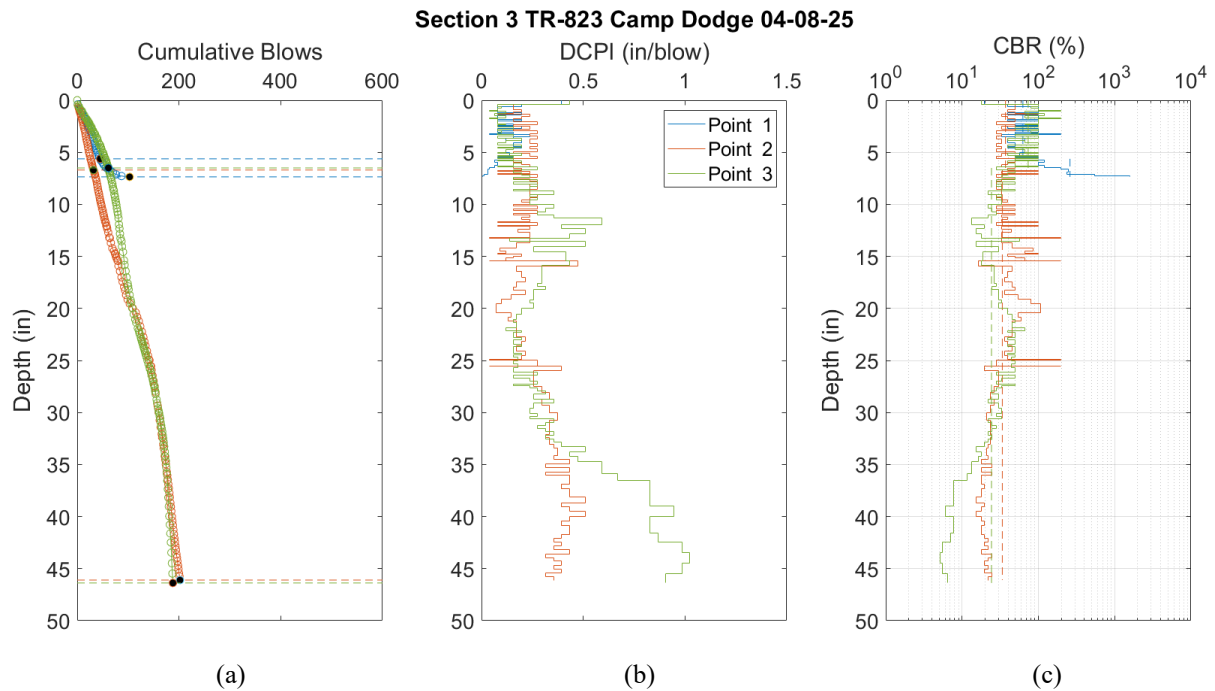


Figure B.18. ADCP results for Section 3 in spring 2025. (a) cumulative blows, (b) DCPI, and (c) DCP-CBR

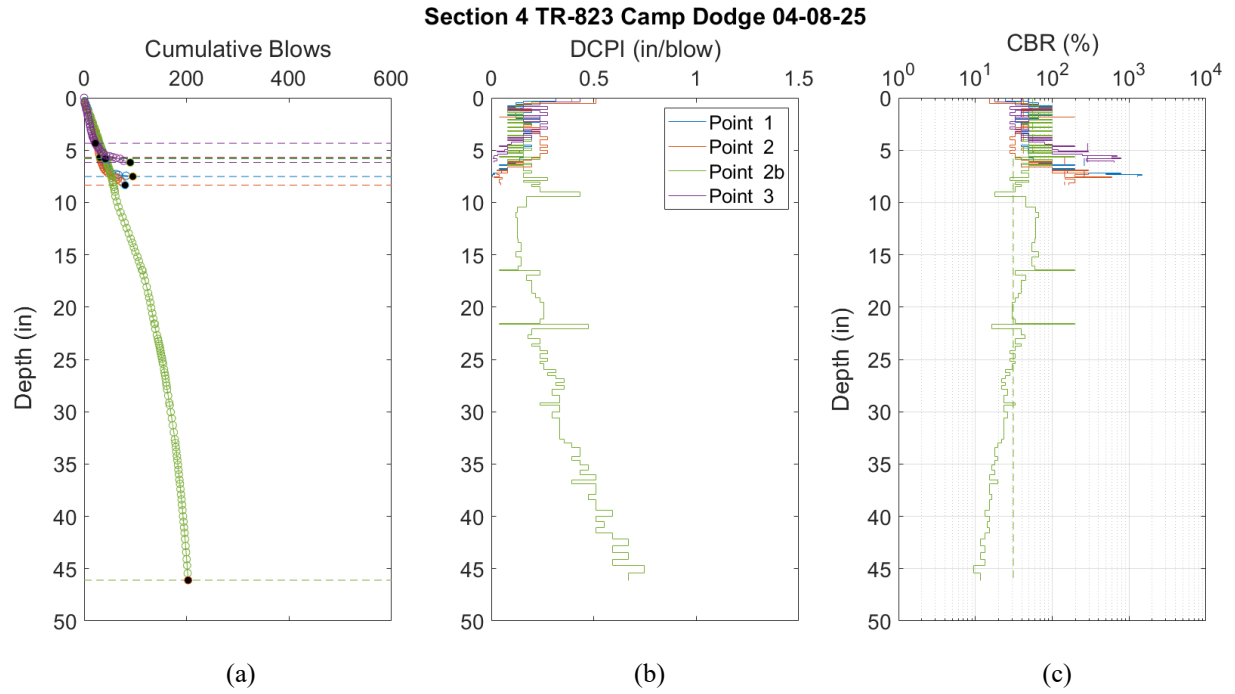


Figure B.19. ADCP results for Section 4 in spring 2025. (a) cumulative blows, (b) DCPI, and (c) DCP-CBR

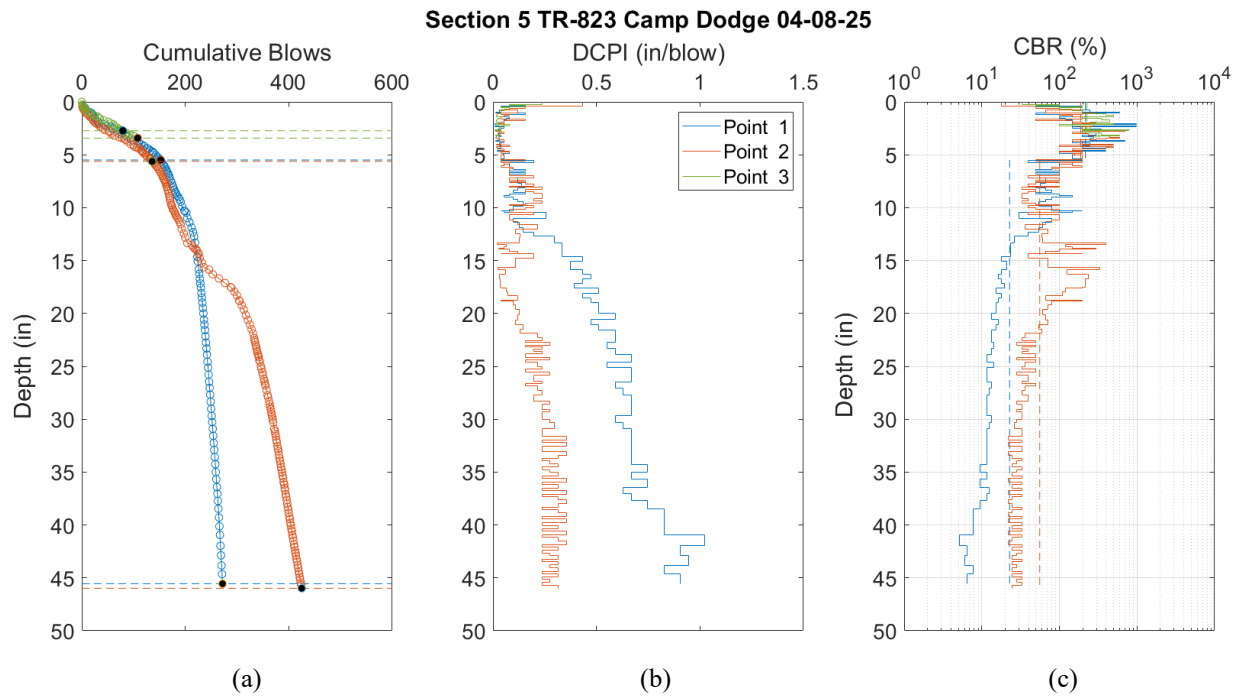


Figure B.20. ADCP results for Section 5 in spring 2025. (a) cumulative blows, (b) DCPI, and (c) DCP-CBR

**APPENDIX C. BREAKAGE RESULTS THROUGH FALL 2024 AND SPRING 2025
FROM PSD CURVES**

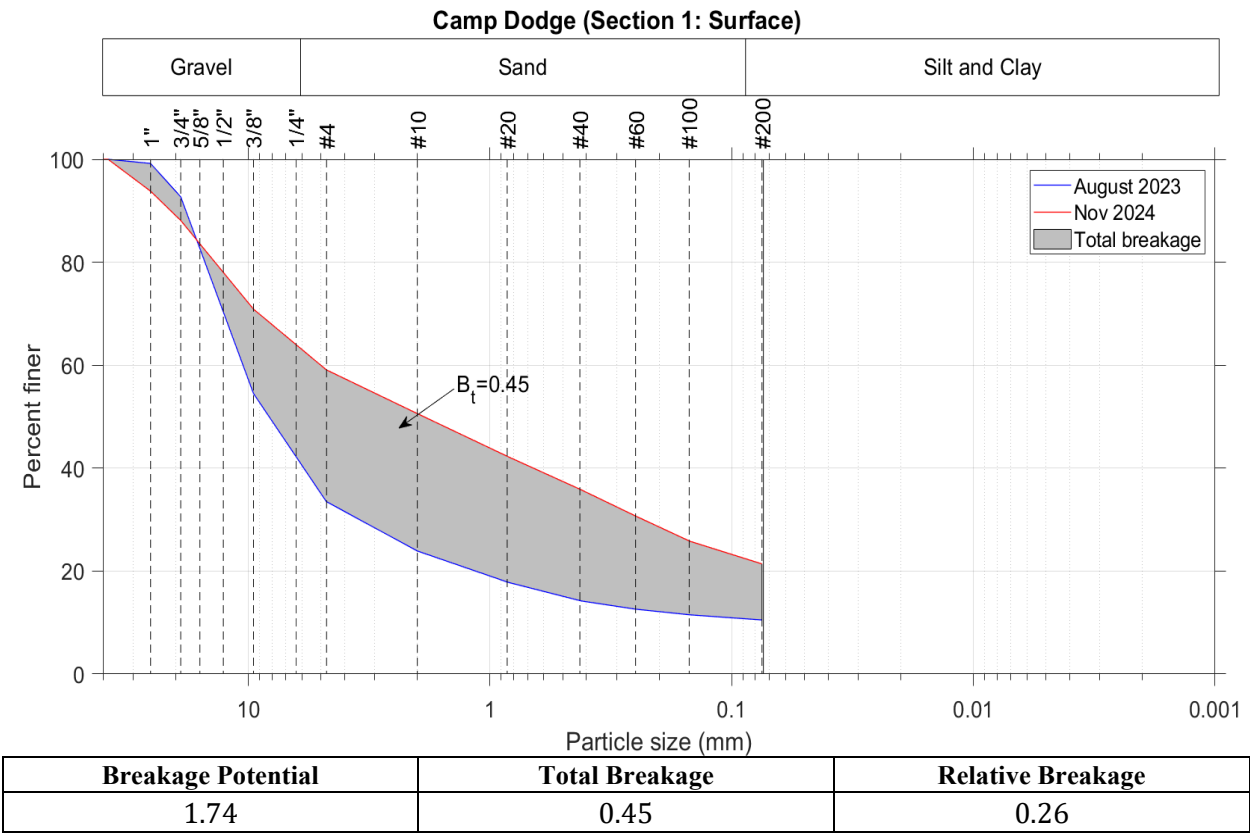


Figure C.1. Breakage characteristics of surface aggregate from Section 1 based on PSD curves from August 2023 to November 2024

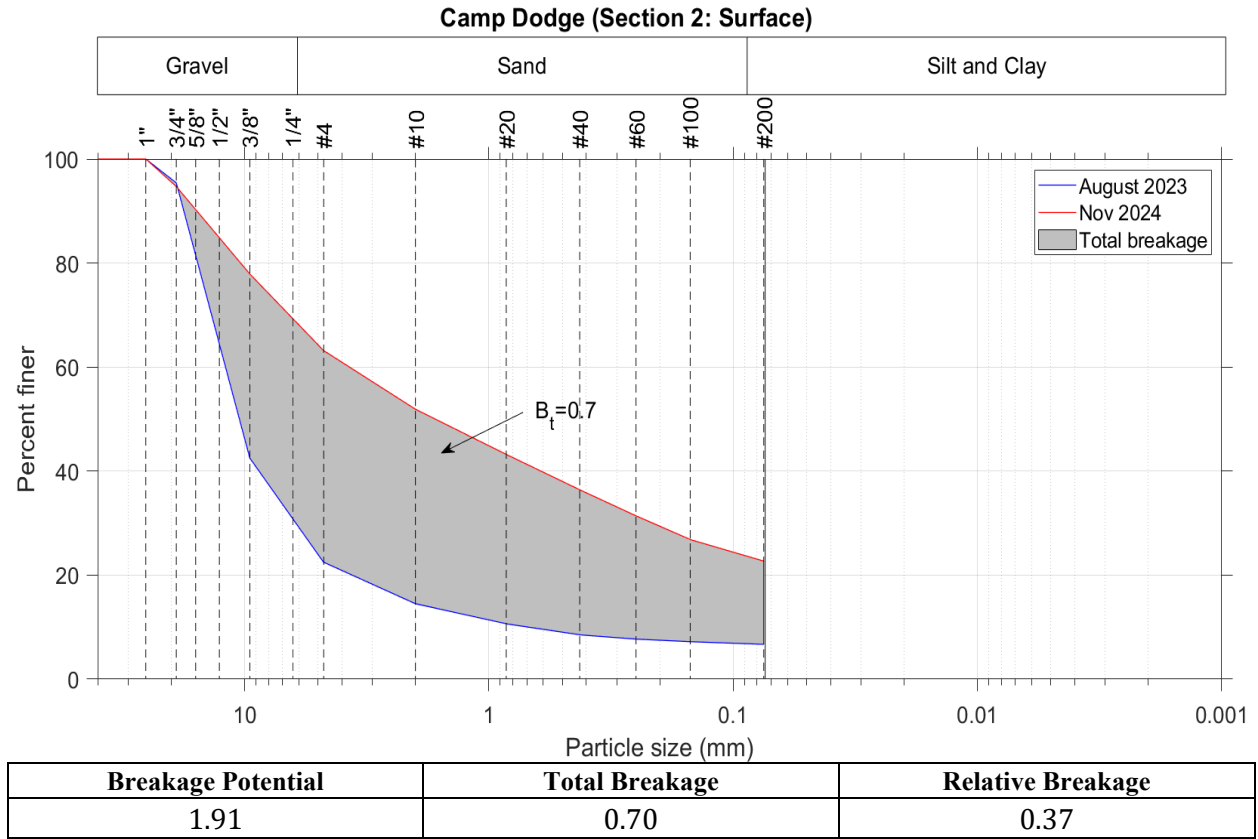


Figure C.2. Breakage characteristics of surface aggregate from Section 2 based on PSD curves from August 2023 to November 2024

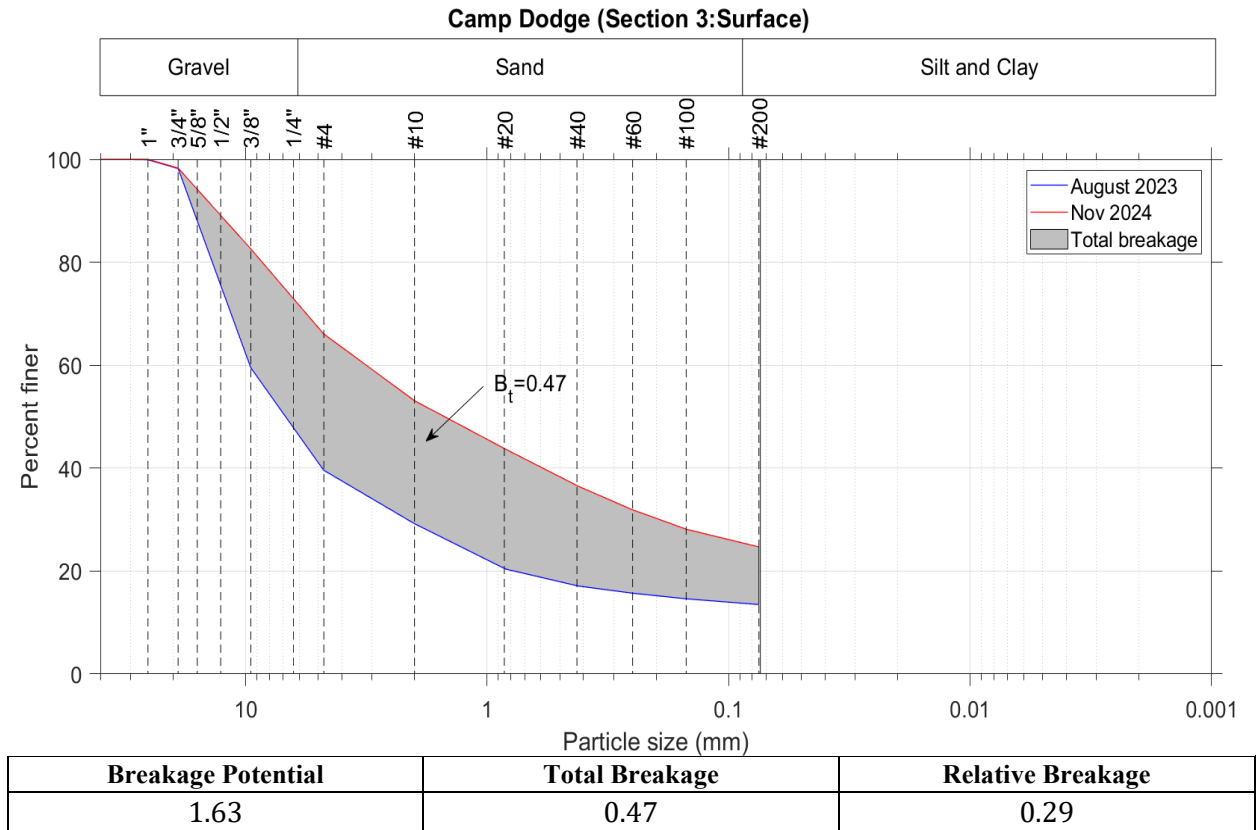


Figure C.3. Breakage characteristics of surface aggregate from Section 3 based on PSD curves from August 2023 to November 2024

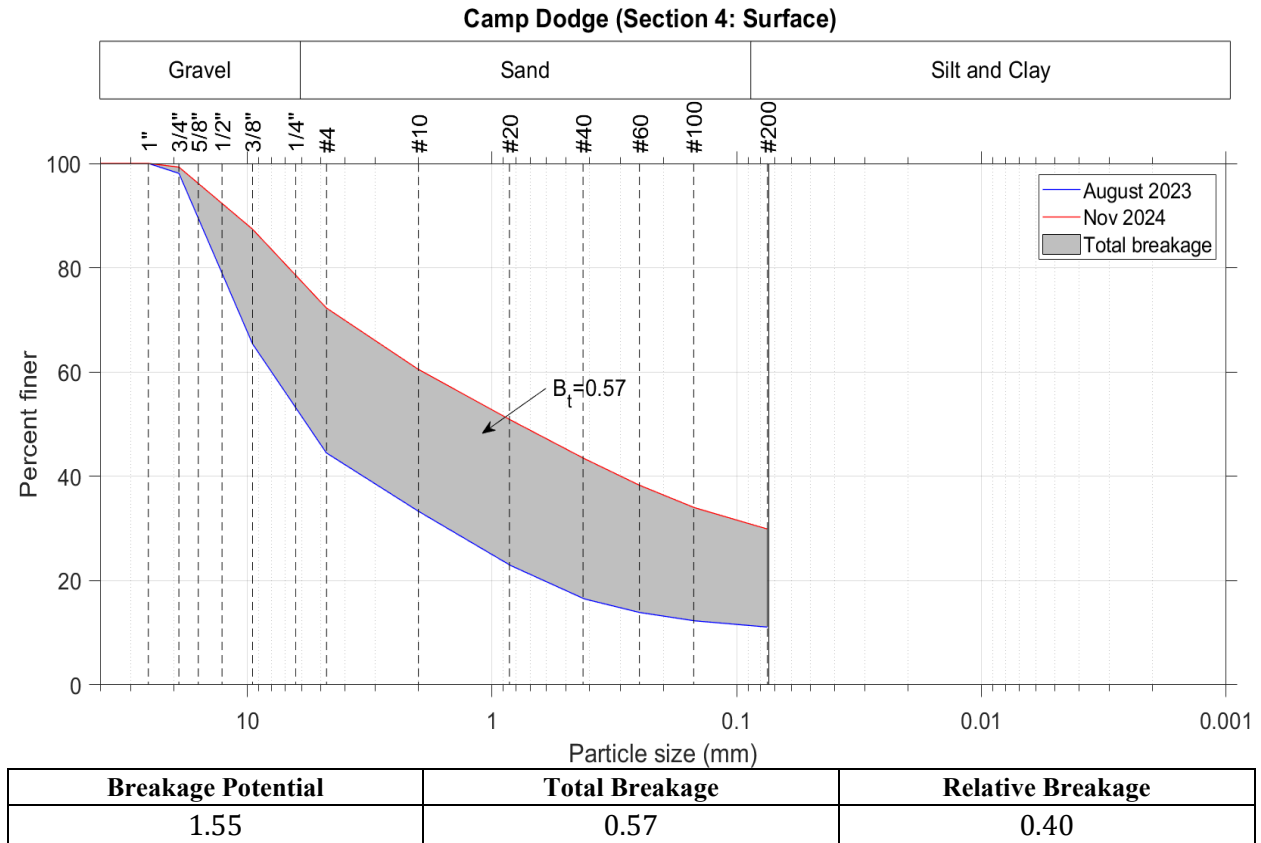


Figure C.4. Breakage characteristics of surface aggregate from Section 3 based on PSD curves from August 2023 to November 2024

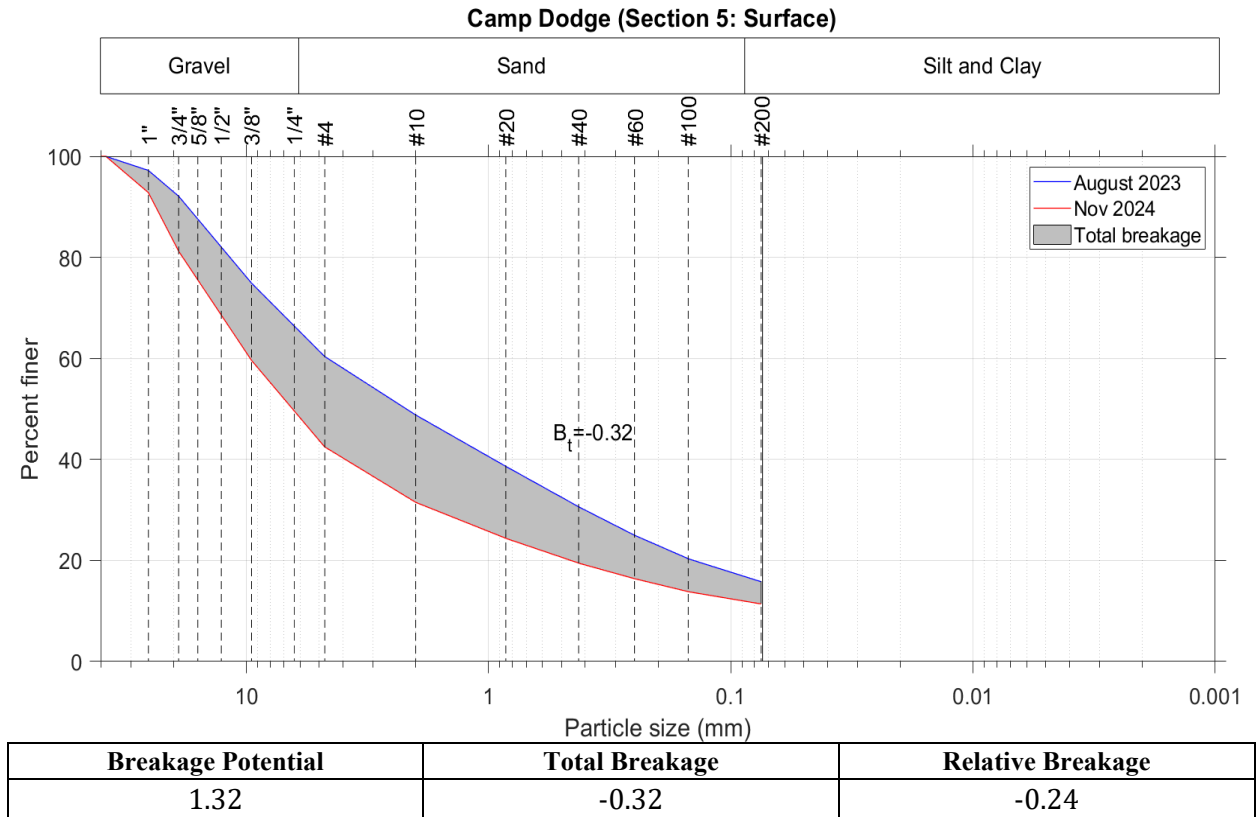


Figure C.5. Breakage characteristics of surface aggregate from Section 3 based on PSD curves from August 2023 to November 2024

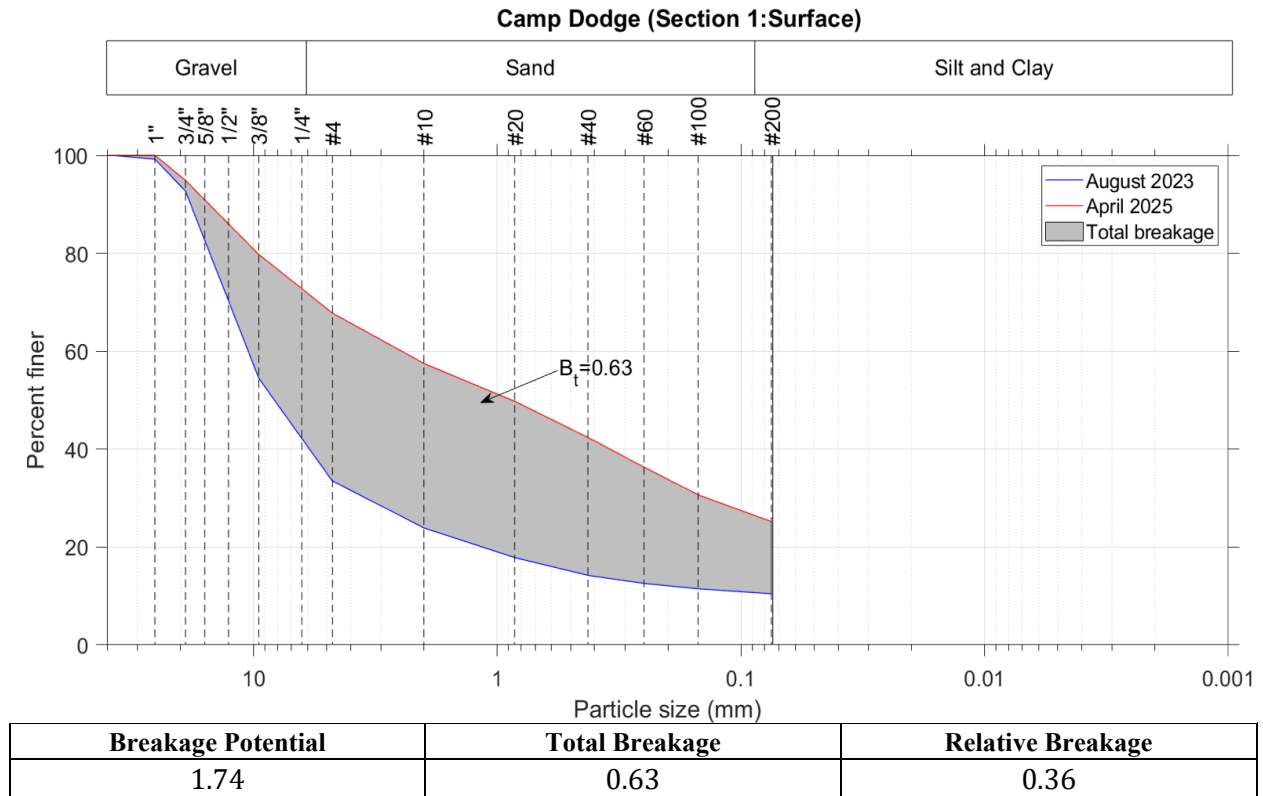


Figure C.6. Breakage characteristics of surface aggregate from Section 1 based on PSD curves from August 2023 to April 2025

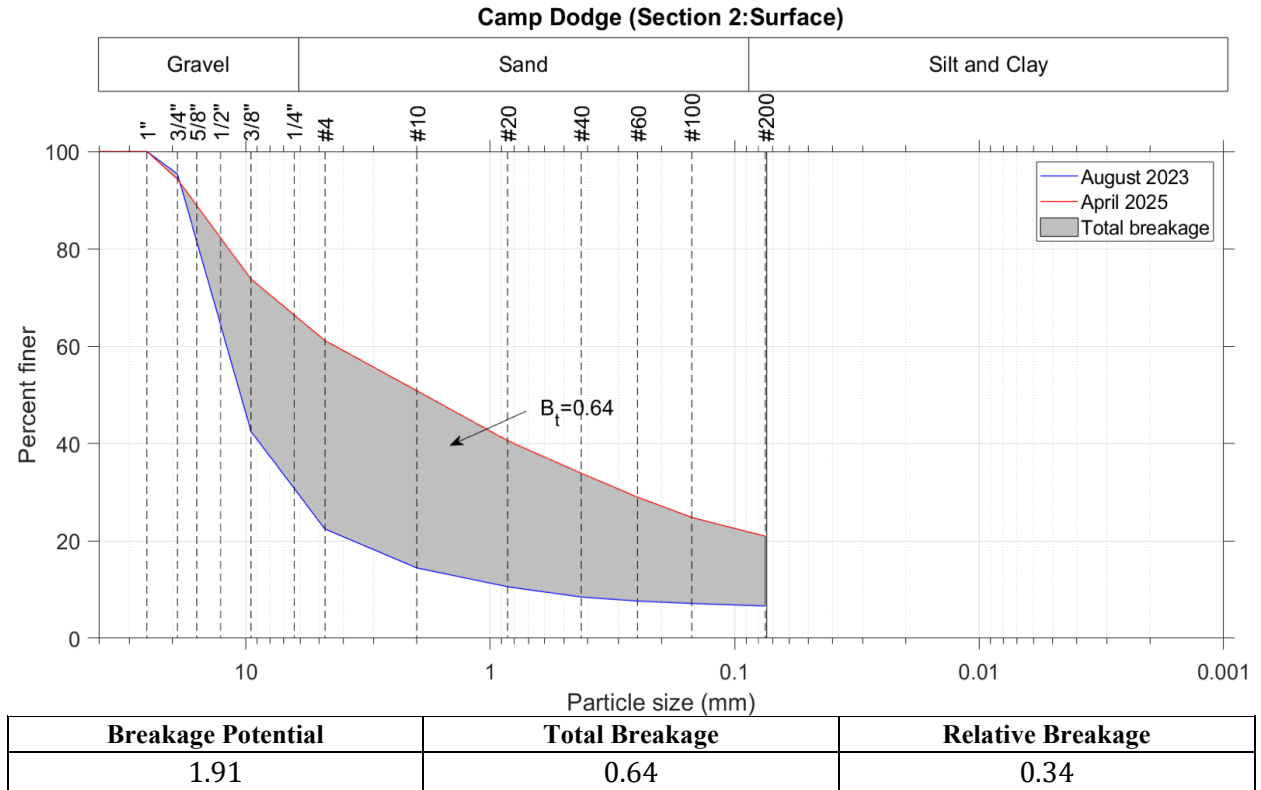


Figure C.7. Breakage characteristics of surface aggregate from Section 2 based on PSD curves from August 2023 to April 2025

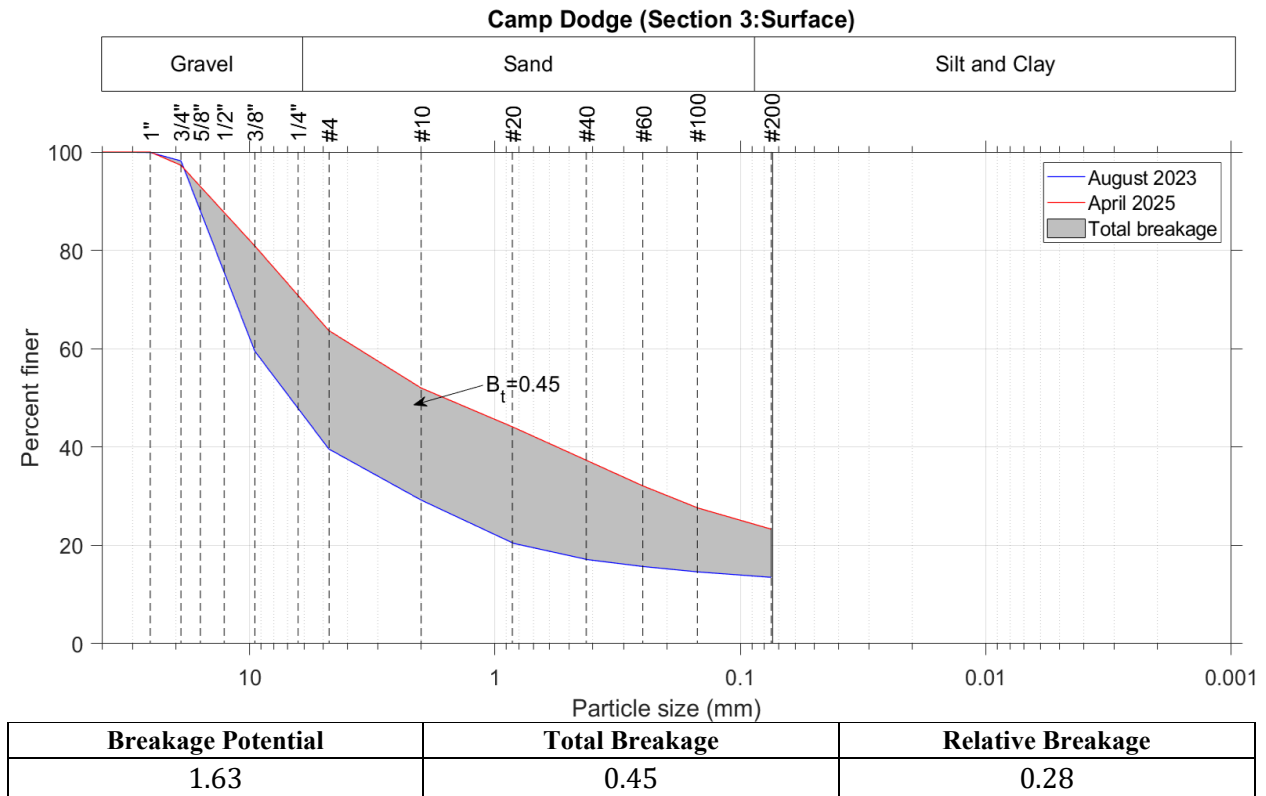


Figure C.8. Breakage characteristics of surface aggregate from Section 3 based on PSD curves from August 2023 to April 2025

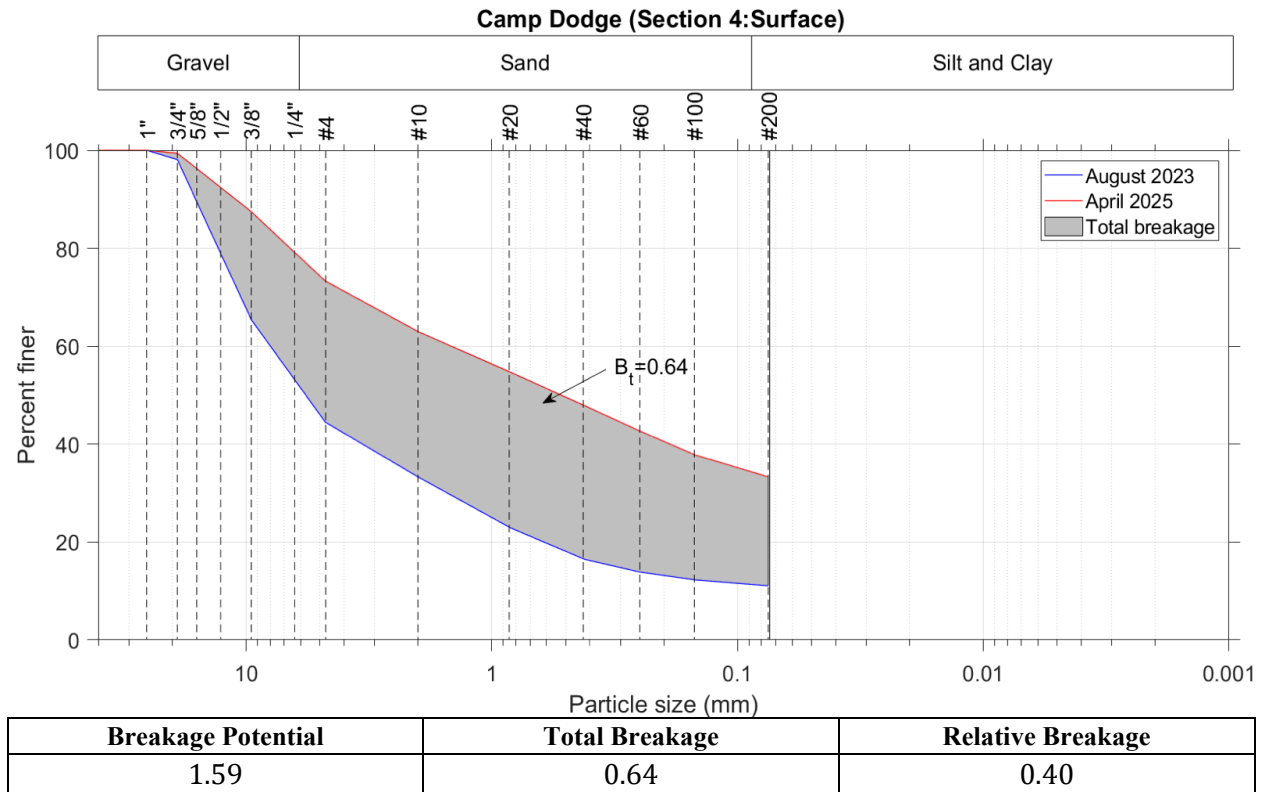


Figure C.9. Breakage characteristics of surface aggregate from Section 4 based on PSD curves from August 2023 to April 2025

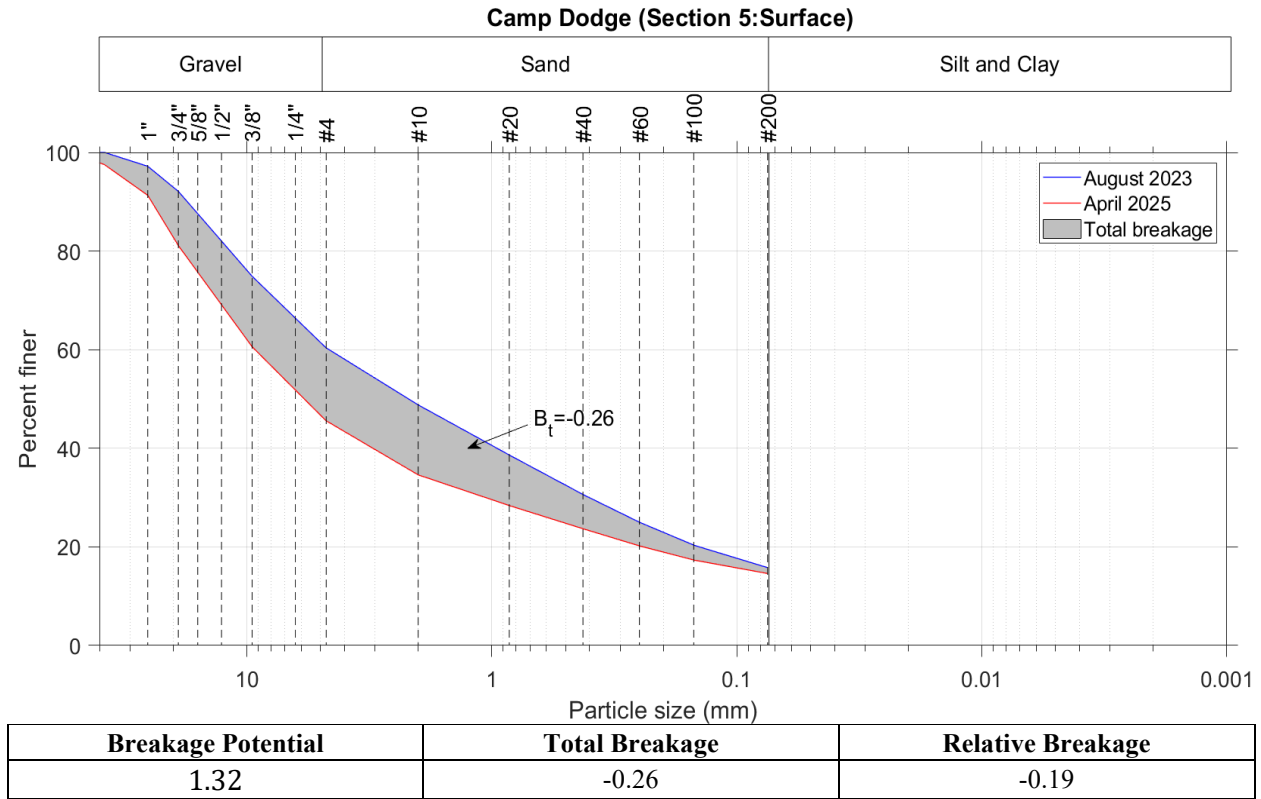


Figure C.10. Breakage characteristics of surface aggregate from Section 5 based on PSD curves from August 2023 to April 2025

APPENDIX D. INTELLIGENT MAPPING REPORT FROM INGIOS

May 9, 2025

Jeramy C. Ashlock, Ph.D.
James M. Hoover Chair in Geotechnical Engineering
Associate Professor
Iowa State University
Civil, Construction & Environmental Engineering
412 Town Engineering Building
Ames, IA 50011-3232
515-294-6176
jashlock@iastate.edu

Re: **Iowa State Subcontract 027681A – Roller Mapping for Effectiveness and Guidance of Aggressive Rehabilitation of Gravel Roads, Camp Dodge, Iowa**

Dear Prof. Ashlock,

This report summarizes the results of COMP-Score® RT roller mapping of five unpaved roadway segments within the Iowa National Guard Facility at Camp Dodge, in Polk County, Iowa. The five segments were reconstructed using different stabilization methods. Mapping was performed in Fall 2023 shortly before and after stabilization, in Spring and Fall 2024, and in Spring 2025. The objective of the mapping is to document structural support capacity (in terms of resilient modulus and modulus of subgrade reaction) of the unpaved roadway segments before and after stabilization and to monitor seasonal variations.

Scope of Work

The COMP-Score RT mapping involved the following tasks:

1. Map each roadway segment with the Ingios' COMP-Score RT roller before and after rehabilitation. The roadway segments are highlighted in Figure 1.
2. Provide e-Compaction reports summarizing:
 - Quality Analysis Metrics (% area Passed and key statistics)
 - Pass Coverage
 - Material ID
 - Engineering Parameter Values (modulus of subgrade reaction (k) value, and composite resilient modulus (M_r) value)
 - Delta Engineering Parameter Value (Measured minus Target Value)
 - Blob analysis maps highlighting contiguous areas not meeting target values.
3. Prepare and submit a memo data report.

Item 1 was accomplished at the project site. Item 2 reports are included in the appendices. Item 3 is this report. Key metrics from the results are discussed herein.

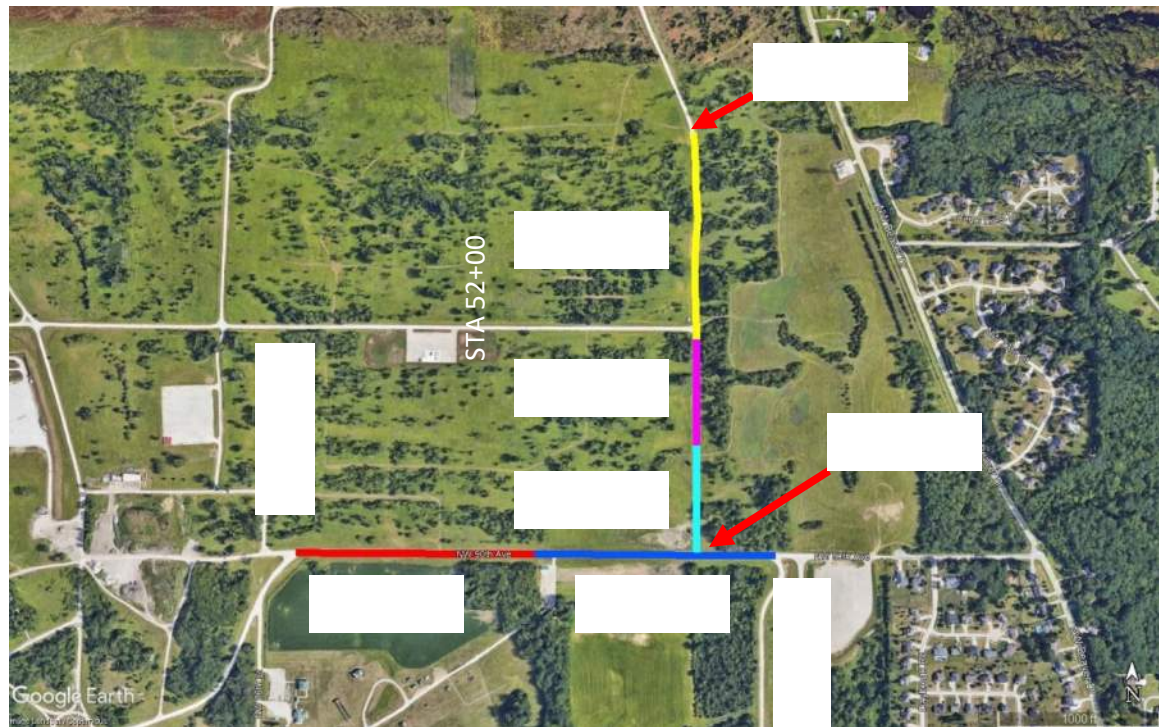


Figure 1. Project site layout with highlighted roadway segments at Camp Dodge Facility.

COMP-Score RT Mapping

Mapping was performed using Ingios’ CS56B vibratory smooth drum machine, enabled with COMP-Score RT pre-calibrated models to measure modulus of subgrade reaction (k-value) and composite resilient modulus (Mr) value. Calibration model details are summarized in Table 1. e-Calibration summaries for the models are included in Appendix A.

Table 1. Summary of calibration models.

Calibration Model Name	Test surface	Model Validity Range
Hamilton_BVC_2022_k	Unpaved gravel road	60 psi/in. to 550 psi/in.
Hamilton_BVC_2022_Mr	Unpaved gravel road	2,000 psi to 20,000 psi.

Mapping was performed on individual segments shown in Figure 1. Project stationing was not provided for this project and Ingios developed the stationing shown in Figure 1 for mapping purposes. The stabilization methods used in the different segments are summarized in Table 2. Pre-stabilization mapping was performed on August 7, 2023. The reconstruction process occurred between August 14 and 18, 2023, with stabilization application occurring on August 16. Post-stabilization mapping was performed on August 31, 2023. Ingios personnel were not

present at the time of reconstruction. The roadway surface was uneven during mapping during the pre- and post-stabilization process. The segments were mapped using two roller passes, where the first pass was used to reduce surface roughness. Mapping results provided herein are from the second roller pass.

The spring 2024 mapping was performed on March 7, 2024, the fall 2024 mapping was performed on October 31, 2024, and the final Spring 2025 mapping was performed on March 31, 2025.

Table 2. Summary of roadway sections

Section	Orientation	Stabilization Method	Station*
1	East-West	Perma-Zyme, Smooth Tire Compaction	00+00 to 15+00
2	East-West	Perma-Zyme, Sheepsfoot Compaction	15+00 to 30+00
3	North-South	Smooth Tire Compaction	00+00 to 06+60
4	North-South	Sheepsfoot Compaction	06+60 to 13+20
5	North-South	None (Control)	13+20 to 26+40

*Note stationing begins at 0+00 for north-south and east-west sections

COMP-Score RT Modulus Mapping Results

e-Compaction reports are provided in Appendix B. The target values for k-value (k-TV) and M_r -value (M_r -TV) were selected as 100 psi/in. and 3,600 psi, respectively, for calculating the delta values (i.e., measured minus the target value) and blob analysis showing (poor support) contiguous areas larger than a defined size (selected as 500 square feet) for measured values less than the target. Project specific design values were not available, and these target values were selected for reference purposes and blob analysis. Results can be re-analyzed using other target values.

Tables 3 to 7 summarize key statistics separately for each map segment from each mapping run for k-value and M_r -values. The statistics include the map area, average value, coefficient of variation (COV), the 20th percentile value, and the reference map ID. Figures 2 and 3 show average and 20th percentile values for k-values and M_r -values as bar charts for each map segment.

Box and whisker plots of k-value and M_r -value results from each map run are included in Appendix C and are organized by segment and mapping date. The limits of the box represent the 25th and 75th percentiles. Whiskers represent the 10th and 90th percentiles. The solid black line inside the box represents the median value. The solid blue line represents the mean value. Raw data is presented as gray points.

Closure

We appreciate the opportunity to provide COMP-Score RT mapping services on this project. We are pleased to discuss any aspects of the results in this submittal at your convenience.

Sincerely,

Pavana Vennapusa

Pavana Vennapusa, Ph.D., P.E.
(Registered in AZ, IA, KY, TN, TX)
Senior Technical Engineering Resource
pavana.vennapusa@ingios.com
(515) 231-9531

Reviewed By:

David J. White

David J. White, Ph.D., P.E.
(Registered in IA, MN, TN, KY)
President and CEO
david.white@ingios.com
(515) 509-7587

Appendix A: e-Calibration Summary Record
Appendix B: e-Calibration Reports
Appendix C: Box Plots and Summary Statistics

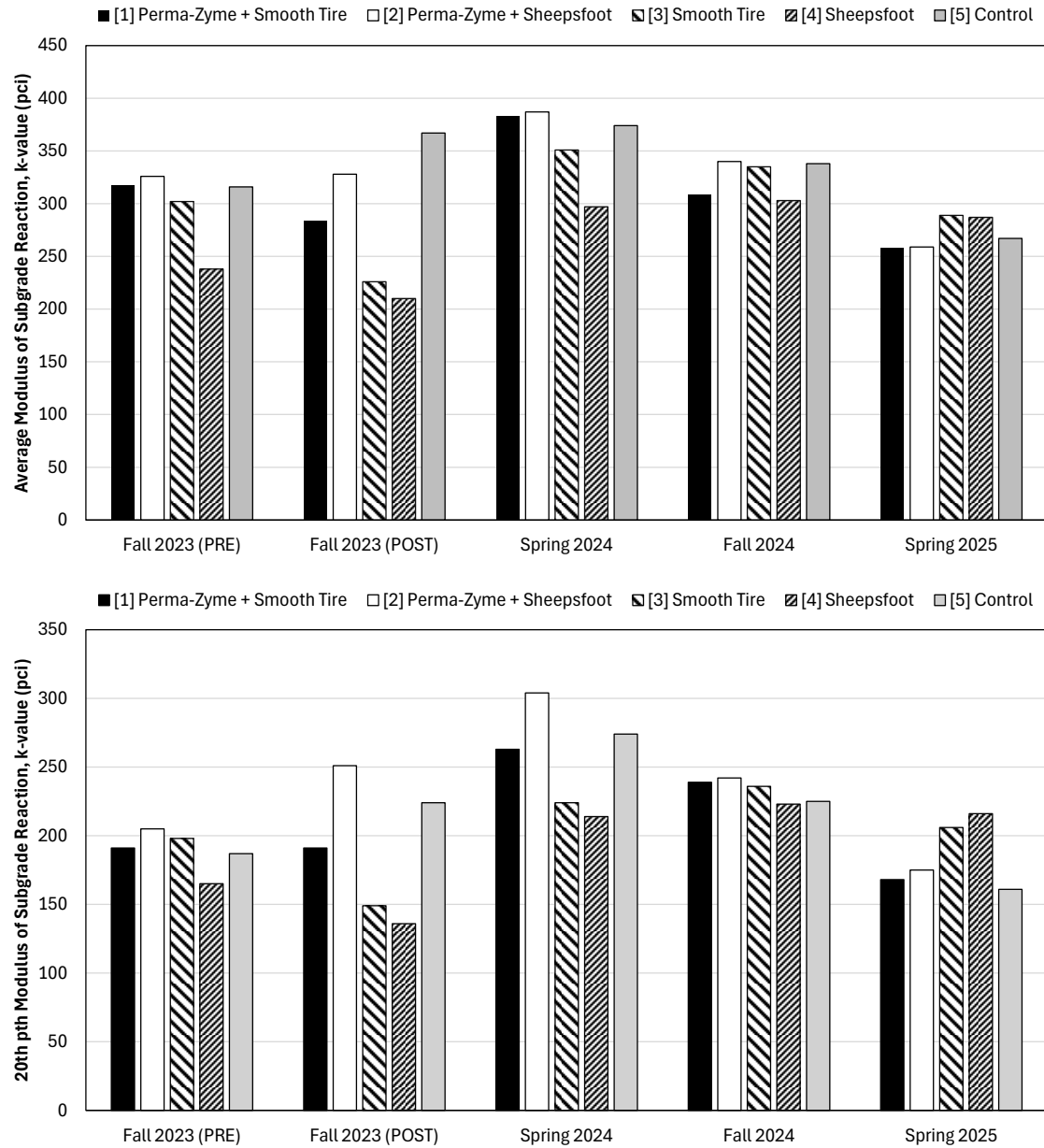


Figure 2. Average and 20th percentile statistics of modulus of subgrade reaction (k-value) for the five segments from pre-stabilization to pos-stabilization (Fall 2023 to Spring 2025)

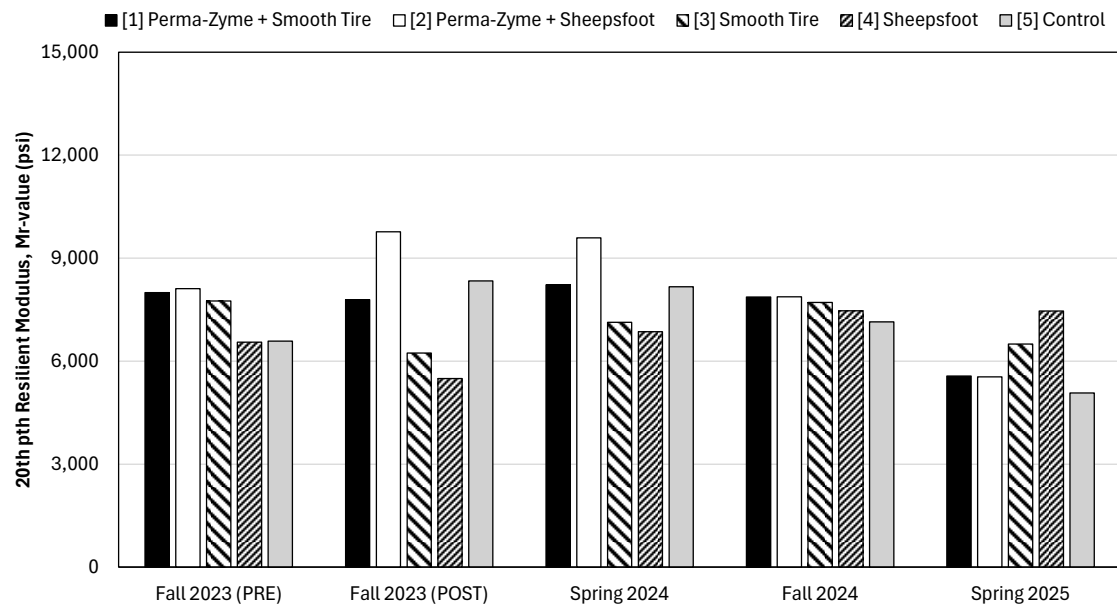
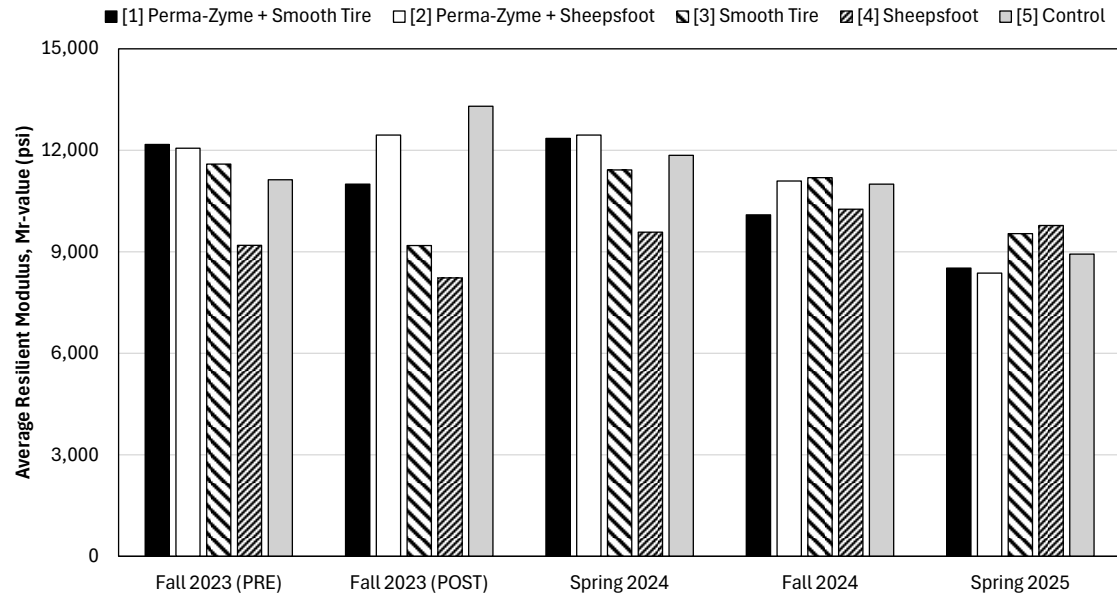


Figure 3. Average and 20th percentile statistics of resilient modulus (Mr-value) for the five segments from pre-stabilization to pos-stabilization (Fall 2023 to Spring 2025)

Table 3. Summary of mapping runs and results for Segment 1

Segment	Date	Stage	Map Area (ft ²)	k-value			M _r			Map ID
				Average (psi/in)	COV (%)	20 th pth (psi/in.)	Average (psi)	COV (%)	20 th pth (psi)	
1: Perma-Zyme+Smooth Tire Compaction	8/7/2023	Fall 2023 Pre-Stabilization	33,512	317	42	191	12,173	36	7,998	ing_polk77-campdodge-2023_cs56b-01047_2023_08_07_120625
	8/31/2023	Fall 2023 Post-Stabilization	32,607	284	37	191	10,996	32	7,791	ing_polk77-campdodge-2023_cs56b-01047_2023_08_31_120427
	3/7/2024	Spring 2024	29,915	383	32	263	12,347	35	8,224	ing_polk77-campdodge-2023_cs56b-01047_2024_03_07_093718
	10/31/2024	Fall 2024	38,454	309	27	239	10,094	27	7,866	ing_polk77-campdodge-2023_cs56b-01047_2024_10_31_110208
	3/31/2025	Spring 2025	33,550	258	43	168	8,516	44	5,566	ing_polk77-campdodge-2025_cs56b-01047_2025_03_31_105035

Table 4. Summary of mapping runs and results for Segment 2

Segment	Date	Stage	Map Area (ft ²)	k-value			M _r			Map ID
				Average (psi/in)	COV (%)	20 th percentile (psi/in.)	Average (psi)	COV (%)	20 th percentile (psi)	
2: Perma-Zyme + Sheepsfoot Compaction	8/7/2023	Fall 2023 Pre-Stabilization	37,049	326	39	205	12,062	35	8,114	ing_polk77-campdodge-2023_cs56b-01047_2023_08_07_125822
	8/31/2023	Fall 2023 Post-Stabilization	33,781	328	27	251	12,449	24	9,766	ing_polk77-campdodge-2023_cs56b-01047_2023_08_31_125937
	3/7/2024	Spring 2024	30,766	387	25	304	12,446	26	9,593	ing_polk77-campdodge-2023_cs56b-01047_2024_03_07_10111

	10/31/2024	Fall 2024	42,261	340	32	242	11,093	34	7,872	ing_polok77-campdodge-2023_cs56b-01047_2024_10_31_112817
	3/31/2025	Spring 2025	34,154	259	40	175	8,369	42	5,545	ing_polok77-campdodge-2025_cs56b-01047_2025_03_31_113857

Table 5. Summary of mapping runs and results for Segment 3

Segment	Date	Stage	Map Area (ft ²)	k-value			M _r			Map ID
				Average (psi/in)	COV (%)	20 th pth (psi/in.)	Average (psi)	COV (%)	20 th pth (psi)	
3: Smooth Tire Compaction	8/7/2023	Fall 2023 Pre-Stabilization	13,307	302	40	198	11,589	36	7,751	ing_polok77-campdodge-2023_cs56b-01047_2023_08_07_134340
	8/31/2023	Fall 2023 Post-Stabilization	13,109	226	41	149	9,182	37	6,238	ing_polok77-campdodge-2023_cs56b-01047_2023_08_31_141424
	3/7/2024	Spring 2024	12,005	351	34	224	11,418	35	7,131	ing_polok77-campdodge-2023_cs56b-01047_2024_03_07_103818
	10/31/2024	Fall 2024	15,017	335	32	236	11,192	34	7,710	ing_polok77-campdodge-2023_cs56b-01047_2024_10_31_104556
	3/31/2025	Spring 2025	12,449	289	35	206	9,535	39	6,500	ing_polok77-campdodge-2025_cs56b-01047_2025_03_31_121517

Table 6. Summary of mapping runs and results from Segment 4

Segment	Date	Stage	Map Area (ft ²)	k-value			M _r			Map ID
				Average (psi/in)	COV (%)	20 th pth (psi/in.)	Average (psi)	COV (%)	20 th pth (psi)	
4: Sheepsfoot Compaction	8/7/2023	Fall 2023 Pre-Stabilization	13,425	238	35	165	9,192	32	6,553	ing_polok77-campdodge-2023_cs56b-01047_2023_08_07_140926
	8/31/2023	Fall 2023 Post-Stabilization	14,481	210	40	136	8,230	36	5,496	ing_polok77-campdodge-2023_cs56b-01047_2023_08_31_144131

	3/7/2024	Spring 2024	12,028	297	31	214	9,582	31	6,857	ing_polk77-campdodge-2023_cs56b-01047_2024_03_07_105155
	10/31/2024	Fall 2024	14,656	303	29	223	10,259	29	7,466	ing_polk77-campdodge-2023_cs56b-01047_2024_10_31_103237
	3/31/2025	Spring 2025 Pass 2	12,569	287	28	216	9,774	27	7,463	ing_polk77-campdodge-2025_cs56b-01047_2025_03_31_123405

Table 7. Summary of mapping runs and results from Segment 5

Segment	Date	Stage	Map Area (ft²)	k-value			M _r			Map ID
				Average (psi/in)	COV (%)	20 th pth (psi/in.)	Average (psi)	COV (%)	20 th pth (psi)	
5: Control	8/7/2023	Fall 2023 Pre-Stabilization	23,488	316	42	187	11,129	43	6,581	ing_polk77-campdodge-2023_cs56b-01047_2023_08_07_144405
	8/31/2023	Fall 2023 Post-Stabilization	23,860	367	39	224	13,298	37	8,336	ing_polk77-campdodge-2023_cs56b-01047_2023_08_31_151652
	3/7/2024	Spring 2024	24,911	374	30	274	11,848	33	8,167	ing_polk77-campdodge-2023_cs56b-01047_2024_03_07_110652
	10/31/2024	Fall 2024	32,038	338	36	225	10,997	39	7,142	ing_polk77-campdodge-2023_cs56b-01047_2024_10_31_101023
	3/31/2025	Spring 2025	30,588	267	43	161	8,933	46	5,074	ing_polk77-campdodge-2025_cs56b-01047_2025_03_31_130357

Appendix A: e-Calibration Summary Record



E-COMPACTION CALIBRATION SUMMARY

Material ID: **Unpaved Gravel Road (not defined)_IADOT**

1 PROJECT DETAILS

Project Name	Unpaved Roads Project	Project ID	BVC_0001 and SIA_0008	Project Location	70th Ave./600th St., Buena Vista County, IA and Vail Avenue, Hamilton County, IA
Project Description / Notes	Mapping and in situ APLTs performed on unpaved gravel road. Mapping results from forward pass data was used in the calibration analysis. Data from BVC_0001 project from 05/26-05/27/22 were combined with three test points obtained from Vail Avenue in Hamilton County, IA on 10/13/2022				
Primary RT Asset ID	Ingios01_CAT CS56B	COMP-Score RT Map Files	bvc_4milegravel_cs56b-ingios01_2022_05_27_104832; bvc_4milegravel_cs56b-ingios01_2022_05_27_083626 ing_hamiltoncogravel_cs56b-ingios01_2022_09_13_105806		
Secondary RT Asset ID	None.	Dates of testing	05/26/2022 to 05/27/2022 (BVC) 10/13/2022 (Hamilton Cty)	Field Personnel	David J. White, Ph.D., P.E. Colby Van Nimwegen

2 RT MACHINE TASKS COMPLETED

☒ Roller health check	☐ RT elevation measurements verification
☐ Roller operator training	☐ Aerial imagery updates on the machine
☐ Assessment of material compactibility	☒ In situ quality inspection testing (see Sec. 3)
☐ Repeatability evaluation on Primary Asset	☐ Laboratory material characterization testing (see Sec. 4)
☐ Repeatability evaluation on Secondary Asset	☐ Other tasks (Describe below)
☐ RT kit hardware upgrades	
☒ RT software/firmware upgrades	

3 IN SITU QUALITY INSPECTION TESTING

☐	ASTM D2216: Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
☒	ASTM D6951/D6951M: Standard Test Method for Use of the Dynamic Cone Penetrometer in Shallow Pavement Applications
☐	ASTM D2937: Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method
☐	ASTM D1556: Standard Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method
☐	ASTM E2583: Standard Test Method for Measuring Deflections with a Light Weight Deflectometer
☐	ASTM D1195/D1195M: Standard Test Method for Repetitive Static Plate Tests of Soils and Flexible Pavement Components for Use in Evaluation and Design of Airport and Highway Pavements
☐	ASTM D1196: Standard Test Method for Nonrepetitive Static Plate Load Tests of Soils and Flexible Pavement Components, for Use in Evaluation and Design of Airport and Highway Pavements
☐	AASHTO-T221: Standard Method of Test for Repetitive Static Plate Load Tests of Soils and Flexible Pavement Components for Use in Evaluation and Design of Airport and Highway Pavements
☐	AASHTO-T222: Standard Method of Test for Nonrepetitive Static Plate Load Test of Soils and Flexible Pavement Components for Use in Evaluation and Design of Airport and Highway Pavements
☐	ING-SOP_INCCY-PF-Low-12: Incremental Cyclic Mr Test with 12 in. plate, low force ram [1,550 cycles – 5, 10, 15, 20, 30, and 40 psi cyclic stress with contact stress of 2 psi]
☐	ING-SOP_INCCY-PF-Low-12_Layered: Incremental Cyclic Mr Test with 2-layered sensor kit with 12 in. plate, low force ram [1,550 cycles – 5, 10, 15, 20, 30, and 40 psi cyclic stress with contact stress of 2 psi]
☐	ING-SOP_INCCY-PF-High-18: Incremental Cyclic Resilient Modulus Test with 18 in. plate, high force ram [1,550 cycles – 5, 10, 15, 20, 30, and 40 psi cyclic stress with contact stress of 5 psi]
☒	ING-SOP_INCST-PF-High-18_Rapid: Incremental static plate load test setup per AASHTO T222 / ASTM D1156 – two cycles, using 18 in. diameter loading plate.
☒	ING-SOP_EXTCY-PF-High-18_100_35: Extended Cyclic Mr Test with 18 in. plate, high force ram [100 cycles – 35 psi cyclic stress with contact stress of 5 psi]

3 LABORATORY MATERIAL CHARACTERIZATION TESTING

☐	ASTM C136: Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
☐	ASTM D422: Standard Test Method for Particle-Size Analysis of Soils
☐	ASTM D698: Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft ³ (600 kN-m/m ³))
☐	ASTM D1556: Standard Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method
☐	ASTM D1557: Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft ³ (2,700 kN-m/m ³))
☐	ASTM D2216: Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
☐	ASTM D2487: Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
☐	ASTM D3282: Standard Practice for Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes
☐	ASTM D4318: Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

4 ASSERTION

Ingios Geotechnics, Inc. performed calibration analysis for use with the specific COMP-Score® RT equipped roller and for the specific field conditions of material type, moisture content, lift thickness, placement operation and conditions, and weather at the time of testing. The results presented herein represent a selected number of measurements per sample group. The test results presented herein are applicable to the specific testing point locations and field conditions at the time of testing.

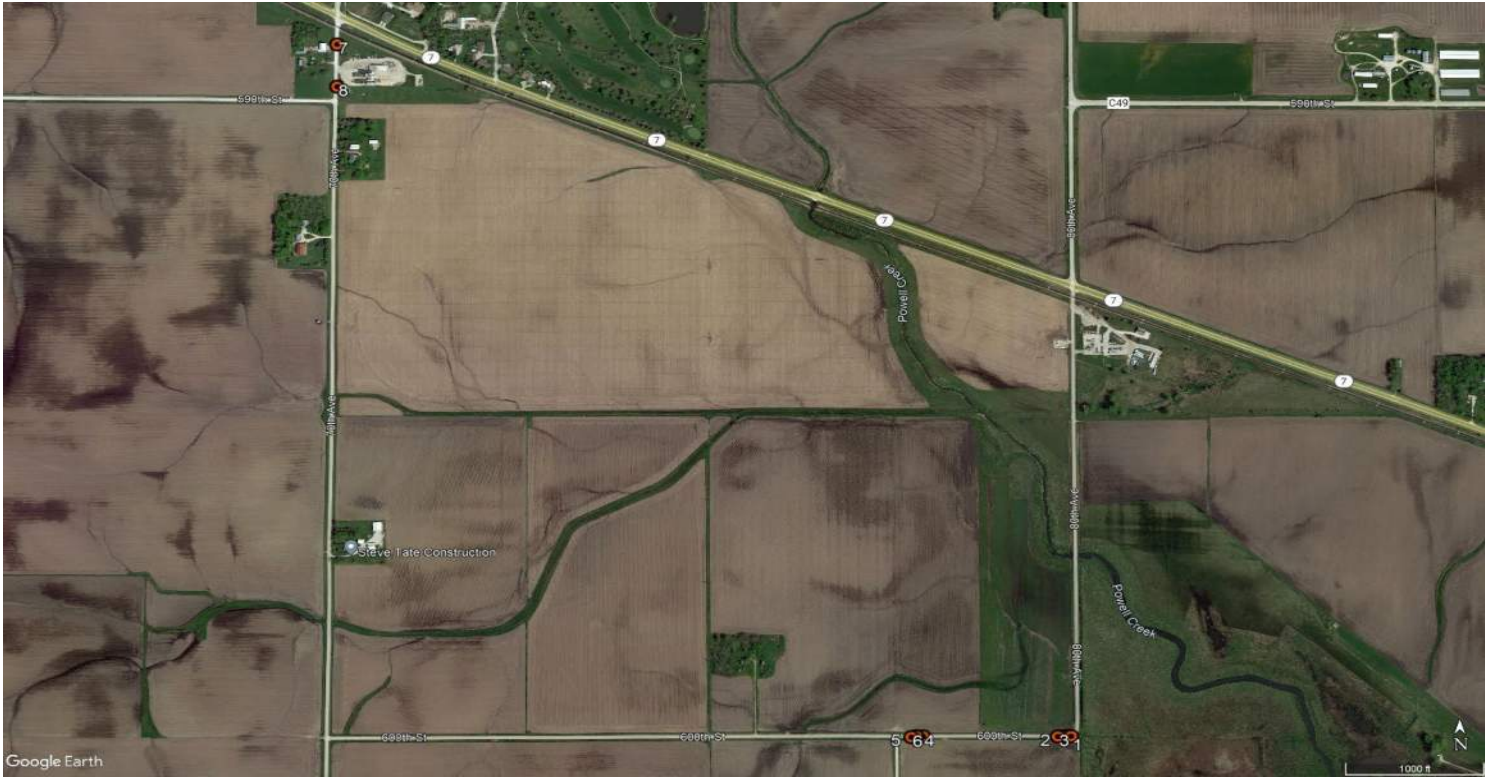
Prepared By

Signature: *Pavana Vennapusa*
 Name: Pavana Vennapusa, Ph.D., P.E. (IA)
 Position: Engineering Services Manager, Ingios
 Date: 8/24/2022

Reviewed By

Signature: *David J. White*
 Name: David J. White, Ph.D., P.E. (IA)
 Title: Vice President
 Date: 8/24/2022

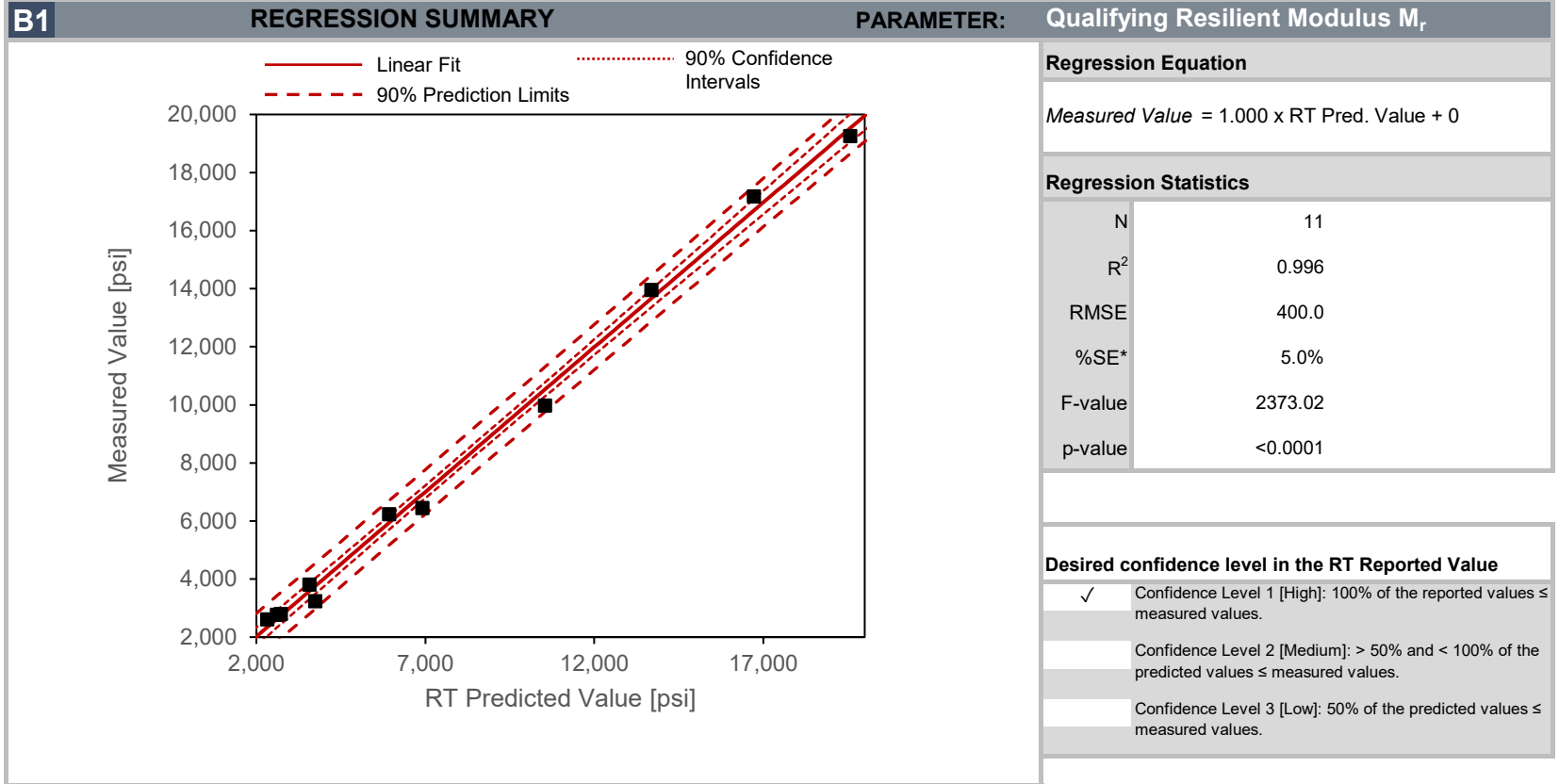
A1TEST POINT LOCATIONS



A2GPS COORDINATES

Test Point	Latitude (deg)	Longitude (deg)	Easting (FT)	Northing (FT)	Elevation (FT)	Station	Notes
PT1	42.6475183	-95.2500817	4450454.0	3703889.0	NA	NA	Unpaved Gravel Road
PT2	42.6475383	-95.2501783	4450423.0	3703889.0	NA	NA	Unpaved Gravel Road
PT3	42.6474933	-95.2504067	4450364.0	3703890.0	NA	NA	Unpaved Gravel Road
PT4	42.6475550	-95.2540450	4449391.0	3703915.0	NA	NA	Unpaved Gravel Road
PT5	42.6474650	-95.2542233	4449340.0	3703917.0	NA	NA	Unpaved Gravel Road
PT6	42.6475383	-95.2543617	4449305.0	3703920.0	NA	NA	Unpaved Gravel Road
PT7	42.6633183	-95.2698900	4445249.0	3709757.0	NA	NA	Unpaved Gravel Road
PT8	42.6623583	-95.2698483	4445241.0	3709408.0	NA	NA	Unpaved Gravel Road
PT1	42.3122400	-93.5602450	4904965.0	3576833.0	NA	NA	Vail Ave Gravel Road
PT2	42.3129550	-93.5602050	4904966.1	3577097.8	NA	NA	Vail Ave Gravel Road
PT3	42.3141933	-93.5602050	4904966.4	3577549.1	NA	NA	Vail Ave Gravel Road

NOTE: Northing and Easting calculated using Iowa North (1401) state plane coordinate system.

Material ID: **Unpaved Gravel Road (not defined)_IADOT**


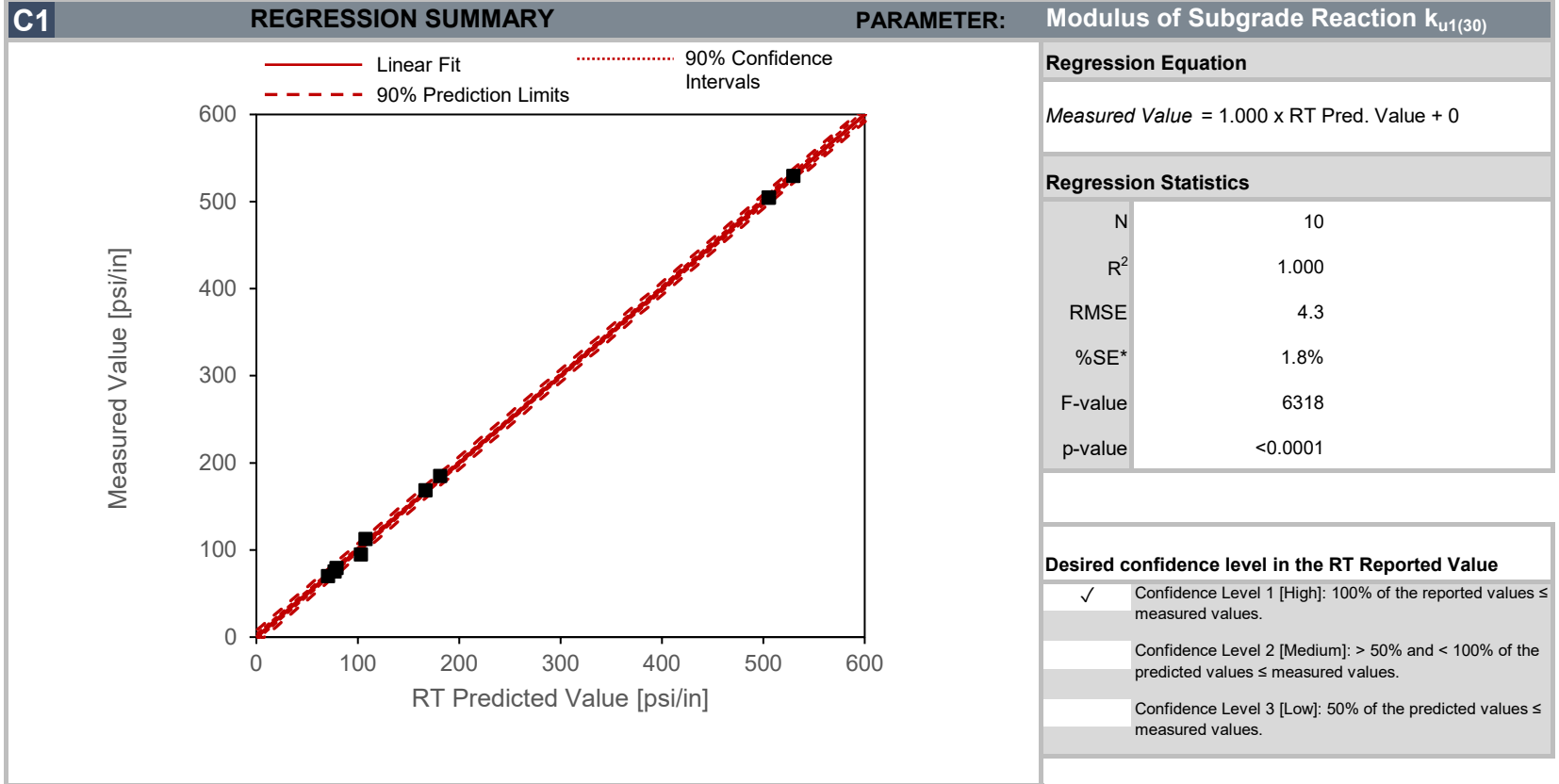
B2 TEST MEASUREMENTS				
Qualifying M_r [psi] at $\sigma_{cyclic} = 35$ psi				
Test Point	Test Surface	RT Map Predicted Value	APLT Measured Value	RT Map Reported Value
PT1	Unpaved Gravel Road	5,921	6,228	5,440
PT2	Unpaved Gravel Road	6,904	6,440	6,374
PT3	Unpaved Gravel Road	3,563	3,808	3,200
PT4	Unpaved Gravel Road	2,317	2,607	2,015
PT5	Unpaved Gravel Road	2,601	2,766	2,285
PT6	Unpaved Gravel Road	2,718	2,803	2,397
PT7	Unpaved Gravel Road	3,735	3,237	3,363
PT8	Unpaved Gravel Road	10,541	9,975	9,829
PT1	Vail Ave Gravel Road	16,716	17,175	15,696
PT2	Vail Ave Gravel Road	13,681	13,963	12,813
PT3	Vail Ave Gravel Road	19,563	19,259	18,402

NOTES:

1. An experimental plan was designed to capture a representative range of stiffness conditions across the test areas and perform statistical regression analysis between the measured and the COMP-Score RT predicted modulus values.
2. The number of test measurements were greater than the minimum number of measurements needed to yield a reliability of > 95% in the predicted values.
3. The regression trend presented shows evidence of correlation between the measured and the predicted values.
4. The coefficient of determination (R^2) value provides a measure of the goodness of the fit on a 0 to 1 scale, between the measured and the predicted values.
5. Root mean squared error (RMSE) is the standard deviation of the residual values (i.e., difference between the measured and the predicted values).
6. High F-value and the low p-value indicate the regression relationship is statistically significant at greater than 95% confidence level.

