Massachusetts Bay Transportation Authority

Rail Transit Tunnel Inspection Manual

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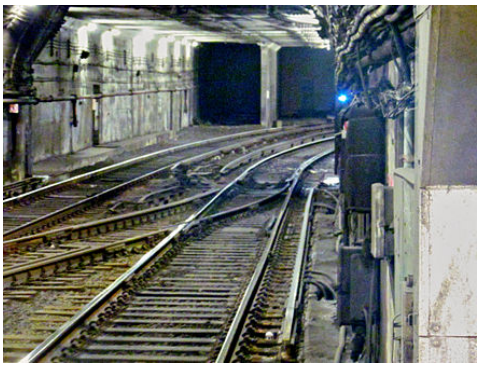




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Executive Summary

This MBTA Rail Transit Tunnel Inspection Manual establishes procedures and practices for the inspection of the MBTA rail transit tunnels comprising the Blue, Red, Green, and Orange lines, including the various abandoned sections of tunnel along these lines, and air-rights structures (within the tunnel envelope) that are constructed by the MBTA or on MBTA property in the future. These procedures and practices may also be used for inspection of MBTA commuter rail tunnels.

The purpose of this manual is to establish best-practice requirements for the inspection of the MBTA rail transit tunnels, as defined above, to ensure the tunnels are kept in a state of good repair, to ensure the safety of the traveling public, and to ensure the continued performance of the rail transit infrastructure.

A brief history of the previous practices leading to the current practices is discussed in the manual. Recent standards using element-level methodology which have been developed for both highway and railroad tunnels are cited and were used and blended to develop this manual. Each of the four subway lines are described and mapped, including plans showing a rational division of all of the tunnels into individual tunnel segments called TINs (Tunnel Identification Numbers). Cross sections are provided to impart more information when planning inspections.

Quality control and quality assurance are described, as are the organization and the roles and responsibilities of the inspection team staff. Minimal qualifications are listed for each member of the inspection team.

Inspection procedures are described in significant detail for the four types of inspections: Initial/Inventory, Routine All-Item, Special Member/Overhead, and Damage/Emergency. Pre-planning and safety requirements for proper access and inspection are provided, including other reference manuals and recommended frequencies for inspection. The protocol for identifying, documenting, and reporting "critical findings" is included.

Several published tunnel inspection manuals are noted as references and guides for the inspectors when performing inspections within the tunnels. In addition to these reference manuals, a guide to identifying deterioration within a transit tunnel for various elements is included herein. This overview of deterioration is accompanied by a brief description of how to identify critical findings in other assets within the tunnels. Checklists and inspection forms are included to ensure consistent and repeatable information is collected that is compatible with the MBTA's asset management system.

Report organization and content for each type of inspection are outlined, and sample reports are included. The sample reports contain condition tables for all applicable elements within that TIN, showing the distribution of the total quantity of each element across five different TERM scale condition states.

TERM coding guide tables are provided to assist in properly coding tunnel identification and attribute information, as well as condition state coding for structural, civil, fire/life/ safety/security, and select mechanical and electrical elements.

This manual is considered a "living" document, which will be revised as the MBTA further develops its asset management program and procedures, to better monitor the State of Good Repair (SGR) of the MBTA's rail transit tunnel infrastructure.

1.0 Introduction

1.1 Summary

This MBTA Rail Transit Tunnel Inspection Manual establishes procedures and practices for the inspection of the MBTA rail transit tunnels comprising the Blue, Red, Green, and Orange lines, including the various abandoned sections of tunnel along these lines, and air-rights structures (within the tunnel envelope) that are constructed by the MBTA or on MBTA property in the future. These procedures and practices may also be used for inspection of MBTA commuter rail tunnels. The inspections outlined in this manual focus on utilizing both visual and in-depth inspection techniques to assess the physical and operational condition of certain elements that comprise and exist within the rail transit tunnels, including structural, electrical, mechanical, and fire life safety. See Section 7 for a full list of potential elements within the tunnel sections.

This manual does not apply to any stations or other MBTA facilities or assets. It also does not include any busway tunnels like the Silver Line, as this line has been designated for the purposes of inspection as a highway tunnel. As such, the highway defined tunnels are regulated by inspection requirements set forth by the latest Federal Highway Administration (FHWA) National Tunnel Inspection Standards (NTIS). These standards do not apply to the MBTA commuter rail that operates on the general railroad system regulated by the Federal Railroad Administration (FRA).

Based on input and material from multiple MBTA departments, stakeholders, and other tunnel owner agencies, this manual defines the means, methods, frequency, and qualifications of inspectors for proper inspection and reporting.

1.2 Scope and Purpose

The purpose of this manual is to establish best-practice requirements for the inspection of the MBTA rail transit tunnels, as defined above, to ensure the tunnels are kept in a state of good repair, to ensure the safety of the traveling public, and to ensure the continued performance of the rail transit infrastructure.

The primary purpose of rail transit tunnel inspections, particularly within the context of an infrastructure management system, is to determine tunnel condition by locating and prioritizing defects for future repairs. Inspections are intended to determine the overall condition, as well as various levels of deterioration of quantifiable portions of each element and system via the Federal Transit Administration's (FTA) Transit Economic Requirements Model (TERM) scale condition rating from 1 to 5, refer to Table 1.2-1 for rating scale and description (please refer to Section 7 for detailed description of condition rating criteria for elements within the tunnel). This model allows for determination of the State of Good Repair (SGR) rating for individual elements, systems, and entire tunnels based on a roll-up weighting system applied by the MBTA asset management group. It will also provide a consistent scale across all disciplines for more objective comparisons, information

needed to make decisions such as the type and urgency of repair, locations where defects are found, and how detrimental those defects are. The prioritization of tunnel defects will dictate needed maintenance within a routine or an emergency maintenance procedure. This approach encourages the most effective management of tunnel repairs, including financing, information storage and retrieval, staff training, and subsequent inspections, all in an integrated fashion. An infrastructure management system ideally establishes well-organized procedures for tunnel inspections and maintenance to ensure tunnels are kept in a state of good repair.

Rating	Condition	Description
5	Excellent	No visible defects, new or near new condition, and may still be under warranty if applicable.
4	Good	Good condition, but no longer new; may have some slightly defective or deteriorated component(s), but is overall functional.
3	Adequate	Moderately deteriorated or defective components but has not exceeded its useful life.
2	Marginal	Defective or deteriorated component(s) in need of replacement; has exceeded useful life.
1	Poor	Critically damaged component(s) or in need of immediate repair; well past useful life.

Table 1.2-1 FTA TERM Condition Assessment Scale

The information developed from tunnel inspections outlined in this manual may be utilized for FTA's National Transit Database (NTD) reporting via the Asset Inventory Module (AIM). The AIM is designed to collect basic information on assets and infrastructure used by US transit agencies. The NTD and the AIM are designed to address reporting of condition data for elements on an annual basis. Use of the same TERM scale condition rating between 1 and 5 by all transit agencies will allow the FTA to better project future capital costs of existing transit assets on a national level.

1.3 Historical Background

At the time of development of this manual, the MBTA's inspection practices consisted of performing structural condition surveys of its rail transit line tunnels using visual inspection techniques that focus on the condition of the concrete tunnel liner (walls and roof slab) on an approximate 4-year inspection frequency. These visual inspections were performed to determine quantities for concrete repairs and documented cracks, areas of spalled concrete, areas of delaminated concrete, and locations where groundwater intrusion was observed. Condition survey reports were developed for each of the four transit line tunnels during each inspection cycle which describe, in general terms, the overall structural condition of the tunnel liner and include a compilation of specific documented deficiencies. Each deficiency was assigned a specific condition and deficiency rating code based on the guidelines contained in the 2005 FHWA/FTA Highway and Rail Transit Tunnel Inspection Manual (HRTTIM). Condition survey reports are submitted to the MBTA in bound hard-copy and PDF formats. Currently, a more in-depth inspection of the liner for each line is being conducted to determine areas of "incipient spalls" in need of attention.

Prior to the development of this manual, the 2005 HRTTIM was the industry standard inspection manual used by most rail transit tunnel agencies, and it still is for many. The HRTTIM provides rail transit tunnel agencies general guidance for establishing procedures and practices for the inspection, documentation, and priority classification of deficiencies for various elements in a tunnel. It was developed for a visual and in-depth inspection of the functional and operational aspects of highway and rail transit tunnels. The manual focuses in detail on the inspection and reporting of functional aspects of the tunnel, including structural, mechanical, and electrical components. The manual includes only brief guidance on the inspection and reporting of operational aspects of tunnels and is meant to impart general knowledge but not in-depth inspection criteria for systems/appurtenances, such as track, traction power, signals, and communications. The frequency of these inspections is based on the age and condition of each tunnel. For new tunnels, the frequency could be as great as 5 years, while for older tunnels, the frequency may be reduced to 2 years. Ultimately, the frequency chosen is at the discretion of the owner.

In mid-2015, the FHWA developed the National Tunnel Inspection Standards (NTIS), the Tunnel Operations, Maintenance, Inspection, and Evaluation (TOMIE) Manual, and the Specifications for the National Tunnel Inventory (SNTI). The SNTI, TOMIE, and NTIS documents supersede the guidelines pertaining to highways in the 2005 FHWA/FTA Highway and Rail Transit Tunnel Inspection Manual. The NTIS contains the regulatory requirements for the tunnel inventory and inspection program of highway tunnels, while the TOMIE provides guidance on the operation, maintenance, inspection, and evaluation of highway tunnels. The SNTI contains instructions for consistent and proper coding of the inventory and physical element data to the FHWA. These manuals were developed for a visual and in-depth inspection of both functional and operational aspects of highway tunnels utilizing element-level condition state evaluation using a scale of 1 to 4. In accordance with Table 4.3 in the NTIS, the frequency for routine inspection of highway tunnels varies between 24 months and 48 months.

Many aspects of the 2015 FHWA standards, especially in regard to condition state coding and reporting methodology, are also applicable to rail transit tunnels and so have been adopted with appropriate modification and supplementation for this MBTA Rail Transit Tunnel Inspection Manual.

1.4 MBTA Inspection Unit Structure

MBTA's inspection unit structure can be described in the organization figure 1.4-1.

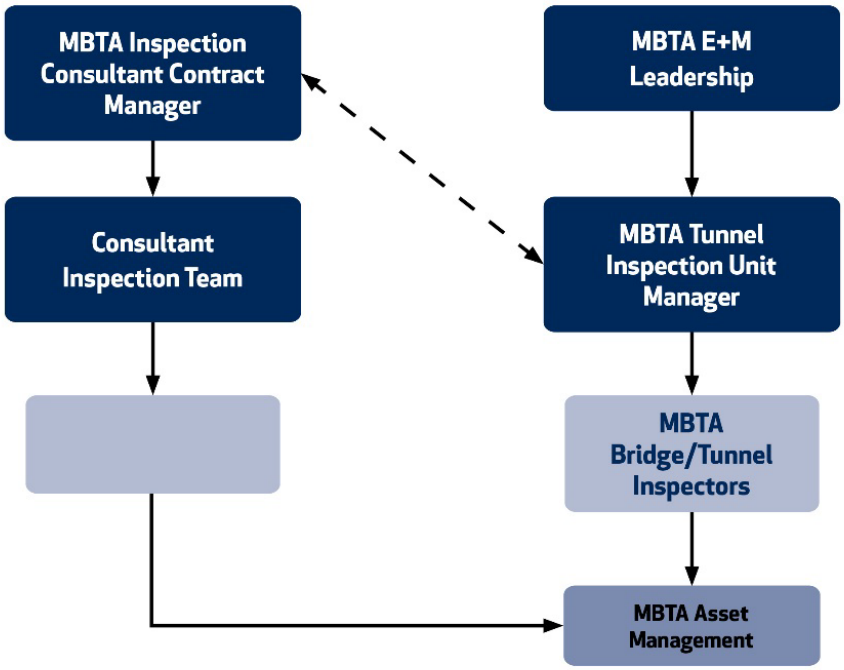

Figure 1.4-1: MBTA Tunnel Inspection Unit Structure

1.5 New Structures/Elements

This manual is designed so that new tunnels or elements added to the MBTA network can be added to the inventory. New tunnel sections would be labeled and elements added consistent with the methodology herein. Any replaced or rehabilitated tunnels or elements would also be updated in the inventory. Future revisions to this manual should include inspection, reporting, and condition coding requirements for any new elements.

1.6 Applicable Reference Material for Inspectors

Tunnel inspection team members are required to be well versed with current manuals that pertain to inspection procedures and techniques related to their responsibilities. In the development of this MBTA manual, multiple publications and manuals were used to provide content and listed in Table 1.6-1.

Author/Agency	Reference Material
Federal Highway Administration (FHWA)	Specifications for the National Tunnel Inventory (SNTI) - July 2015
	Tunnel Operations, Maintenance, Inspection, and Evaluation Manual (TOMIE) - July 2015
American Railway Engineering and Maintenance-of-Way Association (AREMA)	Bridge Inspection Handbook - Chapter 11, Tunnel Inspections
Federal Transit Administration (FTA)	National Transit Database - Asset Inventory Module, 2017-2018 Reporting Guide
	Transit Asset Management (TAM) Facility Performance Measure Reporting Guidebook, Version 1.2 - March 2018
Massachusetts Bay Transportation Authority (MBTA)	Signals and Maintenance Manual 1 (SM.1)
	Signals and Maintenance Manual 2 (SM.2)
American Public Transportation Association (APTA)	Rail Transit Fixed Structures Inspection and Maintenance (RT-FS-S-001-02)
National Fire Protection Association (NFPA)	Standard for Fixed Guideway Transit and Passenger Rail Systems (NFPA 130)

Table 1.6-1: Reference Material for Inspectors

1.7 Manual Revision Procedures

Any revisions to this manual, further explanation, clarification, and/or additional information that may require insertions in the manual will be incorporated and reflected as a revised section to replace the existing published section. In the case of new material, a new stand-alone section will be inserted where applicable. Furthermore, the Table of Contents will be revised to reflect the revised section and date of revision.

1.8 Acronyms

Acronyms used throughout this document are listed below.

AIM ..... Asset Inventory Module
AREMA ..... American Railway Engineering and Maintenance-of-Way Association
CR ..... Critical Rating
CS ..... Condition State, sometimes with subset of 1 to 5 following to represent rating
DF ..... Direct Fixation

EA	Each
E&M	Engineering and Maintenance (MBTA department)
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HRTTIM	Highway and Rail Transit Tunnel Inspection Manual
ID	Identification
LF	Linear Feet
MBTA	Massachusetts Bay Transportation Authority
NBI	National Bridge Inventory
NFPA	National Fire Protection Association
NTD	National Transit Database
NTIED	National Tunnel Inventory Element Database
NTIS	National Tunnel Inspection Standards
OCC	Operations Control Center (MBTA department)
PMP	Project Management Plan
ROW	Right-of-Way
SF	Square Feet
SGR	State of Good Repair
SM	Signal and Maintenance (MBTA department)
SNTI	Specifications for the National Tunnel Inventory
TAM	Transit Asset Management
TERM	Transit Economic Requirements Model
TFM	Transit Facilities and Maintenance (MBTA department)
TIN	Tunnel Identification Number
TOMIE	Tunnel Operations, Maintenance, Inspection, and Evaluation

2.0 MBTA Rail Transit Tunnel Overview

Section 2 is not included in the external version of this manual. The information contained in this section has been removed for security purposes and may be available upon request.

Information within Section 2 that has been removed includes, but is not limited to, the following:

- Tunnel overview and background information.
- Tunnel cross sections and construction methods.
- TIN drawings, which include the following information:
  - Boundaries for each TIN.
  - Track stationing within the tunnels.
  - Location and stationing of transit stations within the tunnels.
  - Locations and limits of power sections and tunnel cross section types within the tunnels.
  - Locations of switches, pump rooms, and egresses within the tunnels.

Along the four main transit lines and including the abandoned sections, there are 26 total tunnels divided into 70 TINs. Refer to Table 2.0-1.

Transit Line	Number of Tunnels	Number of TINs
Blue Line	2	7
Green Line	6	18
Orange Line	9	15
Red Line	3	23
Abandoned	6	6
Total	26	69

Table 2.0-1: Number of Tunnels and TINs

3.0 Quality and Qualifications of Staff

3.1. General

This section describes policies and procedures for quality assurance and quality control as well as qualifications of personnel. Setting and following consistent standards in these areas will help to ensure that the tunnel inspections will be conducted in such a fashion as to provide valuable, actionable information to help maintain the tunnels in a state of good repair.

3.2. Quality Assurance/Quality Control for Tunnel Inspection

QA and QC are both important aspects of tunnel inspection that must be performed to ensure inspections are conducted properly and the resulting inspection reports are produced in a manner that meets the MBTA standards and ultimately helps to ensure the tunnels continue be an efficient and safe mode of travel for the public.

The definitions for QC and QA used for this manual are as follows:

3.2.1 Quality Control

Procedures that are intended to maintain the quality of a tunnel inspection and reporting at or above a specified level.

Quality control helps maintain a level of performance for the inspections conducted and the resulting inspection reports. This level of performance must meet at a minimum the standards set forth by the MBTA. QC procedures may consist of pre-planning activities that are required to be performed in advance of mobilization in order to ensure the proper level of preparedness: enforcement of inspector qualifications, application of condition assessment codes that ensure consistency between inspection cycles, equipment inspection requirements, safety requirements, development of standard inspection forms with data fields included, and adherence to standard processes/procedures/checklists for performing inspections and checking reports and other deliverables.

3.2.2 Quality Assurance

The use of sampling and other measures to ensure the adequacy of quality control procedures in order to verify or measure the quality level of the entire tunnel inspection and reporting.

