Network-Level Pavement Condition Data Collection Quality Management Plan

Connecticut Department of Transportation

Newington, CT

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A. Document Change Control

The following is the document control for revisions made to this document.

Version Number	Date of Issue	Author(s)	Brief Description of Change
1.0	8/21/2018	CTDOT & CTI	FHWA Submission
2.0	6/21/2022	CTDOT	FHWA Submission of Revised DQMP

B. Definitions

The following acronyms, definitions of terms, abbreviations, and standards are used in this document.

Term	Definition
AASHTO	American Association of State Highway Transportation Officials
AASHTO **M328-14** Standard Specification for Inertial Profiler, 2017	The objective of this specification is to define the required attributes of an inertial profiler which, when combined with an operator, becomes a complete inertial profiling system (IPS).
AASHTO **PP67-16** Standard Practice for Quantifying Cracks in Asphalt Pavement Surfaces from Collected Pavement Images Utilizing Automated Methods, 2017	This practice outlines the procedures for quantifying cracking distress at the network level in asphalt pavement surfaces utilizing automated methods.
AASHTO **PP68-14** Standard Practice for Collecting Images of Pavement Surfaces for Distress Detection, 2017	This practice outlines the procedures for collecting images of pavement surfaces utilizing automated methods for the purpose of distress detection for both network- and project-level analysis.
AASHTO **PP69-14** Standard Practice for Determining Pavement Deformation Parameters and Cross Slope from Collected Transverse Profiles, 2017	This practice outlines a method for deriving pavement deformation parameters such as rut depth and cross-slope in pavement surfaces utilizing a transverse profile.
AASHTO **PP70-14** Standard Practice for Collecting the Transverse Pavement Profile, 2017	This practice outlines a method for collecting pavement transverse profile, including its relationship to a level horizontal reference in pavement surfaces utilizing automated measurement devices. The profile can subsequently be used to quantify cross-slope and pavement distresses such as transverse deformation, rut characteristics, water entrapment, or edge drop-off.
AASHTO **R36-13** Standard Practice for Evaluating Faulting of Concrete Pavements	This protocol describes a method for evaluating faulting in jointed concrete pavement surfaces. Faulting is defined as the difference in elevation across a transverse joint or transverse crack.
AASHTO **R43-13** Standard Practice for Quantifying Roughness of Pavements, 2013	This standard practice describes a method for estimating roughness for a pavement section. An International Roughness Index (IRI) statistic is calculated from a single longitudinal profile measured with a road profiler in both the inside and outside wheelpaths of the pavement. The average of these two IRI statistics is reported as the roughness of the pavement section.
AASHTO **R48-10** Standard Practice for Determining Rut Depth in Pavements, 2013	This practice describes a method for determining rut depth in pavement surfaces from transverse profile measurements. Five transverse profile points are the minimum number of points required to determine rut depth.
AASHTO **R55-10** Standard Practice for Quantifying Cracks in Asphalt Pavement Surfaces, 2013	This practice covers the procedures for quantifying cracking in asphalt pavement surfaces, both in wheelpath and non-wheelpath areas.
AASHTO **R56-14** Standard Practice for Certification of Inertial Profiling Systems, 2014	This practice describes a certification procedure for test equipment used to measure a longitudinal surface elevation profile of highways based on an inertial reference system that is mounted on a host vehicle.
AASHTO **R57-14** Standard Practice for Operating Inertial Profiling Systems, 2014	This practice describes the procedure for operating and verifying the calibration of an inertial profiling system. This practice is meant to be performed as a quality control/quality assurance (QC/QA) test for use with the appropriate smoothness specification for paving operations and for network-level data collection.
Acceptance (A) (quality acceptance)	Activities to verify that PMS data meet established quality standards.
Accuracy	The degree to which a measurement, or the mean of a distribution of measurements, tends to coincide with the true population mean (AASHTO 2011).
ARAN	Automatic Road Analyzer™ highway pavement data collection vehicle; CTDOT vehicles identified as vans 8 and 9 are ARAN 9000 models.
ASTM	American Society of Testing and Materials
ASTM **E1166-00 (2005)** Standard Guide for Network level Pavement Management	This guide outlines the basic components of a network level pavement management system (PMS).

ASTM **E1656-94/1656M-11** Standard Guide for Classification of Automated Pavement Condition Survey Equipment, 2016	Guide to classify the measuring capabilities of pavement condition survey equipment that operates at traffic speeds and collect some of the data useful in characterizing pavement conditions.
ASTM **E1926-98 (2003)** Standard Practice for Computing International Roughness Index of Roads from Longitudinal Profile Measurements	This practice covers the mathematical processing of longitudinal profile measurements to produce a road roughness statistic called the International Roughness Index (IRI).
ASTM **E2133 – 03 (2013)** Standard Test Method for Using a Rolling Inclinometer to Measure Longitudinal and Transverse Profiles of a Travelled Surface.	This test method describes the measurement of transverse and longitudinal surface profiles on paved road, bridge, and airport surfaces using a rolling inclinometer traveling at walking speed.
ASTM **E950/E950M-09 (2018)** Standard Test Method for Measuring the Longitudinal Profile of Traveled Surfaces with an Accelerometer-Established Inertial Profiling Reference	This test method covers the measurement and recording of the profile of vehicular-traveled surfaces with an accelerometer-established inertial reference on a profile measuring vehicle.
Calibration	A set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system, or between values represented by a material measure or a reference material, and the corresponding values realized by standards (AASHTO 2011).
Corrective Actions	Improvements/adjustments to an organization's processes taken to eliminate causes of non-conformities or other undesirable situations. Specifically, they are actions to resolve discovered problems with calibration, defective equipment, data errors or missing data.
Crack, (Cracking)	A fissure or discontinuity of the pavement surface not necessarily extending through the entire thickness of the pavement. (FHWA HPMS)
Cracking Percent (Asphalt pavement)	The percentage of the total area exhibiting visible fatigue type cracking for all severity levels in the wheelpath in each section. (FHWA HPMS)
Cracking Percent (Portland Cement Concrete pavement)	The percentage of slabs within the section that exhibit transverse cracking. (FHWA HPMS)
Cross Slope (crossfall)	The average transverse slope of the pavement surface, typically expressed in percent.
CTDOT	Connecticut Department of Transportation
Data Quality Management Plan (DQMP)	A document that specifies the quality management procedures (including quality standards, QC, acceptance, corrective actions and resources) that will be used and how the process will be implemented and assessed for effectiveness (adapted from ISO 2000).
DMI	Distance Measuring Instrument – Automated vehicle onboard instrumentation and software to accurately measure and output distance travelled.
dTIMS™	Deighton's Total Infrastructure Management System; infrastructure asset management software used by CTDOT PMG.
Faulting	Difference in elevation (i.e., vertical misalignment) across a Portland Cement Concrete joint
Geometrics	Roadway geometrics include horizontal curves, vertical curves, tangents, radius of curvature, elevations, grade, cross slope, lane dimensions (widths, lengths), and other parameters that can be used to define positioning of the physical elements of the roadway
GIS	Geographic Information System - A system for the management, display, and analysis of spatial information (FHWA HPMS)
GPS	Global Positioning System
HPMS	Highway Performance Monitoring System - a national level highway information system that includes data on the extent, condition, performance, use and operating characteristics of the nation's highways. (FHWA)
Independent assurance (IA) or verification	Independent verification is an unbiased and independent evaluation of data quality that is performed by someone other than the entity that collected or is receiving the data.

International Roughness Index (IRI)	A statistic used to determine the amount of roughness in a measured longitudinal profile. (AASHTO 2014)
JRCP	Jointed Reinforced Concrete Pavement – A reinforced Portland cement concrete pavement with transverse joints placed at planned intervals (ASTM E867)
LRS	Linear Referencing System - A set of procedures for determining and retaining a record of specific points along a highway. Typical methods used are milepoint, milepost, reference point, and link-node. (FHWA HPMS)
Longitudinal Grade	The slope (hilliness) of the pavement in the longitudinal direction (direction of travel) typically measured and expressed in percent.
Longitudinal Profile	The vertical deviations of the pavement surface taken along a line in the direction of travel referenced to a horizontal datum. (AASHTO 2014)
Mean Roughness Index (MRI)	Average of IRI values for the left and right wheelpaths of a roadway traffic lane
NCHRP	National Cooperative Highway Research Program, A forum for coordinated and collaborative research administered by the Transportation Research Board of the National Academies in Washington D.C.
Pavement Image	A representation of the pavement that describes a characteristic (gray scale, color, temperature, elevation, etc.) of a matrix of points (pixels) on the pavement surface. Images are used for the detection and extraction of pavement cracking data.
PCI	Pavement Condition Index – A formula developed by CTDOT expressing the combined relationship of five pavement indices: cracking, distortion, ride quality, disintegration and drainage, on a scale of 1-9.
PLU	CTDOT Photolog Unit
PM	Preventative maintenance; contracted annual maintenance for CTDOT ARAN vehicles
PMS	Pavement Management System
PMG	CTDOT Pavement Management GroupGroup
Precision	The degree of agreement among a randomly selected series of measurements; or the degree to which tests or measurements on identical samples tend to produce the same results (AASHTO 2011).
PSR	Present Serviceability Rating – A mean rating of the serviceability of a pavement established by a rating panel under controlled conditions. (ASTM E867) Scale 0.1-5.0 (FHWA)
PWL	Percent Within Limits – The cumulative area under a normal distribution curve which represents the estimated percentage of a population that falls above the Lower Specification Limit (LSL), beneath the Upper Specification Limit (USL), or between the Upper and Lower Specification Limits. (NETTCP 2014)
Quality Control (QC)	Activities needed to adjust production processes toward achieving the desired level of quality of pavement condition data.
Quality Standards	Quality standards define, when applicable, the resolution, accuracy, and repeatability or other standards that are used to determine the quality of each deliverable.
Radius of Curvature	For a curve, it equals the radius of the circular arc which best approximates the curve at that point.
Reference Value (Ground Truth)	A value that serves as an agreed-upon reference for comparison, and which is derived as a theoretical or established value, based on scientific principles, an assigned or certified value, based on experimental work of some national or international organization, or a consensus or certified value, based on collaborative experimental work under the auspices of a scientific or engineering group (AASHTO 2011).
Repeatability	Degree of variation among the results obtained by the same operator repeating a test on the same material. The term repeatability is therefore used to designate test precision under a single operator (AASHTO 2011).
Reproducibility	Degree of variation among the test results obtained by different operators performing the same test on the same material (AASHTO 2011).
Resolution	The smallest increment that a characteristic measuring process must distinguish and display (ASTM E867).
Road Profile	The cross-sectional shape of the road surface in relation to the road corridor traversing the surrounding landscape. (PennStateU)
Roughness	The deviation of a surface from a true planar surface with characteristic dimensions that affect vehicle dynamics, ride quality, dynamic loads, and drainage. (ASTM E867)