B3 SUMMARY STATISTICS OF TEST MEASUREMENTS				
Parameter	RT Map Predicted Value	APLT Measured Value	RT Map Reported Value	UNITS
MINIMUM	2,317	2,607	2,015	psi
MAXIMUM	19,563	19,259	18,402	psi
MEAN	8,024	8,024	7,438	psi
MEDIAN	5,921	6,228	5,440	psi
STANDARD DEVIATION	6,174	6,162	5,866	psi
COEFFICIENT OF VARIATION	77%	77%	79%	%

Material ID: Unpaved Gravel Road (not defined)_IADOT



C2 TEST MEASUREMENTS				
Modulus of Subgrade Reaction, $k_{u1(30)}$ [psi/in.]				
Test Point	Test Surface	RT Map Predicted Value	APLT Measured Value	RT Map Reported Value
PT1	Unpaved Gravel Road	167	169	158
PT2	Unpaved Gravel Road	181	185	172
PT3	Unpaved Gravel Road	103	95	95
PT4	Unpaved Gravel Road	70	70	63
PT5	Unpaved Gravel Road	77	75	70
PT6	Unpaved Gravel Road	79	79	72
PT7	Unpaved Gravel Road	107	113	99
PT8	Unpaved Gravel Road	--	--	--
PT1	Vail Ave Gravel Road	505	505	490
PT2	Vail Ave Gravel Road	505	505	490
PT3	Vail Ave Gravel Road	529	529	514

NOTES:

1. An experimental plan was designed to capture a representative range of stiffness conditions across the test areas and perform statistical regression analysis between the measured and the COMP-Score RT predicted modulus values.
2. The number of test measurements were greater than the minimum number of measurements needed to yield a reliability of > 95% in the predicted values.
3. The regression trend presented shows evidence of correlation between the measured and the predicted values.
4. The coefficient of determination (R²) value provides a measure of the goodness of the fit on a 0 to 1 scale, between the measured and the predicted values.
5. Root mean squared error (RMSE) is the standard deviation of the residual values (i.e., difference between the measured and the predicted values).
6. High F-value and the low p-value indicate the regression relationship is statistically significant at greater than 95% confidence level.

B3 SUMMARY STATISTICS OF TEST MEASUREMENTS				
Parameter	RT Map Predicted Value	APLT Measured Value	RT Map Reported Value	UNITS
MINIMUM	70	70	63	psi
MAXIMUM	529	529	514	psi
MEAN	232	232	222	psi
MEDIAN	137	141	129	psi
STANDARD DEVIATION	197	197	194	psi
COEFFICIENT OF VARIATION	85%	85%	87%	%

PICTURES



Figure 1. Picture of the COMP-Score RT enabled roller mapping (Picture taken on 05/27/22 at 10:04 am)



Figure 2. Picture of APLT setup (Picture taken on 05/27/2022 at 05:27 pm)



Figure 3. Picture of APLT setup with 18 in. diameter loading plate (Picture taken on 05/27/2022 at 05:18pm)

Appendix B: e-Compaction Reports

Map ID: ing_pol77-campdodge-2023_cs56b-01047_2023_08_07_120625

Project:	TR-823 Study	Date and Time:	8/7/2023 12:06:25 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.356	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	33512	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	1 - STAB + Smooth Drum

Map Summary

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
XMV	No												
Resilient Modulus	Yes	100.0	106.9	0.6	3600.0	3686.5	12173.3	20000.0	4418.3	36.3	86.5	8573.3	16400.0
k-value	Yes	99.0	112.8	0.6	100.0	84.1	316.6	550.0	134.2	42.4	-15.9	216.6	450.0
Moisture Content	No												

Mapped Area		Pass Count					Elevation (ft)			Position Quality		Velocity (fps)		
square feet	acres	10th percentile	Median	cov(%)	% >= TV	Target Value	min.	avg.	max.	RTK-Q7 (%)	RTK-QA	min.	avg.	max.
33512	0.769	1	1	35.1	100.0	0	914.92	931.25	948.39	99.7	7.98	4.3	5.0	5.9

Materials

name	id	% of total	area-square ft	area-acres	tl-xmv	tl-Mr	tl-k value	tl-w%
Unpaved Gravel Road (not defined)_IADOT	41019	100.0	33512	0.769	100.0	3600.0	100.0	20.5

Blobs

parameter	min. area(ft^2)	# of blobs	blob area(ft^2)	% of map	lower bound-tv	upper bound-tv	poly-tol.
Resilient Modulus	500.0	0	0	0.0	none	0.0	4.0
k-value	500.0	0	0	0.0	none	0.0	4.0

Station

Start	End
0+00	15+50

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_07_120625

Project:	TR-823 Study	Date and Time:	8/7/2023 12:06:25 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.356	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	33512	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	1 - STAB + Smooth Drum

QUALITY ANALYSIS SUMMARY - k-Value

Quality Value	Criteria
112.8	CQI > = 95
99.0	80% of k-Value MVs >= 100
42.4	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_07_120625

Project:	TR-823 Study	Date and Time:	8/7/2023 12:06:25 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.356	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	33512	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	1 - STAB + Smooth Drum

QUALITY ANALYSIS SUMMARY - Resilient Modulus

Quality Value	Criteria
106.9	CQI > = 95
100.0	90% of Resilient Modulus MVs >= 3600
36.3	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

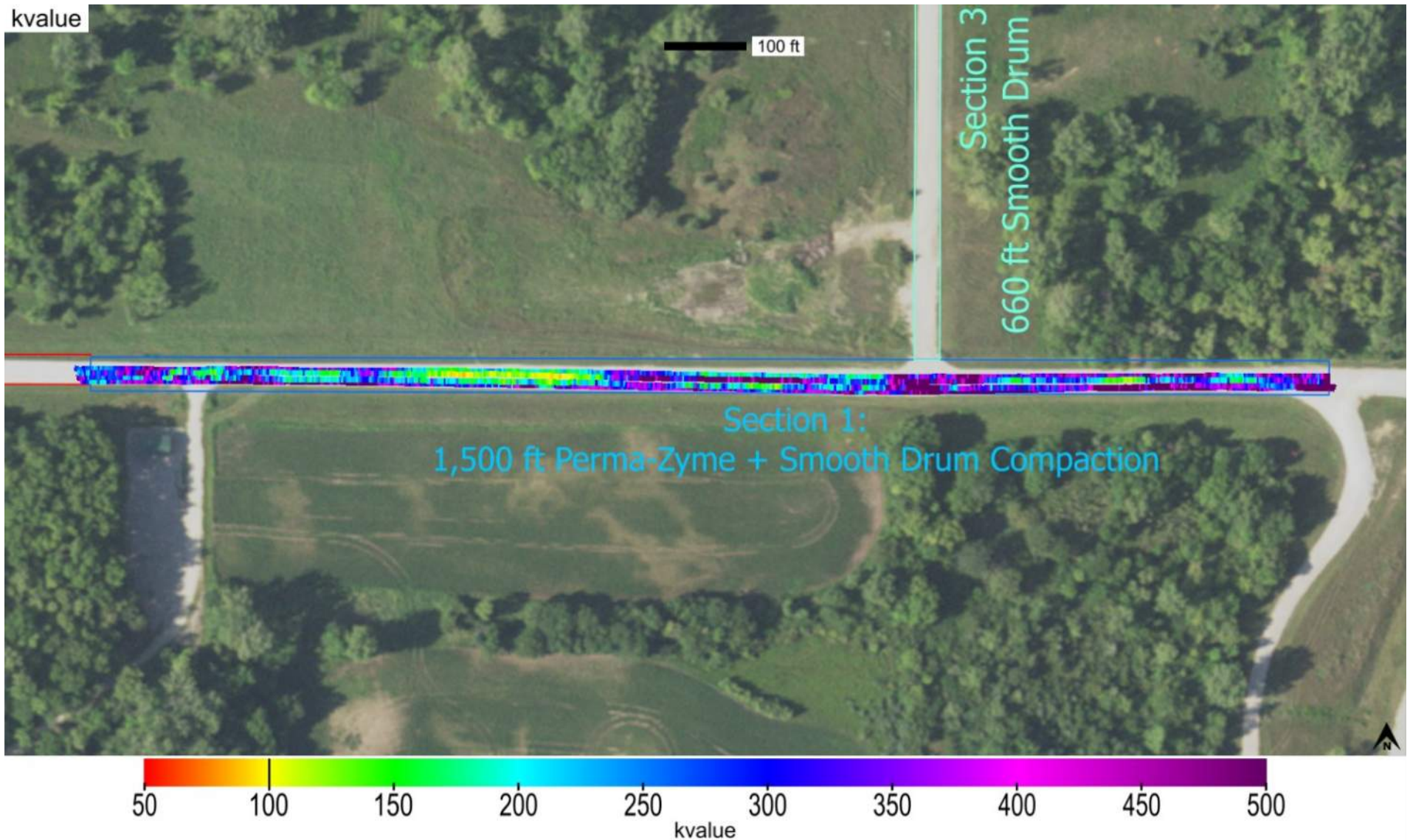
Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

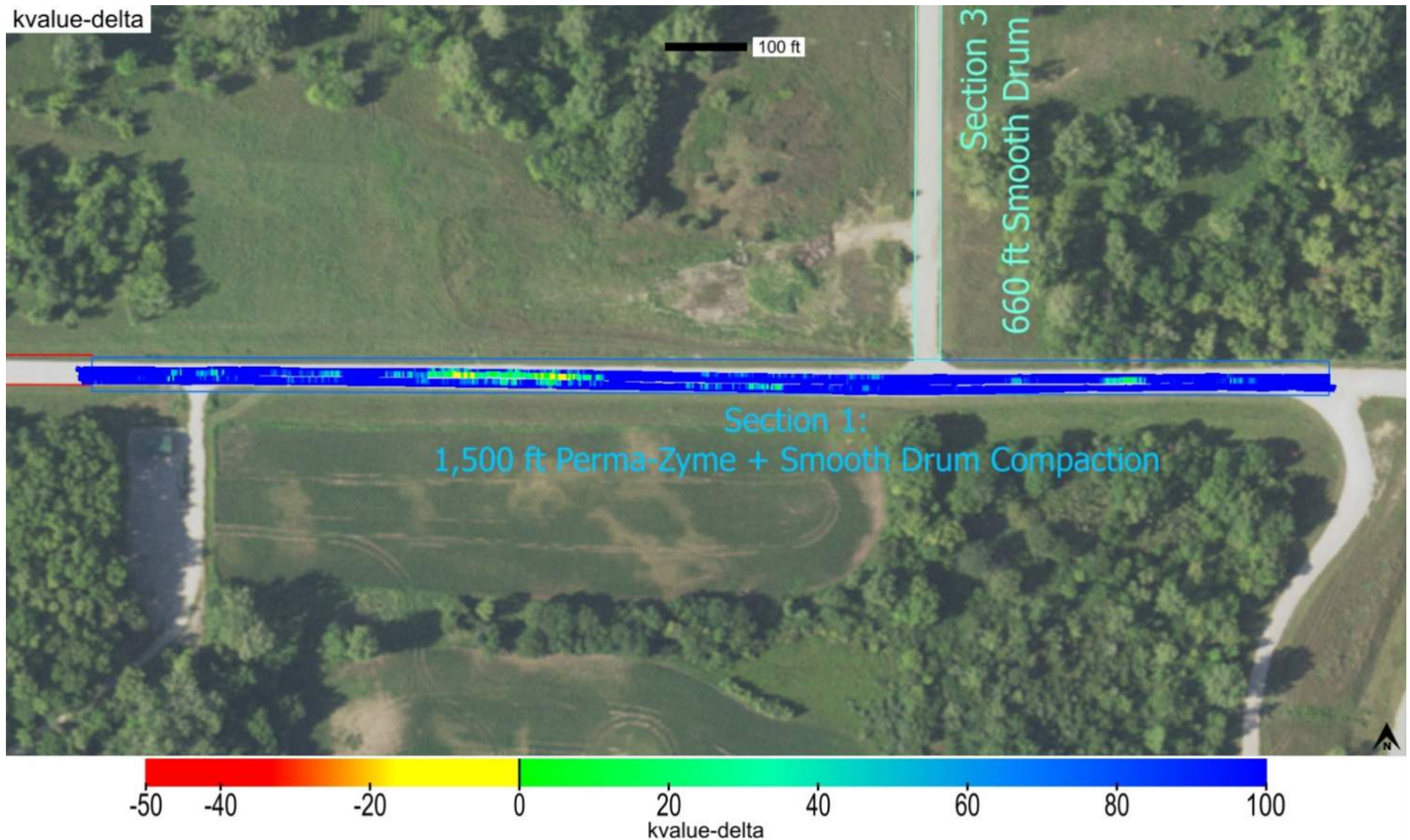
Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

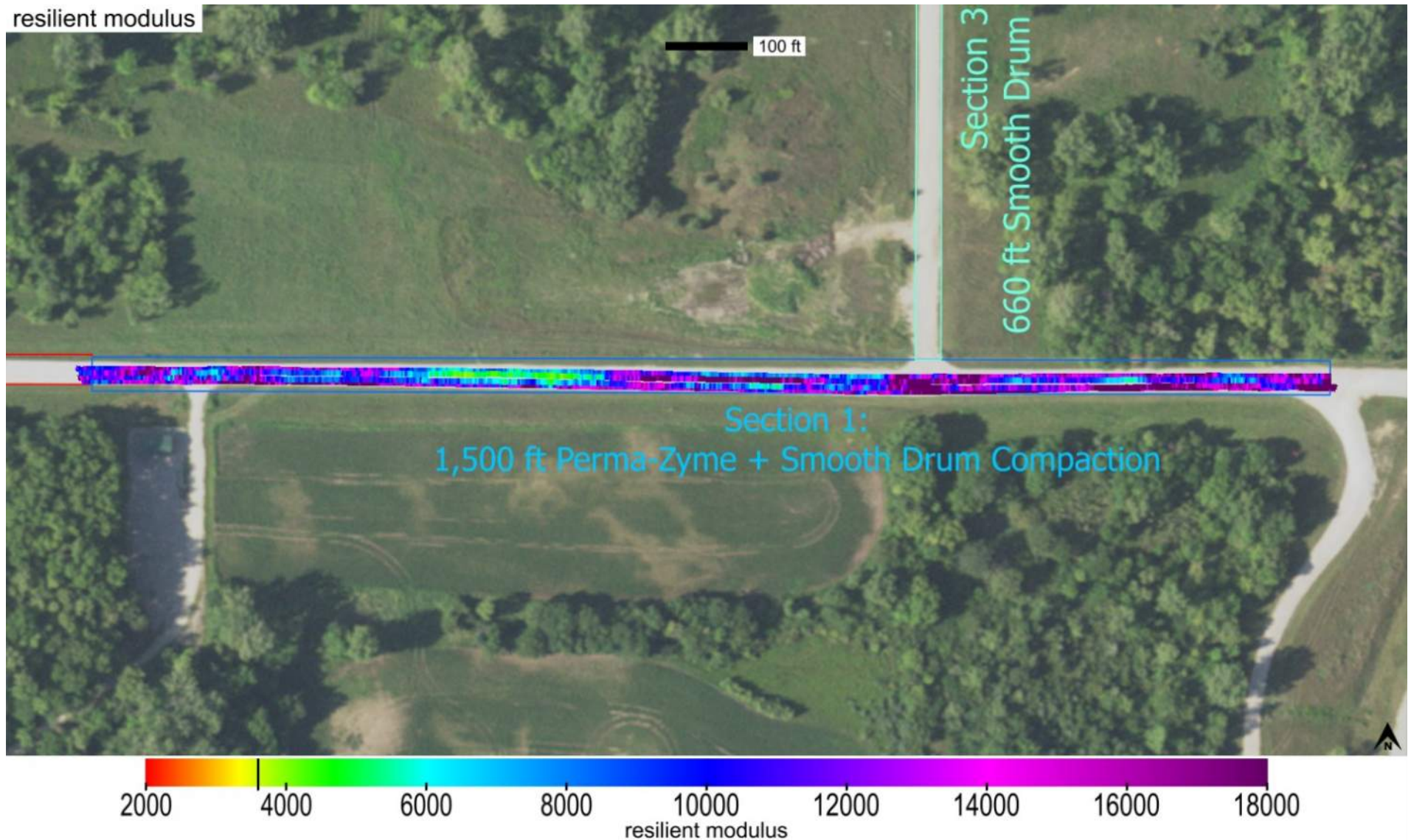
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	99.0	112.8	0.6	100.0	84.1	316.6	550.0	134.2	42.4	-15.9	216.6	450.0



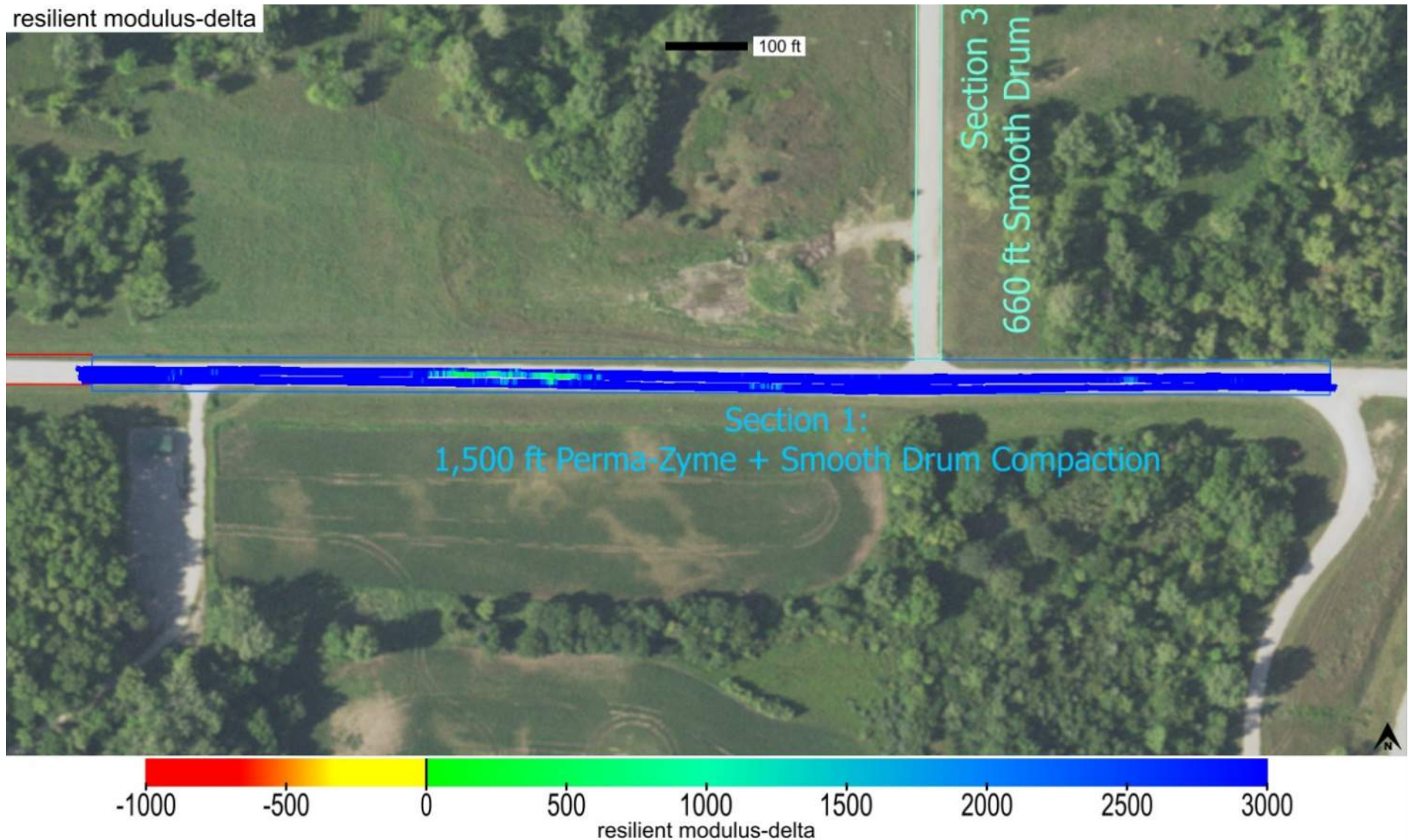
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	99.0	112.8	0.6	100.0	84.1	316.6	550.0	134.2	42.4	-15.9	216.6	450.0



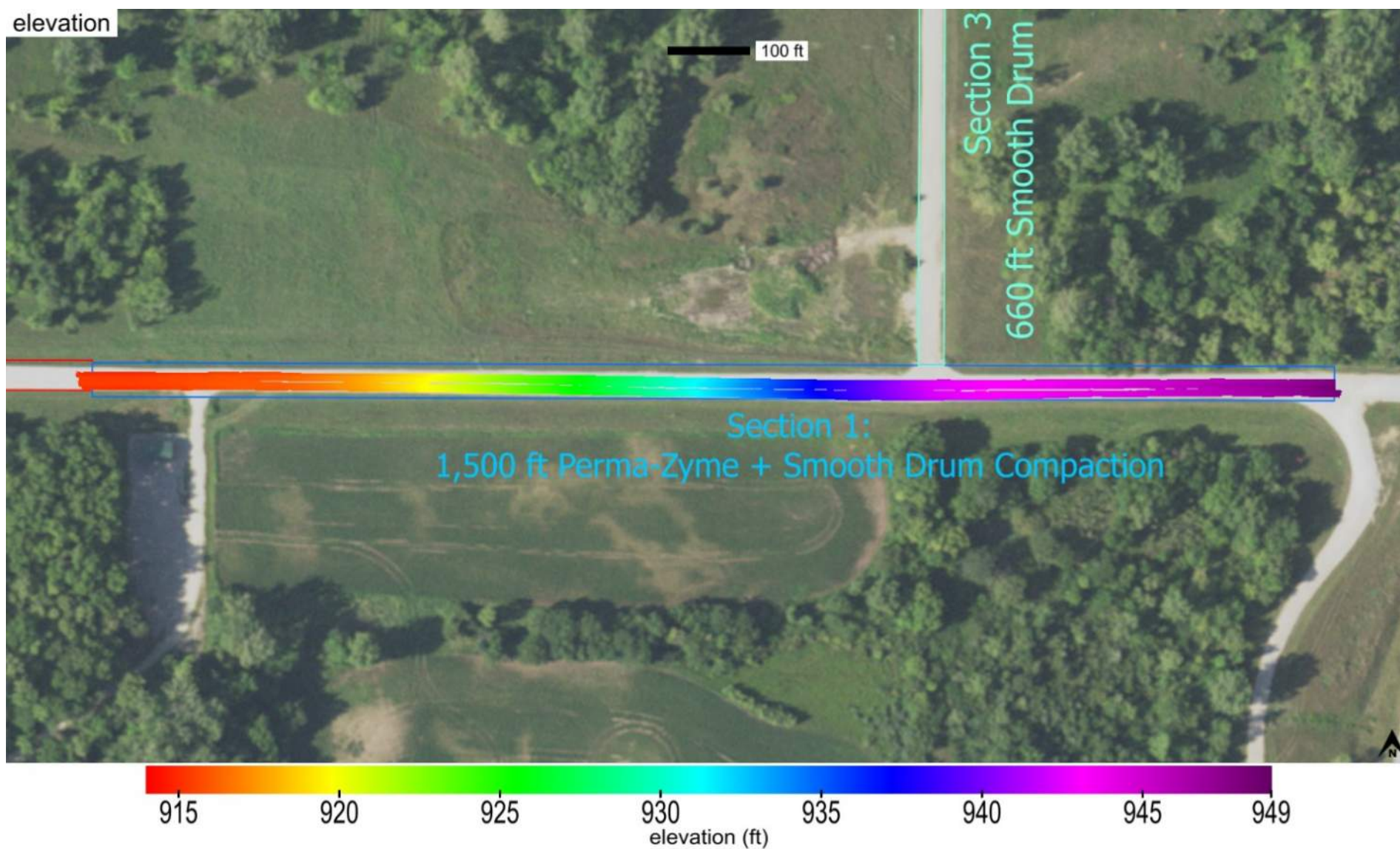
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	106.9	0.6	3600.0	3686.5	12173.3	20000.0	4418.3	36.3	86.5	8573.3	16400.0



Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	106.9	0.6	3600.0	3686.5	12173.3	20000.0	4418.3	36.3	86.5	8573.3	16400.0



minimum	average	maximum	RTK-Q7 (%)	RTK-QA
914.92	931.25	948.39	99.7	7.98





Map ID: ing_pol77-campdodge-2023_cs56b-01047_2023_08_07_125822

Project:	TR-823 Study	Date and Time:	8/7/2023 12:58:22 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.355	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	37049	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	2 - STAB + Sheepsfoot

Map Summary

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
XMV	No												
Resilient Modulus	Yes	100.0	107.7	0.6	3600.0	3941.6	12062.1	20000.0	4183.6	34.7	341.6	8462.1	16400.0
k-value	Yes	100.0	115.5	0.6	100.0	100.6	325.9	550.0	126.8	38.9	0.6	225.9	450.0
Moisture Content	No												

Mapped Area		Pass Count					Elevation (ft)			Position Quality		Velocity (fps)		
square feet	acres	10th percentile	Median	cov(%)	% >= TV	Target Value	min.	avg.	max.	RTK-Q7 (%)	RTK-QA	min.	avg.	max.
37049	0.851	1	1	31.4	100.0	0	894.93	907.79	916.77	98.4	7.97	4.7	5.1	5.8

Materials

name	id	% of total	area-square ft	area-acres	tl-xmv	tl-Mr	tl-k value	tl-w%
Unpaved Gravel Road (not defined)_IADOT	41019	100.0	37049	0.851	100.0	3600.0	100.0	20.5

Blobs

parameter	min. area(ft^2)	# of blobs	blob area(ft^2)	% of map	lower bound-tv	upper bound-tv	poly-tol.
Resilient Modulus	500.0	0	0	0.0	none	0.0	4.0
k-value	500.0	0	0	0.0	none	0.0	4.0

Station

Start	End
15+50	30+00

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_07_125822

Project:	TR-823 Study	Date and Time:	8/7/2023 12:58:22 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.355	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	37049	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	2 - STAB + Sheepsfoot

QUALITY ANALYSIS SUMMARY - k-Value

Quality Value	Criteria
115.5	CQI > = 95
100.0	80% of k-Value MVs >= 100
38.9	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_07_125822

Project:	TR-823 Study	Date and Time:	8/7/2023 12:58:22 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.355	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	37049	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	2 - STAB + Sheepsfoot

QUALITY ANALYSIS SUMMARY - Resilient Modulus

Quality Value	Criteria
107.7	CQI > = 95
100.0	90% of Resilient Modulus MVs >= 3600
34.7	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

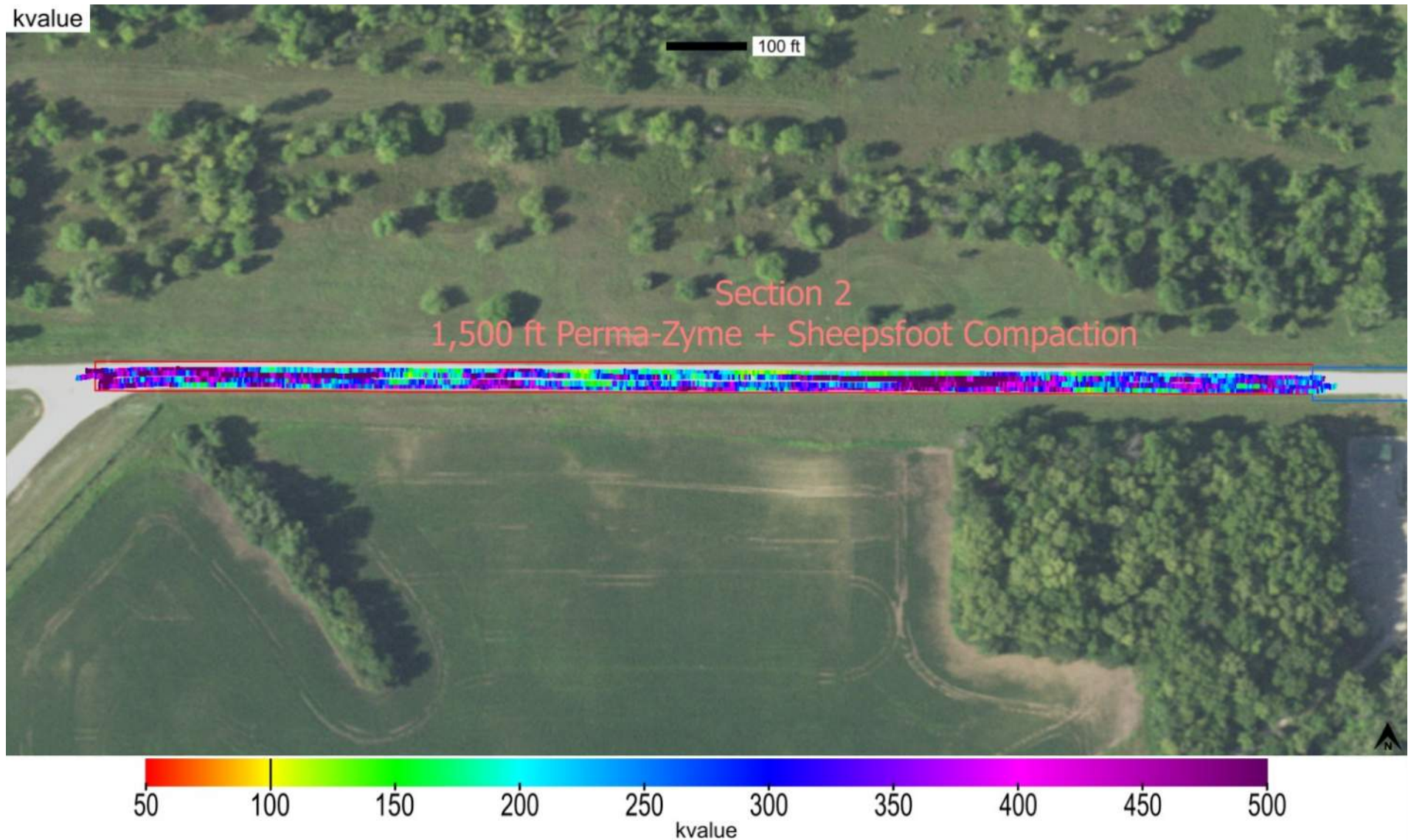
Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

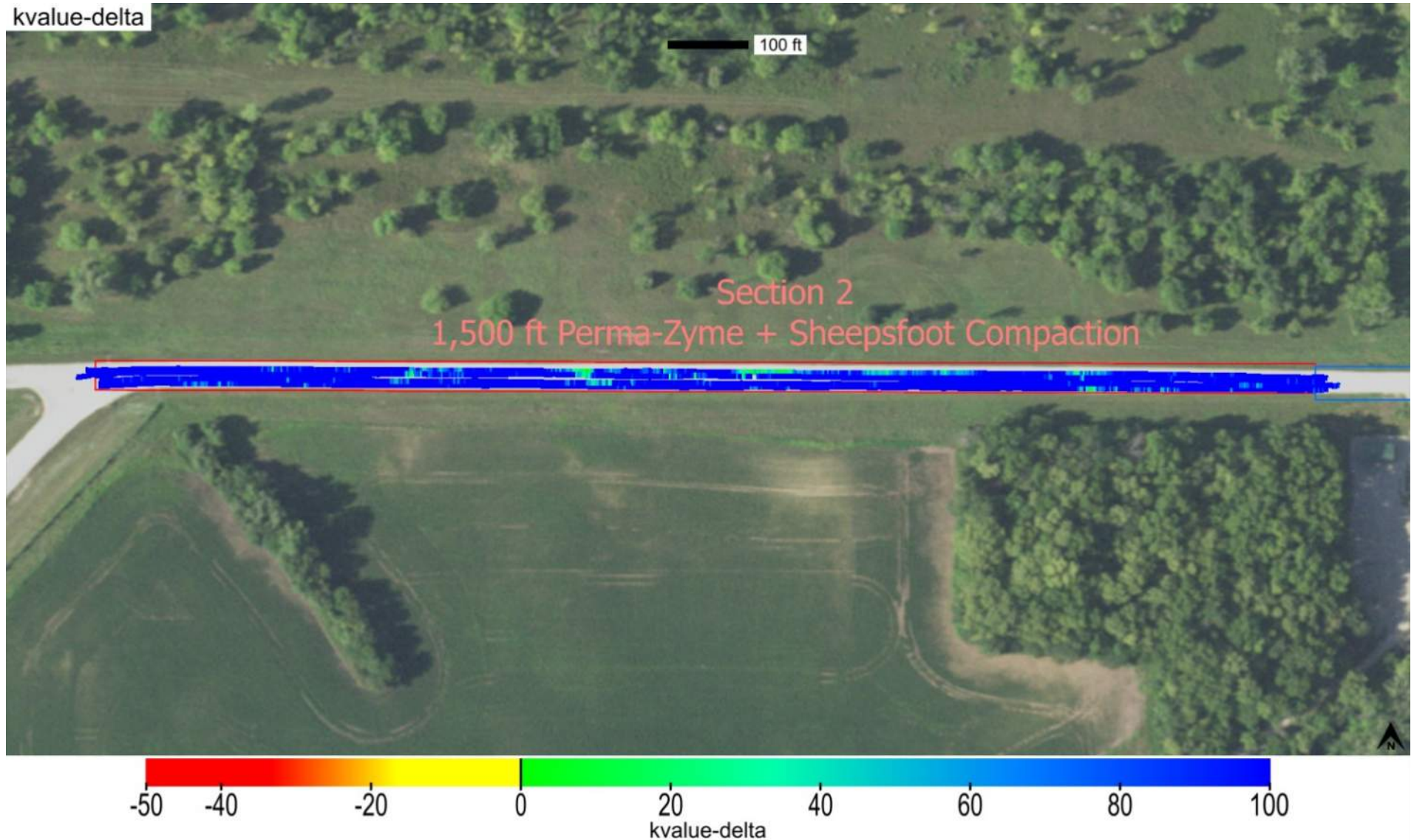
Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	115.5	0.6	100.0	100.6	325.9	550.0	126.8	38.9	0.6	225.9	450.0



Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	115.5	0.6	100.0	100.6	325.9	550.0	126.8	38.9	0.6	225.9	450.0

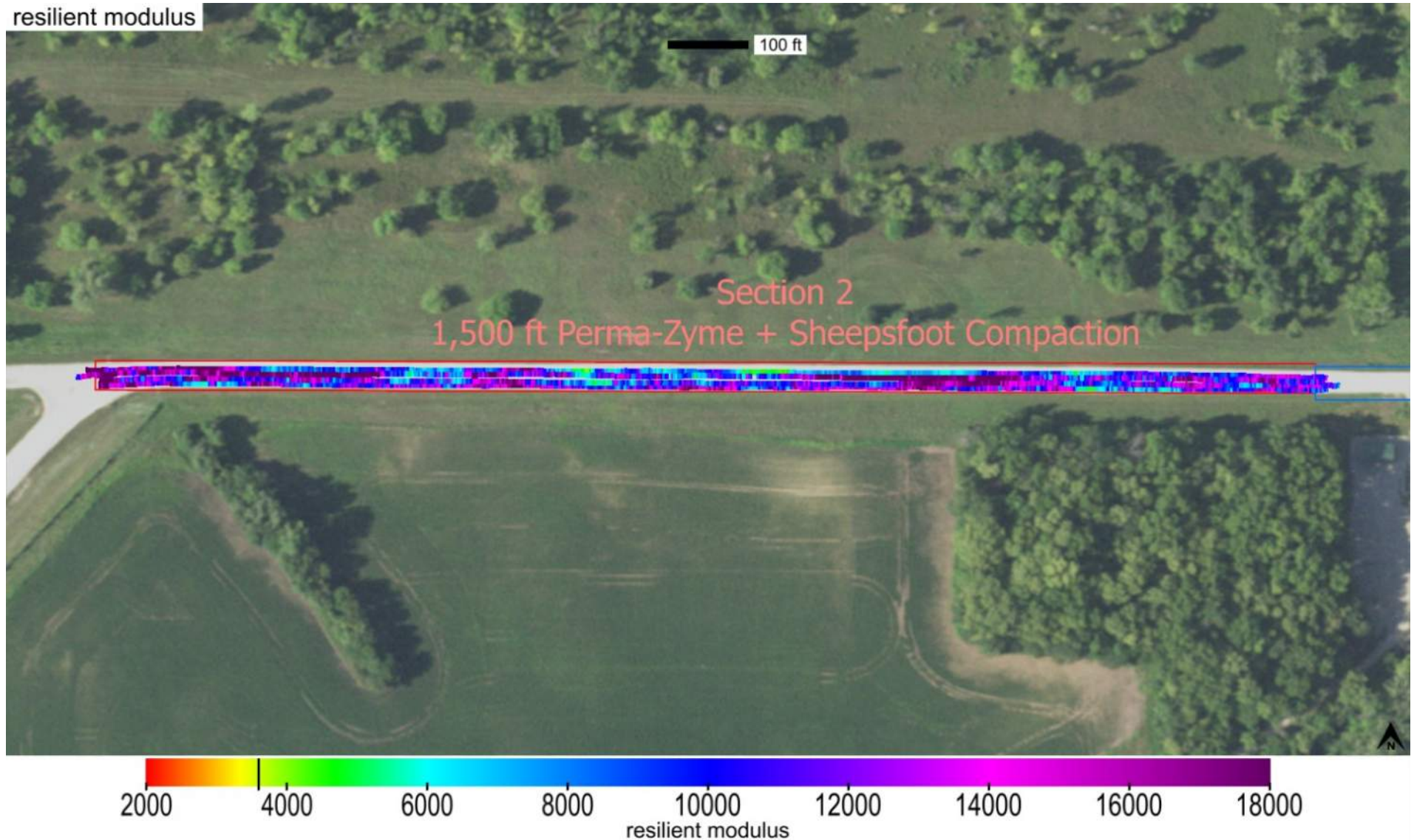


Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_07_125822

Map Type: Verification Map

Map Layer: Unpaved Gravel Road

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	107.7	0.6	3600.0	3941.6	12062.1	20000.0	4183.6	34.7	341.6	8462.1	16400.0



This report is only for use of the client named and it cannot be relied upon by any other person or entity.

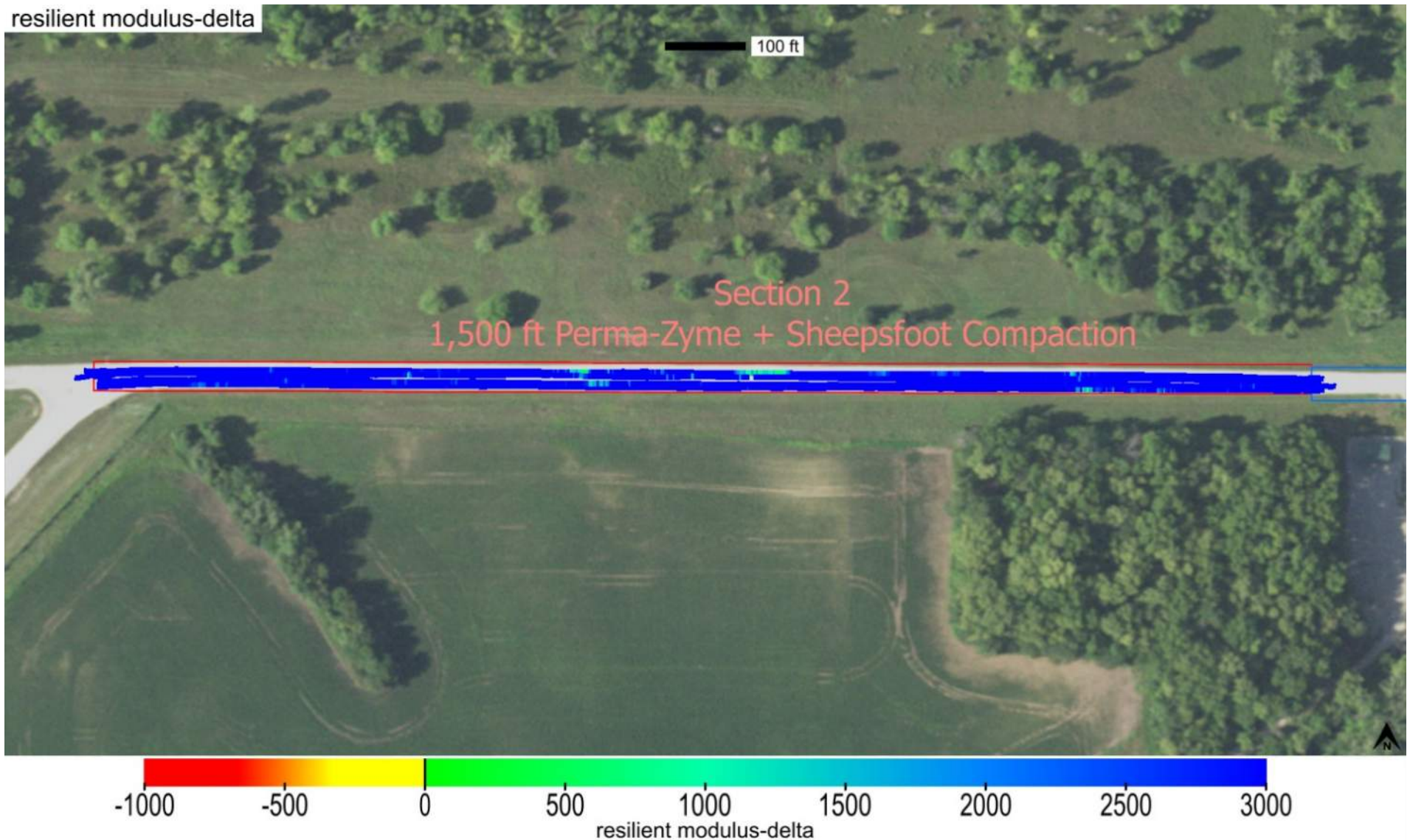
Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_07_125822

Map Type: Verification Map

Map Layer: Unpaved Gravel Road

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	107.7	0.6	3600.0	3941.6	12062.1	20000.0	4183.6	34.7	341.6	8462.1	16400.0

resilient modulus-delta



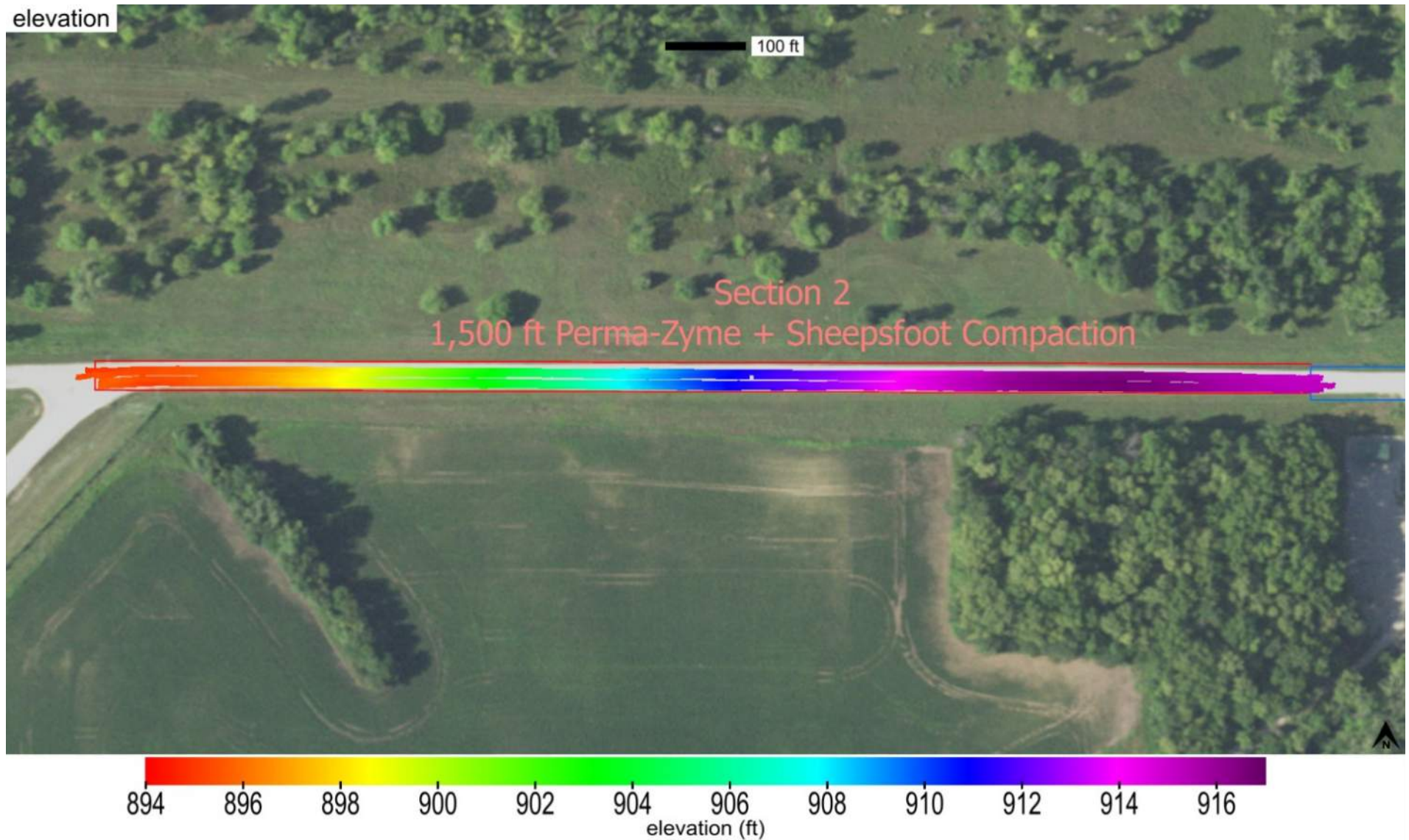
This report is only for use of the client named and it cannot be relied upon by any other person or entity.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_07_125822

Map Type: Verification Map

Map Layer: Unpaved Gravel Road

minimum	average	maximum	RTK-Q7 (%)	RTK-QA
894.93	907.79	916.77	98.4	7.97



This report is only for use of the client named and it cannot be relied upon by any other person or entity.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_07_125822 Map Type: Verification Map Map Layer: Unpaved Gravel Road

ing_polk77-campdodge-2023_cs56b-01047_2023_08_07_125822_20230808T090836_04-Photo-Aug-07-2023--1-22-57-PM.jpg



Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_07_134340

Project:	TR-823 Study	Date and Time:	8/7/2023 1:43:40 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.175	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	13307	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	3 - Smooth Drum

Map Summary

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
XMV	No												
Resilient Modulus	Yes	100.0	107.1	0.7	3600.0	3949.9	11589.1	20000.0	4152.8	35.8	349.9	7989.1	16400.0
k-value	Yes	100.0	115.0	0.7	100.0	106.9	301.9	550.0	121.0	40.1	6.9	201.9	450.0
Moisture Content	No												

Mapped Area		Pass Count					Elevation (ft)			Position Quality		Velocity (fps)		
square feet	acres	10th percentile	Median	cov(%)	% >= TV	Target Value	min.	avg.	max.	RTK-Q7 (%)	RTK-QA	min.	avg.	max.
13307	0.305	1	1	39.4	100.0	0	939.73	942.21	944.08	93.6	7.83	4.2	5.0	6.5

Materials

name	id	% of total	area-square ft	area-acres	tl-xmv	tl-Mr	tl-k value	tl-w%
Unpaved Gravel Road (not defined)_IADOT	41019	100.0	13307	0.305	100.0	3600.0	100.0	20.5

Blobs

parameter	min. area(ft^2)	# of blobs	blob area(ft^2)	% of map	lower bound-tv	upper bound-tv	poly-tol.
Resilient Modulus	500.0	0	0	0.0	none	0.0	4.0
k-value	500.0	0	0	0.0	none	0.0	4.0

Station

Start	End
0+00	6+60

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_07_134340

Project:	TR-823 Study	Date and Time:	8/7/2023 1:43:40 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.175	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	13307	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	3 - Smooth Drum

QUALITY ANALYSIS SUMMARY - k-Value

Quality Value	Criteria
115.0	CQI > = 95
100.0	80% of k-Value MVs >= 100
40.1	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_07_134340

Project:	TR-823 Study	Date and Time:	8/7/2023 1:43:40 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.175	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	13307	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	3 - Smooth Drum

QUALITY ANALYSIS SUMMARY - Resilient Modulus

Quality Value	Criteria
107.1	CQI > = 95
100.0	90% of Resilient Modulus MVs >= 3600
35.8	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

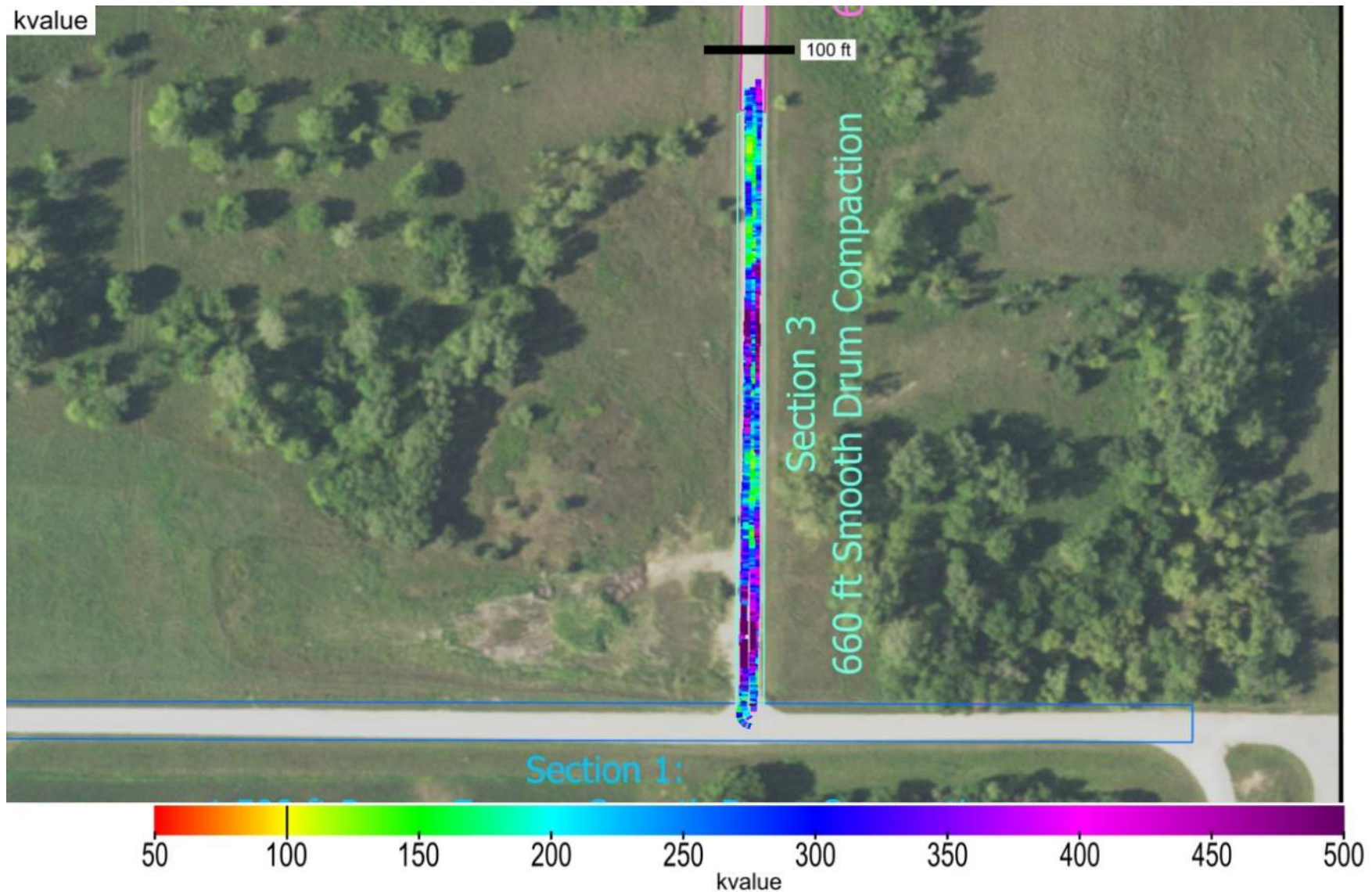
Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

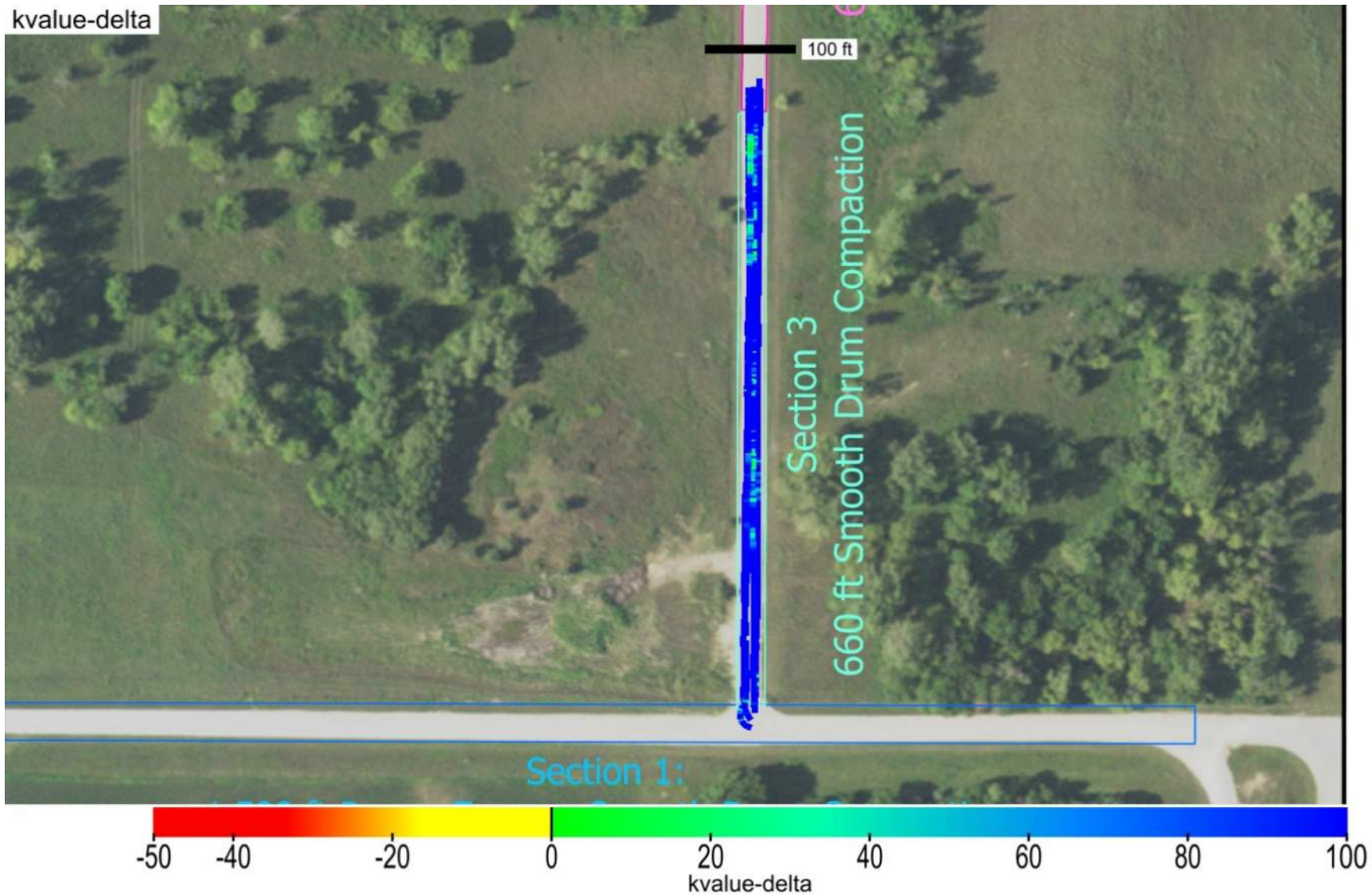
Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

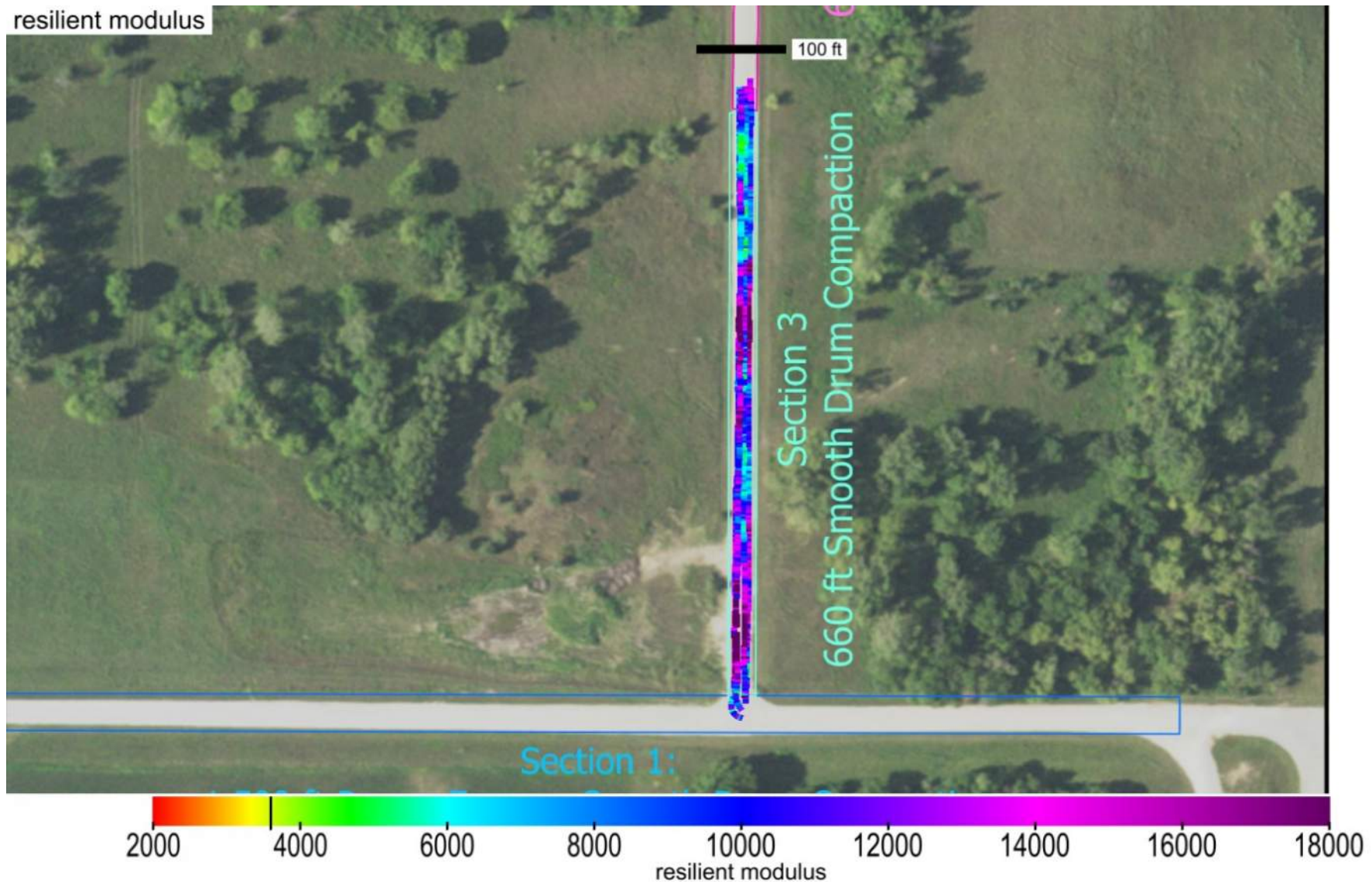
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	115.0	0.7	100.0	106.9	301.9	550.0	121.0	40.1	6.9	201.9	450.0



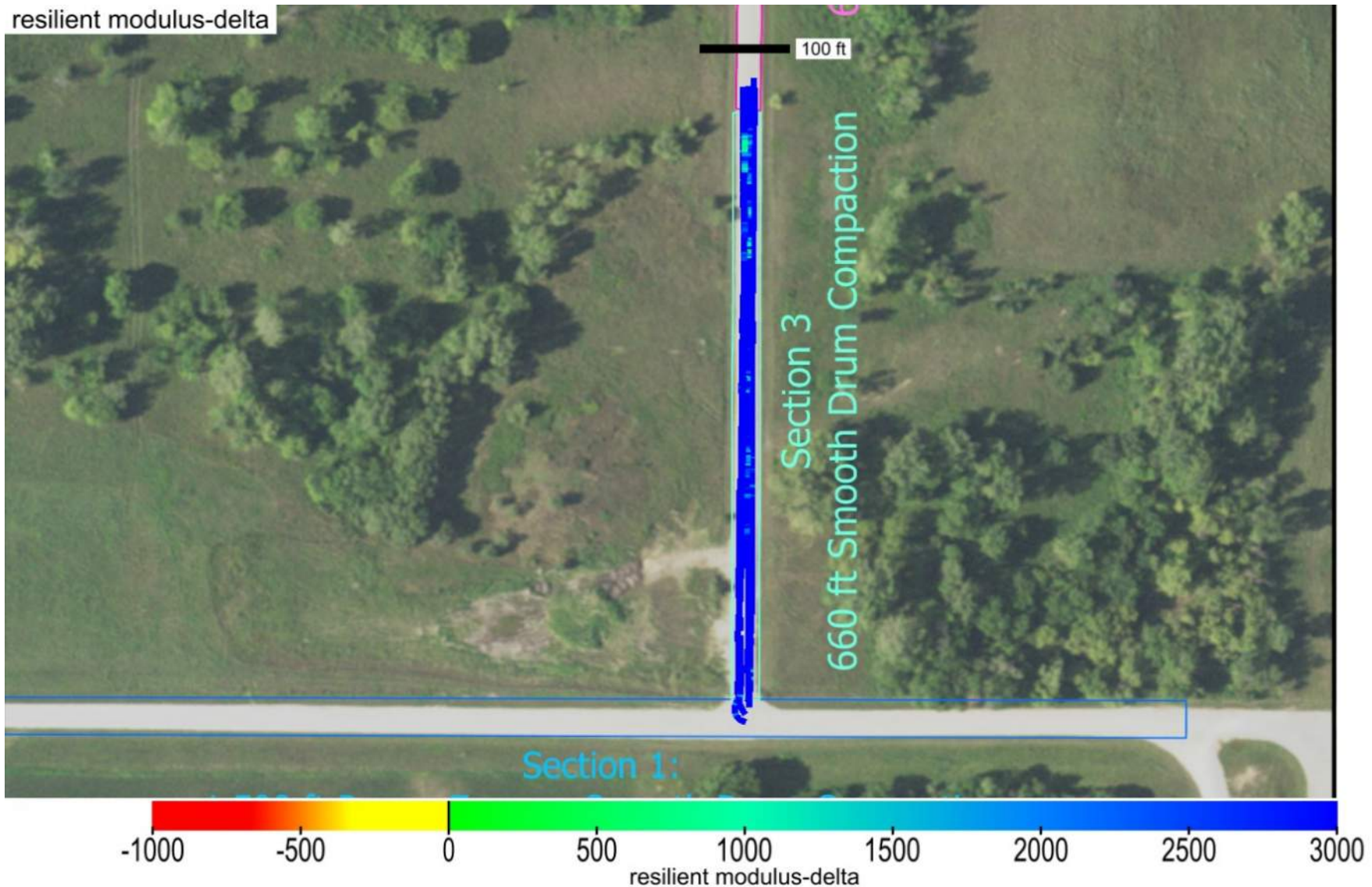
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	115.0	0.7	100.0	106.9	301.9	550.0	121.0	40.1	6.9	201.9	450.0



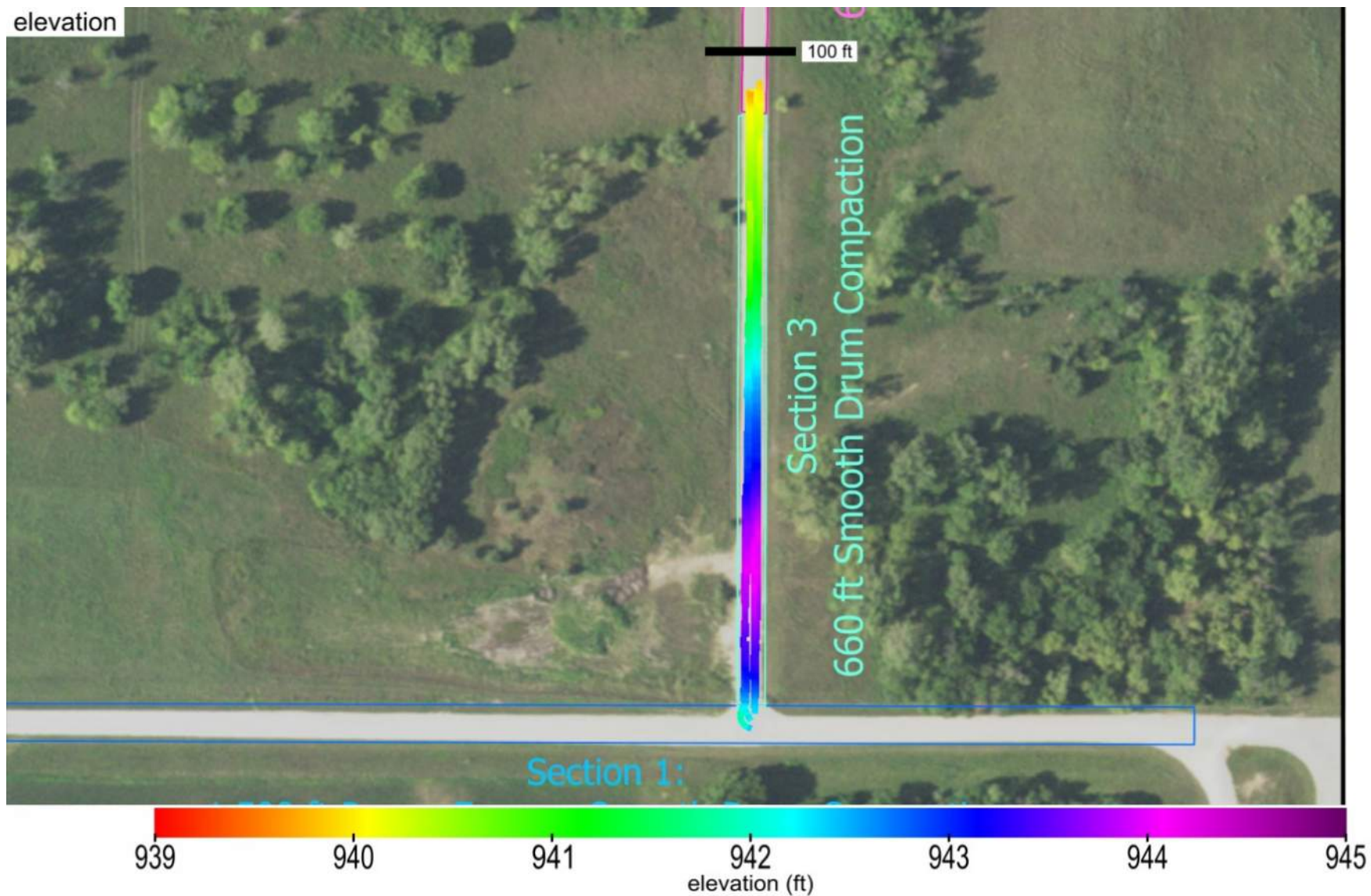
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	107.1	0.7	3600.0	3949.9	11589.1	20000.0	4152.8	35.8	349.9	7989.1	16400.0



Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	107.1	0.7	3600.0	3949.9	11589.1	20000.0	4152.8	35.8	349.9	7989.1	16400.0



minimum	average	maximum	RTK-Q7 (%)	RTK-QA
939.73	942.21	944.08	93.6	7.83



Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_07_134340

Map Type: Verification Map

Map Layer: Unpaved Gravel Road

ing_polk77-campdodge-2023_cs56b-01047_2023_08_07_134340_20230808T090853_06-Photo-Aug-07-2023--1-57-34-PM.jpg



Map ID: ing_pol77-campdodge-2023_cs56b-01047_2023_08_07_140926

Project:	TR-823 Study	Date and Time:	8/7/2023 2:09:26 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.173	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	13425	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	4 - Sheepsfoot

Map Summary

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
XMV	No												
Resilient Modulus	Yes	100.0	108.9	0.8	3600.0	4128.6	9192.4	20000.0	2956.3	32.2	528.6	5592.4	16400.0
k-value	Yes	100.0	117.4	0.9	100.0	102.6	237.9	550.0	83.8	35.2	2.6	137.9	450.0
Moisture Content	No												

Mapped Area		Pass Count					Elevation (ft)			Position Quality		Velocity (fps)		
square feet	acres	10th percentile	Median	cov(%)	% >= TV	Target Value	min.	avg.	max.	RTK-Q7 (%)	RTK-QA	min.	avg.	max.
13425	0.308	1	1	34.3	100.0	0	936.56	938.62	940.17	84.7	7.68	4.7	5.1	5.6

Materials

name	id	% of total	area-square ft	area-acres	tl-xmv	tl-Mr	tl-k value	tl-w%
Unpaved Gravel Road (not defined)_IADOT	41019	100.0	13425	0.308	100.0	3600.0	100.0	20.5

Blobs

parameter	min. area(ft^2)	# of blobs	blob area(ft^2)	% of map	lower bound-tv	upper bound-tv	poly-tol.
Resilient Modulus	500.0	0	0	0.0	none	0.0	4.0
k-value	500.0	0	0	0.0	none	0.0	4.0

Station

Start	End
6+60	13+20

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_07_140926

Project:	TR-823 Study	Date and Time:	8/7/2023 2:09:26 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.173	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	13425	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	4 - Sheepsfoot

QUALITY ANALYSIS SUMMARY - k-Value

Quality Value	Criteria
117.4	CQI > = 95
100.0	80% of k-Value MVs >= 100
35.2	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_07_140926

Project:	TR-823 Study	Date and Time:	8/7/2023 2:09:26 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.173	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	13425	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	4 - Sheepsfoot

QUALITY ANALYSIS SUMMARY - Resilient Modulus

Quality Value	Criteria
108.9	CQI > = 95
100.0	90% of Resilient Modulus MVs >= 3600
32.2	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

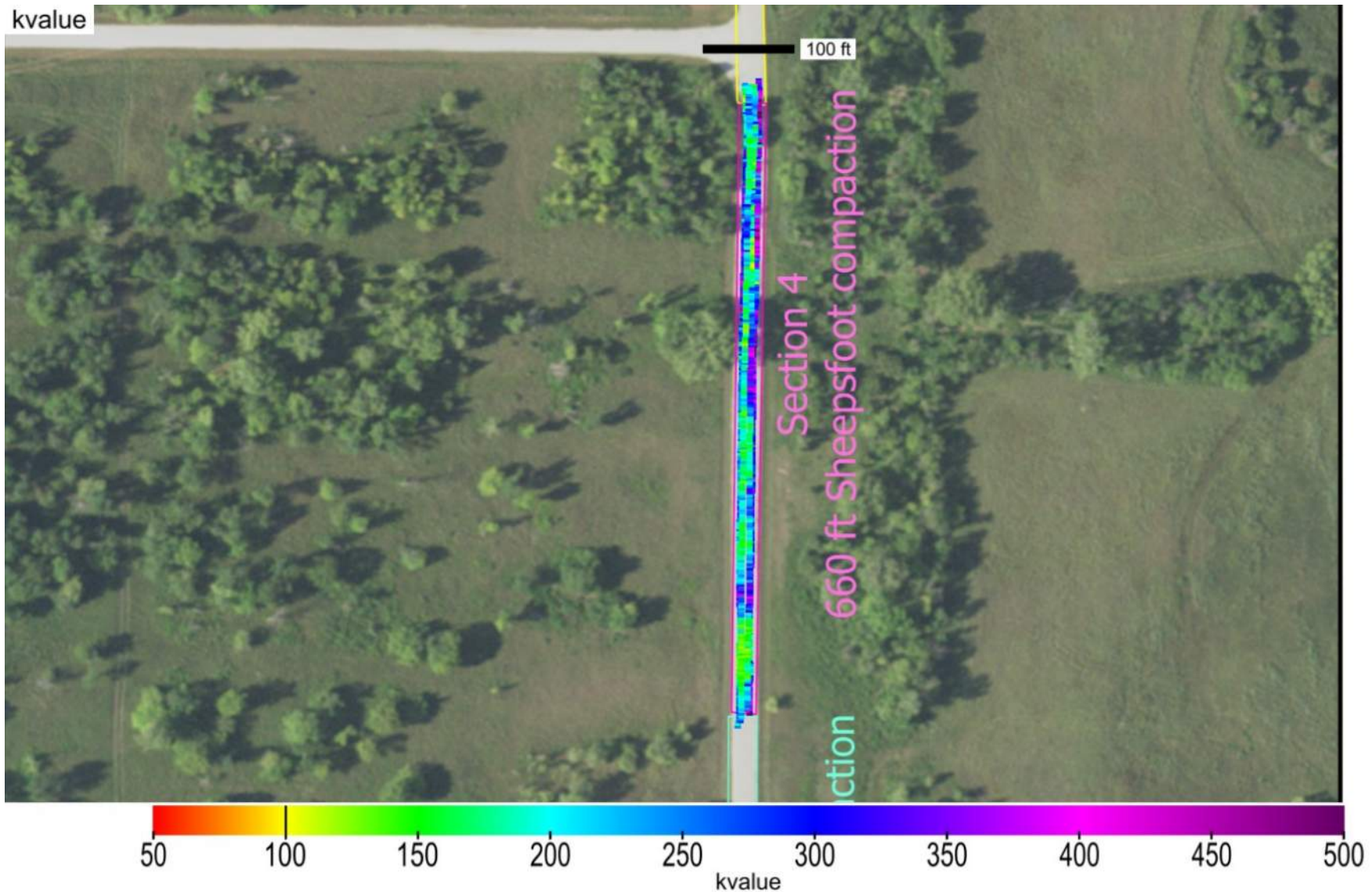
Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	117.4	0.9	100.0	102.6	237.9	550.0	83.8	35.2	2.6	137.9	450.0

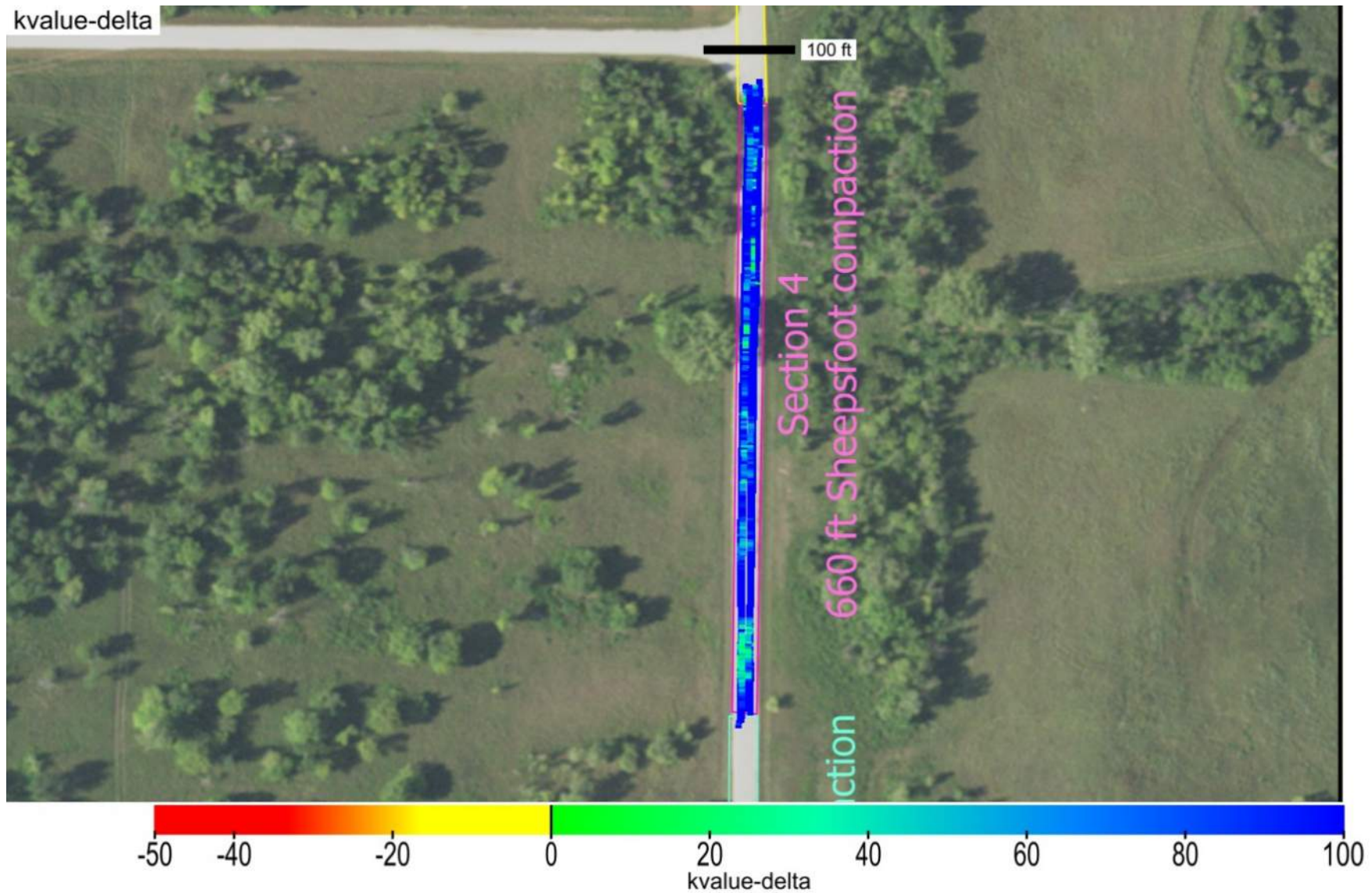


Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_07_140926

Map Type: Verification Map

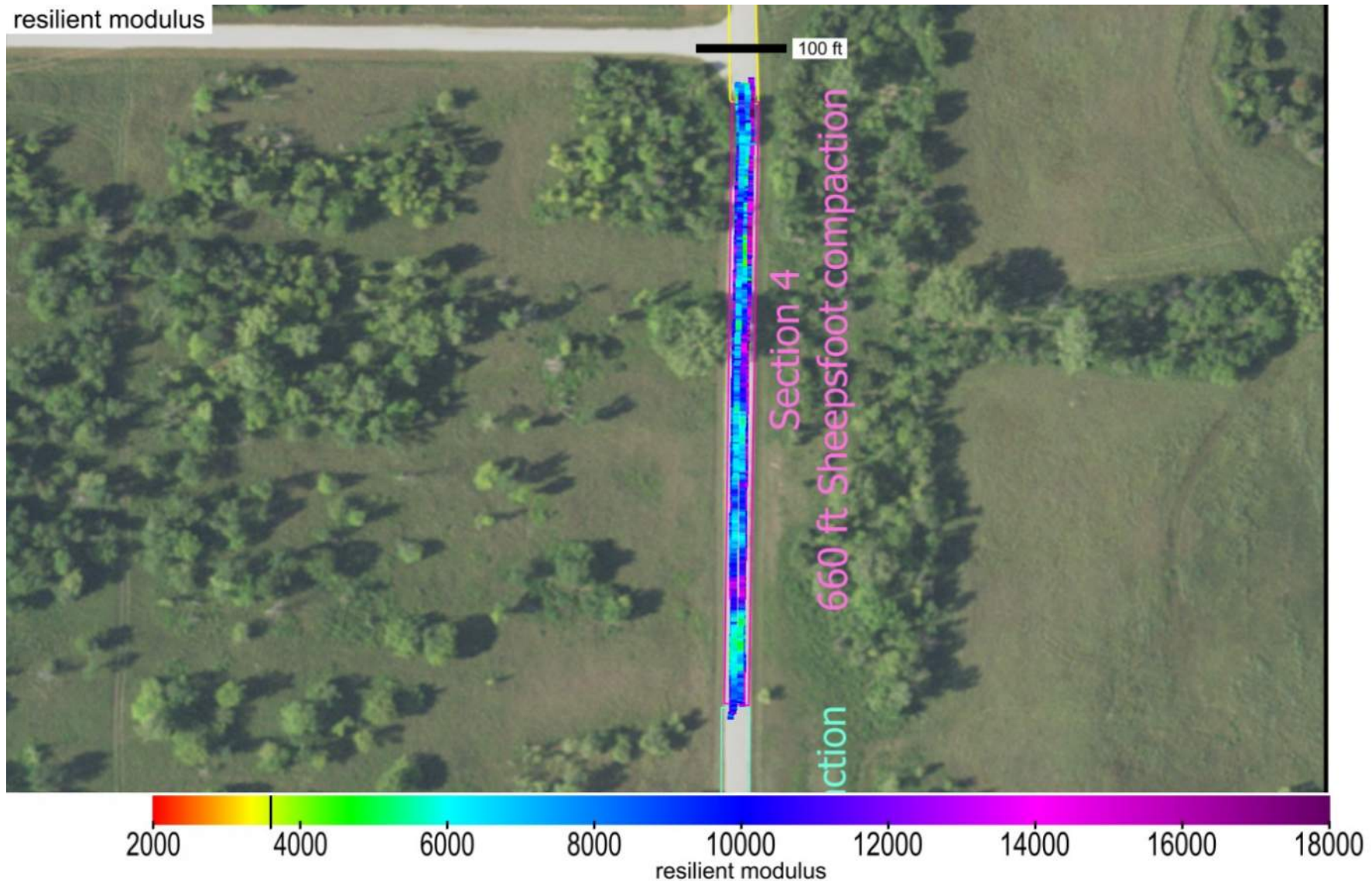
Map Layer: Unpaved Gravel Road

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	117.4	0.9	100.0	102.6	237.9	550.0	83.8	35.2	2.6	137.9	450.0

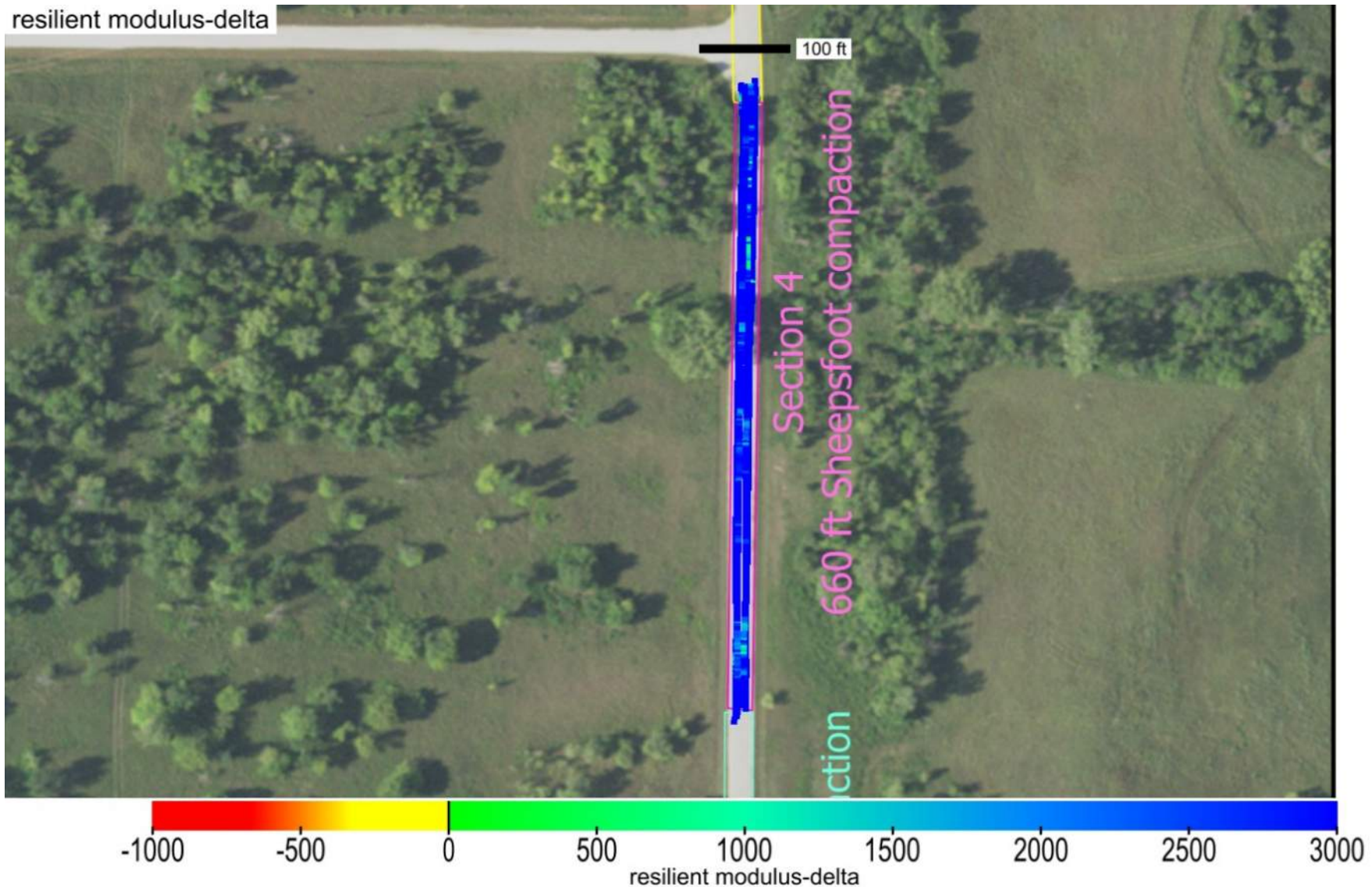


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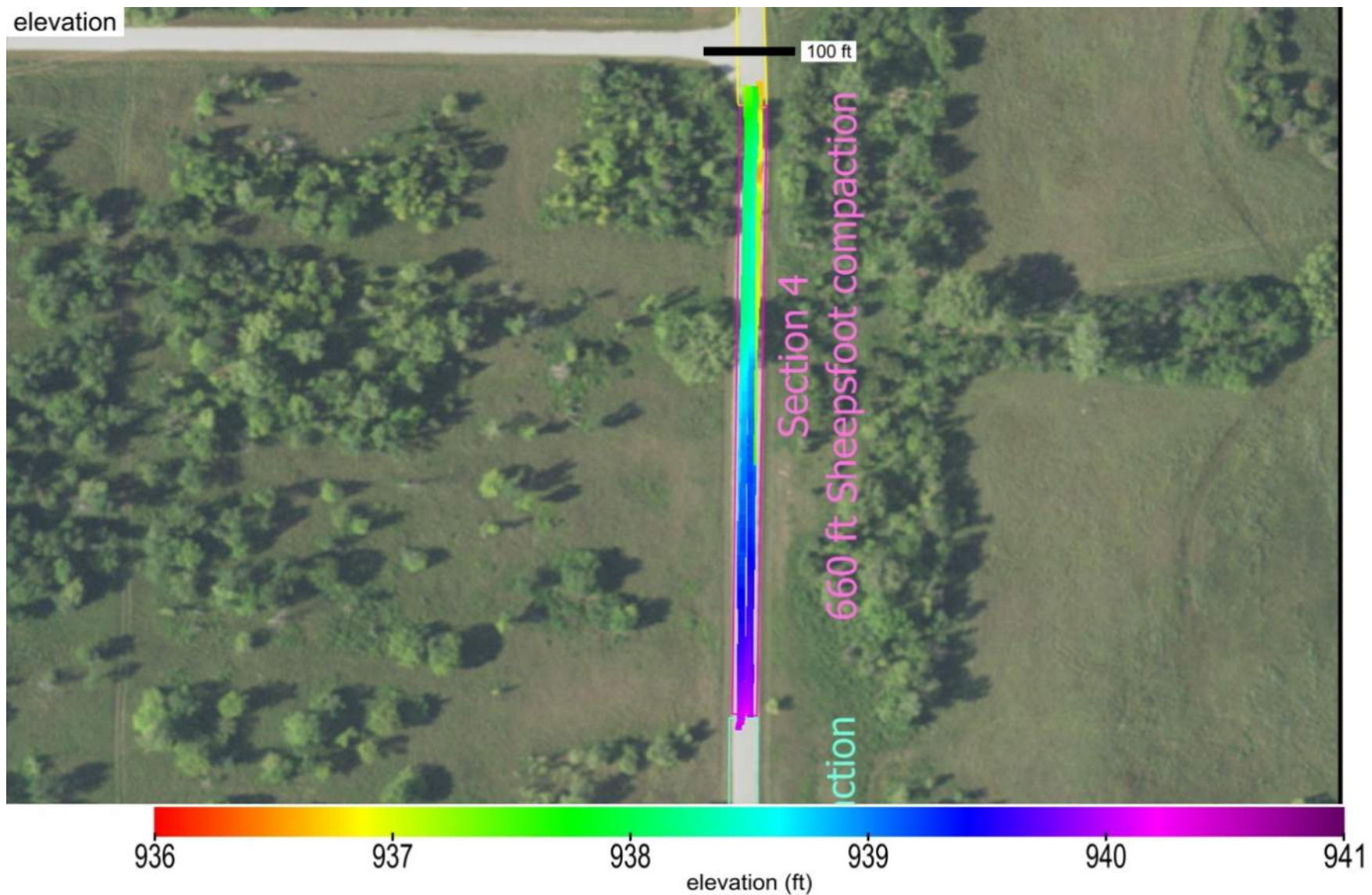
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	108.9	0.8	3600.0	4128.6	9192.4	20000.0	2956.3	32.2	528.6	5592.4	16400.0



Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	108.9	0.8	3600.0	4128.6	9192.4	20000.0	2956.3	32.2	528.6	5592.4	16400.0



minimum	average	maximum	RTK-Q7 (%)	RTK-QA
936.56	938.62	940.17	84.7	7.68



Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_07_140926

Map Type: Verification Map

Map Layer: Unpaved Gravel Road

ing_polk77-campdodge-2023_cs56b-01047_2023_08_07_140926_20230808T090909_08-Photo-Aug-07-2023--2-23-16-PM.jpg



Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_07_144405

Project:	TR-823 Study	Date and Time:	8/7/2023 2:44:05 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.315	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	23488	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	5 - Control

Map Summary

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
XMV	No												
Resilient Modulus	Yes	100.0	103.7	0.6	3600.0	3655.9	11128.8	20000.0	4745.4	42.6	55.9	7528.8	16400.0
k-value	Yes	100.0	113.9	0.6	100.0	103.5	316.3	550.0	133.7	42.3	3.5	216.3	450.0
Moisture Content	No												

Mapped Area		Pass Count					Elevation (ft)			Position Quality		Velocity (fps)		
square feet	acres	10th percentile	Median	cov(%)	% >= TV	Target Value	min.	avg.	max.	RTK-Q7 (%)	RTK-QA	min.	avg.	max.
23488	0.539	1	2	31.3	100.0	0	937.23	943.79	952.75	90.4	7.79	4.5	5.1	5.6

Materials

name	id	% of total	area-square ft	area-acres	tl-xmv	tl-Mr	tl-k value	tl-w%
Unpaved Gravel Road (not defined)_IADOT	41019	100.0	23488	0.539	100.0	3600.0	100.0	20.5

Blobs

parameter	min. area(ft^2)	# of blobs	blob area(ft^2)	% of map	lower bound-tv	upper bound-tv	poly-tol.
Resilient Modulus	500.0	0	0	0.0	none	0.0	4.0
k-value	500.0	0	0	0.0	none	0.0	4.0

Station

Start	End
13+20	26+40

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_07_144405

Project:	TR-823 Study	Date and Time:	8/7/2023 2:44:05 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.315	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	23488	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	5 - Control

QUALITY ANALYSIS SUMMARY - k-Value

Quality Value	Criteria
113.9	CQI > = 95
100.0	80% of k-Value MVs >= 100
42.3	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_07_144405

Project:	TR-823 Study	Date and Time:	8/7/2023 2:44:05 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.315	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	23488	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	5 - Control

QUALITY ANALYSIS SUMMARY - Resilient Modulus

Quality Value	Criteria
103.7	CQI > = 95
100.0	90% of Resilient Modulus MVs >= 3600
42.6	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

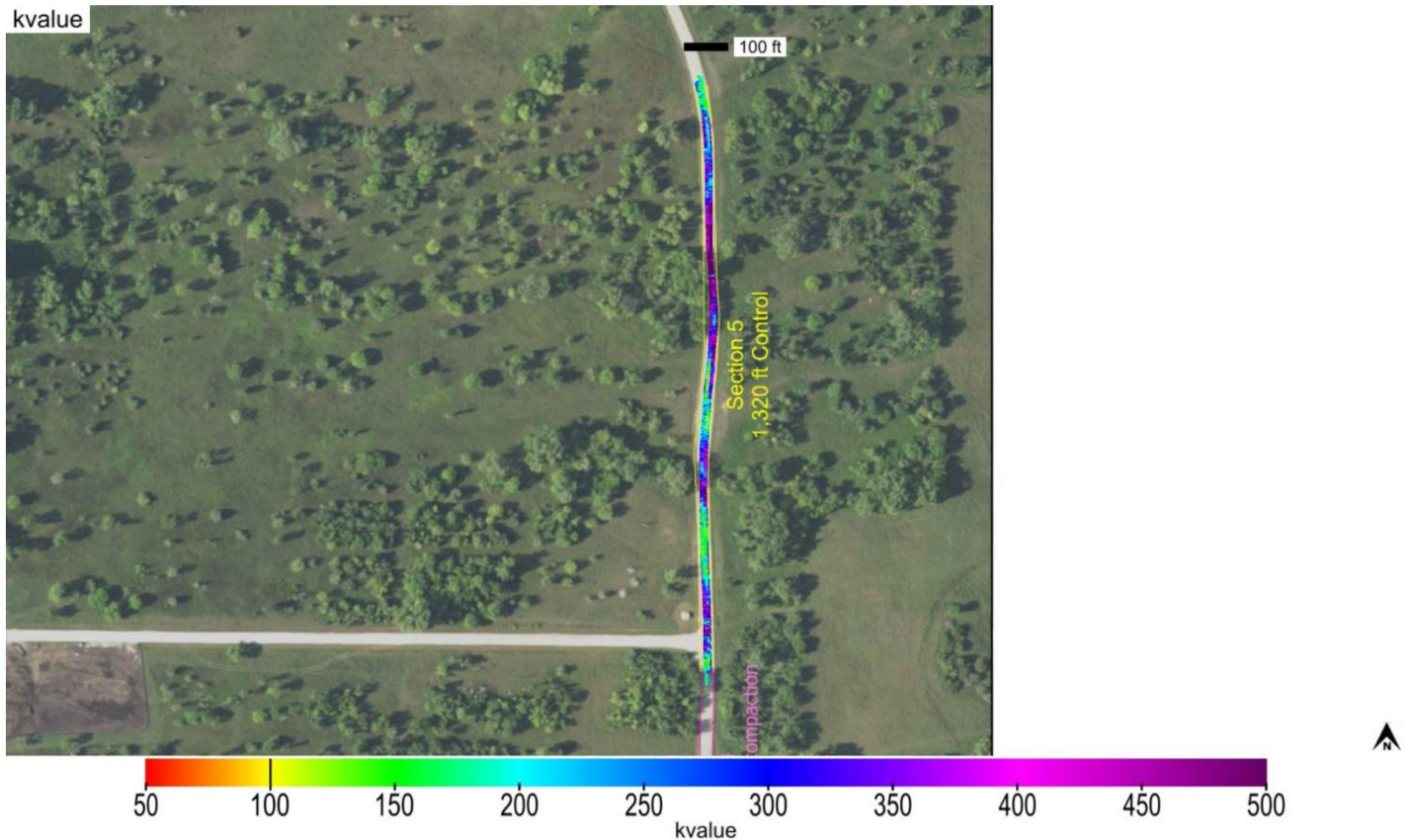
Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_07_144405

Map Type: Verification Map

Map Layer: Unpaved Gravel Road

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	113.9	0.6	100.0	103.5	316.3	550.0	133.7	42.3	3.5	216.3	450.0



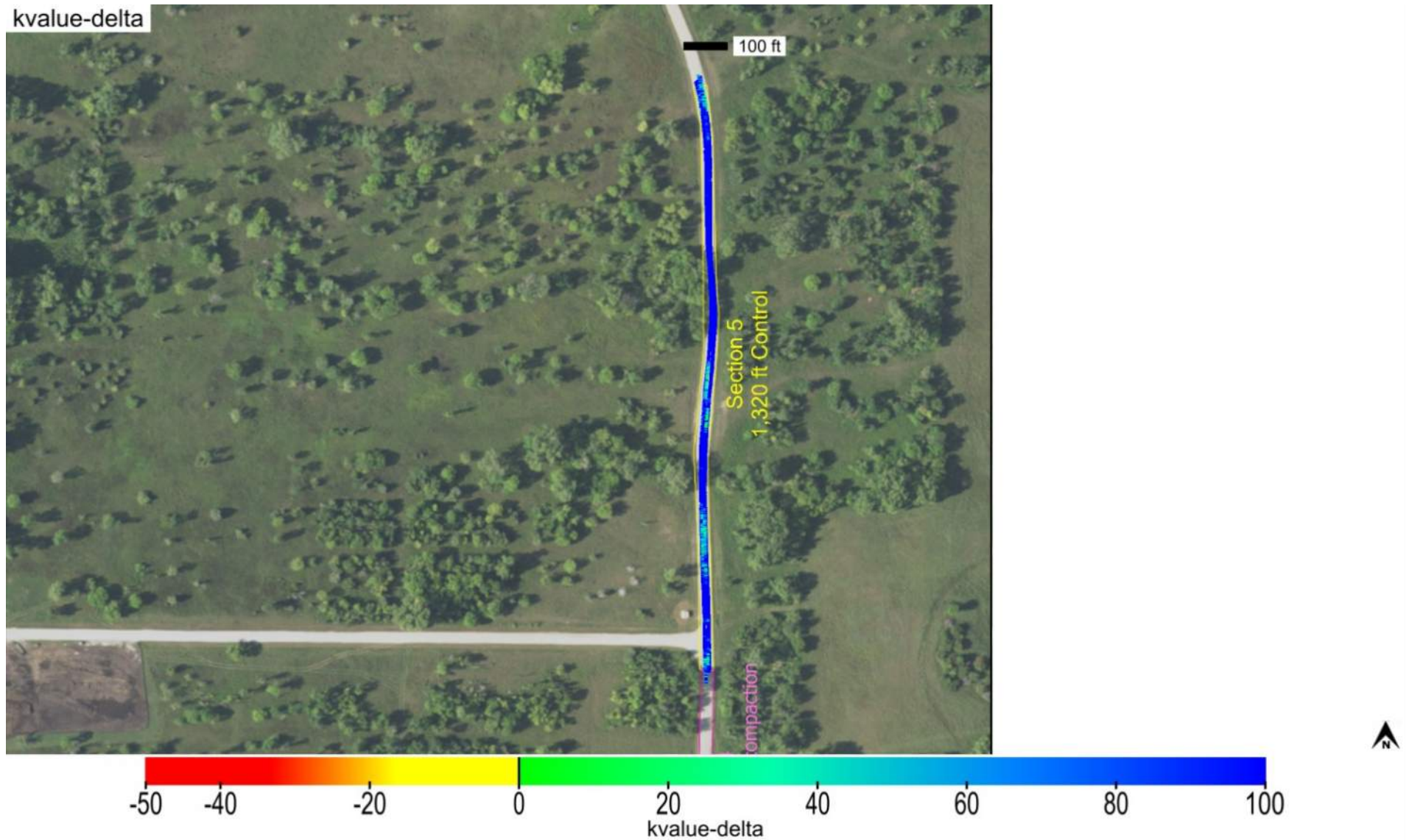
This report is only for use of the client named and it cannot be relied upon by any other person or entity.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_07_144405

Map Type: Verification Map

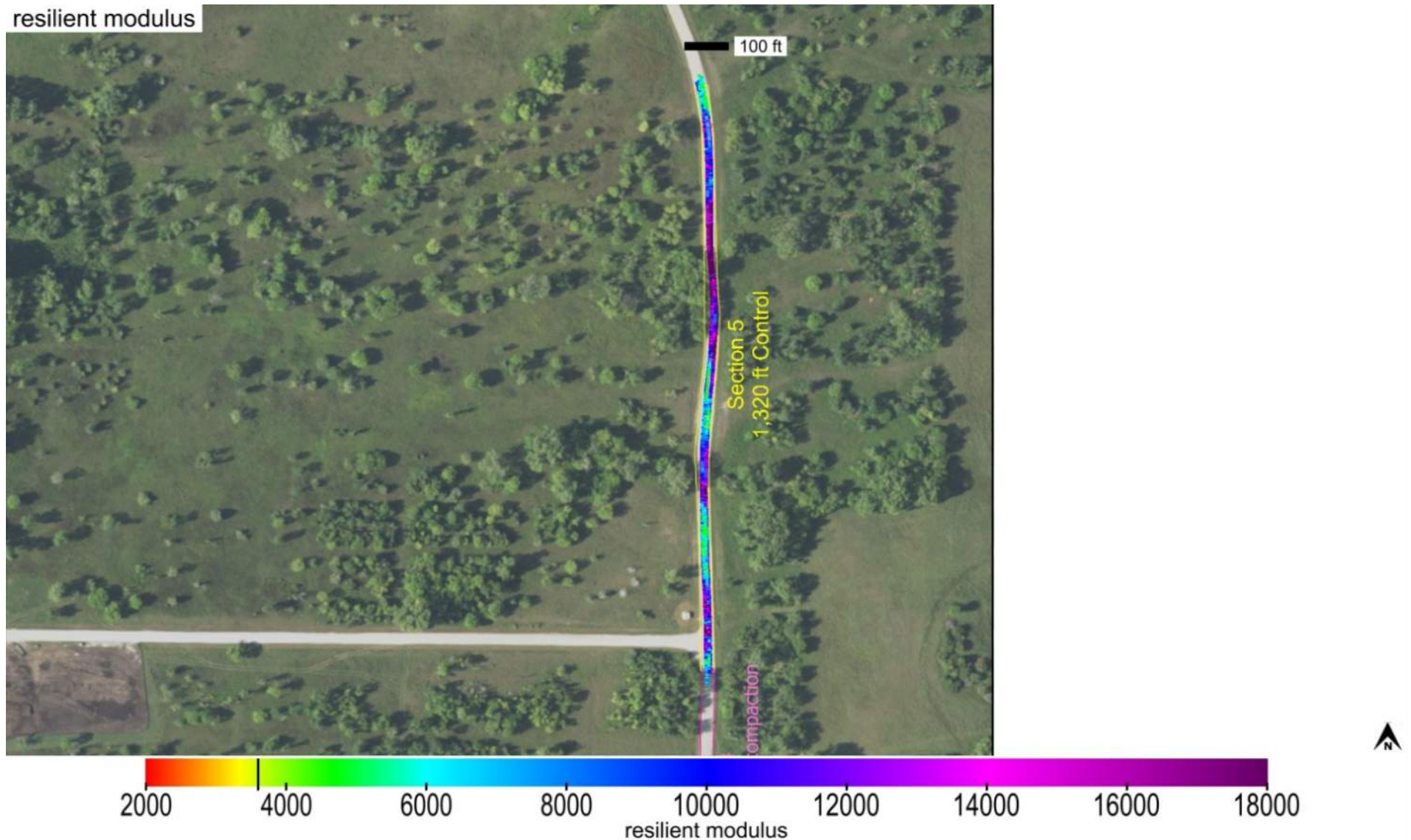
Map Layer: Unpaved Gravel Road

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	113.9	0.6	100.0	103.5	316.3	550.0	133.7	42.3	3.5	216.3	450.0

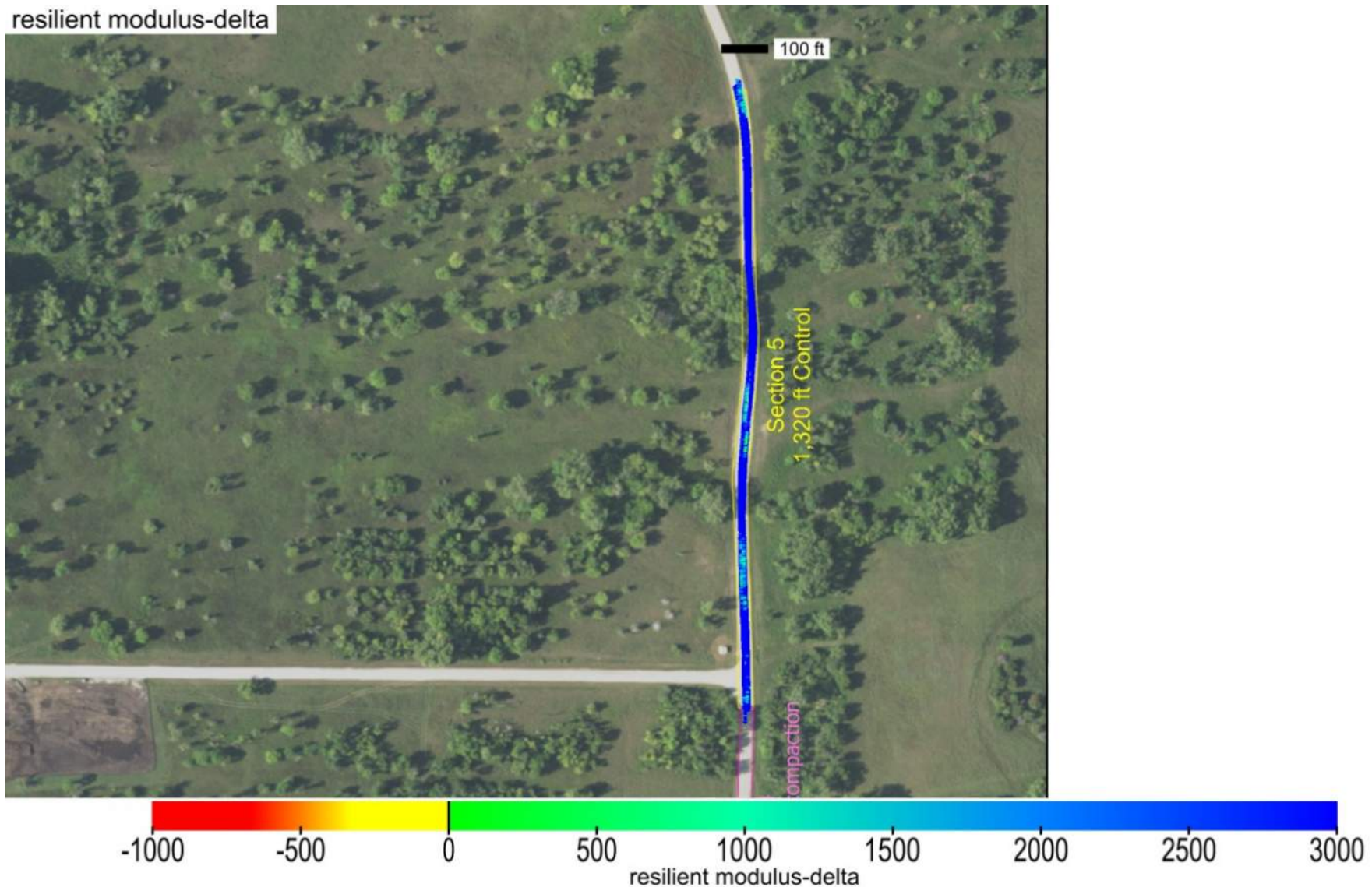


This report is only for use of the client named and it cannot be relied upon by any other person or entity.

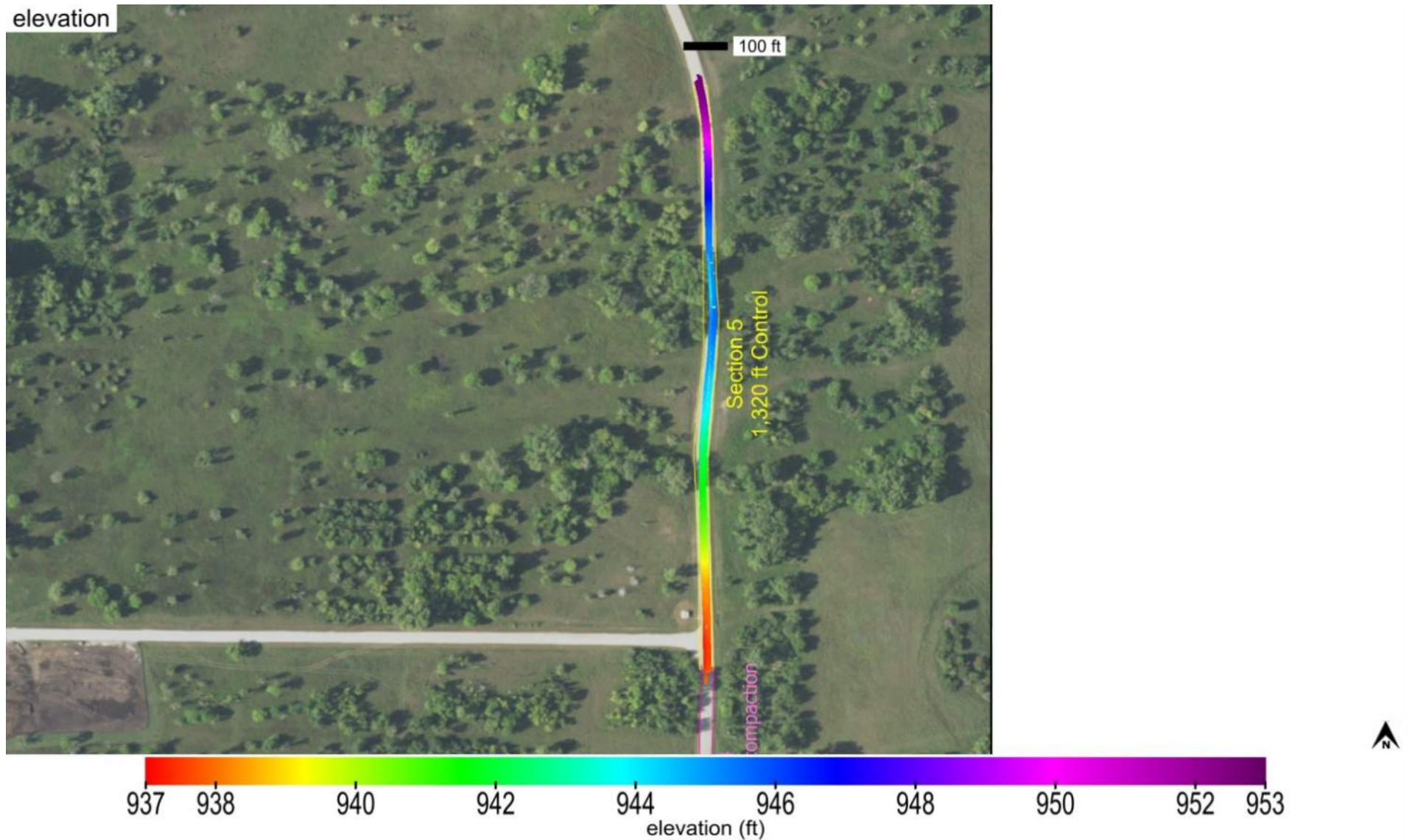
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	103.7	0.6	3600.0	3655.9	11128.8	20000.0	4745.4	42.6	55.9	7528.8	16400.0



Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	103.7	0.6	3600.0	3655.9	11128.8	20000.0	4745.4	42.6	55.9	7528.8	16400.0



minimum	average	maximum	RTK-Q7 (%)	RTK-QA
937.23	943.79	952.75	90.4	7.79



Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_07_144405 Map Type: Verification Map Map Layer: Unpaved Gravel Road

ing_polk77-campdodge-2023_cs56b-01047_2023_08_07_144405_20230808T090926_010-Photo-Aug-07-2023--3-05-34-PM.jpg



Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_31_120427

Project:	TR-823 Study	Date and Time:	8/31/2023 12:04:27 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.364	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	32607	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	1 - STAB + Smooth Drum

Map Summary

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
XMV	No												
Resilient Modulus	Yes	99.9	108.7	0.8	3600.0	3371.9	10996.0	20000.0	3541.9	32.2	-228.1	7396.0	16400.0
k-value	Yes	99.4	116.1	0.8	100.0	83.4	284.3	550.0	104.2	36.6	-16.6	184.3	450.0
Moisture Content	No												

Mapped Area		Pass Count					Elevation (ft)			Position Quality		Velocity (fps)		
square feet	acres	10th percentile	Median	cov(%)	% >= TV	Target Value	min.	avg.	max.	RTK-Q7 (%)	RTK-QA	min.	avg.	max.
32607	0.749	1	1	35.3	100.0	0	915.38	931.28	948.74	97.0	7.93	3.8	5.0	6.3

Materials

name	id	% of total	area-square ft	area-acres	tl-xmv	tl-Mr	tl-k value	tl-w%
Unpaved Gravel Road (not defined)_IADOT	41019	100.0	32607	0.749	100.0	3600.0	100.0	20.5

Blobs

parameter	min. area(ft^2)	# of blobs	blob area(ft^2)	% of map	lower bound-tv	upper bound-tv	poly-tol.
Resilient Modulus	500.0	0	0	0.0	none	0.0	4.0
k-value	500.0	0	0	0.0	none	0.0	4.0

Station

Start	End
0+00	15+00

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_31_120427

Project:	TR-823 Study	Date and Time:	8/31/2023 12:04:27 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.364	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	32607	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	1 - STAB + Smooth Drum

QUALITY ANALYSIS SUMMARY - k-Value

Quality Value	Criteria
116.1	CQI > = 95
99.4	80% of k-Value MVs >= 100
36.6	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_31_120427

Project:	TR-823 Study	Date and Time:	8/31/2023 12:04:27 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.364	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	32607	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	1 - STAB + Smooth Drum

QUALITY ANALYSIS SUMMARY - Resilient Modulus

Quality Value	Criteria
108.7	CQI > = 95
99.9	90% of Resilient Modulus MVs >= 3600
32.2	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

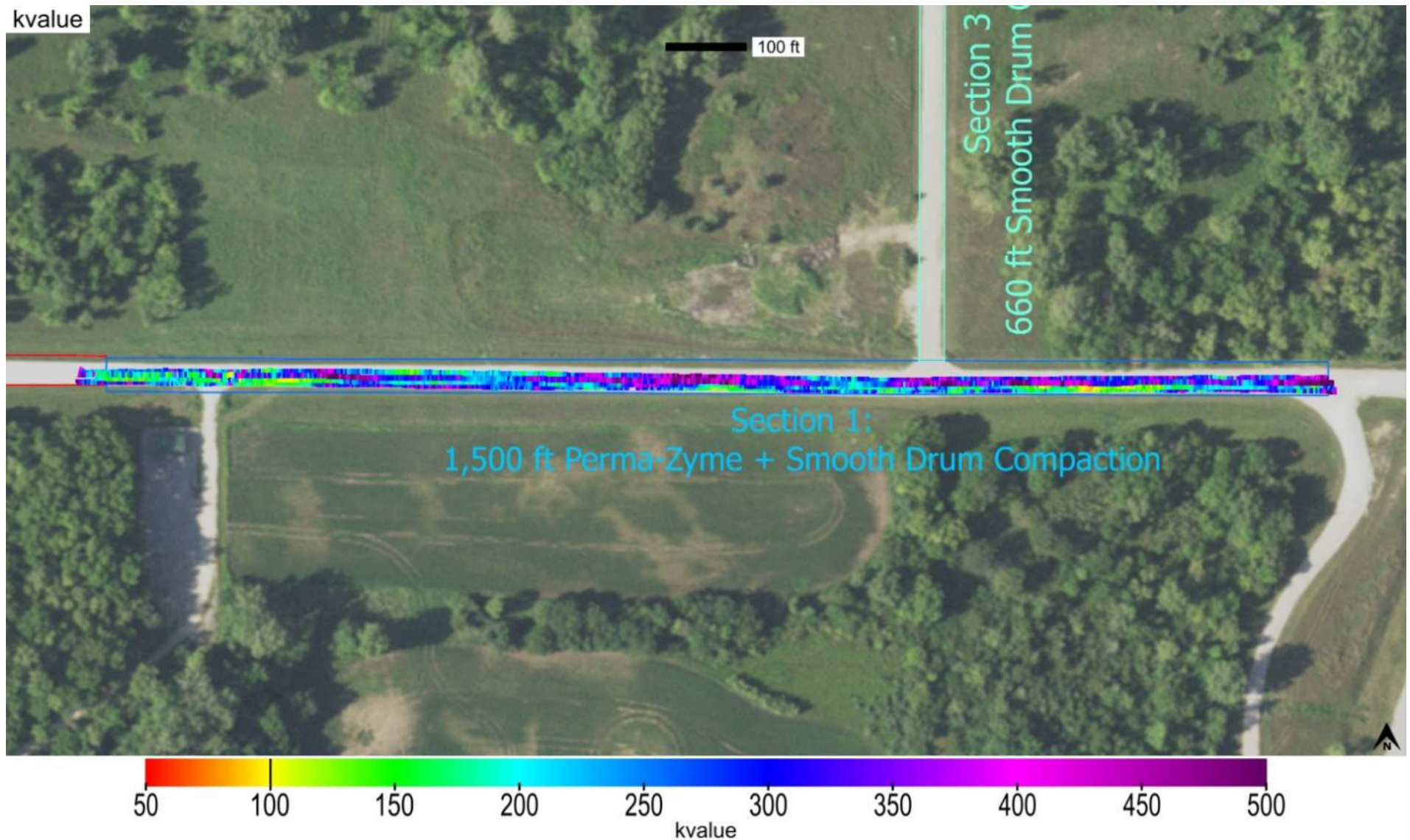
Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

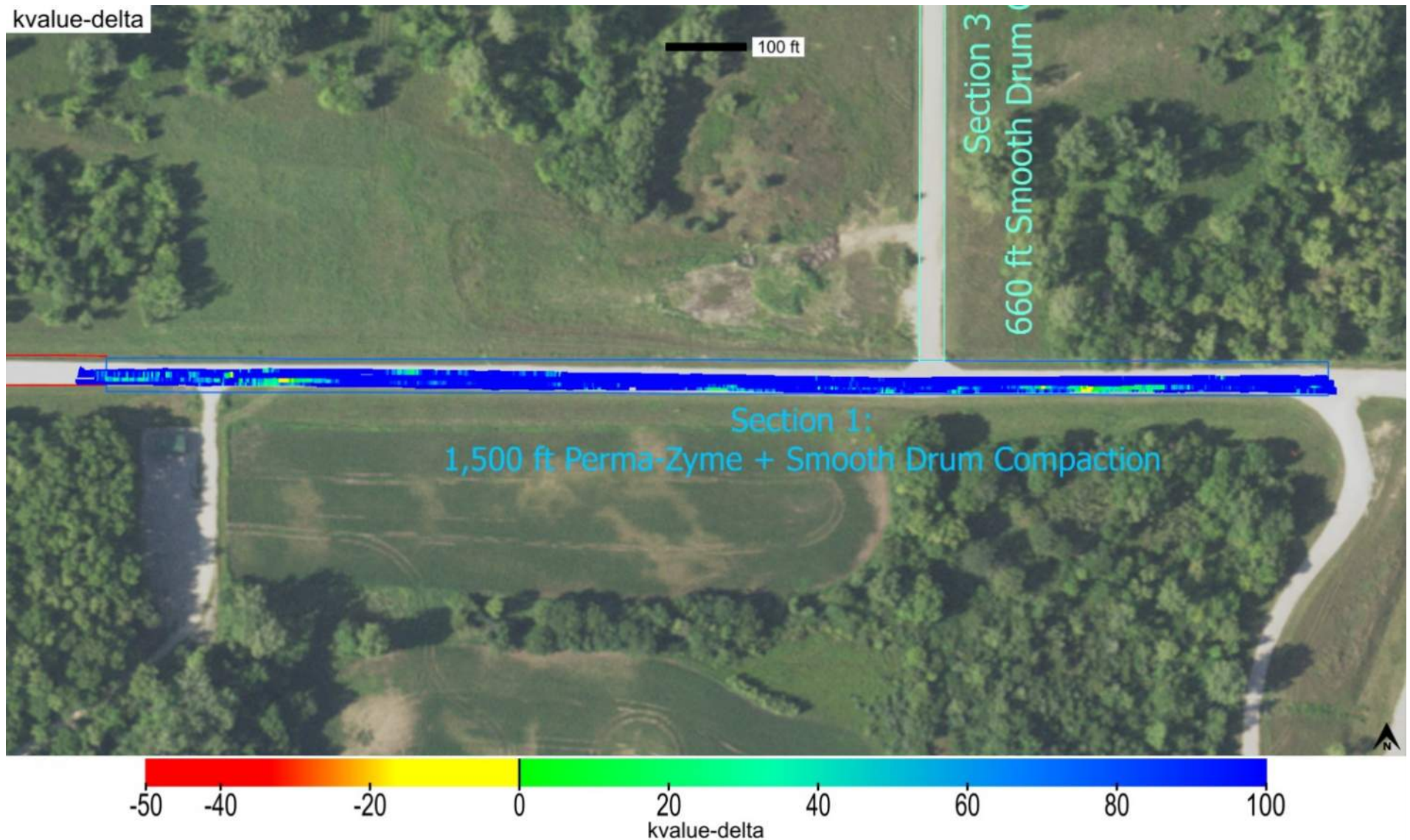
Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

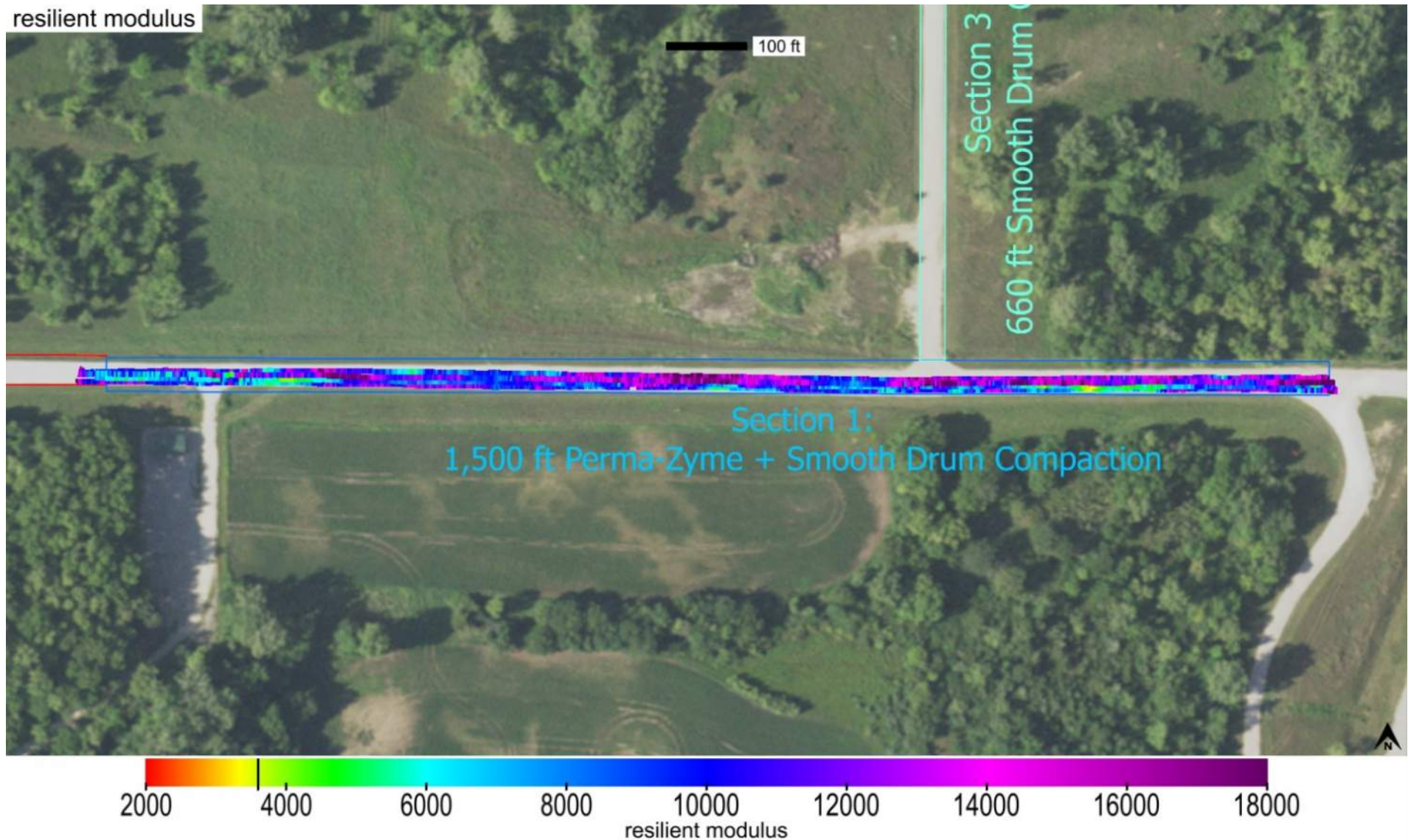
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	99.4	116.1	0.8	100.0	83.4	284.3	550.0	104.2	36.6	-16.6	184.3	450.0



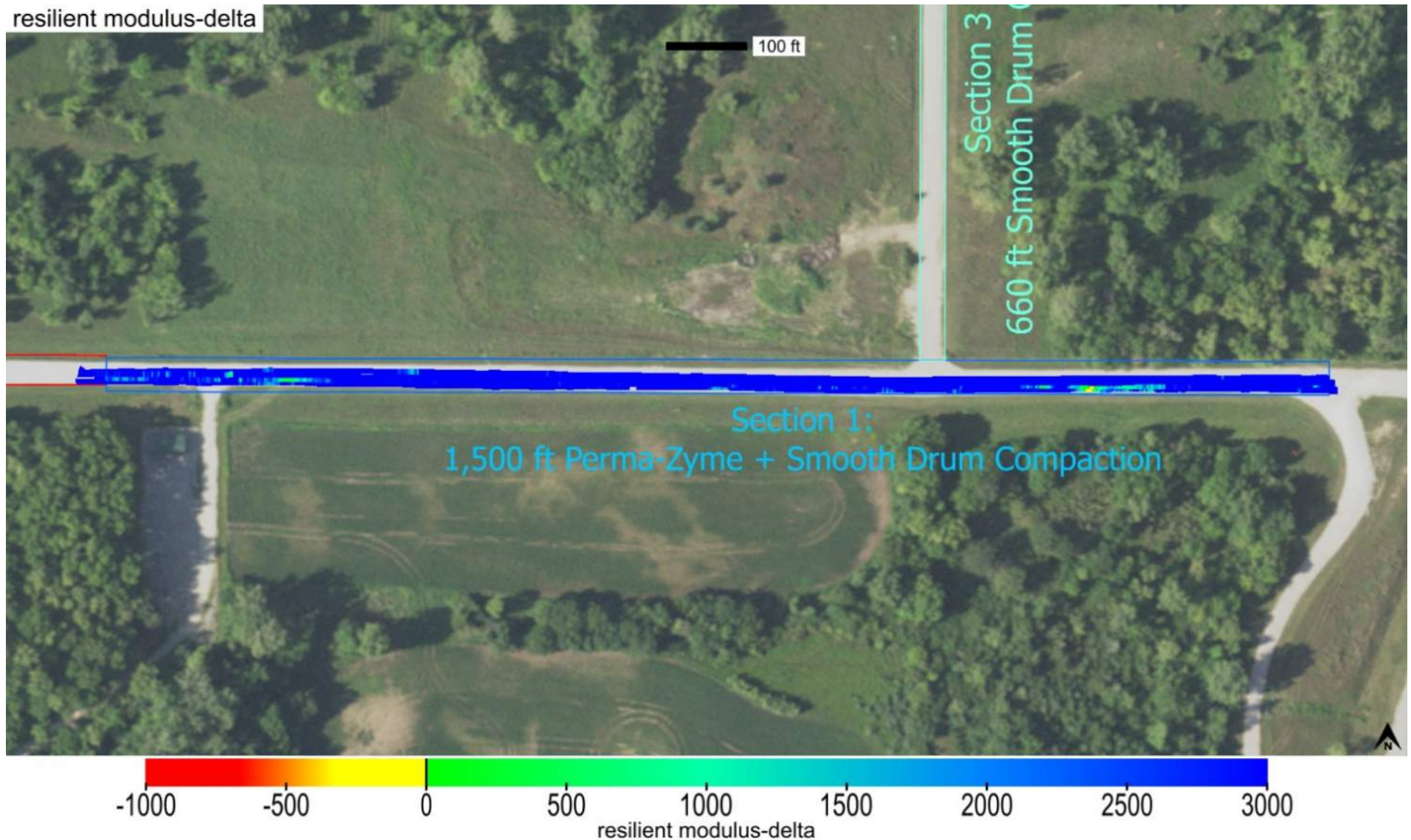
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	99.4	116.1	0.8	100.0	83.4	284.3	550.0	104.2	36.6	-16.6	184.3	450.0



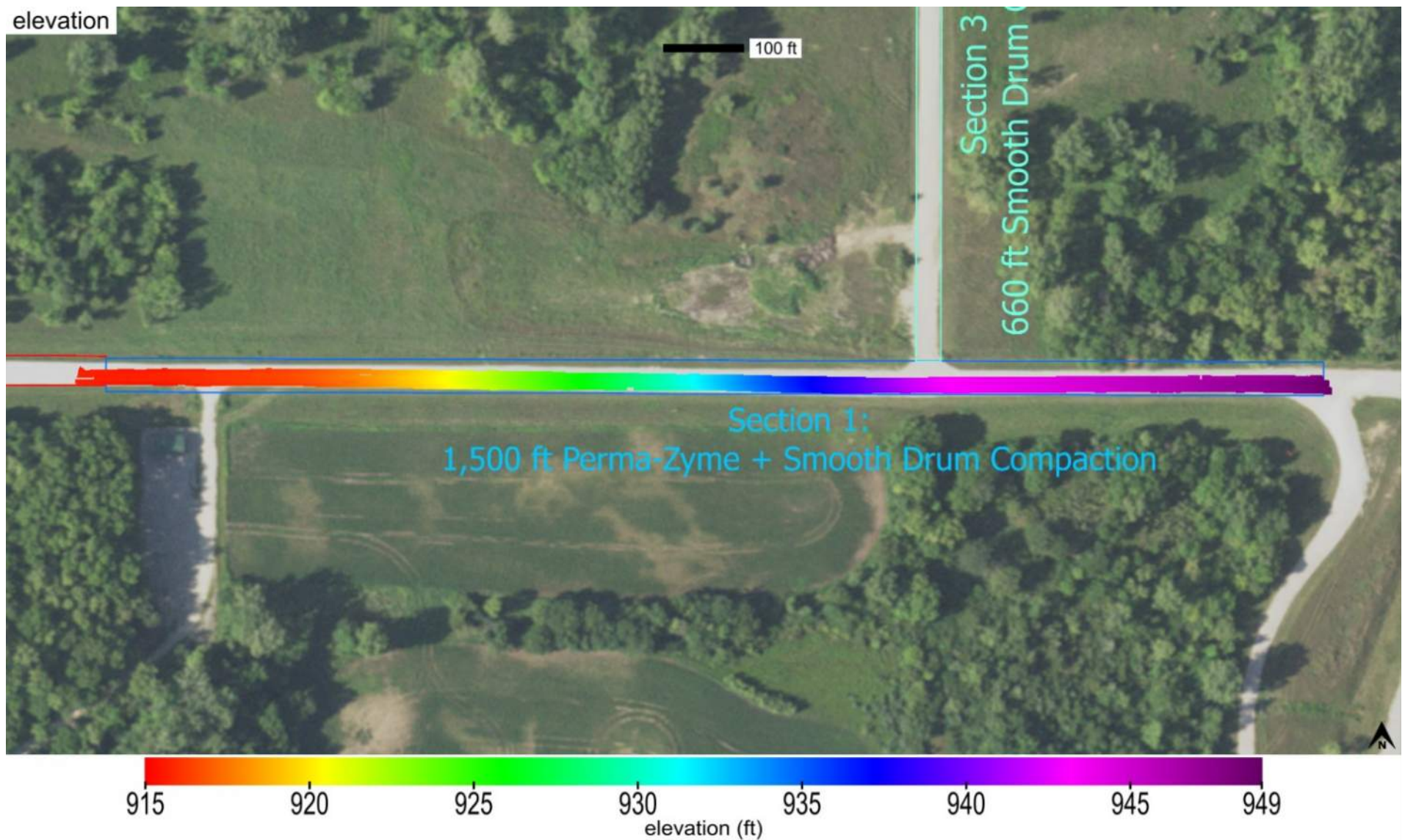
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	99.9	108.7	0.8	3600.0	3371.9	10996.0	20000.0	3541.9	32.2	-228.1	7396.0	16400.0



Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	99.9	108.7	0.8	3600.0	3371.9	10996.0	20000.0	3541.9	32.2	-228.1	7396.0	16400.0



minimum	average	maximum	RTK-Q7 (%)	RTK-QA
915.39	931.28	948.74	97.0	7.93





Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_31_125937

Project:	TR-823 Study	Date and Time:	8/31/2023 12:59:37 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.363	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	33781	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	2 - STAB + Sheepsfoot

Map Summary

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
XMV	No												
Resilient Modulus	Yes	100.0	113.0	0.8	3600.0	5237.2	12449.2	20000.0	2977.1	23.9	1637.2	8849.2	16400.0
k-value	Yes	100.0	121.5	0.8	100.0	121.1	327.8	550.0	88.8	27.1	21.1	227.8	450.0
Moisture Content	No												

Mapped Area		Pass Count					Elevation (ft)			Position Quality		Velocity (fps)		
square feet	acres	10th percentile	Median	cov(%)	% >= TV	Target Value	min.	avg.	max.	RTK-Q7 (%)	RTK-QA	min.	avg.	max.
33781	0.776	1	1	35.3	100.0	0	895.32	907.97	917.06	100.0	8.00	4.5	5.0	5.6

Materials

name	id	% of total	area-square ft	area-acres	tl-xmv	tl-Mr	tl-k value	tl-w%
Unpaved Gravel Road (not defined)_IADOT	41019	100.0	33781	0.776	100.0	3600.0	100.0	20.5

Blobs

parameter	min. area(ft^2)	# of blobs	blob area(ft^2)	% of map	lower bound-tv	upper bound-tv	poly-tol.
Resilient Modulus	500.0	0	0	0.0	none	0.0	4.0
k-value	500.0	0	0	0.0	none	0.0	4.0

Station

Start	End
15+00	30+00

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_31_125937

Project:	TR-823 Study	Date and Time:	8/31/2023 12:59:37 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.363	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	33781	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	2 - STAB + Sheepsfoot

QUALITY ANALYSIS SUMMARY - k-Value

Quality Value	Criteria
121.5	CQI > = 95
100.0	80% of k-Value MVs >= 100
27.1	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_31_125937

Project:	TR-823 Study	Date and Time:	8/31/2023 12:59:37 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.363	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	33781	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	2 - STAB + Sheepsfoot

QUALITY ANALYSIS SUMMARY - Resilient Modulus

Quality Value	Criteria
113.0	CQI > = 95
100.0	90% of Resilient Modulus MVs >= 3600
23.9	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

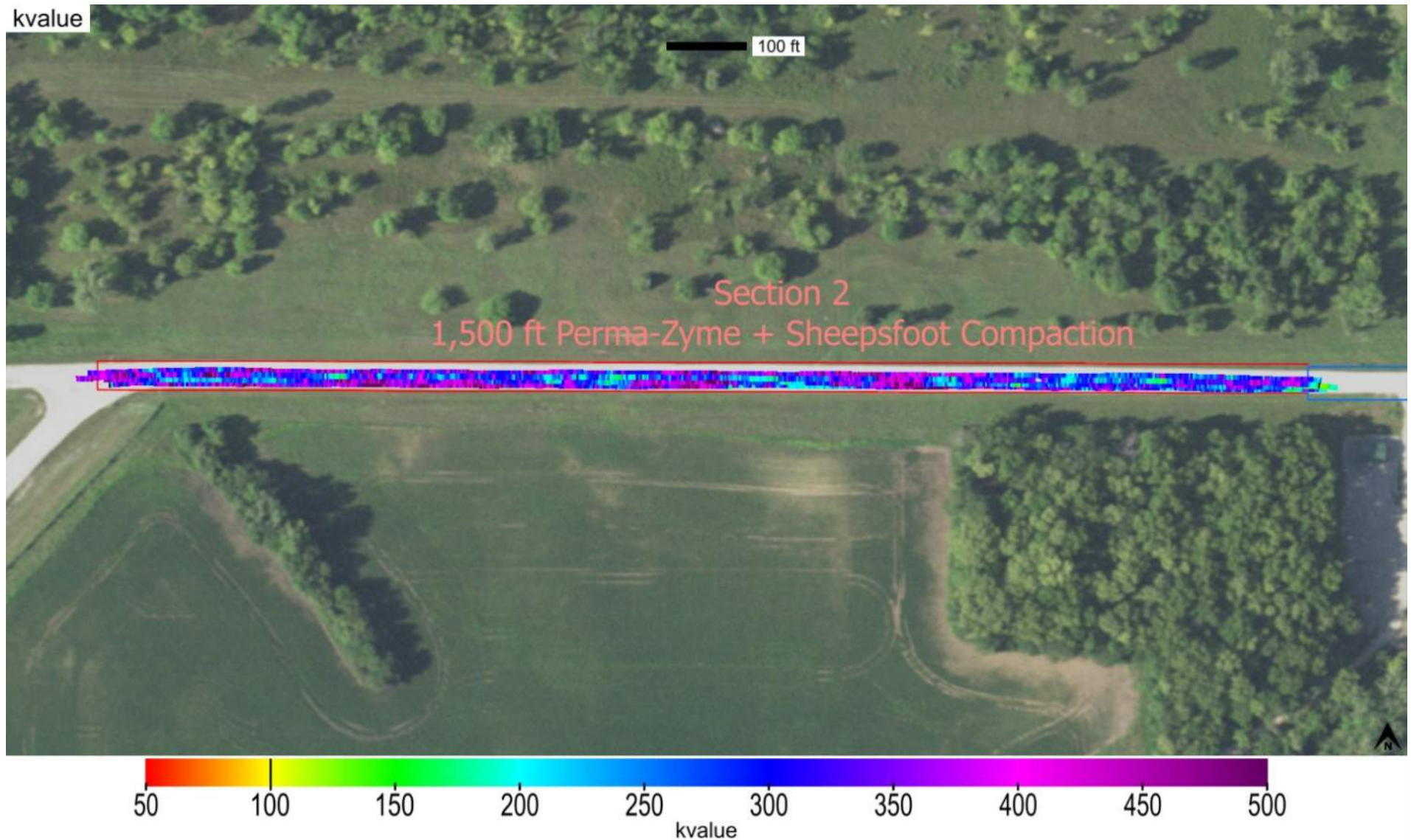
Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_31_125937

Map Type: Verification Map

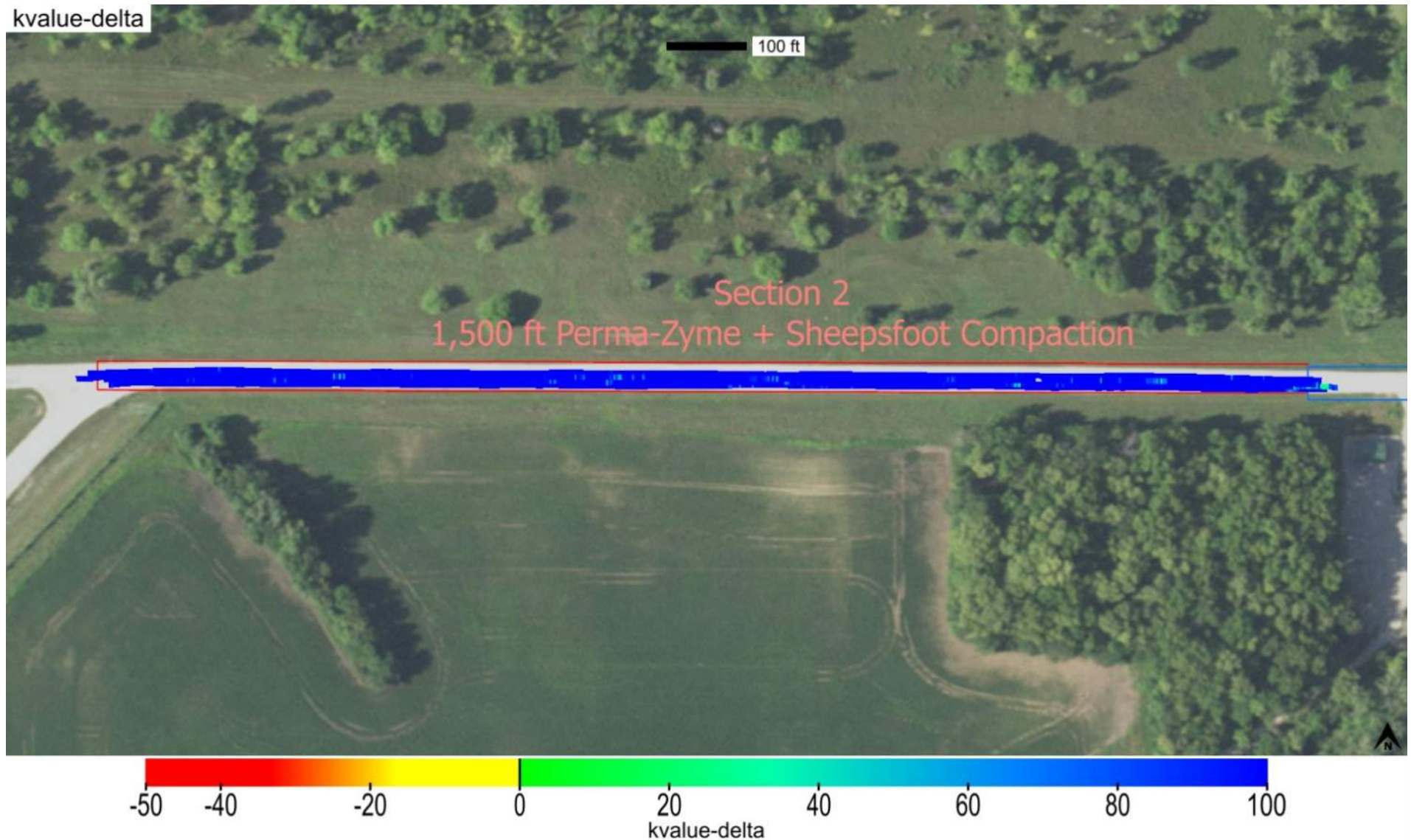
Map Layer: Unpaved Gravel Road

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	121.5	0.8	100.0	121.1	327.8	550.0	88.8	27.1	21.1	227.8	450.0

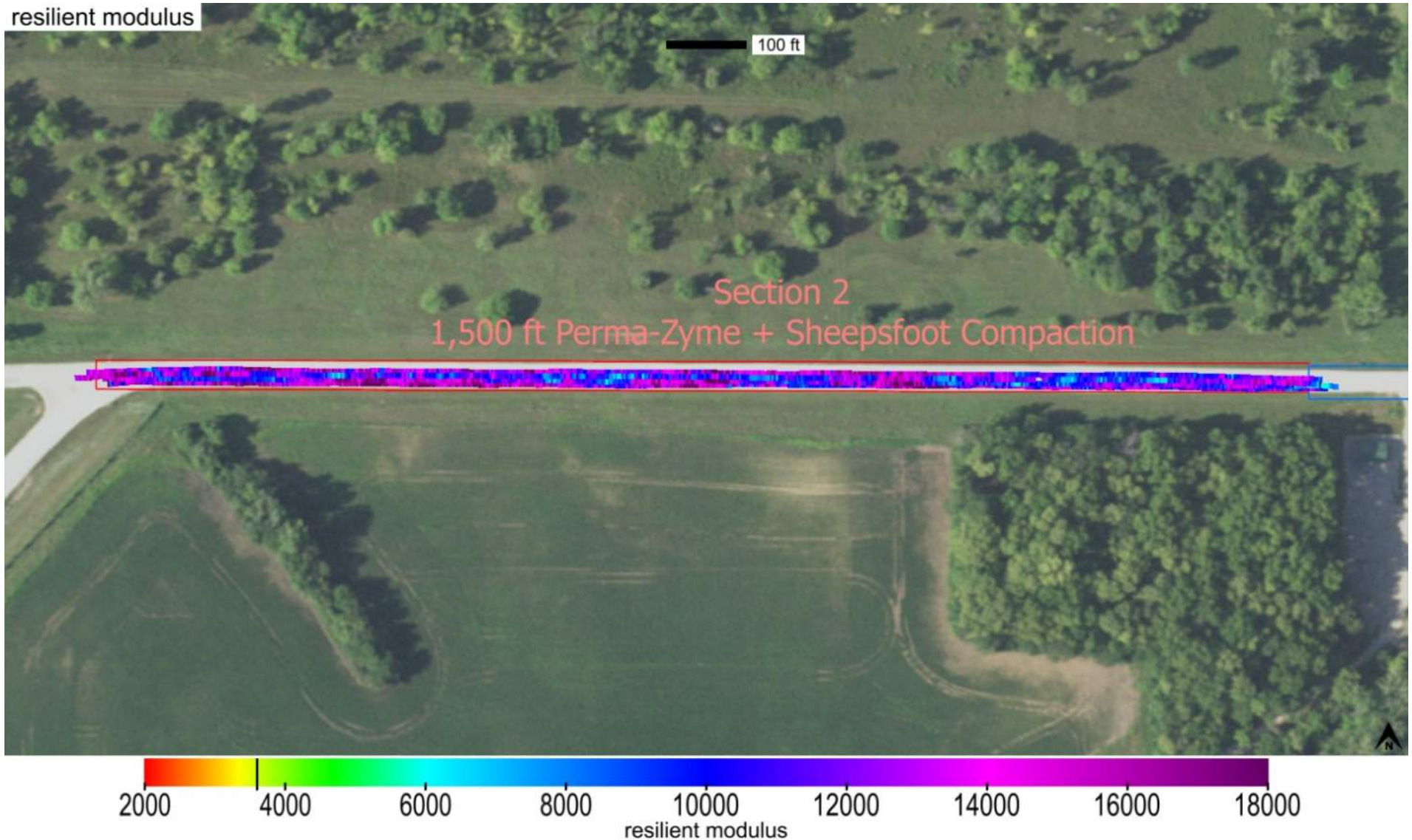


This report is only for use of the client named and it cannot be relied upon by any other person or entity.

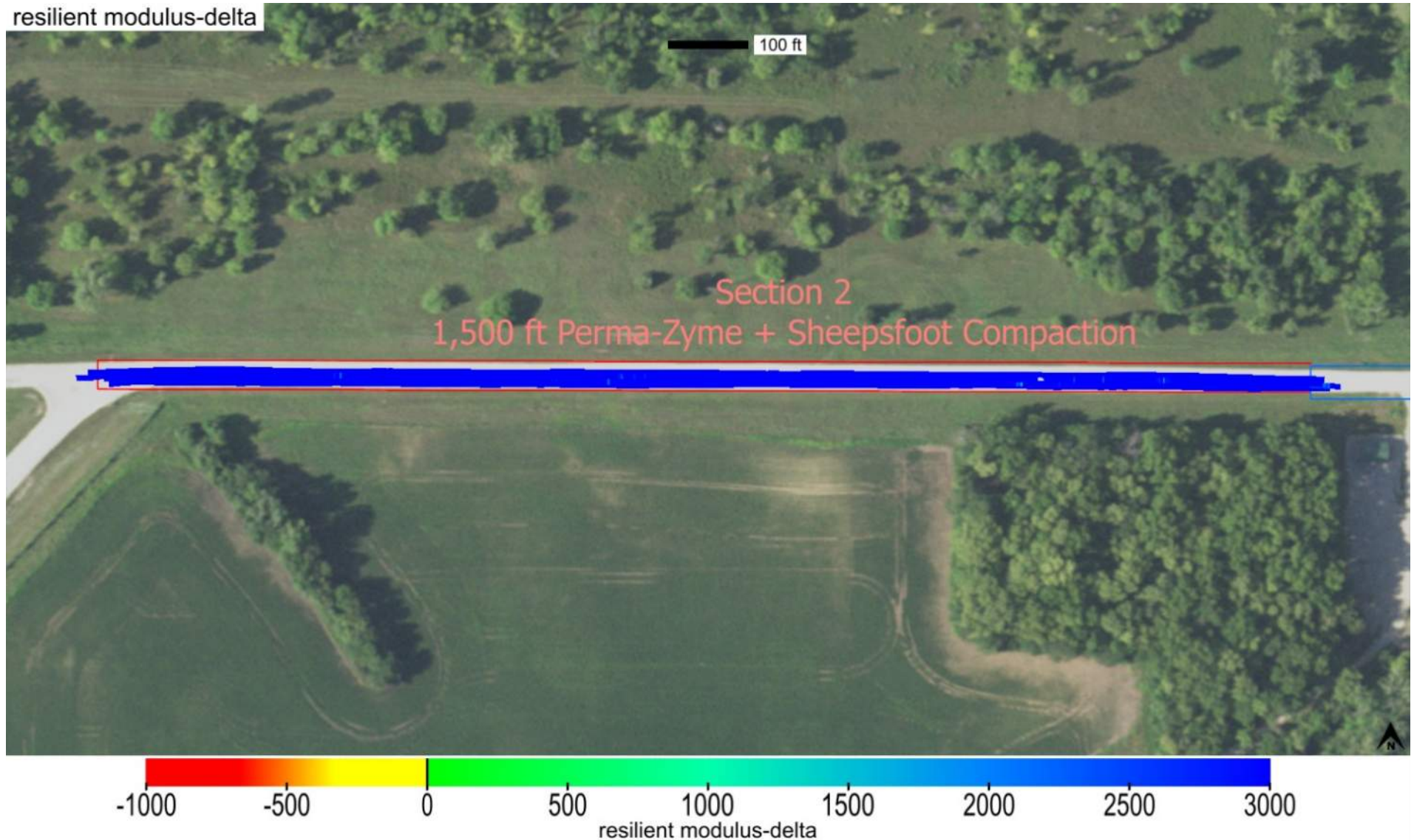
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	121.5	0.8	100.0	121.1	327.8	550.0	88.8	27.1	21.1	227.8	450.0



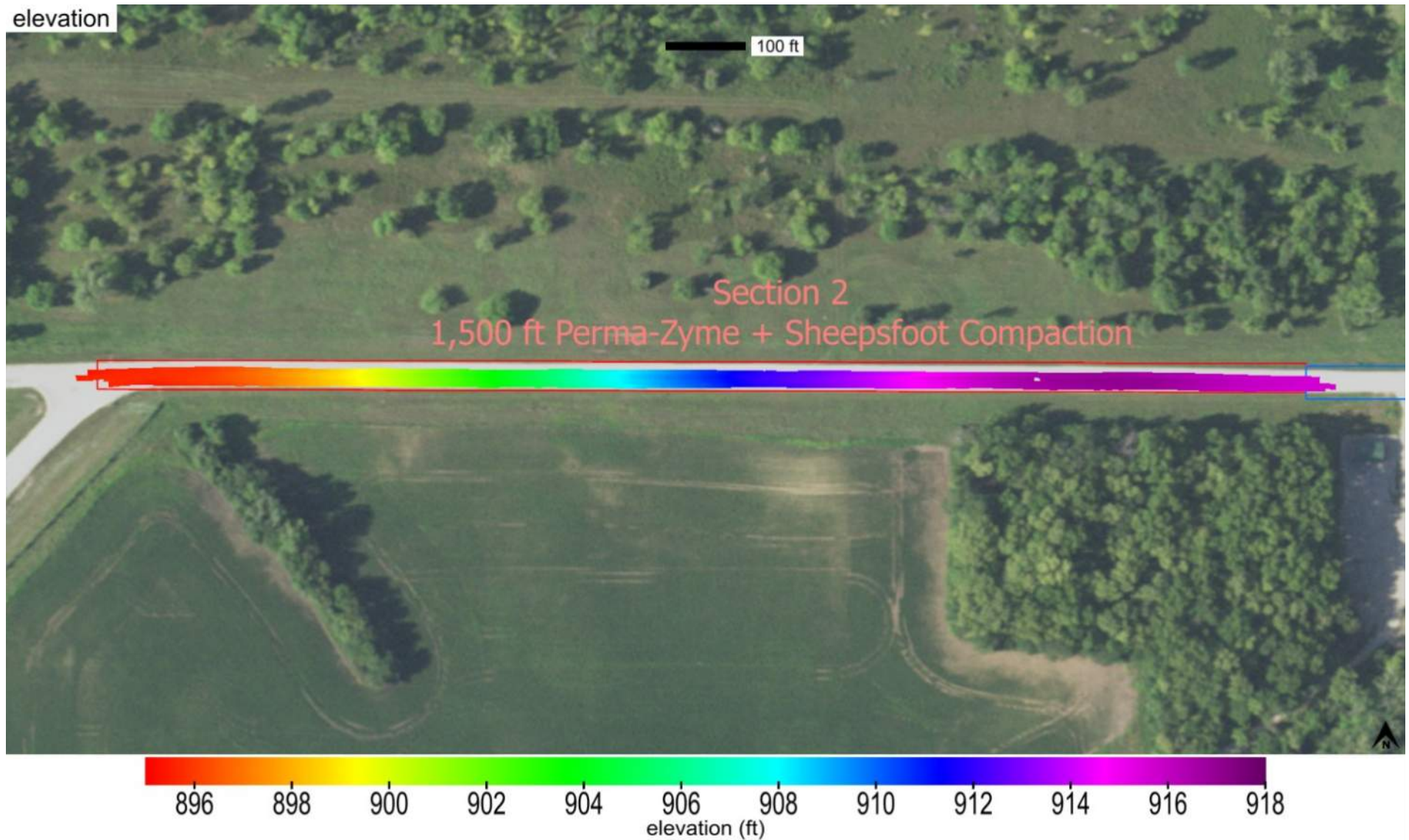
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	113.0	0.8	3600.0	5237.2	12449.2	20000.0	2977.1	23.9	1637.2	8849.2	16400.0



Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	113.0	0.8	3600.0	5237.2	12449.2	20000.0	2977.1	23.9	1637.2	8849.2	16400.0



minimum	average	maximum	RTK-Q7 (%)	RTK-QA
895.32	907.97	917.06	100.0	8.00





Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_31_141424

Project:	TR-823 Study	Date and Time:	8/31/2023 2:14:24 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.18	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	13109	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	3 - Smooth Drum

Map Summary

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
XMV	No												
Resilient Modulus	Yes	100.0	106.3	0.7	3600.0	3744.1	9182.3	20000.0	3426.7	37.3	144.1	5582.3	16400.0
k-value	Yes	99.7	114.3	0.7	100.0	93.4	225.8	550.0	92.4	40.9	-6.6	125.8	450.0
Moisture Content	No												

Mapped Area		Pass Count					Elevation (ft)			Position Quality		Velocity (fps)		
square feet	acres	10th percentile	Median	cov(%)	% >= TV	Target Value	min.	avg.	max.	RTK-Q7 (%)	RTK-QA	min.	avg.	max.
13109	0.301	1	1	34.0	100.0	0	940.56	942.79	944.67	99.6	7.94	4.4	5.1	7.0

Materials

name	id	% of total	area-square ft	area-acres	tl-xmv	tl-Mr	tl-k value	tl-w%
Unpaved Gravel Road (not defined)_IADOT	41019	100.0	13109	0.301	100.0	3600.0	100.0	20.5

Blobs

parameter	min. area(ft^2)	# of blobs	blob area(ft^2)	% of map	lower bound-tv	upper bound-tv	poly-tol.
Resilient Modulus	500.0	0	0	0.0	none	0.0	4.0
k-value	500.0	0	0	0.0	none	0.0	4.0

Station

Start	End
0+00	6+60

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_31_141424

Project:	TR-823 Study	Date and Time:	8/31/2023 2:14:24 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.18	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	13109	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	3 - Smooth Drum

QUALITY ANALYSIS SUMMARY - k-Value

Quality Value	Criteria
114.3	CQI > = 95
99.7	80% of k-Value MVs >= 100
40.9	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_31_141424

Project:	TR-823 Study	Date and Time:	8/31/2023 2:14:24 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.18	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	13109	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	3 - Smooth Drum

QUALITY ANALYSIS SUMMARY - Resilient Modulus

Quality Value	Criteria
106.3	CQI > = 95
100.0	90% of Resilient Modulus MVs >= 3600
37.3	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

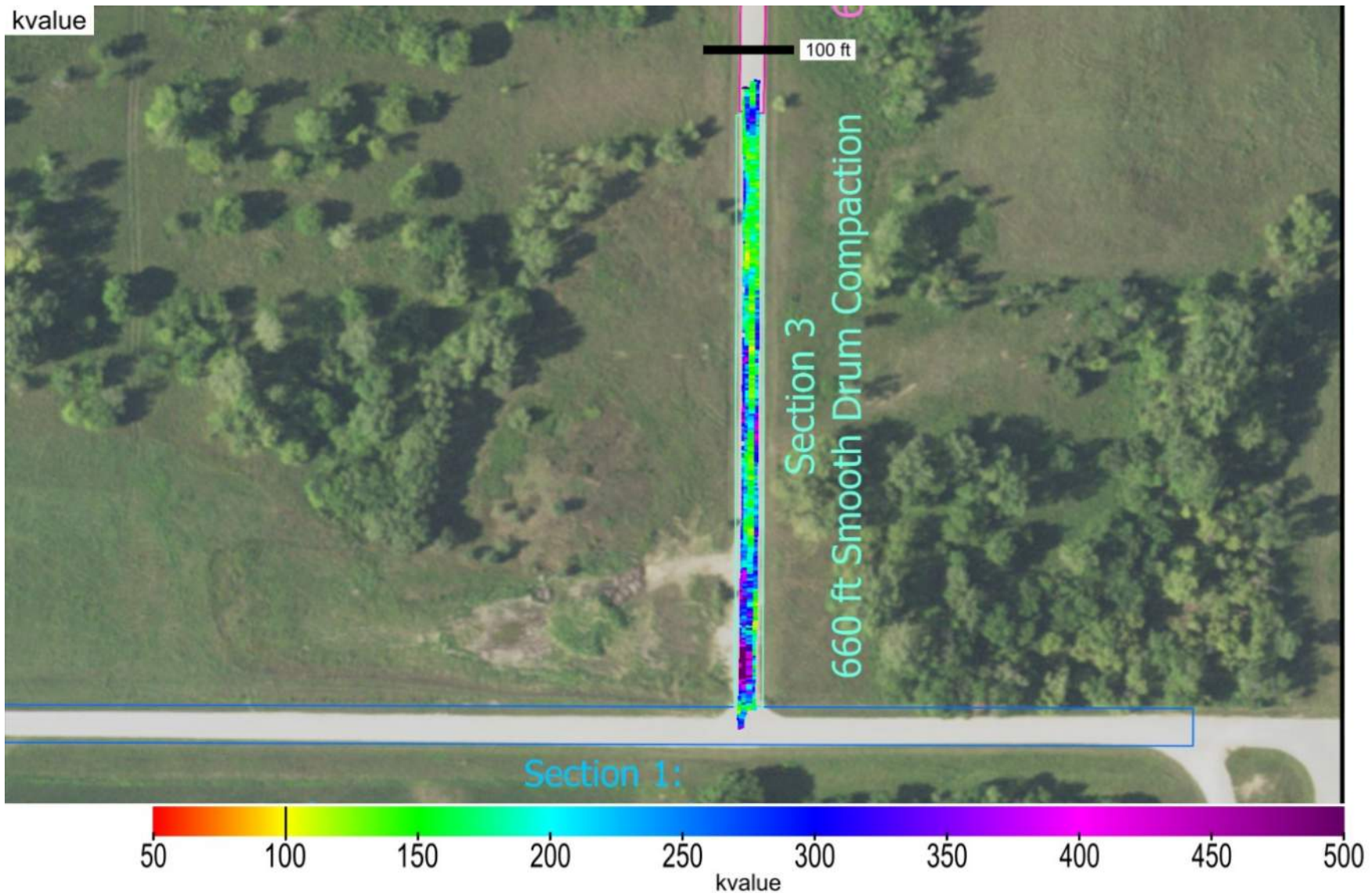
Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_31_141424

Map Type: Verification Map

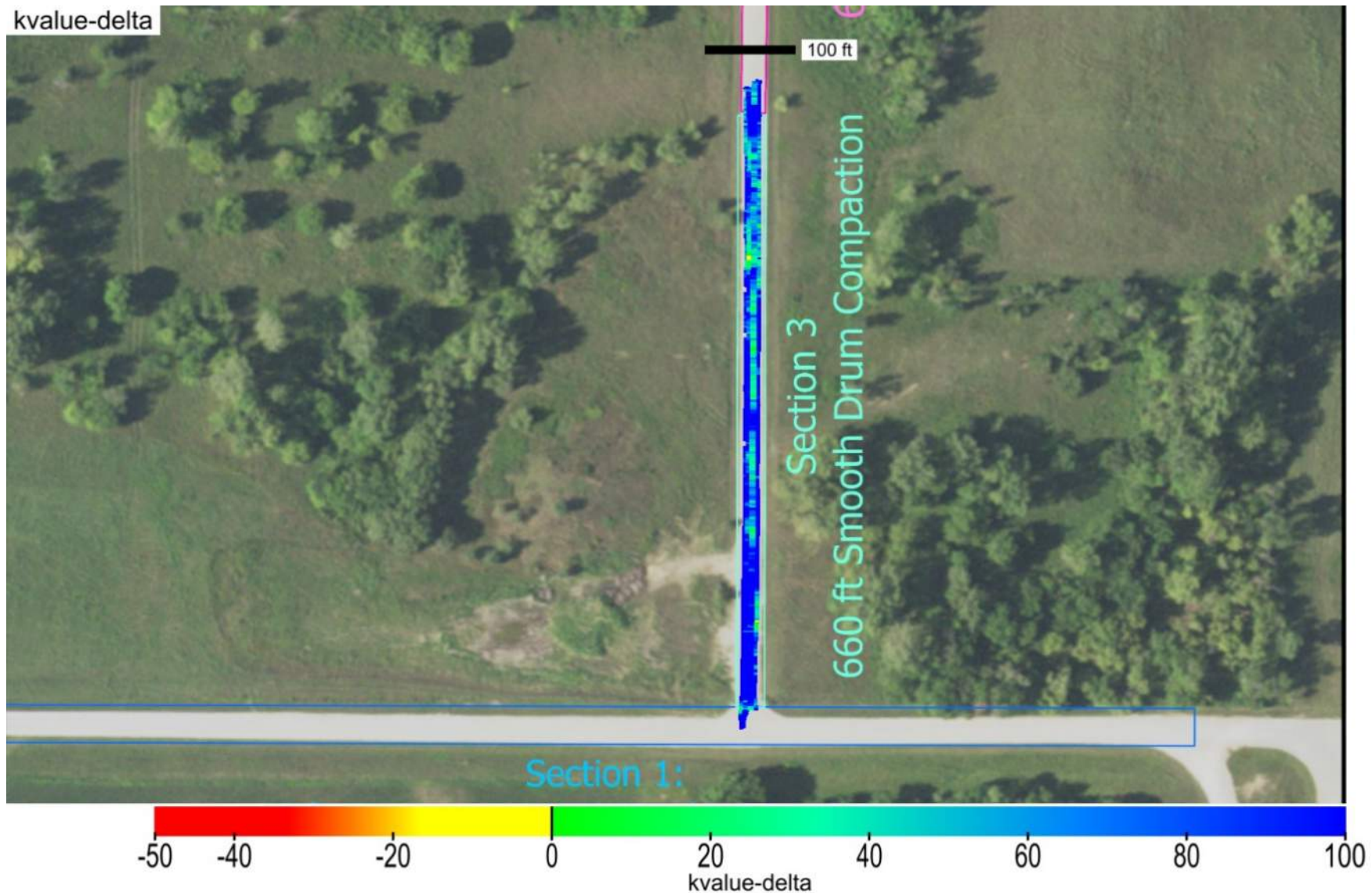
Map Layer: Unpaved Gravel Road

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	99.7	114.3	0.7	100.0	93.4	225.8	550.0	92.4	40.9	-6.6	125.8	450.0

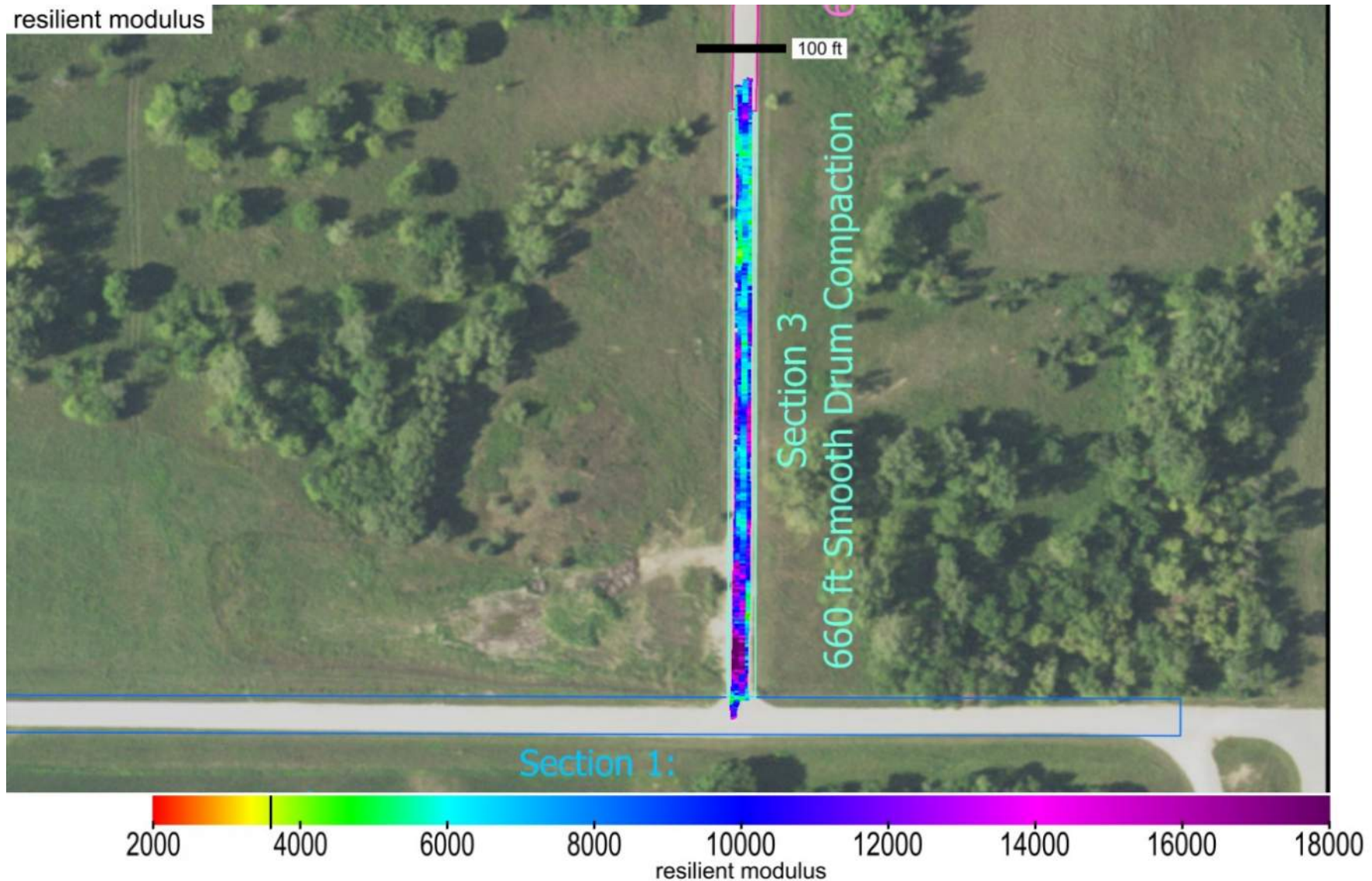


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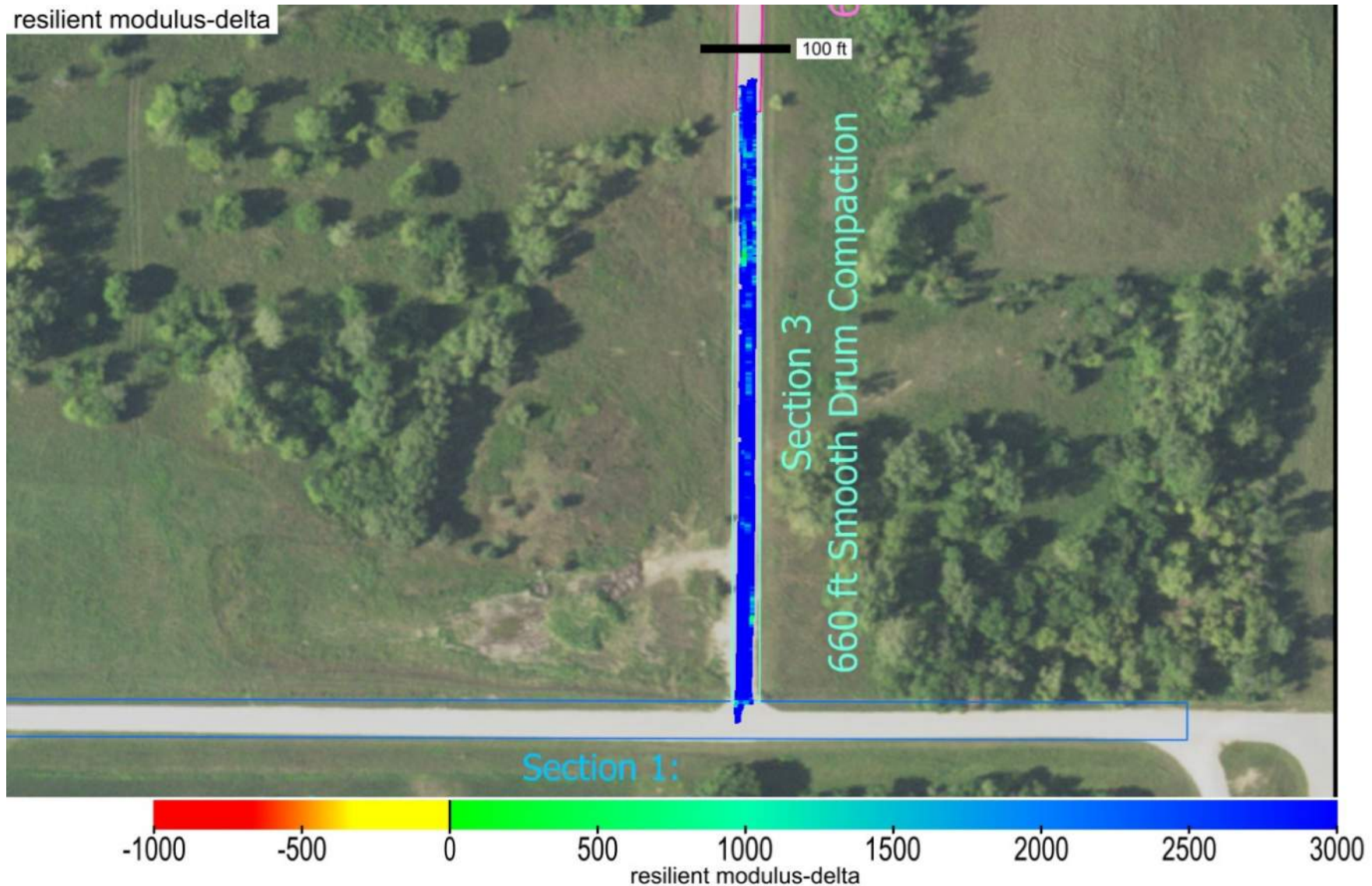
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	99.7	114.3	0.7	100.0	93.4	225.8	550.0	92.4	40.9	-6.6	125.8	450.0