Quality assurance should be performed periodically by person(s) familiar with the quality control requirements, but who are not directly involved with the inspection and reporting, to provide an independent check to confirm that the QC procedures are being followed. Quality assurance reports that indicate nonconformance with the QC plan should be provided every 3 months and result in follow-up actions to correct any non-conformances.

3.3 Inspection Organization

A successful tunnel inspection program requires effective management and qualified staff to form an organization that provides a wide range of functions. Personnel, at minimum, should include a

Client Project Manager, Project Manager, Team Leader, and Team Member, all of whom meet the below qualifications.

The Project Manager and Inspection Team Leaders for structural, mechanical, and electrical inspections require the MBTA's verification of qualifications prior to being involved in any tunnel inspections on MBTA property. This process of verification shall include direct email to the MBTA Project Manager in charge of tunnel inspection with a resume and all required certifications. The MBTA will then review the qualifications and either confirm or deny personnel on a case-by-case basis. See Section 1.4 for the MBTA inspection unit flowchart of tunnel inspection responsibilities.

The qualifications requirements for the tunnel inspection team members listed within Section 3.3 as well as Section 3.4 to 3.6 are to be followed by consultants hired for staff augmentation or for inspection services. Qualifications discussed within Section 3.3 to Section 3.6 shall be meet by all consultants whom have been hired by the MBTA.

The MBTA Chief Engineer shall set the MBTA qualification requirements for the MBTA tunnel inspection team members.

3.3.1 MBTA Tunnel Inspection Team Members

Members of the MBTA tunnel inspection team include, but are not limited to: Project Manager, Inspection Team Leaders, and Inspection Assistant Team Leaders. The MBTA qualifications for these positions shall meet the standards set forth by the MBTA Chief Engineer. The qualifications within Section 3.3 to Section 3.6 shall not apply to the MBTA employees unless required by the MBTA Chief Engineer.

3.3.2 Project Manager

The Project Manager (PM) has the fundamental responsibility of managing a project involving the inspection and reporting of one or multiple tunnels and providing the project services agreed to for the Authority. To accomplish this, the PM must provide leadership for the project team, integrating all the projects' parts to achieve success in terms of technical and financial aspects. Effective management for rail transit tunnel inspection requires experience in responding quickly to evolving situations and performing effective planning that will enable the project to maintain schedule while not adversely affecting tunnel operations. An effective Project Manager must therefore be a "hands-on" person with the flexibility to deal with field operations under varied work schedules and late-night "nonrevenue" hours.

The Project Manager shall possess all the following minimum qualifications:

- Be a registered Professional Engineer.
- Have a minimum of 10 years' experience in tunnel or bridge inspections.
- Have completed and passed the FHWA-NHI-113110 Tunnel Safety Inspection formal training course, covering all facets of highway tunnel inspection.
- Have completed and passed the MBTA Right-of-Way Safety training course within the past year.

3.3.3 Team Leader

The Team Leader (TL) has the fundamental responsibility of directing the day-to-day (shift-to-shift) operations of each tunnel inspection. The TL must be experienced in the performance of condition surveys for the elements that he/she is responsible for inspecting. The TL must exhibit a high degree of leadership, dependability, and the ability to follow through with assigned tasks. The TL will be required to complete assigned tasks in a timely manner, supervise other inspection team members, and report directly to the Project Manager. Minimum qualifications, dependent on discipline, are provided in Sections 3.4 through 3.6.

3.3.4 Assistant Team Leader

The Assistant Team Leader (ATL) has the fundamental responsibility of assisting the TL during the inspection and reporting by way of taking field notes, photos, and measurements and preparing report content or performing any other general task requested by the TL. Minimum qualifications, dependent on discipline, are provided in Sections 3.4 through 3.6.

3.3.5 Team Member

Team Members (TM) are any other inspection staff in addition to the TL and ATL, whose job is to provide additional inspection support, but to work under the direct supervision and guidance of a TL or ATL. Team Members are not required to have any minimum technical training or experience and therefore, they may not perform any inspection independently. They also must have completed all the required safety training.

3.3.6 General Qualifications

In addition to the above requirements, inspection teams, consisting of Team Leader(s) and Team Member(s), should have a basic understanding of how the elements they are inspecting function within a rail transit tunnel. For example, structural inspection teams should be familiar with construction methods, shapes, liner types, invert types, and all the various structural elements. Inspectors should be able to access all elements of the tunnel to the degree specified, to detect deteriorations or defects associated with the tunnel elements they are responsible for, and to accurately record and report on observed conditions.

Personnel who perform tunnel inspection work should meet the following general qualifications:

- Be proficient in the use of access equipment utilized to access the MBTA right-of-way tunnels.
- Be able to evaluate and determine specific types of equipment or testing required to adequately define and document a deficiency.
- Print legibly and be proficient in the development of sketches that are clear, concise, and understandable.
- Be proficient in reading and interpreting design drawings.
- Be proficient in the use of Microsoft Word and Excel, and have general knowledge of AutoCAD, MicroStation, or other equivalent means of developing electronic sketches/drawings.

- Be proficient in proper coding that meets the requirements of this manual and the MBTA's Asset Management goals.

3.4 Structural Element Inspection Personnel Technical Qualifications

Inspection personnel who are charged with conducting an inspection of the transit tunnel shall meet the requirements specified below.

3.4.1 Structural Team Leader

Team Leaders shall possess the following minimum requirements:

- Be a registered Professional Engineer by the time the TIN is classified as a complex tunnel by the controlling authority.
- Have a minimum of 5 years' experience in tunnel or bridge inspection.
- Have completed and passed the FHWA-NHI-130 11 0 Tunnel Safety Inspection formal training course, covering all aspects of highway tunnel inspection.
- Have completed and passed the MBTA Right-of-Way Safety training course within the past year.
- Have completed and passed a Confined Space training course, if entering any confined spaces.

3.4.2 Structural Assistant Team Leader

Assistant Team Leaders shall possess the following minimum qualifications:

- Have a minimum of 2 years' experience in tunnel or bridge inspection.
- Have a bachelor's or associate degree in civil engineering/construction.
- Have completed and passed the MBTA Right-of-Way Safety training course within the past year.
- Have completed and passed a Confined Space training course, if entering any confined spaces.

3.5 Mechanical Element Inspection Personnel Technical Qualifications

Mechanical elements are to be inspected by qualified personnel as detailed below when requested by the Authority. It is not required that mechanical inspection personnel inspect mechanical elements at the same frequency as specified for tunnel inspections in Section 4.4. Mechanical elements shall be inspected at a frequency defined by the Authority on a case-by-case basis when an in-depth examination is required for the mechanical and fire/life/safety elements described in Section 7.

3.5.1 Mechanical Team Leader

Team Leaders shall possess the following minimum requirements:

- Have 5 years of experience in rail or transit mechanical system repair, maintenance, and construction.
- Have a high school diploma or equivalent (GED) from an accredited institution.

- Have the ability to comprehend, communicate, and respond to instructions, orders, signs, notices, inquiries, etc., in English.
- Have completed and passed the MBTA Right-of-Way Safety training course within the past year.
- Have completed and passed a Confined Space training course, if entering any confined spaces.

3.5.2 Mechanical Assistant Team Leader

Assistant Team Leaders shall possess the following minimum qualifications:

- Be a qualified TFM employee (machinists, pipe fitters, plumbers) or have all qualifications required of that personnel.
- Have 2 years of experience in rail or transit mechanical system repair, maintenance, and construction.
- Have a high school diploma or equivalent (GED) from an accredited institution.
- Have the ability to comprehend, communicate, and respond to instructions, orders, signs, notices, inquiries, etc., in English.
- Have completed and passed the MBTA Right-of-Way Safety training course within the past year.
- Have completed and passed a Confined Space training course, if entering any confined spaces.

3.6 Electrical Inspection Personnel Technical Qualifications

Electrical elements are to be inspected by qualified personnel as detailed below when requested by the Authority. It is not required that electrical inspection personnel inspect electrical elements at the same frequency as specified for tunnel inspection in Section 4.4. Electrical elements shall be inspected at a frequency defined by the Authority on a case-by-case basis when an in-depth examination is required for the electrical elements described in Section 7.

3.6.1 Electrical Team Leader

Team Leaders shall possess the following minimum requirements:

- Be a Qualified Foreperson employee.
- Have 5 years of experience in rail or transit power system repair, maintenance, and construction.
- Have a high school diploma or equivalent (GED) from an accredited institution.
- Have the ability to comprehend, communicate, and respond to instructions, orders, signs, notices, inquiries, etc., in English.
- Have completed and passed the MBTA Right-of-Way Safety training course within the past year.
- Have completed and passed a Confined Space training course, if entering any confined spaces.

3.6.2 Electrical Team Member

Team Members shall possess the following minimum qualifications:

- Be a Qualified Power employee (Lineman, Wireman, Power Equipment Technician) or have all qualifications required of that personnel.
- Have 2 years of experience in rail or transit power system repair, maintenance, and construction.
- Have a high school diploma or equivalent (GED) from an accredited institution.
- Have the ability to comprehend, communicate, and respond to instructions, orders, signs, notices, inquiries, etc., in English.
- Have completed and passed the MBTA Right-of-Way Safety training course within the past year.
- Have completed and passed a Confined Space training course, if entering any confined spaces.

4.0 Inspection Procedures

4.1 Introduction

The sections below discuss the means and methods of inspection within the limits of the MBTA tunnels.

As clarified within this section OCC is the main point of contact during an inspection. Any and all deteriorations identified during the inspection that are a safety concern/critical finding to the MBTA shall be directed to OCC. Guidance on identifying these safety concerns are discussed in Section 6, but inspectors should use their engineering judgement and experience to determine safety concern. Outline below in Section 4.7 are the protocols for contact OCC concerning safety concerns/critical findings. See table 4.7.1-1 for OCC contact information.

4.2 Inspection Types

Various types of tunnel inspections are categorized in Section 4.6 of the TOMIE Manual. The categories that specifically relate to the MBTA rail transit tunnel inspections consist of Initial/Inventory, Routine, Special Member/Overhead, and Damage/Emergency (i.e., damage, impact, fire, flood, seismic, and blast events), as summarized below. The interval periods associated with each of these inspections are summarized in Table 4.4-1 herein.

4.2.1 Initial/Inventory Inspection

An initial/inventory inspection shall consist of a visual inspection of the tunnel from the track surface with the intent of making a sufficient number of observations and/or measurements, including taking representative general photographs, that would allow an inspector to identify and quantify the various elements comprising the tunnel. These elements consist of but are not limited to (see Section 7 for the full list of elements):

- Structural/Civil
- Mechanical
- Electrical
- Fire/Life Safety and Security

Initial/inventory inspections may be combined with a routine or other type(s) of inspection(s) described below which would also determine condition states for element(s) within the tunnel. In addition, information from previous inspections and plans may be used in identifying and quantifying elements but should be verified in the next subsequent inspection.

4.2.2 Routine All-Item Inspection

The routine inspection will capture the overall condition of the tunnel. This effort shall be coordinated with the MBTA to accurately report on the condition of the assets within the tunnel

limits. The routine inspection will include the inspection of all elements listed in Section 7 that apply to that tunnel segment. It is the responsibility of the inspection team to collect records from the MBTA of tests performed on elements, other MBTA element inspections, and maintenance records so that the inspection team can assess the condition of the individual elements in Section 7.

Total quantities for applicable elements listed in Section 7 shall be verified during each routine inspection. Section 7 defines the units and method by which each element's total quantities are to be calculated, along with the Section 5 report template. If an element's total quantity from the prior inspection varies more than 5% compared to the most recent total quantity calculated, then the total quantity shall be revised to match the most recent calculations. The most recent calculations shall be sent to the MBTA to be kept as a record of that element.

Mechanical, electrical, and fire life safety elements may require mechanical and/or electrical personnel to perform that inspection when the condition of the element(s) affects the serviceability of the tunnel. Different inspection techniques and documentation may be required, depending on the condition of the elements. The inspection with mechanical and electrical personnel is not limited to occurring only during the routine inspection. The frequency and occurrence of mechanical and electrical personnel inspections shall be determined on a case-by-case basis with direction from the Inspection Team Leader and the MBTA tunnel project manager.

During a routine inspection, elements not listed in Section 7 shall visually be inspected at a cursory level. Track, signal and communication, and power assets shall be inspected for any critical findings present, as detailed in Section 6. The inspection documentation for verifying there are no critical findings will include completing an asset checklist. The checklists can be found in the Section 6 attachments. The notification procedure when something critical is found is described in Section 4.12.

4.2.3 Special Member/Overhead Inspection

A special/overhead inspection would occur after the initial/inventory or routine inspection. Its purpose is to monitor specific issues that require more frequent or in-depth evaluation due to deterioration, safety, or liability.

An overhead inspection may be required between routine inspection cycles when new overhead deteriorations are found. Maintaining the safety and serviceability of the tunnel element areas that are prone to accelerated deterioration may require a more frequent inspection cycle.

A special member inspection may be required when it has been determined, during a routine or other inspection, that the condition of an element with significant defects needs to be monitored. These inspections are required to be performed on portions of elements with assigned TERM ratings of CS1 (poor) and for any portions of important elements rated CS2 (marginal). These types of inspections will continue at adjusted intervals or durations until the

deficiency has a structural review or evaluation performed and/or is repaired or replaced and the reassigned rating is determined to be CS3 (adequate) or higher.

4.2.4 Damage/Emergency Inspection

A damage/emergency inspection is typically performed as a result of an unintended/unexpected event (impact, fire, flood, seismic, or blast) that has adversely affected the integrity of at least one element of the tunnel. A damage inspection is associated with derailments or accidents that cause damage to assets within the tunnel that can create an unsafe and serviceability concern. An emergency inspection is associated with an adverse climate-related issue such as a heavy rain event creating flooding, an earthquake, or a fire. These events would warrant an emergency inspection to assess the condition of tunnel assets and serviceability. A damage/emergency tunnel inspection is initiated at the direction of the MBTA. Refer to Section 4.6 for the inspection protocols for a damage/emergency inspection. When severe damage occurs or following an emergency event, consideration should be given to closing a portion of the tunnel until a damage/emergency inspection has been completed. Structural/functional review and follow-up emergency repairs may be required. During a damage/emergency inspection if a need for immediate repair is identified, the inspection protocols for critical findings in Section 4.7 shall be followed until the asset is repaired or replaced or a corrective action plan has been agreed upon by all parties (the MBTA and the inspection team).

4.3 Pre-Planning Activities/Safety Requirements

Depending on the locations of the element to be inspected and whether such locations are within the rail track bed, the Team Leader should prepare appropriately for the inspection. Scheduling preparations should include:

- Requesting the most recent inspection report from the MBTA.
- Requesting the most recent chart, tables, etc., from previous inspection team(s).
- Reviewing existing structural plans, construction drawings, previous repairs/modifications, track charts, etc.
- Having an MBTA kickoff meeting.
- Review of MBTA Right of Way (ROW) rule book latest edition –preparing for implementation of all applicable rules and requirements.
- Sending a ROW Access Request form to the MBTA; see attachment 4.8.1 and 4.8.2.
- Coordinating as required for temporarily shutting down power, if applicable; see attachment 4.8.3.
- Coordinating the hours available for access within the tunnel and/or ancillary spaces. If hours of access are during revenue hours and a diversion is required. the appropriate forms must be completed and submitted for approval; see attachment 4.8.3.

- Obtaining the equipment needed to perform the inspection that meets MBTA requirements; see Section 4.3.4.
- Developing field forms that work in conjunction with report delivery to expedite the inspection.
- Utilizing proper and consistent labeling and locating of defects.
- Coordinating the teams and training the selected inspection staff for the work to be accomplished.

By completing the pre-inspection measures required during this phase, the length of closure periods for conducting the tunnel inspection within the track bed will be minimized. In addition, the QA measures undertaken during this period will contribute to the quality of the overall inspection.

All tunnel inspection efforts shall be coordinated with the MBTA, the owner of the tunnels and right-of-way, to ensure the safety of personnel working on and/or around the active rail transit tracks and to ensure the safe and timely movement of trains.

4.3.1 Work Access Request

No inspection personnel will be allowed on the MBTA right-of-way without an approved ROW Access Request Form. This form shall be filled out in its entirety and submitted to the MBTA Planning and Scheduling Department (planningandscheduling@mbta.com). All tunnel inspections shall be performed during nonrevenue hours (between 12:00 a.m. and 4:59 a.m.). As such, ROW Access Request Forms must be received before 10:00 a.m., 48 hours in advance of the inspection start date. Failure to comply with these stipulations will result in inspection personnel being denied access to the MBTA right-of-way. See attachment 4.8.1 and 4.8.2 for a blank ROW Access Form.

4.3.2 Work within Electrified Corridor

Any inspection of rail transit tunnels proposed to be performed by walking along the surface of the tracks in the vicinity of an electrified catenary or a third rail requires de-energizing. The requirements for de-energizing the third rail or catenary shall be coordinated with the MBTA prior to access.

The MBTA gives the option of de-energizing the third rail either on-site or remotely by the OCC. If the Team Leader elects to have the power remotely de-energized by the OCC, an MBTA Remote De-energized Approval Form needs to be submitted and approved prior to accessing the right-of-way. See attachment 4.8.4 for a Form 1 Master Schedule Track Outage.

4.3.3 Flagman Protection

Flagman protection shall be used when required by the MBTA. No inspection team shall access the MBTA property without flagman protection or written notification from the MBTA indicating that flagman protection is not required.

4.3.4 Inspection Vehicle Certification

No inspection vehicle shall be allowed on the MBTA right-of-way until such time that the vehicle has been inspected by the MBTA and passed with the issuance of a certified MBTA inspection sticker. See attachment 4.8.5 for inspection vehicle track requirements.