ROW Image	Digital image record of the roadway right of way and adjacent visible surrounding area
Rutting (Rut)	Longitudinal surface depressions in the wheel path. A rut is more specifically defined as—a broad longitudinal depression in the wheel path of the pavement surface with a depth of at least 0.080 in., a width of at least 1.0 ft., and with a longitudinal length of at least 100 ft. (AASHTO 2014)
Segment	A 0.1 mile section of roadway used for HPMS and PMS to summarize pavement attribute data
Smoothness, (ride quality) (IRI)	The measure of a pavement's roughness reported with the International Roughness Index. A statistic used to estimate the amount of roughness in a measured longitudinal profile. (AASHTO 2014)
Tolerance	The defined limits of allowable (acceptable) departure from the true value of a measured quantity. (ASTM E867)
Transverse Profile	Vertical deviations of the pavement surface from a level horizontal reference perpendicular to the lane direction of travel. (AASHTO 2014)
Validation Sites (Annual)	Specified roadway sections for use as reference or "ground truth," whose condition data have been measured by agency personnel using a reference profiler. These sites are used to verify proper data collection procedures, determine accuracy and/or for calibration of the equipment.
Verification Runs	Collection of production-season data on validation sites or verification sections by more than one device so that data collected during the production phase can be compared to verify proper collection procedures, reproducibility and continued calibration of the equipment.
Verification Sections (Monthly)	Roadway sections used on a routine basis to verify proper data collection procedures, accuracy and/or reproducibility of the equipment.
Vision	Desktop data processing and analysis software developed by FUGRO Roadware allowing users to browse and interact with CTDOT collected ARAN data.
Walking Profiler	CTDOT utilizes a Surface Systems & Instruments (SSI) CS8800 Walking Profiler for laying out and checking validation sites.
Wheelpath	CTDOT Wheelpath – A longitudinal strip of pavement 39 inches (1 meter) wide. The inner edges of both wheelpaths are offset from the center of the lane by 14.75 inches (0.375 meters), and are therefore 29.5 inches (0.75 meters) apart.

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C. Foreword

The Connecticut Department of Transportation Pavement Data Collection Quality Management Plan (DQMP), initially developed by Connecticut Transportation Institute (CTI) at UCONN, was submitted and approved by FWHA in August of 2018. Since that time several updates and changes have been implemented as we fine-tuned validation sites and collection of ground truth data, field and data validation, quality control and acceptance procedures, and updated staff assignments and responsibilities. As we continue to improve our policies and procedures and react to new and updated federal policies the DQMP will be revised as necessary over the coming years.

Should any portion of this Data Quality Management Plan become obsolete or otherwise be in need of revision, every reasonable attempt will be made to update the appropriate section(s) in a timely manner. Per 23 cRF490.319(c)(2) all proposed significant changes to the DQMP will be submitted to FHWA for approval prior to implementing the change.

1.0 QUALITY MANAGEMENT APPROACH

Quality Management (QM) assures the quality of the data collection deliverables and describes the processes and procedures to be used for ensuring quality. The Connecticut Department of Transportation (CTDOT) has worked together with the Connecticut Transportation Institute (CTI) at the University of Connecticut to develop a quality management approach for data collection that addresses quality control and quality acceptance for pavement management. Quality Control (QC) is conducted by the CTDOT Photolog Unit (PLU) of the Roadway Information Systems Office in the Bureau of Policy and Planning. Quality Acceptance (QA) is conducted primarily by CTDOT's Pavement Management Group (PMG) in the Bureau of Engineering and Construction, with assistance from the CTI, as needed.

Currently, 7,465.66 directional miles (for the 3,732.83 centerline-mile-state-maintained roadway network) are surveyed each year. This represents 100 percent of the Interstate, Primary and Secondary system of Connecticut's state highway network. In addition, approximately 410.93 centerline miles of the local road network is surveyed as needed for the HPMS program. Pavement condition data are collected during these surveys.

This DQMP identifies key activities, processes, and procedures for ensuring quality.

Below is a brief explanation of each of the sections of the DQMP that follow.

Section 2. Quality Team Roles, Responsibilities & Current Business Processes	Quality-related roles and responsibilities and current business processes for data collection, data reduction, review, acceptance, and reporting for use in FHWA HPMS, CTDOT performance measures, and paving and preservation programs.
Section 3. Certification for Persons Performing Manual Data Collection	Processes used to certify and validate manual pavement condition raters and CTDOT's training procedures.
Section 4. Equipment, Calibration, Certification or Validation & Verification	Detail and description of CTDOT's pavement data collection equipment processes and protocols used to calibrate, certify or validate and verify data collection equipment.
Section 5. Quality Control (QC)	The QC activities that monitor, provide feedback, and verify that the data collection deliverables meet the defined quality standards.
Section 6. Deliverables, Protocols & Quality Standards	The data collection deliverables subject to quality review, protocols used for collection, quality standards that are the measures used to determine a successful outcome for a deliverable, and criteria to describe when each deliverable is considered complete and correct. Deliverables are evaluated against these criteria before they are formally approved.
Section 7. Data Acceptance Criteria and Error Resolution Procedures	The acceptance testing used to determine if quality criteria are met, and corrective actions that must be taken for any deliverables not meeting the quality criteria.

Section 9. Quality Reporting Plan	The documentation of all QM activities—including quality standards, QC, acceptance, and corrective actions—and the format of the final QM report.
Section 10. DQMP Endorsement	Signature page for endorsement of the CTDOT Data Quality Management Plan.

2.0 QUALITY MANAGEMENT *"PROJECT TEAM"* ROLES, RESPONSIBILITIES & CURRENT BUSINESS PROCESS

The following identifies the quality-related responsibilities of each member of the Quality Management ***"Project Team"*** and lists specific quality responsibilities.

Table 2.1 Project Team Roles and Responsibilities

Team Role	Assigned Resource	Quality Management Responsibilities
Agency Managers	Michael Connors Karen Riemer	• Set/Approve quality standards, acceptance criteria, and corrective actions. • Approve each deliverable per quality standards. • Approve resolution of quality issues. • Assess effectiveness of the QM procedures. • Recommend improvements to quality processes.
Quality Assurance Supervisor	John Henault	• Recommend quality standards, acceptance criteria and corrective actions to Agency Managers • Assure deliverables meet broad set of data quality requirements. • Communicate as needed with Agency Managers on any issues that may arise. • Communicate weekly with QC Supervisor. • Assure data acceptance checks. • Assure PMG data processing, analysis and reporting. • Monitor schedule and reporting deadline adherence • Monitor resolution of quality exceptions reported to QC Supervisor. • Assure quality issue resolution and report results to QC Supervisor and Agency Managers. • Prepare QM report.
PMG Data Lead	Jeannine Moriarty	• Maintain acceptance log and submit quality exceptions to QA Supervisor and QC Supervisor. • Document quality audits of processed data • Report any problems using QC log. • Perform data & FIS video acceptance checks and document results. • Perform GIS checks and document results. • Verify that all Vision software LCMS, rating, classification and rutting templates settings/distress schemes are up to date and correct • Track reporting requirements/deadlines for completion of pavement condition data
Quality Control Supervisor	James Spencer	• Recommend quality standards, acceptance criteria, and corrective actions to Agency Managers • Assure deliverables meet broad set of data quality requirements. • Communicate as needed with Agency Managers on issues that may arise. • Communicate daily/weekly with QC Lead, Data Lead and Field Crew Lead. • Communicate daily/weekly with QA Supervisor and PMS Data Lead • Submit acceptance exceptions log to QC Lead, PLU Data Lead and Field Crew Lead. • Supervise manual measurement of Verification and Validation sites.