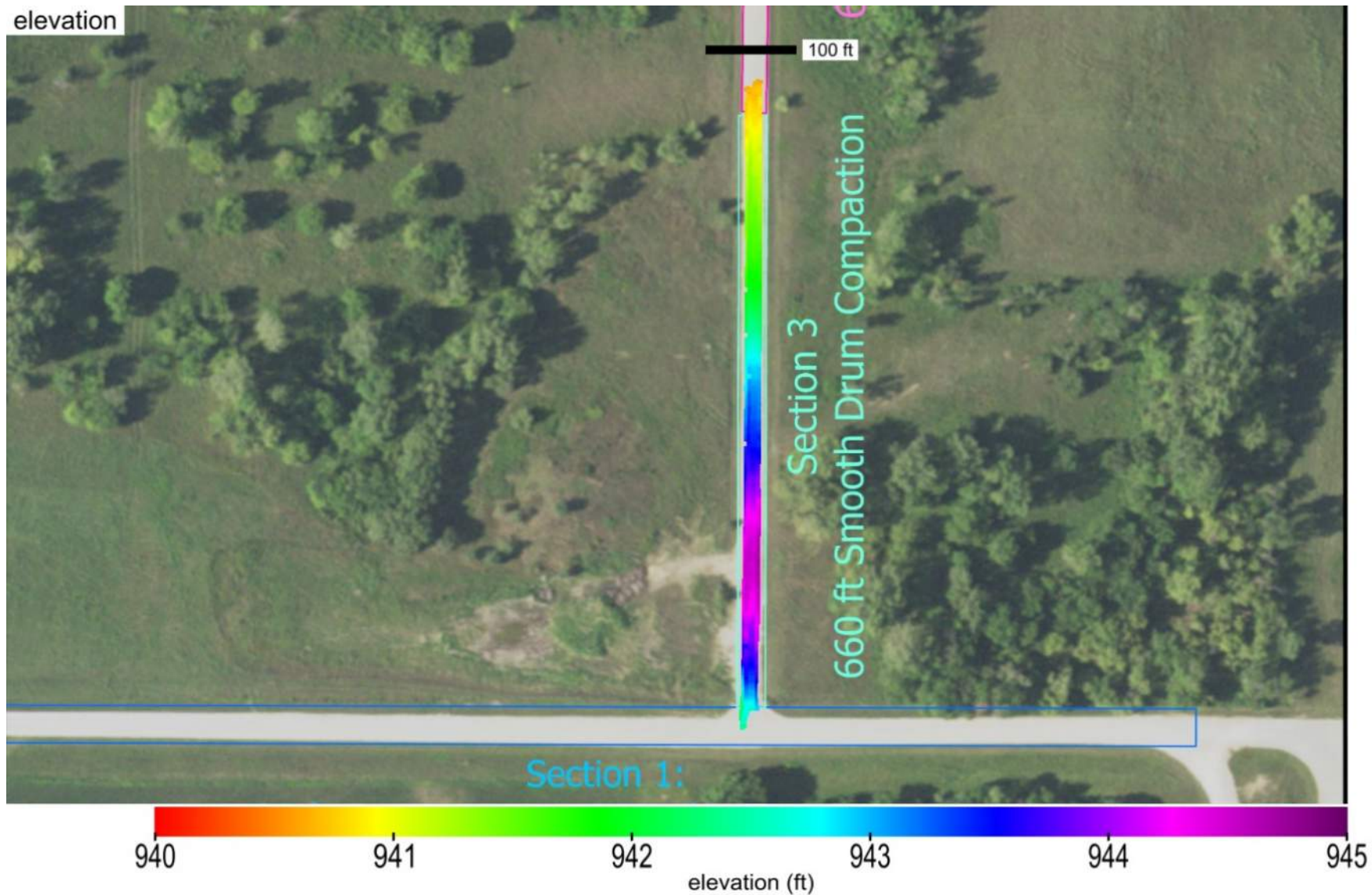
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	106.3	0.7	3600.0	3744.1	9182.3	20000.0	3426.7	37.3	144.1	5582.3	16400.0



Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	106.3	0.7	3600.0	3744.1	9182.3	20000.0	3426.7	37.3	144.1	5582.3	16400.0



minimum	average	maximum	RTK-Q7 (%)	RTK-QA
940.57	942.79	944.67	99.6	7.94





Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_31_144131

Project:	TR-823 Study	Date and Time:	8/31/2023 2:41:31 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.178	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	14481	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	4 - Sheepsfoot

Map Summary

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
XMV	No												
Resilient Modulus	Yes	100.0	107.1	0.7	3600.0	3609.5	8229.7	20000.0	2952.9	35.9	9.5	4629.7	16400.0
k-value	Yes	97.3	112.5	0.8	100.0	86.2	210.0	550.0	83.4	39.7	-13.8	110.0	450.0
Moisture Content	No												

Mapped Area		Pass Count					Elevation (ft)			Position Quality		Velocity (fps)		
square feet	acres	10th percentile	Median	cov(%)	% >= TV	Target Value	min.	avg.	max.	RTK-Q7 (%)	RTK-QA	min.	avg.	max.
14481	0.332	1	1	35.3	100.0	0	937.55	939.20	940.85	95.4	7.84	4.8	5.1	5.6

Materials

name	id	% of total	area-square ft	area-acres	tl-xmv	tl-Mr	tl-k value	tl-w%
Unpaved Gravel Road (not defined)_IADOT	41019	100.0	14481	0.332	100.0	3600.0	100.0	20.5

Blobs

parameter	min. area(ft^2)	# of blobs	blob area(ft^2)	% of map	lower bound-tv	upper bound-tv	poly-tol.
Resilient Modulus	500.0	0	0	0.0	none	0.0	4.0
k-value	500.0	0	0	0.0	none	0.0	4.0

Station

Start	End
6+60	13+20

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_31_144131

Project:	TR-823 Study	Date and Time:	8/31/2023 2:41:31 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.178	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	14481	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	4 - Sheepsfoot

QUALITY ANALYSIS SUMMARY - k-Value

Quality Value	Criteria
112.5	CQI > = 95
97.3	80% of k-Value MVs >= 100
39.7	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_31_144131

Project:	TR-823 Study	Date and Time:	8/31/2023 2:41:31 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.178	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	14481	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	4 - Sheepsfoot

QUALITY ANALYSIS SUMMARY - Resilient Modulus

Quality Value	Criteria
107.1	CQI > = 95
100.0	90% of Resilient Modulus MVs >= 3600
35.9	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

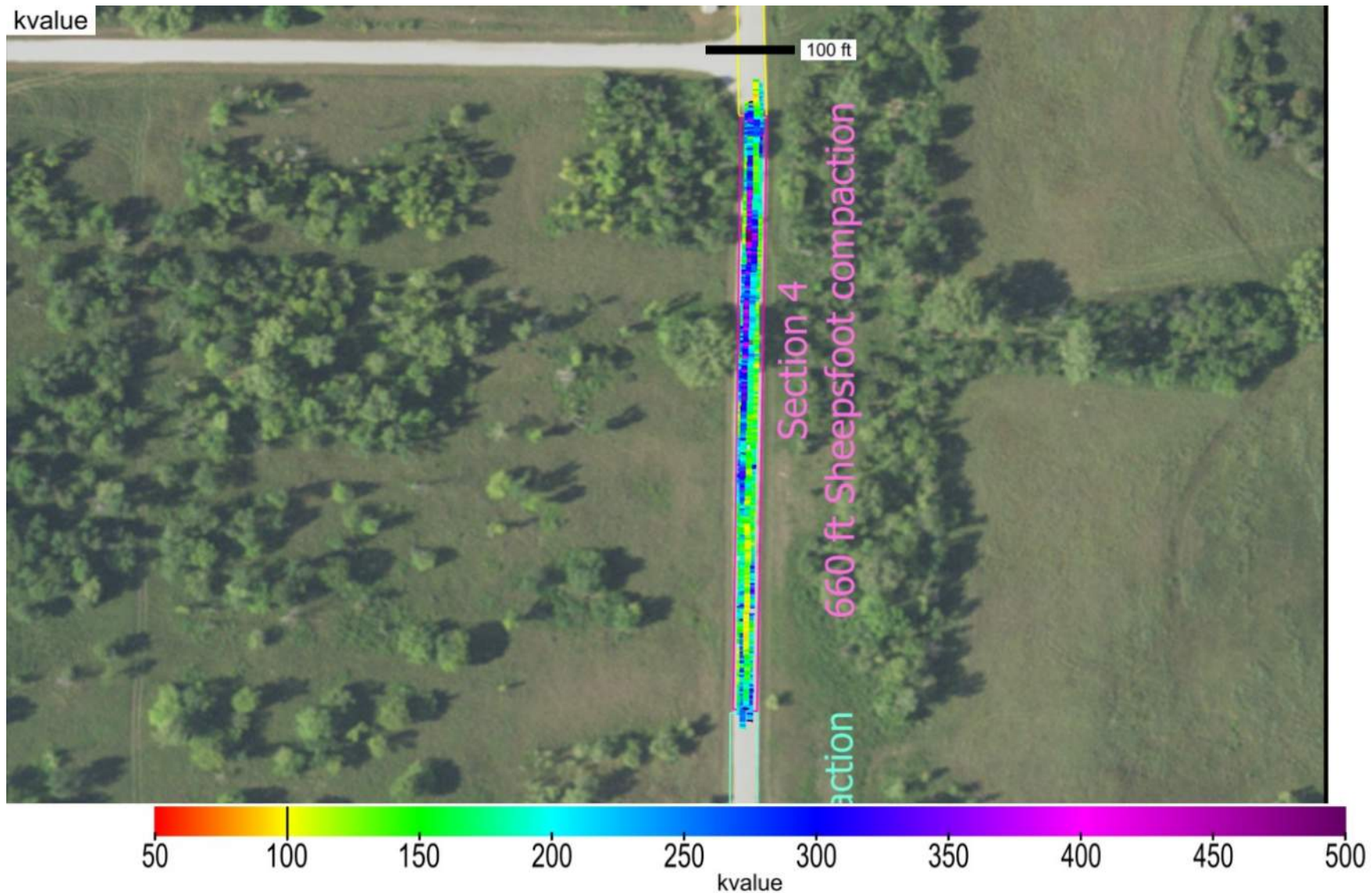
Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	97.3	112.5	0.8	100.0	86.2	210.0	550.0	83.4	39.7	-13.8	110.0	450.0

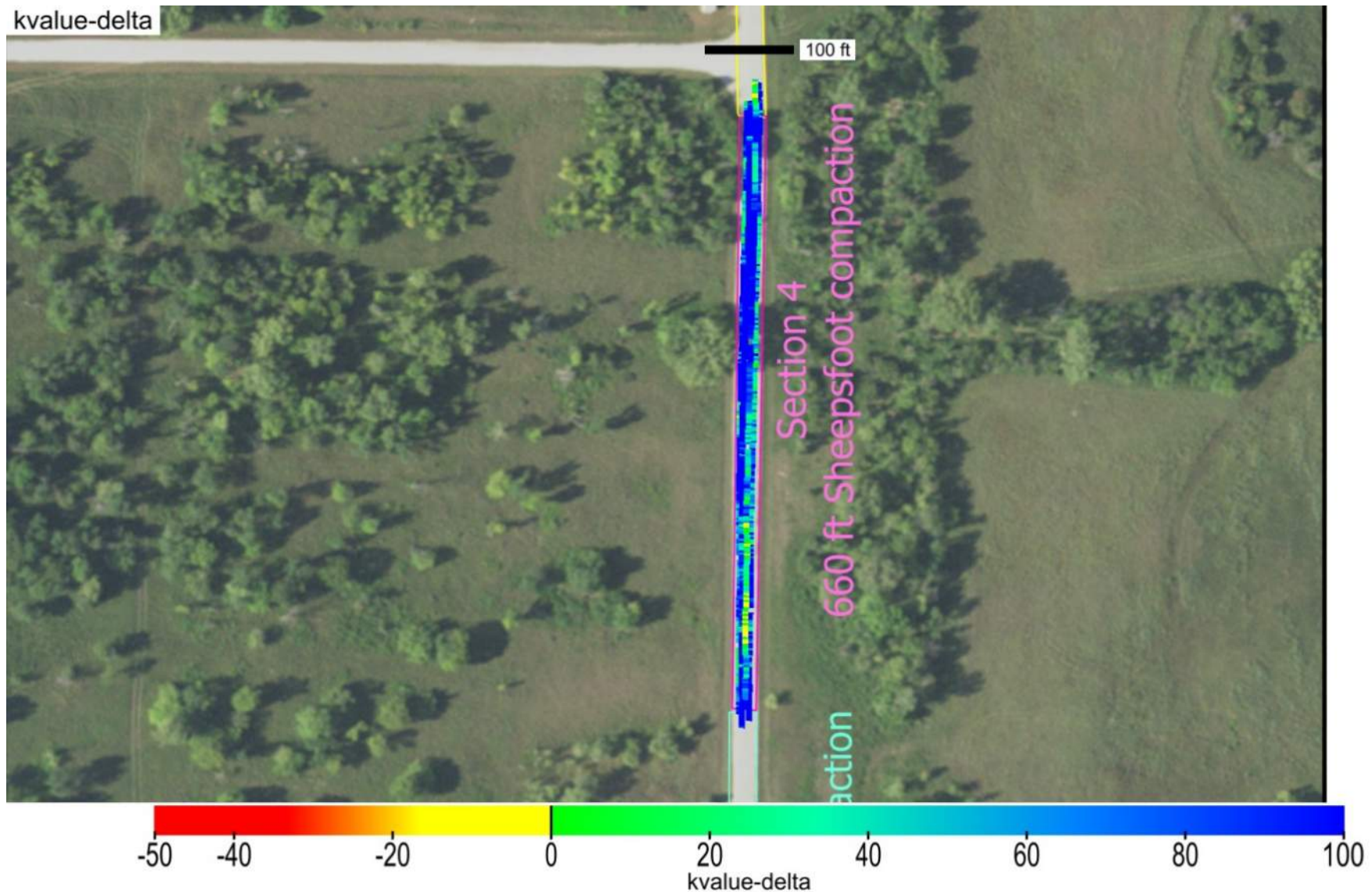


Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_31_144131

Map Type: Verification Map

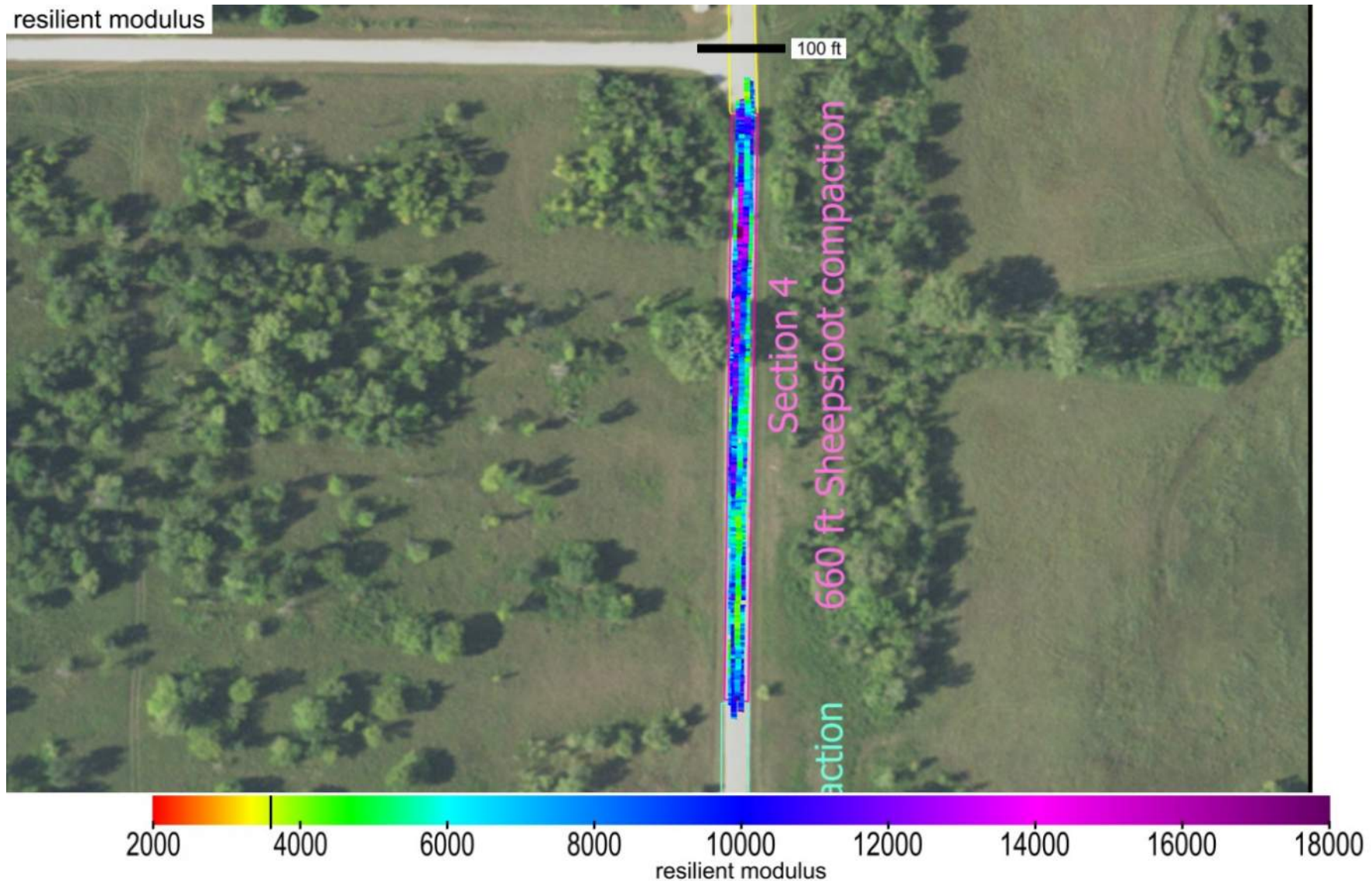
Map Layer: Unpaved Gravel Road

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	97.3	112.5	0.8	100.0	86.2	210.0	550.0	83.4	39.7	-13.8	110.0	450.0

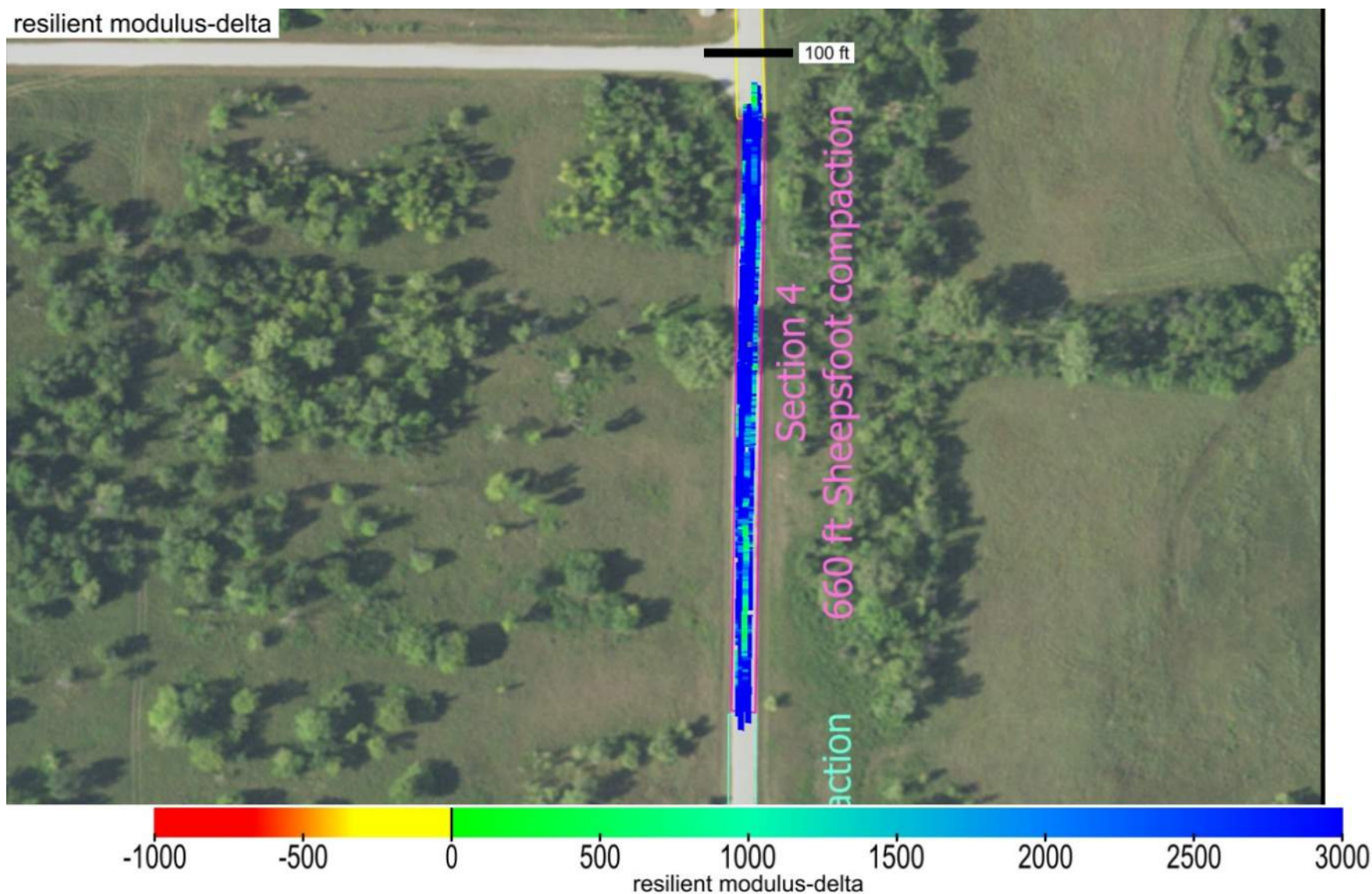


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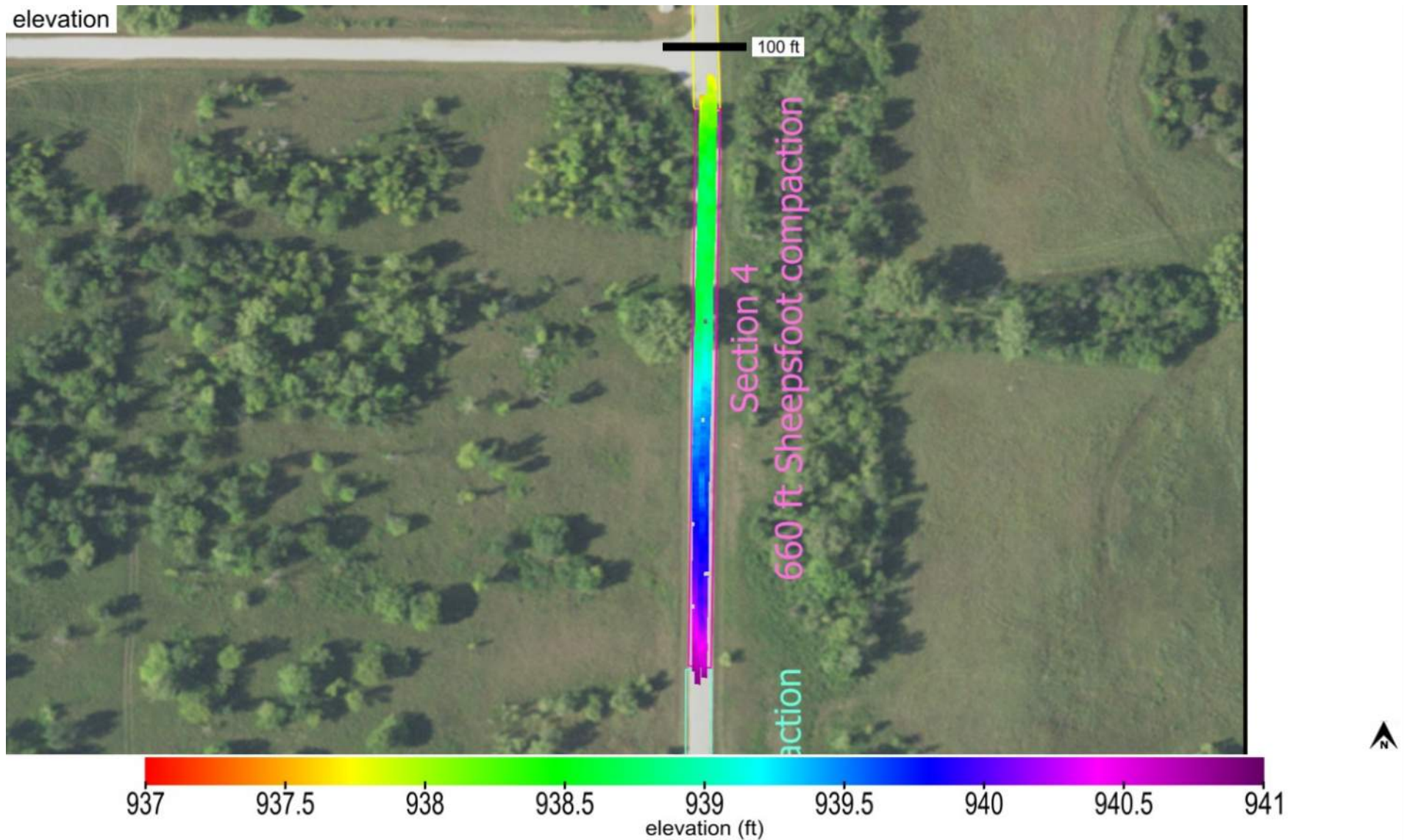
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	107.1	0.7	3600.0	3609.5	8229.7	20000.0	2952.9	35.9	9.5	4629.7	16400.0



Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	107.1	0.7	3600.0	3609.5	8229.7	20000.0	2952.9	35.9	9.5	4629.7	16400.0



minimum	average	maximum	RTK-Q7 (%)	RTK-QA
937.55	939.20	940.85	95.4	7.84





Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_31_151652

Project:	TR-823 Study	Date and Time:	8/31/2023 3:16:52 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.316	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	23860	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	5 - Control

Map Summary

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
XMV	No												
Resilient Modulus	Yes	99.8	106.0	0.4	3600.0	3335.3	13297.8	20000.0	4983.1	37.5	-264.7	9697.8	16400.0
k-value	Yes	99.3	114.8	0.4	100.0	74.6	367.4	550.0	143.6	39.1	-25.4	267.4	450.0
Moisture Content	No												

Mapped Area		Pass Count					Elevation (ft)			Position Quality		Velocity (fps)		
square feet	acres	10th percentile	Median	cov(%)	% >= TV	Target Value	min.	avg.	max.	RTK-Q7 (%)	RTK-QA	min.	avg.	max.
23860	0.548	1	2	37.0	100.0	0	937.37	943.84	952.86	95.2	7.88	4.7	5.1	5.7

Materials

name	id	% of total	area-square ft	area-acres	tl-xmv	tl-Mr	tl-k value	tl-w%
Unpaved Gravel Road (not defined)_IADOT	41019	100.0	23860	0.548	100.0	3600.0	100.0	20.5

Blobs

parameter	min. area(ft^2)	# of blobs	blob area(ft^2)	% of map	lower bound-tv	upper bound-tv	poly-tol.
Resilient Modulus	500.0	0	0	0.0	none	0.0	4.0
k-value	500.0	0	0	0.0	none	0.0	4.0

Station

Start	End
13+20	26+50

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_31_151652

Project:	TR-823 Study	Date and Time:	8/31/2023 3:16:52 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.316	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	23860	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	5 - Control

QUALITY ANALYSIS SUMMARY - k-Value

Quality Value	Criteria
114.8	CQI > = 95
99.3	80% of k-Value MVs >= 100
39.1	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_31_151652

Project:	TR-823 Study	Date and Time:	8/31/2023 3:16:52 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.316	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	23860	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	5 - Control

QUALITY ANALYSIS SUMMARY - Resilient Modulus

Quality Value	Criteria
106.0	CQI > = 95
99.8	90% of Resilient Modulus MVs >= 3600
37.5	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

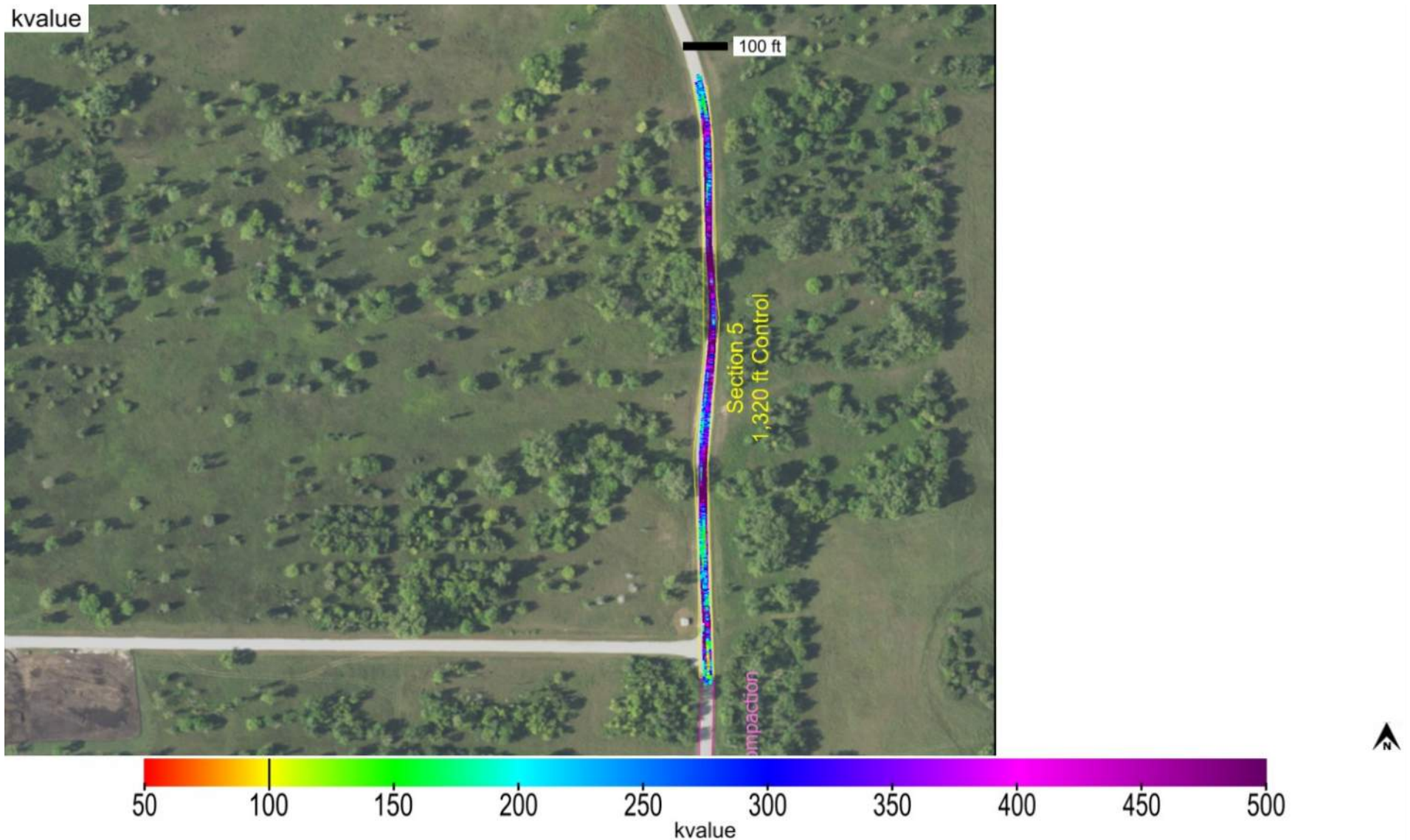
Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_31_151652

Map Type: Verification Map

Map Layer: Unpaved Gravel Road

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	99.3	114.8	0.4	100.0	74.6	367.4	550.0	143.6	39.1	-25.4	267.4	450.0



This report is only for use of the client named and it cannot be relied upon by any other person or entity.

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	99.3	114.8	0.4	100.0	74.6	367.4	550.0	143.6	39.1	-25.4	267.4	450.0

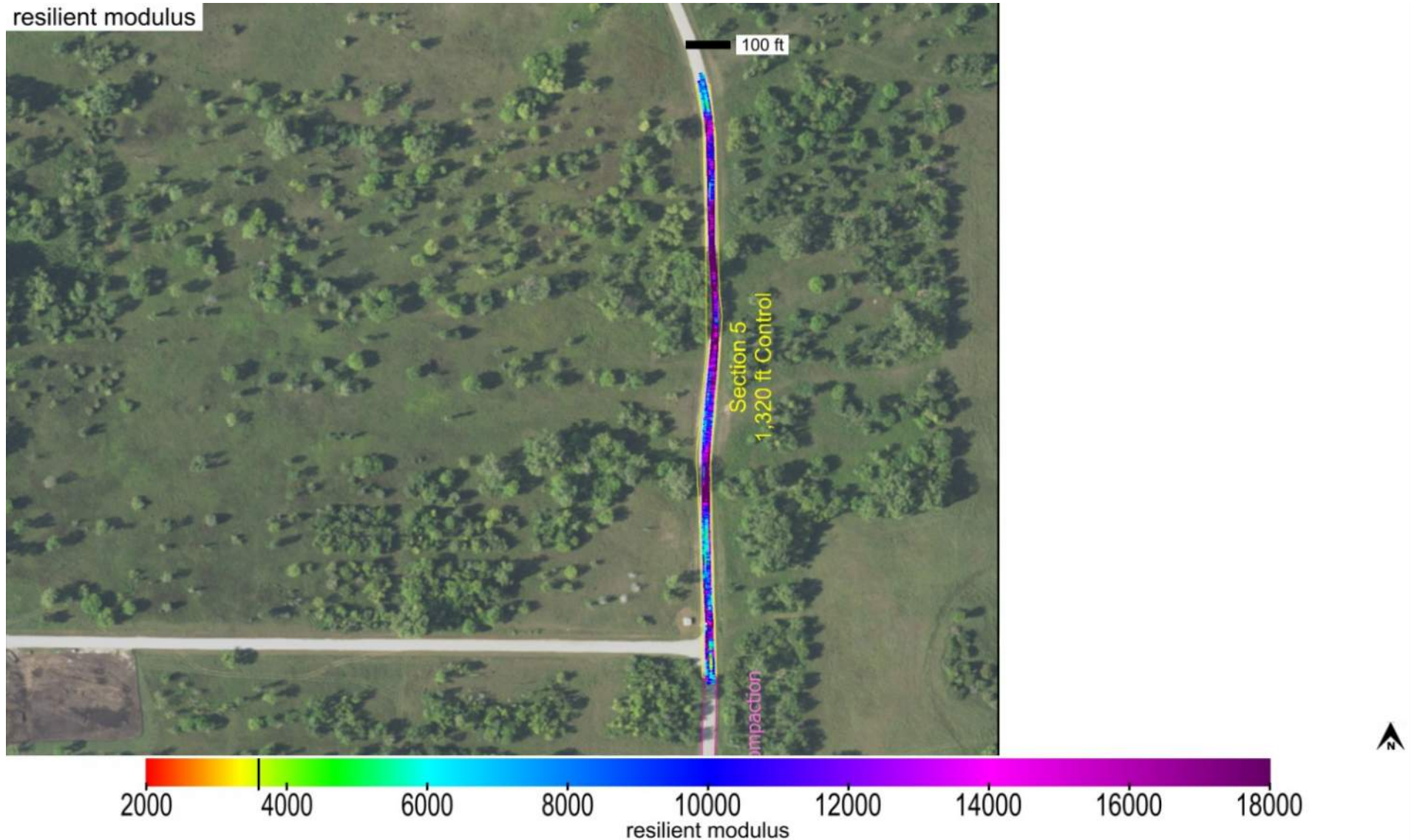


Map ID: ing_polk77-campdodge-2023_cs56b-01047_2023_08_31_151652

Map Type: Verification Map

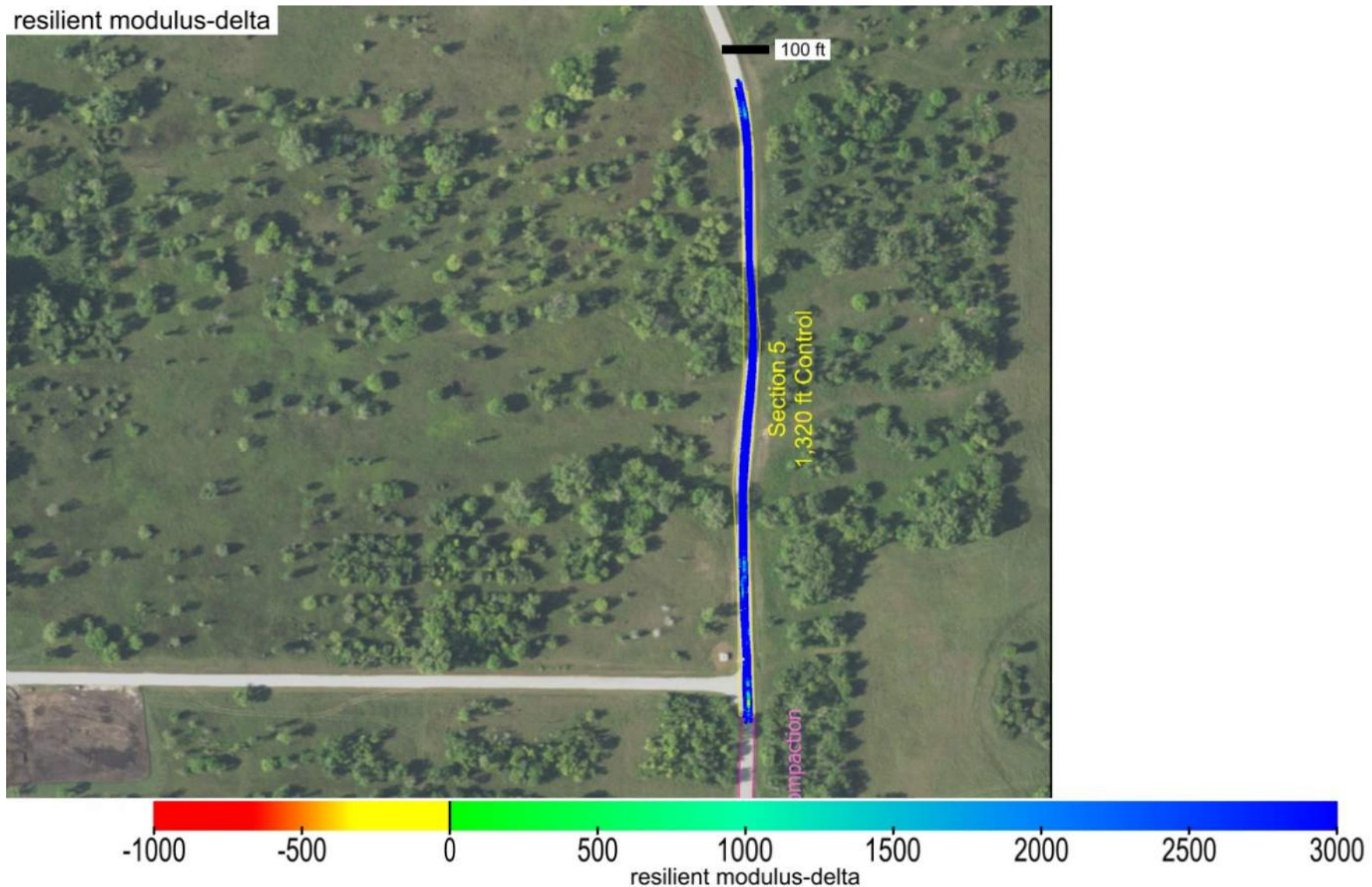
Map Layer: Unpaved Gravel Road

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	99.8	106.0	0.4	3600.0	3335.3	13297.8	20000.0	4983.1	37.5	-264.7	9697.8	16400.0

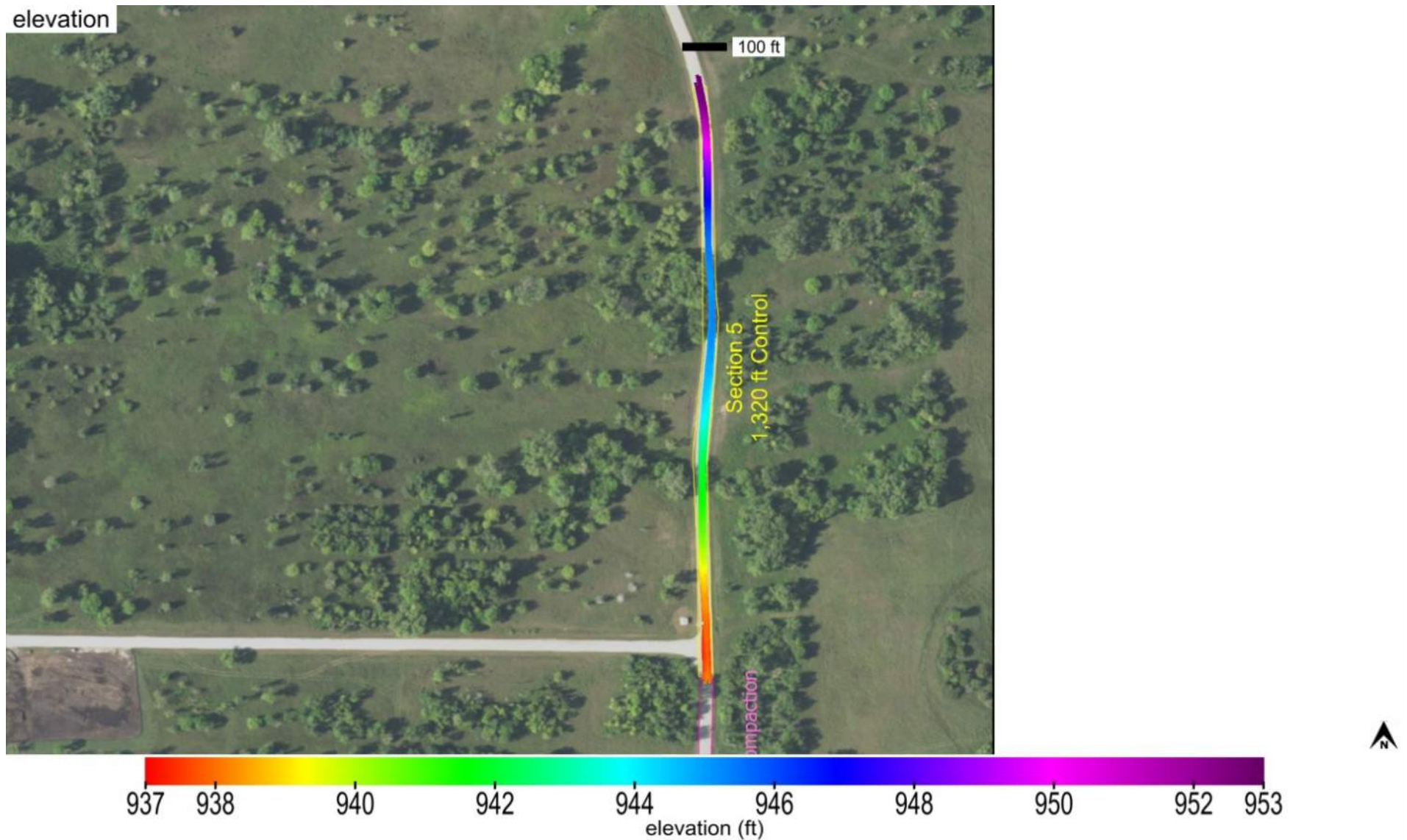


This report is only for use of the client named and it cannot be relied upon by any other person or entity.

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	99.8	106.0	0.4	3600.0	3335.3	13297.8	20000.0	4983.1	37.5	-264.7	9697.8	16400.0



minimum	average	maximum	RTK-Q7 (%)	RTK-QA
937.37	943.84	952.86	95.2	7.88





Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_03_07_093718

Project:	TR-823 Study	Date and Time:	3/7/2024 9:37:18 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.425	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	29915	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	1 - STAB + Smooth Drum

Map Summary

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
XMV	No												
Resilient Modulus	Yes	100.0	107.7	0.6	3600.0	3808.5	12346.8	20000.0	4266.1	34.6	208.5	8746.8	16400.0
k-value	Yes	100.0	119.3	0.5	100.0	119.9	383.5	550.0	120.8	31.5	19.9	283.5	450.0
Moisture Content	No												

Mapped Area		Pass Count					Elevation (ft)			Position Quality		Velocity (fps)		
square feet	acres	10th percentile	Median	cov(%)	% >= TV	Target Value	min.	avg.	max.	RTK-Q7 (%)	RTK-QA	min.	avg.	max.
29915	0.687	1	1	35.8	100.0	0	915.47	931.46	948.81	95.1	7.89	4.3	4.9	5.7

Materials

name	id	% of total	area-square ft	area-acres	tl-xmv	tl-Mr	tl-k value	tl-w%
Unpaved Gravel Road (not defined)_IADOT	41019	100.0	29915	0.687	100.0	3600.0	100.0	20.5

Blobs

parameter	min. area(ft^2)	# of blobs	blob area(ft^2)	% of map	lower bound-tv	upper bound-tv	poly-tol.
Resilient Modulus	500.0	0	0	0.0	none	0.0	4.0
k-value	500.0	0	0	0.0	none	0.0	4.0

Station

Start	End
0+00	15+00

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_03_07_093718

Project:	TR-823 Study	Date and Time:	3/7/2024 9:37:18 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.425	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	29915	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	1 - STAB + Smooth Drum

QUALITY ANALYSIS SUMMARY - k-Value

Quality Value	Criteria
119.3	CQI > = 95
100.0	80% of k-Value MVs >= 100
31.5	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_03_07_093718

Project:	TR-823 Study	Date and Time:	3/7/2024 9:37:18 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.425	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	29915	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	1 - STAB + Smooth Drum

QUALITY ANALYSIS SUMMARY - Resilient Modulus

Quality Value	Criteria
107.7	CQI > = 95
100.0	90% of Resilient Modulus MVs >= 3600
34.6	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

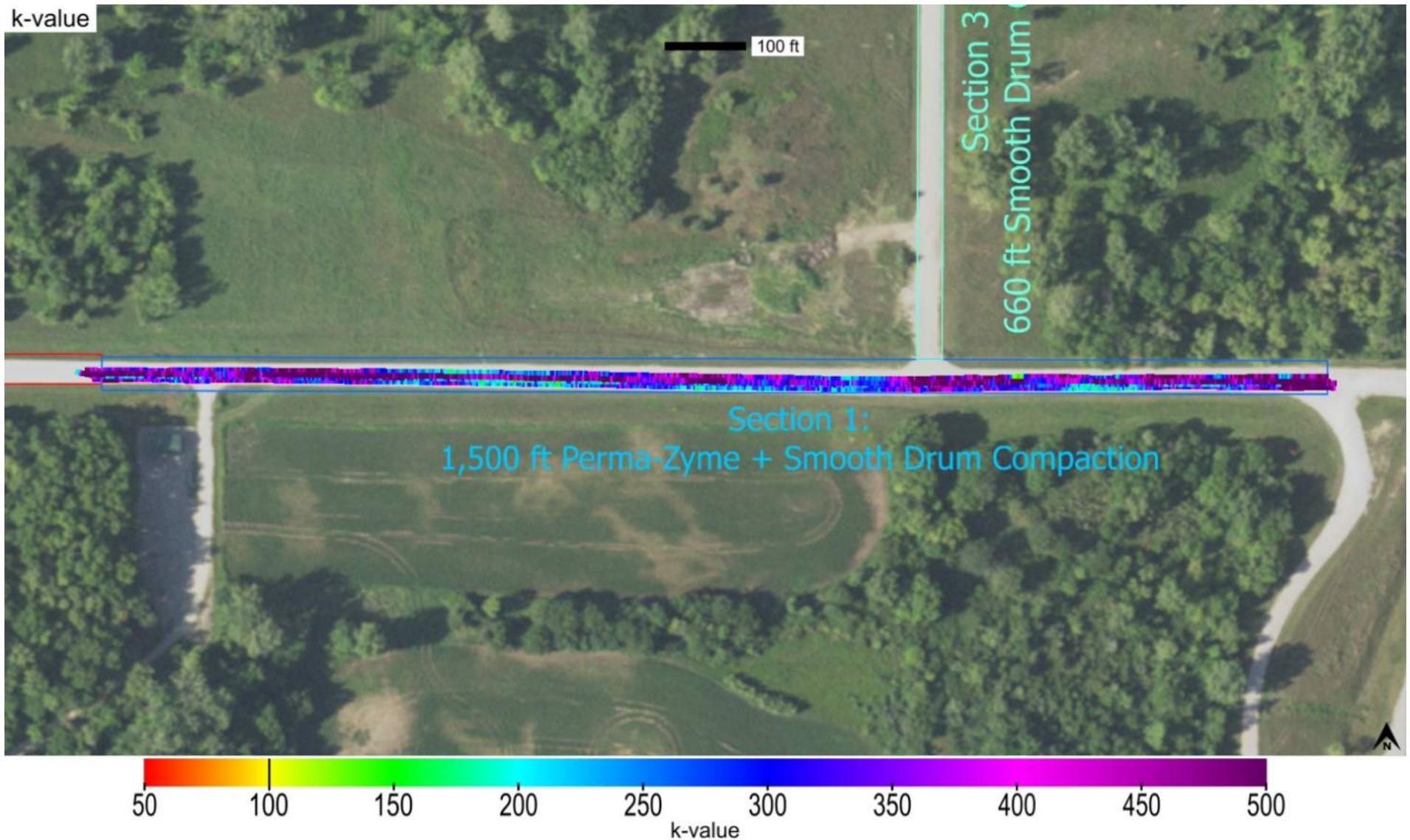
Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

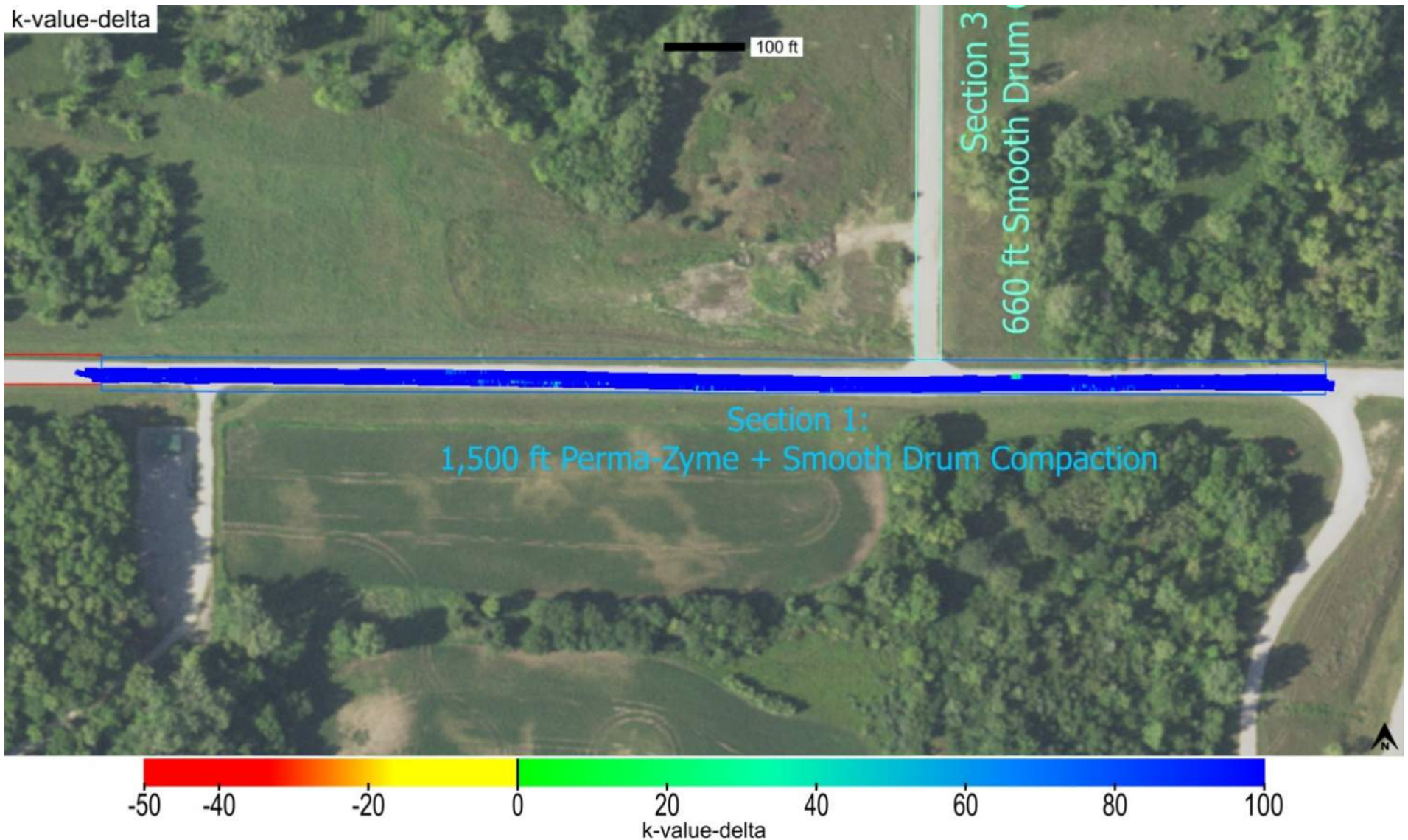
Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

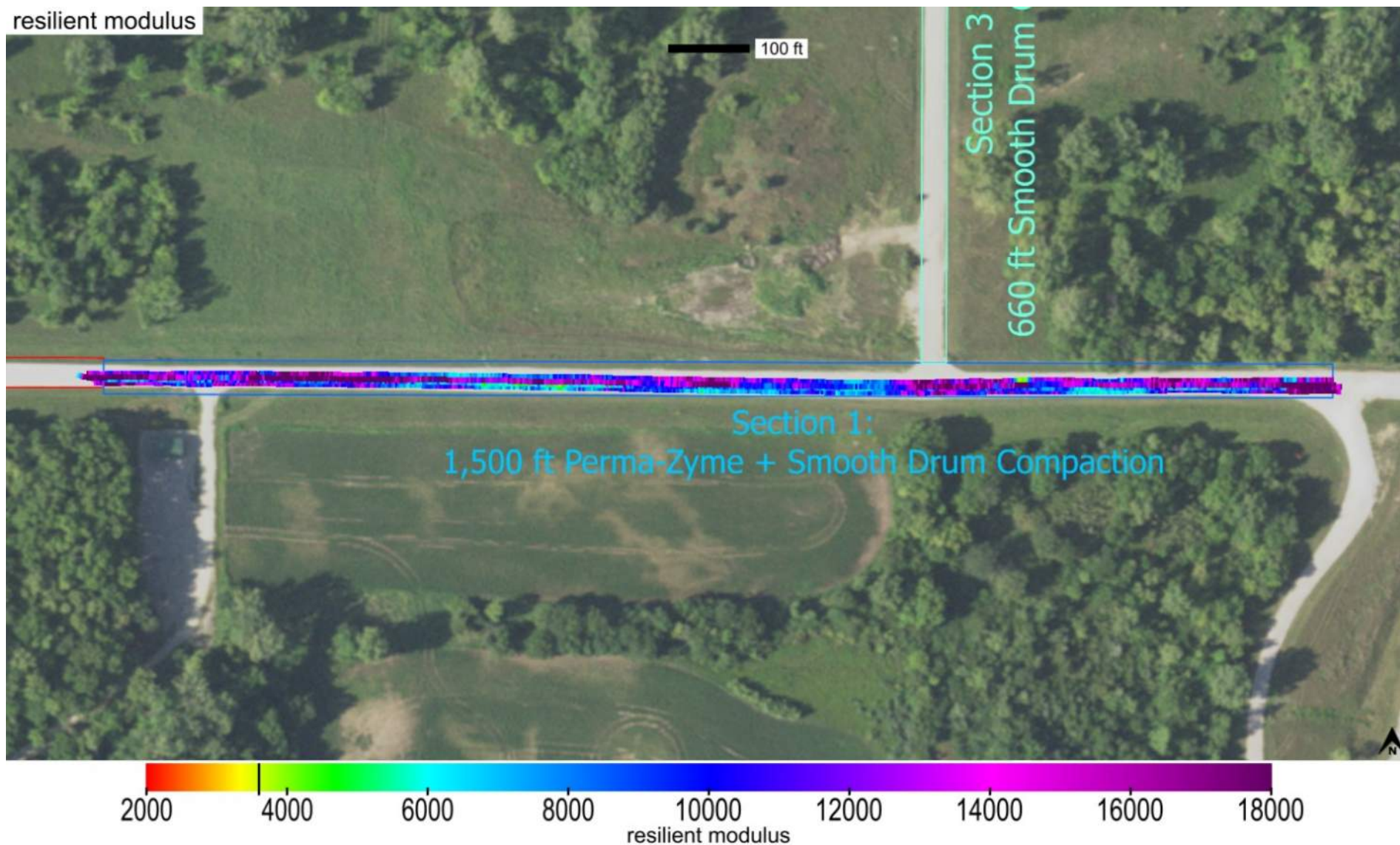
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	119.3	0.5	100.0	119.9	383.5	550.0	120.8	31.5	19.9	283.5	450.0



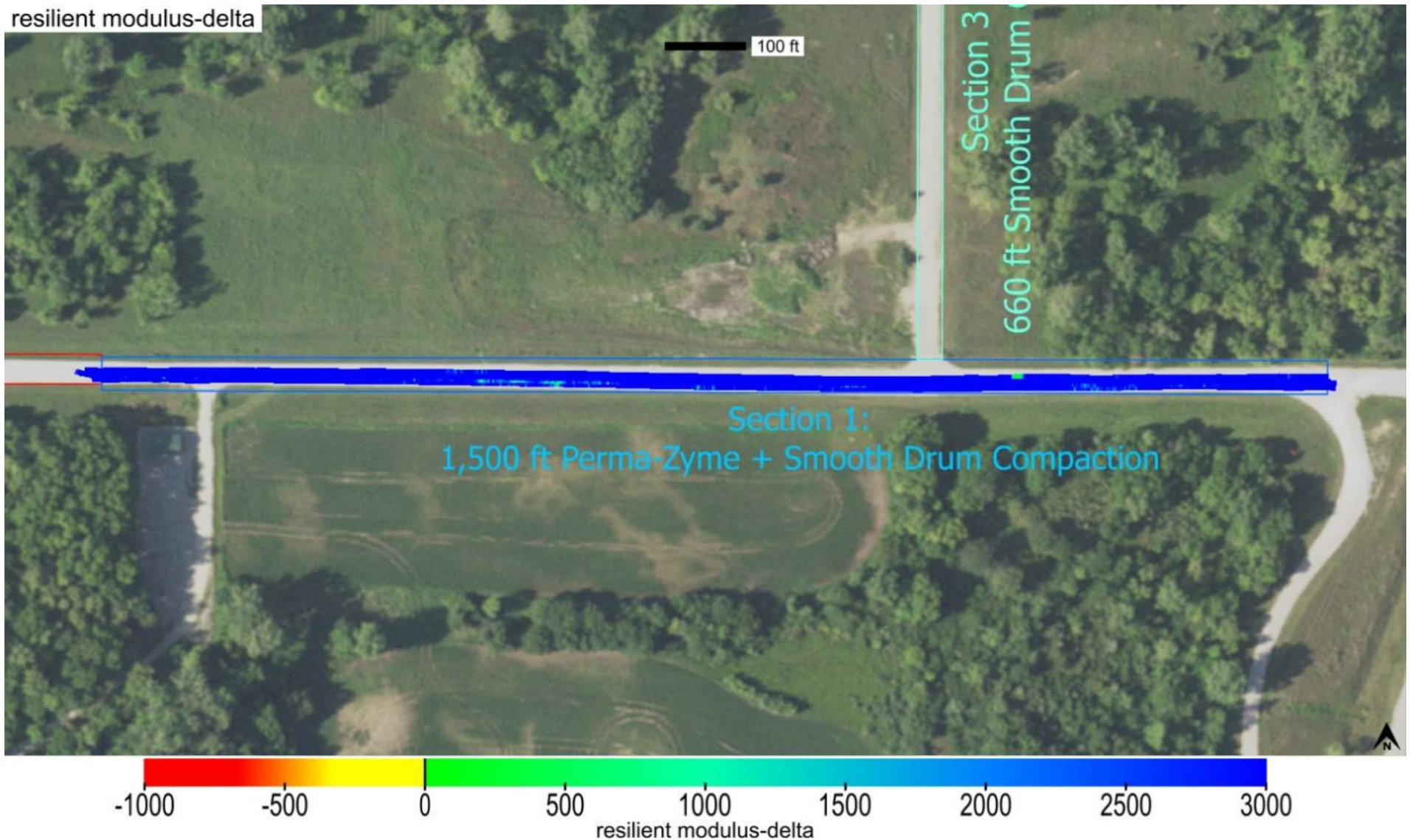
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	119.3	0.5	100.0	119.9	383.5	550.0	120.8	31.5	19.9	283.5	450.0



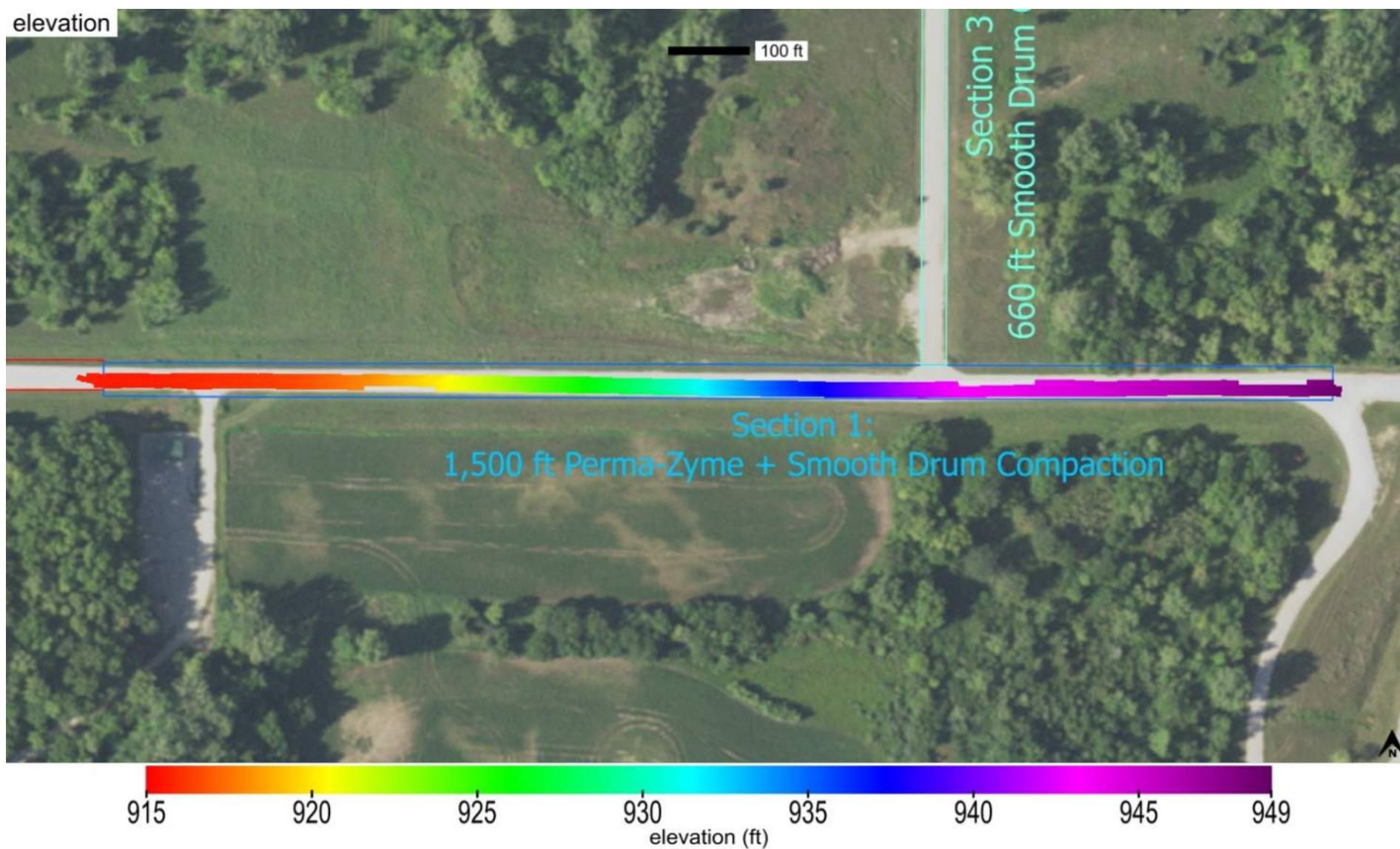
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	107.7	0.6	3600.0	3808.5	12346.8	20000.0	4266.1	34.6	208.5	8746.8	16400.0



Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	107.7	0.6	3600.0	3808.5	12346.8	20000.0	4266.1	34.6	208.5	8746.8	16400.0



minimum	average	maximum	RTK-Q7 (%)	RTK-QA
915.47	931.46	948.81	95.1	7.89





Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_03_07_101119

Project:	TR-823 Study	Date and Time:	3/7/2024 10:11:19 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.362	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	30766	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	2 - STAB + Sheepsfoot

Map Summary

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
XMV	No												
Resilient Modulus	Yes	100.0	112.0	0.8	3600.0	3871.4	12446.0	20000.0	3238.5	26.0	271.4	8846.0	16400.0
k-value	Yes	100.0	122.7	0.6	100.0	118.2	387.0	550.0	95.5	24.7	18.2	287.0	450.0
Moisture Content	No												

Mapped Area		Pass Count					Elevation (ft)			Position Quality		Velocity (fps)		
square feet	acres	10th percentile	Median	cov(%)	% >= TV	Target Value	min.	avg.	max.	RTK-Q7 (%)	RTK-QA	min.	avg.	max.
30766	0.706	1	1	36.3	100.0	0	895.19	907.33	917.16	92.9	7.85	4.6	5.0	5.6

Materials

name	id	% of total	area-square ft	area-acres	tl-xmv	tl-Mr	tl-k value	tl-w%
Unpaved Gravel Road (not defined)_IADOT	41019	100.0	30766	0.706	100.0	3600.0	100.0	20.5

Blobs

parameter	min. area(ft^2)	# of blobs	blob area(ft^2)	% of map	lower bound-tv	upper bound-tv	poly-tol.
Resilient Modulus	500.0	0	0	0.0	none	0.0	4.0
k-value	500.0	0	0	0.0	none	0.0	4.0

Station

Start	End
15+00	30+00

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_03_07_101119

Project:	TR-823 Study	Date and Time:	3/7/2024 10:11:19 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.362	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	30766	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	2 - STAB + Sheepsfoot

QUALITY ANALYSIS SUMMARY - k-Value

Quality Value	Criteria
122.7	CQI > = 95
100.0	80% of k-Value MVs >= 100
24.7	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_03_07_101119

Project:	TR-823 Study	Date and Time:	3/7/2024 10:11:19 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.362	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	30766	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	2 - STAB + Sheepsfoot

QUALITY ANALYSIS SUMMARY - Resilient Modulus

Quality Value	Criteria
112.0	CQI > = 95
100.0	90% of Resilient Modulus MVs >= 3600
26.0	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

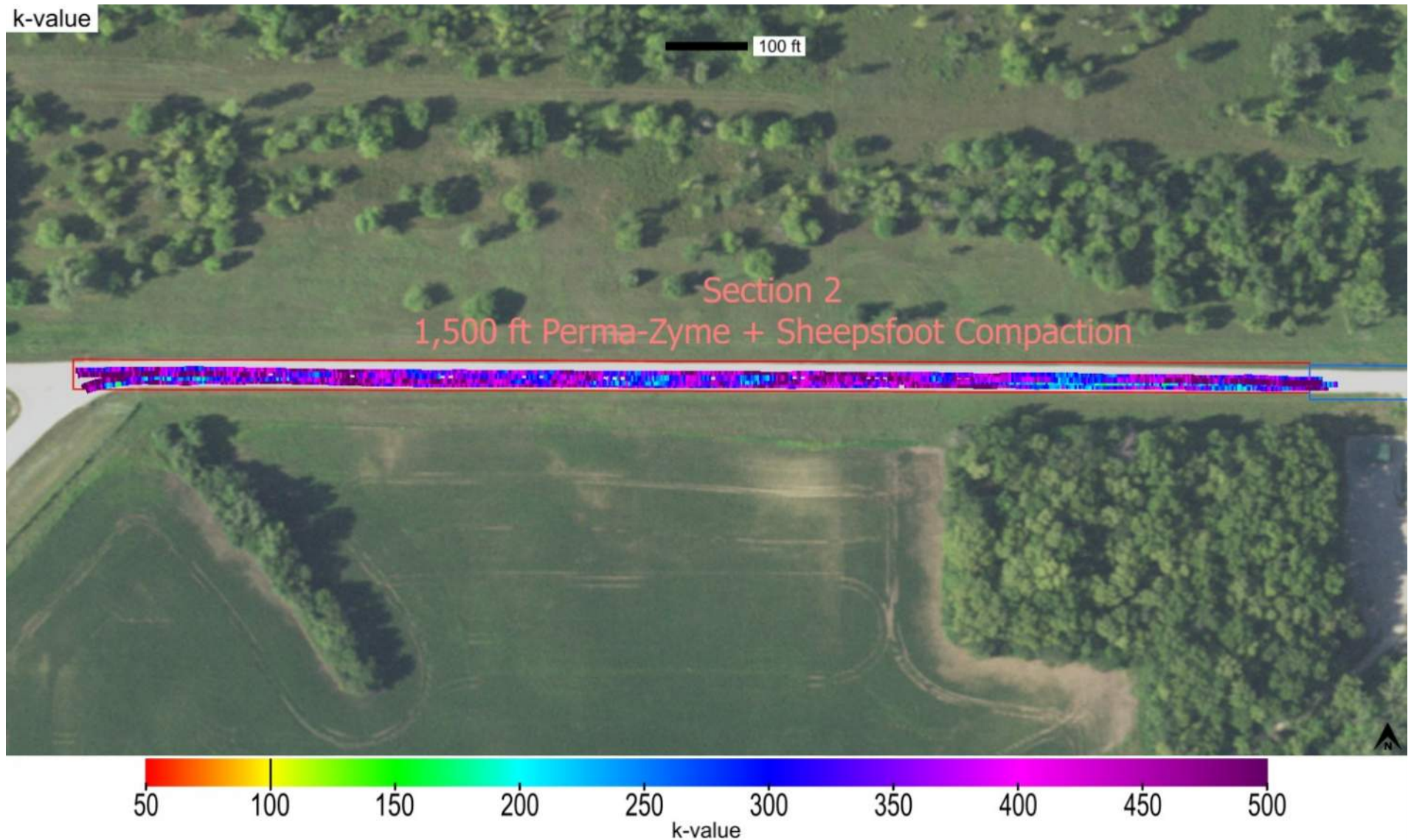
Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

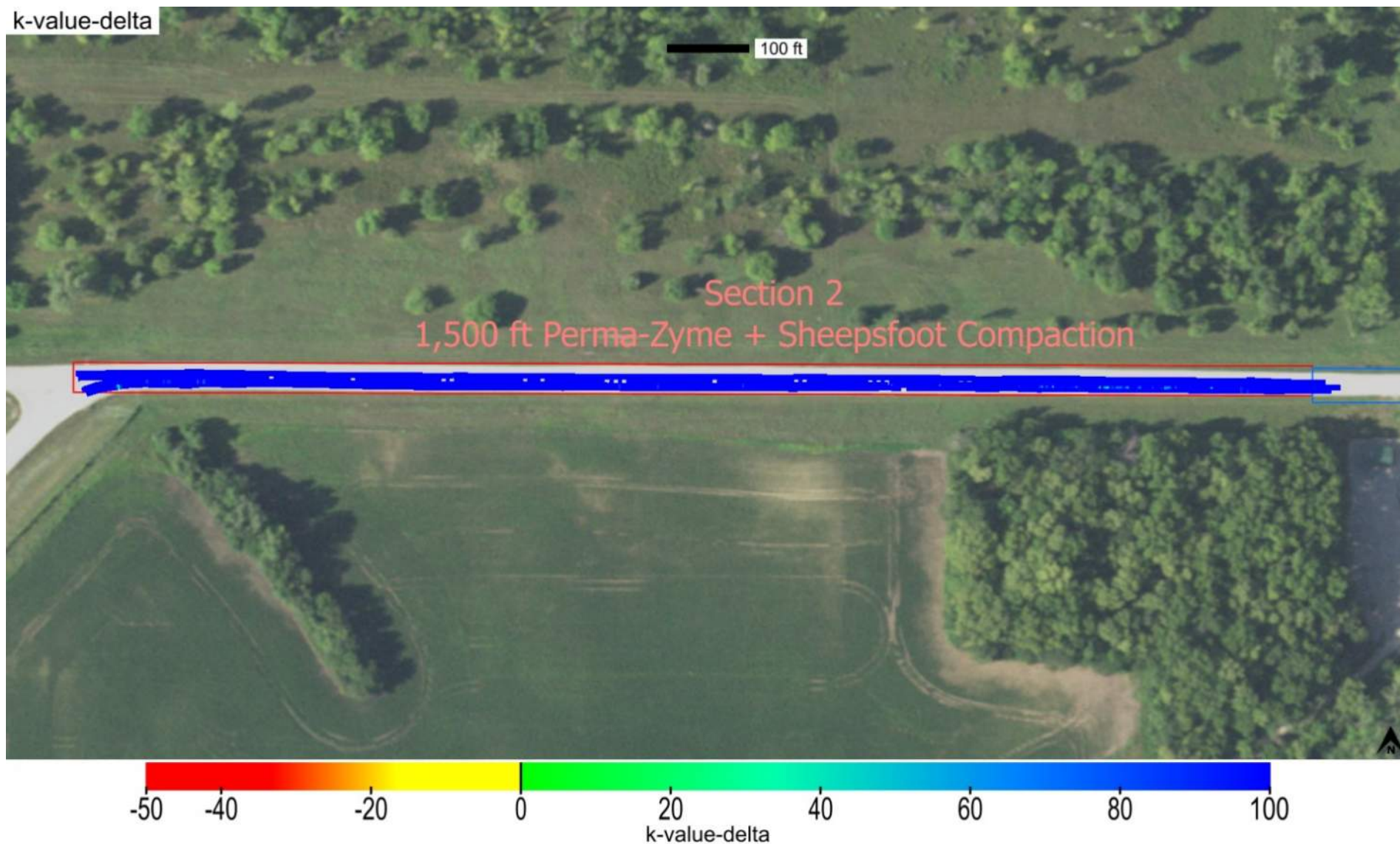
Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

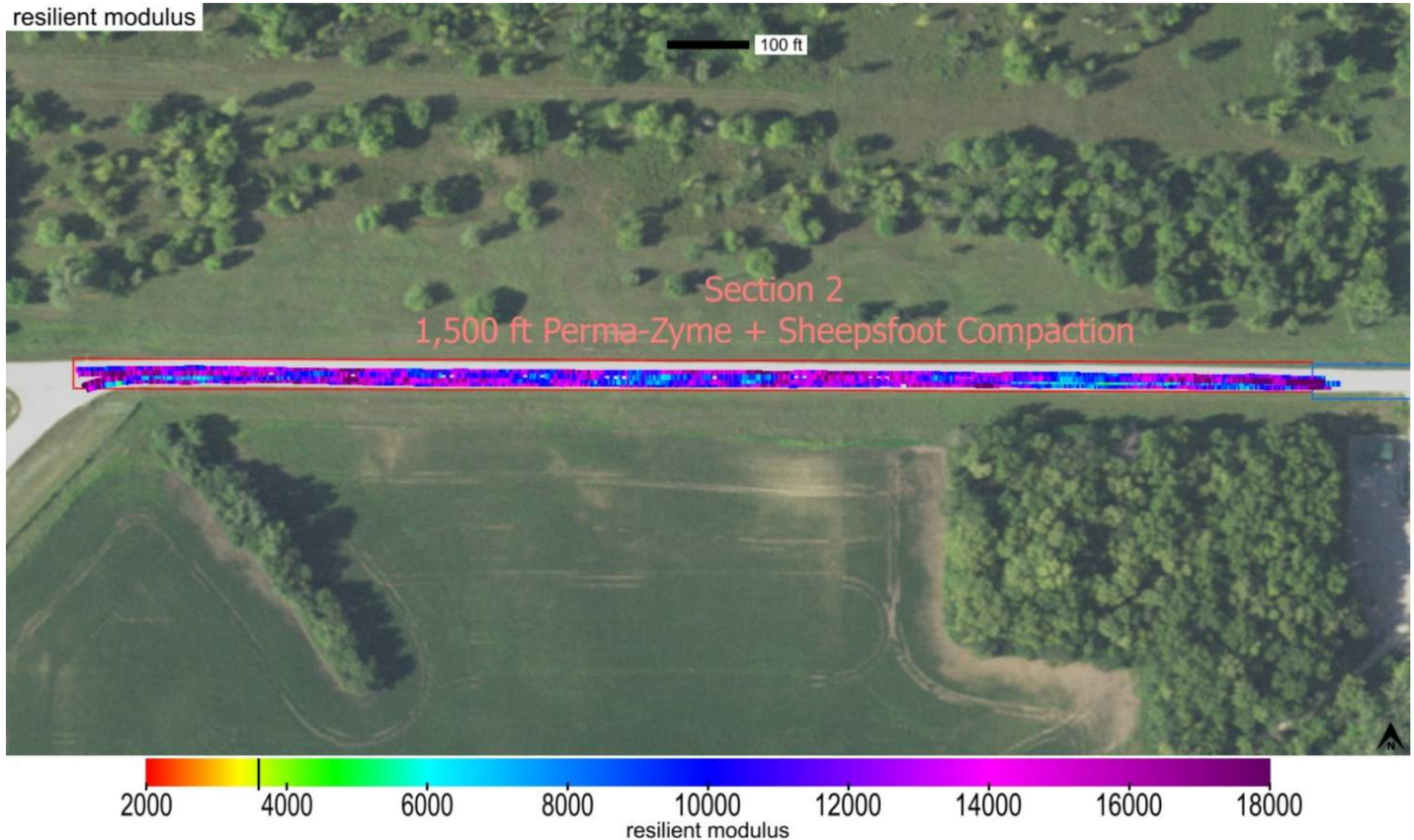
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	122.7	0.6	100.0	118.2	387.0	550.0	95.5	24.7	18.2	287.0	450.0



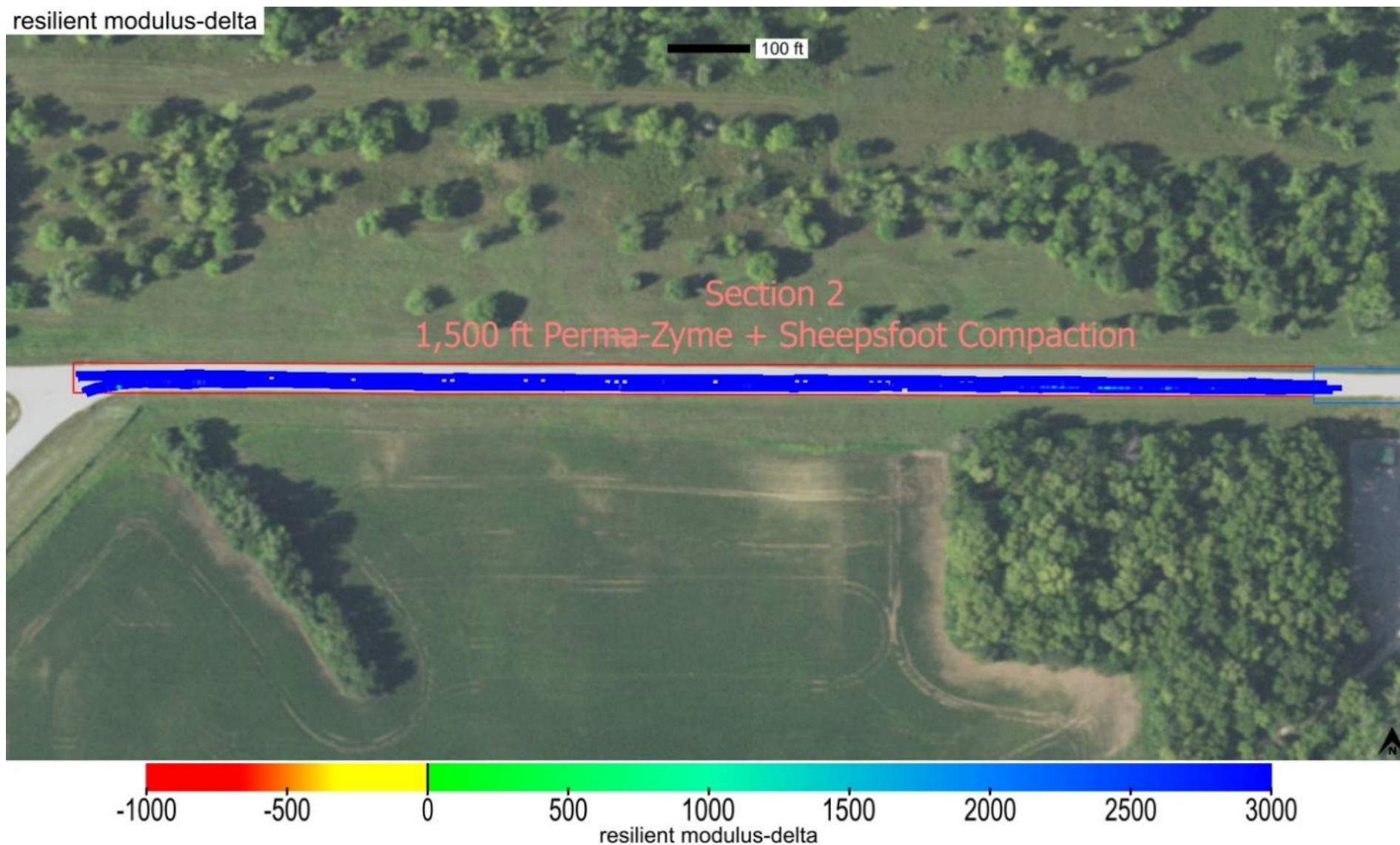
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	122.7	0.6	100.0	118.2	387.0	550.0	95.5	24.7	18.2	287.0	450.0