4.3.5 MBTA Right-of-Way Training

Prior to any inspection crew entering the MBTA right-of-way or otherwise accessing an MBTA tunnel or other structure, all individuals must have completed MBTA Right-of-Way Safety Training, and shall carry on their person an identification indicating that they follow the requirements.

Additionally, all work performed within the MBTA right-of-way or near any MBTA tunnel shall be performed in accordance with the requirements of the MBTA Right of Way (ROW) rule book latest edition.

4.3.6 Existing Manuals

Several published manuals should be used by inspectors to familiarize themselves with inspection procedures, elements, and deficiencies. Refer to Section 6.1 for a list of manuals.

4.3.7 Safety

When performing inspection within the MBTA right-of-way, all individuals shall follow the latest version of the Standard MBTA Safety Specifications, Section 0168.

4.3.8 Limits of Inspection

The limits of inspection shall encompass all elements described in detail in Section 7.5 to 7.8 within the envelop of the tunnel. All elements shall be inspected through stations with the controlling horizontal and vertical limits being that of the edge of platform to edge of platform. Except for the following specific situations:

- In the specific instance where roadway bridges "BIN(s)" intersect the tunnel; no elements that are captured in the BIN inspection are to be inspected. Refer to TIN maps in Section 2 for approximate locations of the bridges. If specific elements are not inspected as part of the BIN inspection, please consult with previous tunnel inspection report on elements to be inspected and/or the MBTA Chief Engineer.
- In specific instance where the ceiling at a station is greater than 30 feet then any elements above that vertical limit shall not be inspected. It is still the responsibility of the inspector to inspect ROW assets below this vertical limit threshold, as well as use good engineering judgement if something critical is visible beyond those limits. The critical findings protocol for handling those situations where a visible critical finding is noted beyond the vertical inspection limit, refer to Section 4.7.

4.3.9 Inspection Orientation

The o'clock direction location system shall be used while always facing in the up-station direction within the tunnel. Please refer to figure 4.3.9-1 for clarification.

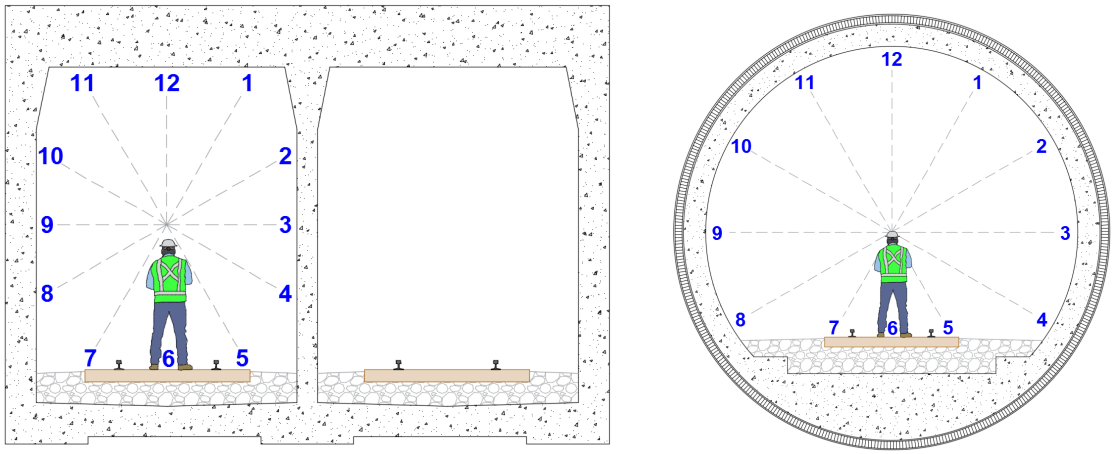

Figure 4.3.9-1 – O'clock directional marks as standing at station 10+00 while facing station 10+15.

4.3.10 Data Collection

The inspection team is responsible for collecting deterioration data for the tunnel accurately and concisely. This data must be input into the reporting charts. Refer to Appendix A for reporting charts.

4.4 Inspection Frequency

The frequency discussed below is for varying types of TIN inspections. The recommended frequency is not intended to replace current inspections, testing, or maintenance performed by the MBTA. The MBTA reserves the right to adjust the frequency of inspection for specific TIN segments, as well as for elements, given their overall condition in relation to the serviceability of the tunnel. Refer to Table 4.4-1 for details on inspection frequency.

Inspection Type	Frequency
Initial/Inventory	Prior to a routine inspection (one time only)
Routine All Item	24 months, where these inspections are staggered so that not all TINs are inspected within one calendar year
Overhead	12 months
Special Member	6 months for element areas rated CS2 3 months for element areas rated CS1
Damage/Emergency	As directed by the MBTA
Out of Service/ Abandoned Structures	Upon an inventory inspection, the subsequent structural rating shall control frequency, but the MBTA can adjust the frequency at any point from the recommended frequency: • Overall Condition Rating of a CS1: frequency to be determined based on safety and stability review • Overall Condition Rating of a CS2: 36 months • Overall Condition Rating of a CS3 to CS5: 60 months

Table 4.4-1 – Summary of Tunnel Inspections

4.5 Inspection Calibration

If multiple inspections teams are scheduled to perform an inspection within a particular TIN, it is necessary to standardize the observations and data documentation between the inspection teams. This standardization by the inspection teams is to be established at the outset of the field inspection by performing a "dry run" through a typical 100-foot section of the tunnel and will determine the team calibration. This dry run is to be an independent inspection of the tunnel section by each of the inspection teams that will actually collect the data. The inspections will then be compared for accuracy and consistency of TERM condition ratings using Section 7 of this manual. Additional instruction or training will be performed for areas of discrepancy. Additional training, if required, is to be performed on an added test section for the inspection calibration.

The MBTA may hold subsequent calibration inspections with consultants and MBTA staff. These exercises would involve a one-night inspection of elements within the tunnel. Later, the MBTA would compare the calculations, reports, field information, and other information gathered during the inspections and then provide comments to create a better baseline for rating and collecting information between inspectors.

4.6 Inspection Protocols for Damage/Emergency Inspection

If contacted by the MBTA to perform a damage or emergency inspection, follow safety protocols for access and use the Damage/Emergency Inspection Report template to provide information to the MBTA. If any critical findings are found, inspectors shall follow the protocols in Section 4.7.

4.7 Inspection Protocols for Critical Findings

A critical finding is defined as a structural or safety related deficiency that requires immediate follow-up inspection or action. A critical finding shall be considered any deterioration that directly affects or can directly affect the serviceability and safety of any individuals within the right-of-way.

During the process of identifying critical findings OCC shall be the main point of contact. Discussed within is procedure for contacting and documenting finding. See table 4.7.1-1 for OCC contact information.

It is the responsibility of the Team Leader to keep his/her PM aware of any critical findings and actions taken throughout the course of identification and the repair/repair plan.

4.7.1 Identification Protocol

Criteria for what qualifies as a critical finding vary from element to element. The Team Leader shall be responsible for confirming and reporting any critical finding(s) using the table 4.7.1-1 Critical Finding Guidance below as guidance.

The follow-up action to a critical finding is often a repair requiring immediate action. Elements rated anywhere between CS2 and CS1 are most likely to require immediate repairs, but note that not every CS2 and CS1 defect will meet the definition of a critical finding or require immediate action.

The table 4.7.1-1 below lists examples of what could qualify as a critical finding depending on the material, location, and impact on safety, but note that not all critical findings are limited to those listed in the table. In the below table, "Primary Members" are defined as members that transfer and support gravity loads. "Secondary Members" do not support gravity loads but do brace

Element (Material) / Asset (Category)	Critical Finding Examples
Steel Elements	Primary Members • Advanced deterioration/defects where the member(s) may not be capable of carrying the imposed loads • Signs of distress • Buckling • Cracking • Loss of section • Overstressed section • Loose fasteners/connections • Impact/fire damage Secondary Members • Loose or unsecured member • Lack of bracing, leading to instability of a primary member
Concrete Elements	Primary Members • Advanced deterioration/defects where the member(s) may not be capable of carrying the imposed loads. • Signs of distress • Structural cracks • Crushing • Potential spall (falling hazard) • Large or deep spalls • Significant primary reinforcing loss • Prestressing loss • Impact/fire damage Secondary Members • Loose or unsecured member • Lack of bracing, leading to instability of a primary member
Timber Elements	Primary Members • Advanced deterioration/defects where the member(s) may not be capable of carrying the imposed loads • Advanced decay • Advanced section loss • Crushing • Heavy splitting • Loose fasteners/connections • Impact/fire damage Secondary Members • Loose or unsecured member • Lack of bracing, leading to instability of a primary member
Masonry Elements	Primary Members • Advanced deterioration/defects where the member(s) may not be capable of carrying the imposed loads. • Structural or settlement cracks • Loose/displaced stones, bricks, or blocks • Significant missing stones, bricks, or blocks • Significant amount of mortar loss

System Elements	A critical finding is dependent on redundancy of systems, but when the widespread failures are noted that affect the serviceability of the tunnel, this shall be deemed a critical finding. For example: • All fans do not operate when output is requested • All emergency egress routes are inaccessible • All utility rooms are flooded, causing failure of equipment housed within • Drainage system cannot mitigate infiltration of water to the point that flooding has occurred to an unsafe point (can damage equipment or impede a train)
Signal/Communication Assets	Refer to Section 6.6.1
Power Assets	Refer to Section 6.6.2
Track Assets	Refer to Section 6.6.3

Table 4.7.1-1: Critical Finding Guidance

Additional protocols should be followed when critical findings are found, as described below:

- Mark the area or item that is considered a critical finding with high visibility marking material, e.g., bright keel, spray paint, survey tape. No marking material shall be placed such that it will be hazardous to the serviceability of trains and other equipment, e.g., no hanging survey tape within the envelope of the train, no placing of tape on or spraying of any electrical components or rail.
- For steel components, inspectors should be able to utilize additional nondestructive test(s) similar to but not limited to D-meter measurements or dye penetration tests. Please refer to the AASHTO Manual for Bridge Evaluation for other tests that might be needed.
- Take dimensional measurements that convey the size of findings in all planes, mark the location within the tunnel (i.e., stationing and element), and record the quantity prior to contacting personnel.
- In the event multiple critical findings are discovered or additional similar findings are anticipated which cannot be recorded within the same inspection shift, the initial findings should be reported, noting that additional findings are possible.
- Take photographs of the area, clearly showing the critical finding. Photos might require a scaling object to be included in the photo, e.g., wooden tape, hand, keel mark-up with dimensions noted.

[Redacted]

Table 4.7.1-2 – Key MBTA Tunnel Inspection Contacts

4.7.2 Documentation Protocol

When reporting on a critical finding found within the tunnel TINs, Form CF-1 shall be filled out and signed by the Team Leader. This form shall be distributed via email according to the protocol in Section 4.7.3.

See attachment 4.8.6 for Form CF-1.

4.7.3 Notification Protocol

When a critical finding is found, the Inspection Team Leader shall alert the OCC Supervisor. The OCC will be given a full description of the critical finding and the OCC will carry out and forward additional notifications. The Team Leader shall remain on-site until such time as a plan of corrective action can be formulated between the parties involved. This plan, at a minimum, temporarily assesses, remedies, or mitigates the finding to allow the tunnel to be safely opened to transit at the soonest possible time.

The Team Leader shall compose an email within 8 hours of the end of the shift to the leadership distribution list (see Table 4.7.1-2) that includes:

- Detailed documentation of the critical finding deficiencies
- Plan of corrective action discussed/taken
- Form CF-1

Additional participants shall be included in the email distribution according to which department owns the item with a critical finding. The MBTA shall notify the Team Leader when corrective actions have been completed.

4.8 Attachments

Attachments have not been included in this external version.

4.8.1 ..... ROW Access Form

4.8.2 ..... ROW Access Form Example

4.8.3 ..... Form 1 Master Schedule Track Outage

4.8.4 ..... Diversion Request Memorandum Example

4.8.5 ..... Clearance & Wheel Mounting Data for Track-Mounted Vehicle

4.8.6 ..... Critical Finding Form CF-1

4.8.7–4.8.9 ..... Critical Finding Supporting Field Sheets

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5.0 Inspection Report

5.1 Introduction

This section contains the MBTA policies and procedures for reporting tunnel inspection data. The section will describe how the data gathered during an inspection will be compiled in a report and what testing records are to accompany the report. As discussed in Section 4, the inspections performed for the MBTA are performed by qualified personnel as outlined in Section 3.

The Tunnel Inspection Management System (4D) includes the reports that correctly and efficiently rate the condition of a structure in electronic format. All report information must be input into this system to track and monitor the condition of the tunnels and their elements. This database is being integrated into the MBTA's overarching asset management program, "Trapeze."

5.2 Standard Reports

The standardization of the inspection reporting charts and forms is a necessary step for a uniform tunnel inspection reporting system. Standardized reporting charts and forms have been created to assist in the report preparation and review process; see Appendix A and Attachment 5.8.1. The charts and forms create uniformity from a reporting side that will assist in the accurate collection and comparison of data from inspection to inspection. These charts and forms are excel based and can be shared with inspection team upon request made to MBTA Chief Tunnel Engineer (note just pdf format of all charts and forms are provided in Appendix A).

All reports are due to the MBTA within 45 days of the end date of inspection. The MBTA is granted a 30-day review period to review the report and submit any questions, clarifications, or changes to the report. Refer to Section 5.7 on procedure for submitting reports.

The three standard inspection report formats used are:

- Routine All-Item Inspection Report: See Section 5.3 for a complete list of required documents.
- Special Member/Overhead Inspection Report: See Section 5.4 for required documents.
- Damage/Emergency Inspection Report: See Section 5.5 for required documents.

See Appendix A for Sample of Routine, Special and Damage/Emergency Inspection Report as well as example of total quantity calculation take offs.

5.3 Routine All-Item Inspection Report Content

5.3.1 QA/QC Report Checklist

The report shall include a checklist verifying that individuals responsible for the inspection and report have conducted a full quality review of the material and its accuracy prior to final

submission to the MBTA program authority. See attachment 5.8.1. This checklist shall be loosely bond to final report delivery as verification of inspection team's development of the final report.

5.3.2 Cover Page

The cover page shall clearly display the rail line, TIN, and start and end stationing. A Massachusetts Professional Engineer (PE) stamp with signature is required on the cover. Required additional information includes the date range for the inspection, the date of report submission, and who the report was prepared by and prepared for.

5.3.3 Table of contents

Table of contents for all material provided in the report.

5.3.4 NTIED

The National Tunnel Inventory and Element Data (NTIED) sheet is a tabulation of inventory items for a given TIN. This sheet includes baseline data for the tunnels to effectively monitor and manage them. The NTIED sheet is to be included in the report and shall be updated with any changes upon completion of the inspection. For instructions on how to fill in the various sheet types, see Section 7.2. Example of filled out NTIED is located with sample report in Appendix A.

5.3.5 Condition State Summary and Breakdown

This sheet summarizes each element condition state as well as structural group condition rating, mechanical group condition rating, electrical group condition rating, fire life safety and security group condition rating, and tunnel overall condition rating. See Appendix A for report condition summary sheet.

5.3.6 General Remarks

The section shall include the TIN station limits, general structure types found in the TIN, and a summary of the more important findings and elements not in a state of good repair.

5.3.7 Orientation

This report section shall include a description of where the elements are in relation and oriented to the cardinal direction and track numbers. For example, the left wall and right wall will be defined in this section to be along the west side and east side of the northbound track respectively. For locations along the liner, hands of the clock shall be used to indicate the areas of deterioration.

5.3.8 Access Notes

This section shall include how the tunnel and associated rooms/vaults are accessed, work windows, the duration of inspection, and the equipment used.

5.3.9 Critical Findings

The report shall include a list of critical findings reported to the MBTA departments, as well as the status of these findings; for example, report and repaired or report and not repaired during the duration of this inspection.

5.3.10 Inspection Findings/Results

This section is to comprise a general discussion for each element, clearly stating the findings that are detailed in other portions of the report via charts and sketches.

5.3.11 Charts

The report must include the reporting charts for each element for quantifying the deterioration with locations. See Appendix A for reporting chart templates for the elements listed in Section 7. The charts included in the report shall only display CS3, CS2, and CS1 coded defects. If an element does not have any CS3, CS2, and CS1 coded defect that element still requires a deterioration or non-deterioration write up, but no chart is required. Inspection teams are required to collect data on all CS5 to CS1 coded defects and deliver that information electronically, see Section 5.3.16 for details.

5.3.12 Sketches

Sketches will include, but not be limited to:

- Location map, displaying station limits of TIN
- Cross section(s) of tunnel
- Track charts
- Section loss drawings
- Any sketches that will help to map or provide a better understanding of the deterioration or condition of individual elements

5.3.13 Other Tunnel Asset Checklists

See Section 6 attachments for field checklists.

5.3.14 Photos

Photos will include, but not be limited to:

- Start station and end station or portal(s) of tunnel from approach
- Typical configuration of elements
- Critical findings found
- Typical deterioration of elements
- Any CS1 element deficiency; if an element has a CS1 deficiency, a minimum of one representative photo should be included

5.3.15 Element Total Quantities

Another required component is a list of elements with total quantities. Initial calculations for determining element total quantities shall be given to the MBTA for their records but are not required to be included in the inspection report.

5.3.16 Electronic Files

Inspection team upon submission of the report will deliver by electronic means the following:

- Scanned Field Notes
- Element Total Quantity Calculations
- Report Charts with all CS5, CS4, CS3, CS2, and CS1 defect condition ratings within
- Any other request information by the MBTA

5.4 Special Member/Overhead Inspection Report Content

These reports shall follow the same format as specified for Routine All-Item Inspection Reports in Section 5.3. However, the Special Member/Overhead Inspection Report shall only report on the condition of the elements that are included in that inspection. Special inspections are typically used to monitor a poor condition and are often performed at greater frequencies.