		• Establish reference values with data collection team. • Monitor schedule adherence. • Assure quality issue resolution with QC Lead and report results to QA Supervisor and Agency Managers.
QC Lead	Lester King	• Assure QC practices are followed. • Assure proper protocols are used. • Assure any training addresses all personnel skill levels. • Assure reviews by Photolog Data Lead. • Assure performance of all quality activities and reporting of all data quality exceptions using a QC log. • Assure correction of all quality issues and changes in procedures as needed. • Perform and document a final deliverables quality review as needed. • Compile documentation of all QC activities.
PLU Data Lead	Jin Sadlowski	• Perform and document checks of total mileage, segment lengths, and comparison with master route file. • Perform, assure and document GIS checks of segment location and completeness. • Document quality audits of uploaded and processed data. • Maintain records of verification runs on validation sites; Analyze and document results. • Perform initial data & video acceptance checks and document results. • Perform GIS checks and document results. • Maintain and report any problems using acceptance log and submit quality exceptions to PMG Data Lead, QA Supervisor and QC Supervisor. • Report any problems using QC log. • Perform data & FIS video acceptance checks and document results. • Maintain and assure all Vision software LCMS, rating, classification and rutting templates settings/distress schemes are up to date and correct, coordinate with PMG Data Lead Track reporting requirements/deadlines for completion of pavement condition data
Office Staff	Kara Chandler	• Handle weekly upload and backup of raw field collected data using daily logs from the ARAN Vans • Perform Segmentation processing • Review route ROW Imagery for wetness or other unacceptable condition • Review completeness of data
Field Crew Lead	Mike Longo	• Assure and document initial equipment configuration, calibration, and verification. • Assure performance of daily and/or periodic equipment start-up checks, tests, inspections, and calibrations. • Assure daily review of data logs and video samples. • Assure real-time monitoring of data and video quality. • Assure performance of monthly verification runs on validation, sites. • Assure documentation of all field QM activities and reporting of any problems using QC log.
Field Crew	Robert Kasica, Anthony Edwards Kara Chandler	• Perform daily and/or periodic equipment start-up checks, tests, inspections, and calibrations. • Perform daily review of data logs and video samples. • Perform real-time monitoring of data and video quality. • Perform documentation daily reports including: End-of-Day Report, QC Log, and ARAN Daily Mileage Summary • Maintain Field Certification

2.1 CURRENT BUSINESS PROCESSES

All pavement data collection and data reduction operations at CTDOT are performed in-house (i.e., no vendors or consultants are used for data collection or processing) using CTDOT's two FUGRO 9000 Series ARAN Vans and Vision Desktop Processing Software Environment. Data collection is done by the Photolog Unit (PLU) within the Roadway Information Systems Office of the Bureau of Policy and Planning. The PLU Field staff are responsible for maintaining the annual program of field collection and quality control of pavement condition, geometric and imagery data for the Department. The PLU office staff are then responsible for uploading this data into the Vision environment, for segmentation and matching the data to LRS, and for the post processing of the data to produce and extract IRI, curve and grade, information on cracking types, zones, severities and extent, rut depths, and faulting. The PLU exports the data out to PMG in batches for further analysis and quality assurance (denoted henceforth as Acceptance) checks; provides the processed geometric (curve and grade) data to the Department's Roadway Systems Information Section as part of the annual submission to FHWA for HPMS; and further processes and exports the Right-of-Way (ROW) imagery and associated condition data for upload to DigitalHiway and Mapillary which are utilized for multiple functions within and outside of CTDOT.

The Pavement Management Group (PMG) within the Project Administration Unit, Bureau of Engineering and Construction imports these batches received from the PLU into a quality assurance SQL Server Express database and performs Acceptance of pavement condition data ; maintains a separate SQL Server Express database to store, sort, and aggregate these data, as well as to calculate various pavement attributes; uses a strategic analysis program (dTIMS™) to evaluate preservation strategies and suggest cost-effective paving projects to maintain highway condition; and produces annual reports that provide the state of the condition of pavements within Connecticut. Data that are prepared by the PMG are forwarded to Roadway Information Systems to be included with the annual HPMS submittal to FHWA. These data are also used for the Transportation Asset Management Plan and annual CTDOT pavement performance measures.

3.0 CERTIFICATION PROCESS FOR PERSONS PERFORMING MANUAL DATA COLLECTION

A certification process for persons performing ***manual rating of data*** must be included in this Data Quality Management Plan (DQMP) according to 23CFR490.319(c)(1)(ii). All of CTDOT pavement condition data are collected by automated or semi-automated methods, with the exception of the following two manual procedures: (1) For Validation Sites and Reference Checks where crack detection is done manually using the Vision/Wise Cracks application where cracks are manually identified off imagery collected from the field and (2) where data is collected manually using the SSI CS8800 Walking Profiler for development of reference values on the validation sites. Each of these procedures requires the experience and knowledge of qualified staff. CTDOT has highly knowledgeable and experienced senior level, field and office staff within its PLU and PMG who have performed these duties for many years. For this purpose, CTDOT considers qualified to be analogous to certified.

Certification/Qualification of Staff Performing Crack Detection

Since the CTDOT will be using manual pavement condition data collection as part of its certification process, manual raters must be capable of collecting data meeting the requirements of 23 CFR 490.309. Accordingly, specialized training is included in this plan for manual raters, which includes refresher training in order to keep staff current.

The lead manual rater for the PMG that is responsible for certifying individuals conducting the manual ratings is Ms. Jeannine Moriarty. She has been involved with pavement condition assessment throughout her 20 years' experience working in the PMG and is CTDOT's subject matter expert on pavement cracking. Ms. Moriarty has experience in using the *Distress Identification Manual for the Long-Term Pavement Performance Program* and is familiar with the definitions of pavement condition metrics identified in the *HPMS Field Manual.* In addition, Ms. Moriarty serves on the committee for NCHRP 01-57A, *Standard Definitions for Comparable Pavement Cracking Data*, where the objective is to develop standard definitions for common cracking types in flexible, rigid, and composite pavements.

CTDOT will adopt the *Distress Identification Manual for the Long-Term Pavement Performance Program* as its reference manual for describing its pavement condition rating methodology. Ms. Moriarty will administer training and testing for any new inexperienced Manual Data Collectors. This training will incorporate the abovementioned distress manual, as well as the HPMS Field Manual. Manual Data Collectors will be expected to be familiar with both reference manuals. After some classroom time, Ms. Moriarty will oversee the students as they conduct pavement condition surveys. The students will then be required to pass a written exam administered by Ms. Moriarty. The training may be waived for new Manual Data Collectors that can document significant experience on the subject, but they will still be required to take written exam. Students that pass the exam will be issued a certification indicating that they meet manual data collection requirements. Manual Data Collectors will be required to recertify every two years.

Example Crack Detection Rater Exam Problems are provided in Appendix A.

Certification/Qualification of Staff using SSI CS8800 Walking Profiler

As part of the procurement of the SSI CS-8800 Walking Profiler, the PLU staff was initially provided with two days of certified vendor training on the calibration and use of the equipment to ensure that accurate ground truth reference measurements would be obtained at CTDOT field validation sites. Annually, prior to the beginning of each collection season, a training refresher course will be conducted by the PLU Senior Level QC Lead per manufacturer's specifications and requirements as detailed within the CS8800 Walking Profiler Operation Manual. During the Refresher Training each employee will be evaluated by the QC Lead for their understanding and effective use of the walking profiler.

The following is a link to view a copy of the Walking Profiler Refresher Training Evaluation Checklist: https://ctgovexec.sharepoint.com/sites/DOTDataQualityManagementPlan/Shared%20Documents/General/References/SSI%20CS8800%20Walking%20Profiler%20Training%20Evaluation%20Report.pdf

3.1 ARAN VAN DRIVER AND OPERATOR TRAINING

All staff that perform field duties will attend an annual refresher course on the calibration, use and operation of the ARAN Van and its subsystems provided and then will be individually evaluated by the PLU Senior Level QC Lead for annual recertification. The training will cover the Manufacturers specifications and procedures as outlined in the ARAN User Manual and will cover the policies and procedures as outlined in Reference 1 - "Connecticut Department of Transportation, Photolog Field Data Collection Standard Operating Procedures – *Working Draft".*

The following link is a copy of the ARAN Field Operations Evaluation Form:
https://ctgovexec.sharepoint.com/sites/DOTDataQualityManagementPlan/Shared%20Documents/General/References/ARAN%20Field%20Operations%20Training%20Evaluation%20Report.pdf

All staff that perform office data processing functions will attend an annual refresher course on the Vision platform and environment and then will be individually evaluated by the PLU Senior Level Data Lead for annual recertification. The training will cover the Manufacturers specifications and procedures as outlined in the Vision User Manual and will cover the policies and procedures as outlined in Reference 1 - "Connecticut Department of Transportation, Photolog Field Data Collection Standard Operating Procedures – *Working Draft".*

New or replacement staff added to the PLU will be provided with vendor-based training on CTDOT's FUGRO ARAN vans, Vision Desktop Suite of software, and on the SSI CS-8800 Walking Profiler, as required. At the State's option this training may be provided by the product vendors (FUGRO Roadware and SSI) via a procurement process or may be provided in-house by senior level staff members, as noted above. After receiving the training, new staff will each be subject to a working test period in a production environment/setting where they will be further supervised by senior level Field Crew Lead to gauge the new employee's competency, knowledge and skill. Once sufficient competency has been shown, the new employee will be deemed qualified to perform the job duties.

4.0 DATA COLLECTION EQUIPMENT, CALIBRATION, CERTIFICATION OR VALIDATION & VERIFICATION

4.1 COLLECTION EQUIPMENT

FUGRO 9000 Series ARAN Vans

CTDOT has two FUGRO ARAN 9000 series Sprinter Style Vans each equipped with 3-D laser scanning technology for collection of transverse profile (rutting) and pavement surface images (cracking). The new laser crack measurement system (LCMS-2) uses high speed cameras, custom optics and laser line projectors to acquire both 2D images (black and white intensity images) and high-resolution 3D profiles (surface elevations) of the road. These ARAN Vans and their onboard systems and sensors meet all federally mandated AASHTO and ASTM standards. A general list of installed equipment is included in Table 4.1 below.

Further detailed information about the data collection equipment can be found in Reference 1 "Connecticut Department of Transportation, Photolog Field Data Collection Standard Operating Procedures – Working Draft", pages 7-15.