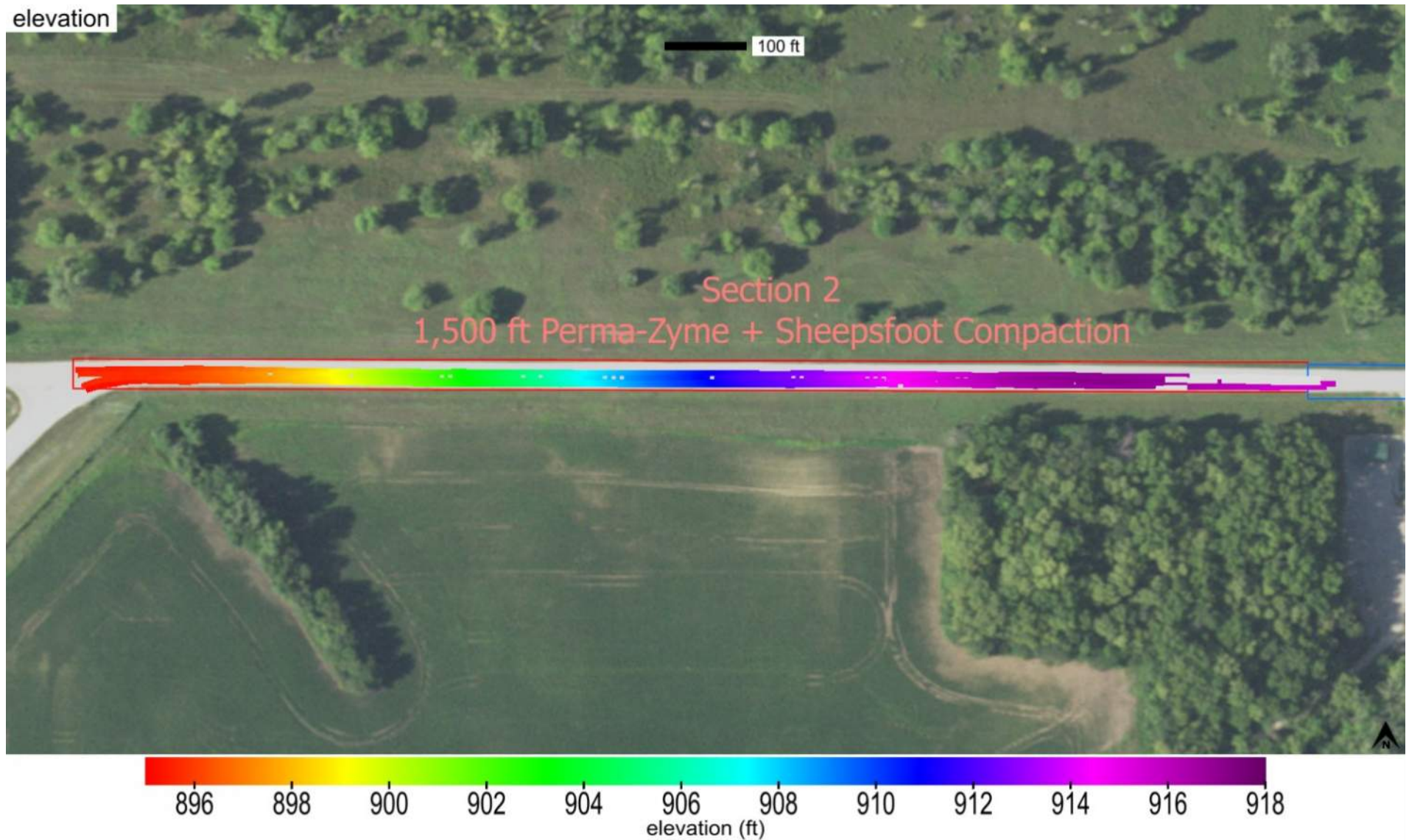
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	112.0	0.8	3600.0	3871.4	12446.0	20000.0	3238.5	26.0	271.4	8846.0	16400.0



Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	112.0	0.8	3600.0	3871.4	12446.0	20000.0	3238.5	26.0	271.4	8846.0	16400.0



minimum	average	maximum	RTK-Q7 (%)	RTK-QA
895.19	907.33	917.16	92.9	7.85





Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_03_07_103818

Project:	TR-823 Study	Date and Time:	3/7/2024 10:38:18 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.16	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	12005	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	3 - Smooth Drum

Map Summary

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
XMV	No												
Resilient Modulus	Yes	100.0	107.4	0.7	3600.0	4362.6	11418.4	20000.0	4008.6	35.1	762.6	7818.4	16400.0
k-value	Yes	100.0	118.3	0.6	100.0	142.8	350.8	550.0	117.5	33.5	42.8	250.8	450.0
Moisture Content	No												

Mapped Area		Pass Count					Elevation (ft)			Position Quality		Velocity (fps)		
square feet	acres	10th percentile	Median	cov(%)	% >= TV	Target Value	min.	avg.	max.	RTK-Q7 (%)	RTK-QA	min.	avg.	max.
12005	0.276	1	1	33.6	100.0	0	940.35	942.54	944.50	89.4	7.74	4.6	5.0	6.1

Materials

name	id	% of total	area-square ft	area-acres	tl-xmv	tl-Mr	tl-k value	tl-w%
Unpaved Gravel Road (not defined)_IADOT	41019	100.0	12005	0.276	100.0	3600.0	100.0	20.5

Blobs

parameter	min. area(ft^2)	# of blobs	blob area(ft^2)	% of map	lower bound-tv	upper bound-tv	poly-tol.
Resilient Modulus	500.0	0	0	0.0	none	0.0	4.0
k-value	500.0	0	0	0.0	none	0.0	4.0

Station

Start	End
0+00	6+60

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_03_07_103818

Project:	TR-823 Study	Date and Time:	3/7/2024 10:38:18 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.16	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	12005	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	3 - Smooth Drum

QUALITY ANALYSIS SUMMARY - k-Value

Quality Value	Criteria
118.3	CQI > = 95
100.0	80% of k-Value MVs >= 100
33.5	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_03_07_103818

Project:	TR-823 Study	Date and Time:	3/7/2024 10:38:18 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.16	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	12005	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	3 - Smooth Drum

QUALITY ANALYSIS SUMMARY - Resilient Modulus

Quality Value	Criteria
107.4	CQI > = 95
100.0	90% of Resilient Modulus MVs >= 3600
35.1	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

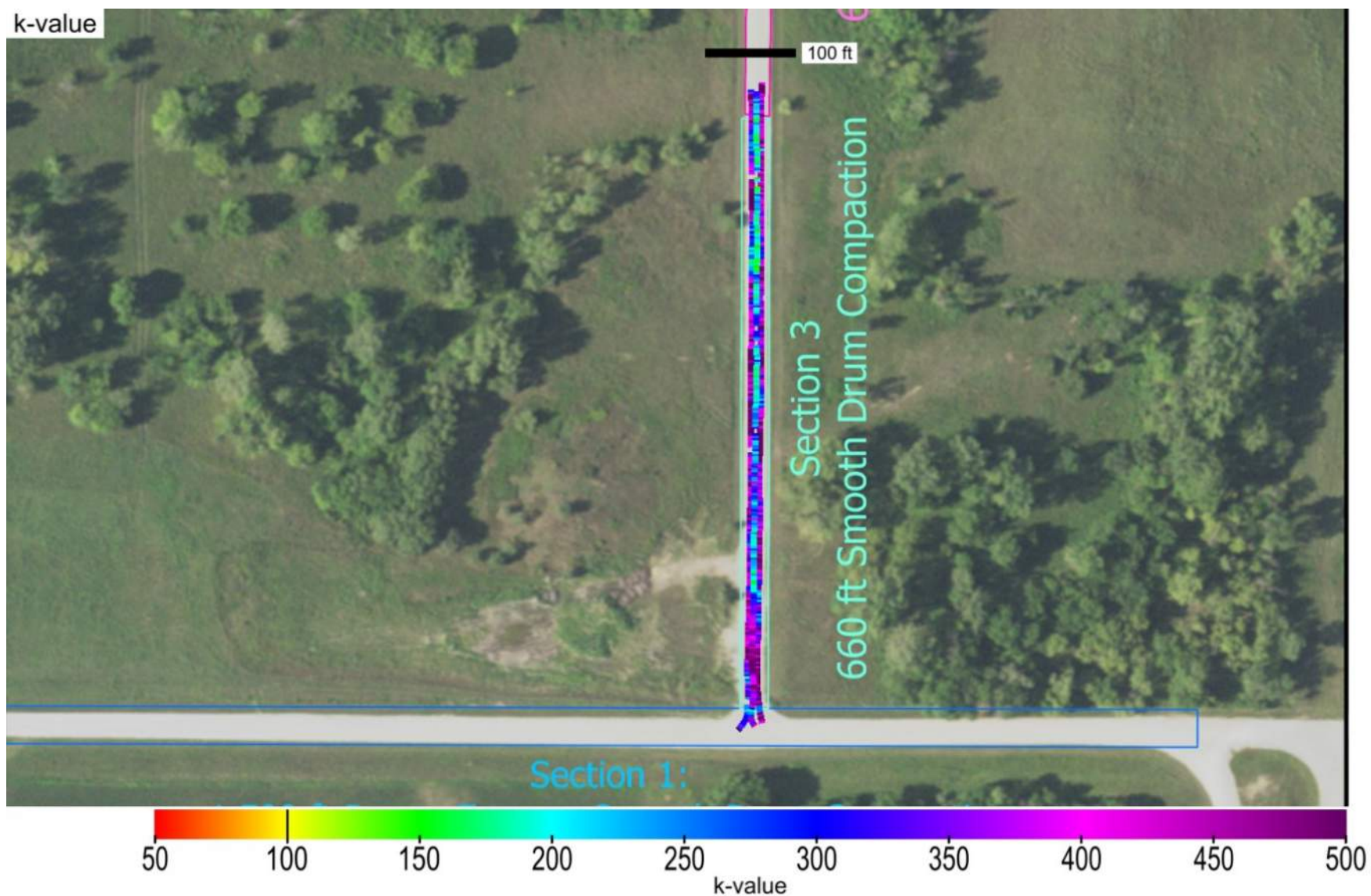
Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

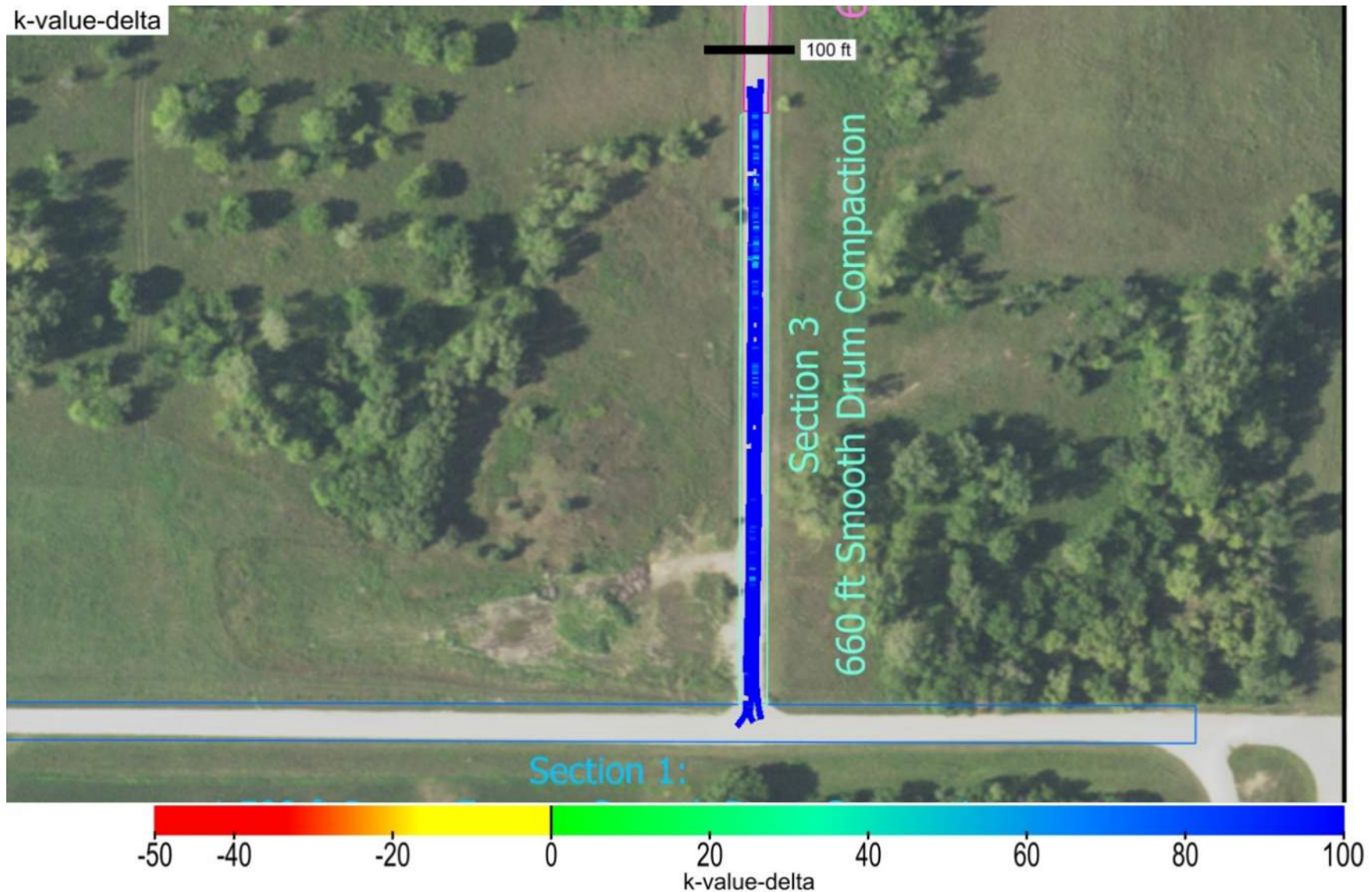
Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

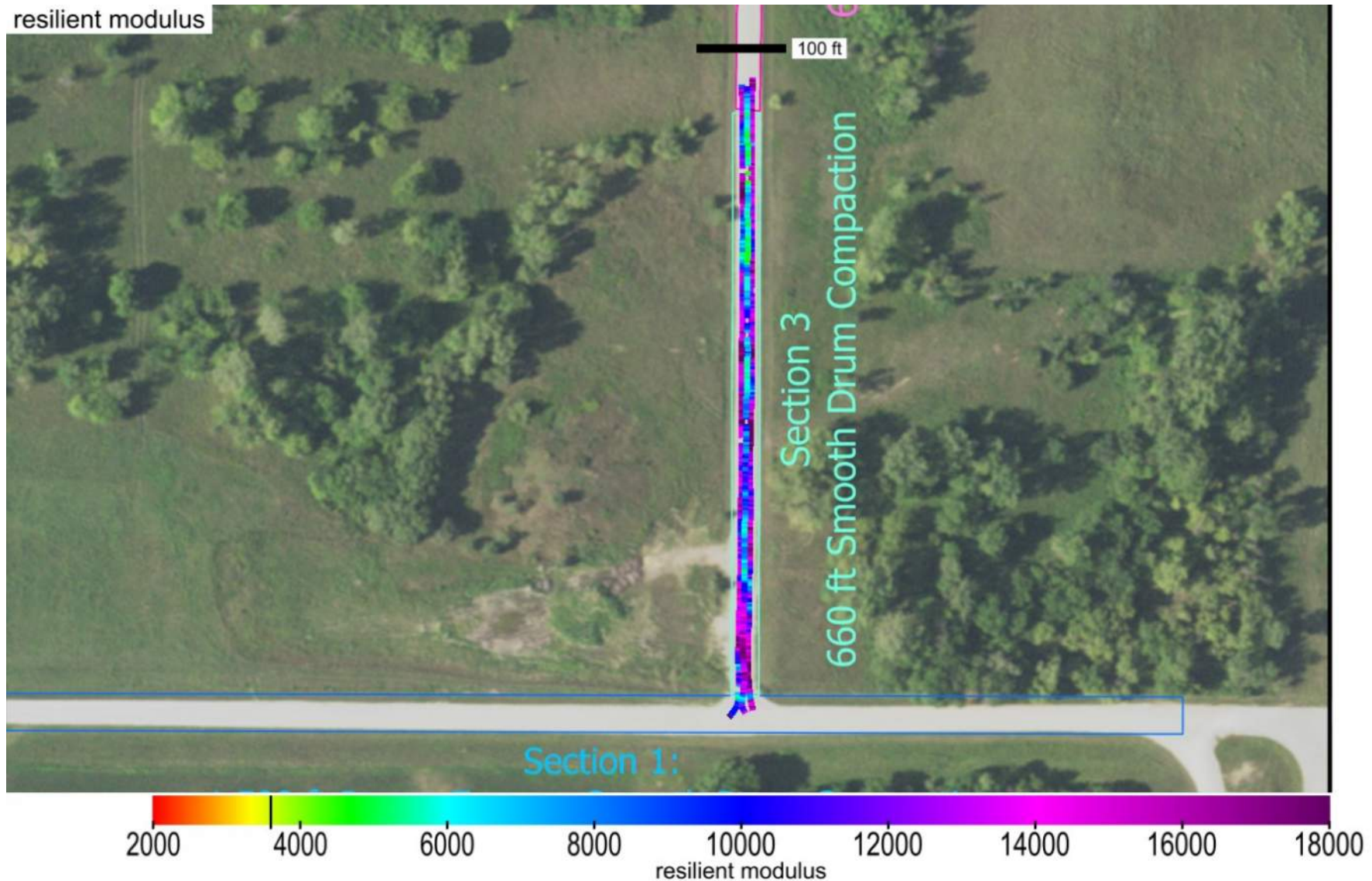
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	118.3	0.6	100.0	142.8	350.8	550.0	117.5	33.5	42.8	250.8	450.0



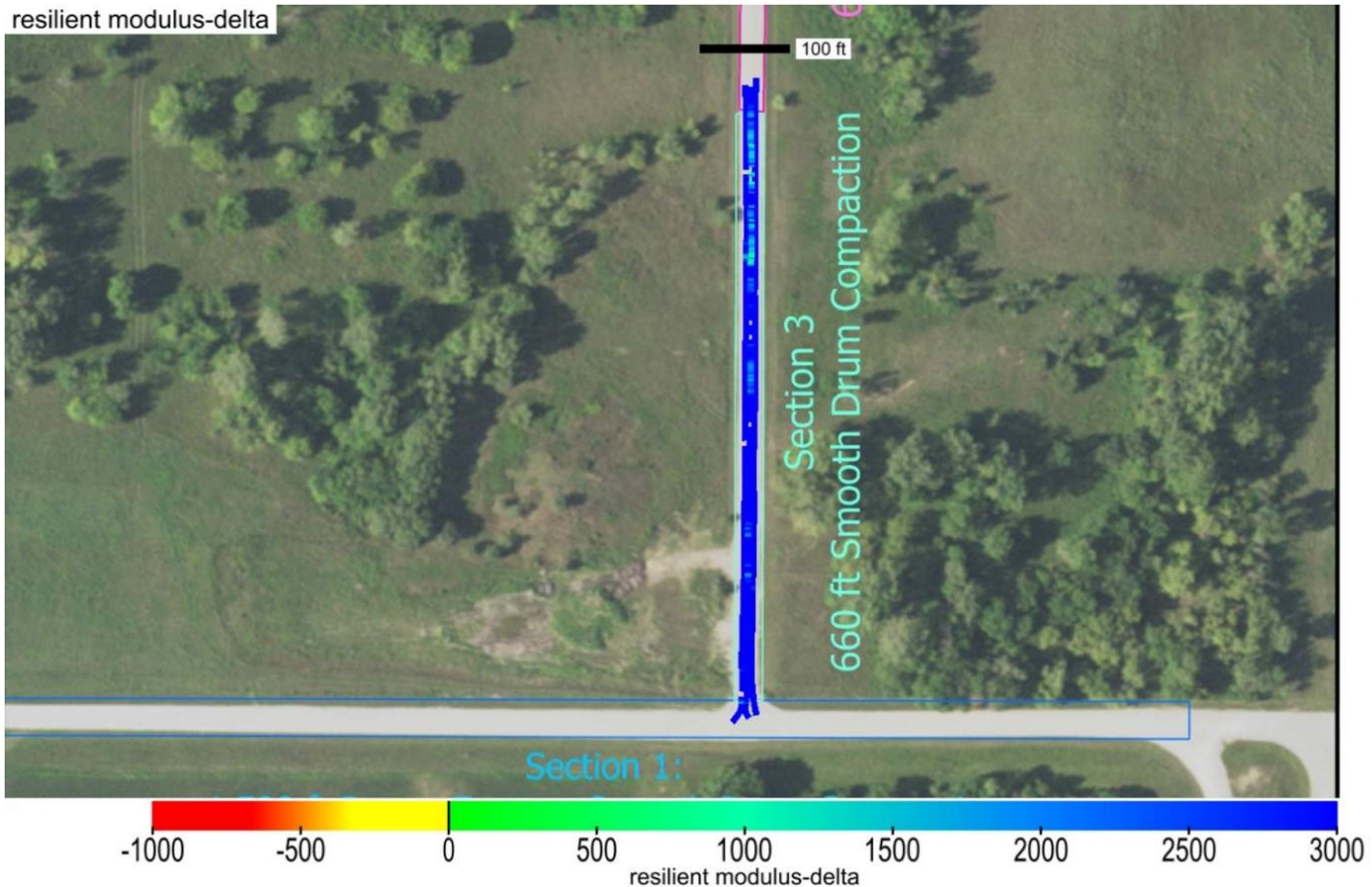
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	118.3	0.6	100.0	142.8	350.8	550.0	117.5	33.5	42.8	250.8	450.0



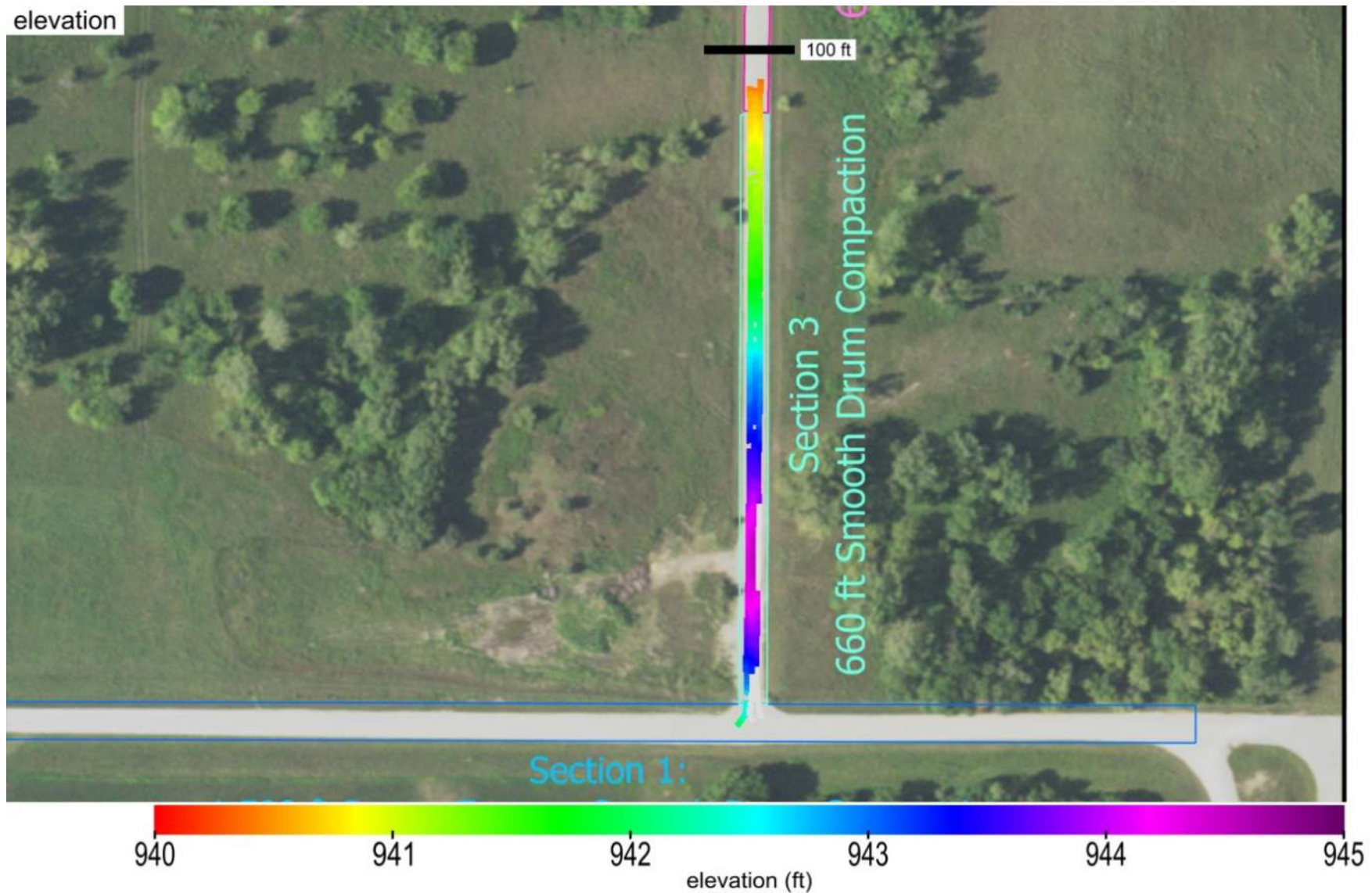
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	107.4	0.7	3600.0	4362.6	11418.4	20000.0	4008.6	35.1	762.6	7818.4	16400.0



Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	107.4	0.7	3600.0	4362.6	11418.4	20000.0	4008.6	35.1	762.6	7818.4	16400.0



minimum	average	maximum	RTK-Q7 (%)	RTK-QA
940.35	942.54	944.50	89.4	7.74





Map ID: ing_pol77-campdodge-2023_cs56b-01047_2024_03_07_105155

Project:	TR-823 Study	Date and Time:	3/7/2024 10:51:55 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.135	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	12028	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	4 - Sheepsfoot

Map Summary

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
XMV	No												
Resilient Modulus	Yes	100.0	109.3	0.8	3600.0	4065.1	9582.4	20000.0	3003.9	31.4	465.1	5982.4	16400.0
k-value	Yes	100.0	119.5	0.9	100.0	129.1	297.1	550.0	92.1	31.0	29.1	197.1	450.0
Moisture Content	No												

Mapped Area		Pass Count					Elevation (ft)			Position Quality		Velocity (fps)		
square feet	acres	10th percentile	Median	cov(%)	% >= TV	Target Value	min.	avg.	max.	RTK-Q7 (%)	RTK-QA	min.	avg.	max.
12028	0.276	1	1	33.3	100.0	0	937.54	939.16	940.64	78.4	7.47	4.6	5.0	6.4

Materials

name	id	% of total	area-square ft	area-acres	tl-xmv	tl-Mr	tl-k value	tl-w%
Unpaved Gravel Road (not defined)_IADOT	41019	100.0	12028	0.276	100.0	3600.0	100.0	20.5

Blobs

parameter	min. area(ft^2)	# of blobs	blob area(ft^2)	% of map	lower bound-tv	upper bound-tv	poly-tol.
Resilient Modulus	500.0	0	0	0.0	none	0.0	4.0
k-value	500.0	0	0	0.0	none	0.0	4.0

Station

Start	End
6+60	13+20

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_03_07_105155

Project:	TR-823 Study	Date and Time:	3/7/2024 10:51:55 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.135	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	12028	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	4 - Sheepsfoot

QUALITY ANALYSIS SUMMARY - k-Value

Quality Value	Criteria
119.5	CQI > = 95
100.0	80% of k-Value MVs >= 100
31.0	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_03_07_105155

Project:	TR-823 Study	Date and Time:	3/7/2024 10:51:55 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.135	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	12028	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	4 - Sheepsfoot

QUALITY ANALYSIS SUMMARY - Resilient Modulus

Quality Value	Criteria
109.3	CQI > = 95
100.0	90% of Resilient Modulus MVs >= 3600
31.4	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

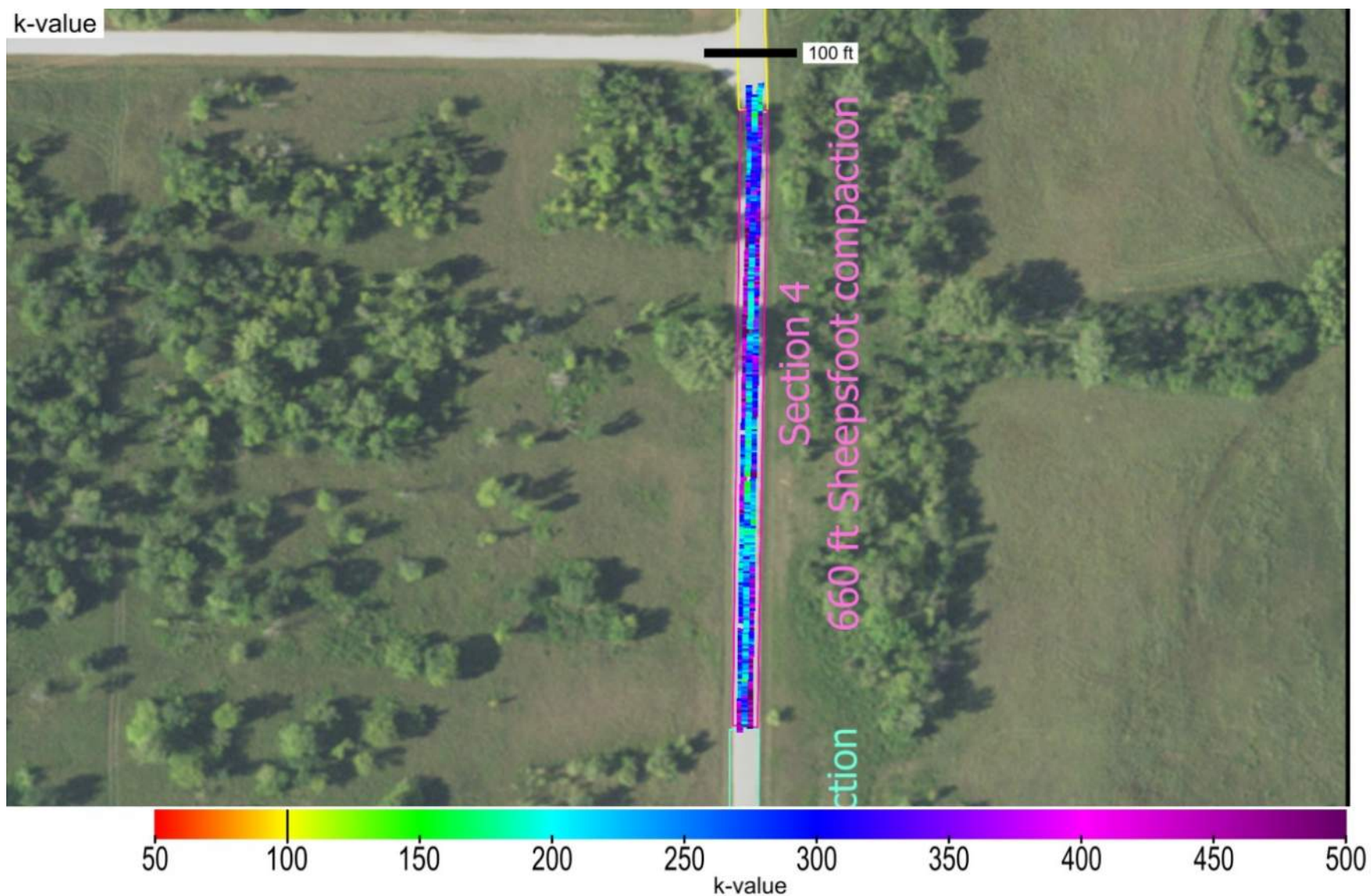
Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

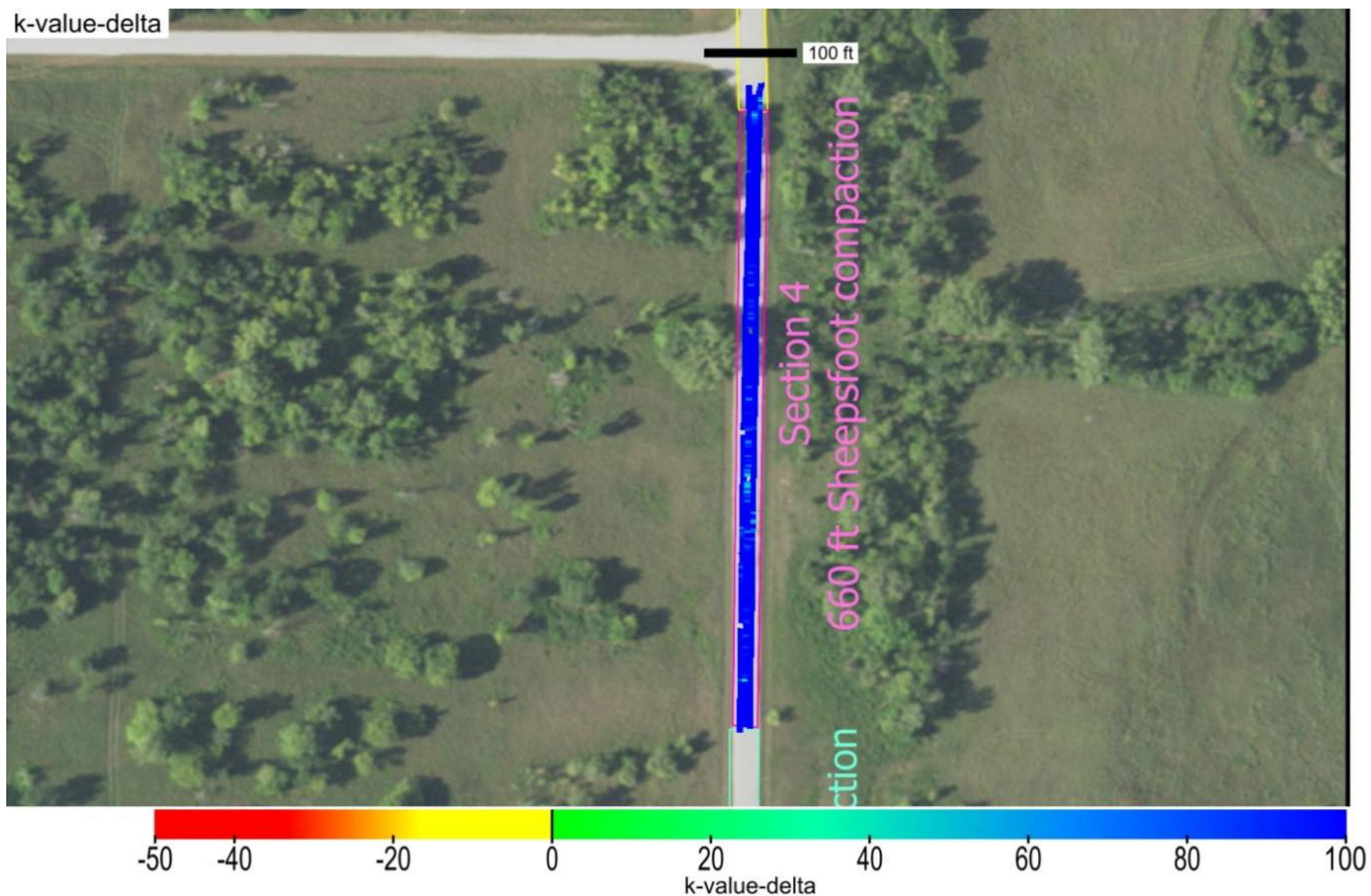
Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

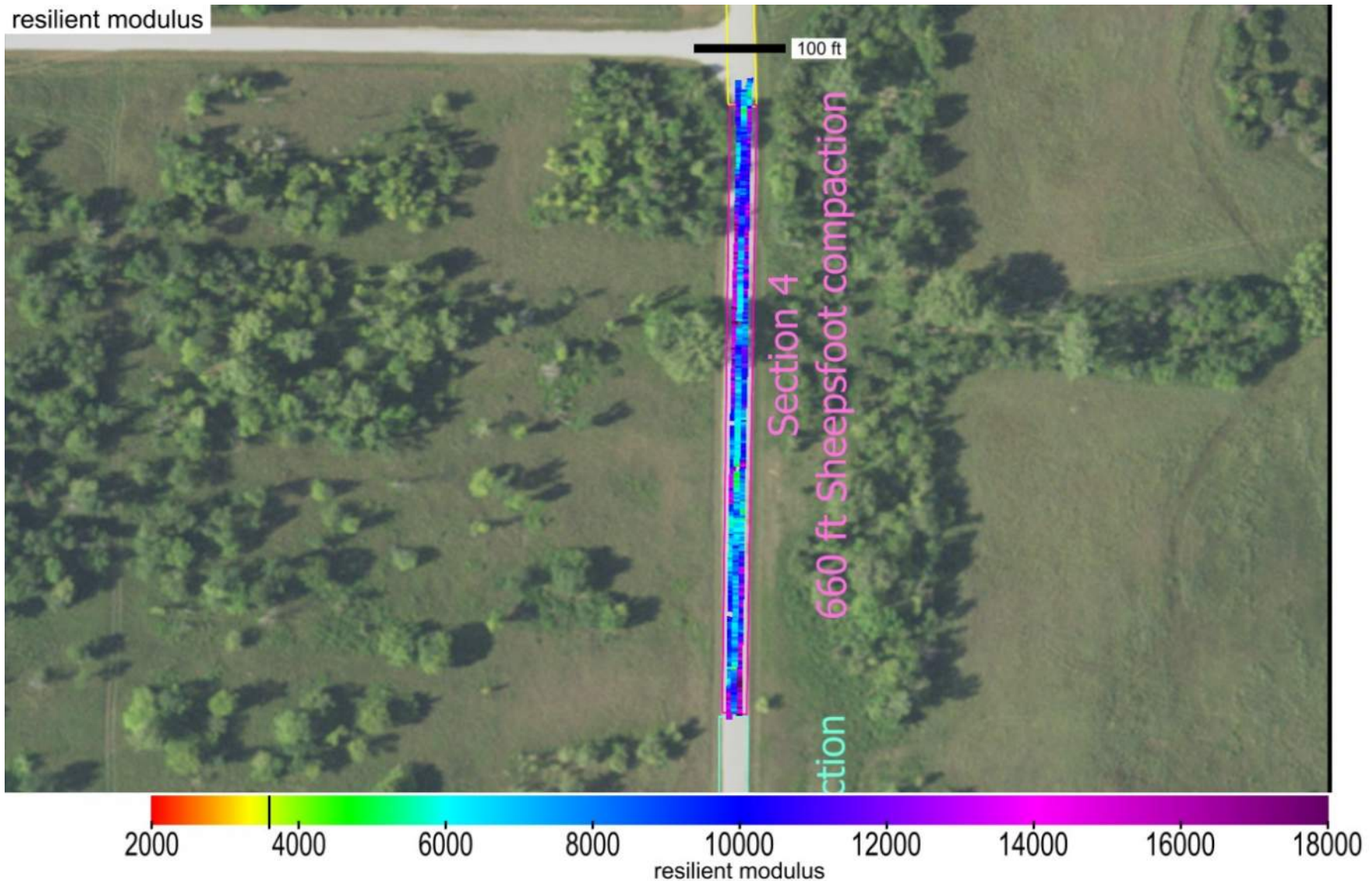
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	119.5	0.9	100.0	129.1	297.1	550.0	92.1	31.0	29.1	197.1	450.0



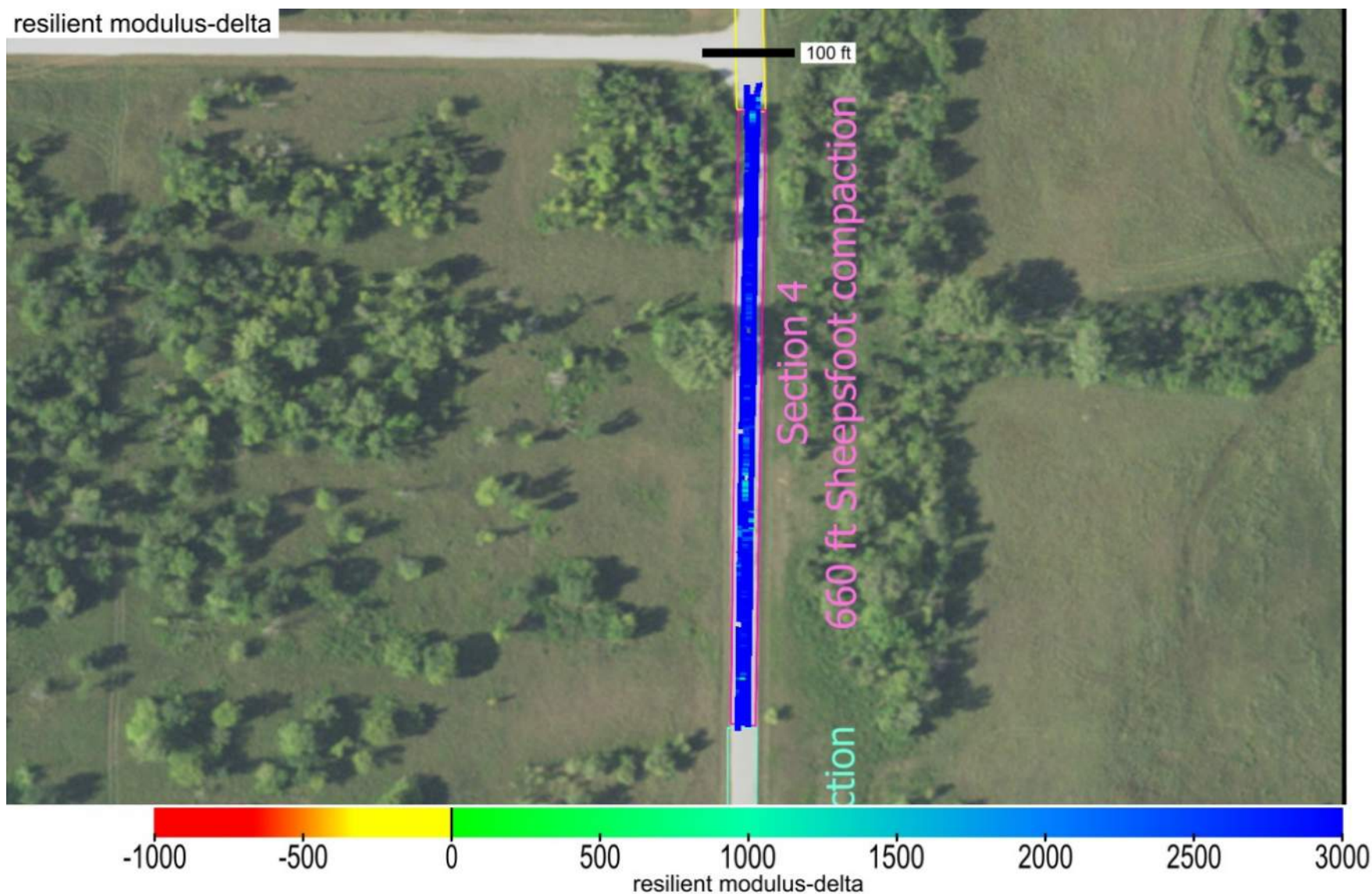
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	119.5	0.9	100.0	129.1	297.1	550.0	92.1	31.0	29.1	197.1	450.0



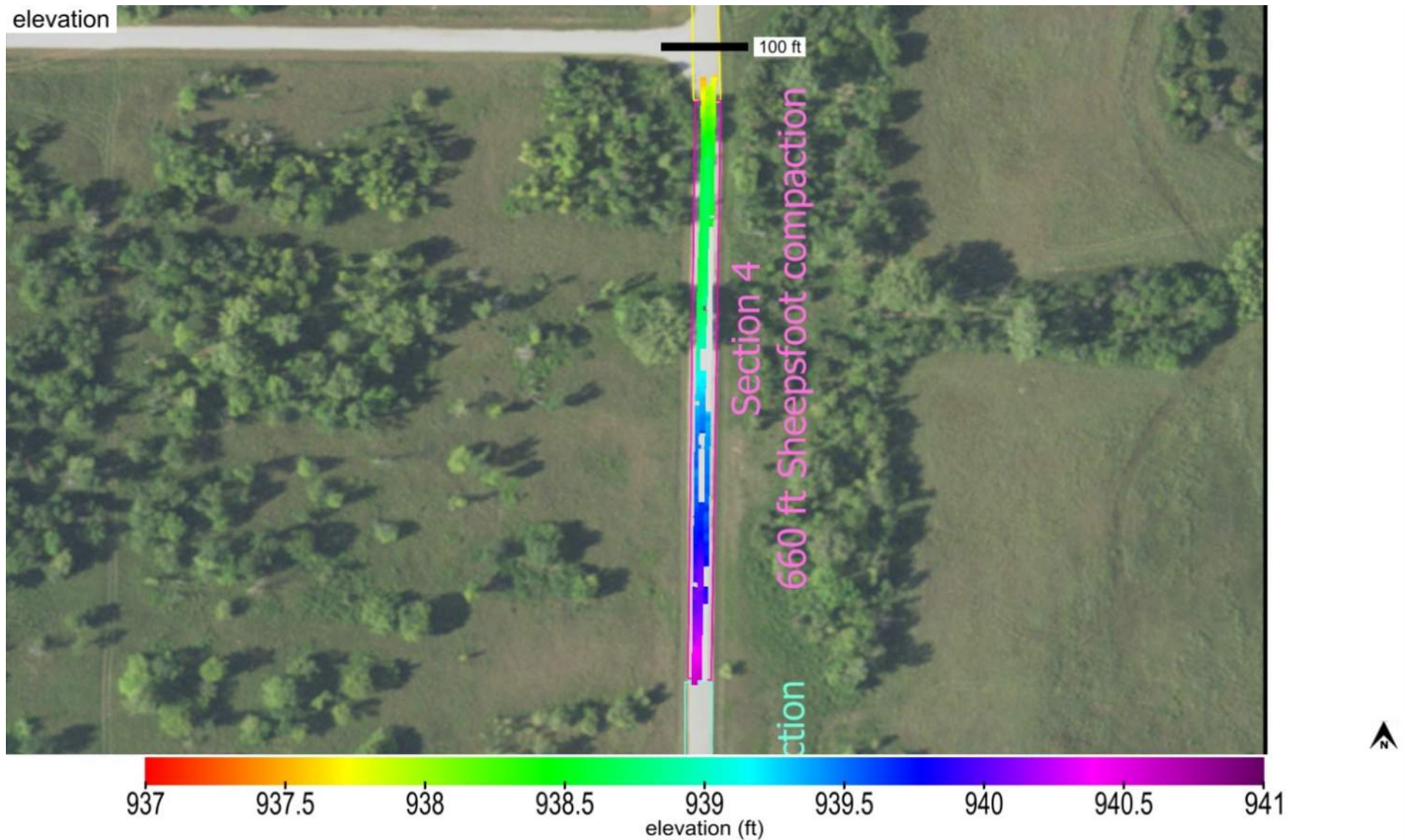
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	109.3	0.8	3600.0	4065.1	9582.4	20000.0	3003.9	31.4	465.1	5982.4	16400.0



Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	109.3	0.8	3600.0	4065.1	9582.4	20000.0	3003.9	31.4	465.1	5982.4	16400.0



minimum	average	maximum	RTK-Q7 (%)	RTK-QA
937.54	939.16	940.64	78.4	7.47





Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_03_07_110652

Project:	TR-823 Study	Date and Time:	3/7/2024 11:06:52 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.322	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	24911	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	5 - Control

Map Summary

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
XMV	No												
Resilient Modulus	Yes	99.8	108.1	0.7	3600.0	3491.2	11847.6	20000.0	3965.3	33.5	-108.8	8247.6	16400.0
k-value	Yes	100.0	120.0	0.5	100.0	107.5	374.2	550.0	112.5	30.1	7.5	274.2	450.0
Moisture Content	No												

Mapped Area		Pass Count					Elevation (ft)			Position Quality		Velocity (fps)		
square feet	acres	10th percentile	Median	cov(%)	% >= TV	Target Value	min.	avg.	max.	RTK-Q7 (%)	RTK-QA	min.	avg.	max.
24911	0.572	1	1	40.4	100.0	0	937.36	943.89	952.81	91.2	7.80	4.5	5.0	5.6

Materials

name	id	% of total	area-square ft	area-acres	tl-xmv	tl-Mr	tl-k value	tl-w%
Unpaved Gravel Road (not defined)_IADOT	41019	100.0	24911	0.572	100.0	3600.0	100.0	20.5

Blobs

parameter	min. area(ft^2)	# of blobs	blob area(ft^2)	% of map	lower bound-tv	upper bound-tv	poly-tol.
Resilient Modulus	500.0	0	0	0.0	none	0.0	4.0
k-value	500.0	0	0	0.0	none	0.0	4.0

Station

Start	End
13+20	26+40

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_03_07_110652

Project:	TR-823 Study	Date and Time:	3/7/2024 11:06:52 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.322	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	24911	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	5 - Control

QUALITY ANALYSIS SUMMARY - k-Value

Quality Value	Criteria
120.0	CQI > = 95
100.0	80% of k-Value MVs >= 100
30.1	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_03_07_110652

Project:	TR-823 Study	Date and Time:	3/7/2024 11:06:52 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.322	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	24911	Machine Operator ID:	822
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	5 - Control

QUALITY ANALYSIS SUMMARY - Resilient Modulus

Quality Value	Criteria
108.1	CQI > = 95
99.8	90% of Resilient Modulus MVs >= 3600
33.5	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

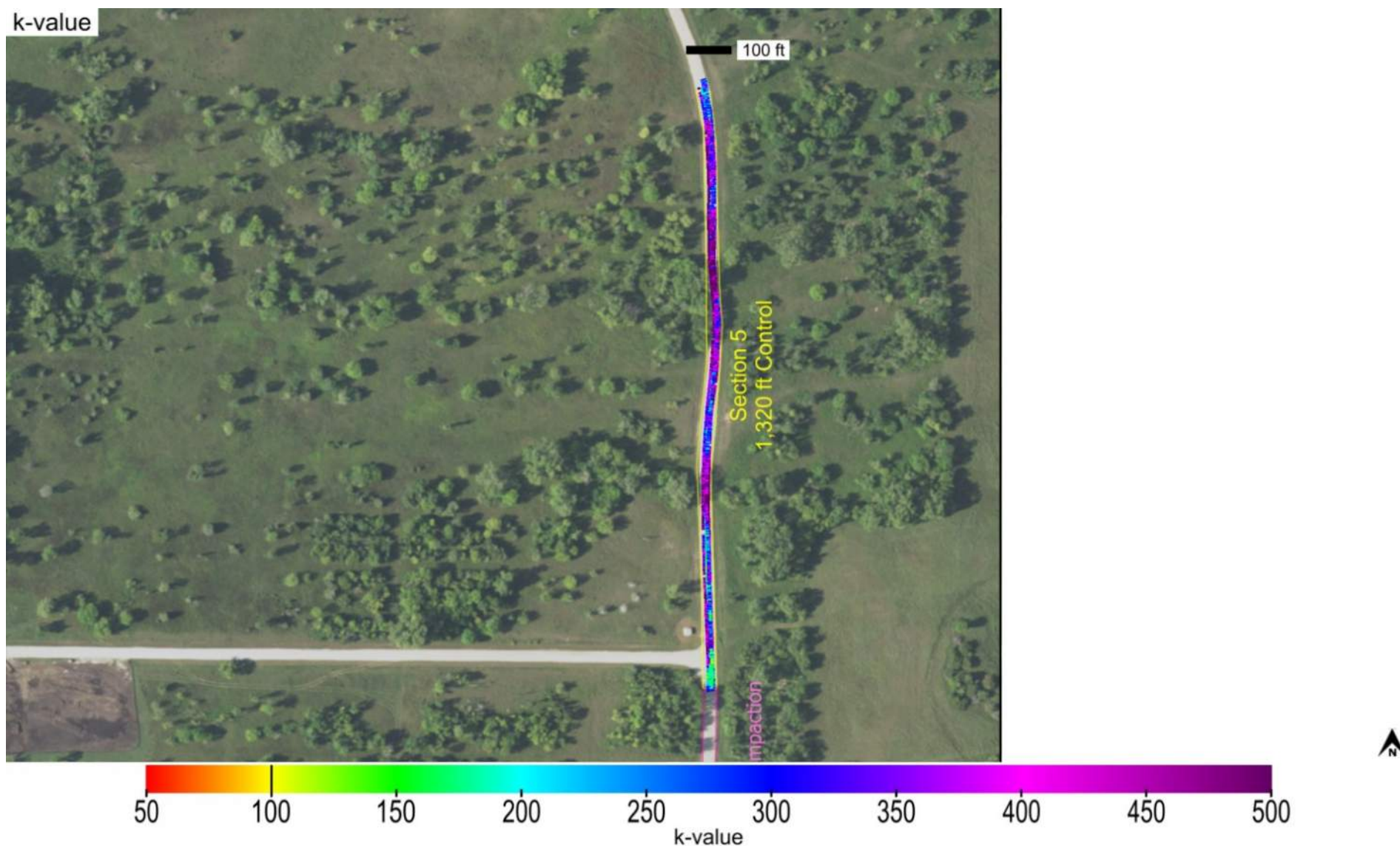
Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

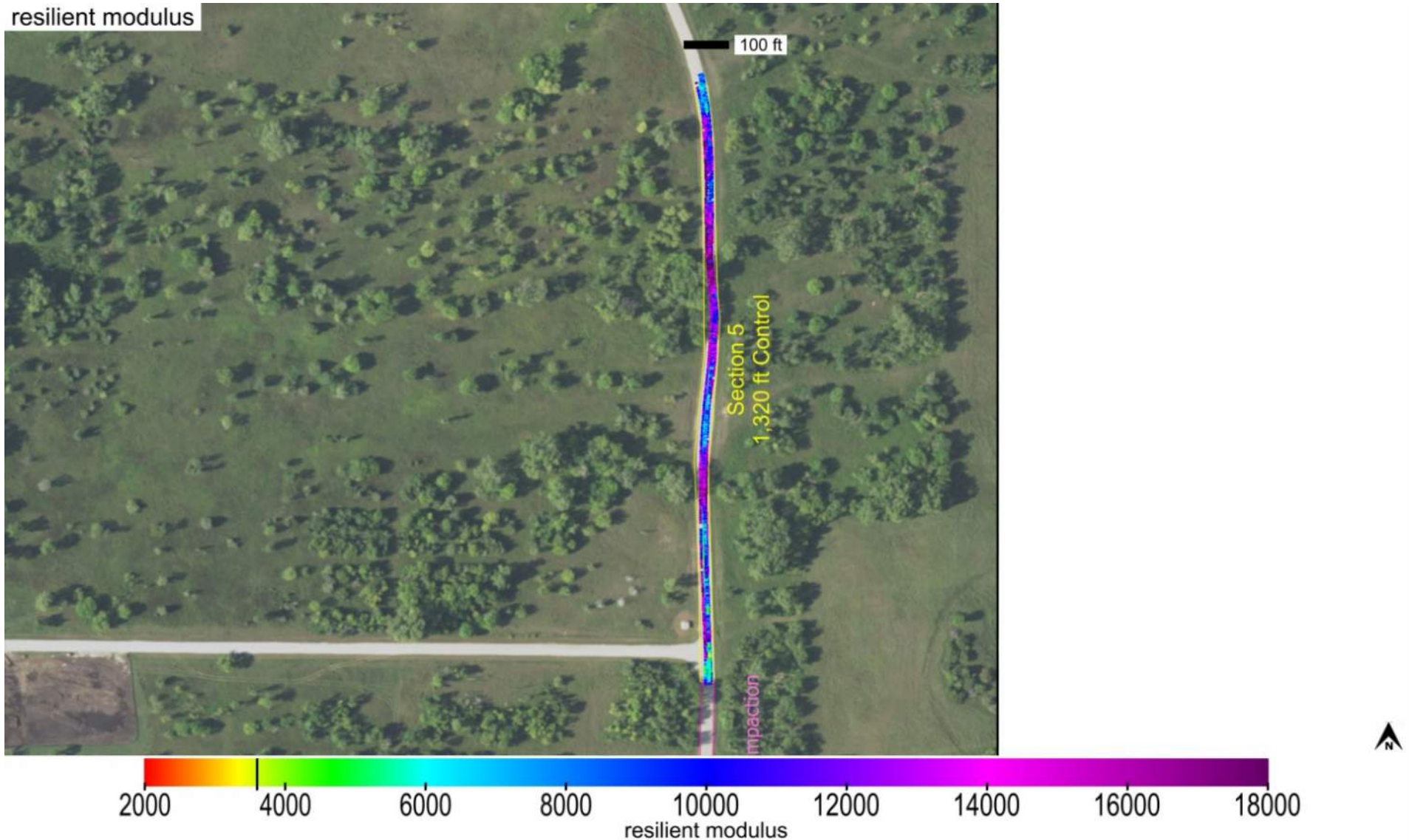
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	120.0	0.5	100.0	107.5	374.2	550.0	112.5	30.1	7.5	274.2	450.0



Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	120.0	0.5	100.0	107.5	374.2	550.0	112.5	30.1	7.5	274.2	450.0

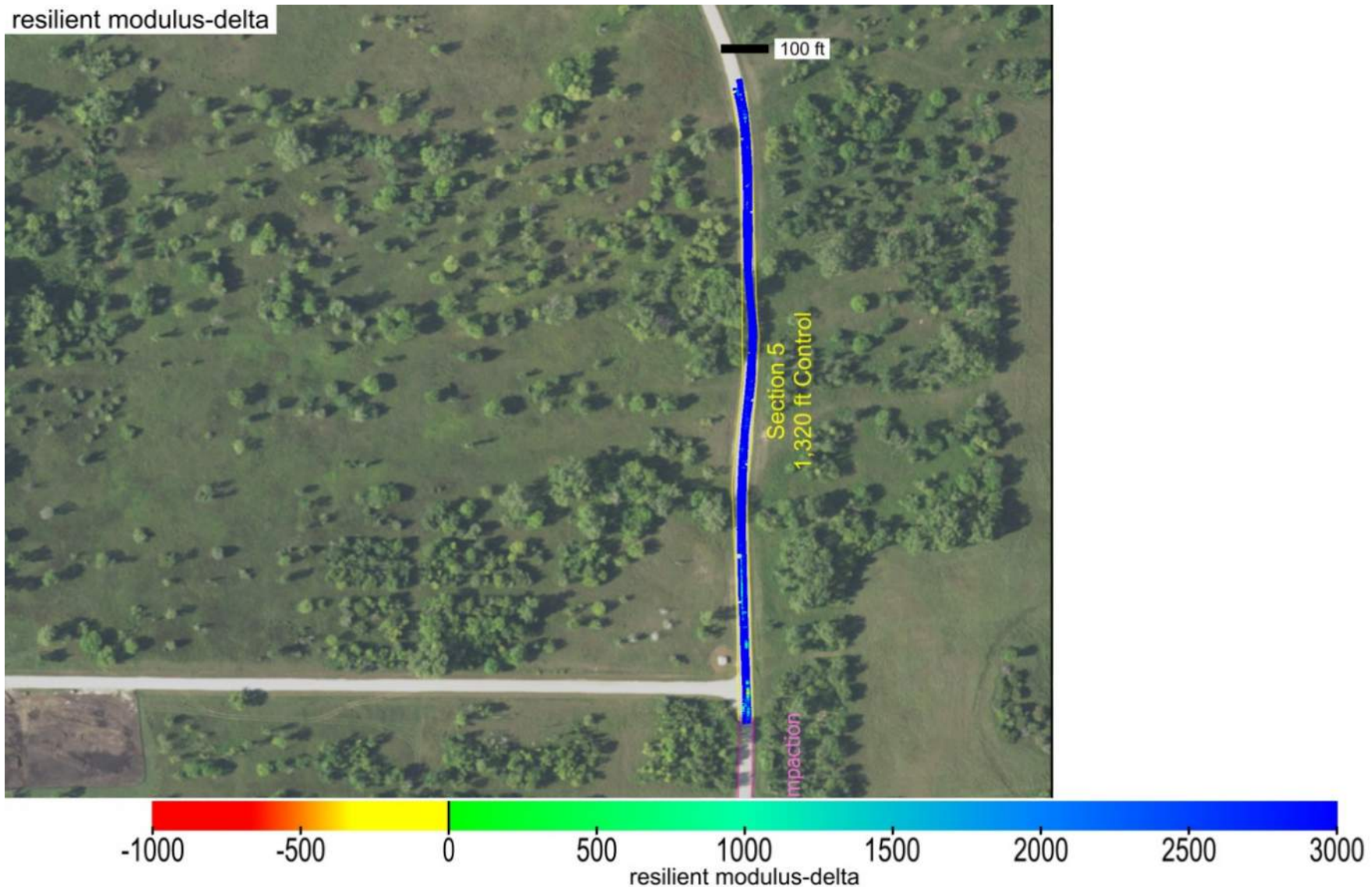


Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	99.8	108.1	0.7	3600.0	3491.2	11847.6	20000.0	3965.3	33.5	-108.8	8247.6	16400.0

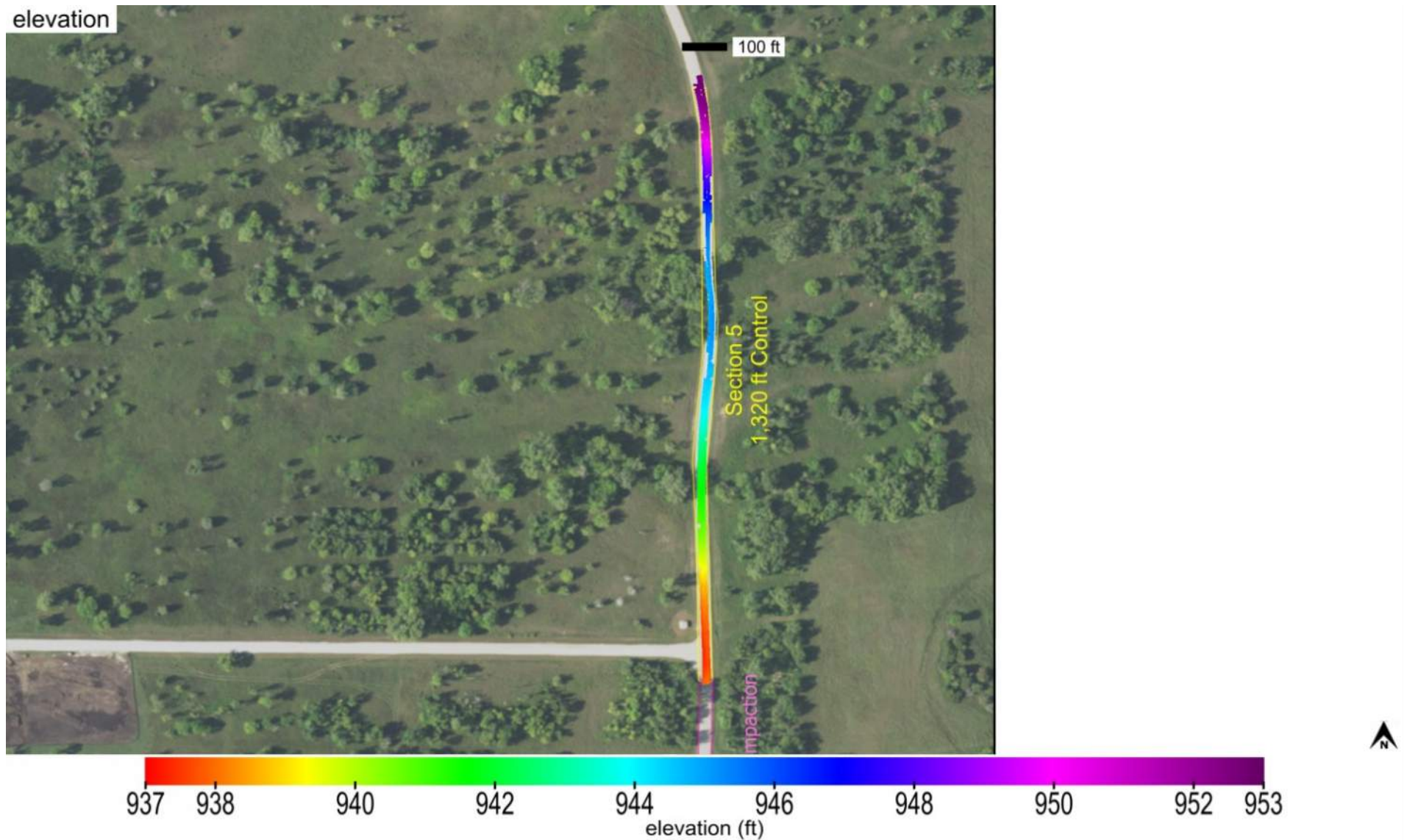


Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	99.8	108.1	0.7	3600.0	3491.2	11847.6	20000.0	3965.3	33.5	-108.8	8247.6	16400.0

resilient modulus-delta



minimum	average	maximum	RTK-Q7 (%)	RTK-QA
937.36	943.89	952.81	91.2	7.80



Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_03_07_110652 Map Type: Verification Map Map Layer: Unpaved Gravel Road

ing_polk77-campdodge-2023_cs56b-01047_2024_03_07_110652_20240307T122059_IMG-1163.jpeg



Map ID: ing_pol77-campdodge-2023_cs56b-01047_2024_10_31_110208

Project:	TR-823 Study	Date and Time:	10/31/2024 11:02:08 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.374	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	38454	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	1 - STAB + Smooth Drum

Map Summary

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
XMV	No												
Resilient Modulus	Yes	100.0	111.6	1.0	3600.0	4225.5	10094.0	20000.0	2698.9	26.7	625.5	6494.0	16400.0
k-value	Yes	100.0	121.3	0.9	100.0	129.3	308.9	550.0	84.8	27.4	29.3	208.9	450.0
Moisture Content	No												

Mapped Area		Pass Count					Elevation (ft)			Position Quality		Velocity (fps)		
square feet	acres	10th percentile	Median	cov(%)	% >= TV	Target Value	min.	avg.	max.	RTK-Q7 (%)	RTK-QA	min.	avg.	max.
38454	0.883	1	1	30.5	100.0	0	915.11	931.36	949.12	100.0	8.00	4.4	5.2	5.8

Materials

name	id	% of total	area-square ft	area-acres	tl-xmv	tl-Mr	tl-k value	tl-w%
Unpaved Gravel Road (not defined)_IADOT	41019	100.0	38454	0.883	100.0	3600.0	100.0	20.5

Blobs

parameter	min. area(ft^2)	# of blobs	blob area(ft^2)	% of map	lower bound-tv	upper bound-tv	poly-tol.
Resilient Modulus	500.0	0	0	0.0	none	0.0	4.0
k-value	500.0	0	0	0.0	none	0.0	4.0

Station

Start	End
0+00	0+00

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_10_31_110208

Project:	TR-823 Study	Date and Time:	10/31/2024 11:02:08 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.374	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	38454	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	1 - STAB + Smooth Drum

QUALITY ANALYSIS SUMMARY - k-Value

Quality Value	Criteria
121.3	CQI > = 95
100.0	80% of k-Value MVs >= 100
27.4	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_10_31_110208

Project:	TR-823 Study	Date and Time:	10/31/2024 11:02:08 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.374	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	38454	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	1 - STAB + Smooth Drum

QUALITY ANALYSIS SUMMARY - Resilient Modulus

Quality Value	Criteria
111.6	CQI > = 95
100.0	90% of Resilient Modulus MVs >= 3600
26.7	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

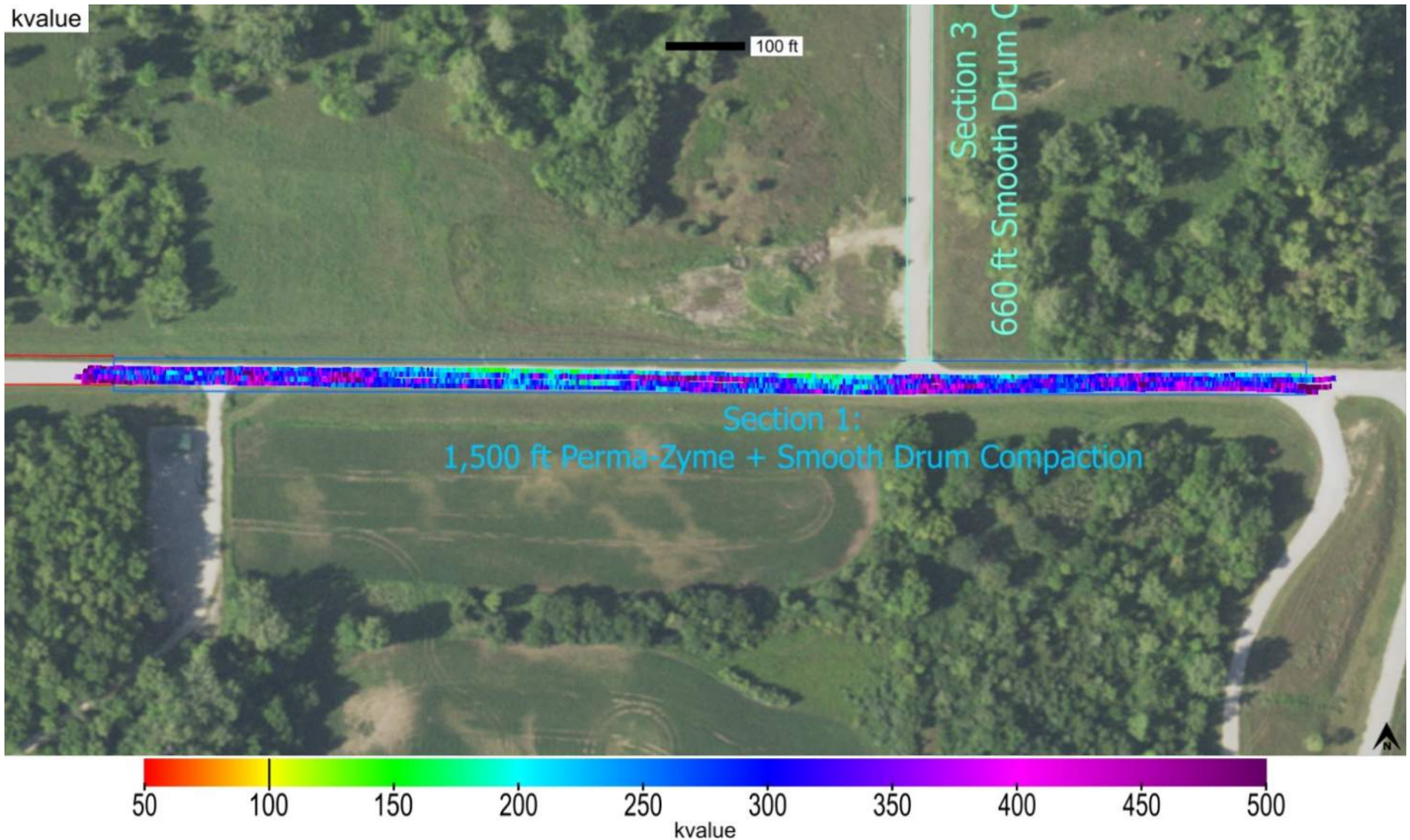
Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

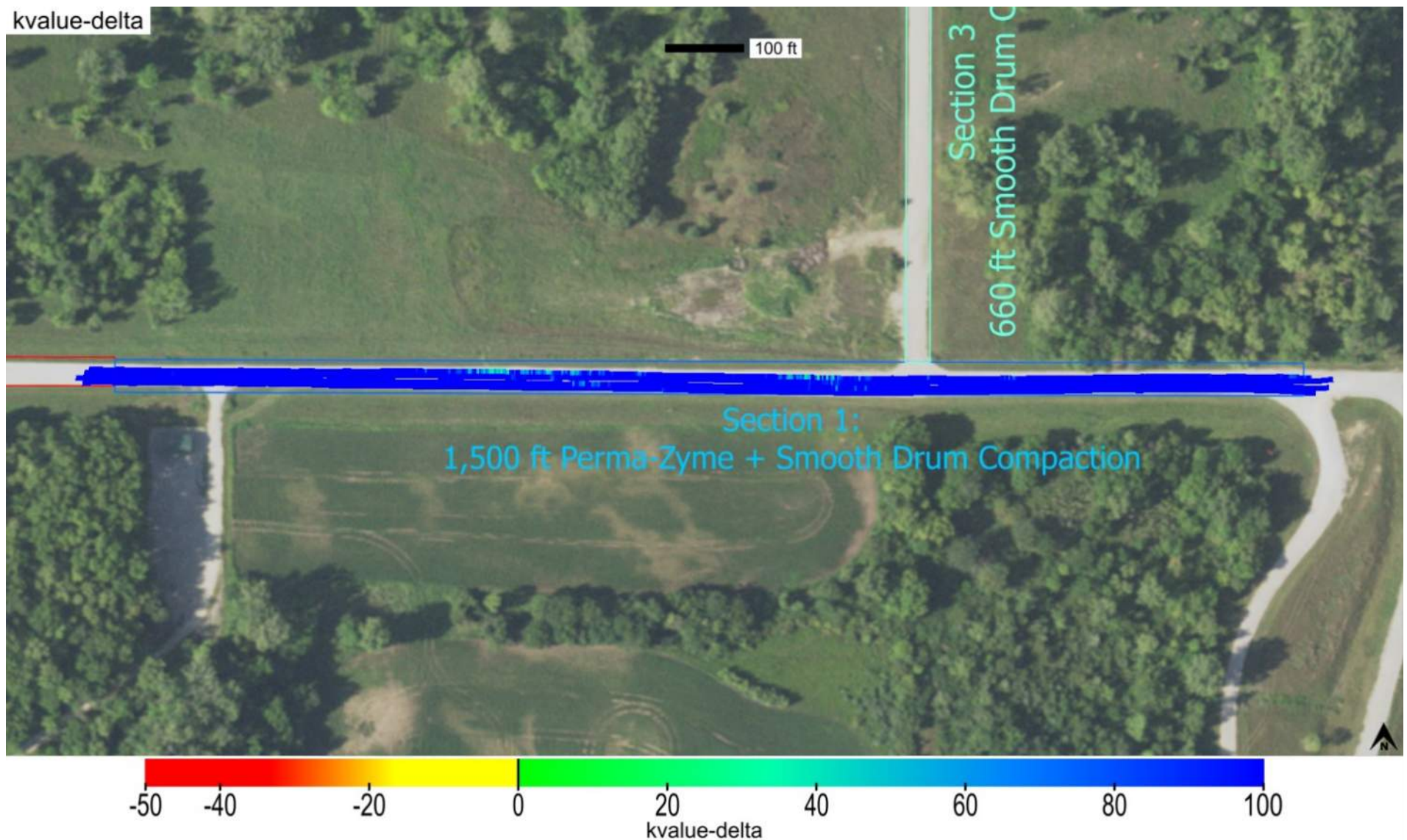
Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

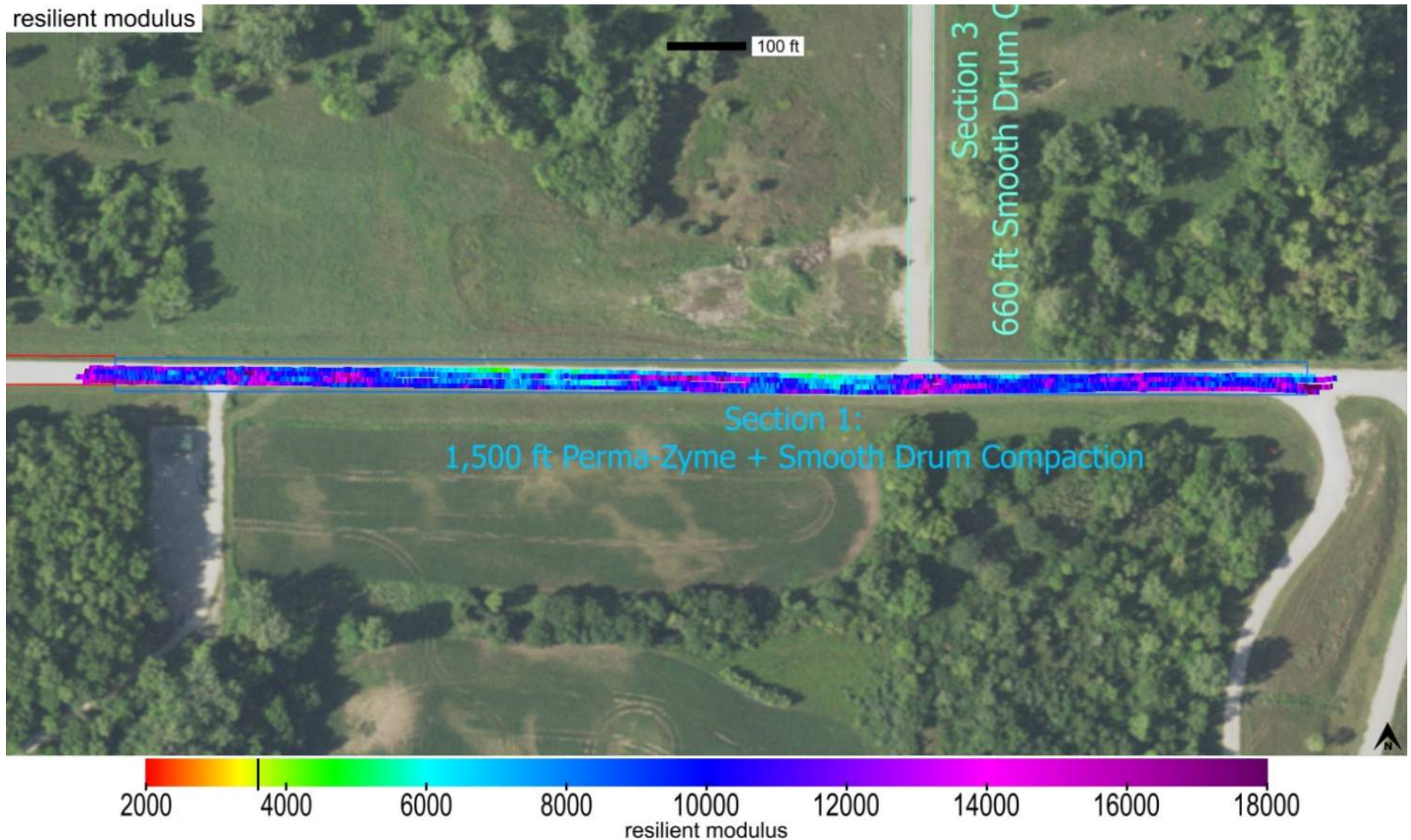
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	121.3	0.9	100.0	129.3	308.9	550.0	84.8	27.4	29.3	208.9	450.0



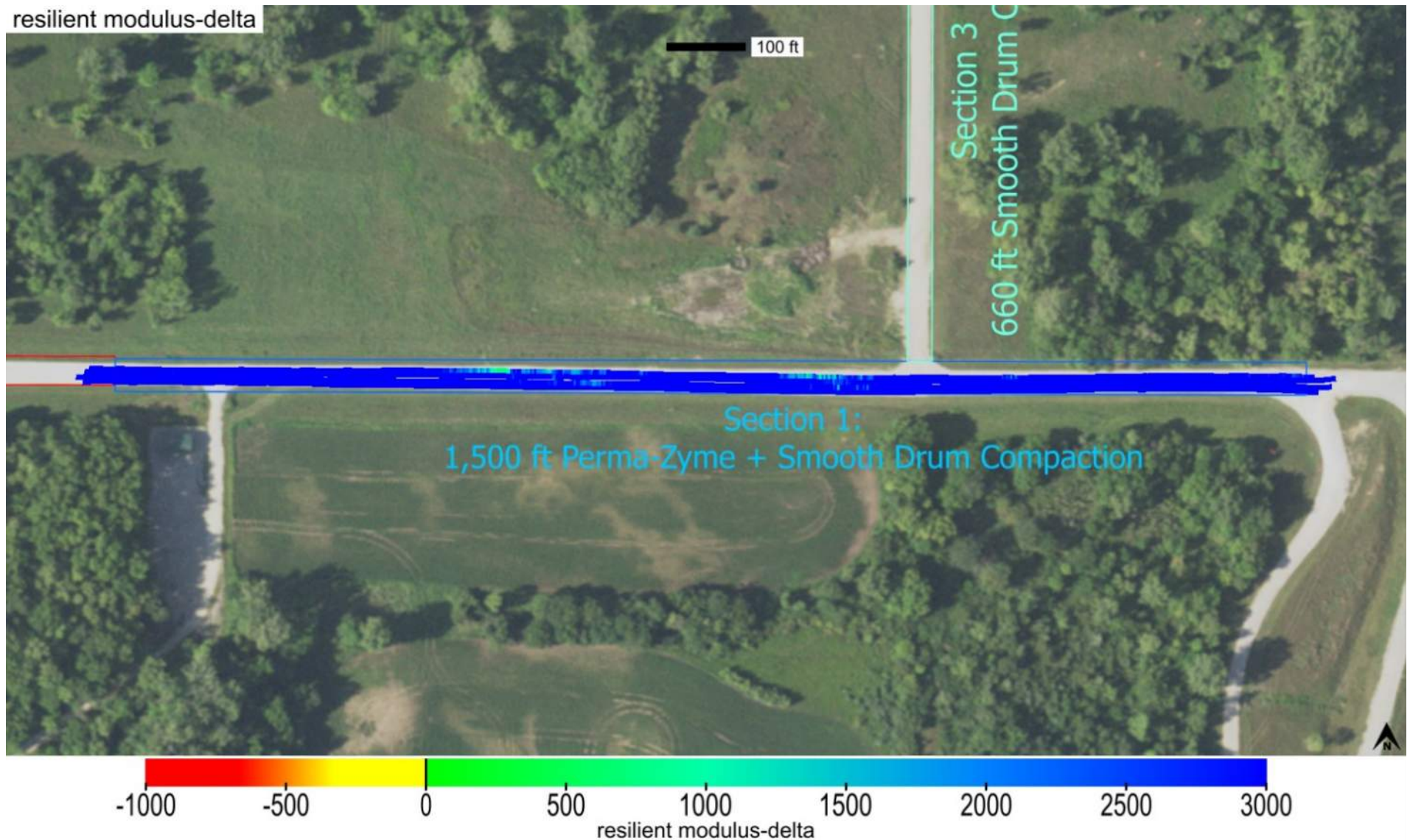
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	121.3	0.9	100.0	129.3	308.9	550.0	84.8	27.4	29.3	208.9	450.0



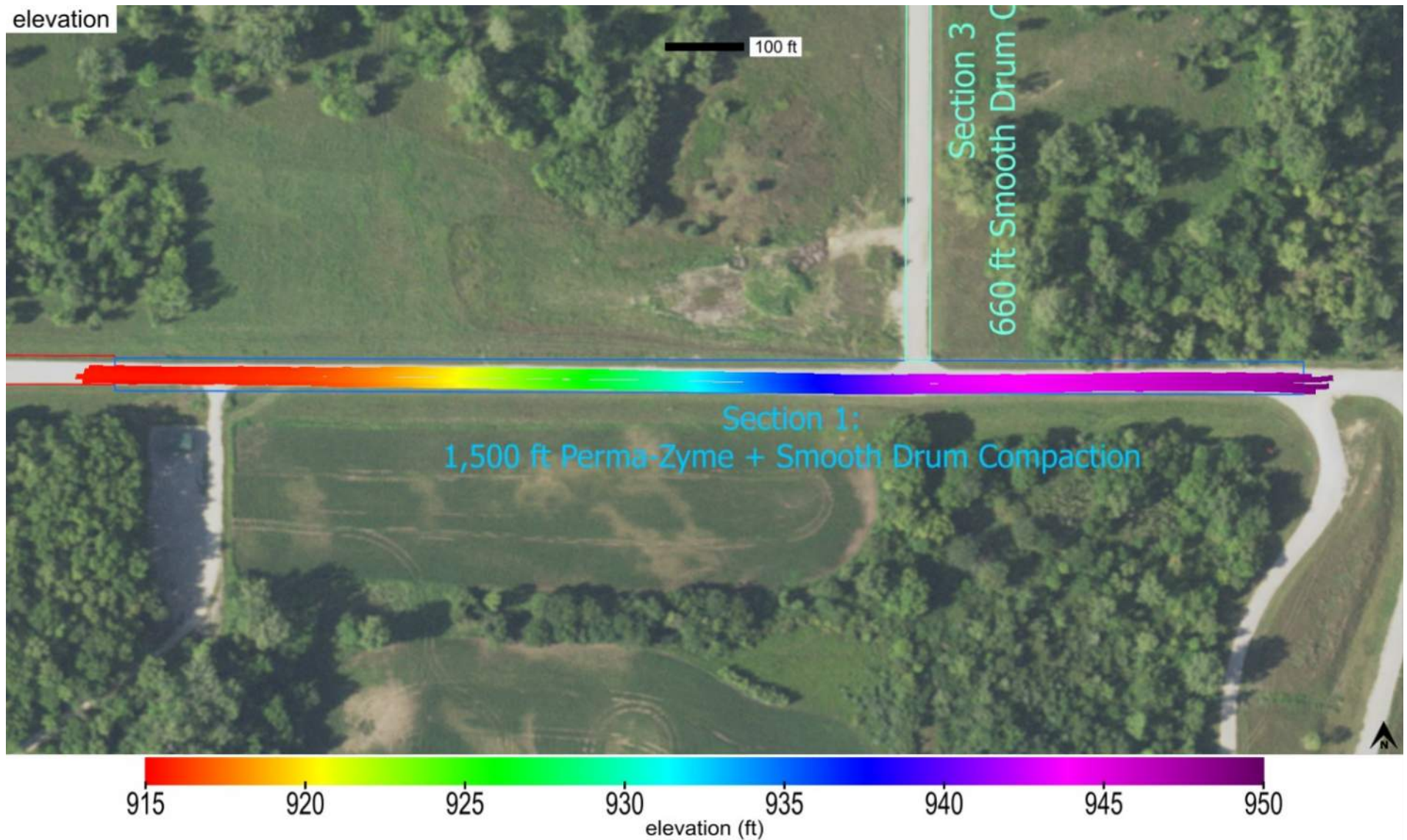
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	111.6	1.0	3600.0	4225.5	10094.0	20000.0	2698.9	26.7	625.5	6494.0	16400.0