5.5 Damage/Emergency Inspection Report Content

The intent of this report is to provide details related to a specific incident that caused damage to portions of the tunnel. The damage could be due to collision, flooding, fire, earthquake, or explosion. This report shall follow the same format as specified for Routine All-Item Inspection Reports in Section 5.3. The information in this report will focus on the affected elements only.

The sections listed below shall be incorporated after the above-noted sections.

5.5.1 Element(s) with Condition Rating

The section shall specify the element(s) condition with previous and new condition state ratings displayed.

5.5.2 Damage Details

The section will detail the damage done to element(s) and will include information such as location, dimensions of damage, and how the area was damaged.

5.5.3 Corrective Action

If any corrective action was already taken, that information shall be included in this section. To be included is information on what, when, where, and why repairs were made, as well as whether the repairs are intended to be temporary or permanent in nature.

5.5.4 Photos

Photos of damage/repairs.

5.5.5 Sketches

Sketches of damage/repairs, if details provided in Section 5.5.2 do not cover the full extent of damage.

5.6 Database Entry

Database entry shall be managed through the trapeze system of the MBTA. This data entry shall be handled by the MBTA. The system is currently under construction to receive data extrapolation from the reporting charts that are required to be included in each report.

5.7 Report Submission

The inspection team Project Manager is responsible for adhering to the reporting structure and process as outlined within Section 5.

Draft reports shall be submitted electronically as a pdf file and two hard copies shall be delivered to the MBTA for review. The MBTA review period begins once the two hard copies of the reports have been delivered.

Once the MBTA review has been concluded an email shall be sent notifying the inspection team that their report with comments are available for pick up at the MBTA. It is the responsibility of the inspection team to coordinate with the MBTA personnel on receiving these comments. Once the inspection team has been notified via email that the comments are available, the inspection team has 10 days to revise and submit a final report. Any conflict with revision comments shall be sorted out within this timeframe. Additional draft submission may be required within this timeframe. If so, the MBTA shall be granted a 20-day review period after each additional draft submission.

Upon final revision and approval of the draft report, two signed copies of the final report shall be delivered to the MBTA along with an electronic pdf of the signed report and any electronic files that have changed based on comments received. Both an electronic and a hard copy of the approved report should be maintained by the Inspection Project Manager for a minimum of 6 years after the inspection is completed.

5.8 Attachments

5.8.1.....QA/QC Report Checklist

Tunnel Inspection Report Consultant QA/QC Submission Checklist

Tunnel TIN Number_____ Date: _____

Tunnel TIN Overall Condition Rating_____

NTIED

☐ All revisions marked in RED

Report

☐ Signed by PM or other qualified QA/QC Engineer (same quals as PM)

☐ Signed by Team Leader

☐ All elements completed

☐ All defects outside CS5 have corresponding defect code

☐ All defect have appropriate backup information

☐ All CS1 & CS2 defects are located and have details regard their condition

☐ All critical findings have been repaired or action plan has been developed

☐ All inspection information (quantity calculation, field sheets, etc.) has been sent to MBTA

☐ All charts, sketches, & photos properly referenced in report

☐ Printed double sided

☐ All charts, sketches & photos in color

☐ Two copies of NTIED & Report are provided

6.0 Deterioration Identification Guide

6.1 Introduction

This section provides guidance for identifying the various forms of deterioration in rail transit tunnels. This deterioration guidance is further outlined in Section 7, along with information on how it relates to the condition state rating of specific tunnel elements.

Section 6.6 is a brief overview of tunnel assets that are not listed in the Section 7 elements. These assets are also outlined in portions of Section 4, as they are only to be inspected for any critical findings that may be present.

Inspectors shall use the following sections as a deterioration identification guide for elements and assets located within the rail transit tunnels. In addition, inspectors shall be familiar with other publications addressing tunnel deterioration, some of which are listed below.

- AASHTO The Manual for Bridge Evaluation, 3rd Edition – 2018
- Specifications for the National Tunnel Inventory (SNTI) – July 2015
- Tunnel Operations, Maintenance, Inspection, and Evaluation (TOMIE) Manual – July 2015
- AREMA Bridge Inspection Handbook – Chapter 11, Tunnel Inspections
- SM.1 – MBTA Signal and Maintenance Manual 1
- SM.2 – MBTA Signal and Maintenance Manual 2

6.2 Structural/Civil Deficiencies

Inspection of Structural Elements

Routine inspection of the MBTA rail transit tunnels consists of using both visual, hands-on, and up-close inspection techniques on the elements comprising the tunnels but not limited to those elements listed in Section 7. Inspection of structural elements includes some of the following:

- Tunnel liner consisting of tunnel walls, roof slab, and invert slab
- Roof girders and stay-in-place forms
- Columns and interior walls
- Portals
- Expansion/contraction joints/gaskets
- Appurtenances such as safety niches
- Utility rooms
- Emergency egresses
- Cross passages

A determination as to the condition of the tunnel's structural elements shall be based on the categories of deficiencies described herein in conjunction with using the TERM coding tables in Section 7 of this manual.

An in-depth inspection of the tunnel liner walls and roof slab shall not be allowed to proceed until the Team Leader coordinates with the MBTA to protect communication cables within the limits of a particular inspection shift. The Team Leader shall keep track of the limits of the inspection with respect to the protected cables and shall closely coordinate with the MBTA during the inspection shift if an extension of these limits is necessary as the inspection work progresses.

6.2.1 Concrete Deficiencies

Exposed concrete surfaces should be visually scanned, paying particular attention to areas that exhibit characteristics of distress such as map cracks, pattern cracks with visible separation between adjacent surfaces, wide cracks, cracks with efflorescence, rust staining or active leakage, or existing or incipient spalls. Conditions such as these dictate that an in-depth inspection of the area is warranted.

An in-depth inspection of the tunnel's concrete elements should be performed with the use of masonry hammers by tapping around the perimeter of the distressed area to determine the overall size/extent of the distressed area, along with taking appropriate measurements of the deficiencies in the area for documentation purposes.

Typical concrete deficiencies that inspectors should be prepared to encounter and appropriately document include, but are not limited to, the following:

a) Spalls: Spalls are visually apparent along the concrete surfaces of the tunnel. Spalls are roughly circular or oval depressions caused by the separation and subsequent removal of a portion of the concrete revealing a fracture that is roughly parallel, or slightly inclined, to the surface. Often, portions of the main reinforcing steel or prestressing strands are exposed and exhibit varying degrees of corrosion and/or section loss if not epoxy coated.

   Spalls should be documented in length and width or length and height (depending on the plane on which the spall is found) with a corresponding depth and should be classified into different defect codes as discussed in Section 7. The presence and condition of exposed reinforcement should also be documented, as this can affect the condition state coding.

Figure 6.2.1-1 Concrete Deficiency: Spall with Exposed Reinforcing Steel

b) Delamination (sometimes referred to as incipient spalls): A delaminated area of concrete is one that produces a hollow sound when struck by a hammer. Delaminated areas are more difficult to detect than spalls since they are laminar to the surface of the concrete.

   Areas of delamination that are visibly apparent due to the presence of cracks (such as map or pattern cracks that may encompass the full perimeter of the area with noticeable distress, movement, or separation between adjacent surfaces) are often referred to as incipient spalls. Incipient spalls are considered critical findings if they present a safety issue and should be dealt with immediately in accordance with the provisions outlined in Section 4.7.

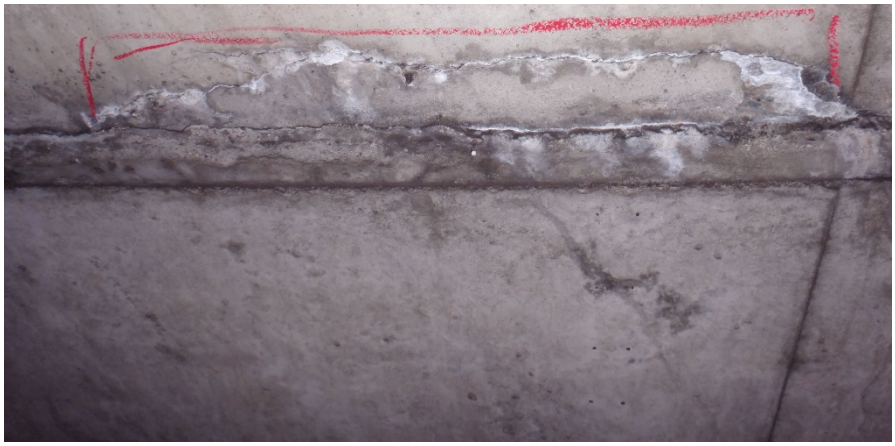


Figure 6.2.1-2 Concrete Deficiency: Delamination

c) Cracks: A structural crack is a linear fracture in the concrete caused by tensile or shear forces exceeding the strength of the concrete. Nonstructural cracks typically occur due to shrinkage during curing or from temperature changes, whereas structural cracks are a result of external service loads.

Cracks should be documented by their width, length, and spacing using the guidance developed in Section 7.5 for concrete elements.

Various types of cracks should be documented in accordance with the following classifications:

- Transverse Cracks — Cracks that are mostly straight and roughly perpendicular to the span of the member.
- Longitudinal Cracks — Cracks that are mostly straight and roughly parallel to the span of the member.
- Horizontal Cracks — Cracks that are oriented horizontally and generally occur in walls or other vertical surfaces.
- Vertical Cracks — Cracks that are oriented vertically and generally occur in walls or other vertical surfaces.
- Diagonal Cracks — Cracks that are roughly inclined at a 45-degree angle. When found along the vertical face of beams at or near a support, they signify a potentially insufficient amount or an improper placement of shear reinforcement.
- Pattern or Map Cracks — Cracks that are interconnected, vary in size, and form networks like that of spider cracking observed in dry areas. They vary in width from barely visible fine cracks to well-defined openings.

Figure 6.2.1-3 Concrete Deficiency: Map Cracks

- Random Cracks — Meandering irregular cracks on the surface of concrete. They have no form and do not logically fall into any of the classifications described above.

d) Rust Staining: Rust staining is a visibly apparent discoloration of the concrete's surface caused by dissolved materials passing through cracks and being deposited on the surface when the water emerges and evaporates. Rust staining is typically brown or red

in color and is usually an indication of corrosion of the reinforcing steel or of the steel that is embedded within the element.

It is not uncommon for rust staining to be the result of corrosion of ancillary metal items or brackets that are supported from the concrete element. This type of rust staining is not structural and is typically superficial. The inspector should clearly make a distinction between the two.

Rust staining should be documented in accordance with the classifications developed in Section 7.

Figure 6.2.1-4 Concrete Deficiency: Rust Staining

e) Efflorescence: Efflorescence, similar to rust staining, is a visibly apparent discoloration of the surface of the concrete caused by a combination of calcium carbonate leached out of the cement paste and other recrystallized carbonate and chloride compounds that form on the concrete surface.

Efflorescence should be documented in accordance with the guidance developed in Section 7 for concrete elements.

Figure 6.2.1-5 Concrete Deficiency: Efflorescence

f) Wetness: Wetness is visibly apparent and typically occurs on regions of the concrete liner (walls, roof, or invert slab) where water is visible penetrating either through existing cracks or through construction/expansion joints. The type of structure and the method of construction may greatly contribute to the likelihood of encountering wetness within a segment of tunnel.

g) Scaling: Scaling is the visibly apparent gradual and continuing loss of surface mortar and aggregate. It should be documented noting an associated length/height or height/width with corresponding depth. Various degrees of scaling are discussed in Section 7.

Figure 6.2.1-6 Concrete Deficiency: Scaling

h) Pop-Outs: Pop-outs are visibly apparent conical fragments that break out of the surface of the concrete, leaving small holes. Generally, a shattered aggregate particle will be found at the bottom of the hole, with part of the fragment still adhering to the small end of the pop-out cone.

   Pop-outs should be documented with an associated length and depth under the classifications developed in Section 7.

i) Mudballs: Mudballs are visibly apparent small holes that are left in the surface by the dissolution of clay balls or soft shale particles. Mudballs should be documented and classified in a manner similar to that used for pop-outs.

j) Honeycomb: Honeycomb represents areas of typically small voids within concrete and represents construction defects that result from insufficient vibration of concrete. When honeycomb is at the surface, it is visible as small irregular-shaped voids, often exposing aggregate or other embedded items.

Figure 6.2.1-7 Concrete Deficiency: Honeycomb

k) Concrete Deficiencies: In addition to the typical concrete deficiencies noted above, attention should be given to documenting the following:

- Differential settlement that may have occurred along expansion joints or in transition areas of the tunnel, such as at the interface between an arch section and a box section or between a tunnel section and a station.

Figure 6.2.1-8 Concrete Deficiency: Differential Settlement

- Deformation or distortion in the shape of the arch, particularly the tunnel liner above the spring line. Conditions such as these may be an indication of support settlement or changes to the soil structure above that could have a detrimental effect on the compressive behavior of the arch.
- Invert slabs in tunnels are, for the most part, hidden by the tracks and ballast. If the inspector has reason to believe that the current condition of the ballast might be an indication of possible deterioration to the invert slab below (e.g., ballast settlement, loss of ballast, seepage of water up through the ballast), the inspector should document the extent of the area in question. At the end of the inspection shift, the inspector should submit a request to the MBTA for the

removal of select areas of ballast during subsequent inspection shifts for a more in-depth inspection of the invert slab. Otherwise, the invert slab shall be documented as hidden and a statement should be added to the inspection report stating that based on the current condition of the ballast, there was no apparent reason to remove the ballast for a closer inspection of the invert slab.

- Incipient spalls at concrete-encased steel beams, particularly where longitudinal separation cracks are visually apparent along the flange of the beam or where active leaks are readily apparent.

Figure 6.2.1-9 Concrete Deficiency: Incipient Spall at Concrete Encased Steel Beam

6.2.2 Steel Deficiencies

Typical steel deficiencies that inspectors should be prepared to encounter and appropriately document include, but are not limited to, the following:

a) Corrosion: Corroded steel varies in color from dark red to dark brown. Initially, corrosion is fine grained, but as it progresses, it becomes flaky or scaly in character. Eventually, corrosion causes pitting or section loss in the member. All locations, characteristics, and extent of the corroded areas should be documented. The depth of severe pitting should be measured, and the size of any perforation caused by corrosion recorded. If section loss is present, the inspectors shall measure the actual remaining element thickness and not attempt to guess or estimate the percentage lost.

   Corrosion may be classified under the following categories:

   - Minor — A light, loose formation of corrosion that easily brushes off the surface.

Figure 6.2.2-1 Steel Deficiency: Light Corrosion

- Moderate — A looser corrosion formation with scales or flakes forming. Definite areas of corrosion are discernible.

Figure 6.2.2-2 Steel Deficiency: Moderate Corrosion

- Severe — A heavy, stratified corrosion or corrosion scale with pitting of the metal surface. This corrosion condition eventually culminates in loss of steel section and generally occurs where there is water infiltration.

Figure 6.2.2-3 Steel Deficiency: Severe Corrosion

b) Cracks: Cracks in the steel may vary from hairline thickness to a width sufficient to transmit light through the member. Any type of crack in a primary steel member is serious and should be reported at once. Look for cracks radiating from problematic details such as cuts, notches, and weldments. All cracks in the steel will be classified as severe.

c) Connection: Steel connections may consist of riveted, bolted, or welded connections. For riveted or bolted connections, individual fasteners may be missing, loose, or corroded. Welded connections should be checked for cracks.

Figure 6.2.2-4 Steel Deficiency: Connection (Light Corrosion)

d) Distortion: Distortion develops primarily because of damage arising from thermal strain, overload, or added load conditions. Erection or collision damage may also cause buckles, kinks, and cuts.

Figure 6.2.2-5 Steel Deficiency: Distortion

6.2.3 Masonry

Masonry in tunnels can consist of bricks, concrete blocks, or stones. Typical masonry defects that inspectors should be prepared to find and document include, but are not limited to, the following:

a) Efflorescence, Rust Staining: Efflorescence and rust staining are defined in Section 6.2.1 d) and e) above. The presence of either in masonry structures or facades typically manifests through cracked or defective mortar joints. The presence of rust staining would also likely indicate that the reinforcing steel behind the masonry facing is corroding.

b) Mortar Breakdown: Mortar should be checked for its soundness and bonding to the masonry units. It is important to note cracked and missing mortar, especially the depth and extent of missing mortar.

Figure 6.2.3-1 Masonry Deficiency: Mortar Breakdown and Efflorescence

c) Split/Spall: The presence of split or spalled masonry could imply overstress in that location. It is more often found in areas of high bearing stresses, like under beam ends.

d) Patched Areas: Spalled masonry is rarely patched; however, large spalls or missing masonry units are sometimes patched with concrete. Replacement of missing mortar is known as repointing and is also a form of patching.

e) Masonry Displacement: As the name implies, this defect occurs when individual masonry units have become misaligned with respect to adjacent units. This is usually due to defects in the mortar that hold the unit in place but can also be a sign of overloading. Regardless, the extent of the misalignment should be measured and monitored.

f) Settlement: Because masonry construction is rigid, signs of differential settlement would be cracks that propagate the full height or width of a masonry liner, wall, or partition. Cracks exhibiting surface displacement or variable width are signs of differential lateral shifting or tilting settlement.