Table 4.1 Equipment Installed on CTDOT ARAN 9000 Series Vans

CTDOT Systems/ Equipment	CTDOT ARAN Vehicles		
	VAN 8	VAN 9	Van 10
Service Dates	1/2010– Entered into Service 9/2015 – System Upgraded 2/2021 - Retired	8/2015 - Entered into Service 2/2021 - Systems Upgraded	8/2021 Entered into Service
Chassis	ARAN 9000, 2010 Dodge Sprinter	ARAN 9000, 2015 Mercedes Benz Sprinter	ARAN 9000, 2020 Mercedes Benz Sprinter
Geographic Coordinates	Real-Time Differential GPS +POS LV Inertial Positioning System (1 meter accuracy) using OmniStar	Real-Time Differential GPS +POS LV Inertial Positioning System (1 meter accuracy) using OmniStar	Real-Time Differential GPS +POS LV Inertial Positioning System (1 meter accuracy) using OmniStar
Distance	Wheel-mounted Distance Measurement Instrument (DMI) Measures linear distance within ± 0.005%	Wheel-mounted Distance Measurement Instrument (DMI) Measures linear distance within ± 0.005%	Wheel-mounted Distance Measurement Instrument (DMI) Measures linear distance within ± 0.005%
Roughness (IRI)/Longitudinal Profile	South Dakota Profiler with Roline Sensors Class 1 Profiler under ASTM E950, AASHTO R56-10 Certification & ASTM E1926	South Dakota Profiler with Gocator Sensors Class 1 Profiler under ASTM E950, AASHTO R56-10 Certification & ASTM E1926	South Dakota Profiler with Gocator Sensors Class 1 Profiler under ASTM E950, AASHTO R56-10 Certification & ASTM E1926
Crack Detection, Classification & Rating, Texture, Rutting & Transverse Profile	Pave3D Pavemetrics Laser Crack Measurement System (LCMS)	Pave3D Pavemetrics New Laser Crack Measurement System II (LCMS-2)	Pave3D Pavemetrics Laser Crack Measurement System II (LCMS-2)
Right of Way (Front View) Imagery	SONY HD Camera w/90 Degree Field of View Lens	SONY HD Camera w/90 Degree Field of View Lens	SONY HD Camera w/90 Degree Field of View Lens

Data that are collected with, or derived (calculated) from, the ARAN vehicles include: right-of-way imagery, chainage (distance), GPS coordinates, longitudinal grade, transverse slope (cross slope), roughness (IRI), rutting, faulting, cracking, geometric curvatures (vertical and horizontal), and other pavement surface distress conditions.

Surface Systems & Instruments, Inc. (SSI) CS8800 Walking Profiler

In June of 2017, CTDOT purchased a SSI CS8800 Walking Profiler to establish ground truth reference measurements for IRI. It is certified as meeting the following standards and criteria:

- Classification: ASTM E2133 compliant.
- Rating: ASTM Class 1 and World Bank Standard Class 1.
- Ability: measure longitudinal distances to within +/- 0.1 percent of the actual distance.
- Profile Accuracy: +/- 2mm/50m plus level for non-closed loop surveys.
- Computed Roughness Index: IRI with ability to demonstrate repeatability of pavement roughness data on multiple same surface test runs of at least:

- 0.98% for IRI waveband.
- 0.98% in the long waveband.
- 0.98% in the medium waveband.
- 0.94% in the short waveband.

4.2 EQUIPMENT CALIBRATION

FUGRO 9000 Series Vans

CTDOT has contracted with the equipment manufacturer, FUGRO Roadware, to: (1) perform annual preventative maintenance and calibration of CTDOT's two ARAN vans prior to the start of each collection season in accordance their own calibration specifications and procedures, with AASHTO standards or protocols as detailed in Table 6.1, ASTM standards, FHWA's HPMS Field manual (2016), and CTDOT documents and procedures to ensure that the ARAN vans are operating at peak efficiency and are collecting the highest quality level data possible; and (2) provide documentation of the calibration processes used and proof of the successful equipment calibration prior to certification testing. This documentation is then signed by the Photolog Unit Supervisor and FUGRO Technician as approved.

The following is a URL link to the latest Annual Preventative Maintenance Reports for the ARAN Vans: https://ctgovexec.sharepoint.com/sites/DOTDataQualityManagementPlan/Shared%20Documents/General/ARAN%20Van%20Annual%20Preventative%20Maintenance

In addition, Photolog field staff are responsible for calibration of the ARAN Vans in accordance with FUGRO's recommendations, on a monthly basis, after any significant repair work done on the vans, or as requested when the results from the certification, validation and verification testing indicate the need for recalibration. All equipment calibration records and testing results done on the ARAN Vans during the data collection schedule will be maintained and will be provided to the Project Team (as detailed in Table 2.1 Project Team Roles and Responsibilities) for review.

The following is a link to the monthly CDOT ARAN Van Calibration Reports: https://ctgovexec.sharepoint.com/sites/DOTDataQualityManagementPlan/Shared%20Documents/General/ARAN%20Van%20Calibration%20Reports

Further detail on ARAN Equipment calibration is included in Ref. 4: Fugro Roadware, " ARAN 9000 Manual, Version 2.0", Fugro Roadware, Mississauga, Ontario, November 29, 2016

SSI CS8800 Walking Profiler

The CS8800 Walking Profiler is recalibrated prior to each use by trained Photolog staff in accordance with manufacturer's specifications and recommendations as outlined in the CS8800 User Manual.

Further detail on the CS8800 Walking Profiler is included in Ref. 5: Surface Systems & Instruments, Inc., " CS8800 Profiler VS Operation Manual," Version 3.2.7.11, Surface Systems & Instruments, Inc., Auburn , CA., March 27, 2011

4.3 EQUIPMENT CERTIFICATION/VALIDATION

FUGRO's South Dakota Profiler RoLine – 4" Footprint Line Lasers (Laser SDP/2) installed on each of the CTDOT's ARAN Vans are nationally recognized as Class 1 Profiling devices under ASTM E950, AASHTO R56-10 Certification & ASTM E1926; however there are no nationally recognized certification procedures currently available for the LCMS or for the other equipment components. In order to validate these sub-equipment components lacking certification procedures, CTDOT has planned and will be implementing new Validation Sites where annual and periodic verification testing will be conducted (per Table 5.1 Specific QC Procedures) to evaluate the accuracy and precision of the data (per Table 6.1 Deliverables, Protocols and Quality Standards for Automated Data Collection) reported in the field under conditions representative to the ones anticipated during actual data collection.

Additional dynamic testing for the inertial profilers is recommended to establish minimum valid operating speed. This might best be carried out at the Consumer Reports Test Track, where IRI can be measured at an optimum speed, and then measured at constant (or nearly constant) lower-speed intervals (35 mph, 30 mph, 25 mph, etc.) to determine the speed at which IRI values begin to deviate from measured values at optimum speed.

Testing to determine maximum valid deceleration, invalid range near deceleration, and invalid range near stops should also be considered.

Validation Sites

Validation sites are selected and established by CTDOT to calibrate the distress rating process and to establish the precision and bias for the roughness, faulting and rutting information on asphalt concrete pavements (ACP) and jointed reinforced concrete pavements (JRCP), as appropriate. The validation sites are up to of 1 mile in length, and they are purposely selected with various levels of roughness and distress. CTDOT's CS8800 Walking Profiler is used on the selected sites to establish ground truth (reference values) for:

- Transverse Profile
- Rutting
- Roughness (IRI) (longitudinal profile)
- Faulting
- Distance calibration (DMI)

Implementation Plan for Validation Sites

The validation sites outlined in Ref. 2*: Connecticut Transportation Institute, "Manual for Quality Control of Pavement Condition Data Collection – DRAFT*," were implemented during the summer of 2018. The precise development schedule for the validation sites is dependent on the resources needed to conduct the field work. As each of the new Validation Sites is implemented, ARAN Verification Surveys will be performed to collect data for analysis of repeatability and reproducibility, per Table 6.1 Deliverables, Protocols and Quality Standards for Automated Data Collection.

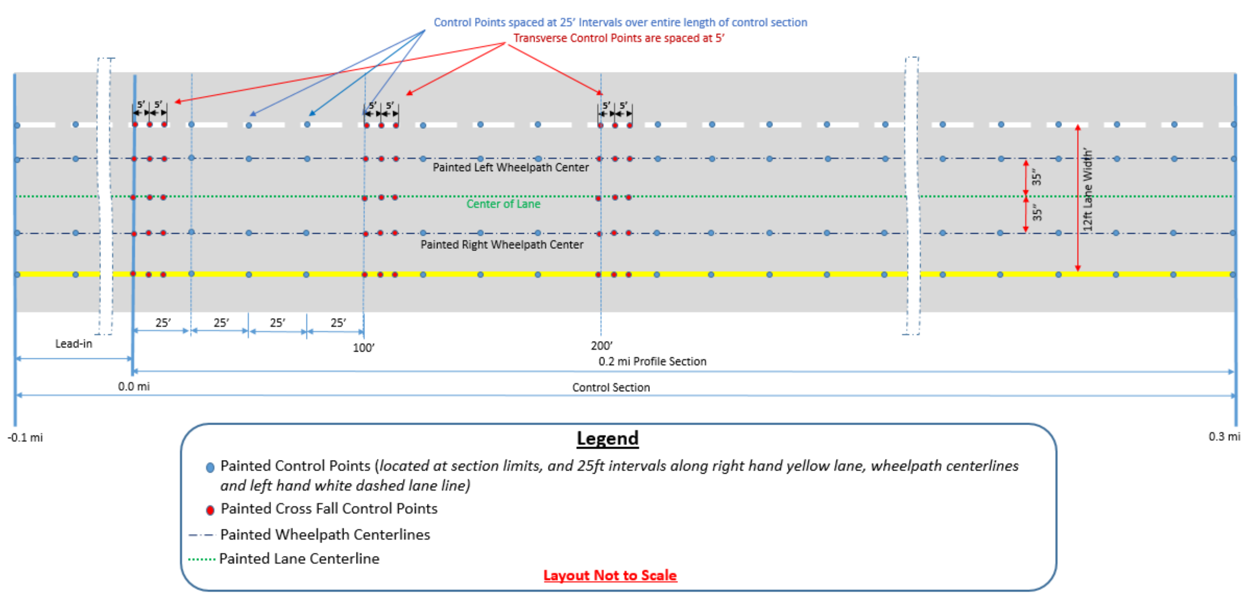
Specific details on Validation Sites Selection, Site Parameters and Site Implementation, are included under Sections 2.2, 2.3 & 2.4 of Ref. 2: Connecticut Transportation Institute, "Manual for Quality Control of Pavement Condition Data Collection – DRAFT," pages 2-4 thru 2-12.