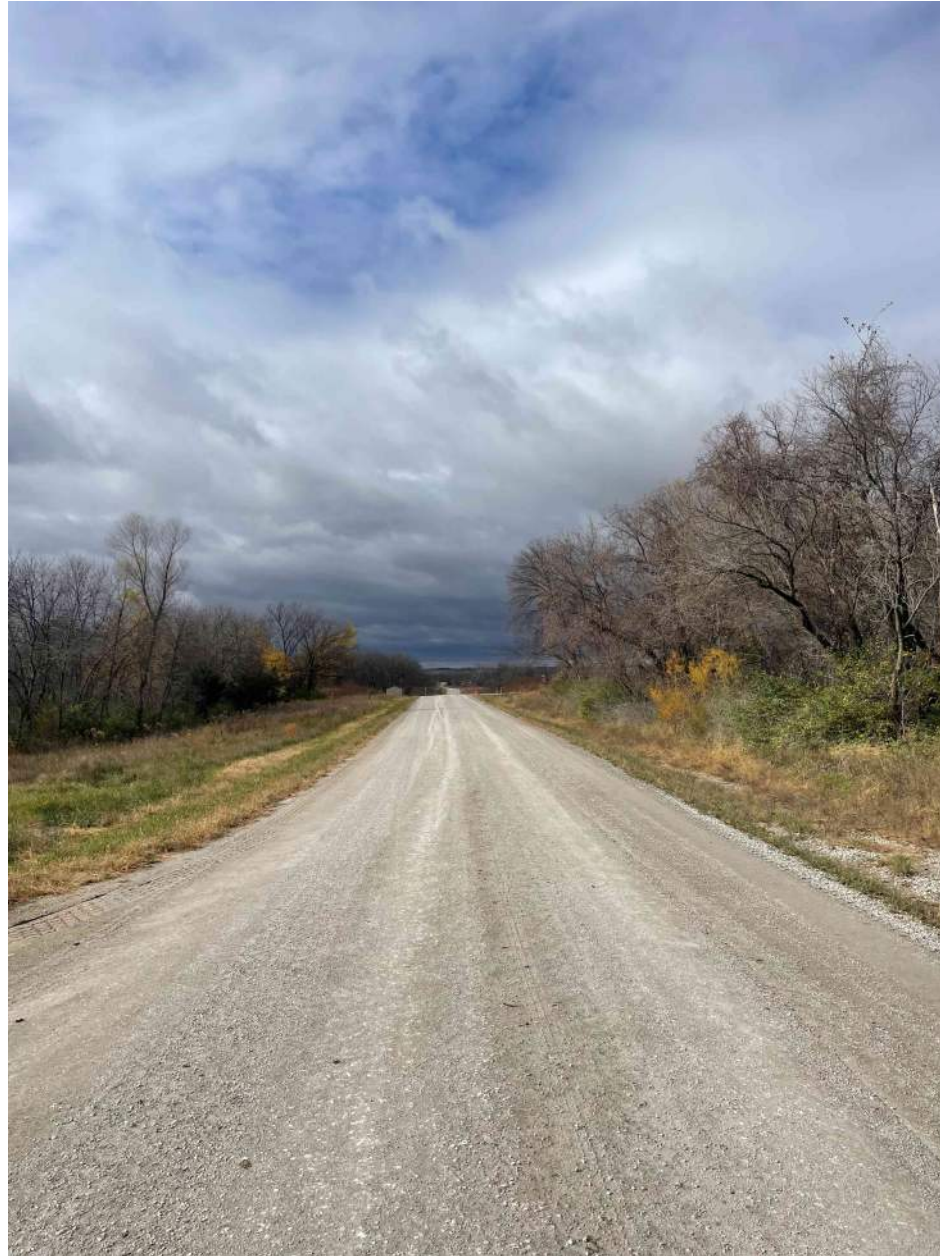


Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	111.6	1.0	3600.0	4225.5	10094.0	20000.0	2698.9	26.7	625.5	6494.0	16400.0



minimum	average	maximum	RTK-Q7 (%)	RTK-QA
915.11	931.36	949.13	100.0	8.00





Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_10_31_112817

Project:	TR-823 Study	Date and Time:	10/31/2024 11:28:17 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.457	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	42261	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	2 - STAB + Sheepsfoot

Map Summary

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
XMV	No												
Resilient Modulus	Yes	100.0	108.2	0.8	3600.0	4281.1	11092.7	20000.0	3719.9	33.5	681.1	7492.7	16400.0
k-value	Yes	100.0	119.0	0.6	100.0	131.3	339.7	550.0	108.5	31.9	31.3	239.7	450.0
Moisture Content	No												

Mapped Area		Pass Count					Elevation (ft)			Position Quality		Velocity (fps)		
square feet	acres	10th percentile	Median	cov(%)	% >= TV	Target Value	min.	avg.	max.	RTK-Q7 (%)	RTK-QA	min.	avg.	max.
42261	0.970	1	1	35.8	100.0	0	894.01	907.24	916.87	100.0	8.00	4.9	5.3	6.4

Materials

name	id	% of total	area-square ft	area-acres	tl-xmv	tl-Mr	tl-k value	tl-w%
Unpaved Gravel Road (not defined)_IADOT	41019	100.0	42261	0.970	100.0	3600.0	100.0	20.5

Blobs

parameter	min. area(ft^2)	# of blobs	blob area(ft^2)	% of map	lower bound-tv	upper bound-tv	poly-tol.
Resilient Modulus	500.0	0	0	0.0	none	0.0	4.0
k-value	500.0	0	0	0.0	none	0.0	4.0

Station

Start	End
0+00	0+00

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_10_31_112817

Project:	TR-823 Study	Date and Time:	10/31/2024 11:28:17 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.457	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	42261	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	2 - STAB + Sheepsfoot

QUALITY ANALYSIS SUMMARY - k-Value

Quality Value	Criteria
119.0	CQI > = 95
100.0	80% of k-Value MVs >= 100
31.9	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_10_31_112817

Project:	TR-823 Study	Date and Time:	10/31/2024 11:28:17 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.457	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	42261	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	2 - STAB + Sheepsfoot

QUALITY ANALYSIS SUMMARY - Resilient Modulus

Quality Value	Criteria
108.2	CQI > = 95
100.0	90% of Resilient Modulus MVs >= 3600
33.5	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

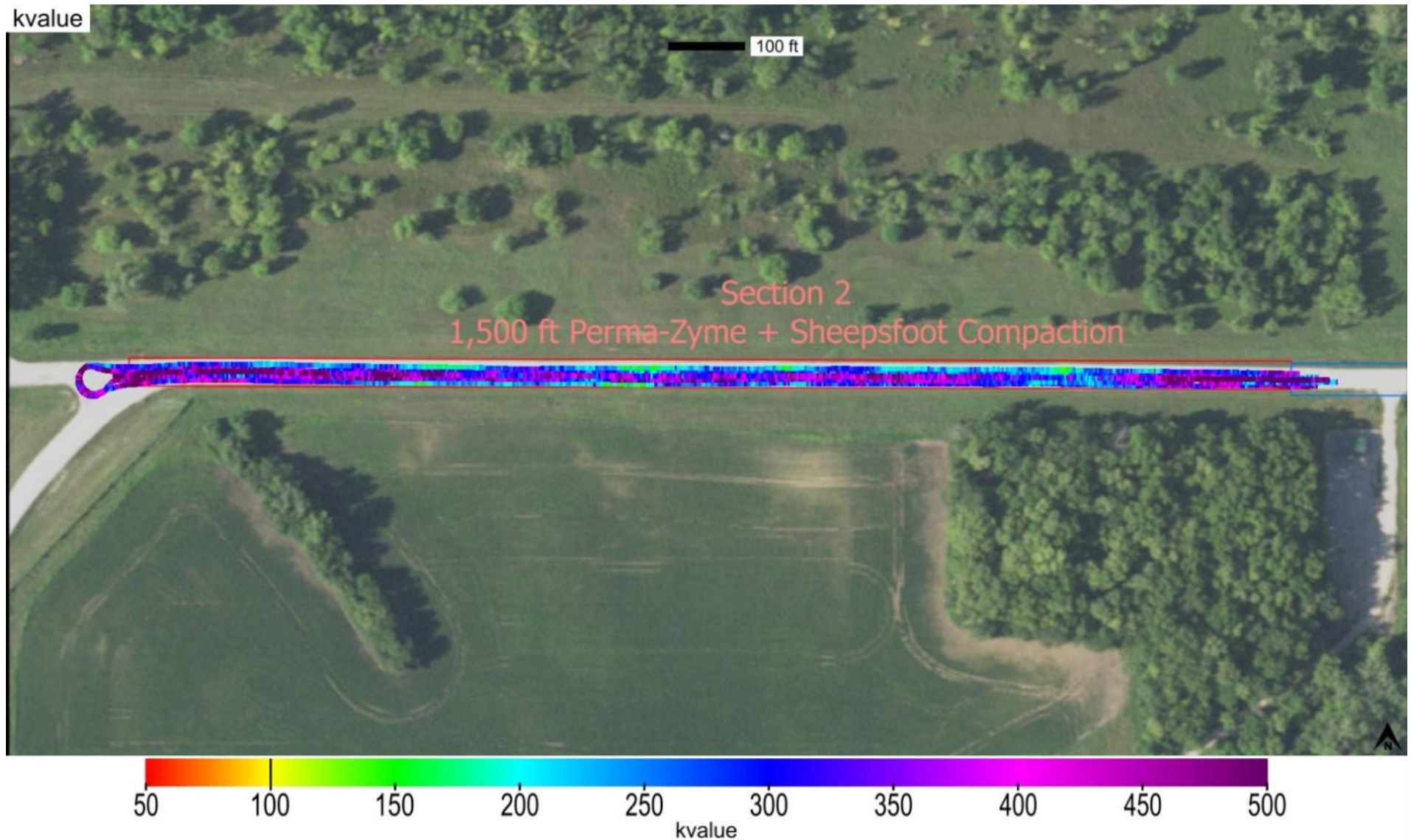
Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

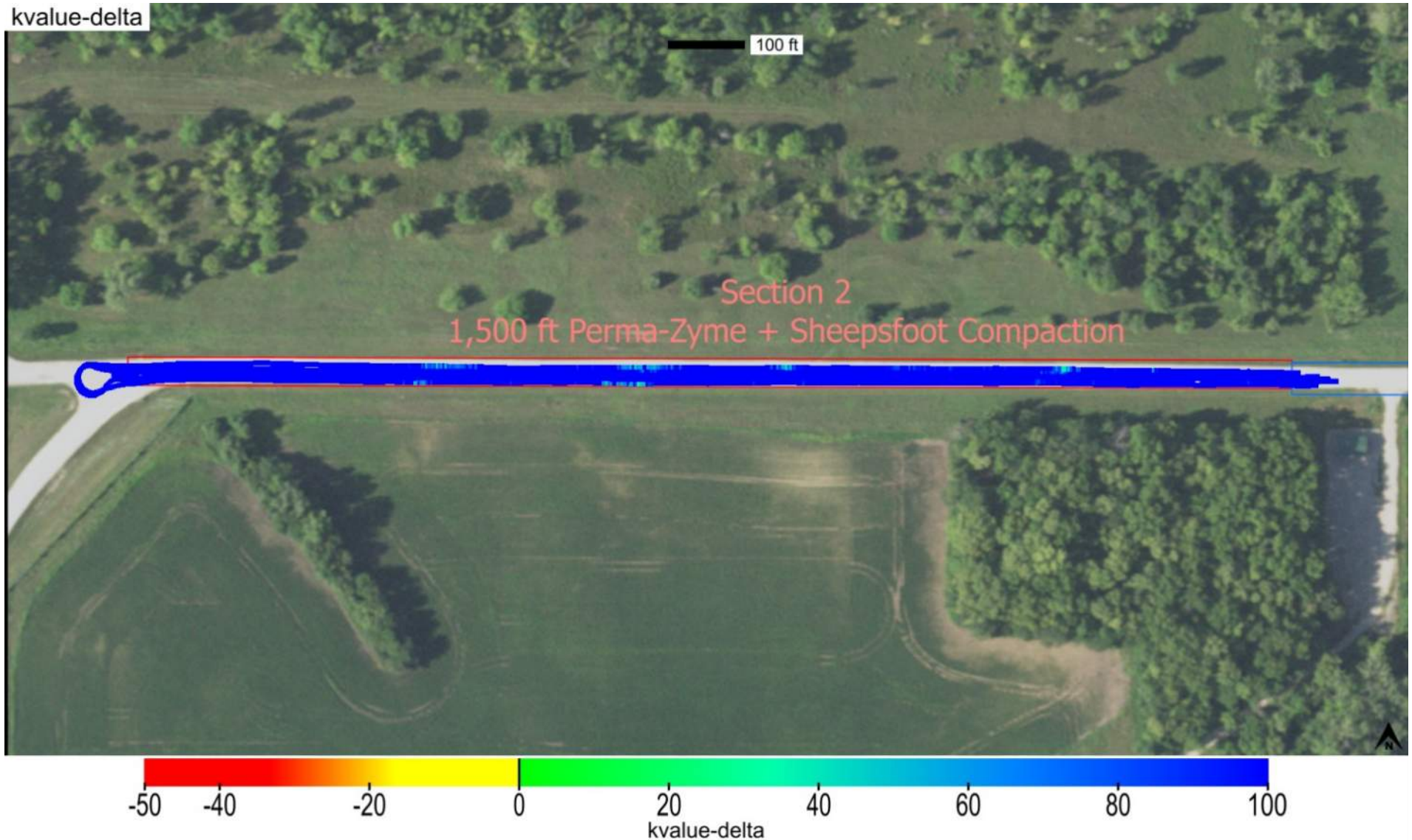
Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

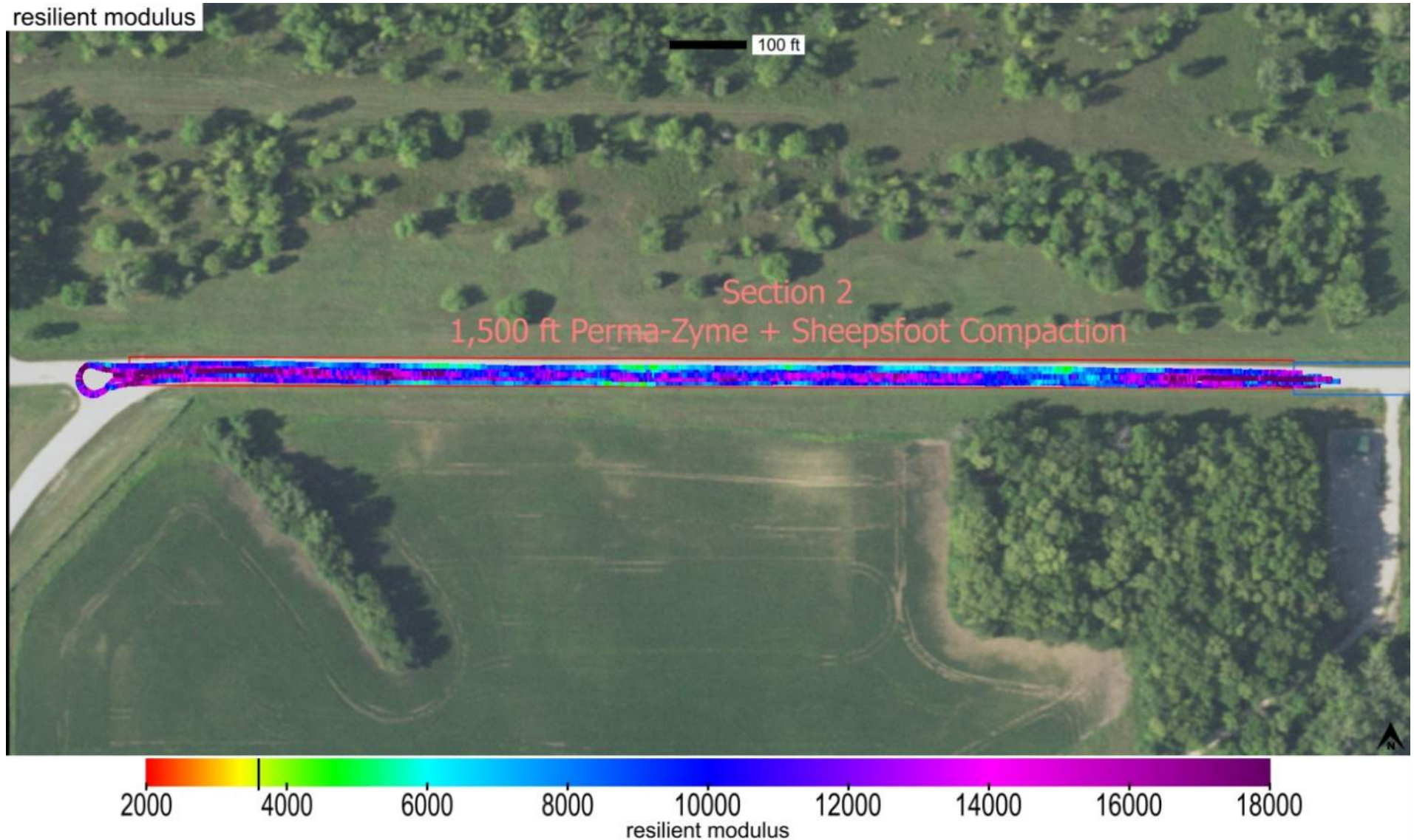
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	119.0	0.6	100.0	131.3	339.7	550.0	108.5	31.9	31.3	239.7	450.0



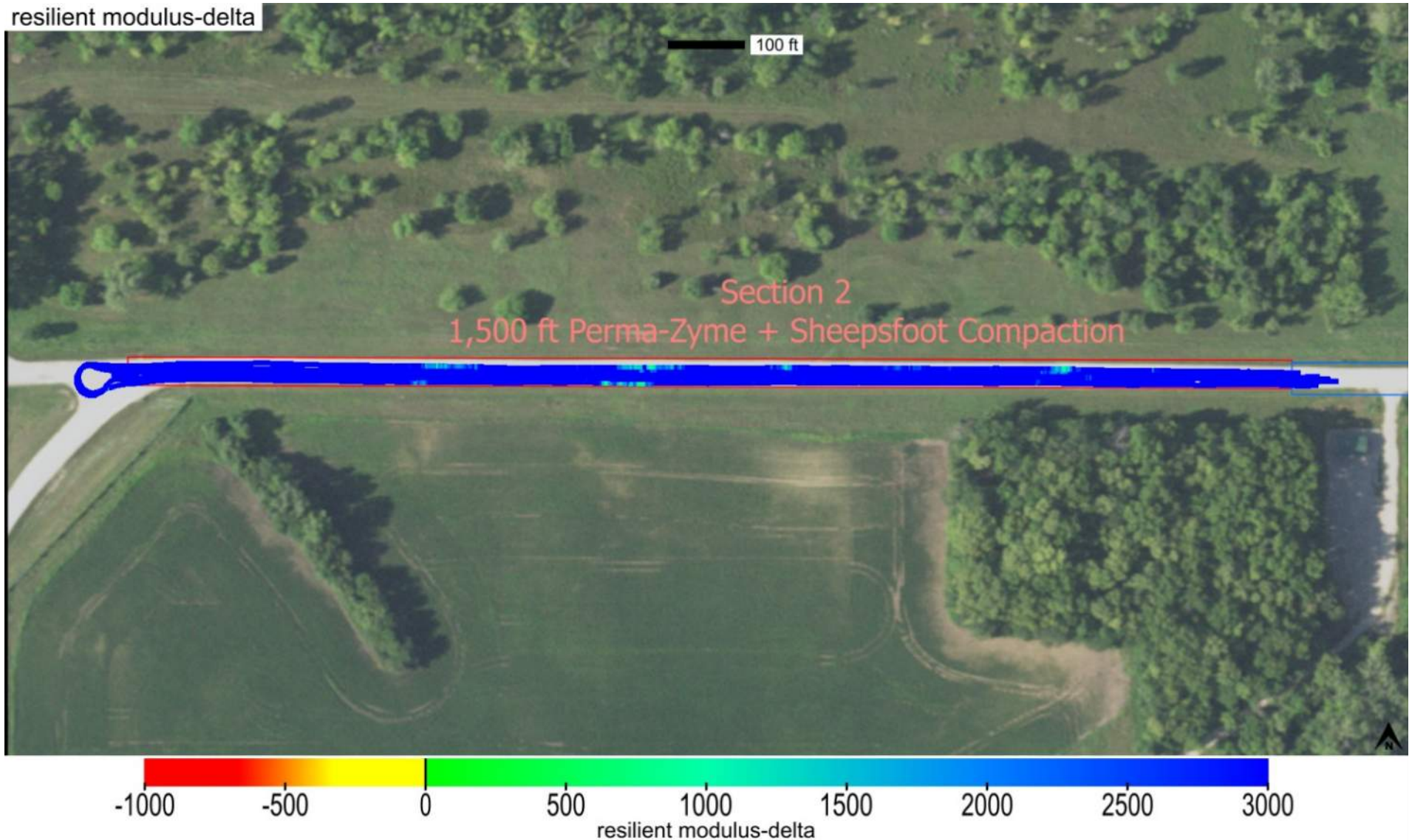
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	119.0	0.6	100.0	131.3	339.7	550.0	108.5	31.9	31.3	239.7	450.0



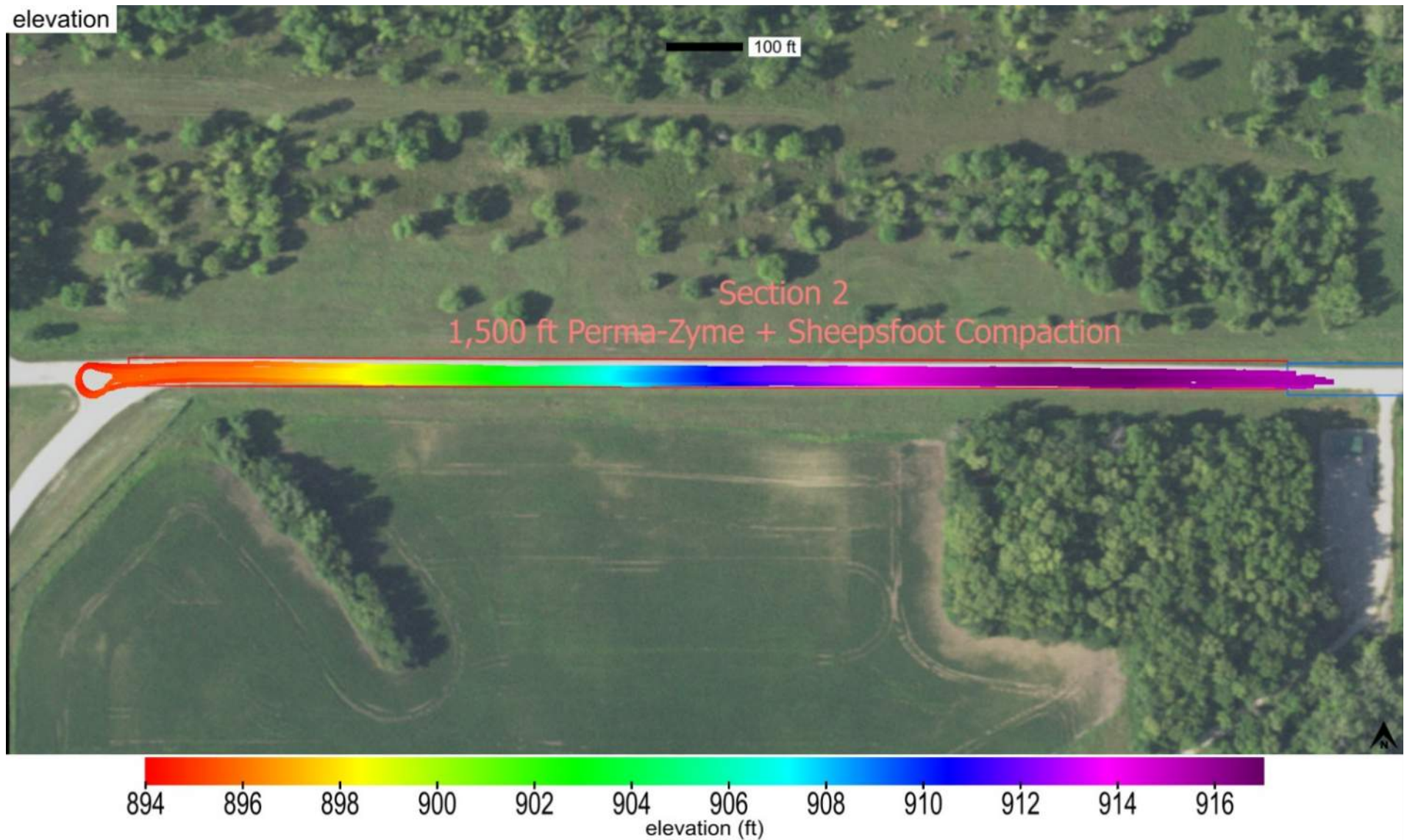
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	108.2	0.8	3600.0	4281.1	11092.7	20000.0	3719.9	33.5	681.1	7492.7	16400.0



Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	108.2	0.8	3600.0	4281.1	11092.7	20000.0	3719.9	33.5	681.1	7492.7	16400.0



minimum	average	maximum	RTK-Q7 (%)	RTK-QA
894.01	907.24	916.87	100.0	8.00





Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_10_31_104556

Project:	TR-823 Study	Date and Time:	10/31/2024 10:45:56 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.175	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	15017	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	3 - Smooth Drum

Map Summary

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
XMV	No												
Resilient Modulus	Yes	99.9	108.0	0.8	3600.0	3519.2	11192.4	20000.0	3798.6	33.9	-80.8	7592.4	16400.0
k-value	Yes	100.0	118.8	0.7	100.0	122.7	335.2	550.0	108.5	32.4	22.7	235.2	450.0
Moisture Content	No												

Mapped Area		Pass Count					Elevation (ft)			Position Quality		Velocity (fps)		
square feet	acres	10th percentile	Median	cov(%)	% >= TV	Target Value	min.	avg.	max.	RTK-Q7 (%)	RTK-QA	min.	avg.	max.
15017	0.345	1	1	35.2	100.0	0	939.99	942.42	944.26	100.0	7.94	4.8	5.3	6.4

Materials

name	id	% of total	area-square ft	area-acres	tl-xmv	tl-Mr	tl-k value	tl-w%
Unpaved Gravel Road (not defined)_IADOT	41019	100.0	15017	0.345	100.0	3600.0	100.0	20.5

Blobs

parameter	min. area(ft^2)	# of blobs	blob area(ft^2)	% of map	lower bound-tv	upper bound-tv	poly-tol.
Resilient Modulus	500.0	0	0	0.0	none	0.0	4.0
k-value	500.0	0	0	0.0	none	0.0	4.0

Station

Start	End
0+00	0+00

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_10_31_104556

Project:	TR-823 Study	Date and Time:	10/31/2024 10:45:56 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.175	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	15017	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	3 - Smooth Drum

QUALITY ANALYSIS SUMMARY - k-Value

Quality Value	Criteria
118.8	CQI > = 95
100.0	80% of k-Value MVs >= 100
32.4	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_10_31_104556

Project:	TR-823 Study	Date and Time:	10/31/2024 10:45:56 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.175	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	15017	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	3 - Smooth Drum

QUALITY ANALYSIS SUMMARY - Resilient Modulus

Quality Value	Criteria
108.0	CQI > = 95
99.9	90% of Resilient Modulus MVs >= 3600
33.9	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

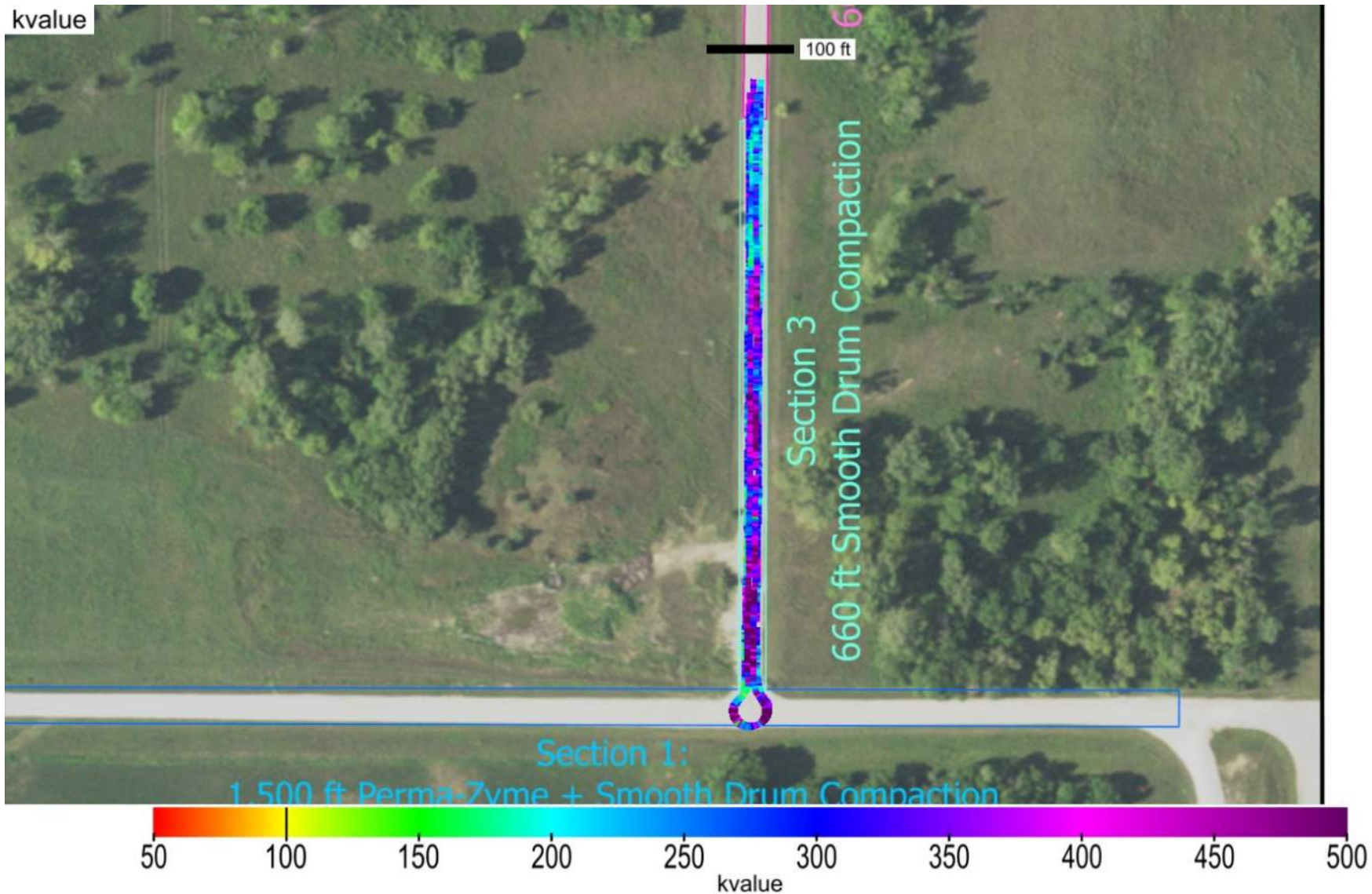
Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

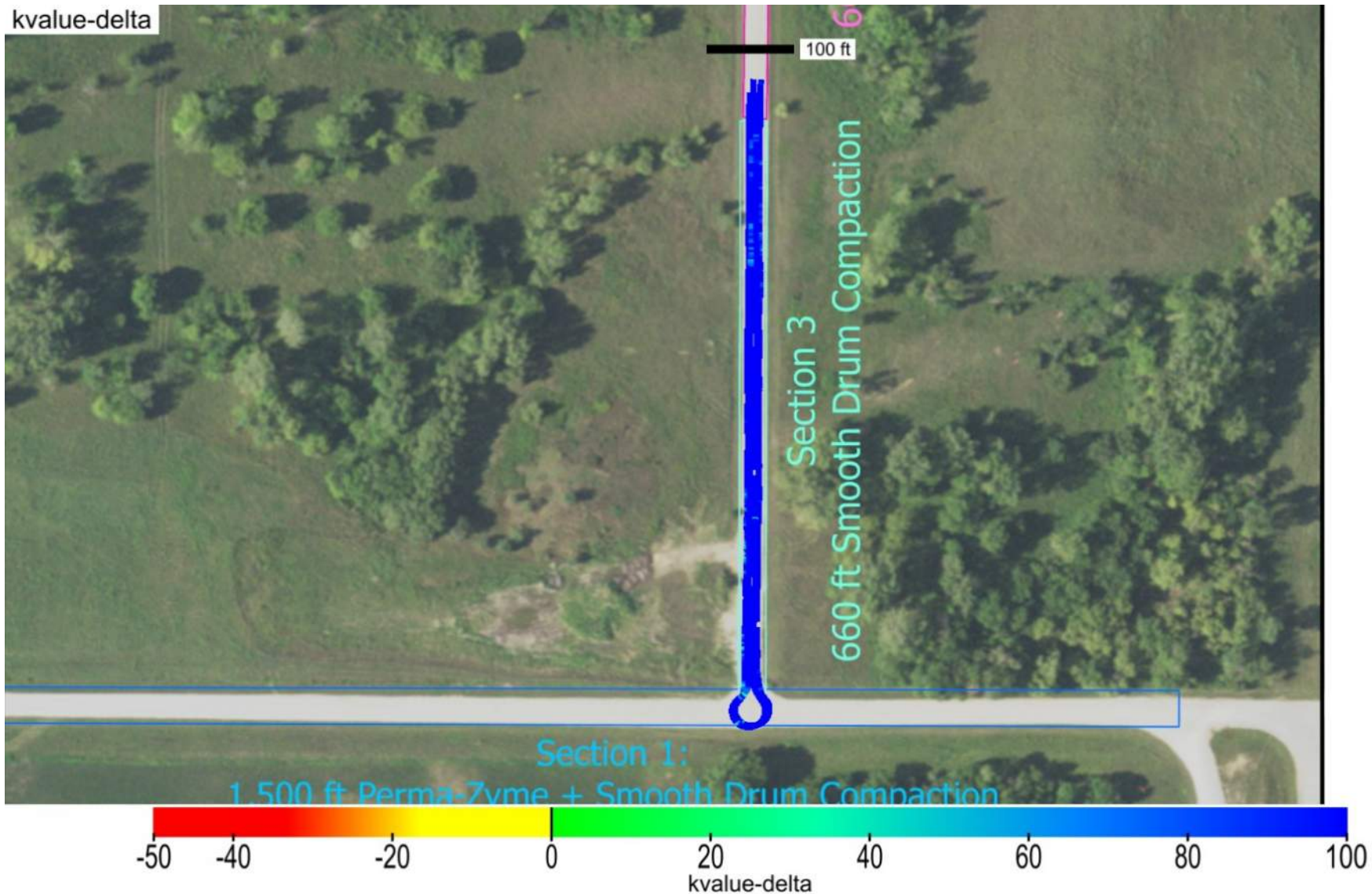
Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

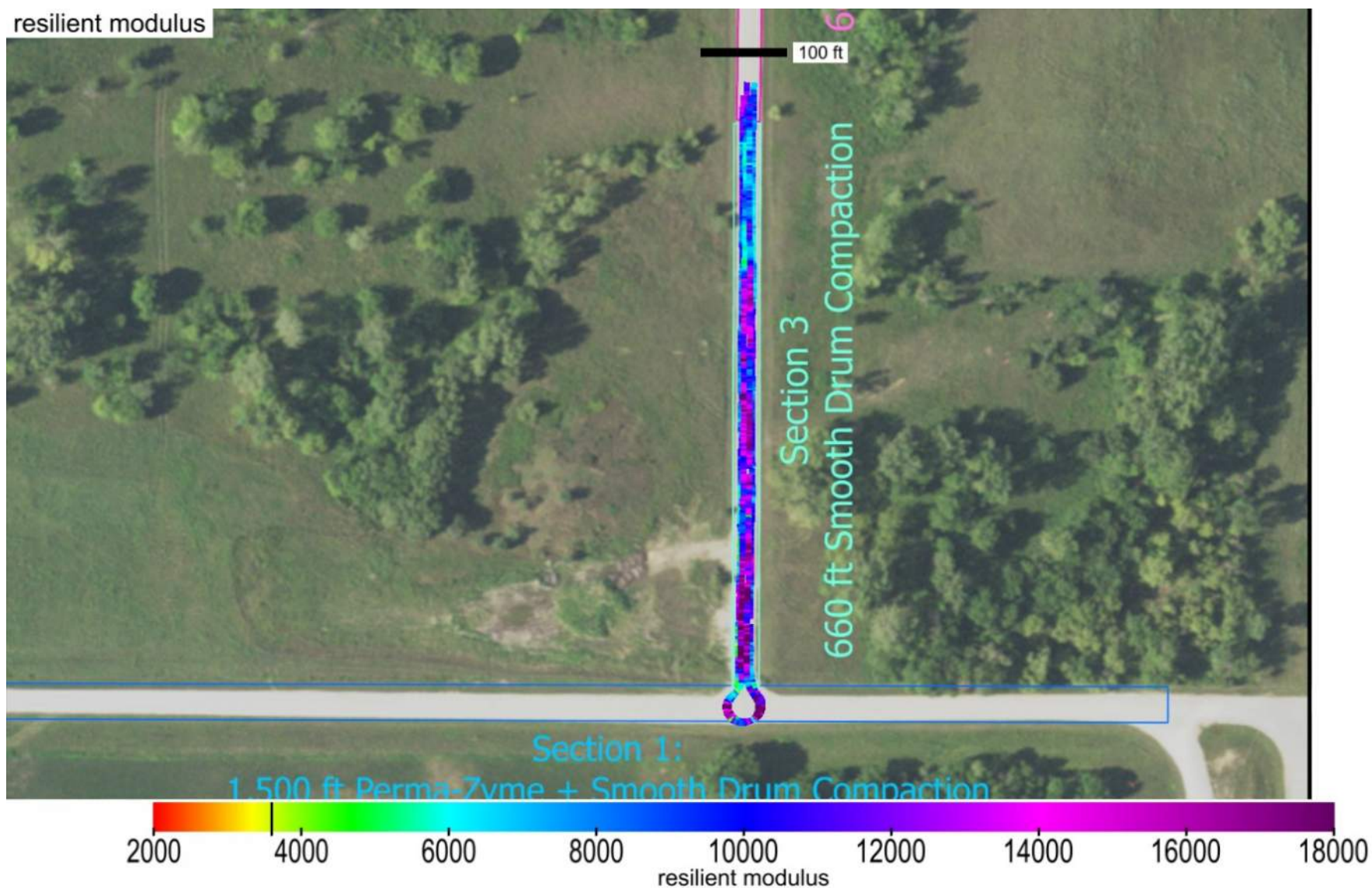
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	118.8	0.7	100.0	122.7	335.2	550.0	108.5	32.4	22.7	235.2	450.0



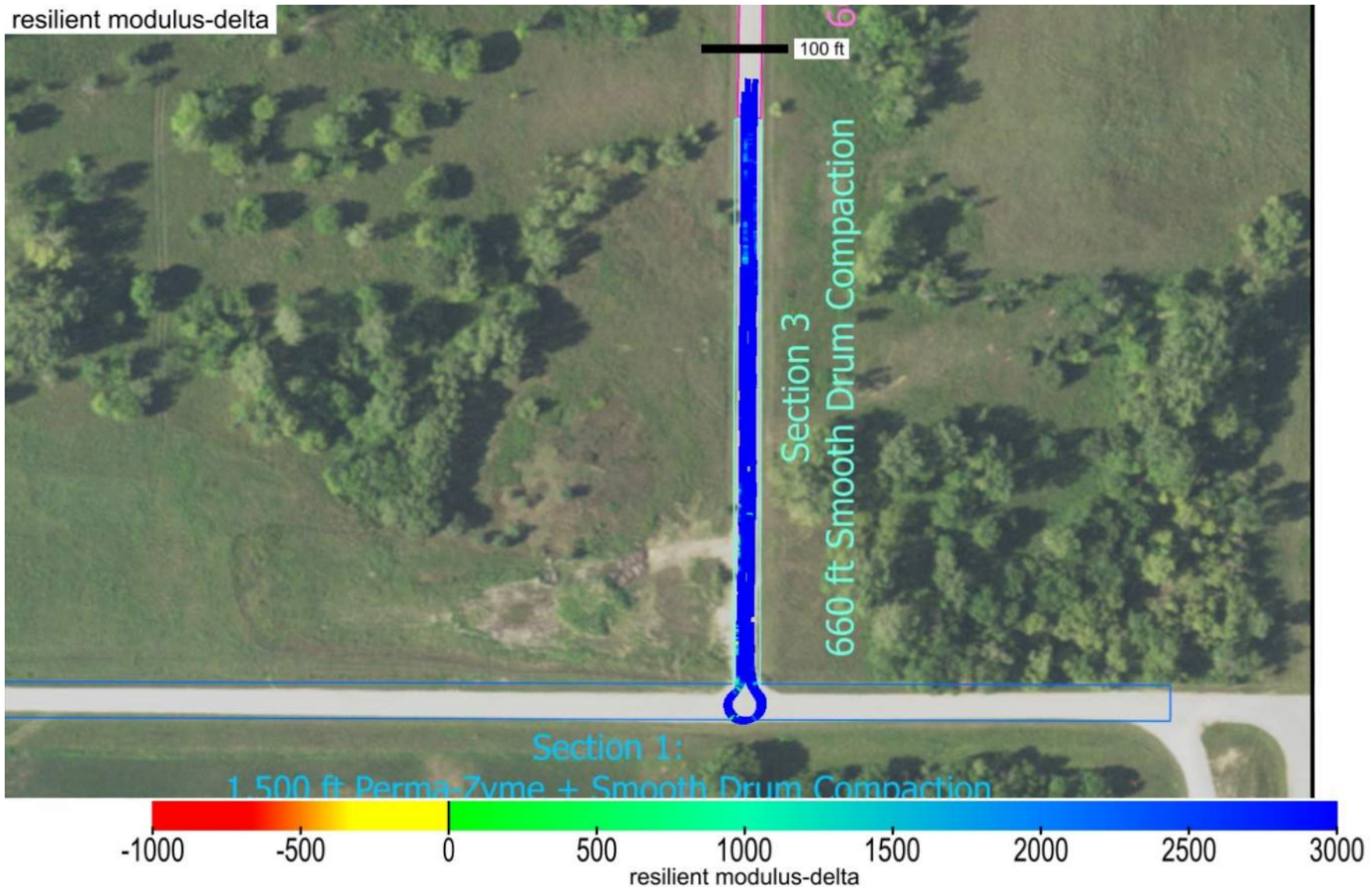
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	118.8	0.7	100.0	122.7	335.2	550.0	108.5	32.4	22.7	235.2	450.0



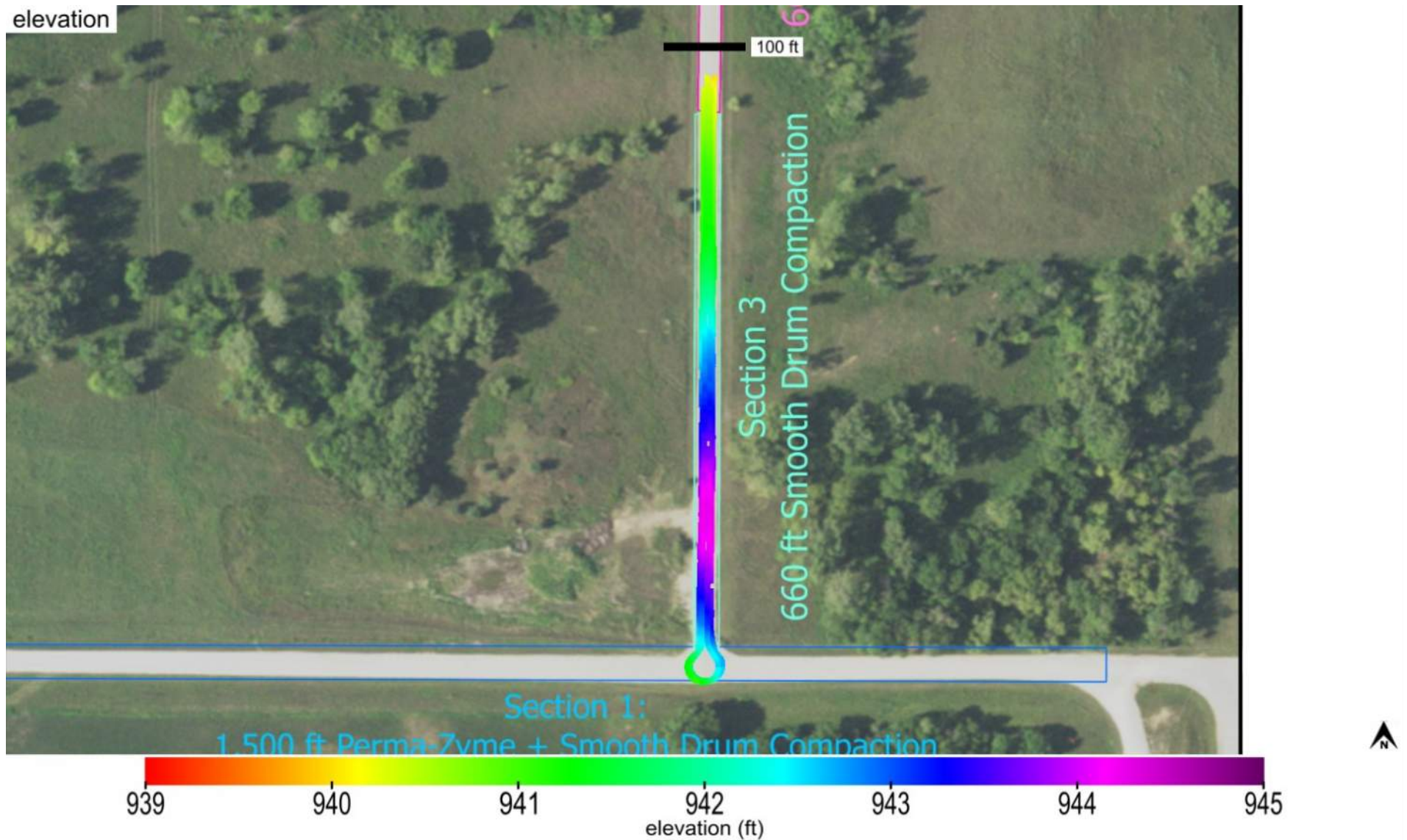
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	99.9	108.0	0.8	3600.0	3519.2	11192.4	20000.0	3798.6	33.9	-80.8	7592.4	16400.0

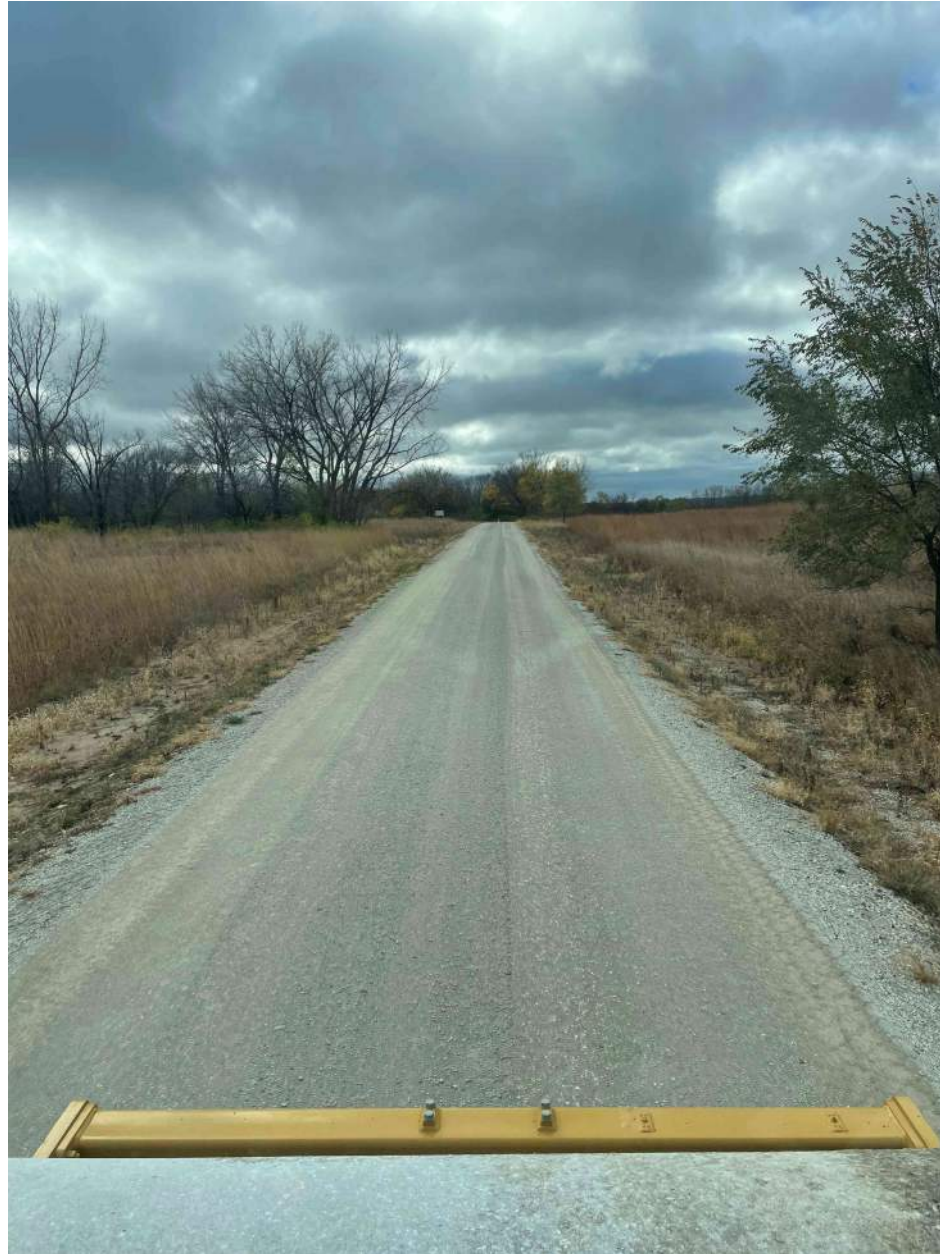


Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	99.9	108.0	0.8	3600.0	3519.2	11192.4	20000.0	3798.6	33.9	-80.8	7592.4	16400.0



minimum	average	maximum	RTK-Q7 (%)	RTK-QA
939.99	942.42	944.26	100.0	7.94





Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_10_31_103237

Project:	TR-823 Study	Date and Time:	10/31/2024 10:32:37 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.185	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	14656	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	4 - Sheepsfoot

Map Summary

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
XMV	No												
Resilient Modulus	Yes	100.0	110.4	0.9	3600.0	4404.2	10258.6	20000.0	2998.2	29.2	804.2	6658.6	16400.0
k-value	Yes	100.0	120.5	0.9	100.0	130.5	302.8	550.0	87.9	29.0	30.5	202.8	450.0
Moisture Content	No												

Mapped Area		Pass Count					Elevation (ft)			Position Quality		Velocity (fps)		
square feet	acres	10th percentile	Median	cov(%)	% >= TV	Target Value	min.	avg.	max.	RTK-Q7 (%)	RTK-QA	min.	avg.	max.
14656	0.336	1	1	35.4	100.0	0	936.92	938.85	940.67	100.0	7.83	5.0	5.2	5.6

Materials

name	id	% of total	area-square ft	area-acres	tl-xmv	tl-Mr	tl-k value	tl-w%
Unpaved Gravel Road (not defined)_IADOT	41019	100.0	14656	0.336	100.0	3600.0	100.0	20.5

Blobs

parameter	min. area(ft^2)	# of blobs	blob area(ft^2)	% of map	lower bound-tv	upper bound-tv	poly-tol.
Resilient Modulus	500.0	0	0	0.0	none	0.0	4.0
k-value	500.0	0	0	0.0	none	0.0	4.0

Station

Start	End
0+00	0+00

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_10_31_103237

Project:	TR-823 Study	Date and Time:	10/31/2024 10:32:37 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.185	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	14656	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	4 - Sheepsfoot

QUALITY ANALYSIS SUMMARY - k-Value

Quality Value	Criteria
120.5	CQI > = 95
100.0	80% of k-Value MVs >= 100
29.0	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_10_31_103237

Project:	TR-823 Study	Date and Time:	10/31/2024 10:32:37 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.185	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	14656	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	4 - Sheepsfoot

QUALITY ANALYSIS SUMMARY - Resilient Modulus

Quality Value	Criteria
110.4	CQI > = 95
100.0	90% of Resilient Modulus MVs >= 3600
29.2	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

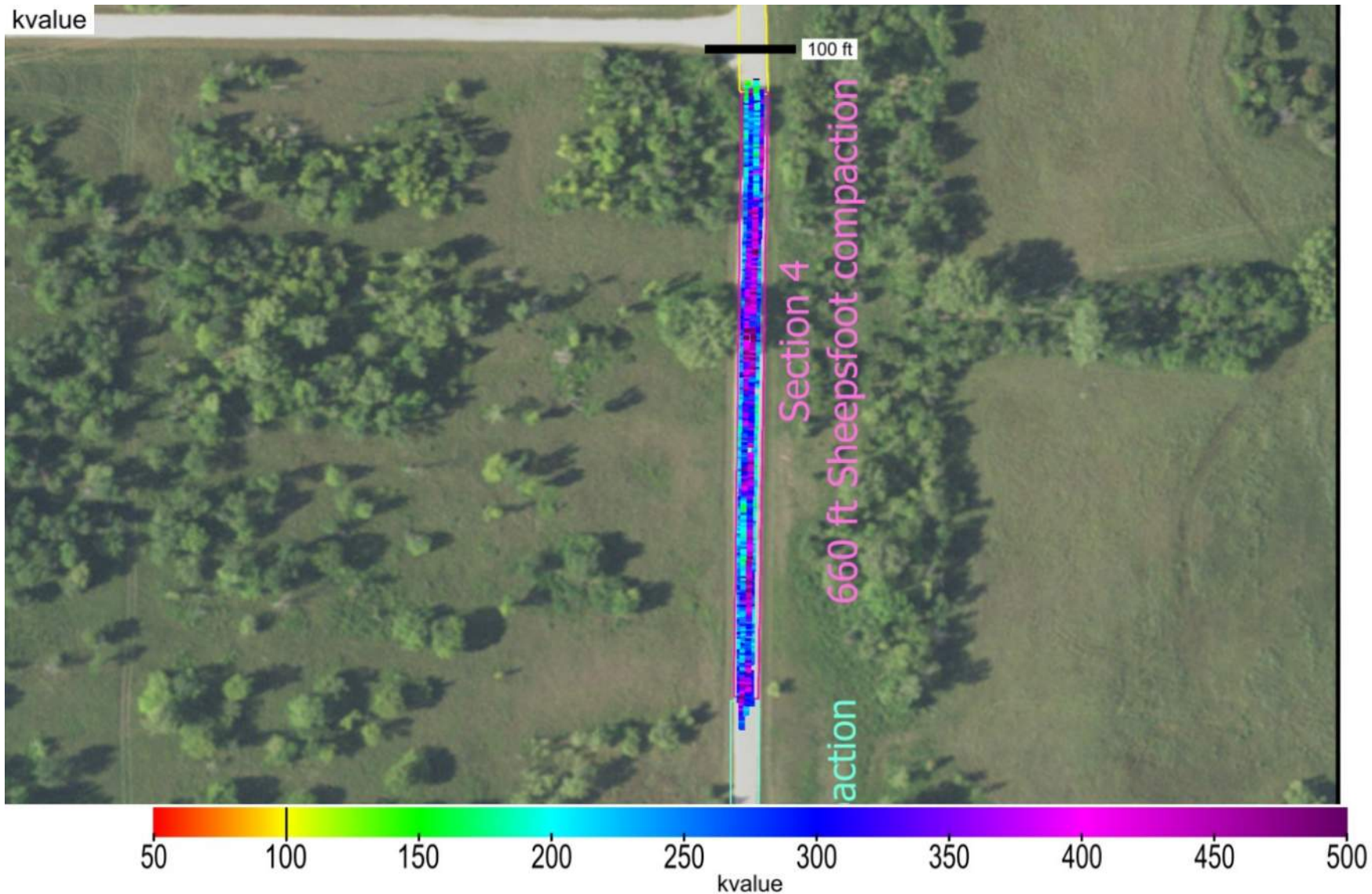
Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_10_31_103237

Map Type: Verification Map

Map Layer: Unpaved Gravel Road

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	120.5	0.9	100.0	130.5	302.8	550.0	87.9	29.0	30.5	202.8	450.0



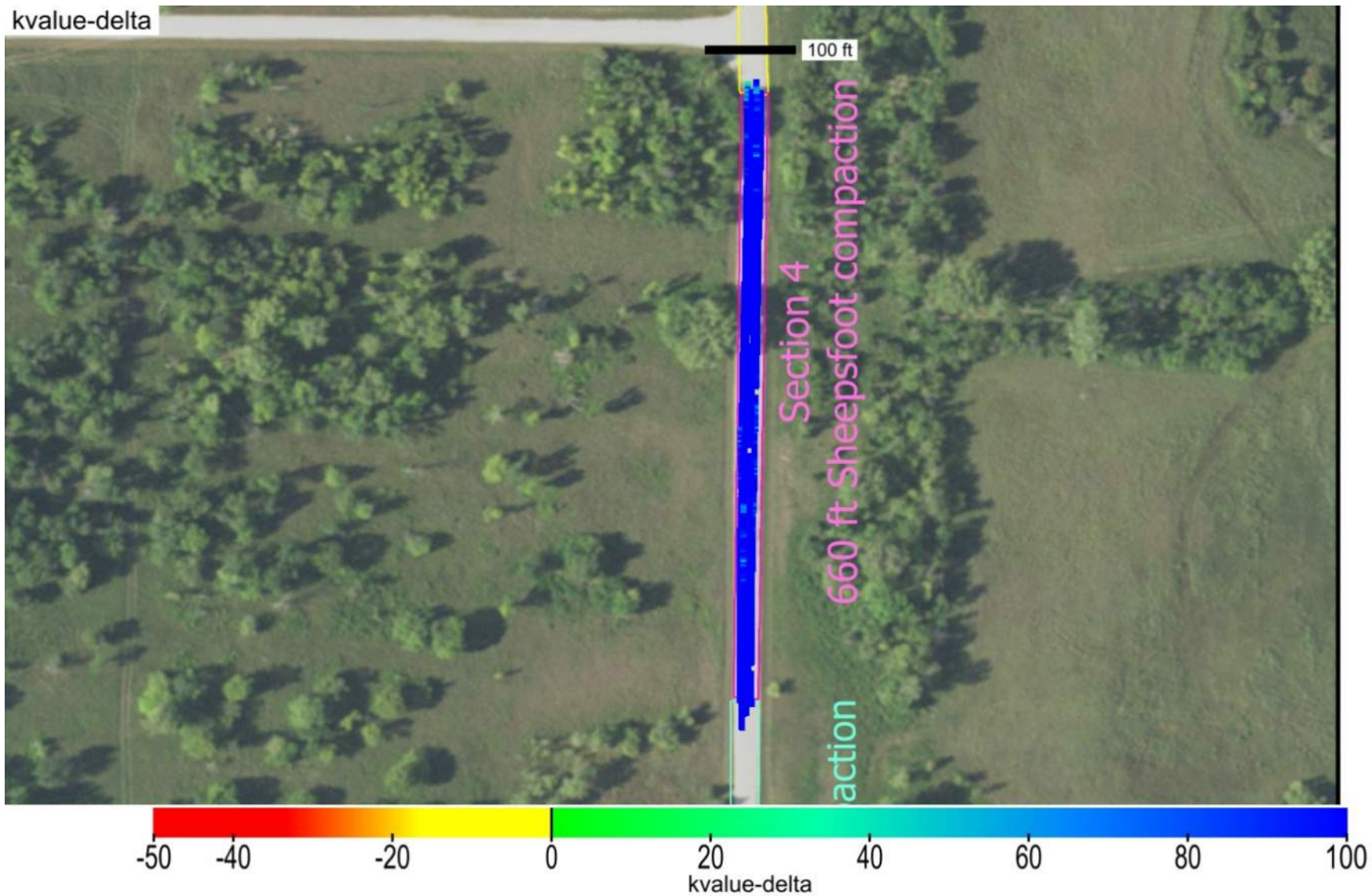
This report is only for use of the client named and it cannot be relied upon by any other person or entity.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_10_31_103237

Map Type: Verification Map

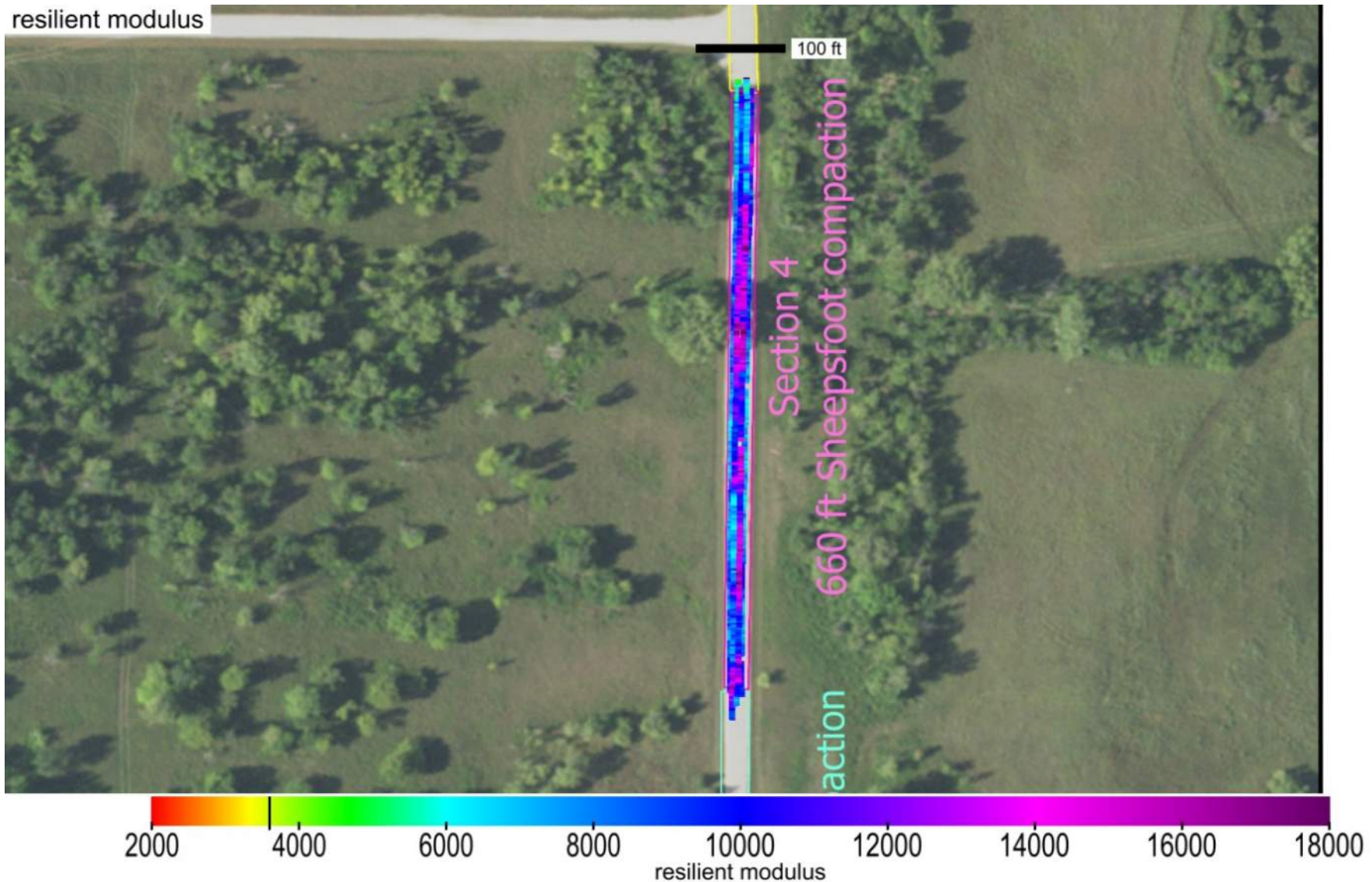
Map Layer: Unpaved Gravel Road

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	120.5	0.9	100.0	130.5	302.8	550.0	87.9	29.0	30.5	202.8	450.0

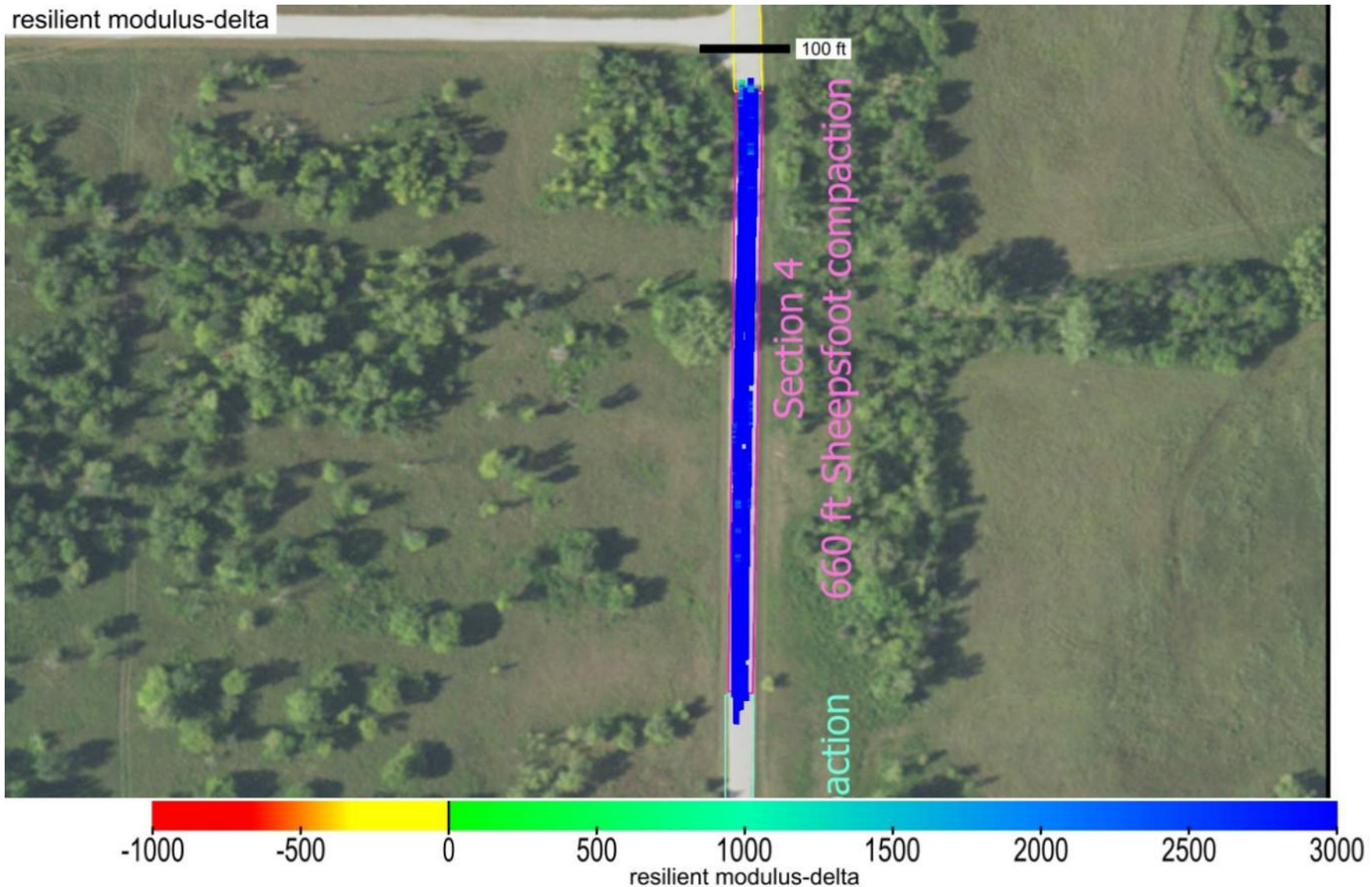


This report is only for use of the client named and it cannot be relied upon by any other person or entity.

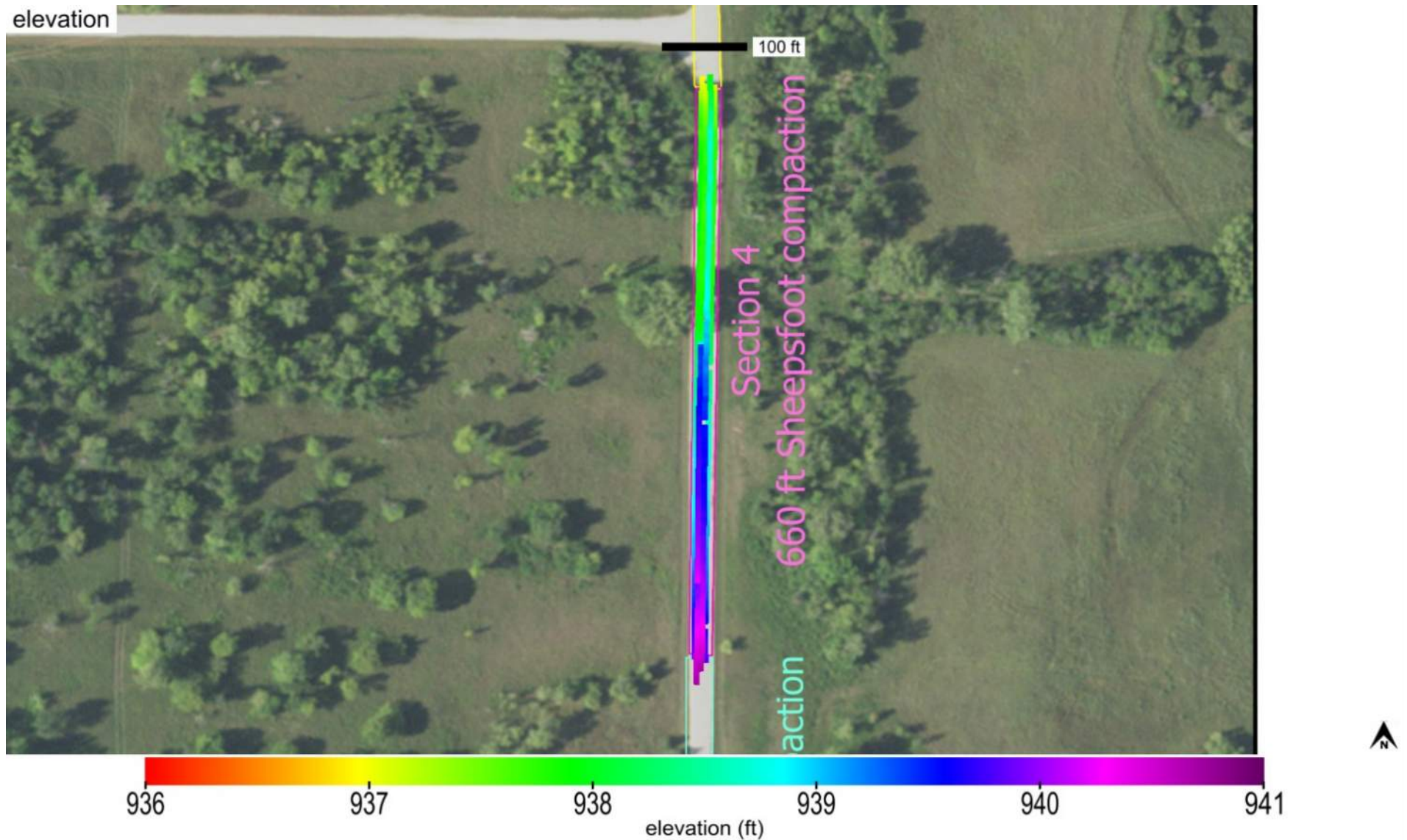
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	110.4	0.9	3600.0	4404.2	10258.6	20000.0	2998.2	29.2	804.2	6658.6	16400.0



Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	110.4	0.9	3600.0	4404.2	10258.6	20000.0	2998.2	29.2	804.2	6658.6	16400.0



minimum	average	maximum	RTK-Q7 (%)	RTK-QA
936.92	938.85	940.67	100.0	7.83





Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_10_31_101023

Project:	TR-823 Study	Date and Time:	10/31/2024 10:10:23 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.316	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	32038	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	5 - Control

Map Summary

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
XMV	No												
Resilient Modulus	Yes	99.3	105.0	0.7	3600.0	2867.5	10997.0	20000.0	4244.3	38.6	-732.5	7397.0	16400.0
k-value	Yes	99.7	116.6	0.6	100.0	89.2	337.7	550.0	122.3	36.2	-10.8	237.7	450.0
Moisture Content	No												

Mapped Area		Pass Count					Elevation (ft)			Position Quality		Velocity (fps)		
square feet	acres	10th percentile	Median	cov(%)	% >= TV	Target Value	min.	avg.	max.	RTK-Q7 (%)	RTK-QA	min.	avg.	max.
32038	0.735	1	1	32.3	100.0	0	936.55	943.76	953.01	85.9	7.10	4.8	5.2	6.1

Materials

name	id	% of total	area-square ft	area-acres	tl-xmv	tl-Mr	tl-k value	tl-w%
Unpaved Gravel Road (not defined)_IADOT	41019	100.0	32038	0.735	100.0	3600.0	100.0	20.5

Blobs

parameter	min. area(ft^2)	# of blobs	blob area(ft^2)	% of map	lower bound-tv	upper bound-tv	poly-tol.
Resilient Modulus	500.0	0	0	0.0	none	0.0	4.0
k-value	500.0	0	0	0.0	none	0.0	4.0

Station

Start	End
0+00	0+00

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_10_31_101023

Project:	TR-823 Study	Date and Time:	10/31/2024 10:10:23 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.316	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	32038	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	5 - Control

QUALITY ANALYSIS SUMMARY - k-Value

Quality Value	Criteria
116.6	CQI > = 95
99.7	80% of k-Value MVs >= 100
36.2	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_10_31_101023

Project:	TR-823 Study	Date and Time:	10/31/2024 10:10:23 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.316	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	32038	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	5 - Control

QUALITY ANALYSIS SUMMARY - Resilient Modulus

Quality Value	Criteria
105.0	CQI > = 95
99.3	90% of Resilient Modulus MVs >= 3600
38.6	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

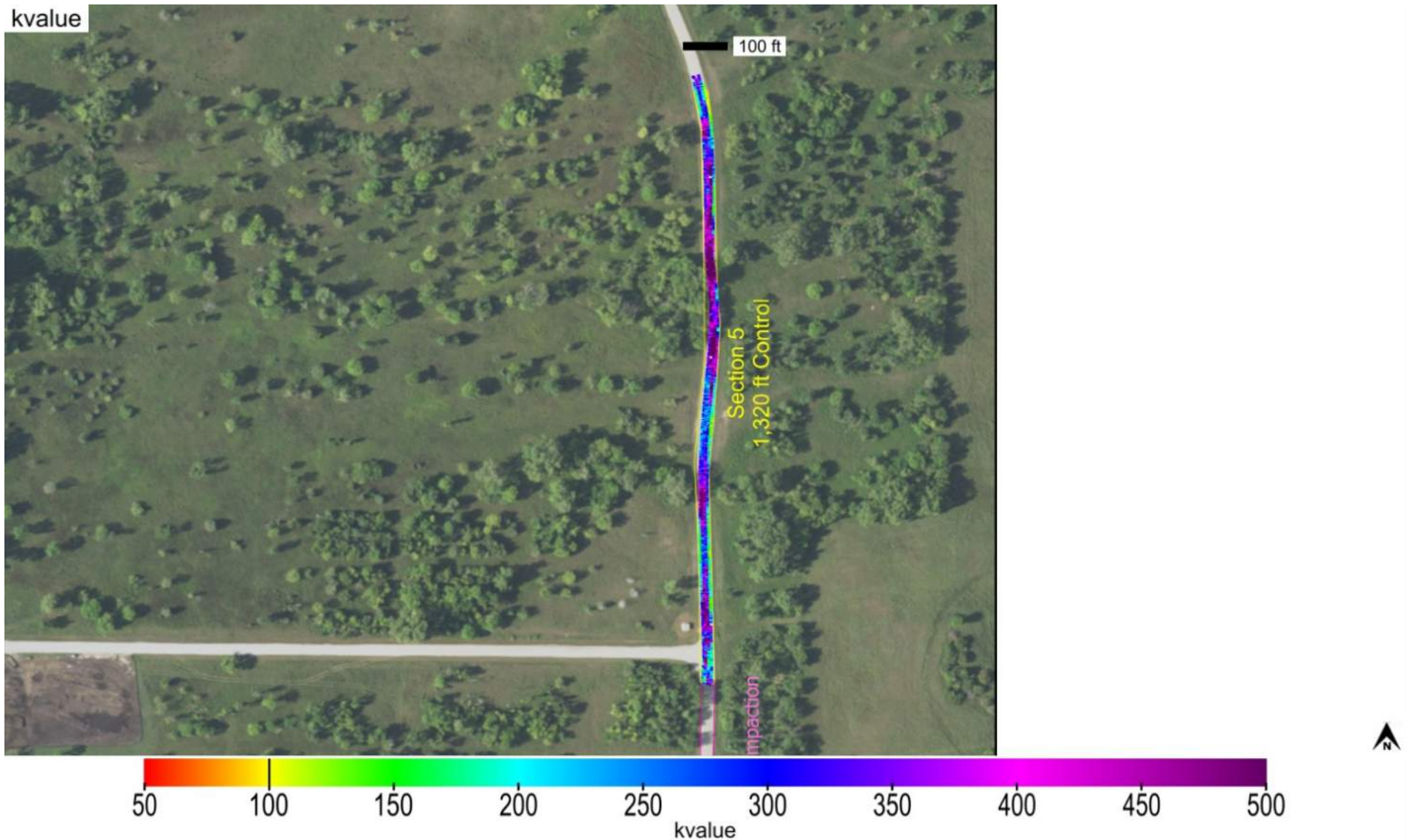
Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2023_cs56b-01047_2024_10_31_101023

Map Type: Verification Map

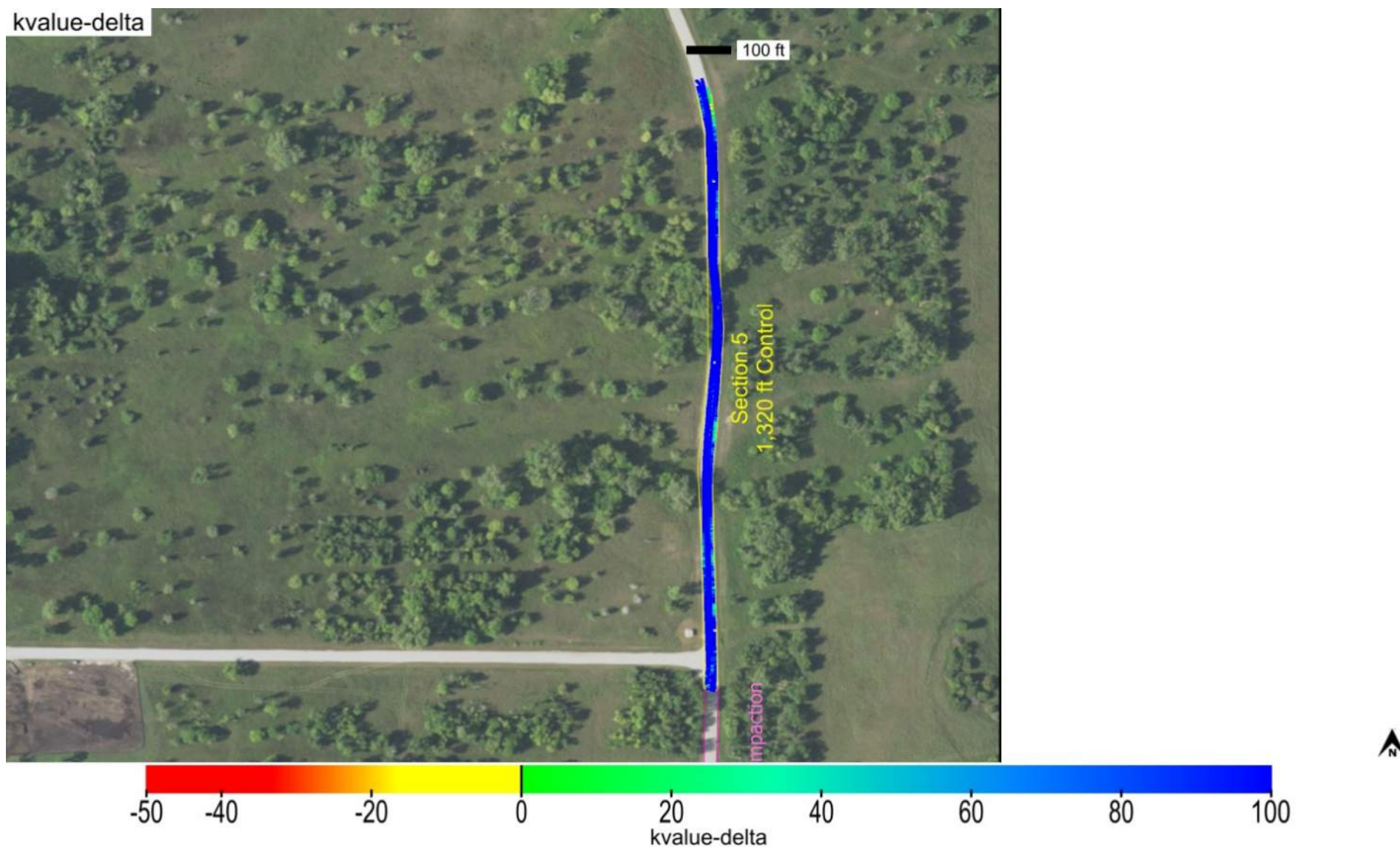
Map Layer: Unpaved Gravel Road

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	99.7	116.6	0.6	100.0	89.2	337.7	550.0	122.3	36.2	-10.8	237.7	450.0

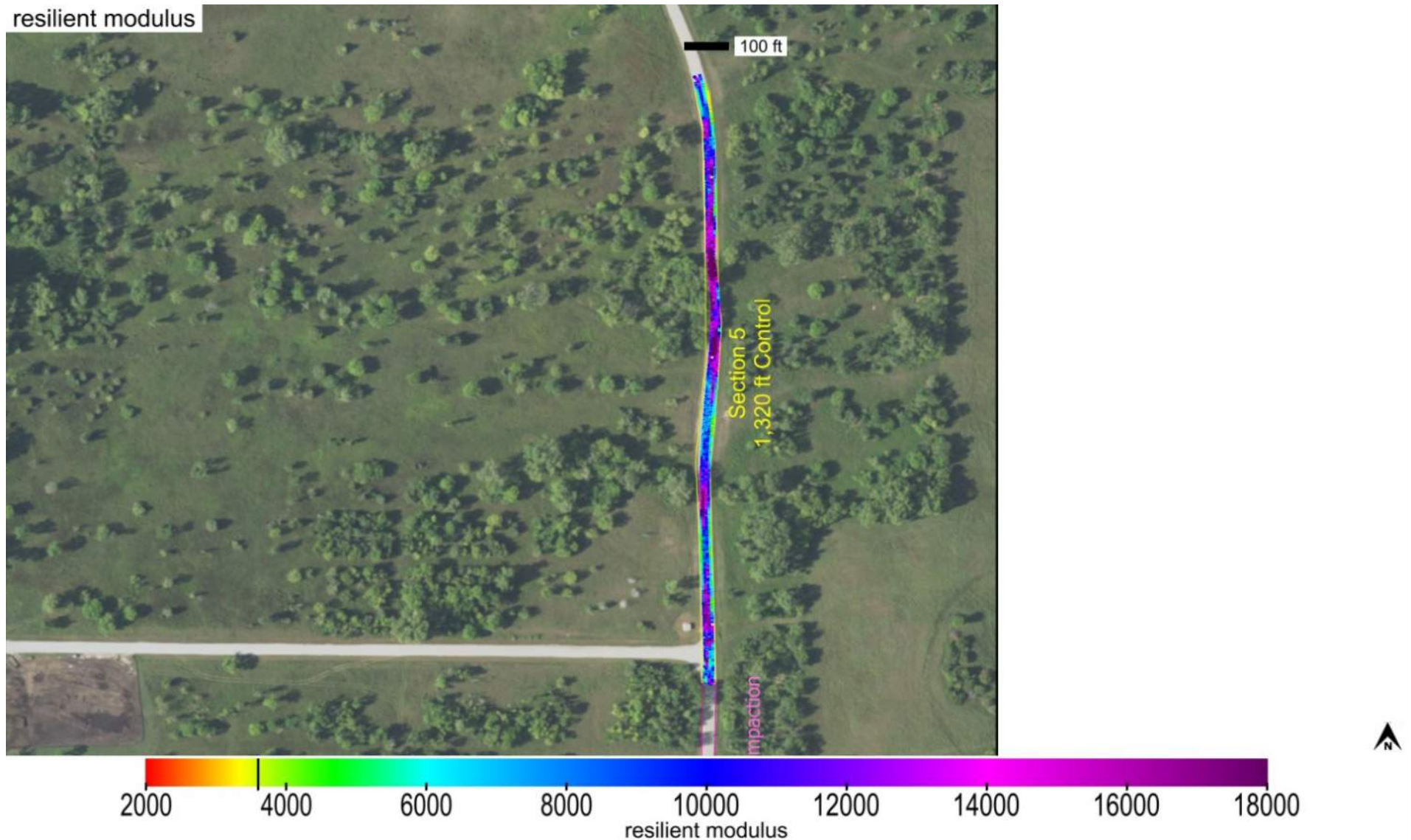


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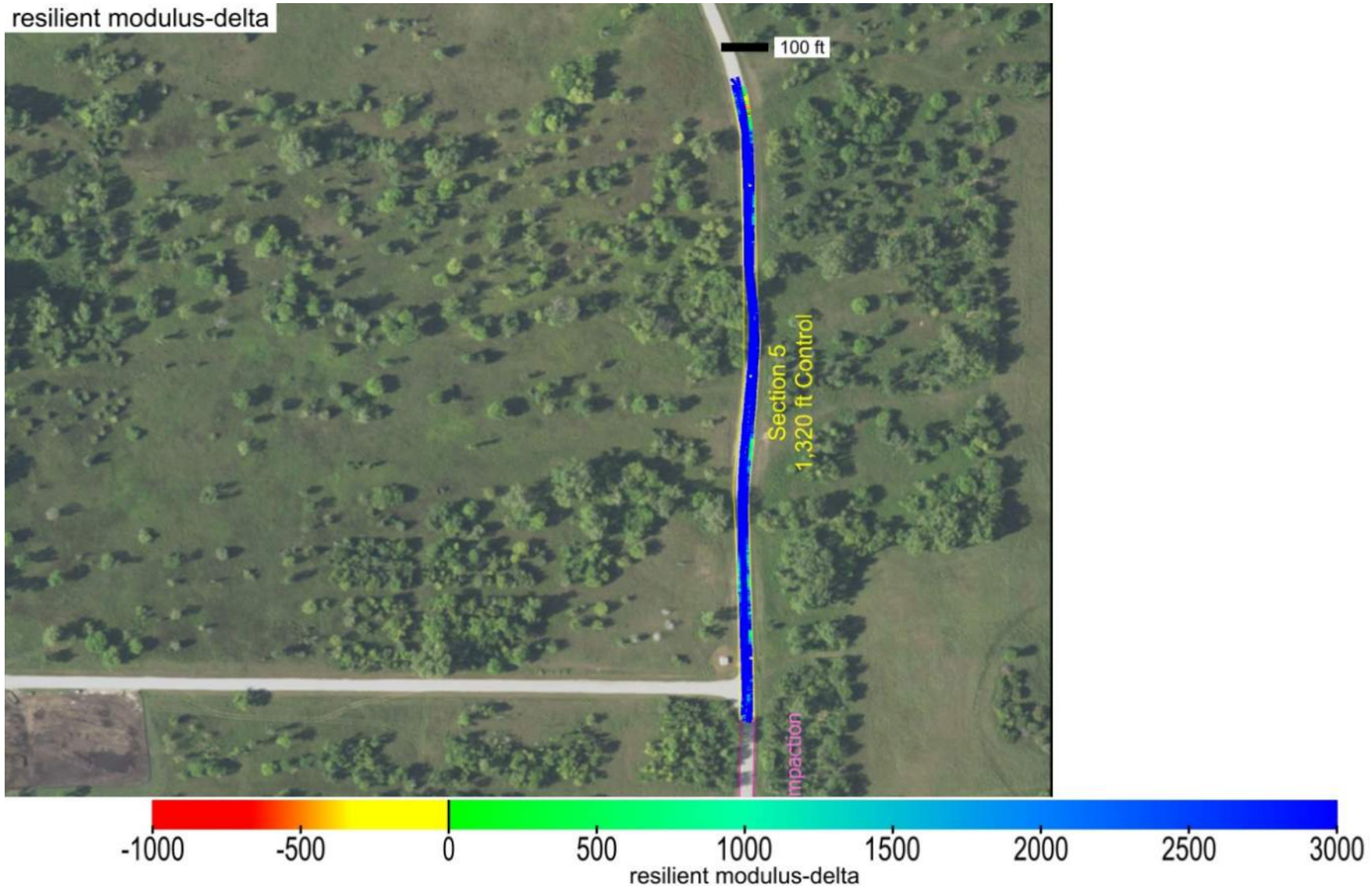
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	99.7	116.6	0.6	100.0	89.2	337.7	550.0	122.3	36.2	-10.8	237.7	450.0



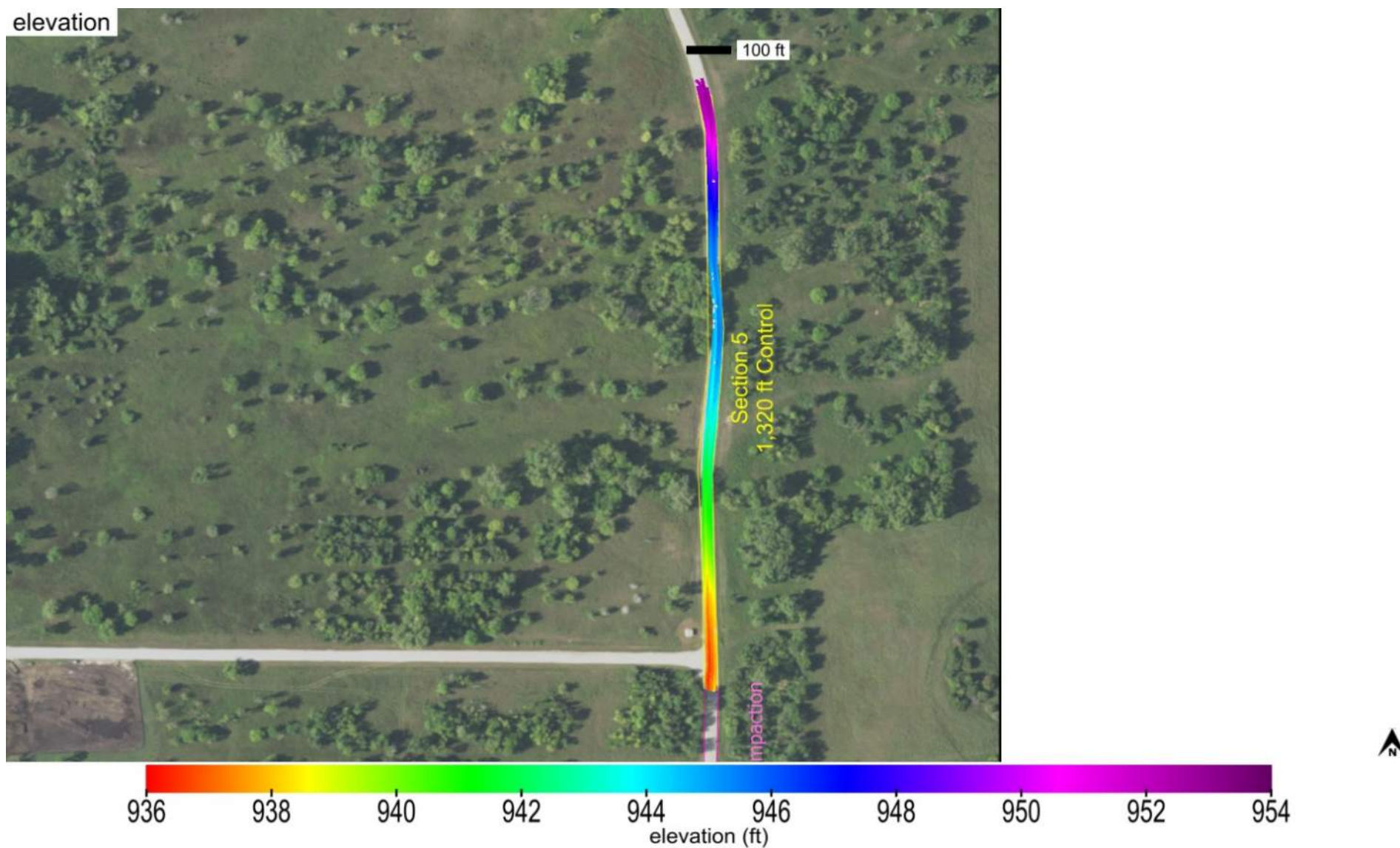
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	99.3	105.0	0.7	3600.0	2867.5	10997.0	20000.0	4244.3	38.6	-732.5	7397.0	16400.0



Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	99.3	105.0	0.7	3600.0	2867.5	10997.0	20000.0	4244.3	38.6	-732.5	7397.0	16400.0



minimum	average	maximum	RTK-Q7 (%)	RTK-QA
936.55	943.76	953.01	85.9	7.10





Map ID: ing_polk77-campdodge-2025_cs56b-01047_2025_03_31_105035

Project:	TR-823 Study	Date and Time:	3/31/2025 10:50:35 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.373	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	33550	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	1 - STAB + Smooth Drum

Map Summary

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
XMV	No												
Resilient Modulus	Yes	99.8	102.6	0.6	3600.0	3268.4	8516.4	20000.0	3778.9	44.4	-331.6	4916.4	16400.0
k-value	Yes	100.0	113.2	0.7	100.0	99.4	258.0	550.0	112.2	43.5	-0.6	158.0	450.0
Moisture Content	No												

Mapped Area		Pass Count					Elevation (ft)			Position Quality		Velocity (fps)		
square feet	acres	10th percentile	Median	cov(%)	% >= TV	Target Value	min.	avg.	max.	RTK-Q7 (%)	RTK-QA	min.	avg.	max.
33550	0.770	1	1	35.4	100.0	0	915.17	931.58	949.00	100.0	8.00	4.0	5.2	5.7

Materials

name	id	% of total	area-square ft	area-acres	tl-xmv	tl-Mr	tl-k value	tl-w%
Unpaved Gravel Road (not defined)_IADOT	41019	100.0	33550	0.770	100.0	3600.0	100.0	20.5

Blobs

parameter	min. area(ft^2)	# of blobs	blob area(ft^2)	% of map	lower bound-tv	upper bound-tv	poly-tol.
Resilient Modulus	500.0	0	0	0.0	none	0.0	4.0
k-value	500.0	0	0	0.0	none	0.0	4.0

Station

Start	End
0+00	0+00

If the Calibration Index (CI) < 0.5, expand the measurement range with additional calibration test points at the limits.
If 0.5 > CI < 1.0, monitor for a downward trend and perform additional calibration test points.
If CI > 1.0, perform periodic calibration test points to verify the model.