6.2.4 Timber

Timber elements within the tunnels can consist of timber ties, manufactured lumber, and timber beams. Typical timber defects that inspectors should be prepared to find and document include, but are not limited to, the following:

a) Decay or Rot: Decay is the primary cause of timber deterioration. It is produced by living fungi that feed on the cell walls of timber members. Decay occurs in areas where moisture is present and causes a black, brown, or white discoloration on the surface. This leads to soft wood and section loss, which should be investigated and documented.

Figure 6.2.4-1 Timber Deficiency: Decay or Rot

b) Voids: Voids in this context refer to the presence of voids in the earth material behind lagging and not voids within the timber itself. These can sometimes be seen between the planks or detected by probing with a wire.

c) Cracks, Splits, Checks: Cracks in timber members are classified as checks, which penetrate to a partial depth, and splits, which penetrate completely through the member.

The extent and location of both should be identified, with special emphasis on splits within timber beams.

Figure 6.2.4-2 Timber Deficiency: Cracks and Splits

d) Timber Distortion: The misalignment or offset between adjacent or connected timber members is termed distortion for assessment purposes. The magnitude of the offsets or misalignment should be measured where noticeable.

6.2.5 Wetness/Leak Guidance

Typical wetness/leak deficiencies that inspectors should be prepared to encounter and appropriately document include, but are not limited to, the following:

a) Saturated Surface: A saturated surface is created when water has seeped through the element. The saturated surface will show a discoloration of the existing element color. The surface will sometimes glisten in the beam of a flashlight. A saturated surface can cause concrete elements to spall, honeycomb, scale, and/or exhibit efflorescence when the water in the saturated area evaporates. Saturated steel elements will begin to lose their protective coating over time and then develop rust and section loss. When finding an area of saturation, inspectors should note the location and quantity of the saturated surface.

b) Leakage: Leakage occurs when water is dripping at some rate from the element. The severity of the leak can be determined by measuring the number of drips per minute. Leaks usually occur along open joints or around pipe/utility penetrations. Leaks can affect multiple elements, depending on the amount of water flowing. Leakage will accelerate the concrete and steel deficiencies on a saturated surface. An additional danger of leaks that do not get arrested is freeze/thaw, which can cause separation in elements. These separations will increase over time with frequent freeze/thaw cycles. Inspectors should note the drips per minute. If the leakage is greater than 100 drips per minute, it should be considered as flowing.

c) Pooling Water: Pooling of water will happen when drainage systems fail, a leak with significant flow is not arrested, or grading has created a low point away from the existing drainage system. Pooling water typically will occur along low points in the tunnel but has also been known to occur along the top of the bottom flanges of beams, the tops of beam shelves, and other horizontal surfaces. Pooling water can cause significant accelerated deterioration to surrounding elements. Pooling water when frozen can cause a safety hazard due to a slippery surface, can create heaving of ballast which may create geometry concerns with rail, can freeze/restrict bearing movement, and can introduce undesigned forces to elements. When inspectors encounter pooling water, they should document the location to which the water extends and its quantity, as well as the maximum water depth. Waders and a wooden ruler might be required in some cases to determine the maximum depth of pooling water. Inspectors should always use caution and good safety judgment when entering a pool of water, as there can be electrification hazards if a cable is below the surface of the water. If an inspector cannot confirm that the water does not border an electrification hazard, the inspector should notify MBTA personnel of the concern and not enter the pooled water until receiving confirmation that no electrical hazards are present.

6.3 Mechanical Deficiencies

6.3.1 Drain System Deficiencies

Typical drain deficiencies that inspectors should be prepared to encounter and appropriately document include, but are not limited to, the following:

- Clogs
- Cracked pipes (see photo below for an example of deterioration)

Figure 6.3.1-1 Drain System Deficiency: Cracked Pipe

- Misaligned fittings that could cause leaks or leaks when water runs through them
- Pump failure

6.3.2 Pump Deficiencies

Typical pump deficiencies that inspectors should be prepared to encounter and appropriately document include, but are not limited to, the following:

- Lack of power
- Leaking gasket or bad seals
- Worn impeller or wear plate
- Bearing issues
- Damaged motor
- Pump failure

6.3.3 Flood Gate Deficiencies

Typical flood gate deficiencies that inspectors should be prepared to encounter and appropriately document include, but are not limited to, the following:

- Damaged hinges
- Damaged seals or gaskets
- Lack of power
- Damaged motor

6.3.4 Utility Room Deficiencies

Typical utility room deficiencies that inspectors should be prepared to encounter and appropriately document include, but are not limited to, the following:

- No access (i.e., door won't open and/or key to access room cannot be found)
- Restricted access (i.e., door will open partially but the inspector can still get in). This deficiency is still of concern when equipment or personnel need to enter the room and restricted access prevents the team from making the immediately needed repair.
- Structural integrity: Refer to concrete deficiencies in Section 6.2.1 or to steel deficiencies in Section 6.2.2, depending on the utility room's construction. Concerns with structural deterioration to the utility room include the potential for debris to fall on equipment.
- Water: Refer to Section 6.2.5. Additional concerns when water is present in a utility room are short-circuiting or damaging of equipment, rusting of conduits along the floor, and slipping hazards.

6.4 Electrical Deficiencies

6.4.1 Lighting and Emergency Lighting Deficiencies

Typical lighting and emergency lighting deficiencies that inspectors should be prepared to encounter and appropriately document include, but are not limited to, the following:

- Frayed conductors
- Broken conductors
- Broken or dirty fixtures
- Damaged generator
- Cracked lenses
- Poor illumination
- Not operating
- Overheating
- Damage to supports

6.4.2 Catenary Support System Deficiencies

Typical support deficiencies that inspectors should be prepared to encounter and appropriately document include, but are not limited to, the following

a) Registration Arm Failure: Arm will begin to flex under distress and eventually become unstable.

b) Registration Connection Failure – Flexing and Failure of Rods: The rods that support the catenary system can flex or break because of an object strike or fatigue, or from frequent arcing. A picture of a registration arm can be seen below.

c) Support Anchor Failure: A support anchor deficiency can range from loose to failed, which will create an unstable situation.

d) Broken or Dirty Insulators: Dirt will begin to collect and create arching situations. These arching situations can crack/break insulators.

6.5 Fire Life Safety Security Deficiencies

6.5.1 Fire Detection Deficiencies

Typical fire detection deficiencies that inspectors should be prepared to encounter and appropriately document include, but are not limited to, the following:

a) Faulty sensors or controls

b) Defective pull stations

c) Defective notification appliances (strobes, horns, etc.)

d) Loss of power

6.5.2 Standpipe Deficiencies

Typical fire suppression deficiencies that inspectors should be prepared to encounter and appropriately document include, but are not limited to, the following:

a) Misalignment of pipe fittings
b) Corroded pipes
c) Defects to main fire pump or jockey pump
d) Defects on valves (pressure relief and air release)

6.5.3 Emergency Communication Deficiencies

Typical emergency communication deficiencies that inspectors should be prepared to encounter and appropriately document include, but are not limited to, the following:

a) Damaged devices
b) Bad cable connection
c) Missing, incorrect, or outdated signage

6.5.4 Tunnel Operations and Security System Deficiencies

Typical security system deficiencies that inspectors should be prepared to encounter and appropriately document include, but are not limited to, the following:

a) Lack of power supply
b) Bad cable connection
c) Damaged devices
d) Inoperable cameras
e) Nonfunctioning portal alert system

6.5.5 Ventilation System and Fan Deficiencies

Typical ventilation system deficiencies that inspectors should be prepared to encounter and appropriately document include, but are not limited to, the following:

a) Damaged fan motors
b) Lack of power supply
c) Clogged vents
d) Loose fan belt
e) Typical structural and concrete deficiencies to components
f) Excessive noise
g) Excessive vibration
h) Overheating
i) Damper controls do not function, damper frozen shut or open

6.6 Other Element Deficiencies

This section lists other asset deficiencies inspectors might encounter during their inspection. These assets are currently inspected and tested more frequently by others to maintain service. During inspection of these elements, inspectors are required to visually review the following assets for any critical deficiencies. Critical deficiencies to look for during this inspection are described below. Any critical deficiencies that affect the immediate serviceability of the tunnel shall be reported to the MBTA according to Section 4.7.

For routine and initial inspections of the TINs, inspectors are to only perform a visual cursory inspection of these assets and complete the appropriate field checklist sheet; refer to attachment 6.7.1.

For determining significant defects of asset components inspectors are recommended to review the SM1, SM2, and the E&M Manual.

6.6.1 Signal/Communication Asset Deficiencies

All signal/communication assets are required to be inspected and tested by others according to SM1 and SM2.

Typical signal/communication critical findings that inspectors should be prepared to encounter and appropriately document include, but are not limited to, the following:

- Cables/Fiber Optics
  - Deterioration, nicks, cuts, and rodent attacks that expose the conductors within the cable
  - Loose cable run supports on the tunnel wall that will cause the cable to "droop" into the train path or walkway
  - Loose connections to avoid "open connections"
  - Exposed splicing connections or anywhere a cable is connected
- Switch Machines
  - Cracked, broken switch rods
  - Debris in switch points
  - Evidence of water infiltration such as ponding
  - Unevenness or not level, which can cause malfunction of the switch machine operation
  - Unusual noise or vibration
  - Missing locks for housings and hand throw lever, where applicable
  - Switch points open
  - Loose hardware on switch rods
  - Missing locks for housing compartments
- Signals
  - Cracked or broken lenses
  - Light out
  - Broken or bent hoods that affect proper visual sighting

        - Evidence of water infiltration such as ponding
        - Loose hardware
        - Unevenness or not level, which can cause improper visual sighting
        - Unusual noise or vibration
        - Missing locks
    - Train Stops
        - Cracked or broken rocker shaft arm, trip arm, and hold down lock
        - Debris that can cause trip arm proper movement
        - Evidence of water infiltration such as ponding
        - Unevenness or not level, which can cause malfunction of the train stop operation
        - Unusual noise or vibration
        - Missing locks for main housing compartment
    - Bungalows, Cases, and Relay Rooms
        - Cracks in walls of bungalows and cases
        - Missing or broken door handles
        - Excessive rust
        - Evidence of water infiltration such as ponding
        - Unusual vibration or noise
        - Noticeable alarms
        - Missing locks for bungalows, cases, or relay rooms
    - Antennas
        - Cracked or broken antenna that can cause improper operation
        - Missing antennas that can cause improper operation
        - Loose antenna supports that can cause improper operation
        - Loose antenna connections that can cause improper operation

6.6.2 Power Asset Deficiencies

Typical power asset deficiencies that inspectors should be prepared to encounter and appropriately document include, but are not limited to, the following:

a) Power/Cable Conductor
    - Broken cables/conductors — Cables and conductors can break apart during extreme changes in temperature and from fatigue, progressive burning, and improper application.

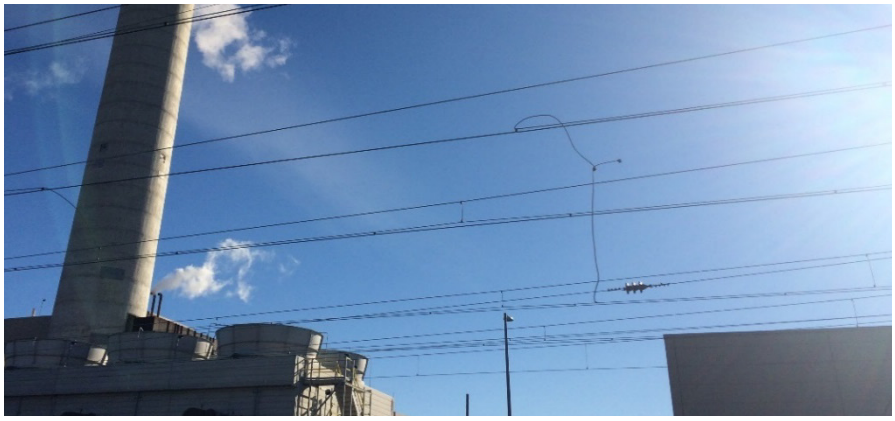


Figure 6.6.2-1 Power Asset Deficiency: Fatigue Break of a Conductor

- Signs of arcing — The protective cover or sheath can be damaged from the outside in by arcing. This type of damage can appear as burn marks on the cable's sheath or the sheath being completely melted through, as seen in the photo below.

Figure 6.6.2-2 Power Asset Deficiency: Signs of Arcing on Cable

- Corrosion — Corrosion can occur at the end of power cables on the taps. Corrosion can be caused by stray current, improper tightening, exposure to salt water, etc. The following photograph illustrates an example of a corroded tap.

Figure 6.6.2-3 Power Asset Deficiency: Corrosion

- Frayed conductors — Stranded conductors can come apart.

Figure 6.6.2-4 Power Asset Deficiency: Frayed Conductor

- Broken hangers — The rods on hangers between the messenger and trolley wires in the catenary system can crack or break.

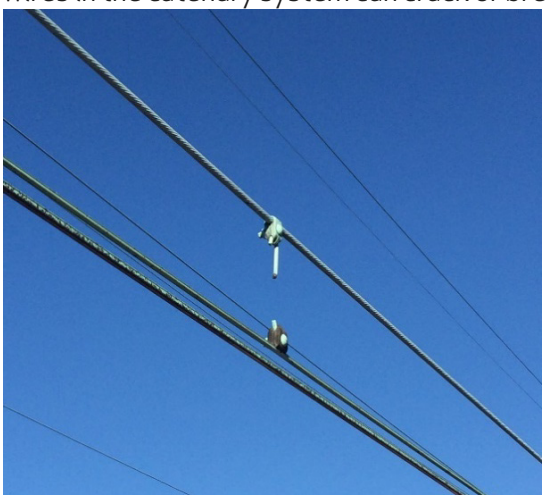


Figure 6.6.2-5 Power Asset Deficiency: Broken Hanger

b) Substation Deficiencies
   - Damage to enclosure — Take notice of any abnormal conditions on the transformer enclosure. Damage could be in the form of vandalism, broken hinges or latches, burn marks, etc.

Figure 6.6.2-6 Typical Electrical Room

6.6.3 Track Asset Deficiencies

Typical signal deficiencies that inspectors should be prepared to encounter and appropriately document include, but are not limited to, the deficiencies described below.

a) Broken Rail: A rail can be cracked through with a transverse fracture that goes from the top to the bottom of the rail. Such cracks will affect the signal system and power return. Emergency clamps can be used to allow trains to pass until the broken rail section can be replaced with a new rail or joint. Other external cracks such as fissures and fractures are visible to the eye. Internal failures include splits, piping, fissures, cracks, or separations inside the rail and can only be found using tests such as ultrasounds or x-rays. Hence, the visual inspection can only pick up defects visible on the outside of the rail, not internal defects.

Figure 6.6.3-1 Track Asset Deficiency: Broken Rail

b) Weld Failures: Weld failures are separations at the weld, be it a shop weld or a field weld. Field weld failures are usually identified using x-ray or ultrasound testing and may not be visible on the outside of the rail until failure of the rail has occurred. See the photograph below for a visual aid to determining deterioration.

Figure 6.6.3-2 Track Asset Deficiency: Weld Failure

c) Rail Head Wear: Worn rail can be measured with a hand gauge. A common rail wear is vertical head wear and horizontal side wear from the gauge side of the rail. Side wear can create a shelf formed by the wheel flange that migrates inward toward the center of the rail. Track standards dictate the amount of allowable wear, after which the rail must be replaced. Head wear is common on curves, on both inside and outside rails of curves, and even on tangent track in station transit areas where braking and wheel slippage cause excessive rail wear. Gauge deviation can also create wheel hunting that generates side wear on tangents.

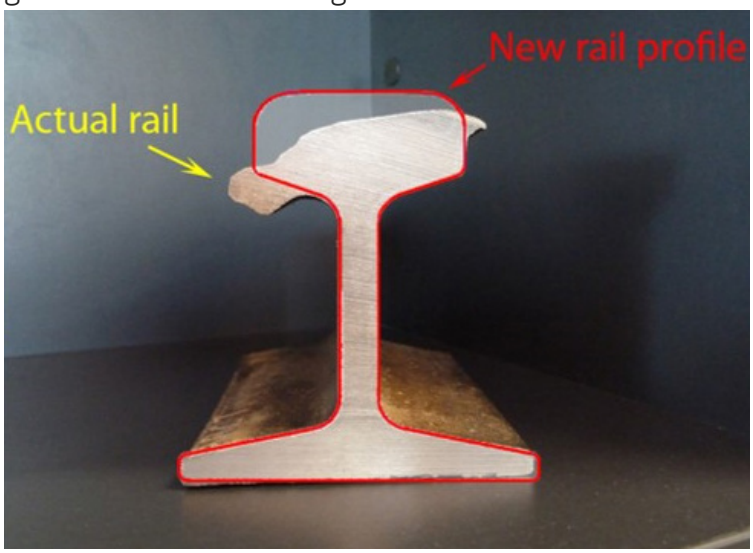


Figure 6.6.3-3 Track Asset Deficiency: Rail Head Wear

d) Restraining Rail Wear: The restraining rail is sacrificial and is expected to wear as a result of the back of the wheel scraping against the face of the restraining rail normally placed on the inside rail of a curve, but sometimes against the outside rail, depending on the degree of curvature.

The restraining rail wear can be quantified by measuring the throat-way distance, or the space between the running rail and the restraining rail. This distance can be tightened or loosened by adjusting bolts, inserting or removing shims, and making other adjustments, depending on the type of fastener used.