Interim, Continued and Final Plan

The practice of performing monthly verification surveys for reproducibility against historical survey data and repeatability between ARAN Vans on CTDOT's existing Control Sections, located on Brook Street and Elm Street in Rocky Hill, Thornbush Road in Wethersfield, and Willard Avenue in Newington will continue after the validation sites are available.   Five consecutive repeat runs are done with each ARAN Van on each site and then the data are analyzed to ensure that results fall within acceptability ranges for FHWA HPMS Reporting and that they meet the quality standards as detailed in Table 6.1 below. Results of the verification surveys are then documented and sent to the Project Team.

After exhaustive review of other potential sites across the state, including use of airports and rest-areas, On July 10, 2019, the Department entered an agreement with Consumer Reports to make use of their Test Track Facility to setup a validation site as the best site available. The site was laid out on a section of the test track where multiple criteria could be evaluated as shown below.

Photolog Equipment Calibration Site Requirements
Consumer Reports Test Track



The site proved to be viable for the verification of IRI, Longitudinal and cross slopes, and rutting, however it did not provide for a good location to validate cracking or faulting data, so alternate sites were used for these.

With the assistance of UCONN, the Pavement Management Unit and Photolog Section further researched alternative locations for a new and more comprehensive validation site. In September of 2021, Route 85 NB from MP 2.21 from MP 2.41 in Waterford was selected near the Crystal Mall. UConn was on site and help conduct the survey layout so that we could ensure accuracy of the collection site and data. Now in production the Route 85 validation site has proven to be highly reliable and has been accepted for use by UConn, Pavement Management and the Photolog Section.

Copies of the and monthly validation site results can be found in the Photolog MS SharePoint site via this URL Link:
https://ctgovexec.sharepoint.com/sites/DOTDataQualityManagementPlan/Shared%20Documents/General/ARAN%20Van%20Calibration%20Reports

4.4 EQUIPMENT VERIFICATION TESTING

CTDOT's PLU will conduct verification survey testing on both ARAN Vans on a monthly basis, or additionally when necessary, to verify proper data collection procedures, accuracy, reproducibility and continued calibration of the equipment. Verification survey testing is comprised of performing 5 sequential runs on each of CTDOT's Validation sites with each ARAN Van. The data collected are then compared against the established ground truth for reproducibility and for comparability between vans and historical data per Table 6.1. A Verification Survey Testing Report (Appendix F) is then provided to the Project Team.

5.0 DATA COLLECTION QUALITY CONTROL MEASURES

The focus of Quality Control (QC) is on data collection deliverables and processes. The PLU is responsible for proper operation and calibration of the ARAN vans and their data collection systems. Quality Control procedures and measures will be performed by the PLU field crew both before annual data collection begins and then monthly, or as needed, during the data collection season in accordance with Table 5.1. The Photolog Daily Collection Check List is used to confirm that the QC Procedures are followed.

The following is a link to an example of the Photolog Daily Collection Check List:
https://ctgovexec.sharepoint.com/sites/DOTDataQualityManagementPlan/Shared%20Documents/General/References/Photolog%20Daily%20Collection%20Check%20List.pdf

As described above, all equipment is calibrated according to manufacturer's recommendations during annually scheduled Preventative Maintenance done by FUGRO Roadware before initiation of the annual data collection activities. Calibration checks on the data collection equipment are then performed monthly or as needed throughout the year, at manufacturer's specified intervals to assure that the equipment remains properly calibrated and functional. The PLU then monitors the collection process and deliverables to ensure that they are of acceptable quality and are complete and correct throughout the collection season.

Further details on ARAN equipment calibration are included in Ref. 4: Fugro Roadware, " ARAN 9000 Manual, Version 2.0", Fugro Roadware, Mississauga, Ontario, November 29, 2016

Identified in Table 5.1 below are:

• The major deliverables tested for satisfactory quality level.

• The quality expectations for the deliverables.

• The QC activities executed to control and monitor the quality of the deliverables.

• The frequency and interval when the QC activities are performed.

Table 5.1 Data Collection Quality Control Measures

Deliverable	Quality Expectations*	QC Activity	Frequency/Interval
Vehicle Configuration	• Inspect and clean laser apertures, windshield, and camera lenses • Inspect hardware and mountings • Check tire pressure • Collect small sample route	Check	Prior to daily collection
	• GPS accuracy ≤ 3 meters • Image quality and lane placement • Monitor ARAN collection system errors • Data completeness	Check	During active collection
	• Bounce and block tests, crack measurement system height check	Validation	Monthly
Profiler	• Bounce test ≤ 8 inch/mile • Block check ± 0.01 inch of appropriate height	Calibration	Pre-Season PM and on monthly basis
DMI Pulse Counts	• ≤0.1 difference (five runs)	Validation	Pre-Season PM and on monthly basis
Location of Segment	• Mileage – 100% compliance with standards	Validation	Daily
IRI	• Std. dev. ≤ 5% (five 0.1 mile runs) • Symmetrical appearance of mult. runs	Validation	Pre-Season
	• ≥ 30 inch/mile IRI ≤ 400 inch/mile • Left & right IRI values differ ≤ 50 in/mi	Check	Daily/Weekly
Rutting	• Std. dev. ≤ 0.40 inch (five 0.1 mile runs)	Validation	Pre-Season
	• Values ≤ 0.35 inch • Left & right rutting values dif. ≤ 0.25 in	Check	Weekly
Percent Cracking	• Std. dev. ≤ 20% total length (five 0.1 mile runs)	Validation	Pre-Season
	• AC pavement values ≤ 50% • JPCP pavement values ≤ 100% • CRCP pavement values ≤ 100%	Check	Weekly
Faulting	• Values ≤ 1.0 inch • Faulting values > 0 when joints are present	Check	Weekly
Imagery	• 98 % compliance with standards • Focus, color, luminance quality	Check	Daily
		Check uploaded imagery	Weekly
		Validation	Pre-Season
Horizontal and Vertical Curves	• Std. dev. ≤ 10% (five 0.1 mile runs)	Check	Daily
		Validation	Pre-Season

*NOTE: The Connecticut DOT Photolog Operating Procedures Manual (ref. 1) will be followed. However, if after appropriate corrective action has been taken, an unacceptable quantity of data fall outside of acceptable thresholds, the equipment manufacturer shall be brought in to find a viable solution.

Table 5.2 Specific QC Procedures

QC Procedure	Action Performed	Frequency	Quantity
Preventive maintenance and calibration of ARAN equipment	Perform height sensor bounce tests, laser calibration block tests, accelerometer calibration checks, distance calibration, sample IRI calculation and other checks,	Annually, or as specified by manufacturer	As prescribed by manufacturer
Testing of reference validation sites	Perform at least five runs each on designated sections for IRI, cracking, transverse profile, rutting and faulting	Start of season and following equipment upgrades or calibrations	~50 (5 runs on ~10 sections (or the number of sections designated))
Verification testing of reference validation sites during production	Collect same data with both ARAN vans	Monthly	Run all verification sites
Real-time viewing of data and data collection systems operation	Monitor collection systems and data collected within the vehicles in real time	Continuous	Per manufacturer allowance
Check for missing road segments or data elements, and if data are within expected ranges	Run collected data through software checks while downloading	Weekly during data download	All data screened
Periodic testing of designated verification sections	Collect data on designated verification sections(s) with both vans	Min. weekly	At least 1 site
Record events for out of lane (construction zones), other lane deviations, and railroad crossings	Record events during data collection with ARANs	Daily, as events encountered	All noted events
Automated Global database checks. • Statistical routines that check for inconsistencies in the data • Completeness of data, • improper file structure, • start and end points for all segments match inventory, • null or negative values • reasonable range of values	Run software at or immediately after download	Weekly	100% of routes

6.0. DELIVERABLES, PROTOCOLS, AND QUALITY STANDARDS

The key deliverables, protocols used for data collection, processing and reporting, and associated quality standards are described below in Tables 6.1 & 6.2. Quality standards define, when applicable, the resolution, accuracy, and repeatability or other standards used to determine the quality of each deliverable. See Section 7 for the Acceptance Testing Plan. Please note that these quality standards will continue to be evaluated and adjusted, if necessary, as data are collected and refinements are made.