This report is only for use of the client named and it cannot be relied upon by any other person or entity.

Map ID: ing_polk77-campdodge-2025_cs56b-01047_2025_03_31_105035

Project:	TR-823 Study	Date and Time:	3/31/2025 10:50:35 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.373	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	33550	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	1 - STAB + Smooth Drum

QUALITY ANALYSIS SUMMARY - k-Value

Quality Value	Criteria
113.2	CQI > = 95
100.0	80% of k-Value MVs >= 100
43.5	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2025_cs56b-01047_2025_03_31_105035

Project:	TR-823 Study	Date and Time:	3/31/2025 10:50:35 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.373	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	33550	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	1 - STAB + Smooth Drum

QUALITY ANALYSIS SUMMARY - Resilient Modulus

Quality Value	Criteria
102.6	CQI > = 95
99.8	90% of Resilient Modulus MVs >= 3600
44.4	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

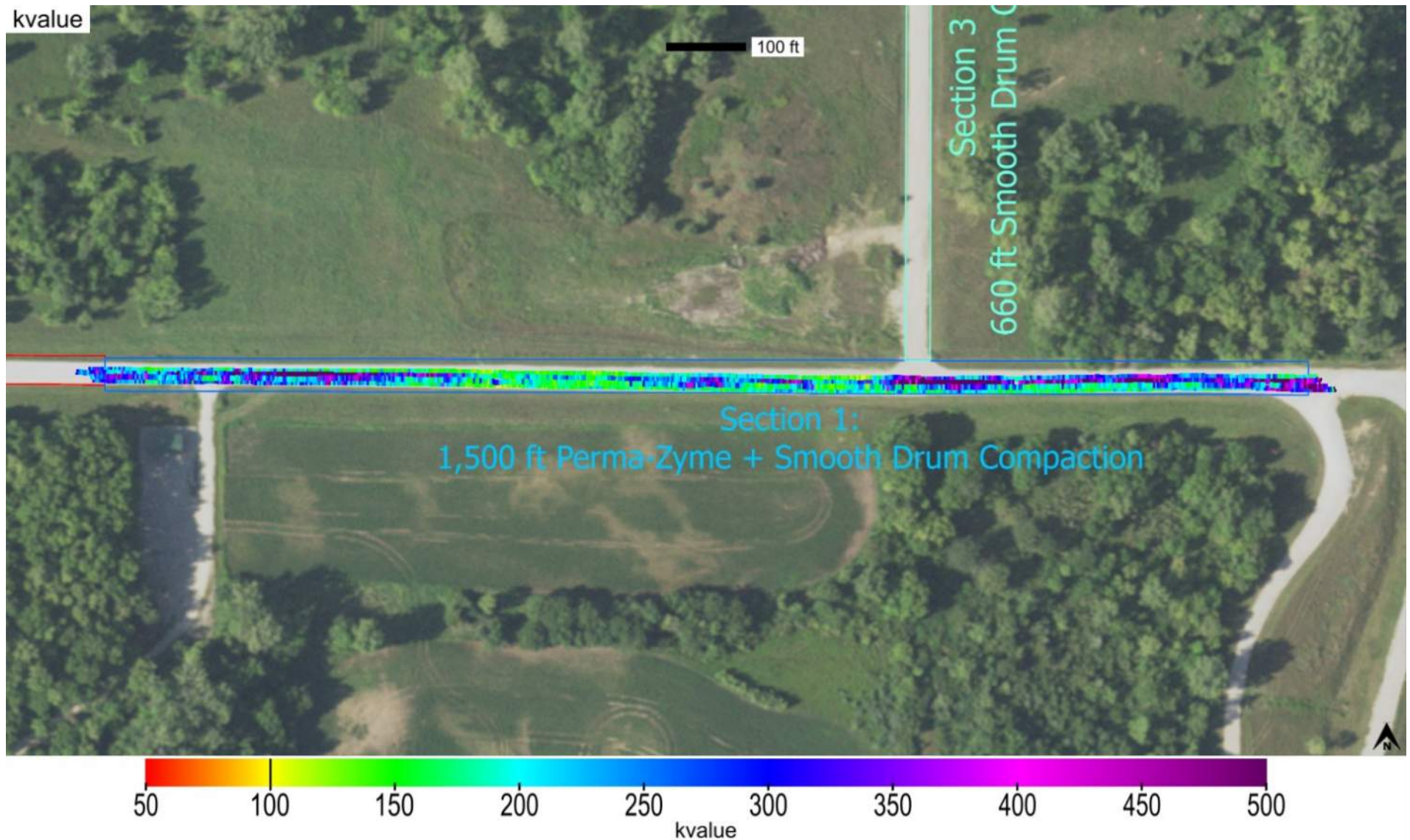
Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

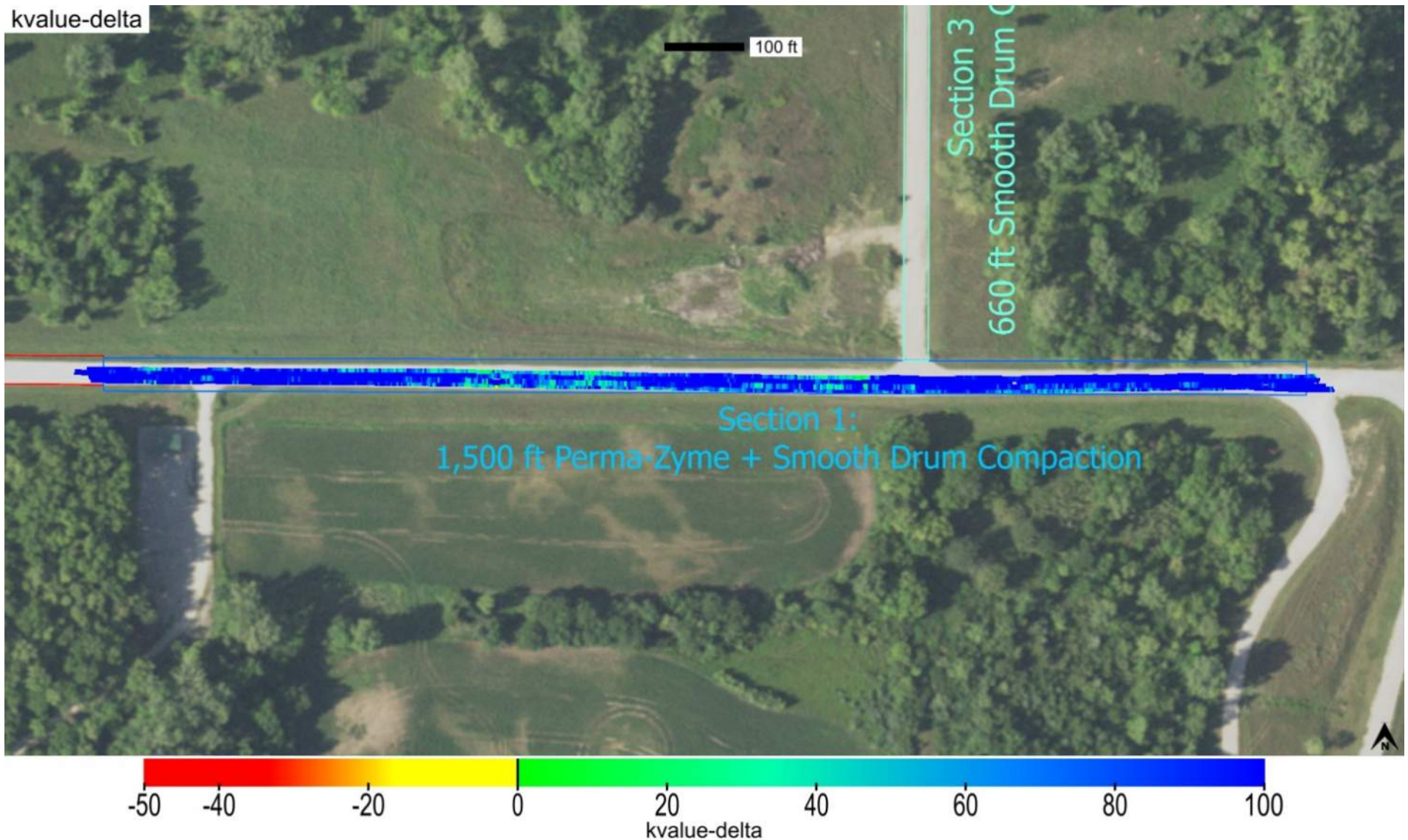
Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

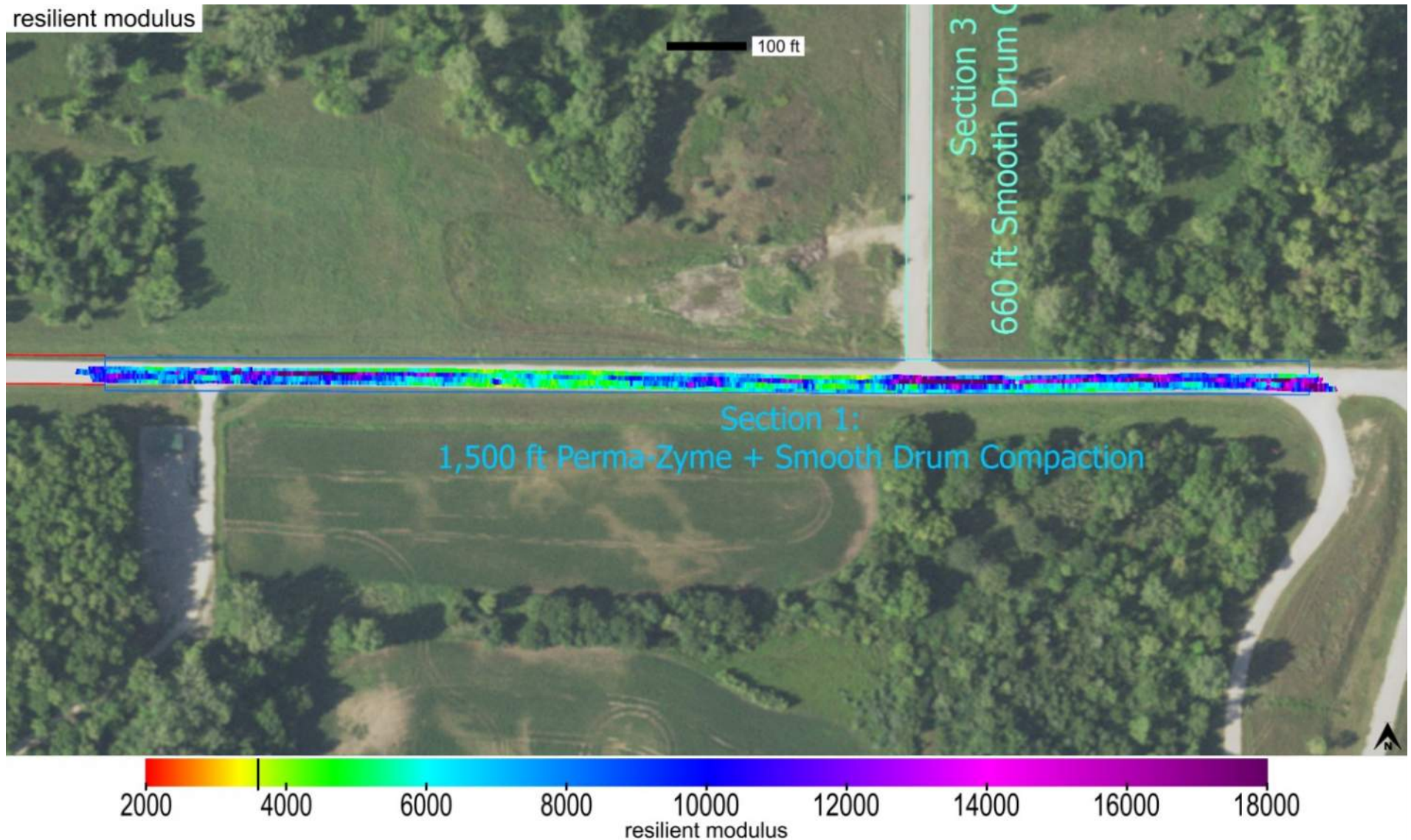
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	113.2	0.7	100.0	99.4	258.0	550.0	112.2	43.5	-0.6	158.0	450.0



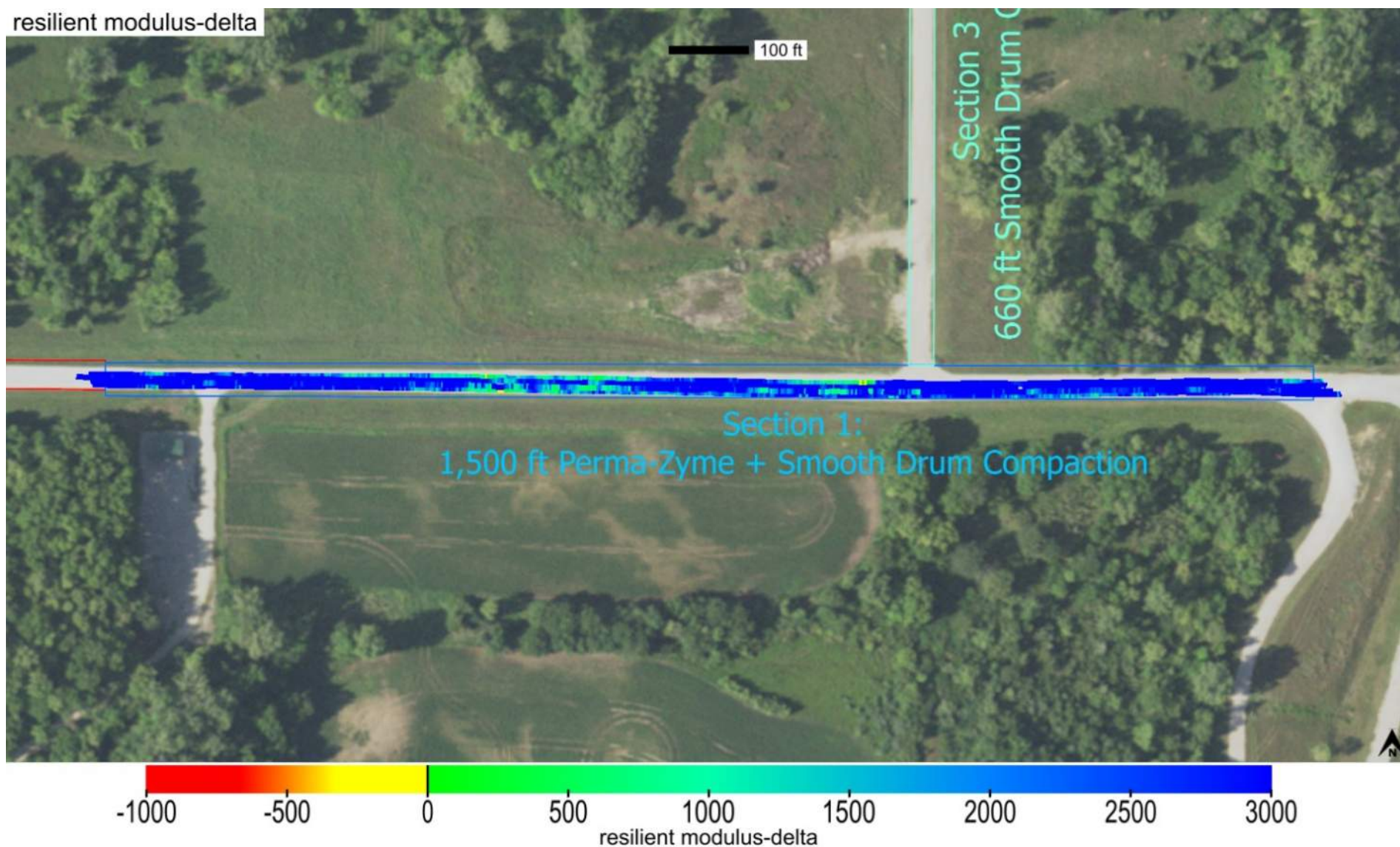
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	113.2	0.7	100.0	99.4	258.0	550.0	112.2	43.5	-0.6	158.0	450.0



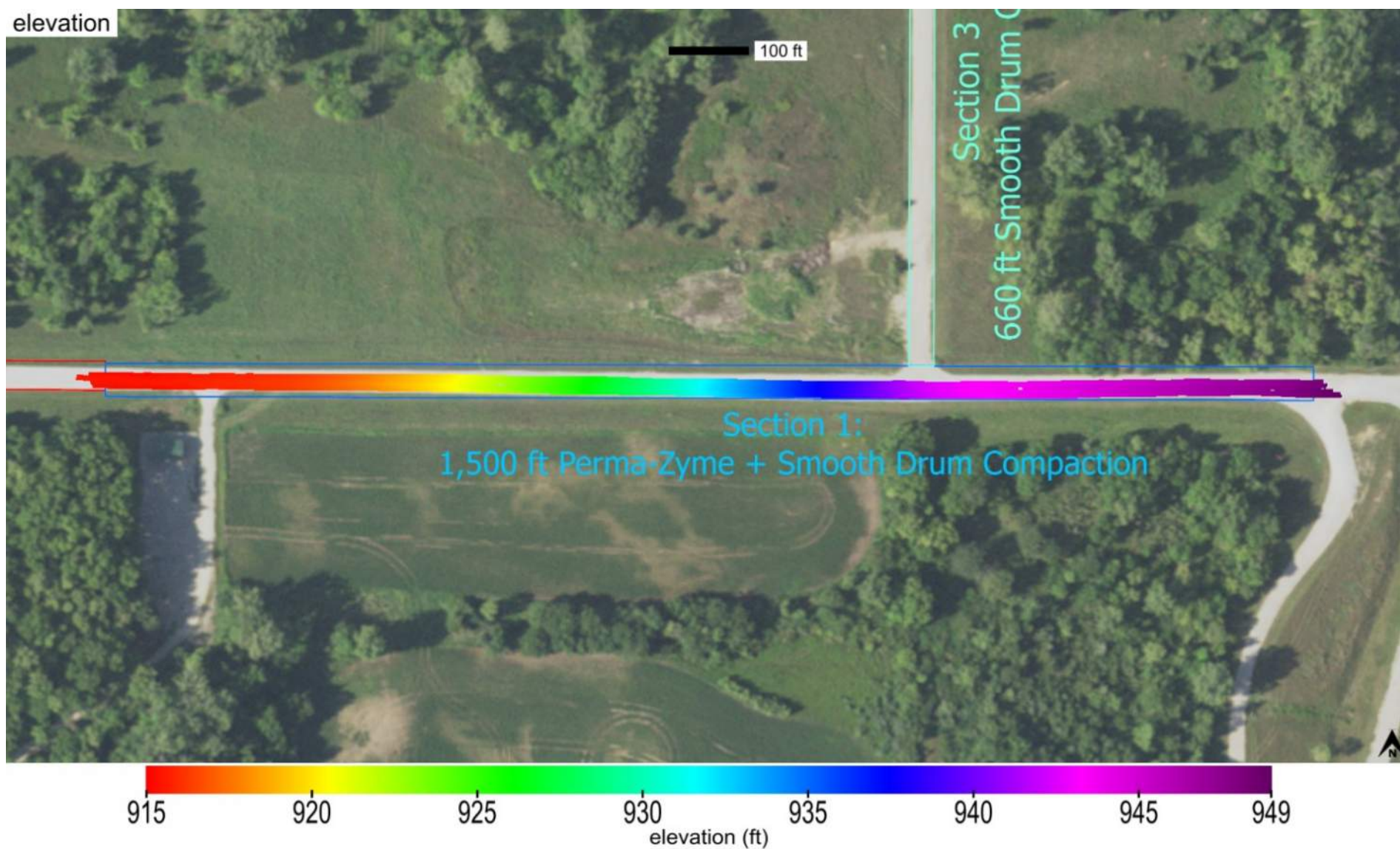
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	99.8	102.6	0.6	3600.0	3268.4	8516.4	20000.0	3778.9	44.4	-331.6	4916.4	16400.0



Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	99.8	102.6	0.6	3600.0	3268.4	8516.4	20000.0	3778.9	44.4	-331.6	4916.4	16400.0



minimum	average	maximum	RTK-Q7 (%)	RTK-QA
915.17	931.58	949.00	100.0	8.00





Map ID: ing_polk77-campdodge-2025_cs56b-01047_2025_03_31_113857

Project:	TR-823 Study	Date and Time:	3/31/2025 11:38:57 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.359	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	34154	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	2 - STAB + Sheepsfoot

Map Summary

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
XMV	No												
Resilient Modulus	Yes	99.0	103.0	0.6	3600.0	2813.9	8369.4	20000.0	3527.6	42.2	-786.1	4769.4	16400.0
k-value	Yes	99.9	114.8	0.8	100.0	89.8	259.0	550.0	104.2	40.2	-10.2	159.0	450.0
Moisture Content	No												

Mapped Area		Pass Count					Elevation (ft)			Position Quality		Velocity (fps)		
square feet	acres	10th percentile	Median	cov(%)	% >= TV	Target Value	min.	avg.	max.	RTK-Q7 (%)	RTK-QA	min.	avg.	max.
34154	0.784	1	1	35.1	100.0	0	894.92	907.80	916.78	100.0	8.00	5.0	5.3	6.0

Materials

name	id	% of total	area-square ft	area-acres	tl-xmv	tl-Mr	tl-k value	tl-w%
Unpaved Gravel Road (not defined)_IADOT	41019	100.0	34154	0.784	100.0	3600.0	100.0	20.5

Blobs

parameter	min. area(ft^2)	# of blobs	blob area(ft^2)	% of map	lower bound-tv	upper bound-tv	poly-tol.
Resilient Modulus	500.0	0	0	0.0	none	0.0	4.0
k-value	500.0	0	0	0.0	none	0.0	4.0

Station

Start	End
0+00	0+00

If the Calibration Index (CI) < 0.5, expand the measurement range with additional calibration test points at the limits.
If 0.5 > CI < 1.0, monitor for a downward trend and perform additional calibration test points.
If CI > 1.0, perform periodic calibration test points to verify the model.

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Map ID: ing_polk77-campdodge-2025_cs56b-01047_2025_03_31_113857

Project:	TR-823 Study	Date and Time:	3/31/2025 11:38:57 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.359	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	34154	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	2 - STAB + Sheepsfoot

QUALITY ANALYSIS SUMMARY - k-Value

Quality Value	Criteria
114.8	CQI > = 95
99.9	80% of k-Value MVs >= 100
40.2	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2025_cs56b-01047_2025_03_31_113857

Project:	TR-823 Study	Date and Time:	3/31/2025 11:38:57 AM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.359	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	34154	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	2 - STAB + Sheepsfoot

QUALITY ANALYSIS SUMMARY - Resilient Modulus

Quality Value	Criteria
103.0	CQI > = 95
99.0	90% of Resilient Modulus MVs >= 3600
42.2	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

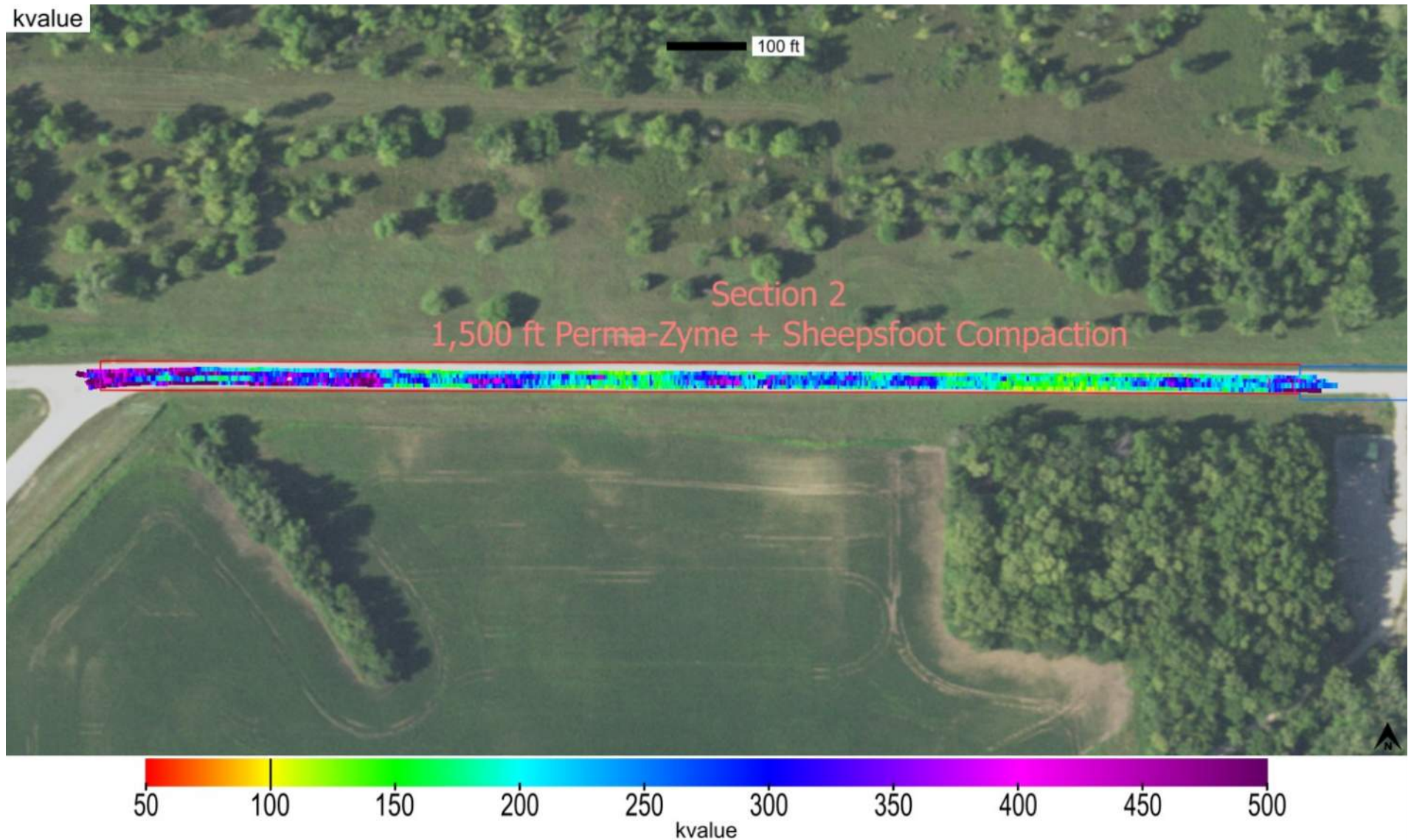
Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

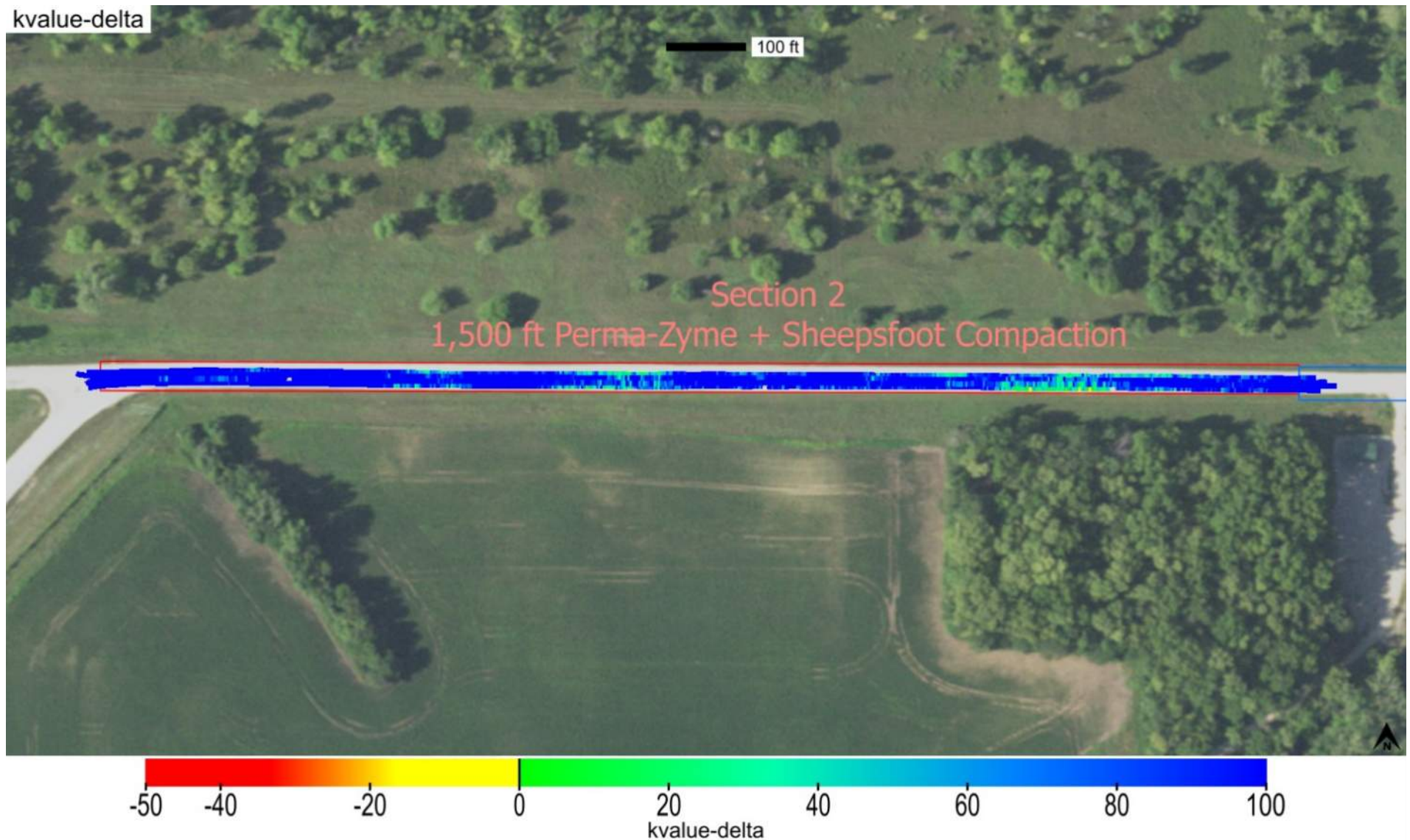
Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

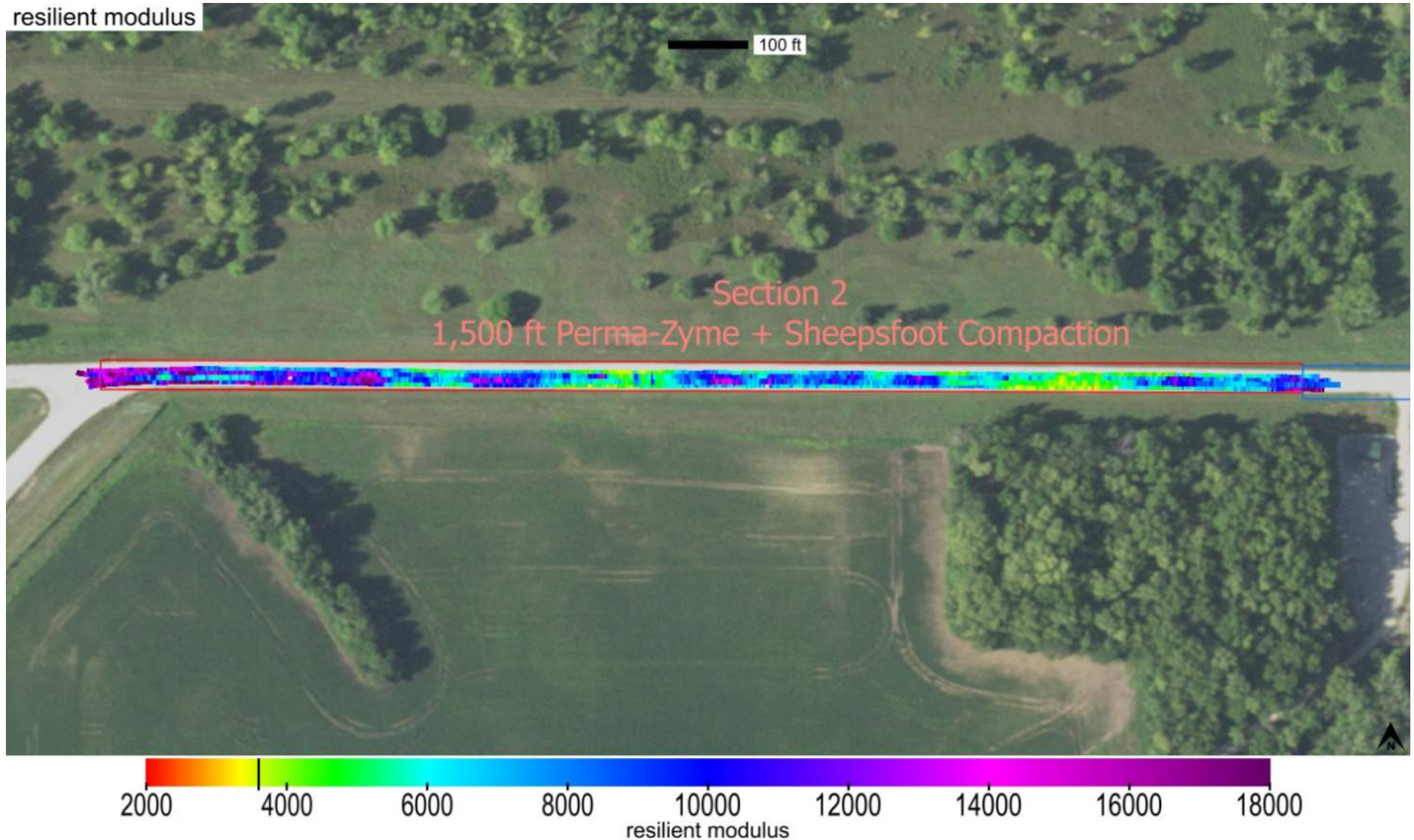
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	99.9	114.8	0.8	100.0	89.8	259.0	550.0	104.2	40.2	-10.2	159.0	450.0



Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	99.9	114.8	0.8	100.0	89.8	259.0	550.0	104.2	40.2	-10.2	159.0	450.0



Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	99.0	103.0	0.6	3600.0	2813.9	8369.4	20000.0	3527.6	42.2	-786.1	4769.4	16400.0

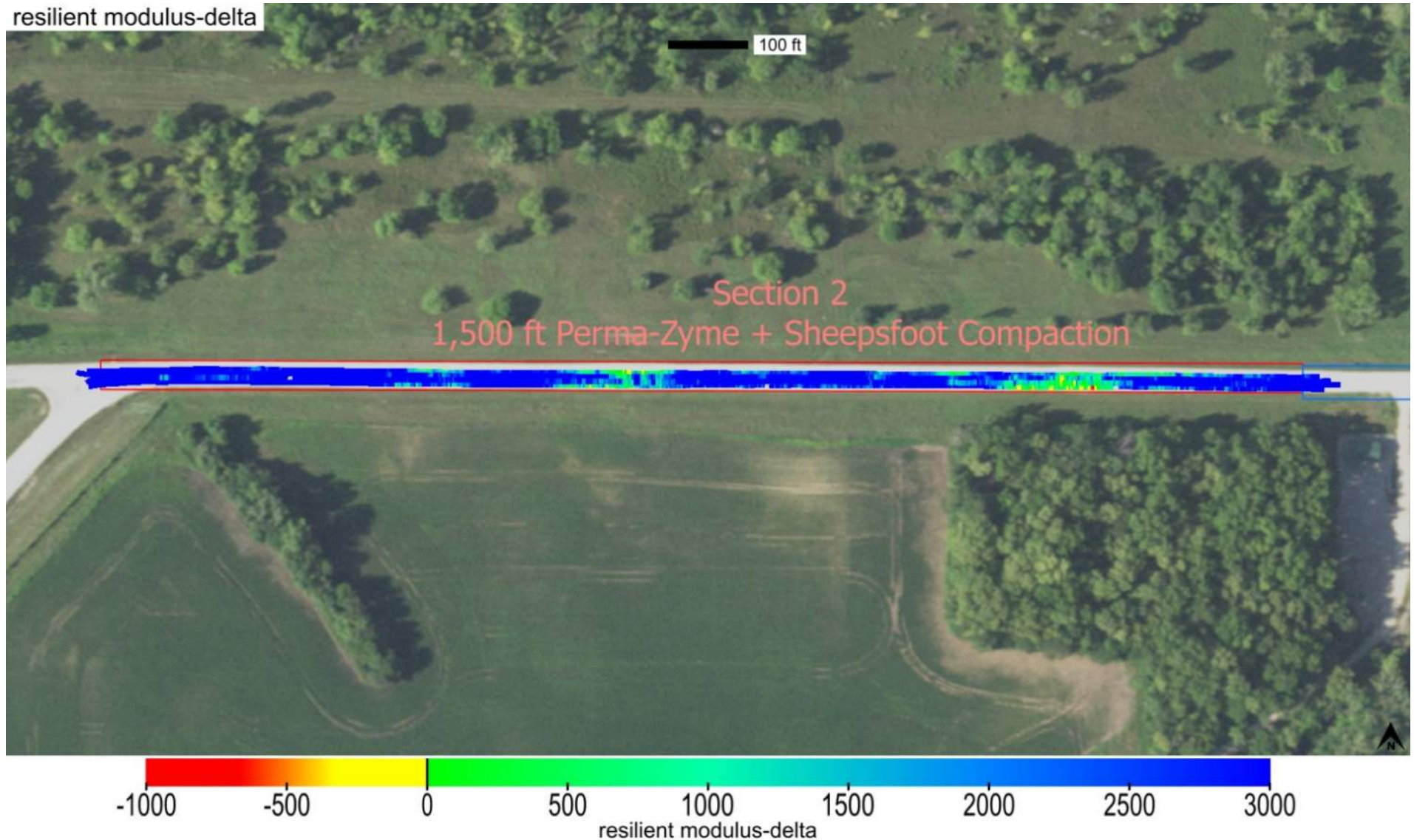


Map ID: ing_polk77-campdodge-2025_cs56b-01047_2025_03_31_113857

Map Type: Verification Map

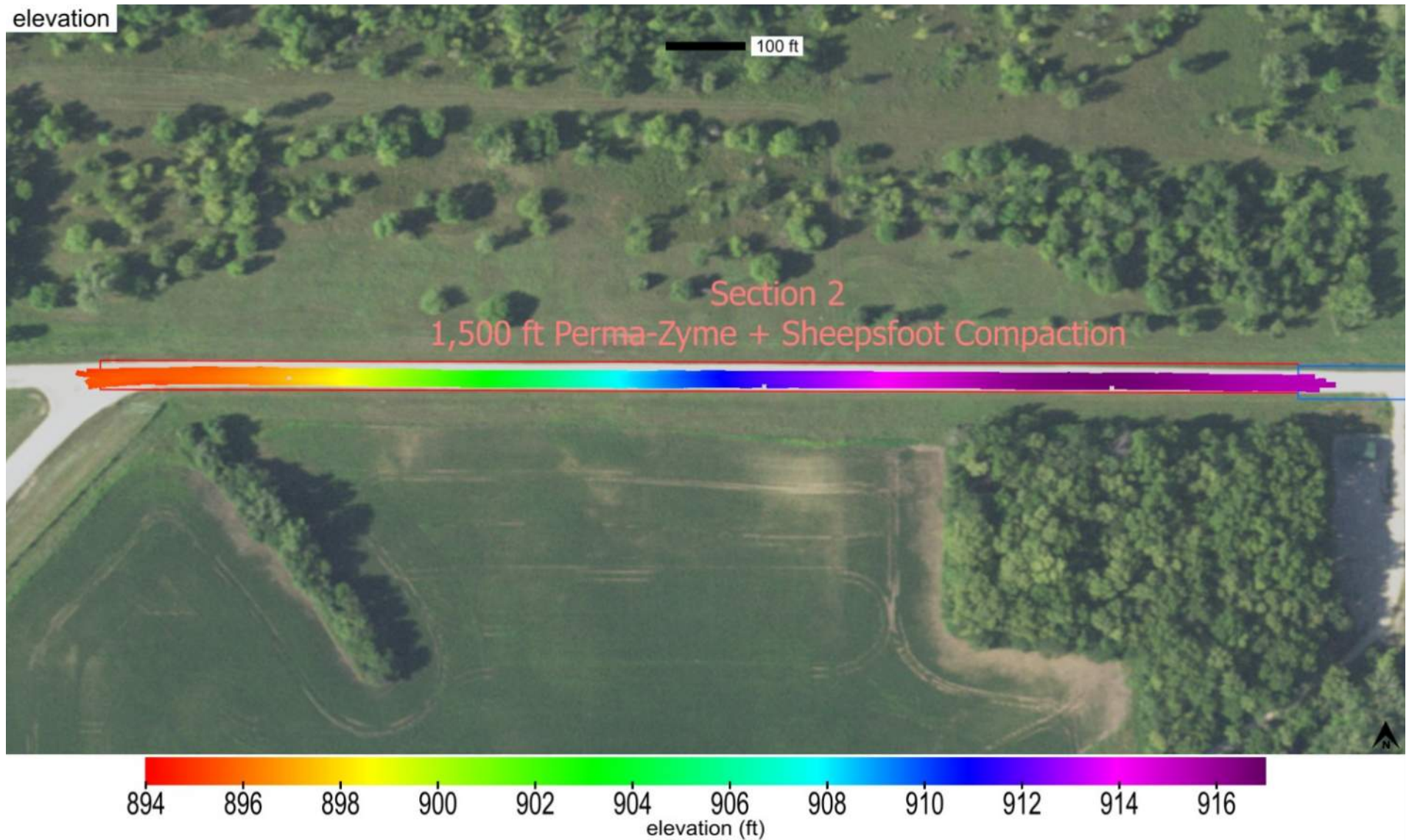
Map Layer: Unpaved Gravel Road

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	99.0	103.0	0.6	3600.0	2813.9	8369.4	20000.0	3527.6	42.2	-786.1	4769.4	16400.0



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minimum	average	maximum	RTK-Q7 (%)	RTK-QA
894.92	907.80	916.78	100.0	8.00





Map ID: ing_polk77-campdodge-2025_cs56b-01047_2025_03_31_121517

Project:	TR-823 Study	Date and Time:	3/31/2025 12:15:17 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.132	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	12449	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	3 - Smooth Drum

Map Summary

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
XMV	No												
Resilient Modulus	Yes	99.7	105.3	0.7	3600.0	3377.6	9534.9	20000.0	3690.4	38.7	-222.4	5934.9	16400.0
k-value	Yes	99.9	117.2	0.9	100.0	97.9	288.7	550.0	101.9	35.3	-2.1	188.7	450.0
Moisture Content	No												

Mapped Area

Pass Count

Elevation (ft)

Position Quality

Velocity (fps)

square feet	acres	10th percentile	Median	cov(%)	% >= TV	Target Value	min.	avg.	max.	RTK-Q7 (%)	RTK-QA	min.	avg.	max.
12449	0.286	1	1	33.1	100.0	0	940.20	942.45	944.23	100.0	8.00	5.1	5.3	6.1

Materials

name	id	% of total	area-square ft	area-acres	tl-xmv	tl-Mr	tl-k value	tl-w%
Unpaved Gravel Road (not defined)_IADOT	41019	100.0	12449	0.286	100.0	3600.0	100.0	20.5

Blobs

parameter	min. area(ft^2)	# of blobs	blob area(ft^2)	% of map	lower bound-tv	upper bound-tv	poly-tol.
Resilient Modulus	500.0	0	0	0.0	none	0.0	4.0
k-value	500.0	0	0	0.0	none	0.0	4.0

Station

Start	End
0+00	0+00

If the Calibration Index (CI) < 0.5, expand the measurement range with additional calibration test points at the limits.
If 0.5 > CI < 1.0, monitor for a downward trend and perform additional calibration test points.
If CI > 1.0, perform periodic calibration test points to verify the model.

This report is only for use of the client named and it cannot be relied upon by any other person or entity.

Map ID: ing_polk77-campdodge-2025_cs56b-01047_2025_03_31_121517

Project:	TR-823 Study	Date and Time:	3/31/2025 12:15:17 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.132	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	12449	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	3 - Smooth Drum

QUALITY ANALYSIS SUMMARY - k-Value

Quality Value	Criteria
117.2	CQI > = 95
99.9	80% of k-Value MVs >= 100
35.3	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2025_cs56b-01047_2025_03_31_121517

Project:	TR-823 Study	Date and Time:	3/31/2025 12:15:17 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.132	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	12449	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	3 - Smooth Drum

QUALITY ANALYSIS SUMMARY - Resilient Modulus

Quality Value	Criteria
105.3	CQI > = 95
99.7	90% of Resilient Modulus MVs >= 3600
38.7	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

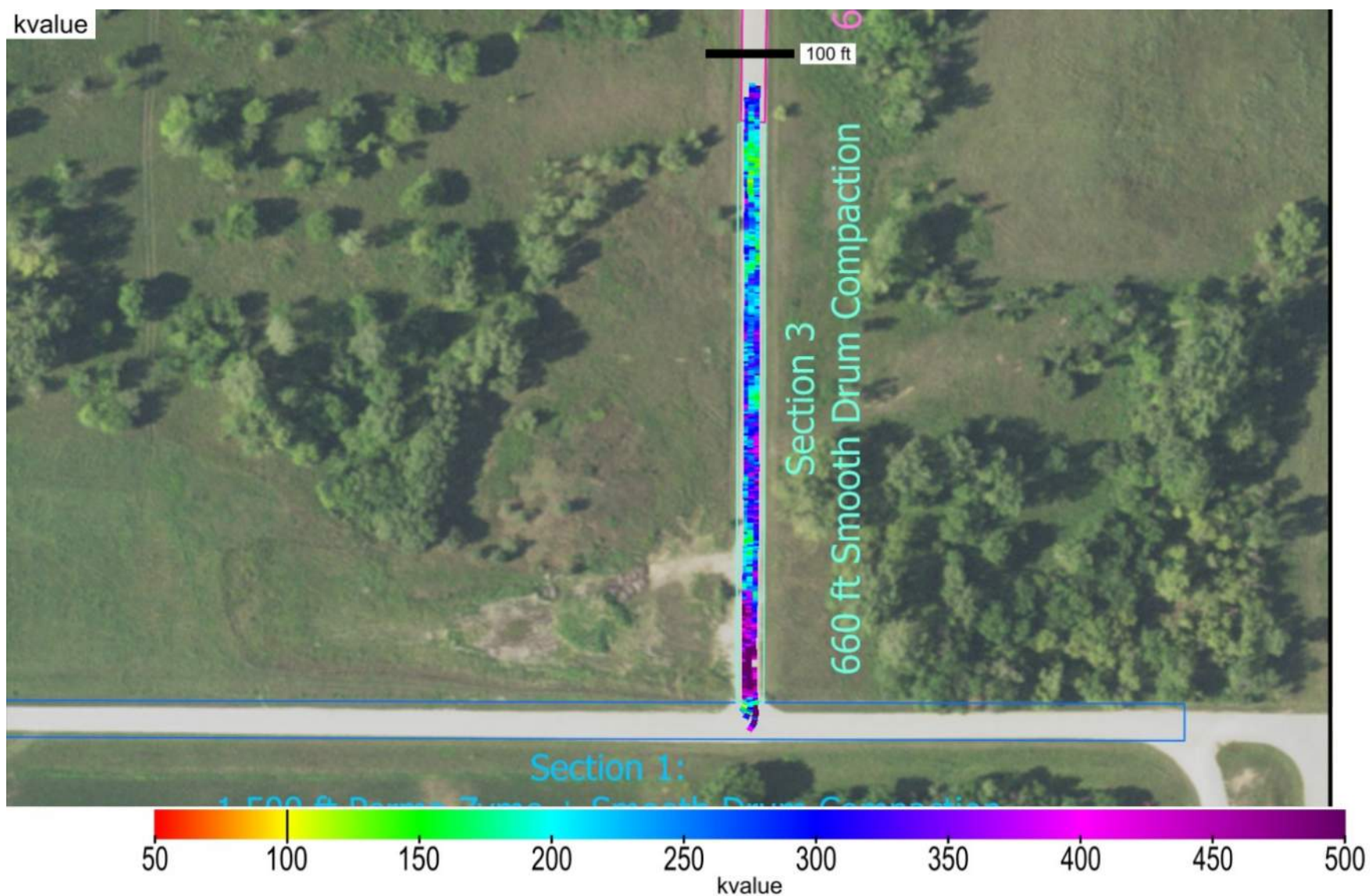
Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

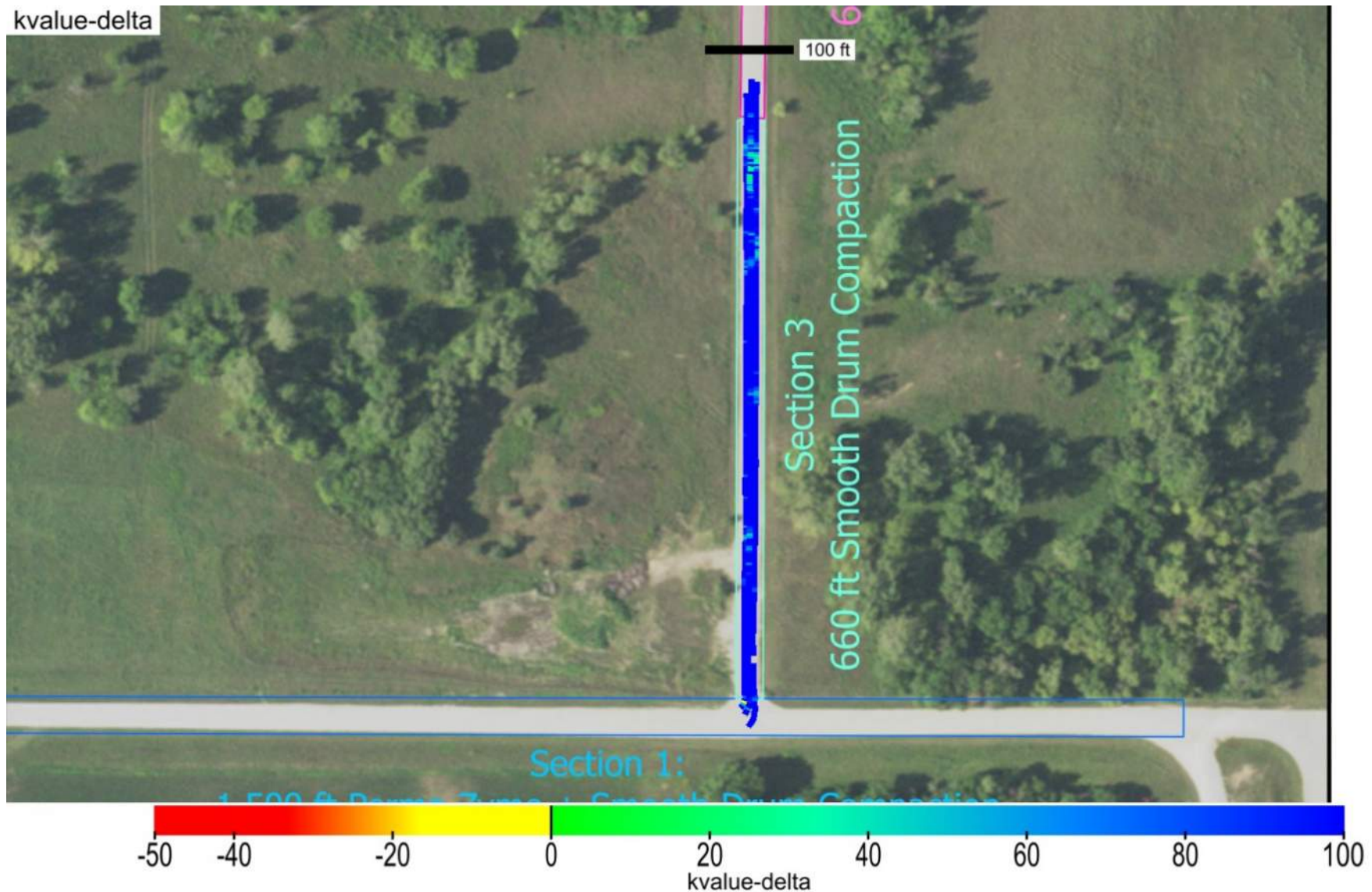
Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

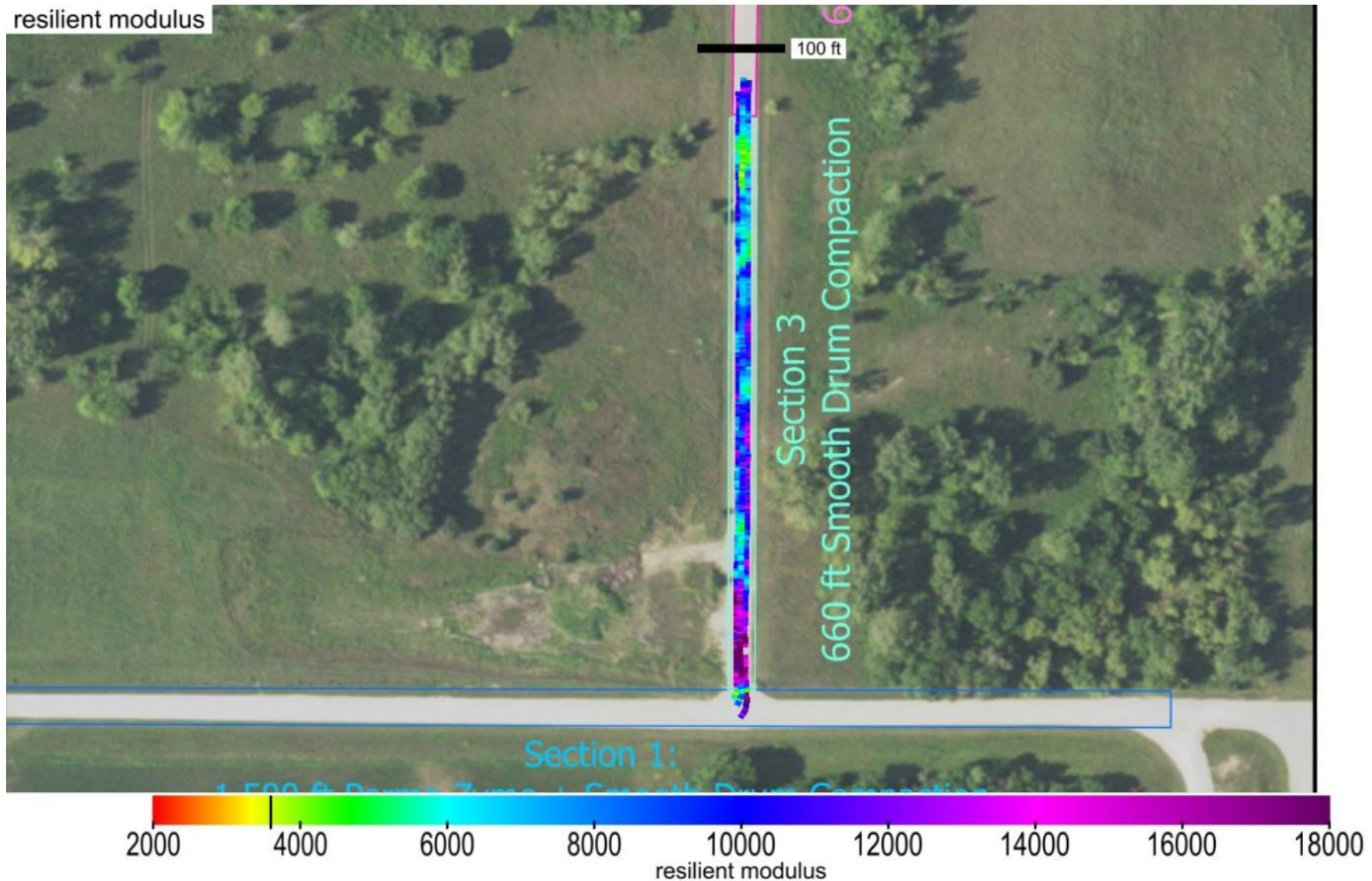
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	99.9	117.2	0.9	100.0	97.9	288.7	550.0	101.9	35.3	-2.1	188.7	450.0



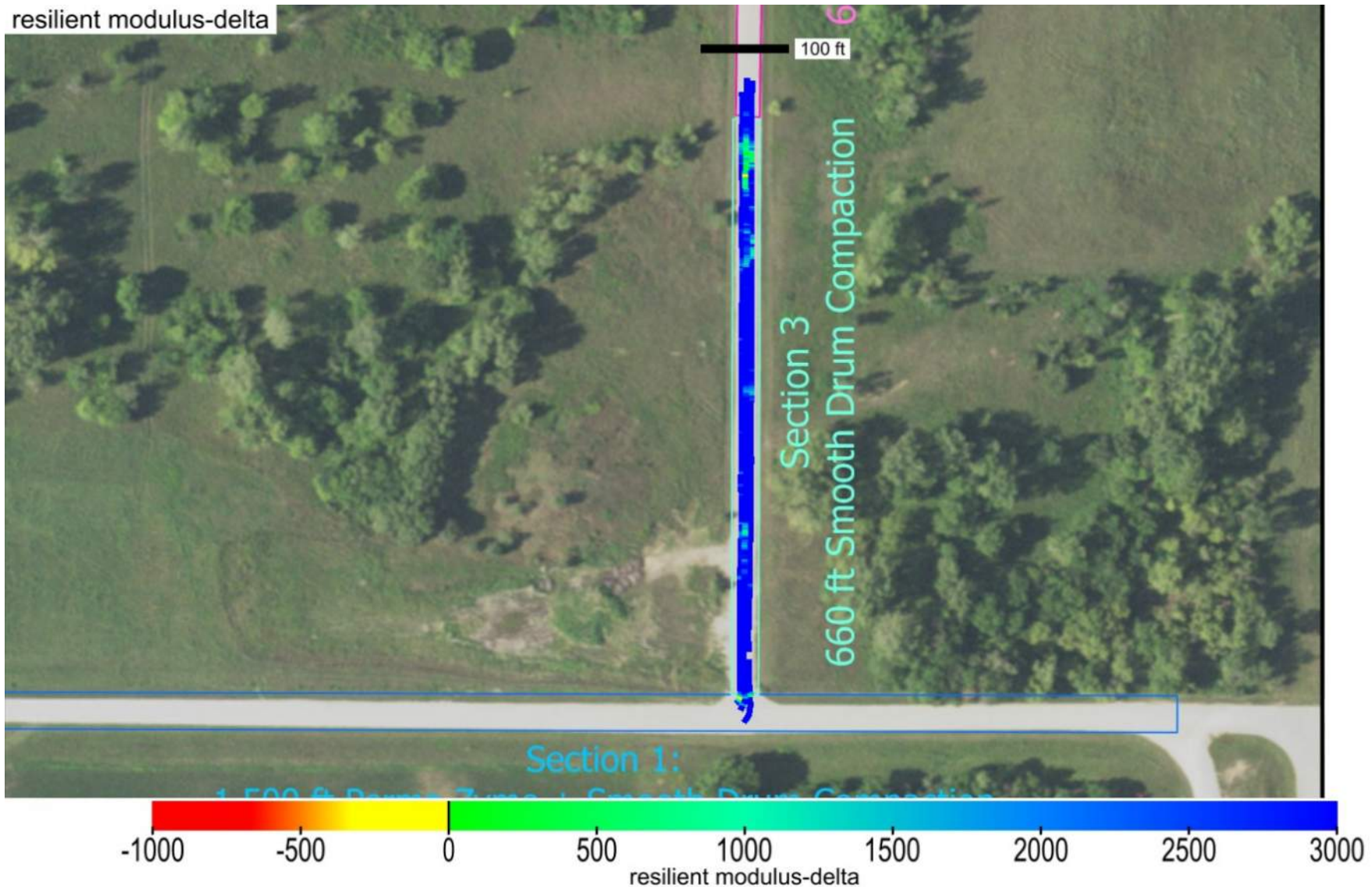
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	99.9	117.2	0.9	100.0	97.9	288.7	550.0	101.9	35.3	-2.1	188.7	450.0



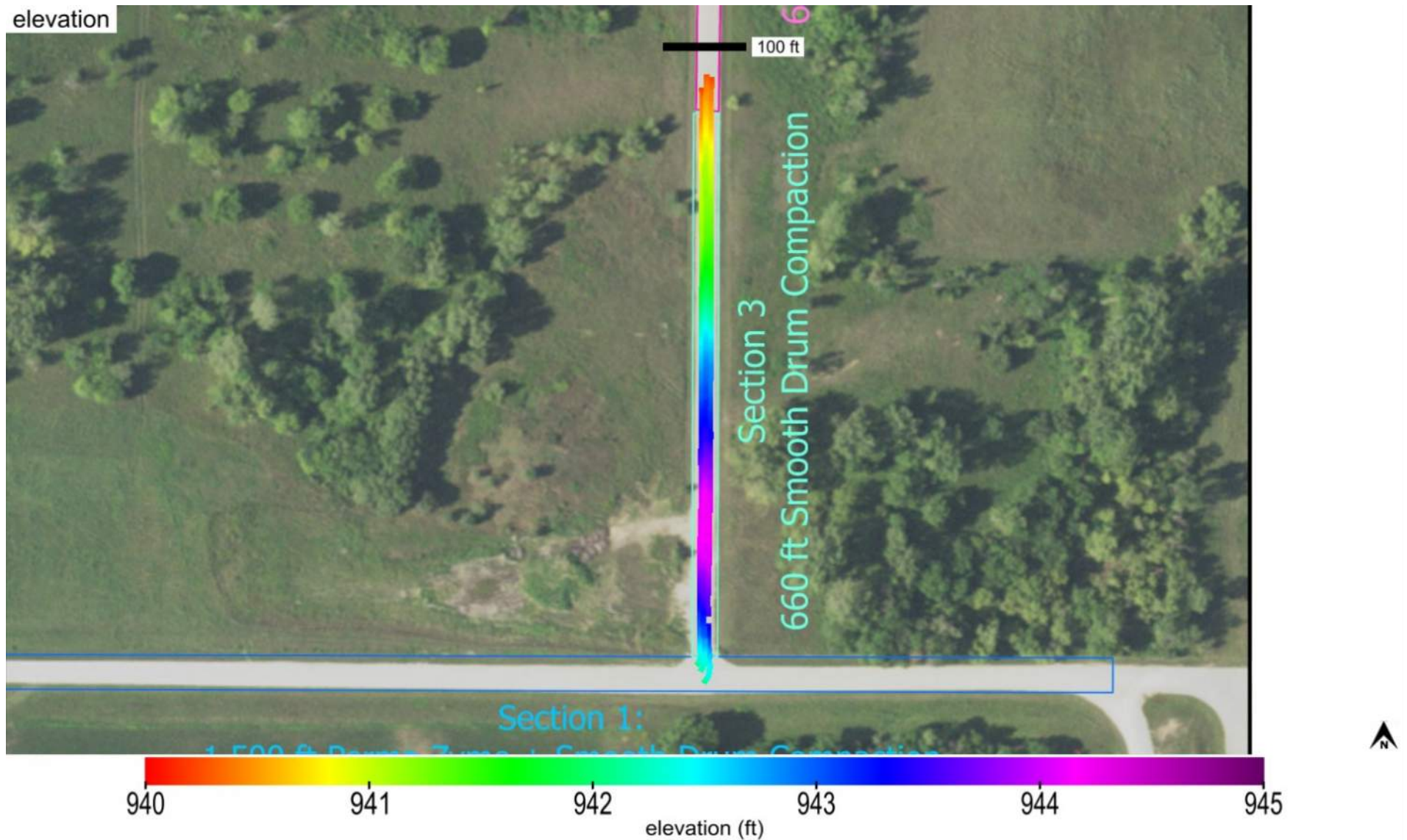
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	99.7	105.3	0.7	3600.0	3377.6	9534.9	20000.0	3690.4	38.7	-222.4	5934.9	16400.0



Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	99.7	105.3	0.7	3600.0	3377.6	9534.9	20000.0	3690.4	38.7	-222.4	5934.9	16400.0



minimum	average	maximum	RTK-Q7 (%)	RTK-QA
940.20	942.45	944.23	100.0	8.00





Map ID: ing_polk77-campdodge-2025_cs56b-01047_2025_03_31_123405

Project:	TR-823 Study	Date and Time:	3/31/2025 12:34:05 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.131	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	12569	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	4 - Sheepsfoot

Map Summary

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
XMV	No												
Resilient Modulus	Yes	100.0	111.3	1.0	3600.0	3766.6	9774.1	19980.0	2671.5	27.3	166.6	6174.1	16380.0
k-value	Yes	100.0	121.2	1.1	100.0	109.5	287.0	550.0	79.4	27.7	9.5	187.0	450.0
Moisture Content	No												

Mapped Area		Pass Count					Elevation (ft)			Position Quality		Velocity (fps)		
square feet	acres	10th percentile	Median	cov(%)	% >= TV	Target Value	min.	avg.	max.	RTK-Q7 (%)	RTK-QA	min.	avg.	max.
12569	0.289	1	1	33.0	100.0	0	936.96	939.13	940.71	100.0	8.00	5.1	5.3	6.0

Materials

name	id	% of total	area-square ft	area-acres	tl-xmv	tl-Mr	tl-k value	tl-w%
Unpaved Gravel Road (not defined)_IADOT	41019	100.0	12569	0.289	100.0	3600.0	100.0	20.5

Blobs

parameter	min. area(ft^2)	# of blobs	blob area(ft^2)	% of map	lower bound-tv	upper bound-tv	poly-tol.
Resilient Modulus	500.0	0	0	0.0	none	0.0	4.0
k-value	500.0	0	0	0.0	none	0.0	4.0

Station

Start	End
0+00	0+00

If the Calibration Index (CI) < 0.5, expand the measurement range with additional calibration test points at the limits.
If 0.5 > CI < 1.0, monitor for a downward trend and perform additional calibration test points.
If CI > 1.0, perform periodic calibration test points to verify the model.