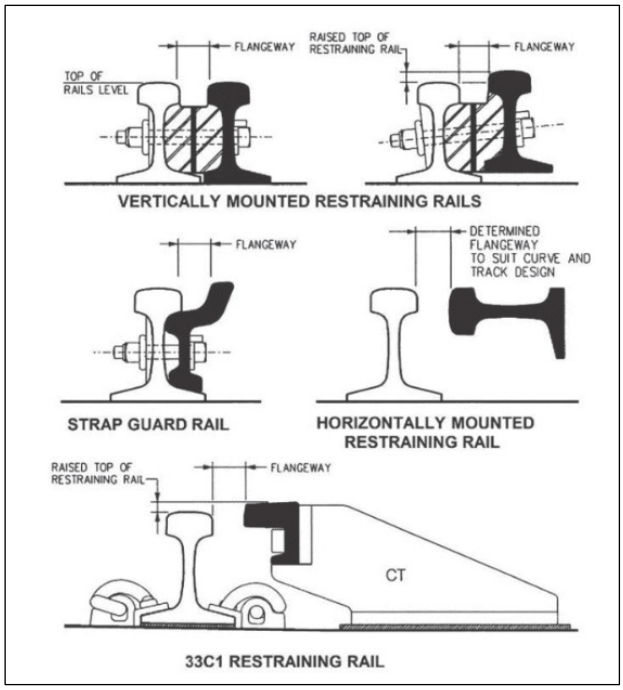


Figure 6.6.3-4 Types of Restraining Rails

e) Corrugation: Corrugation, or "washboarding," occurs on the rail head due to factors that include wheel slippage. It creates a wave pattern on the rail head that can generate noise and vibration. It is observed through visual inspection. Corrugation can be ground away with a rail grinder, or the rail can be replaced.

Figure 6.6.3-5 Track Asset Deficiency: Corrugation

f) Joint Defect: Joint bar hole cracks can only be seen if the bars are removed or if the crack permeates beyond the joint bar. Where rail is welded, there will not be that many joint bars except in turnouts or in power or signal block areas where insulated joint may be involved. Joint bar inspection must include the bolts themselves to determine whether they have cracked and fallen off. Torqueing bolts too tight may overstrain the bolts, leading to crack failures. Loose joint bars can be easily detected through visual inspection and by tapping with a hammer.

Figure 6.6.3-6 Track Asset Deficiency: Joint Defect

g) Rail Fasteners and Tie Plates: Rail fasteners include plates, spikes, Pandrol spring clips, and other systems for fastening or anchoring the rail to the ties. These include direct fixation resilient fasteners, concrete embedded shoulders in concrete ties with spring clips, and special resilient fasteners on timber ties or in concrete. Traditional cut spikes provide lateral support but little vertical support. Train movements can loosen the spikes. Spring fasteners, screw spikes, and other fasteners are designed for both lateral and vertical holding strength. In addition, spring clips provide longitudinal resistance against longitudinal thermal forces in the rail. Deficiencies normally include loosening of the components and missing and broken parts. Loose spikes, loose screw spike, clips out of position, loose bolts and washers, deteriorated resilient material, excessive rust, out of position rail anchors, and missing or misaligned insulators are examples of components that should be inspected.

h) Timber Ties: Deficiencies include timber splits, spike worn doles, insect infestation, water damage, excessive warping, misalignment, timber decay, fire damage, dragging equipment damage, and other surface defects. Ties may be in worse shape internally than they appear on the surface. Timber ties may appear sound on the surface but could be hollow just beneath the surface. Penetration with a sharp metal probe, or hammer testing, may reveal subsurface voids in the timber tie.

i) Direct Fixation (DF) Concrete: DF concrete slab/tie deficiencies can be identified visually or with a hammer. Those deficiencies can include, but are not limited to, surface cracks, spalling, and/or hollow areas. Typically, deficiencies will begin to develop around the fastener areas and include excessive fastener rust, exposure of reinforcing bars, damage from equipment dragging, and visible chemical reactions between the aggregate and the cement. Spring clips "welded" to the fastener with rust can be detected visually and with hammer tapping. Ties of any type that appear skewed indicate track shifting likely caused by rail expansion and contraction where anchoring devices have failed.

j) Ballast: Ballast deficiency includes fouling of the ballast with brake dust and general dust and fine particles, oil, or mud that fills the voids and reduces the ballast's effectiveness in providing intended drainage. Badly fouled ballast may cause electrical leakage, affecting signal circuits and electrolysis. Ballast deficiency is likely to occur slowly over many years, so its condition can be monitored over time before taking corrective action. A sudden change to ballast can occur when pooling water within the ballast frost heaves, which can create geometry issue with the track. Shifting track can be observed by noticing the color of the ballast at the edge of a series of ties. If the ballast appears cleaner along the edge of the ties than in the rest of the ballast, the track structure may have shifted, disturbing the ballast by exposing previously hidden clean ballast particle surfaces. This can be common on curves, which expand outward or inward, depending on the temperature swing. Also, a poorly distributed ballast condition exists when ballast is piled too high over the tops of ties or too low below

the top of ties, creating hollow tie cribs. The ballast outside the shoulder needs to be uniform, especially on curves, to resist lateral forces. Ballast should be neatly regulated throughout the track structure for best performance.

k) Turnouts: Turnouts have similar deficiencies as existing track with the addition of switches and other working mechanics. For a list of the mechanical deteriorations that could be encountered, please refer to Section 6.3.

l) Third Rail: Third rail deficiencies include loose joint bolt and nut connections, third rail anchor loosening or detachment, broken insulators, disconnected cables from third rail tabs, detached or loose heater rods, risers or runoffs pointing too high or low, cracked rail, and excessive pitting and gauge with running rail. It is also important to observe whether any foreign objects lying in the right-of-way appear too close to the third rail such that they could cause a ground short if contact with the third rail is made.

m) Cable: Typical cable deficiencies that inspectors should be prepared to encounter and appropriately document include, but are not limited to, the following

- Loose joint bolt and nut connections
- Loose or detached third rail anchor
- Dirty or broken insulators

Figure 6.6.3-7 Track Asset Deficiency: Cable

- Disconnected cables from third rail tabs

Figure 6.6.3-8 Track Asset Deficiency: Cable

- Detached or loose heater rods

Figure 6.6.3-9 Track Asset Deficiency: Cable

- Risers or run-offs pointing too high or low

Figure 6.6.3-10 Track Asset Deficiency: Cable

- Cracked rail, excessive pitting, and gauge with running rail; see the photo below of a typical running rail

Figure 6.6.3-11 Track Asset Deficiency: Cable

- Foreign objects. It is important to observe whether any foreign objects lying in the right-of-way appear too close to the third rail such that they could cause a ground short if contact with the third rail is made.

n) Track Geometry and General Track Condition: Track geometry deficiencies include incorrect gauge, kinks, surface sags or sumps, angle point at joints, deviating tangent alignment, incorrect restraining rail gauge, foreign objects on tracks, excessive grease or oil on rails, trash on tracks, sand deposits, clogged flangeways, and flooding and ice buildup in tunnels.

6.7 Attachments

6.7.1.....Asset Checklist

Asset Checklist

TIN _____ Date: _____

Inspection TL _____ Inspection ATL _____

Notes:

Please refer to MBTA Tranist Tunnel Manual for specifics on how to identify critical deteriorations, complete asset deficiency checklist, and handling critical findings

TRACK	No Critical Findings Found	Critical Finding Found	Fixed
Rail			
Welds			
Head wear			
Restraining rail			
Corrugation			
Joint			
Rail Fasteners and Tie Plates			
Timber Ties			
Direct Fixation			
Ballast			
Turnouts			
Third Rail			
Third Rail Cable			
Track Geometry and General Track Condition			
Power	**No Critical Findings Found**	**Critical Finding Found**	**Fixed**
Power Cable			
Substations			
Caternary			
Signals/Communications	**No Critical Findings Found**	**Critical Finding Found**	**Fixed**
Cables/Fiber Optics			
Switch Machines			
Signals			
Train Stops			
Bungalows, Cases, and Relay Rooms			
Antennas			

* if component(s) are in need of immediate repair than critical finding protocol shall be followed as detailed in the MBTA Transit Tunnel Manual

7.0 Elements (TERM Coding Guide)

7.1 Introduction

The purpose of this section is to identify and provide condition state coding guidance for all tunnel inventory items and physical elements that are covered by this manual. The inventory items are identified by category, with coding guidance tables in Section 7.2. These items are always coded as part of an initial inspection, but seldom change afterward. This section also describes the formulas used to determine a weighted average State of Good Repair (SGR) rating number for an element, element system and for an entire tunnel. The FTA TERM scale condition rating model allows for determination of the State of Good Repair (SGR) rating for individual elements, systems, and entire tunnels based on a roll-up weighting system applied by the MBTA asset management group, refer to Table 7.1-1 for the general TERM rating scale and descriptions (please refer to Section 7.3 for a more detailed and focused description of condition rating criteria for elements within the tunnel).

Rating	Condition	Description
5	Excellent	No visible defects, new or near new condition, and may still be under warranty if applicable.
4	Good	Good condition, but no longer new; may have some slightly defective or deteriorated component(s), but is overall functional.
3	Adequate	Moderately deteriorated or defective components but has not exceeded its useful life.
2	Marginal	Defective or deteriorated component(s) in need of replacement; has exceeded useful life.
1	Poor	Critically damaged component(s) or in need of immediate repair; well past useful life.

Table 7.1-1 FTA TERM Condition Assessment Scale

Section 7.3 identifies the unit of measure and how to quantify for each physical element, as every element will have a unit of measure, either Each (EA), Length (LF), or Area (SF). The physical elements are listed and grouped by discipline in Section 7.4. Sections 7.5 through 7.8 include FTA TERM scale 1–5 coding tables to provide guidance on how to condition rate each element.

7.2 Tunnel Inventory Item Coding

7.2.1 Introduction

This section comprises tunnel inventory items arranged by category, so that every unique tunnel will have identifying and classifying information associated with it. The coding tables in this section provide guidance on the proper way to assign and code these attributes for each tunnel.

Below is an inventory item template legend to illustrate the meaning and format for coding information for each field. Each inventory item table will have six fields as illustrated and described below.

Item ID Inventory Item Name	
Format Example Coding	Item ID Example ID
Specification	**Commentary**
Detailed description of requirements for each inventory item.	A series of explanations for each inventory item.
Example(s)	
Example Description: Example Coding	

Table 7.2-1 Item ID Inventory Item Name

Inventory Item Template

The format of an item is broken into six parts: (1) Inventory Item Name, (2) Format, (3) Item ID, (4) Specification, (5) Commentary, and (6) Examples.

The Inventory Item Name is the name used to describe that particular item.

The Format details how the item should be coded by using one of the following four descriptions and lengths:

XXA-YY-ZZ-NNN (alphanumeric - where XXA, YY, and ZZ are letters and NNN are numbers)

AN# (alphanumeric - where # is the length of the field)

AN2 is an example of an alphanumeric code with a limit of 2 characters, such as BL

N (X,Y) (numeric - where X is the length of the field and Y is the number of decimal places)

N (3,1) is an example of a numerical code such as 14.2

N (5,2) is an example of a numerical code such as 234.19

D (date recorded as MMDDYYYY)

06152019 is an example of a date (D), for June 15, 2019

Leading zeros are required for date formats

The Item ID is a unique indicator assigned to each tunnel item; it is a letter followed by a number. Inventory items are identified by a letter based on the section and a number based on the order of appearance in that section. Identification items are identified with an "I", Age and Service

items are identified with an "A", Classification items with a "C", Geometric Data items with a "G", Inspection items with a "D", Load Rating and Posting items with an "L", Navigation items with an "N", and Structure Type & Material items with an "S".

The Specification and Commentary portions in Sections 7.5 through 7.8 provide a detailed description of each inventory item and some explanation or additional clarification to consider for coding each item. The Specification portion is the required information to be recorded and shall be followed. If there is ambiguity in applying the Specification, the MBTA should be consulted for clarification and/or additional guidance. The Commentary portion is intended to provide clarifying information and general guidance for recommended methods to meet the Specification.

The Examples portion provides examples of how to code the item in certain situations.

7.2.2 Identification Items

This section provides coding guidance on all items that identify and locate a tunnel.

Item ID

I.1 Tunnel Identification Number (TIN)

I.2 Line Code

I.3 Branch Code

I.4 Stationing Direction

I.5 Transit Station – Start

I.6 Transit Station – End

I.7 Stationing – Start

I.8 Stationing – End

I.9 Latitude

I.10 Longitude

I.11 Portal to Portal Name

I.1 Tunnel Identification Number (TIN)

Format	Item ID
XXA-YY-ZZ-NNN	I.1

Specification	Commentary
The tunnel identification number is typically referred to as the TIN. Record a unique TIN based on the following legend: XX - Abbreviated color line BL = Blue Line GL = Green Line OL = Orange Line RL = Red Line AB = Abandoned A - Primary direction of train traffic N = Northbound S = Southbound E = Eastbound W = Westbound M = Multiple YY - Abbreviated portal-to-portal designated tunnel name. ZZ - Abbreviated first initial of each transit station that the tunnel is located between, beginning with the lower numbered station along the line. NNN - Represents a particular tunnel within the section identified above, but separated by power block, transit stations, construction type, and/or shape. They should be numbered consecutively 101, 102, 103... working from the lowest stationing toward the highest stationing.	Since it was decided that power blocks would be used to separate one TIN from another (because of the need to shut them down for safe access for many inspection activities), the NNN numbering system is used to accomplish this. In general, each power block provides power for a specific length for one direction of traffic. Therefore, each cross section typically has two different TINs in it. Consult the MBTA for questions concerning assigning tunnel numbers to unique or complex tunnels or for ambiguous situations. Abandoned sections of tunnels may or may not have platforms. If not, code for the nearest pedestrian stations to the location of abandoned tunnel. Note that ZZ is coded based on the direction of stationing, not the primary direction of the traffic in that tunnel. NNN will be in 100-increment series, starting with 100 at the beginning of the first portal-to-portal tunnel, then 200 at the start of the second portal-to-portal tunnel, and progressing likewise to the end of that line.

Examples

Blue Line Westbound - East Boston Tunnel - Aquarium to Maverick - 2nd westbound section: BLW-EB-AM-102

Orange Line Multiple - Forest Hills Tunnel - Portal to Forest Hills -1st tunnel: OLM-FH-PF-100

Table 7.2.2-1 Tunnel Identification Number (TIN)

I.2 Line Code	
Format AN9	Item ID I.2

Specification	Commentary
Record the name of the Color of the Line choosing from the below options: BLUE GREEN ORANGE RED ABANDONED	—

Examples	
Green Line	Code: GREEN
Abandoned	Code: ABANDONED

Table 7.2.2-2 Line Code

I.3 Branch Code	
Format AN30	Item ID I.3

Specification	Commentary
Record the name of the Branch for the Line that the tunnel is located on based on the name of the last station on the branch. If it is on the main line then code "MAIN".	For the Blue and Orange Line tunnels code MAIN, since there are no branch lines. Include spaces in multi-word branch names.

Examples	
Riverside Branch of the Green Line	Code: RIVERSIDE
Cleveland Circle Branch of the Green Line	Code: CLEVELAND CIRCLE

Table 7.2.2-3 Branch Code

I.4 Stationing Direction	
Format AN2	Item ID I.4

Specification	Commentary
Record the primary direction of the stationing within the tunnel. South to North = SN North to South = NS West to East = WE East to West = EW	—

Example	
Stationing increases from West to East	Code: WE

Table 7.2.2-4 Stationing Direction

I.5 Transit Station - Start	
Format AN32	Item ID I.5

Specification	Commentary
Record the full name of the transit station that is nearest to the end of the tunnel (the lower stationing end). It should be the same as the name that is represented by the 7th alphanumeric letter in the TIN number (e.g., RLN-CA- AD-102 = Alewife).	Note that the transit station could be within or outside of the TIN limits but is the one that represents the closest to the end of that TIN.

Examples
Alewife Maverick Portal

Table 7.2.2-5 Transit Station - Start

I.6 Transit Station - End	
Format AN32	Item ID I.6

Specification	Commentary
Record the full name of the transit station that is nearest to the end of the tunnel (the higher stationing end). It should be the same as the name that is represented by the 7th alphanumeric letter in the TIN number (e.g., RLN-CA- AD-102 = Davis).	Note that the transit station could be within or outside of the TIN limits, but is the one that represents the closest to the end of that TIN.

Examples
Alewife Maverick Portal

Table 7.2.2-6 Transit Station – End

I.7 Stationing - Start	
Format N (5,0)	Item ID I.7

Specification	Commentary
Record the stationing point to the nearest foot for the location of the beginning of the tunnel. The stationing should be consistent with existing track chart stationing and be the lower station of the two stations that mark the beginning and end of the TIN. Include leading zeros for all stationing as needed.	—

Examples	
Station 81+45 of the Blue Line	Code: 08145
Station 149+55 of the Green Line	Code: 14955

Table 7.2.2-7 Stationing - Start

I.8 Stationing - End	
Format N (5,0)	Item ID I.8
Specification	**Commentary**
Record the stationing point to the nearest foot for the location of the end of the tunnel. The stationing should be consistent with the existing track chart stationing and be the lower station of the two stations that mark the beginning and end of the TIN. Include leading zeros for all stationing as needed.	–
Examples	
Station 81+45 of the Blue Line	Code: 08145
Station 149+55 of the Green Line	Code: 14955

Table 7.2.2-8 Stationing – End

I.9 Latitude	
Format N (7,5)	Item ID I.9

Specification	Commentary
For the stationing location identified in Item 1.7, record the latitude of the tunnel portal in decimal degrees. Record the latitude at the tunnel start along the centerline of existing track(s).	Values recorded are assumed to be for the Northern Hemisphere and are to be consistent with data that uses the North American Datum 1983.