Table 6.1 Deliverables, Protocols and Quality Standards for Automated Data Collection

Deliverable	Reference Protocols/Standards	Required Measurement Resolution	Required Accuracy Limits (compared to reference values) **	Required Reproducibility Limits (between CTDOT vehicles)***	Required Repeatability Limits (for five consecutive runs)***
IRI (left, right, and MRI average over 0.1-mi sections)	❖ AASHTO R 43-13 ❖ AASHTO R 56-14 ❖ AASHTO R 57-14 ❖ AASHTO M328-14 ❖ ASTM E1926-98 ❖ HPMS Field Manual (2016)	**1 in/mi**	**± 8 percent**	**Absolute Difference in IRI <10 in/mi (95% PWL****)**	**Each run within ± 5 percent of the mean of five runs (95% PWL****)**
Rut depth (average of right and left wheelpath over 0.1-mi sections)	❖ AASHTO R 48-10 ❖ AASHTO PP 70-14 ❖ AASHTO PP 69-14 ❖ HPMS Field Manual (2016)	**≤0.04 in.**	**± 0.08 in.**	**Absolute Difference in rut depth <0.06 in (95% PWL)**	**Within ± 0.06 in. Standard Deviation from mean of five runs (95%PWL)**
Faulting (average of right wheel path including only faults over 0.2 in)	❖ AASHTO R 36-13 ❖ AASHTO R-57 ❖ AASHTO M328-14 ❖ HPMS Field Manual (2016)	**0.04 in**	**± 0.08 in.**	**Absolute Difference in fault <0.06 in (95% PWL)**	**Within ± 0.06 in. Standard Deviation from mean of five runs (95%PWL)**
Asphalt Pavement Cracking* a) HPMS Percent Cracking – wheelpath fatigue percent area per 0.1 lane-mile b) CTDOT Network – length per 10 lane-meters	❖ AASHTO PP 68-14 ❖ AASHTO R 55-10 ❖ AASHTO PP 67-16 ❖ HPMS Field Manual (2016)	**a) 1 percent (HPMS -fatigue area)** **b) 0.1 ft. (CTDOT - length)**	**± 30 percent**	**<10% C.o.V. in Total Cracking (95%PWL) <20% C.o.V. in Longitudinal, Transverse, or Area Cracking (95% PWL); <40% C.o.V. in Total wheelpath Cracking (95% PWL); <60% C.o.V. in Total Non-wheelpath cracking (95% PWL)**	**<10% C.o.V. in Total Cracking (95% PWL) <15% C.o.V. in Longitudinal, Transverse, or Area Cracking (95% PWL); <30% C.o.V. in Total wheelpath Cracking (95% PWL); <50% C.o.V. in Total Non-wheelpath cracking (95% PWL)**
Concrete Pavement Cracking a) HPMS - % cracked slabs b) CTDOT Network	❖ HPMS Field Manual (2016) ❖ Cracked slabs and total slabs counted using ROW imagery	**a) 1percent (HPMS)** **b) 0.1 ft.(CTDOT)**	**± 20 percent**	**± 20 percent**	**± 20 percent**
GPS (degrees of latitude or longitude)	N/A	**0.00001 degrees**	**± 0.00005 degree**	**± 0.00005 degree**	**± 0.00005 degree**
Cross slope (100*rise/run)	❖ AASHTO PP 69-14 ❖ AASHTO PP 70-14	**0.01 percent**	**± 0.5 percent**	**Absolute Difference < 0.5 percent (99% PWL)**	**St.Dev. <0.05 percent (99% PWL)**
Longitudinal grade (100*rise/run)	N/A	**0.01 percent**	**± 0.1 percent**	**Absolute Difference < 0.1 percent (99% PWL)**	**St.Dev. <0.1 percent (99% PWL)**
Radius of curvature	N/A	**1 ft.**	**N/A**	**N/A**	**± 10 percent**
Linear Reference (DMI)	❖ FUGRO Manual ❖ AASHTO R57-14 ❖ AASHTO R56-14	**0.0001 ft.**	**Abs Diff < 0.15 percent (e.g.,998.5 – 1001.5 ft./1000ft)**	**N/A**	**N/A**

Table 6.1 Deliverables, Protocols and Quality Standards for Automated Data Collection (continued)

Deliverable	❖ Reference Protocols/Standards	Required Measurement Resolution	Required Accuracy Limits (compared to reference values) **	Required Reproducibility Limits (between CTDOT vehicles)***	Required Repeatability Limits (for five consecutive runs)***
1) Road segments Start boundary End boundary 2) Segment Length	❖ PMS Database ❖ Field Check**	**1) 0.00006 mi** **2) Max. Length 0.11 mi.(per HPMS)**	**All assigned segments surveyed and assigned correct location:** **Start point ± 0.05 mi**	**N/A**	**N/A**
ROW images	❖ FUGRO Manual ❖ Field Check**	**10 in. letter height visible at 15 ft.**	**Signs legible, proper exposure and color balance**	**N/A**	**N/A**
Pavement images	❖ AASHTO PP 68-14 ❖ Field Check**	**N/A**	**1/8-in wide cracking visible on asphalt and concrete pavements**	**N/A**	**N/A**

Notes:
* CTDOT collects images per every 10 lane-meters
** Accuracy standards will be updated as validation sites are added and reference data for these sections determined over the next 1to 3 years.
*** Values to be reviewed/refined as more data are collected
****Minimum percentage of data to meet the specified range of values
PWL = Percent Within Limit;
N/A = Not Applicable
C.o.V. = Coefficient of Variation (Ratio of Standard Deviation over Mean);
St.Dev. = Standard Deviation from mean value of 5 runs

Table 6.2 Data Review Criteria for Automated Condition Data Collection [1]

Deliverable	Criteria* for Data Checks (Routine 0.10 mile CTDOT Network Sections)	Criteria** for Data Checks (HPMS 0.1 mile Sections)
IRI (left, right, and MRI average per section)	30-400 in./mile (99%****)	• Min. 30 in/mi. • Max. 400 in/mi.
Rut Depth (average of right and left wheelpath per section)	≤0.5 in. (99%)	Max. - 1.00 in.
Faulting (average of right wheel path per section for faults greater than 0.2 in)	≤0.5 in. (90%)	Max. - 1.00 in.
Asphalt Pavement Cracking* a) CTDOT Network – length per 5 lane-meters (pavement-surface image) b) HPMS Percent Cracking – wheelpath fatigue percent area per 0.1 lane-mile	≤150 ft./5 lane-m (99%)	• Min. 0% area per 0.1 lane (12-ft wide) mile. • Max. 54.0 % area per 0.1 lane-(12-ft wide) mile
Concrete Pavement Cracking a) CTDOT Network- cracked slabs and total slabs counted using ROW imagery b) HPMS – Percent Cracking – percent cracked slabs	<100% cracked slabs	• Min. 0% cracked slabs • Max. 100% cracked slabs
Cross Slope (100*rise/run)	≤10 %(100%)	N/A
Longitudinal Grade (100*rise/run)	≤16 %(99%)	N/A
Radius of curvature	N/A	N/A
1) Road **Segments** Start boundary End boundary 2) Segment Length	< 1 mismatch (0.1 mi.) segment per 10 miles (99%)	N/A
Pavement Images	< 1 missing image per 0.062 mi. (99%)	N/A

[1] In general, when values for 0.1-mile sections fall outside criteria stated in this table, as a check the data should be reviewed and verified for validity. For HPMS, section lengths will vary.
* Criteria was developed by CTI using CTDOT network data for years 2008-2016
** Criteria from FHWA, Nov 2017 (ref. 3)
*** CTDOT collects images per every 10 lane-meters
****Minimum percentage of data expected to fall within the specified range of values. See also note [1]

7.0. DATA ACCEPTANCE CRITERIA AND ERROR RESOLUTION PROCEDURES

The focus of Acceptance is to validate that deliverables meet the established quality standards. The Pavement Management Group in the Bureau of Engineering and Construction has the final authority to reject data and information that cannot be reconciled and/or fails to meet quality standards upon review and re-sampling. The Photolog Unit works cooperatively with the PMG to resolve any discrepancies in data quality that are found during the quality management process.

This section of the DQMP documents data sampling, review, and checking processes that CTDOT performs to verify proper data format, completeness (including checks for missing data), consistency, and range.

The PLU delivers data to the PMG in batches approximately every two weeks throughout the data collection phase of the project. The delivered data includes pavement smoothness (IRI) data elements, but post-processing of 3-D data with Vision software is required to produce cracking, rutting and faulting data elements.

These Vision software post-processing procedures are performed in batches. Once post-processing of a batch is complete, the entire dataset of that batch is screened for proper data format and completeness by PMG staff. The data elements to be reviewed for proper format and completeness include cracking, roughness (IRI), and rutting. In addition, grade, cross slope, surface type, location information and video images are screened.

Special post-processing of 3-D images with Vision software is performed separately to produce faulting data for JRCPs because this dataset is small enough that it can be broken out separately. JRCPs only make up approximately 0.5% of the entire network in Connecticut. Each fault is located in Vision or DigitalHiway to validate whether an actual fault was measured, or if the measured value represents some other feature, such as a bridge joint.

Cracking percent values for asphalt-surfaced pavements are reviewed for completeness following further post-processing calculations in SQL Server Express. Additional screening for completeness is also performed on the entire data set following each SQL Server Express procedure where data are aggregated, such as from a 5-meter granularity to 0.1-mile granularity. Criteria contained in Table 6.2 will be checked both before and after these post-processing calculations.

DigitalHiway and/or Vision software images will be manually reviewed to determine cracking percent values for JRCPs. PMG staff will count the number of cracked slabs according to the HPMS Field Manual and divide that quantity by the total number of slabs. The quotient, expressed as a percentage, is reported as the cracking percent (JRCP pavements only).

Missing data is flagged and evaluated to determine why data are missing, and whether any roadways need to be resurveyed. For example, the evaluation will include a review of ROW imagery to determine if any construction zones were encountered, or any other unusual events were encountered that would result in missing data.

Year-on-year comparisons between current and legacy data are carried out by graphing pavement metrics (IRI, cracking, rutting, cross slope, and grade) for the current year versus prior years. Where the current year deviates significantly from prior year(s), exceptions are noted for follow-up checks to resolve discrepancies. For cases where errors are identified, corrective actions are taken, up to and including recollection. A minimum sampling rate of 15% for each batch is used for these comparisons. As experience with these comparisons is gained, tolerances for acceptable changes between years will be established to identify significant differences that should be flagged for further review.

Errors can occur during data collection because of equipment failures, poor image quality, or insufficient calibration; during data collection because operators are using incorrect procedures or standards; or during post-processing because of flawed procedures to calculate pavement condition metrics. Error resolution procedures will be followed and corrective actions will be taken when data do not meet established quality requirements and defined acceptance criteria.

Error logs are maintained throughout the entire process: beginning with data collection, during quality control, and finally during post-processing. Corrective actions may be taken during each of these processes, including re-collection, re-calibration of equipment, re-analyzing raw data, or even re-training staff responsible for data collection or data analysis. Error resolution procedures contained herein present actions that will be taken to reduce conflict when a problem is discovered.