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Map ID: ing_polk77-campdodge-2025_cs56b-01047_2025_03_31_123405

Project:	TR-823 Study	Date and Time:	3/31/2025 12:34:05 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.131	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	12569	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	4 - Sheepsfoot

QUALITY ANALYSIS SUMMARY - k-Value

Quality Value	Criteria
121.2	CQI > = 95
100.0	80% of k-Value MVs >= 100
27.7	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2025_cs56b-01047_2025_03_31_123405

Project:	TR-823 Study	Date and Time:	3/31/2025 12:34:05 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.131	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	12569	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	4 - Sheepsfoot

QUALITY ANALYSIS SUMMARY - Resilient Modulus

Quality Value	Criteria
111.3	CQI > = 95
100.0	90% of Resilient Modulus MVs >= 3600
27.3	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

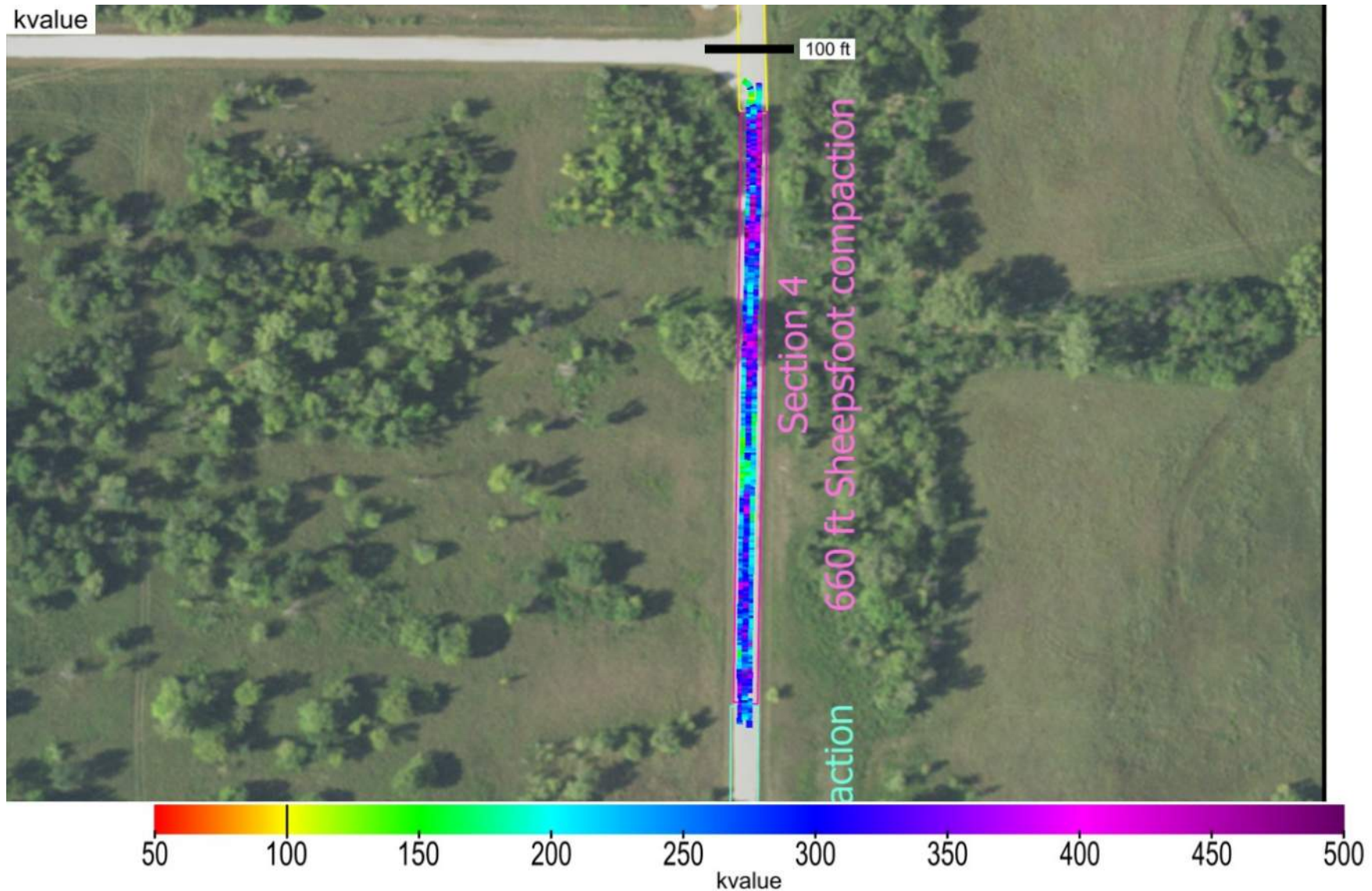
Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2025_cs56b-01047_2025_03_31_123405

Map Type: Verification Map

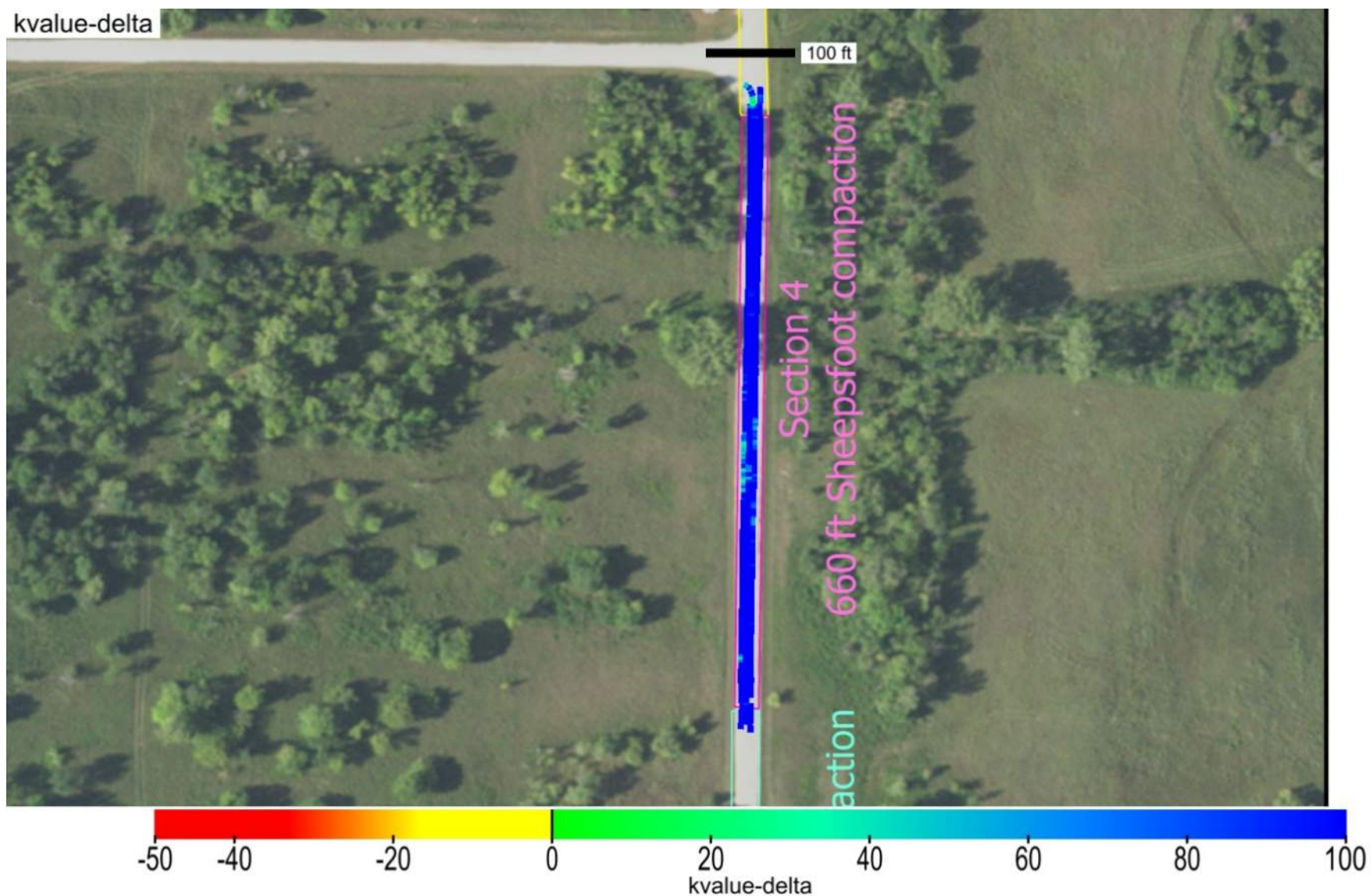
Map Layer: Unpaved Gravel Road

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	121.2	1.1	100.0	109.5	287.0	550.0	79.4	27.7	9.5	187.0	450.0

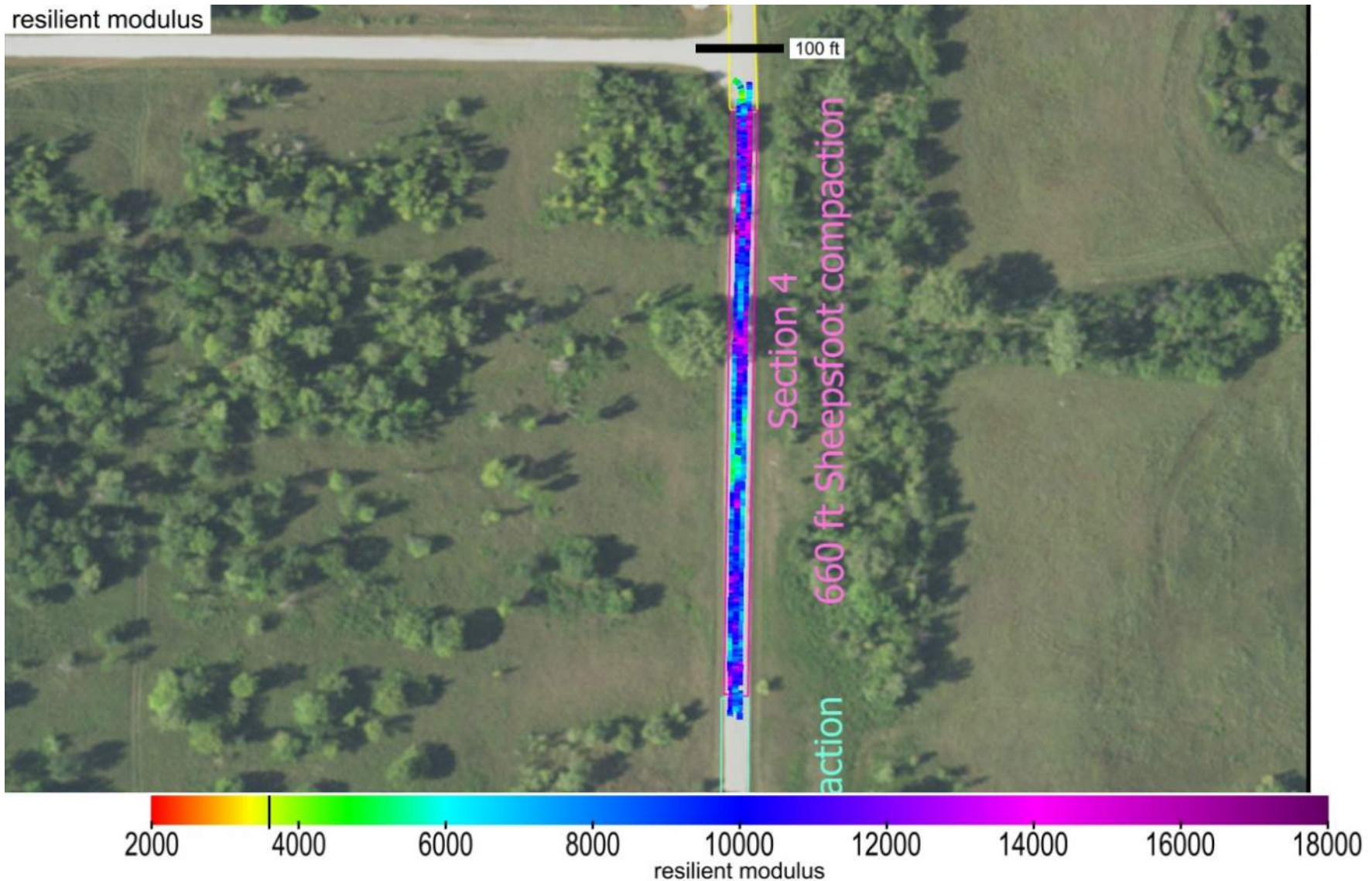


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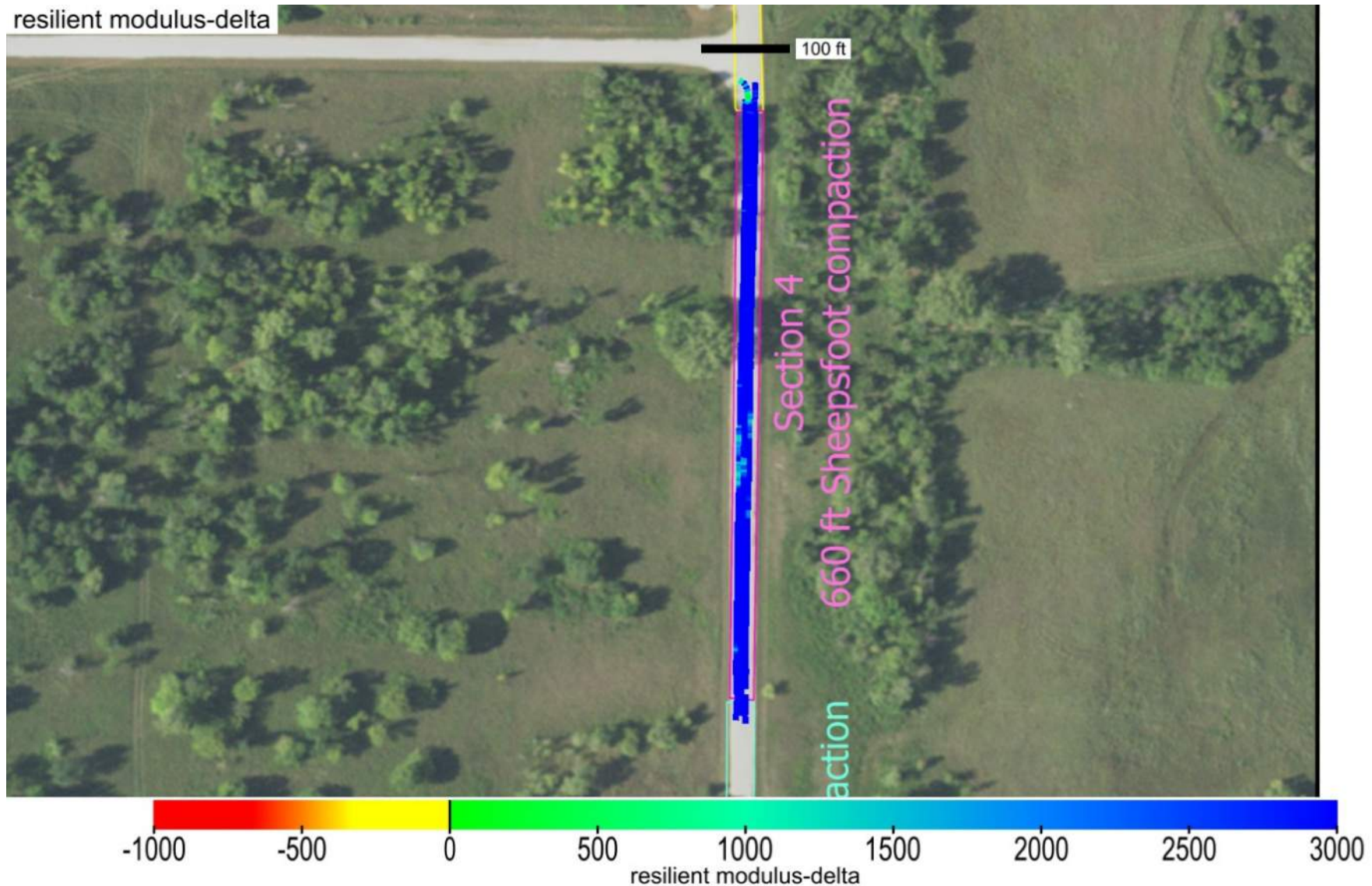
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	100.0	121.2	1.1	100.0	109.5	287.0	550.0	79.4	27.7	9.5	187.0	450.0



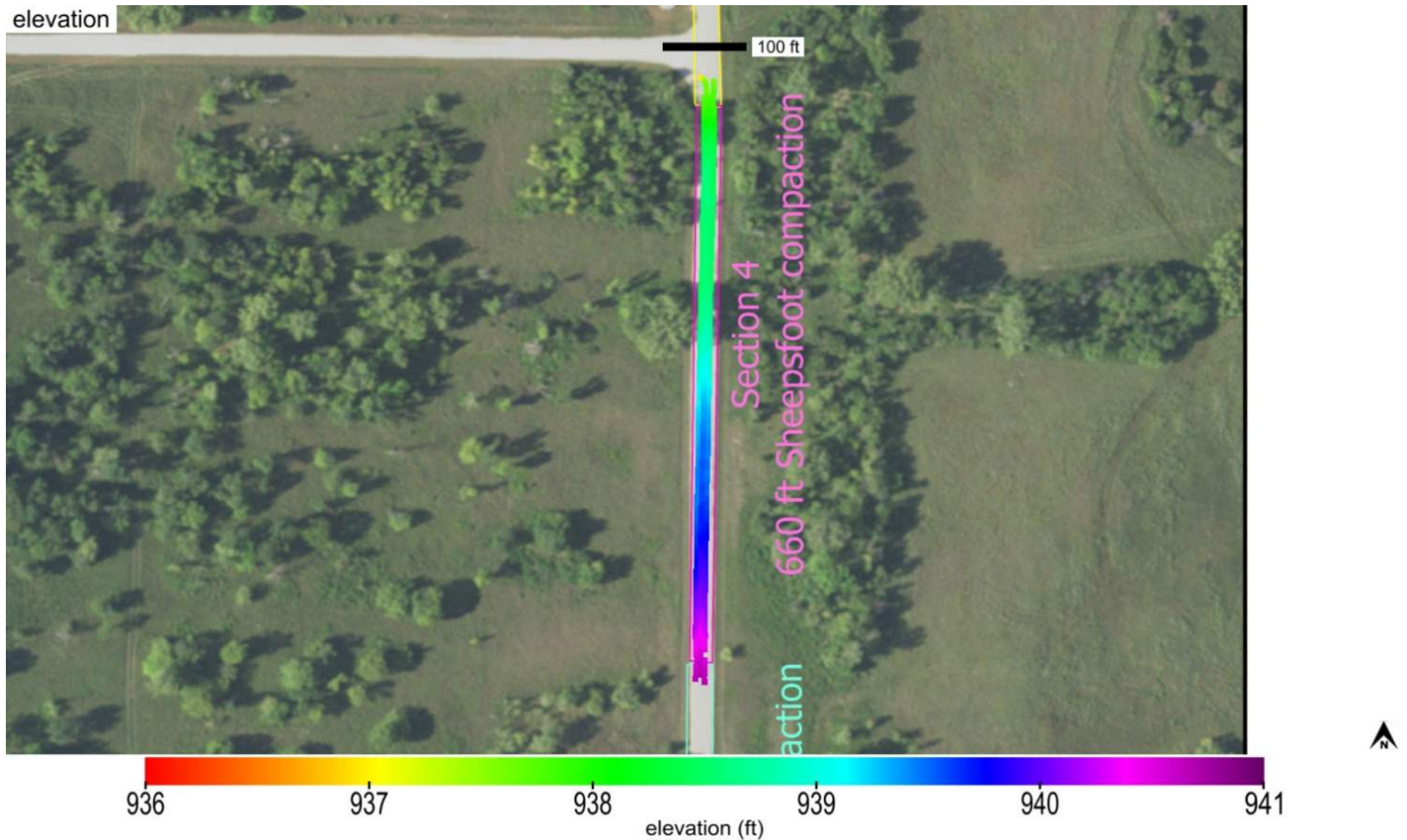
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	111.3	1.0	3600.0	3766.6	9774.1	19980.0	2671.5	27.3	166.6	6174.1	16380.0



Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	100.0	111.3	1.0	3600.0	3766.6	9774.1	19980.0	2671.5	27.3	166.6	6174.1	16380.0



minimum	average	maximum	RTK-Q7 (%)	RTK-QA
936.97	939.13	940.71	100.0	8.00





Map ID: ing_polk77-campdodge-2025_cs56b-01047_2025_03_31_130357

Project:	TR-823 Study	Date and Time:	3/31/2025 1:03:57 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.442	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	30588	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	5 - Control

Map Summary

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
XMV	No												
Resilient Modulus	Yes	97.3	99.1	0.6	3600.0	2745.3	8933.0	20000.0	4152.9	46.5	-854.7	5333.0	16400.0
k-value	Yes	99.4	112.8	0.7	100.0	86.5	266.6	550.0	115.5	43.3	-13.5	166.6	450.0
Moisture Content	No												

Mapped Area		Pass Count					Elevation (ft)			Position Quality		Velocity (fps)		
square feet	acres	10th percentile	Median	cov(%)	% >= TV	Target Value	min.	avg.	max.	RTK-Q7 (%)	RTK-QA	min.	avg.	max.
30588	0.702	1	1	34.8	100.0	0	937.12	943.83	952.69	100.0	8.00	4.9	5.3	6.0

Materials

name	id	% of total	area-square ft	area-acres	tl-xmv	tl-Mr	tl-k value	tl-w%
Unpaved Gravel Road (not defined)_IADOT	41019	100.0	30588	0.702	100.0	3600.0	100.0	20.5

Blobs

parameter	min. area(ft^2)	# of blobs	blob area(ft^2)	% of map	lower bound-tv	upper bound-tv	poly-tol.
Resilient Modulus	500.0	0	0	0.0	none	0.0	4.0
k-value	500.0	0	0	0.0	none	0.0	4.0

Station

Start	End
0+00	0+00

If the Calibration Index (CI) < 0.5, expand the measurement range with additional calibration test points at the limits.
If 0.5 > CI < 1.0, monitor for a downward trend and perform additional calibration test points.
If CI > 1.0, perform periodic calibration test points to verify the model.

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Map ID: ing_polk77-campdodge-2025_cs56b-01047_2025_03_31_130357

Project:	TR-823 Study	Date and Time:	3/31/2025 1:03:57 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.442	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	30588	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	5 - Control

QUALITY ANALYSIS SUMMARY - k-Value

Quality Value	Criteria
112.8	CQI > = 95
99.4	80% of k-Value MVs >= 100
43.3	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2025_cs56b-01047_2025_03_31_130357

Project:	TR-823 Study	Date and Time:	3/31/2025 1:03:57 PM	Machine ID:	Ingios
Description:	IHRB Gravel Research Roads	Mapping Duration (hrs):	0.442	Operator:	Ingios01
Location:	Camp Dodge - Johnston IA USA	No. of Measurements:	30588	Machine Operator ID:	582
Review Status:	Review Required	Map Type:	Verification Map	State Plane:	1402 IOWA SOUTH
		Map Layer:	Unpaved Gravel Road	Segment:	5 - Control

QUALITY ANALYSIS SUMMARY - Resilient Modulus

Quality Value	Criteria
99.1	CQI > = 95
97.3	90% of Resilient Modulus MVs >= 3600
46.5	COV <= 30
0.0	% i-Score Blob Area >= 500 ft^2
N/A	Lift Thickness Median Value (in.)
1	Pass Count >= 0

Compaction Quality Index(CQI): Relative compaction quality index based on the percentage of the geospatial area that meets the minimum target values and accounts for the uniformity of compaction. The default minimum target CQI is 95% using a uniformity weight factor of 50%.

Percent Passing Target Values: Number of geospatial grid points from the output that meet or exceed the target value (TV) for the selected material. Level I target % Passing TV = 80%. Level II target % Passing TV = 90%.

Coefficient of Variation (COV): Calculated from the ratio of the standard deviation to the mean based on the measurement values (MV) reported at each grid point of the mapping area. Description of COV ranges: <= 20% = Low Variability; 20 to 40% = Moderate Variability; > 40% = High Variability. The default target COV is <= 30%.

i-Score Blob (%): The percentage of the map area analyzed with contiguous blob areas with MVs < TV. Control Level 1 >= 100 sq. ft.; Control Level 2 >= 200 sq. ft.; Control Level 3 >= 500 sq. ft.; Control Level 4 >= 1,000 sq. ft.; Control Level 5 >= 2,000 sq. ft.

Lift thickness: Green: 75th percentile value <= TV; Yellow: median value <= TV and 75th percentile > TV; Red: median value (50th percentile) > TV.

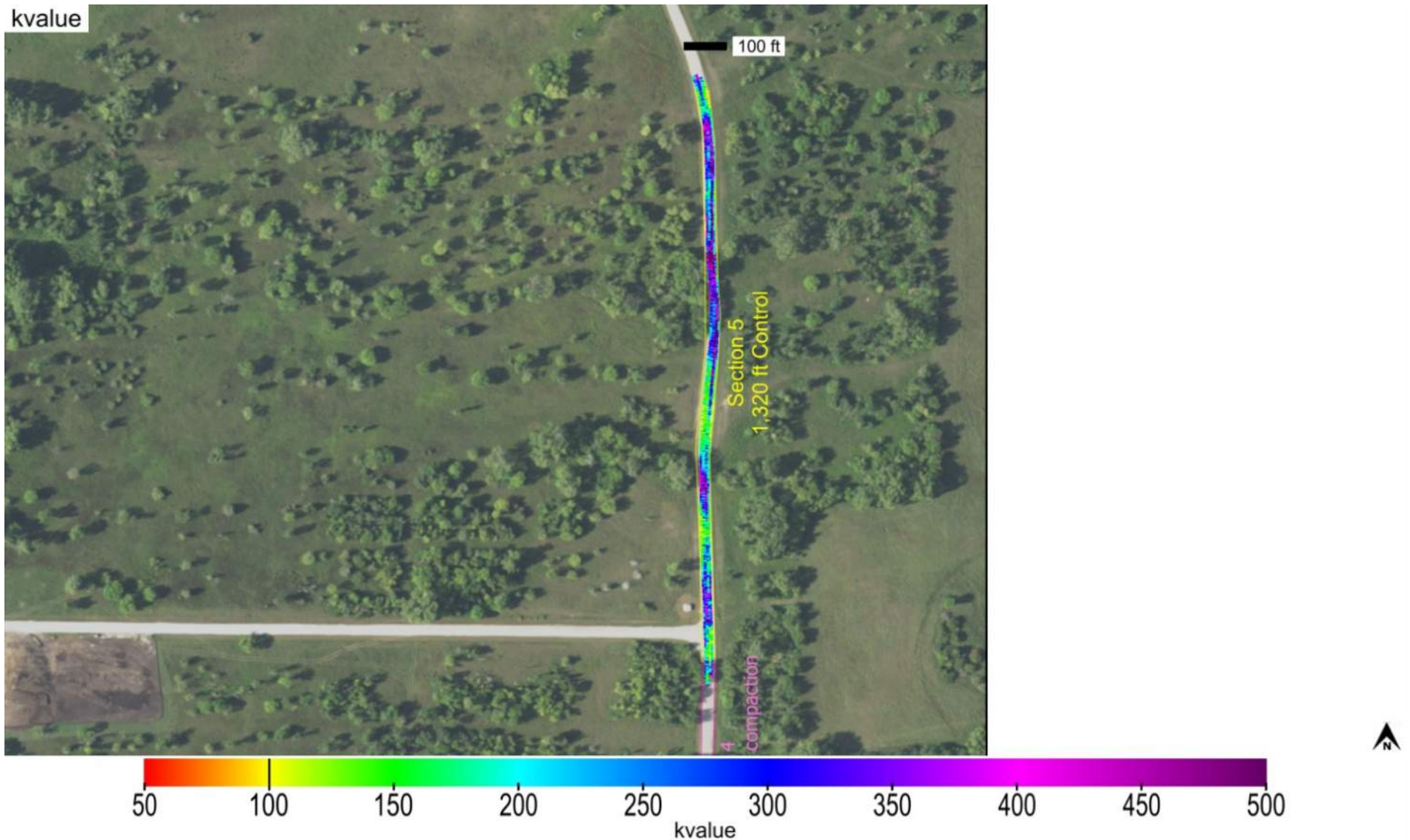
Pass Count: Green: 10th percentile value >= TV; Yellow: 10th percentile value >= TV and cov% > 50%; Red: 10th percentile value < TV.

Map ID: ing_polk77-campdodge-2025_cs56b-01047_2025_03_31_130357

Map Type: Verification Map

Map Layer: Unpaved Gravel Road

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	99.4	112.8	0.7	100.0	86.5	266.6	550.0	115.5	43.3	-13.5	166.6	450.0



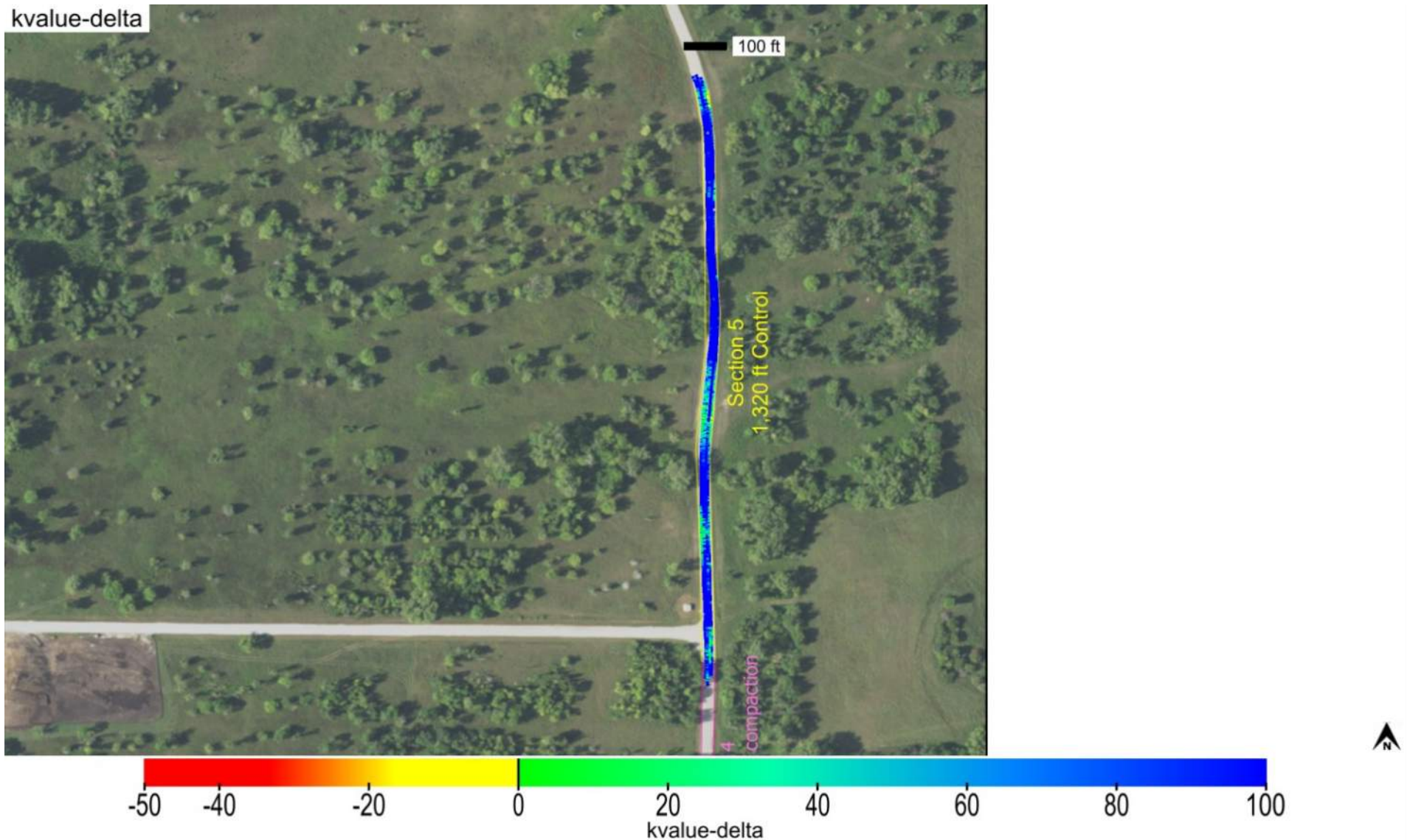
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Map ID: ing_polk77-campdodge-2025_cs56b-01047_2025_03_31_130357

Map Type: Verification Map

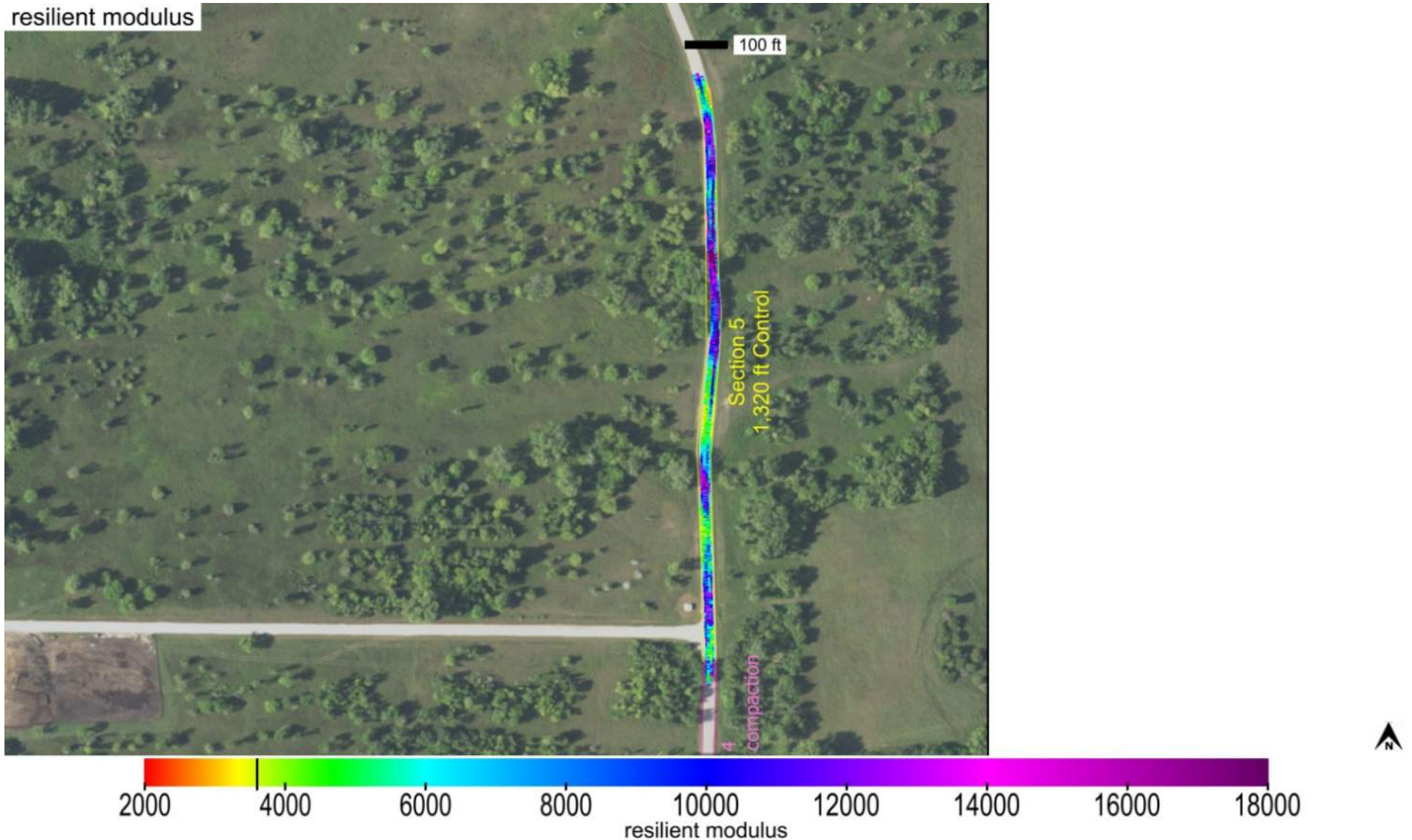
Map Layer: Unpaved Gravel Road

Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
k-value	Yes	99.4	112.8	0.7	100.0	86.5	266.6	550.0	115.5	43.3	-13.5	166.6	450.0

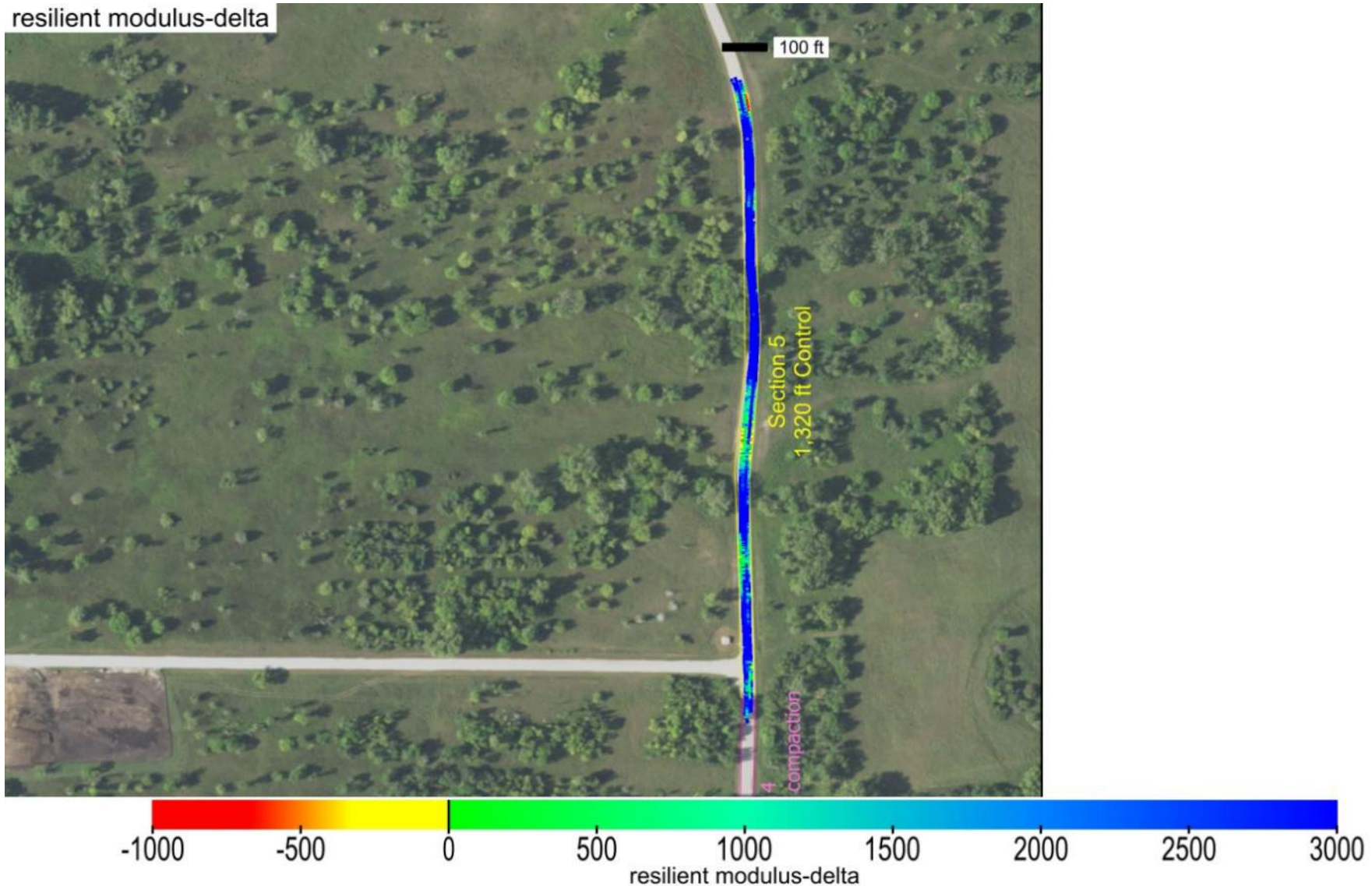


This report is only for use of the client named and it cannot be relied upon by any other person or entity.

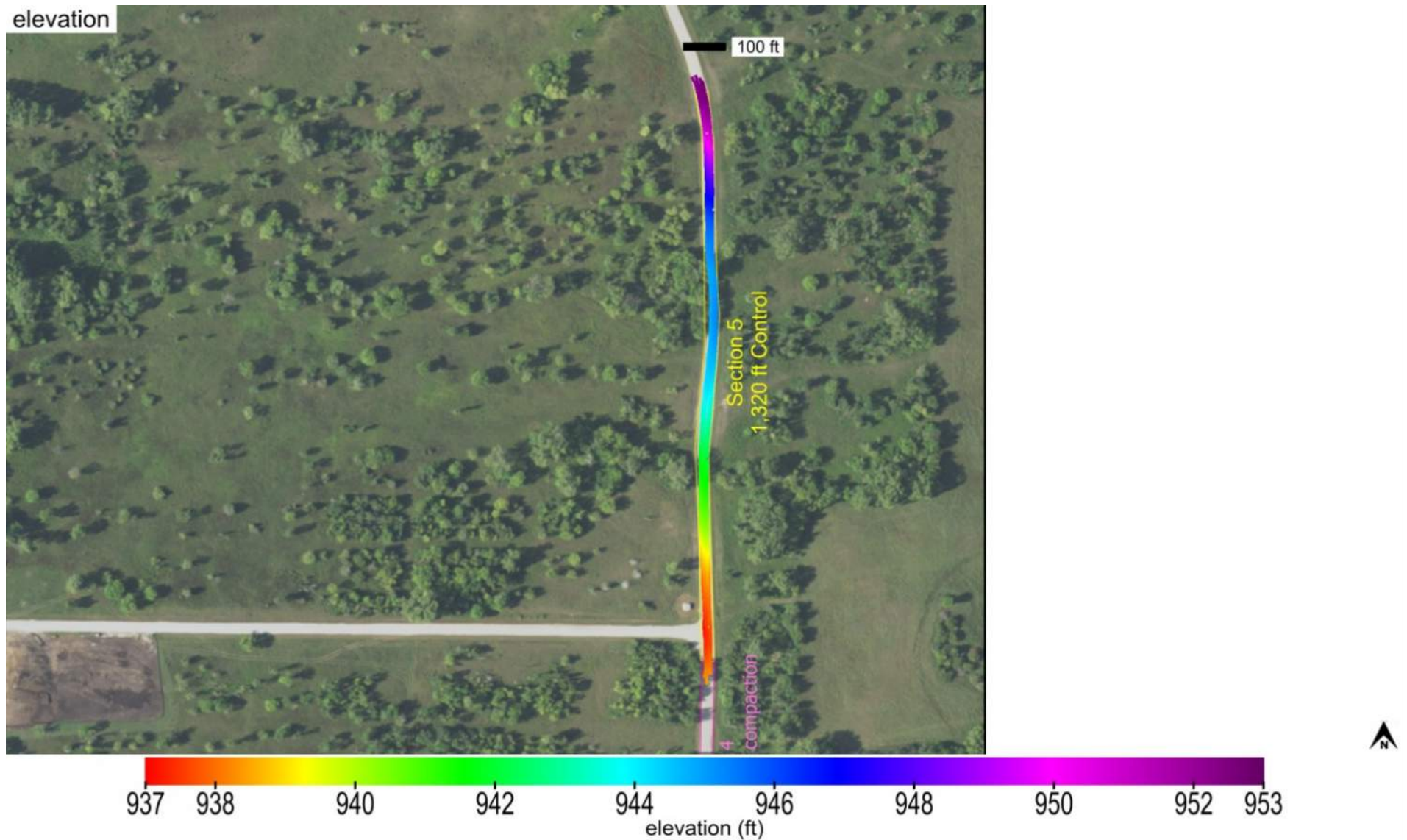
Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	97.3	99.1	0.6	3600.0	2745.3	8933.0	20000.0	4152.9	46.5	-854.7	5333.0	16400.0



Parameter	Measured	% Passing	CQI	CI	Calc. TV	min.	avg.	max.	std. dev.	cov(%)	min.-delta	avg.-delta	max.-delta
resilient modulus	Yes	97.3	99.1	0.6	3600.0	2745.3	8933.0	20000.0	4152.9	46.5	-854.7	5333.0	16400.0



minimum	average	maximum	RTK-Q7 (%)	RTK-QA
937.12	943.83	952.69	100.0	8.00





Appendix C: Box and Whisker Plots and Summary Statistics

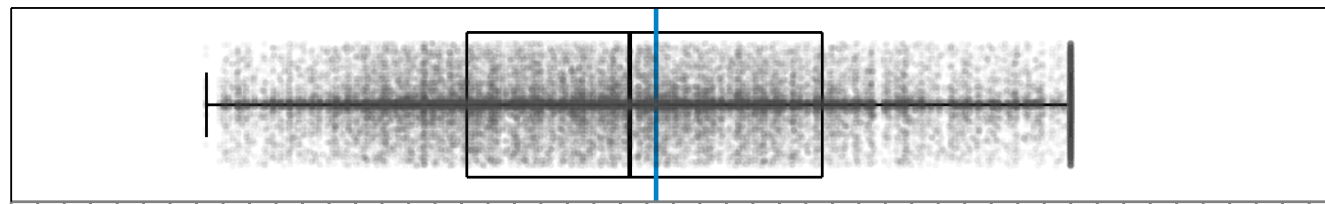
Notes on how to read box and whisker plots:

- *The box's limits represent the 25th and 75th percentiles.*
- *The black line inside the box represents the median value, and the blue line represents the mean value.*
- *The lower and upper whiskers represent the 10th and 90th percentile values.*

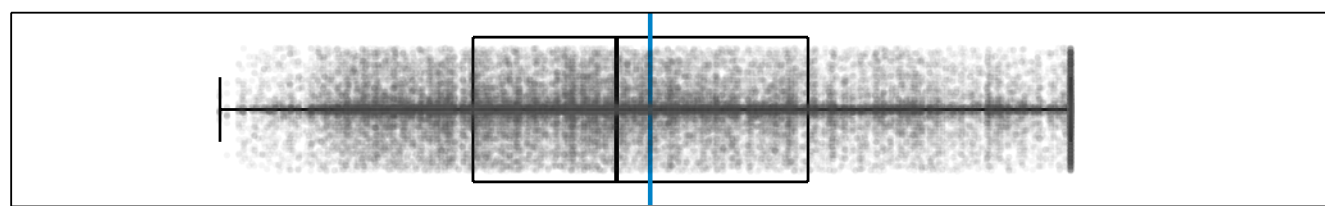
Camp Dodge (Johnston, IA) – Unpaved Gravel Road

08/07/2023

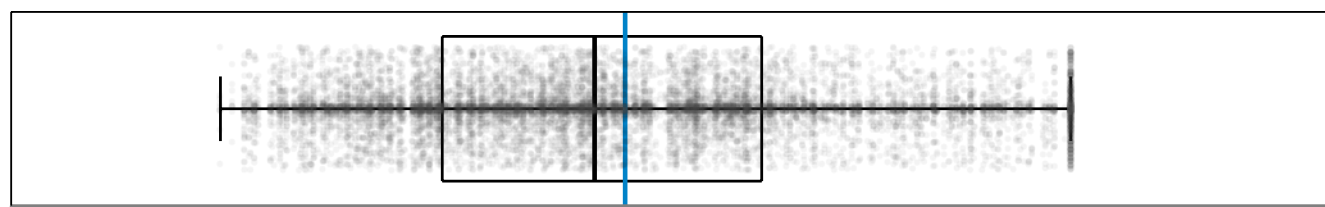
Section 1: Before re-compaction/stabilization



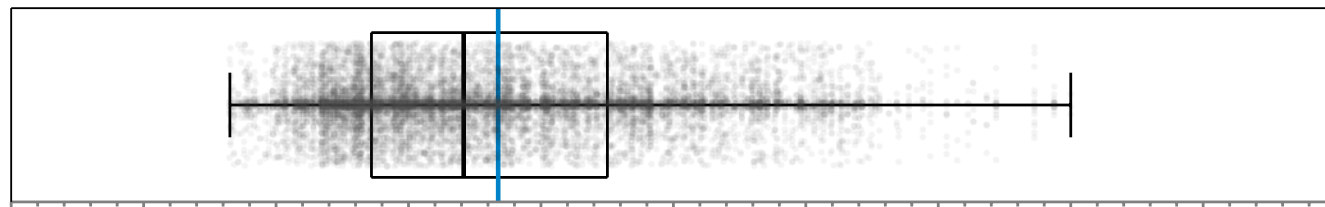
Section 2: Before re-compaction/stabilization



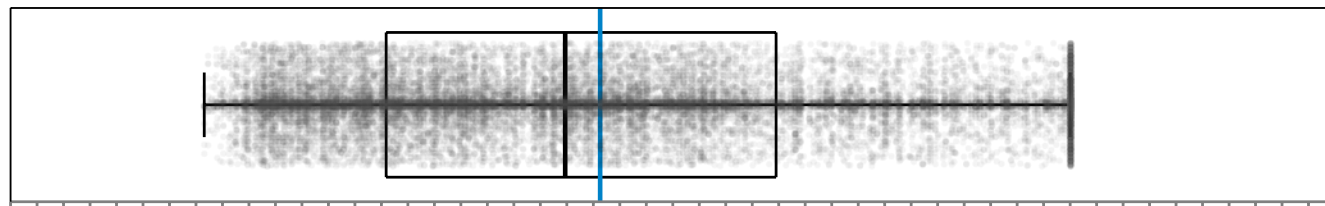
Section 3: Before re-compaction/stabilization



Section 4: Before re-compaction/stabilization

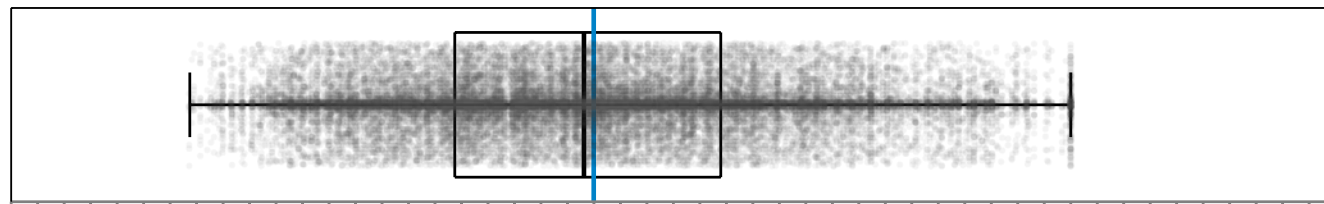


Section 5: Control

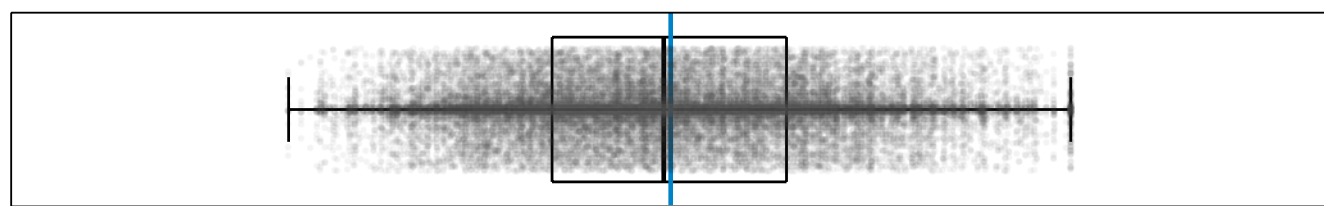


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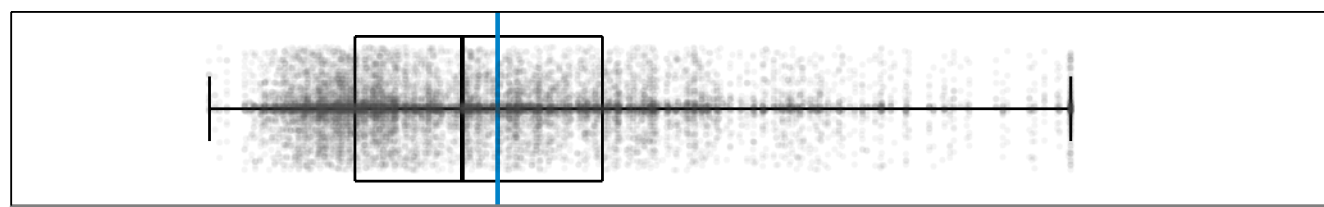
Section 1: After 1,500 ft Perma-Zyme + Smooth Drum Compaction



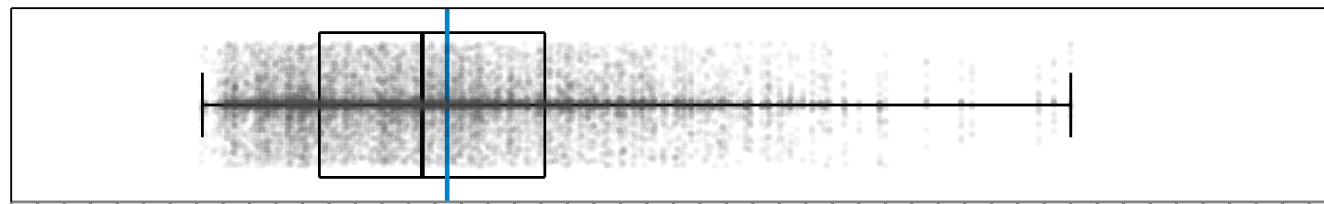
Section 2: After 1,500 ft Perma-Zyme + Sheepfoot Compaction



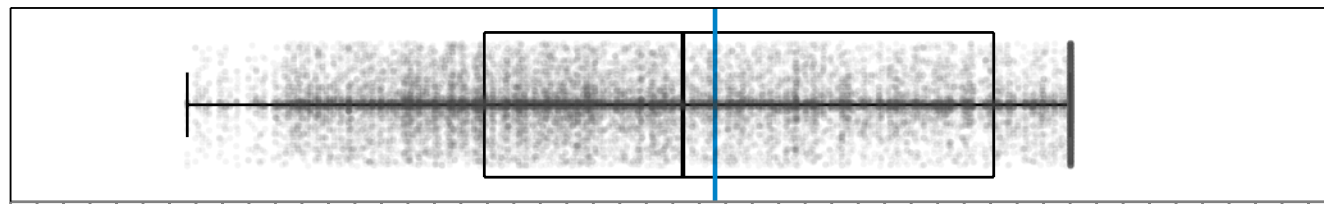
Section 3: After 660 ft Smooth Drum Compaction



Section 4: After 660 ft Sheepfoot Compaction

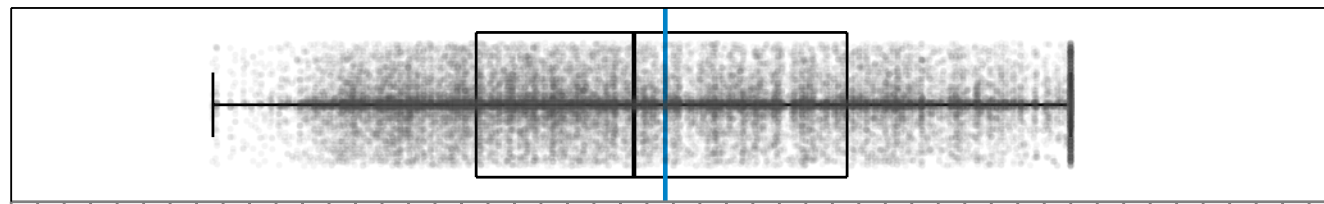


Section 5: 1,320 ft Control

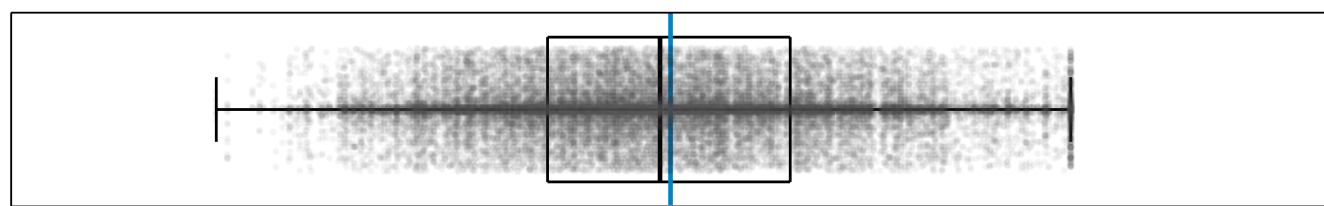


Camp Dodge (Johnston, IA) – Unpaved Gravel Road **03/07/2024**

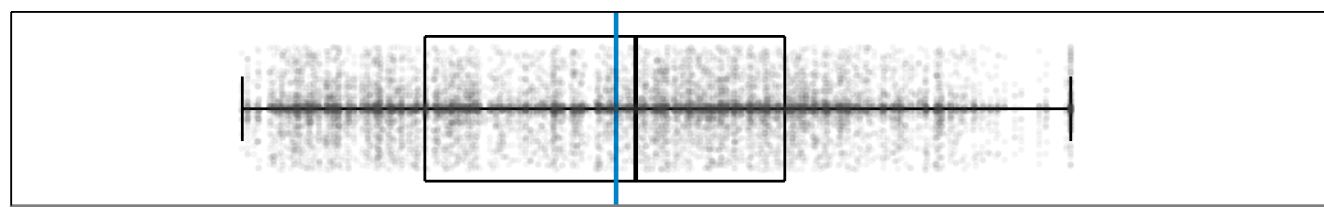
Section 1: After 1,500 ft Perma-Zyme + Smooth Drum Compaction



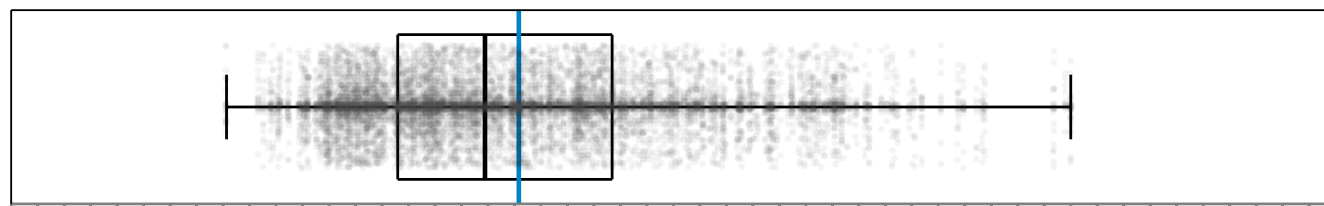
Section 2: After 1,500 ft Perma-Zyme + Sheepfoot Compaction



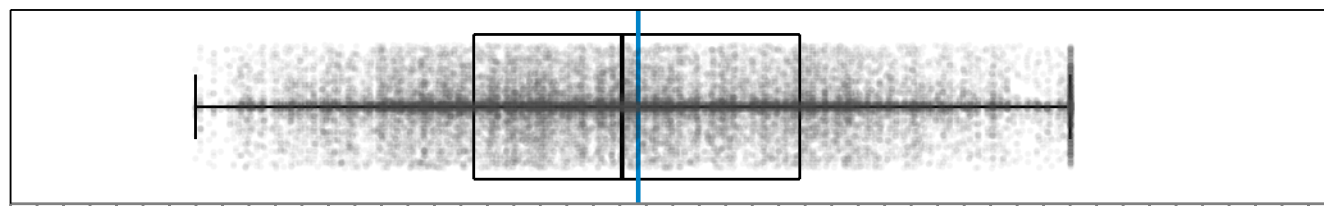
Section 3: After 660 ft Smooth Drum Compaction



Section 4: After 660 ft Sheepfoot Compaction

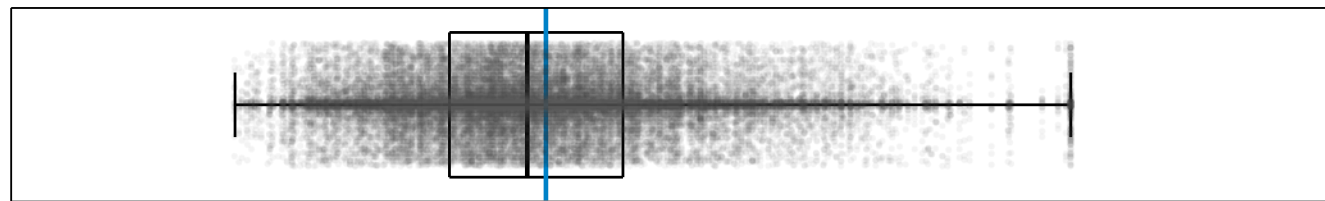


Section 5: 1,320 ft Control

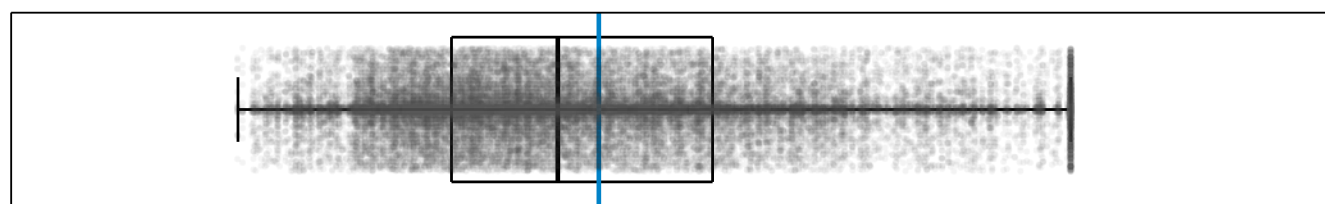


Camp Dodge (Johnston, IA) – Unpaved Gravel Road **10/31/2024**

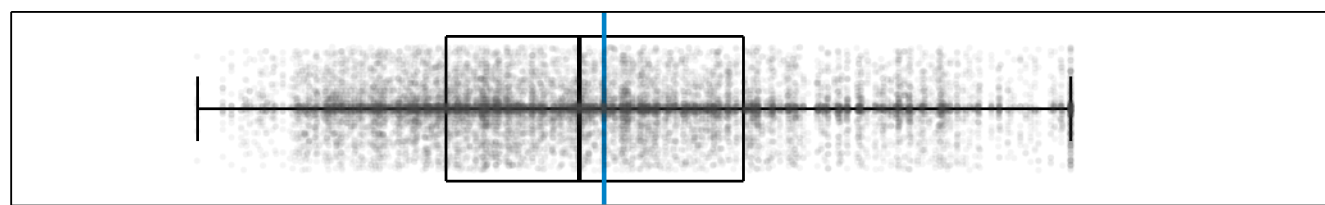
Section 1: After 1,500 ft Perma-Zyme + Smooth Drum Compaction



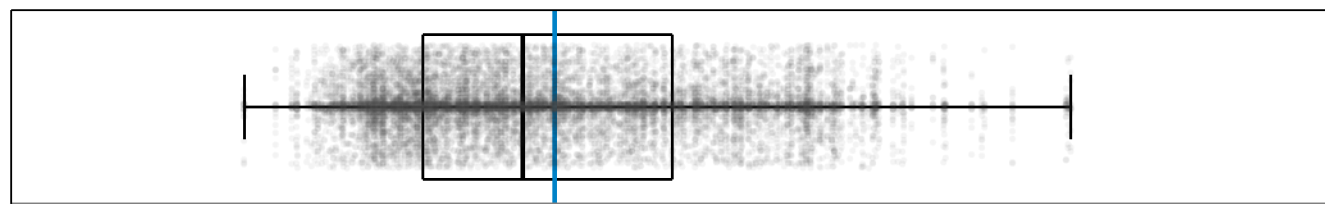
Section 2: After 1,500 ft Perma-Zyme + Sheepfoot Compaction



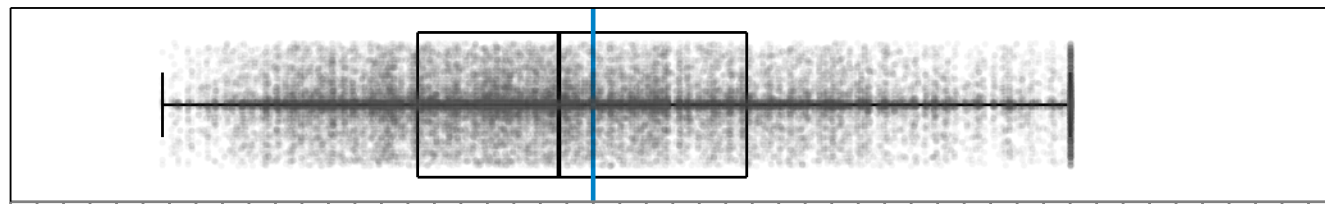
Section 3: After 660 ft Smooth Drum Compaction



Section 4: After 660 ft Sheepfoot Compaction

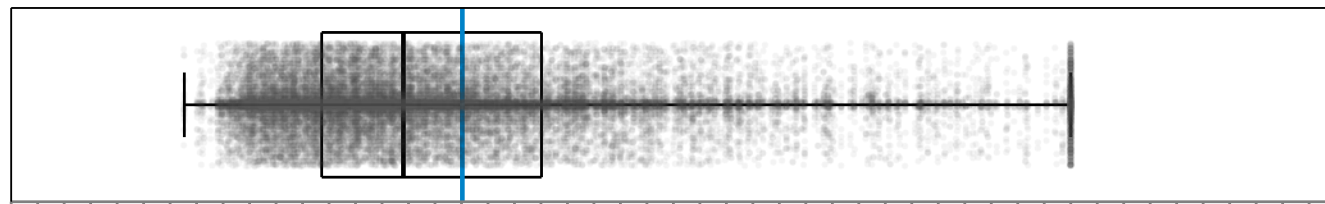


Section 5: 1,320 ft Control

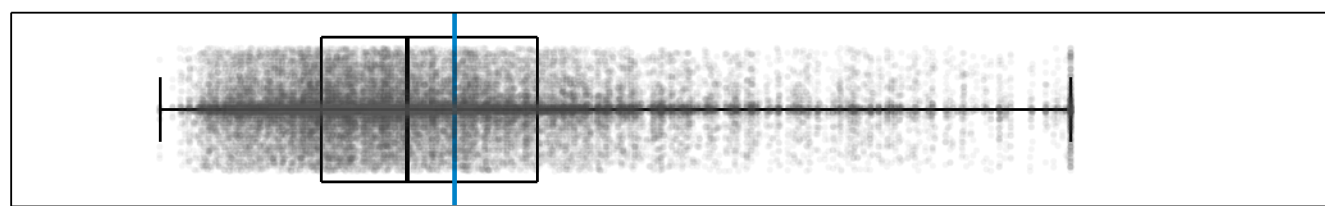


Camp Dodge (Johnston, IA) – Unpaved Gravel Road 3/31/2025

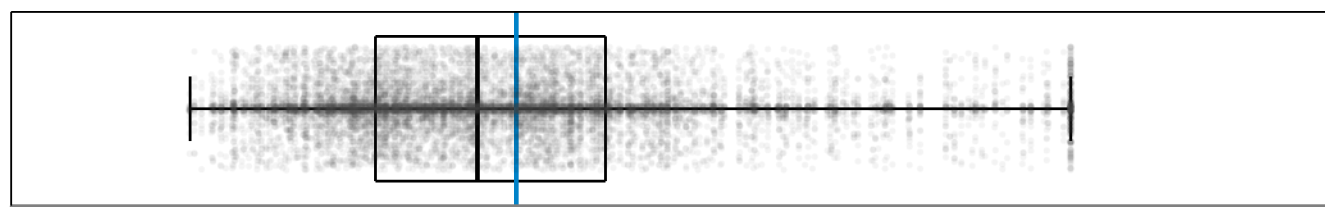
Section 1: After 1,500 ft Perma-Zyme + Smooth Drum Compaction



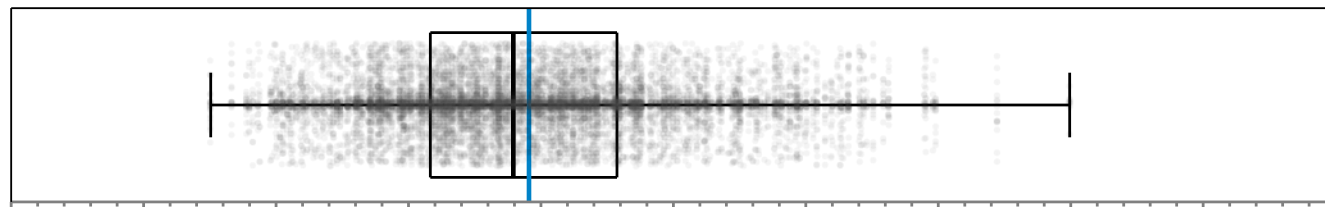
Section 2: After 1,500 ft Perma-Zyme + Sheepfoot Compaction



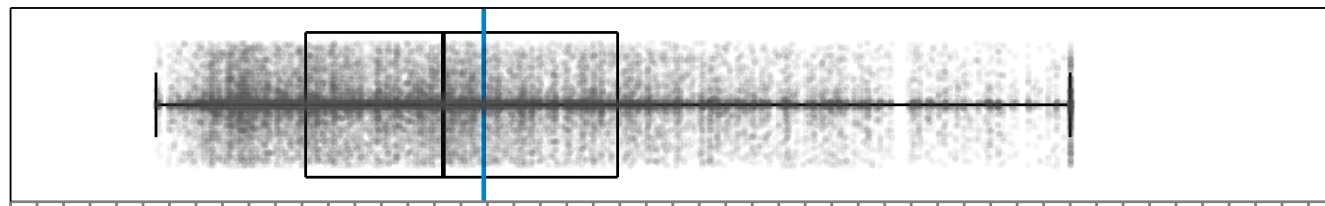
Section 3: After 660 ft Smooth Drum Compaction



Section 4: After 660 ft Sheepfoot Compaction



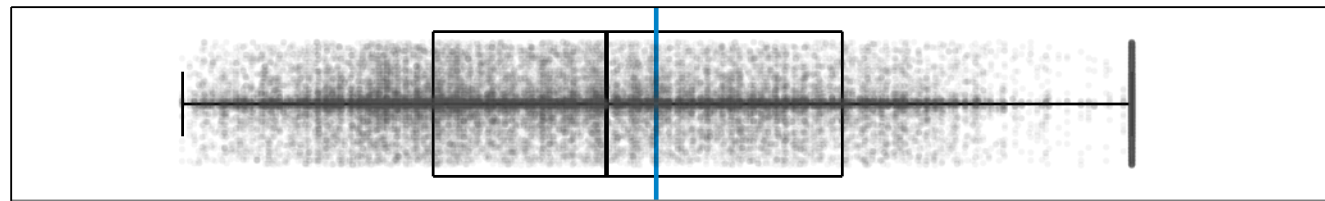
Section 5: 1,320 ft Control



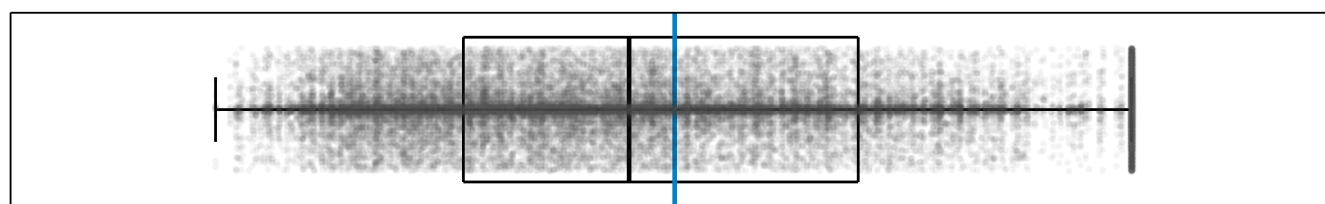
Camp Dodge (Johnston, IA) – Unpaved Gravel Road

08/07/2023

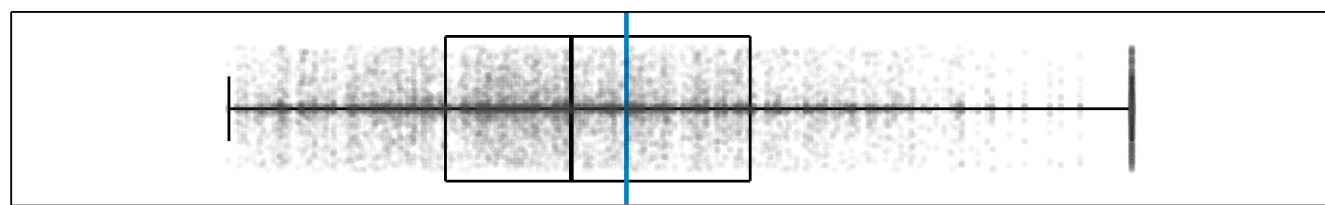
Section 1: Before re-compaction/stabilization



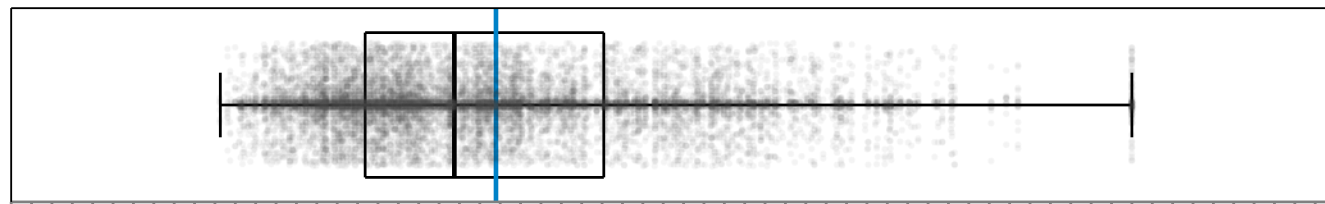
Section 2: Before re-compaction/stabilization



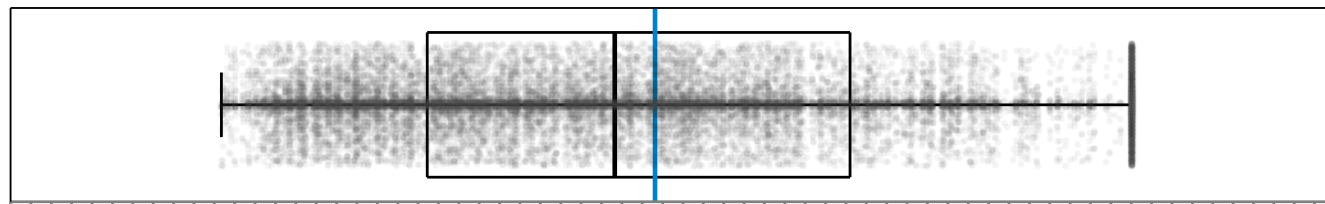
Section 3: Before re-compaction/stabilization



Section 4: Before re-compaction/stabilization

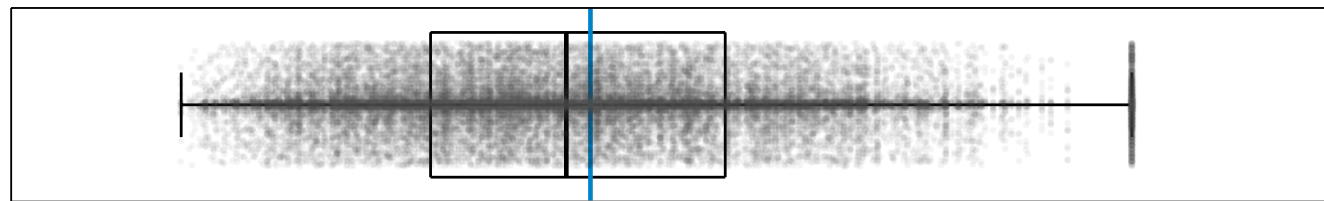


Section 5: Control

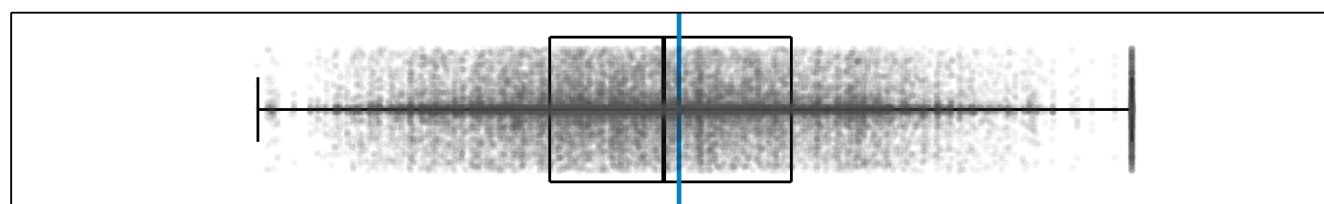


Camp Dodge (Johnston, IA) – Unpaved Gravel Road **08/31/2023**

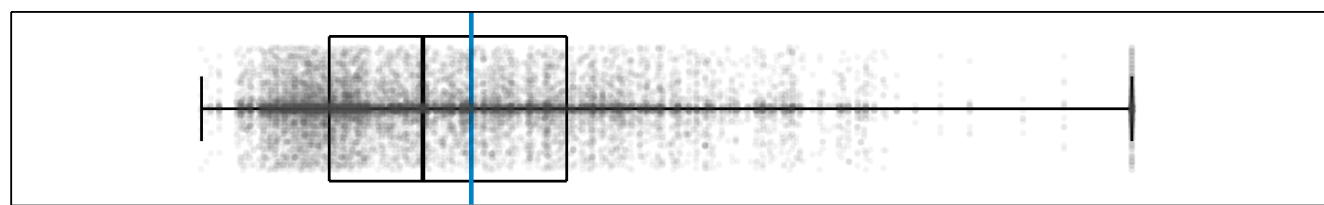
Section 1: After 1,500 ft Perma-Zyme + Smooth Drum Compaction



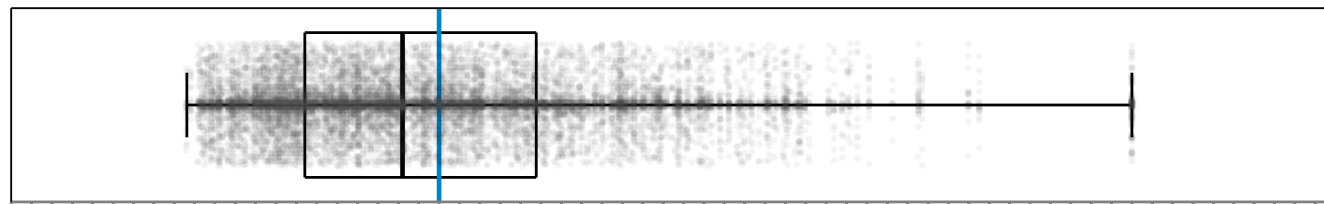
Section 2: After 1,500 ft Perma-Zyme + Sheepfoot Compaction



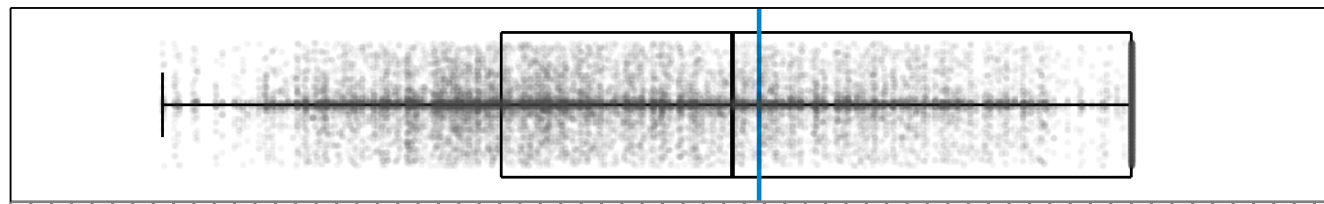
Section 3: After 660 ft Smooth Drum Compaction



Section 4: After 660 ft Sheepfoot Compaction

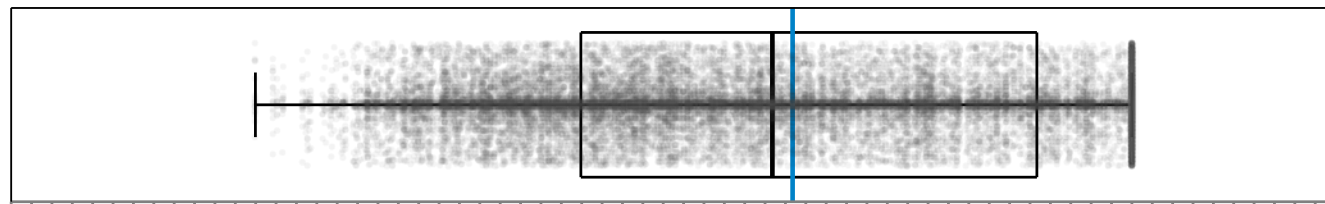


Section 5: 1,320 ft Control

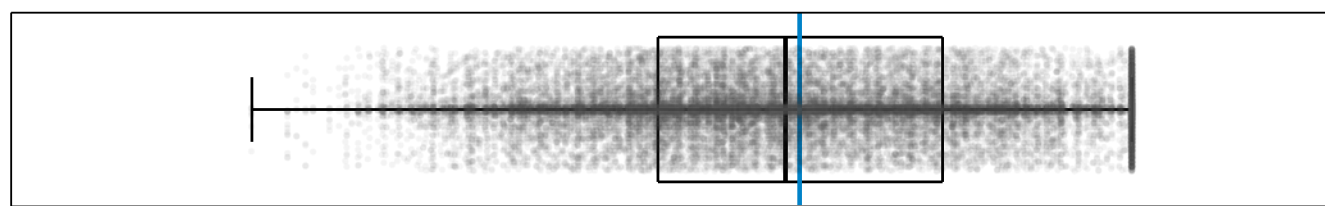


Camp Dodge (Johnston, IA) – Unpaved Gravel Road **03/07/2024**

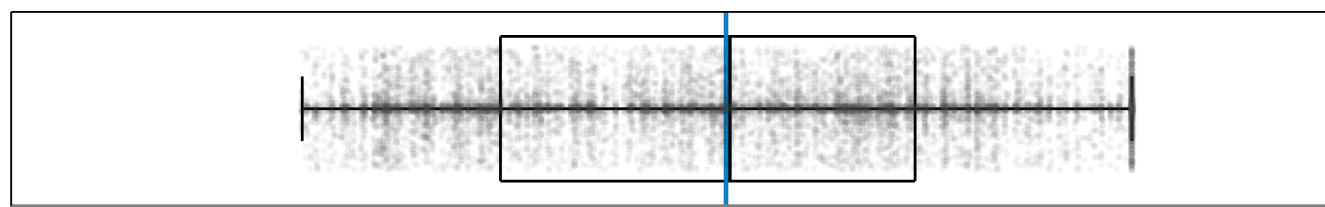
Section 1: After 1,500 ft Perma-Zyme + Smooth Drum Compaction



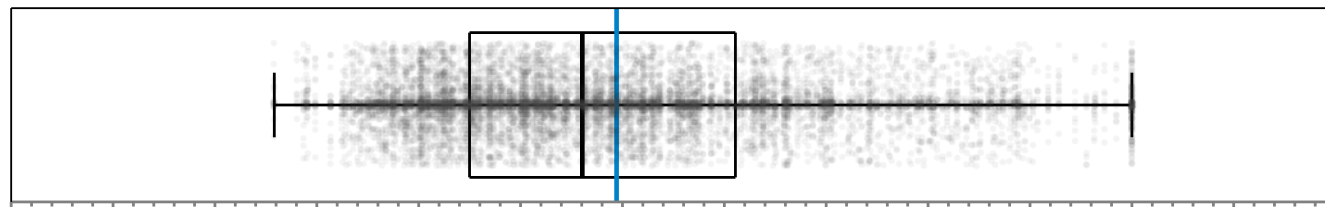
Section 2: After 1,500 ft Perma-Zyme + Sheepfoot Compaction



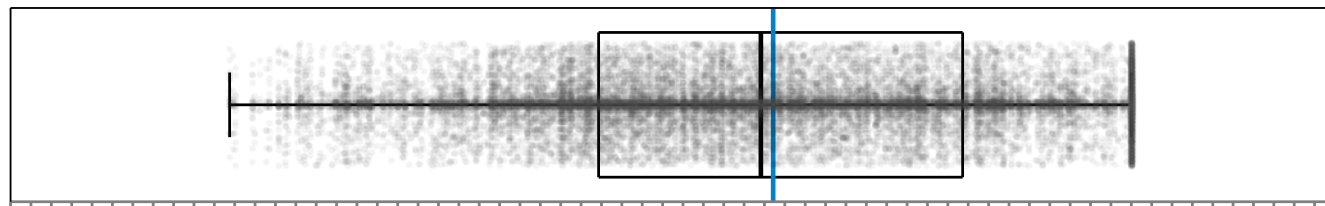
Section 3: After 660 ft Smooth Drum Compaction



Section 4: After 660 ft Sheepfoot Compaction



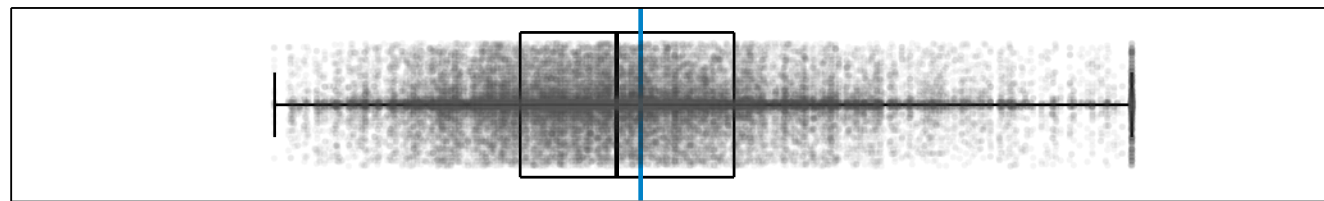
Section 5: 1,320 ft Control



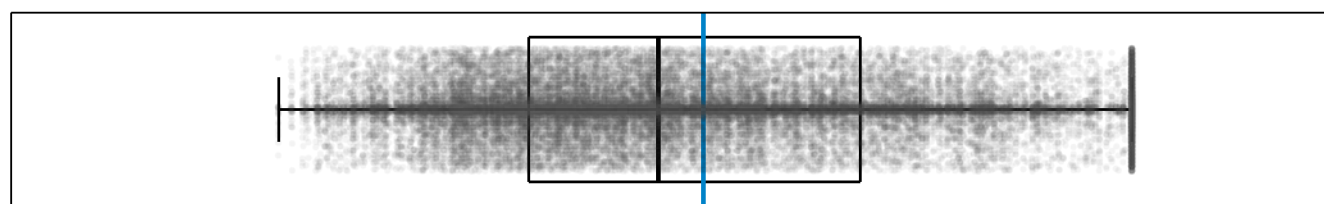
Camp Dodge (Johnston, IA) – Unpaved Gravel Road

10/31/2024

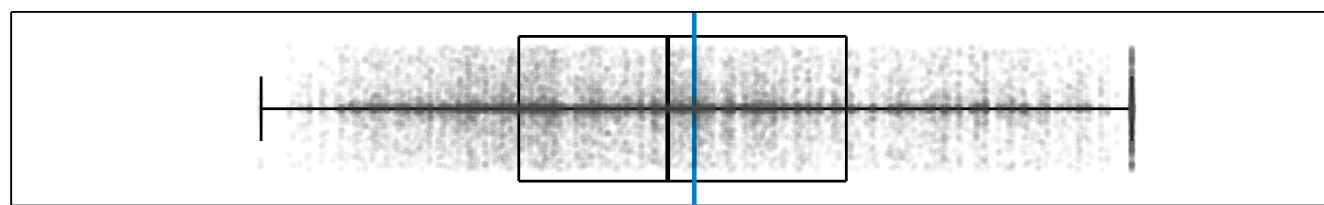
Section 1: After 1,500 ft Perma-Zyme + Smooth Drum Compaction



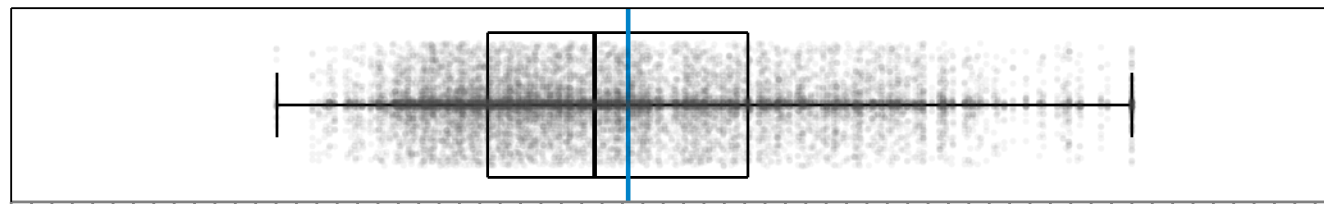
Section 2: After 1,500 ft Perma-Zyme + Sheepfoot Compaction



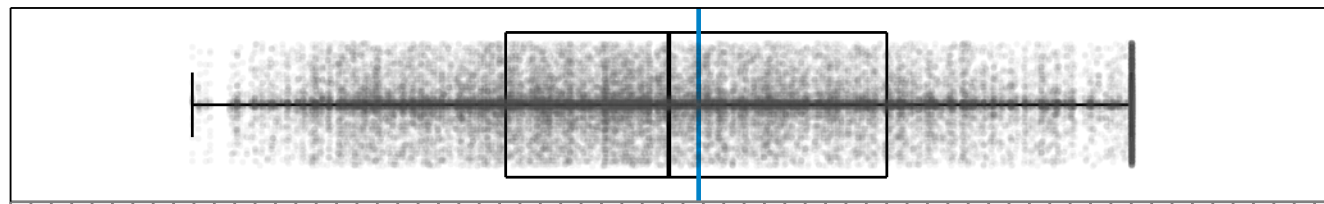
Section 3: After 660 ft Smooth Drum Compaction



Section 4: After 660 ft Sheepfoot Compaction

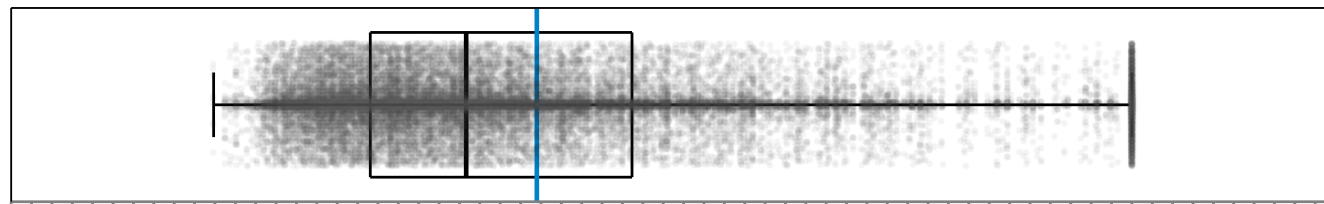


Section 5: 1,320 ft Control

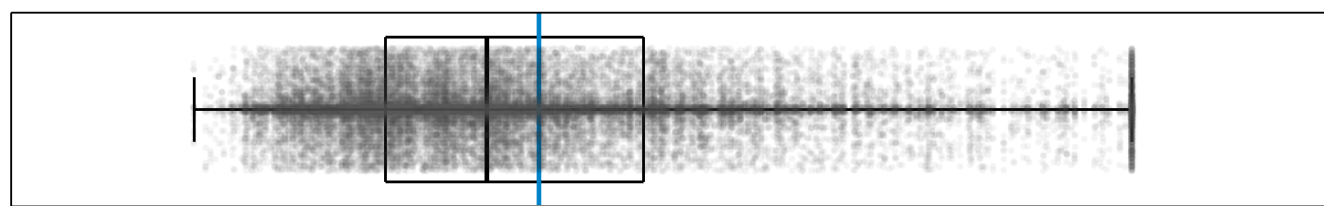


Camp Dodge (Johnston, IA) – Unpaved Gravel Road **3/31/2025**

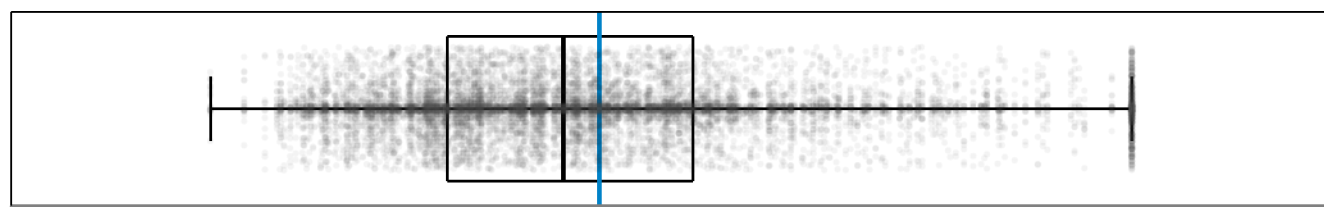
Section 1: After 1,500 ft Perma-Zyme + Smooth Drum Compaction



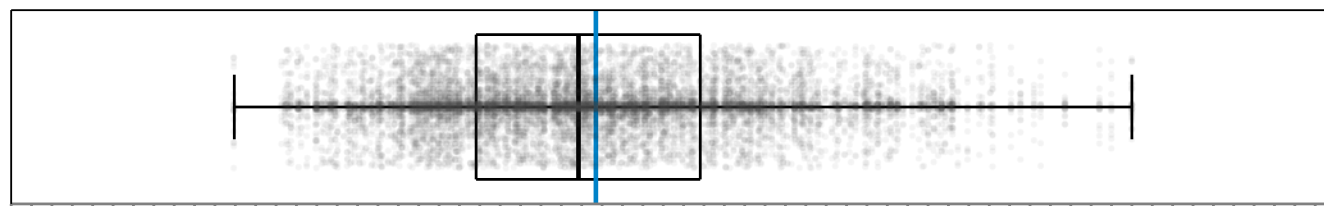
Section 2: After 1,500 ft Perma-Zyme + Sheepfoot Compaction



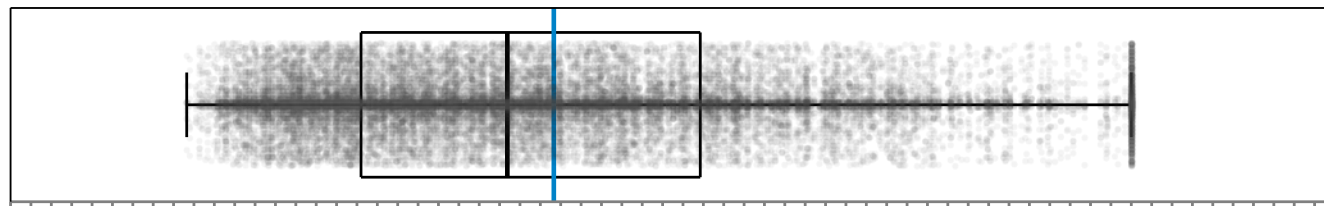
Section 3: After 660 ft Smooth Drum Compaction



Section 4: After 660 ft Sheepfoot Compaction



Section 5: 1,320 ft Control



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