Example	
42° 25' 38"	Code: 42.42722

Table 7.2.2-9 Latitude

I.10 Longitude	
Format N (7,5)	Item ID I.10

Specification	Commentary
For the stationing location identified in Item 1.7, record the longitude of the tunnel portal in decimal degrees. Record the longitude at the tunnel start along the centerline of existing track(s).	Values recorded are assumed to be for the Northern Hemisphere and are to be consistent with data that uses the North American Datum 1983.

Example	
71° 3' 25"	Code: 71.05694

Table 7.2.2-10 Longitude

I.11 Portal-to-Portal Name	
Format AN32	Item ID I.11
Specification	**Commentary**
Record the commonly used full name that describes the underground "portal-to-portal" portion of the line within which the TIN is located. Using the Red Line as an example, the options for the portal-to-portal names would be Cambridge Tunnel, Boston Tunnel, or Dorchester Tunnel.	See Section 2 of this manual for line maps, showing the portal-to-portal names for all lines. If it is an abandoned TIN, code the portal-to-portal tunnel name that it would be associated with.
Examples	
Prescott Tube Ruggles Tunnel D Branch Tunnel	

Table 7.2.2-11 Portal to Portal Name

7.2.3 Age and Service Items

This section provides coding guidance for items that define the tunnel's construction, reconstruction, and level of service.

Item ID

A.1 Year Built

A.2 Year Rehabilitated

A.3 Total Number of Tracks

A.4 Average Number of Trains per Day

A.5 Year of Average Number of Trains per Day

A.6 Power Section

A.7 Service in Tunnel

A.1 Year Built	
Format N (4,0)	Item ID A.1
Specification	**Commentary**
Record the year in which construction was completed and the tunnel was able to carry traffic.	Provide a best estimate when the year built is unknown. Do not assign a default value. Rehabilitation or abandonment of a structure does not change the year built.
Examples	
1911 1932	

Table 7.2.3-1 Year Built

A.2 Year Rehabilitated	
Format N (4,0)	Item ID A.2

Specification	Commentary
Record the year in which the most recent rehabilitation of the structure was completed. Record "0" if the tunnel has not been rehabilitated. Do not count repairs, whether temporary or permanent in nature, as rehabilitation.	An example of rehabilitation would be relining the tunnel. Examples that would not be considered rehabilitation would be patching of the liner or replacement of the track, ballast, or mechanical/electrical systems or equipment.

Examples
1967
1988

Table 7.2.3-2 Year Rehabilitated

A.3 Total Number of Tracks	
Format N (1,0)	Item ID A.3

Specification	Commentary
Record the number of railroad tracks within the TIN. Include any inactive tracks, as long as the rails exist. If there are a varying number of tracks within the TIN, code the maximum number within any given cross section.	—

Examples
1
3

Table 7.2.3-3 Total Number of Tracks

A.4 Average Number of Trains per Day	
Format N (4,0)	Item ID A.4
Specification	**Commentary**
Record the average number of trains per day that travel through the tunnel for the most recent full calendar year that these records are available. Include leading zeros as necessary.	For tunnels with bidirectional traffic, use the sum of each direction. While it is preferable to have a full year's worth of daily volume data, this item can be coded based on less than a full calendar years' worth of data.
Examples	
0024 0103	

Table 7.2.3-4 Average Number of Trains per Day

A.5 Year of Average Number of Trains per Day	
Format N (4,0)	Item ID A.5
Specification	**Commentary**
Record the year associated with the data recorded in Item ID A.4 - Average Number of Trains per Day.	—
Examples	
2015 2017	

Table 7.2.3-5 Year of Average Number of Trains per Day

A.6 Power Section	
Format AN8	Item ID A.6

Specification	Commentary
Record the appropriate power section "block" designation for this TIN, based on the mapping and labeling in Section 2 of this manual.	Note that the TINs have been determined with power sections in mind, such that only one power section provides power for an entire TIN. Thus, there should not be a situation where there is more than one power section per TIN. If there is, then consideration should be given to dividing that TIN into two TINs.

Examples	
CS-21	R-10E
90	H-5A

Table 7.2.3-6 Power Section

A.7 Service in Tunnel	
Format AN16	Item ID A.7

Specification	Commentary
Record the type of rail traffic within the TIN. Choose from the following options: Heavy Rail Light Rail Other None	The Red, Blue and Orange lines accommodate heavy rail, while the Green line accommodates light rail. If for some reason it is not one of the above, then code "Other". If it is an abandoned tunnel then code "None".

Examples
Heavy Rail
Light Rail

Table 7.2.3-7 Service in Tunnel

7.2.4 Classification Items

This section provides coding guidance for designating the owner, operator, and the nature of the train traffic.

Item ID

C.1 Owner

C.2 Operator

C.3 Users

C.4 On a Revenue Line

C.1 Owner	
Format N2	Item ID C.1
Specification	**Commentary**
Record the name of the primary owner of the tunnel. 01 = State Department of Transportation 02 = Other State Agency 03 = Private 04 =Other	—
Example	
Massachusetts Department of Transportation (MassDOT)	Code: 01

Table 7.2.4-1 Owner

C.2 Operator	
Format N2	Item ID C.2

Specification	Commentary
Record the name of the tunnel operator. 01 = State Department of Transportation 02 = Other State Agency 03= Private 04 =Other	—

Example	
Massachusetts Bay Transportation Authority (MBTA)	Code: 02

Table 7.2.4-2 Operator

C.3 Users	
Format N2	Item ID C.3

Specification	Commentary
Record the users of the tunnel. 01 = General Public 02 = Other	—

Example	
General Public	Code: 01

Table 7.2.4-3 Users

C.4 On a Revenue Line	
Format N2	Item ID C.4
Specification	**Commentary**
Record whether the tunnel is on a revenue line or non-revenue line. 01 = Revenue Line 02 = Non-revenue Line 03= Other	—
Example	
Revenue Line Code: 01	

Table 7.2.4-4 On a Revenue Line

7.2.5 Geometric Data Items

This section provides coding guidance for significant dimensional and clearance information.

Item ID	
G.1	Tunnel Length
G.2	Minimum Vertical Clearance above Track
G.3	Minimum Total Lateral Clearance
G.4	Minimum Left Clearance
G.5	Minimum Right Clearance

G.1 Tunnel Length

Format	Item ID
N (5,0)	G.1

Specification	Commentary
Record the length of the tunnel to the nearest foot along the centerline of the tunnel track (or set of tracks, if more than one). Include leading zeros as necessary.	The length of the tunnel should be equal to the difference be- tween the Stationing - End (Item 1.8) and Stationing - Start (Item 1.7) values. For example: Station 81+45 minus 69+32 = 08145 - 06932 = 01213. It may be possible and even desirable to have this be a calculated value instead of a manually input value.

Examples

1,213 feet	Code: 01213
460 feet	Code: 00460

Table 7.2.5-1 Tunnel Length

G.2 Minimum Vertical Clearance above Track

Format	Item ID
N (3,1)	G.2

Specification	Commentary
Record the minimum vertical clearance in feet from the top of rail to the any overhead restriction (i.e., ceiling, beams, overhead signs, lighting, signals, etc.). Round all measurements downward to the nearest 10th of a foot.	The clearance should be measured vertically to any overhead restriction that is within 4.5 feet of the centerline of track, measured horizontally (this represents the train envelope). For tunnels without tracks, measure as if standard tracks were present.

Examples

22.48'	Code: 22.4
22'-8"	Code: 22.6

Table 7.2.5-2 Minimum Vertical Clearance above Track

G.3 Minimum Total Lateral Clearance	
Format N (3,1)	Item ID G.3

Specification	Commentary
Record the most restrictive minimum horizontal distance in feet from sidewall to sidewall or any other permanent barrier or fixture that is within the train envelope height (i.e., liner components, columns, crash walls, signage, lighting, signals, equipment enclosures, etc.). Round all measurements downward to the nearest 10th of a foot.	The clearance should be measured horizontally between the most restrictive features that are from 0 to 11.5 feet above the top of rail (this represents the tunnel envelope). For tunnels without tracks, measure as if standard tracks were present.

Examples	
44.48'	Code: 44.4
42'-8"	Code: 42.6

Table 7.2.5-3 Minimum Total Lateral Clearance

G.4 Minimum Left Clearance	
Format N (3,1)	Item ID G.4

Specification	Commentary
Record the most restrictive minimum horizontal distance in feet from the centerline of the leftmost track (facing upstation) to the left sidewall or any other permanent barrier or fixture that is within the train envelope height (e.g., liner components, columns, crash walls, signage, lighting signals, equipment enclosures, etc.). Round all measurements downward to the nearest 10th of a foot and include any necessary leading zeros.	The clearance should be measured horizontally to the most restrictive feature that is located from 0 to 11.5 feet above the top of rail (this represents the train envelope). For tunnels without tracks, measure as if standard tracks were present.

Examples	
8.48'	Code: 08.4
10'-8"	Code: 10.6

Table 7.2.5-4 Minimum Left Clearance

G.5 Minimum Right Clearance	
Format N (3,1)	Item ID G.5

Specification	Commentary
Record the most restrictive minimum horizontal distance in feet from the centerline of the rightmost track (facing up-station) to the right sidewall or any other permanent barrier or fixture that is within the train envelope height (e.g., liner components, columns, crash walls, signage, lighting signals, equipment enclosures, etc.). Round all measurements downward to the nearest 10th of a foot and include any necessary leading zeros.	The clearance should be measured horizontally to the most restrictive feature that is located from 0 to 11.5 feet above the top of rail (this represents the tunnel envelope). For tunnels without tracks, measure as if standard tracks were present.

Examples	
8.48'	Code: 08.4
10'-8"	Code: 10.6

Table 7.2.5-5 Minimum Right Clearance

7.2.6 Inspection Items

This section provides coding guidance to show the type and date of inspections.

Item ID

D.1 Routine Inspection Target Date

D.2 Actual Routine Inspection Start Date

D.3 Actual Routine Inspection End Date

D.4 Routine Inspection Interval

D.5 Damage Inspection Date

D.6 Special Inspection Date

D.1 Routine Inspection Target Date	
Format D	Item ID D.1
Specification	**Commentary**
Record the routine inspection target start date based on routine inspection intervals. Code an 8-digit number to represent the month, day, and year. The number of the month should be the first two digits (with a leading zero as required), the number of the day should be coded as the 3rd and 4th digits (with a leading zero as required), and the year coded as the 5th through 8th digits.	The initial date should be set by the MBTA; however, future target dates should be entered based on the previous Actual Routine Inspection Date (Item D.2) and the inspection interval established for this TIN. Item D.2, Actual Routine Inspection Date, should be started within 2 months of the target date. These dates should be for the first day of inspection.
Examples	
June 15, 2019	Code: 06152019
April 14, 2020	Code: 04142020

Table 7.2.6-1 Routine Inspection Target Date

D.2 Actual Routine Inspection Start Date	
Format D	Item ID D.2

Specification	Commentary
Record the actual routine inspection start date for the first day of the inspection. Code an 8-digit number to represent the month, day, and year. The number of the month should be the first two digits (with a leading zero as required), the number of the day should be coded as the 3rd and 4th digits (with a leading zero as required), and the year coded as the 5th through 8th digits.	This date indicates when the field inspection actually began and should be started within 2 months of the Routine Inspection Target Date (Item D.1). These dates should be for the first day of inspection.

Examples	
January 29, 2020	Code: 01292020
June 15, 2019	Code: 06152019

Table 7.2.6-2 Actual Routine Inspection Start Date

D.3 Actual Routine Inspection End Date	
Format D	Item ID D.3

Specification	Commentary
Record the actual routine inspection end date for the last day of the inspection. Code an 8-digit number to represent the month, day, and year. The number of the month should be the first two digits (with a leading zero as required), the number of the day should be coded as the 3rd and 4th digits (with a leading zero as required), and the year coded as the 5th through 8th digits.	This date indicates when the field inspection actually ended. These dates should be for the last day of inspection.

Examples	
January 29, 2020	Code: 01292020
June 15, 2019	Code: 06152019

Table 7.2.6-3 Actual Routine Inspection End Date

D.4 Routine Inspection Interval

Format	Item ID
N (2,0)	D.4

Specification	Commentary
Record the number of months between the designated routine inspections (with a leading zero as required). The routine inspection interval can vary from inspection to inspection, depending on the condition of the tunnel at the time of inspection and the procedures established by the MBTA Transit Tunnel Inspection Program.	If during a routine inspection, there are conditions which warrant consideration for a reduced interval, this should be a recommendation in the report. The reverse can also be true for improvements made since the previous inspection. However, the final decision to change the interval will be made by the MBTA Program Manager or a representative. Note that the routine inspection interval should not be adjusted based on isolated defects or poor/unusual conditions. For these affected elements, a special inspection should be scheduled (see Item D.6).

Examples

Every 24 months	Code: 24
Every 6 months	Code: 06

Table 7.2.6-4 Routine Inspection Interval

D.5 Damage Inspection Date

Format	Item ID
D	D.5

Specification	Commentary
If this inspection is related to a reported damage condition that requires inspection, record the actual inspection date of the first day of the damage inspection. Code an 8-digit number to represent the month, day, and year. The number of the month should be the first two digits (with a leading zero as required), the number of the day should be coded as the 3rd and 4th digits (with a leading zero as required), and the year coded as the 5th through 8th digits.	This is an unscheduled inspection to assess any damage or potential damage resulting from environmental factors or human actions. Examples would be collision, flooding, earth- quake, or explosions. This date would be recoded each time there is a damage inspection.

Examples

June 27, 2019	Code: 06272019
April 14, 2020	Code: 04142020

Table 7.2.6-5 Damage Inspection Date

D.6 Special Inspection Date

Format	Item ID
D	D.6

Specification	Commentary
If this inspection is related to a special inspection, record the actual inspection date of the first day of the inspection. Code an 8-digit number to represent the month, day, and year. The number of the month should be the first two digits (with a leading zero as required), the number of the day should be coded as the 3rd and 4th digits (with a leading zero as required), and the year coded as the 5th through 8th digits.	This is an inspection scheduled at the discretion of the MBTA, used to monitor a particular known or suspected deficiency or elements/areas of concern or higher liability. Examples would include overhead inspection, significant deterioration, or defects on specific elements or portions of the tunnel. This date would be recoded each time there is a damage inspection.

Examples

June 3, 2019	Code: 06032019
June 7, 2020	Code: 06072020

Table 7.2.6-6 Special Inspection Date

7.2.7 Structure Type and Material Items

This section provides coding guidance to define the number and shape of the bore(s) and the surrounding ground conditions.

Item ID

S.1 Number of Bores

S.2 Tunnel Shape

S.3 Ground Conditions

S.1 Number of Bores	
Format N (1,0)	Item ID S.1
Specification	**Commentary**
Record a one-digit number defining the number of bores in a tunnel. When recording and coding this item, use the number of bores associated with Item 1.1, Tunnel Identification Number (TIN).	For most if not all TINs, the number of bores will be one. If a single bore "excavation" includes dividing wall(s) between cells, it is still considered one bore. Multiple bores would be separated by earth or stone between them. If one or more TINs exist in parallel with another TIN within the same bore, each TIN would still be coded with 1 as the number of bores.
Examples	
Single Bore	Code: 1
Double Bore	Code:2

Table 7.2.7-1 Number of Bores

S.2 Tunnel Shape

Format	Item ID
N (1,0)	S.2

Specification	Commentary
Record the predominant type of tunnel shape using one of the following codes: 1 = Horseshoe 2 = Rectangular 3 = Circular 4 = Oval 5 = Other	One of the factors used to define and separate the individual TINs from each other is the tunnel shape; therefore, it would be rare to have more than one shape within a TIN. However, if there are multiple shapes, code the shape that comprises most of the length of the TIN.

Examples

Rectangular	Code: 2
Oval	Code: 4

Table 7.2.7-2 Tunnel Shape

S.3 Ground Conditions

Format	Item ID
N (1,0)	S.3

Specification	Commentary
Record the type of ground conditions surrounding the tunnel using one of the following codes: 1 = Soil 2 = Rock 3 = Mixed Face 4 = Unknown	Definitions: Soil should be coded for ground conditions consisting primarily of clay, silt, sand, gravel, or a mixture of these. Rock should be coded for ground conditions consisting primarily of any type of weathered or sound rock. Mixed Face should be coded for ground conditions that vary between soil and rock along the length or height of the TIN. Ground conditions would be determined from boring logs or as-built plans. If not available, then code as Unknown.

Examples

Rock	Code: 2
Unknown	Code:4

Table 7.2.7-3 Ground Conditions

7.3 Tunnel Overall Rating Formula

Each tunnel consists of numerous elements, which combine into systems and groups of elements. The SGR rating formulas for those systems and groups are described in Section 7.3.1. For asset management purposes and to assist in prioritizing maintenance and rehabilitation for various tunnels in the MBTA network, a weighted average combining each element group's SGR rating number—Structural/Civil (S), Mechanical (M), Electrical (E), and Fire Life Safety (FLS)—is provided below.

Tunnel SGR Rating
$$SGR_{rating} = (S_{factor} \times SE_{rating\ .S}) + (M_{factor} \times SE_{rating\ .M}) + (E_{factor} \times SE_{rating\ .E}) + (FLS_{factor} \times SE_{rating\ .FLS})$$

Where:

S_{factor}	= 0.3 (the weighted factor for the Structural / Civil group of elements)
$SE_{rating.S}$	= System Element Rating for the Structural / Civil group of elements
M_{factor}	= 0.2 (the weighted factor for the Mechanical group of elements)
$SE_{rating.M}$	= System Element Rating for the Mechanical group of elements
E_{factor}	= 0.3 (the weighted factor for the Electrical group of elements)
$SE_{rating.E}$	= System Element Rating for the Electrical group of elements
FLS_{factor}	= 0.2 (the weighted factor for the Fire Life Safety group of elements)
$SE_{rating.FLS}$	= System Element Rating for the Fire Life Safety group of elements

Note: The factors shown above (S_{factor}=0.3, M_{factor}=0.2, E_{factor}=0.3, and FLS_{factor}=0.2) are applicable when there are elements from each group that exist in the TIN in which the rating is being calculated for. Different factors must be applied to each group when there are certain groups of elements that do not exist within the TIN. These factors are shown in Table 7.3-1.