Following in Table 7.1 is a description of acceptance testing, the frequency for testing, and corrective actions for items that fail to meet criteria. Table 7.2 contains specific acceptance procedures. These are CTDOTs data acceptance criteria and error resolution procedures.

Table 7.1 General Acceptance Expectations and Deliverables

Deliverable	**Acceptance *(Percent Within Limits)**	**Acceptance Testing & Frequency**	**Corrective Action**
IRI, rut depth, faulting, cracking, cross slope, longitudinal grade	See Tables 6.1 & 6.2	1. Monthly (min.) verification using validation sites 2. Global database check for range, consistency, logic, and completeness 3. Inspection of all suspect data	1. Re-calibration of vehicle equipment 2. Reject deliverable; data must be re-collected 3. Use of GIS for further inspection 4. Determine reason for suspect data; or reject deliverable, data must be re-collected
Segment (section) boundaries and lengths	See Table 6.1	1. Plot on base map using GIS. 2. Create list of unmatched segment boundaries.	Return deliverable for correction, as needed.
Pavement images	See Table 6.1	1. Monthly inspection of validation site video. 2. 5 to 10 percent sample inspection upon delivery.	Reject deliverable; images must be re-collected.

*NOTE: If following corrective action and re collection of data, an unacceptable quantity of data fall outside of acceptable thresholds, the equipment manufacturer(s) and/or software developers are contacted to solicit advice for a viable solution.

Table 7.2 Specific Acceptance Procedures

Acceptance Procedures	Action Performed	Frequency	Quantity
Checks of Periodic testing of known validation sites during production	Review QC findings	As needed	50%
Checks of Cross Measurements for reproducibility	Review QC findings	As needed	50%
Global database checks:			
• Missing Routes	Check for missing routes	Annually	100%
• Data exists for all road segments.	Check for missing data by segment	Annually	100%
• Data file structure.	Check format of file structure	As needed	As needed
• Start and end boundaries for all road segments.	Find and List segments containing incorrect boundaries; investigate	Annually	100%
• Null and negative values.	Find and list out of tolerance data, investigate, edit as necessary	As needed	As needed
• Minimum and maximum tolerance parameters.	Find and list out of tolerance data; Investigate, edit as necessary	As needed	As needed
• Duplicate records.	Find, list and delete	Annually	100%
• Wrong pavement type.	Find, list and correct	Annually	100%
• Abrupt change in roughness and rut depth.	Check for excessive variability within segments	Annually	100%
• Reasonable maximum extent of distress.	Check quantities for unreasonable high values	Annually	100%
• Non-numeric data in a numeric field.	Find, list and correct	Annually	100%

8.0. QUALITY REPORTING PLAN

The Data Collection Quality Control Supervisor monitors quality through QC activities, and records and reports data quality exceptions as part of internal weekly status reporting, or more frequently if conditions warrant. Overall quality is monitored through acceptance testing, and quality issues are reported to the data collection team as soon as issues are discovered.

A QC log is used by the data collection team to itemize, document, and track to closure concerns and issues reported through the QC process.

A copy of the latest QC Log can be found via the following URL Link:
https://ctgovexec.sharepoint.com/sites/DOTDataQualityManagementPlan/Shared%20Documents/General/Quality%20Control%20and%20Acceptance%20Log

An acceptance log is used by the PMS Data Lead to itemize, document, and track to closure items reported through the acceptance process. Examples of QC and Acceptance Log formats can be found in reference 2, *Manual for Quality Control of Pavement Condition Data Collection*.

8.1 Quality Management Reporting

An annual quality management report will be prepared to address and summarize the QC, Acceptance and Procedural issues that occurred over the previous data collection year.

QC Report

Upon delivery of the final database and other deliverables, the data collection team provides a copy of the QC logs, a summary of scope and schedule (including any deviations from the planned schedule), a list of the collection vehicles and personnel used on the project, documentation of equipment calibration and maintenance, results of all verification runs on validation sites, and documentation of other problems encountered (not listed on the QC log) and corrective actions taken. Specifically, as a minimum, the QC report will address the following:

- Equipment and key personnel used during data collection.
- Documentation of initial and continuing calibration/checks/maintenance for field equipment, any equipment problems, and corrective actions taken.
- Schedule adherence and the reasons for any changes.
- Documentation of collection procedures and protocols used.
- Reporting of any variances in standard operating procedures or changes in collection methods made in the field.
- Applicable guidance documents.
- Reporting of all validation site testing and results.
- Summary of all QC activities and resultant checks of expected values.

- Log of all quality issues identified through QC activities, and corrective actions taken.
- Summary of Annual review of all QC processes performed.

Acceptance and Quality Management Report

Upon acceptance of the final database and all other deliverables, the Data Processing Quality Assurance Supervisor will prepare the final annual Quality Management Report (QMR), which will incorporate the QC report and include a section on Acceptance. A copy of the QMR must be provided to the Data Collection Quality Control Supervisor for review and feedback. The QMR report will include a summary of scope and schedule, description of validation site testing (including reference values and an analysis of results), description of global database checks and other sampling tests performed and the results, and recommendations for improvement.

9.0. CTDOT DATA QUALITY MANAGEMENT PLAN ENDORSEMENT

This Quality Management Plan is endorsed by the CTDOT DQMP designated Agency Managers:

____ Date: _________________________

Michael Connors
Trans. Assistant Planning Director
Roadway Information Systems
Bureau of Policy and Planning

____ Date: _________________________

Karen M. Riemer, P.E.
Trans. Principal Engineer
Project Administration Unit
Bureau of Engineering and Construction

9.1 Quality Management Plan Revisions

Should any portion of this Quality Management Plan become obsolete, outdated, or simply in need of revision, every reasonable attempt will be made to update the appropriate section(s) in a timely manner, usually on an annual basis. If a change is significant and its effect on data collection immediate, FHWA will be notified in writing of the change in process, and its projected effect on data quality, if any.

10.0. REFERENCES

Note: The general structure/format of this QUALITY MANAGEMENT PLAN is patterned after "FHWA Practical Guide for Quality Management of Pavement Condition Data Collection," Pierce, McGovern and Zimmerman, Feb, 2013.

Ref. 1:
https://ctgovexec.sharepoint.com/sites/DOTDataQualityManagementPlan/Shared%20Documents/General/Photolog%20Standard%20Operating%20Procedures Office of Roadway Information Systems, "Connecticut Department of Transportation, Photolog Field Data Collection Standard Operating Procedures – *Working Draft*," Connecticut Department of Transportation, Newington, CT, May 2018.

Ref. 2:
https://ctgovexec.sharepoint.com/sites/DOTDataQualityManagementPlan/Shared%20Documents/General/References/Ref%202.,%20Manual%20for%20QC%20of%20Pavt%20Data%20Collection%205_18_18_%20Submitted.pdf, Connecticut Transportation Institute, "Manual for Quality Control of Pavement Condition Data Collection - DRAFT," University of Connecticut, Storrs, CT, May 2018.

Ref. 3: Max G. Grogg. Highway Information Seminar, 2016 HPMS Pavement Data Submission, FHWA, USDOT, Nov 16, 2017. https://www.fhwa.dot.gov/policyinformation/hisconf/thu03_hpms_and_tpm-part_3_2016_hpms_pavement_data_submission_max_grogg.pdf Accessed on April 18, 2018.

Ref. 4:
https://ctgovexec.sharepoint.com/sites/DOTDataQualityManagementPlan/Shared%20Documents/General/References/ARAN%20Van%20Documents/ARAN_USER_MANUAL_2.0.pdf, Fugro Roadware, " ARAN 9000 Manual, Version 2.0", Fugro Roadware, Mississauga, Ontario, November 29, 2016

Ref. 5:
https://ctgovexec.sharepoint.com/sites/DOTDataQualityManagementPlan/Shared%20Documents/General/References/SSI%20Walking%20Profiler/SSI%20Profiler%20V3%20WalkPro%20Manual_32744.pdf
Surface Systems & Instruments, Inc., " CS8800 Profiler VS Operation Manual," Version 3.2.7.11, Surface Systems & Instruments, Inc., Auburn , CA, March, 2011

Appendix A

Example Crack Detection Rater Exam Problems

1. Match these cracking distresses for pavement with asphalt concrete surfaces with their best descriptions by placing the letter of the distress or Not Applicable (NA) next to the correct description.

Distress	Description
A. Longitudinal Cracking	___ Develops into many-sided, sharp-angled pieces in later stages
B. Block Cracking	___ Cracks that are predominantly perpendicular to pavement centerline
C. Fatigue Cracking	___Cracks in AC overlay surfaces that occur over joints in concrete pavements
D. Transverse Cracking	___ A pattern of cracks that divides the pavement into approximately rectangular pieces
E. Reflection Cracking at Joints	___ Cracks that are predominantly parallel to pavement centerline.

2. When does wheel path longitudinal cracking become fatigue (alligator) cracking?
   a) When the crack has a mean width > 6 mm and ≤ 19 mm and is less than 1 m in length
   b) When it has associated random cracking or meanders and has a quantifiable area
   c) When longitudinal surface depressions are visible in the wheel path
   d) When the surface binder has worn away to expose coarse aggregate

3. How is fatigue (alligator) cracking quantified?
   a) Length
   b) Width
   c) Area
   d) Depth

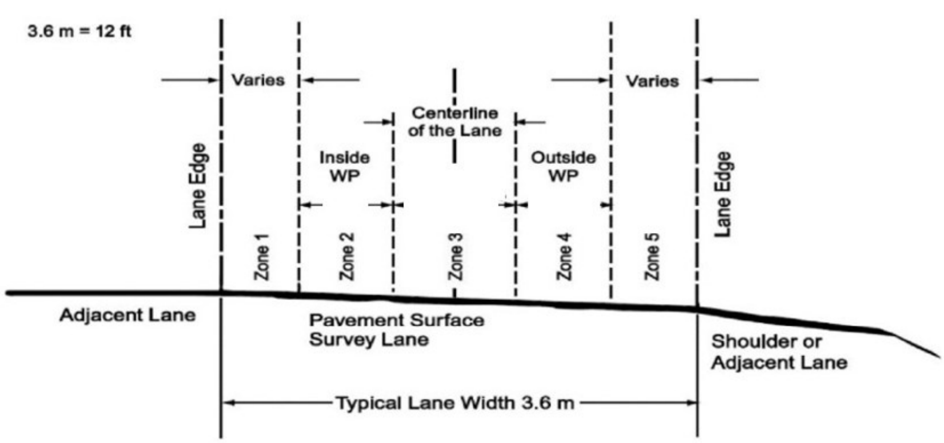
4. Fatigue (alligator) cracking may indicate improper design or weak structural layers? True or False

5. According to the HPMS Field Manual, Cracking Percent for Asphalt pavements is
    a) The percentage of the total area exhibiting visible fatigue type cracking for all severity levels in the wheel paths in each section
    b) The percentage of the total area exhibiting visible fatigue type cracking for all severity levels outside the wheel paths in each section
    c) The percentage of the area of the section exhibiting longitudinal cracking, punchouts, and/or patching
    d) The percentage of the slabs within the section that exhibit transverse cracking

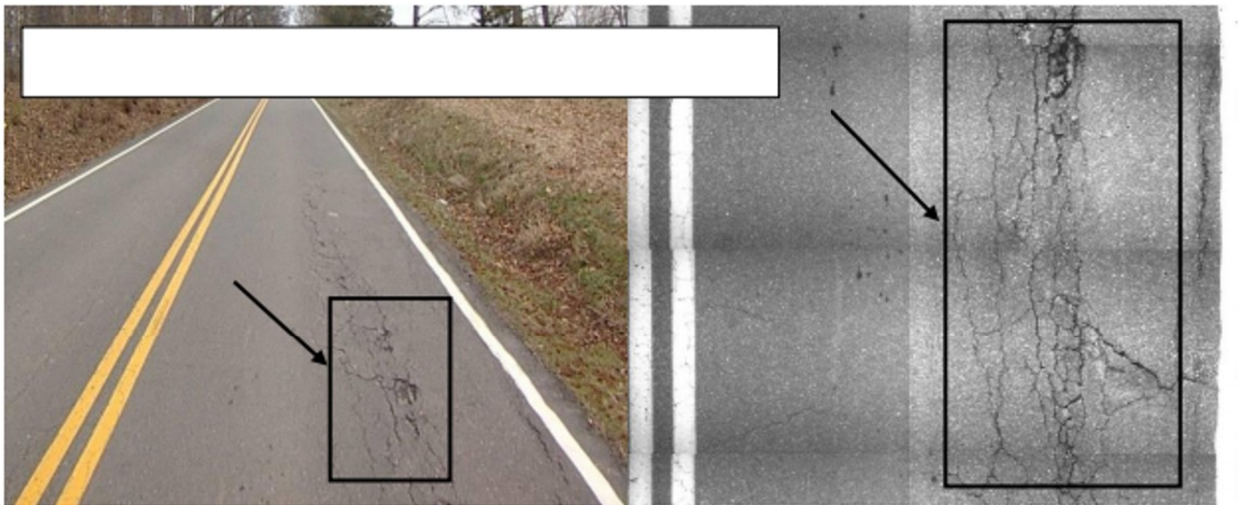
6. According to the HPMS Field Manual, Cracking Percent for Jointed Concrete Pavement is
    a) The percentage of the area of the section exhibiting longitudinal cracking, punchouts, and/or patching
    b) The percentage of the total area exhibiting visible fatigue type cracking for all severity levels in the wheel paths in each section
    c) The percentage of the slabs within the section that exhibit transverse cracking
    d) The percentage of fissures or discontinuity of the pavement surface, not necessarily extending through the entire thickness of the pavement, in the roadway shoulders

7. For purposes of reporting cracking data to HPMS, each wheelpath width is to be ________.
    a) 39 inches (1.0 m)
    b) 30 inches (0.75 m)
    c) 49 inches (1.25 m)
    d) 20 inches (0.5 m)

8. According to the HPMS Field Manual and associated standards, what are the following dimensions shown in the figure below?
    a) Zone 2 (Inside WP) = _____
    b) Zone 4 (Outside WP) = ______
    c) Zone 3 (distance between the wheelpaths) = _____



9. What distress type is predominant in this image?
   a) Fatigue (alligator) WP cracking
   b) Fatigue (alligator) NWP cracking
   c) Longitudinal Cracking
   d) Reflective Cracking



10. Given the following fatigue (alligator) cracking areas below, as well as the dimensions shown in the figure below, calculate the Cracking Percent according to the HPMS Field Manual:

∑ Left Exterior Zone Fatigue Cracking = 10.0 SF

∑ Left Wheel Path Zone Fatigue Cracking = 150.0 SF

∑ Center Zone Fatigue Cracking = 20.0 SF

∑ Right Wheel Path Zone Fatigue Cracking = 50.0 SF

∑ Right Exterior Zone Cracking = 20.0 SF

Cracking Percent = ___________

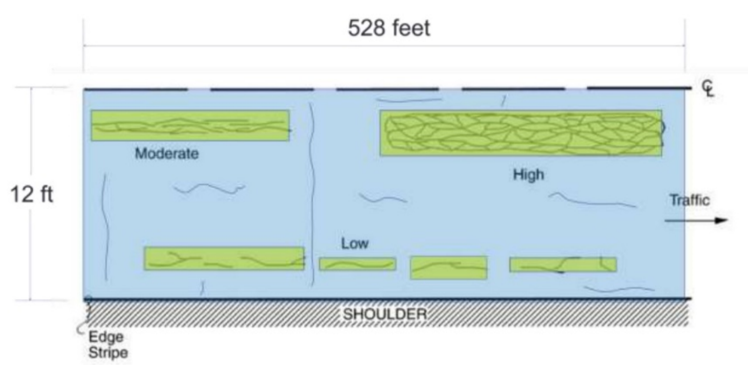


Figure 1

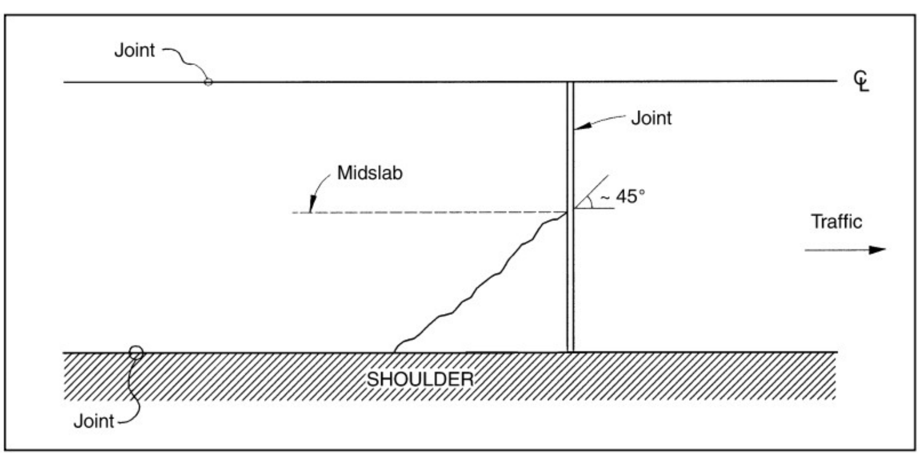
Not to Scale

11. What is the maximum Cracking Percent possible for a 528 ft long by 12 ft wide pavement section according to the HPMS Field Manual?

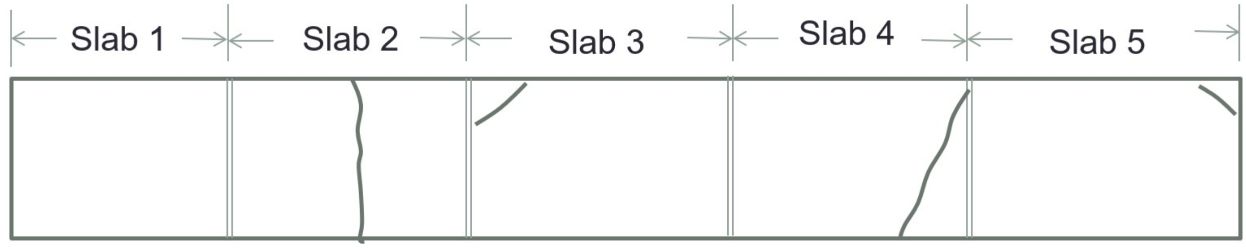
12. Match these words with their definitions according to the *LTPP Distress Identification Manual* Glossary:

Glossary Word	Definition
A. Popout	___ Cracking, breaking, chipping, or fraying of the concrete slab surface within 0.6 m of a joint or crack
B. Spalling	___ Small pieces of pavement broken loose from the surface
C. Pumping	___ Difference in elevation between opposing sides of a joint or crack
D. Blowup	___ The result of localized upward movement or shattering of a slab along a transverse joint or crack
E. Fault	___ The ejection of water and fine materials through cracks in the pavement under moving loads

13. What type of distress is shown in the figure below for this Jointed Concrete Pavement (JCP) section:
    a) Durability Cracking
    b) Transverse Cracking
    c) Spalling of Transverse Joint
    d) Corner Break



14. What is the Cracking Percent of this JCP Section according to the HPMS Field Manual?



15. In about 300 words, describe the education and experience that you possess to qualify you as a *crack detection rater* according to the CTDOT Data Quality Management Plan. Include examples of some projects you worked on, if any, where you performed manual distress surveys or similar.