Group Missing	S_{factor}	M_{factor}	E_{factor}	FLS_{factor}
None - all present	0.3	0.2	0.3	0.2
FLS missing	$0.3\overline{6}$	$0.2\overline{6}$	$0.3\overline{6}$	0
FLS & E missing	0.55	0.45	0	0
FLS & M missing	0.5	0	0.5	0
FLS, E, & M missing	1	0	0	0
E missing	0.4	0.3	0	0.3
E & M missing	0.55	0	0	0.45
M missing	$0.3\overline{6}$	0	$0.3\overline{6}$	$0.2\overline{6}$

Table 7.3-1 SGR Rating - Weighted Factors

7.3.1 System Element Rating Formula

As noted in the above paragraph, there are four established groups of elements. As each of these groups comprises multiple individual elements with varying levels of importance, it is necessary to provide a weighted formula for each group to be able to arrive at an SGR rating for each group. The resulting SGR ratings can be used for comparison between different groups within a tunnel or among the same group in different tunnels to assist in making inspection frequency and asset management decisions.

System Element Rating (for S, M, E, and FLS)

$$SE_{rating\ .n} = \sum \frac{PE_{factor}}{PE_{quantity\ .n}} \times CS_{weight\ .P.n} + \sum \frac{SE_{factor}}{SE_{quantity\ .n}} \times CS_{weight\ .S.n}$$

Where:
- PE_{factor} = 0.8 (the weighted factor for what are considered primary elements)
- $PE_{quantity.n}$ = the number of primary elements in a given TIN
- $CS_{weight.P.n}$ = the weighted condition state of a primary element
- SE_{factor} = 0.2 (the weighted factor for what are considered secondary elements)
- $SE_{quantity.n}$ = the number of secondary elements in a given TIN
- $CS_{weight.S.n}$ = the weighted condition state of a secondary element

Note: The factors shown above (PE_{factor}=0.8 and SE_{factor}=0.2) are applicable when primary and secondary elements are both present. If there are no secondary elements within a group present, but there are primary elements, then the PE_{factor} will be 1.0. If there are no primary elements within a group present, but there are secondary elements, then the SE_{factor} will be 1.0. See Table 7.3.1-1.

Element Type Missing	PEfactor	SEfactor
None - both present	0.8	0.2
Secondary Missing	1	0
Primary Missing	0	1

Table 7.3.1-1 SE Rating - Weighted Factors

The weighted condition state (CS_{weight}) of an element is defined as:

Element - Weighted Condition State

$$CS_{weight} = \frac{(CS1_{qty} \times 1) + (CS2_{qty} \times 2) + (CS3_{qty} \times 3) + (CS4_{qty} \times 4) + (CS5_{qty} \times 5)}{(CS1_{qty} + CS2_{qty} + CS3_{qty} + CS4_{qty} + CS5_{qty})}$$

Shown below is a list of the primary and secondary elements within each group. Primary elements are defined as elements that are a major component to the functionality of the tunnel. Secondary elements are defined as elements that do provide meaningful services, but do not necessarily impact the overall functionality of the tunnel.

Group	Primary Elements	Secondary Elements
Structural / Civil	Liner	Cross Passageway
	Girders	Portal
	Columns | Piles	Joint
	Invert Slab	Niches
	Slab-on-grade	Manholes
	Invert Girders	Safety Walk
	Steel Tie | Tension Member	Fireproofing
	Soil Anchors	Ladders
Mechanical	Drainage System	Utility Rooms
	Pumps	
	Flood Gate	
Electrical	Emergency Generator System	Tunnel Lighting Distribution System
	Emergency Lighting Distribution System	Tunnel Lighting Fixtures
	Emergency Lighting Fixtures	
	Catenary Support Systems	
Fire Life Safety	Fire Detection System	Cameras
	Emergency Communication System	Portal Alert System
	Tunnel Operations and Security System	
	Emergency Egress	
	Ventilation System	
	Fans	
	Standpipes	

Table 7.3.1-2 Primary and Secondary Elements

7.3.2 NBI Rating Conversion

The NBI rating scale of 0–9 has been used for the rating of bridges owned by the MBTA as well as older pre-manual tunnel inspections. This rating conversion formula is meant to assist inspectors and the agency to compare past reports that used the old rating scale to the manual required rating scale.

The NBI rating is determined in the same fashion as shown in sections 7.3 and 7.3.1 with the following exception: rather than using the weighted condition state (CS_{weight}) shown in section 7.3.1, a weighted NBI condition rating (NBI_{weight}) will need to be determined. This is defined as:

Element - Weighted Condition State (NBI Scale)
$$\mathrm{NBI}_{\mathrm{weight}} = \frac{(\mathrm{CS1}_{\mathrm{qty}} \times 3) + (\mathrm{CS2}_{\mathrm{qty}} \times 4) + (\mathrm{CS3}_{\mathrm{qty}} \times 6) + (\mathrm{CS4}_{\mathrm{qty}} \times 7) + (\mathrm{CS5}_{\mathrm{qty}} \times 8)}{(\mathrm{CS1}_{\mathrm{qty}} + \mathrm{CS2}_{\mathrm{qty}} + \mathrm{CS3}_{\mathrm{qty}} + \mathrm{CS4}_{\mathrm{qty}} + \mathrm{CS5}_{\mathrm{qty}})}$$

Once the weighted NBI condition rating is determined, the system element rating and the tunnel overall rating (or SGR rating) can be calculated on an NBI scale. The NBI rating shall be rounded to the nearest whole number.

7.3.3 Example Rating Calculation

Say the following elements and condition state quantities exist within a TIN:

No.	Element	System / Group	Primary or Secondary	Units	CS Quantity				
					CS5	CS4	CS3	CS2	CS1
S1	Liner	Structural / Civil	Primary	SF	1000	100	300	500	100
S2	Girders	Structural / Civil	Primary	LF	300	50	20	10	10
S3	Columns	Structural / Civil	Primary	EA	30	3	0	4	2
S4	Cross Passage.	Structural / Civil	Secondary	LF	86	10	10	5	0
S5	Portal	Structural / Civil	Secondary	SF	45	5	7	10	5
M1	Drainage System	Mechanical	Primary	EA	0	1	1	0	1
M2	Flood Gate	Mechanical	Primary	EA	1	0	0	0	0
M3	Pumps	Mechanical	Primary	EA	1	1	1	0	0
M4	Utility Rooms	Mechanical	Secondary	EA	1	0	1	0	1
E1	Emer. Generator	Electrical	Primary	EA	0	1	0	0	0
E2	Emer. Light Sys.	Electrical	Primary	EA	0	1	0	0	0
E3	Emer. Light Fix.	Electrical	Primary	EA	50	5	10	2	0
E4	Tunnel Light Sys.	Electrical	Secondary	EA	0	1	0	0	0
E5	Tunnel Light Fix.	Electrical	Secondary	EA	300	50	8	5	1
FLS1	Fire Detection Sys.	Fire Life Safety	Primary	EA	0	1	0	0	0
FLS2	Emer. Comm. Sys.	Fire Life Safety	Primary	EA	1	0	0	0	0
FLS3	Emer. Egress	Fire Life Safety	Primary	EA	2	1	0	0	0
FLS4	Cameras	Fire Life Safety	Secondary	EA	3	0	1	0	0
FLS5	Portal Alert Sys.	Fire Life Safety	Secondary	EA	1	0	0	0	0

Table 7.3.3-1 Example Calculation - Element Inventory

Step 1. Determine the weighted condition state (CS_{weight}) of each element. A few examples are shown below.

Element No. S1 - Liner

$$CS_{weight} = \frac{(CS1_{qty} \times 1) + (CS2_{qty} \times 2) + (CS3_{qty} \times 3) + (CS4_{qty} \times 4) + (CS5_{qty} \times 5)}{(CS1_{qty} + CS2_{qty} + CS3_{qty} + CS4_{qty} + CS5_{qty})}$$

$$CS_{weight.S_1} = \frac{(100 \times 1) + (500 \times 2) + (300 \times 3) + (100 \times 4) + (1000 \times 5)}{(100 + 500 + 300 + 100 + 1000)}$$

$$CS_{weight.S_1} = \frac{7400}{2000} = 3.7$$

Element No. M4 - Utility Rooms

$$CS_{weight.M_4} = \frac{(1 \times 1) + (0 \times 2) + (1 \times 3) + (0 \times 4) + (1 \times 5)}{(1 + 0 + 1 + 0 + 1)}$$

$$CS_{weight.M_4} = \frac{9}{3} = 3.0$$

Step 2. Determine the system element rating (SE_{rating}) for each group of elements.

Structural / Civil System Element Rating:

$$SE_{rating.S} = \sum \frac{PE_{factor}}{PE_{quantity.S}} \times CS_{weight.P.S} + \sum \frac{SE_{factor}}{SE_{quantity.S}} \times CS_{weight.S.S}$$

Where: $PE_{quantity.S}$ = the number of structural primary elements

$CS_{weight.P.S}$ = the weighted condition state of a primary structural element

$SE_{quantity.S}$ = the number of structural secondary elements

$CS_{weight.S.S}$ = the weighted condition state of a secondary structural element

The weighted condition states of each individual element were calculated as shown in step 1 but are not shown here. Refer to Figures 7.3.3-1 to 7.3.3-7 for the complete calculations.

The resulting value of the left side (primary elements) of the system element rating equation is:

$$\sum \frac{PE_{factor}}{PE_{quantity.S}} \times CS_{weight.P.S} = 3.39$$

The resulting value of the right side (secondary elements) of the system element rating eq. is:

$$\sum \frac{SE_{factor}}{SE_{quantity.S}} \times CS_{weight.S.S} = 0.86$$

Structural / Civil System Element Rating: NBI Scale:

$SE_{CS.rating.S} = 3.39 + 0.86 = 4.25$ $SE_{NBI.rating.S} = 7.09$

Mechanical System Element Rating:

$SE_{CS.rating.M} = 3.11 + 0.6 = 3.71$ $SE_{NBI.rating.M} = 6.56$

Electrical System Element Rating:

$SE_{CS.rating.E} = 3.34 + 0.88 = 4.22$ $SE_{NBI.rating.E} = 7.21$

Fire Life Safety System Element Rating:

$SE_{CS.rating.FLS} = 3.64 + 0.95 = 4.59$ $SE_{NBI.rating.FLS} = 7.59$

Step 3. Determine the State of Good Repair rating (SGR_{rating}) for the TIN.

$$SR_{rating} = (S_{factor} \times SE_{rating.S}) + (M_{factor} \times SE_{rating.M}) + (E_{factor} \times SE_{rating.E}) + (FLS_{factor} \times SE_{rating.FLS})$$

$$SR_{CS.rating} = (0.3 \times 4.25) + (0.2 \times 3.71) + (0.3 \times 4.22) + (0.2 \times 4.59) = 4.201, \text{rounded to } 4.2$$

$$SR_{NBI.rating} = (0.3 \times 7.09) + (0.2 \times 6.56) + (0.3 \times 7.21) + (0.2 \times 7.59) = 7.12, \text{rounded to } 7$$

Shown below are the rating calculations for this example.

Element Inventory Matrix:

	CS5	CS4	CS3	CS2	CS1
	1000	100	300	500	100
	300	50	20	10	10
	30	3	0	4	2
	86	10	10	5	0
	45	5	7	10	5
	0	1	1	0	1
	1	0	0	0	0
	1	1	1	0	0
	1	0	1	0	1
E1 :=	0	1	0	0	0
	0	1	0	0	0
	50	5	10	2	0
	0	1	0	0	0
	300	50	8	5	1
	0	1	0	0	0
	1	0	0	0	0
	2	1	0	0	0
	3	0	1	0	0
	1	0	0	0	0

Condition State Matrix:

	5	4	3	2	1
	5	4	3	2	1
	5	4	3	2	1
	5	4	3	2	1
	5	4	3	2	1
	5	4	3	2	1
	5	4	3	2	1
	5	4	3	2	1
	5	4	3	2	1
CS :=	5	4	3	2	1
	5	4	3	2	1
	5	4	3	2	1
	5	4	3	2	1
	5	4	3	2	1
	5	4	3	2	1
	5	4	3	2	1
	5	4	3	2	1
	5	4	3	2	1
	5	4	3	2	1

NBI Scale Matrix:

	8	7	6	4	3
	8	7	6	4	3
	8	7	6	4	3
	8	7	6	4	3
	8	7	6	4	3
	8	7	6	4	3
	8	7	6	4	3
	8	7	6	4	3
	8	7	6	4	3
NBI :=	8	7	6	4	3
	8	7	6	4	3
	8	7	6	4	3
	8	7	6	4	3
	8	7	6	4	3
	8	7	6	4	3
	8	7	6	4	3
	8	7	6	4	3
	8	7	6	4	3
	8	7	6	4	3

Figure 7.3.3-1 Inventory, Condition State, and NBI Scale Matrices

Step 1: Weighted Condition States

Structural Primary Elements:

$$CS_{weight.S.P} := \left[\frac{\sum\left[\overrightarrow{(EI \cdot CS)}^{T}\right]^{\langle 0\rangle^{T}}}{\sum\left[\overrightarrow{(EI)}^{T}\right]^{\langle 0\rangle^{T}}} \quad \frac{\sum\left[\overrightarrow{(EI \cdot CS)}^{T}\right]^{\langle 1\rangle^{T}}}{\sum\left[\overrightarrow{(EI)}^{T}\right]^{\langle 1\rangle^{T}}} \quad \frac{\sum\left[\overrightarrow{(EI \cdot CS)}^{T}\right]^{\langle 2\rangle^{T}}}{\sum\left[\overrightarrow{(EI)}^{T}\right]^{\langle 2\rangle^{T}}}\right] = \begin{pmatrix} 3.7 \\ 4.59 \\ 4.41 \end{pmatrix}$$

Mechanical Primary Elements:

$$CS_{weight.M.P} := \left[\frac{\sum\left[\overrightarrow{(EI \cdot CS)}^{T}\right]^{\langle 5\rangle^{T}}}{\sum\left[\overrightarrow{(EI)}^{T}\right]^{\langle 5\rangle^{T}}} \quad \frac{\sum\left[\overrightarrow{(EI \cdot CS)}^{T}\right]^{\langle 6\rangle^{T}}}{\sum\left[\overrightarrow{(EI)}^{T}\right]^{\langle 6\rangle^{T}}} \quad \frac{\sum\left[\overrightarrow{(EI \cdot CS)}^{T}\right]^{\langle 7\rangle^{T}}}{\sum\left[\overrightarrow{(EI)}^{T}\right]^{\langle 7\rangle^{T}}}\right] = \begin{pmatrix} 2.667 \\ 5 \\ 4 \end{pmatrix}$$

The weighted condition states using the NBI scale are calculated in the same fashion as above.

$$NBI_{weight.S.P} = \begin{pmatrix} 6.4 \\ 7.538 \\ 7.256 \end{pmatrix}$$

$$NBI_{weight.M.P} = \begin{pmatrix} 5.333 \\ 8 \\ 7 \end{pmatrix}$$

Structural Secondary Elements:

$$CS_{weight.S.S} := \left[\frac{\sum\left[\overrightarrow{(EI \cdot CS)}^{T}\right]^{\langle 3\rangle^{T}}}{\sum\left[\overrightarrow{(EI)}^{T}\right]^{\langle 3\rangle^{T}}} \quad \frac{\sum\left[\overrightarrow{(EI \cdot CS)}^{T}\right]^{\langle 4\rangle^{T}}}{\sum\left[\overrightarrow{(EI)}^{T}\right]^{\langle 4\rangle^{T}}}\right] = \begin{pmatrix} 4.595 \\ 4.042 \end{pmatrix}$$

Mechanical Secondary Elements:

$$CS_{weight.M.S} := \left[\frac{\sum\left[\overrightarrow{(EI \cdot CS)}^{T}\right]^{\langle 8\rangle^{T}}}{\sum\left[\overrightarrow{(EI)}^{T}\right]^{\langle 8\rangle^{T}}}\right] = (3)$$

The weighted condition states using the NBI scale are calculated in the same fashion as above.

$$NBI_{weight.S.S} = \begin{pmatrix} 7.55 \\ 6.833 \end{pmatrix}$$

$$NBI_{weight.M.S} = (5.667)$$

Figure 7.3.3-2 Step 1: Weighted Condition States - (S) and (M)

Step 1: Weighted Condition States

Electrical Primary Elements:

$$CS_{weight.E.P} := \begin{bmatrix} \frac{\sum\left[\overrightarrow{(El \cdot CS)}^{T}\right]^{\langle 9\rangle^{T}}}{\sum\left[\overrightarrow{(El)}^{T}\right]^{\langle 9\rangle^{T}}} \\ \frac{\sum\left[\overrightarrow{(El \cdot CS)}^{T}\right]^{\langle 10\rangle^{T}}}{\sum\left[\overrightarrow{(El)}^{T}\right]^{\langle 10\rangle^{T}}} \\ \frac{\sum\left[\overrightarrow{(El \cdot CS)}^{T}\right]^{\langle 11\rangle^{T}}}{\sum\left[\overrightarrow{(El)}^{T}\right]^{\langle 11\rangle^{T}}} \end{bmatrix} = \begin{pmatrix} 4 \\ 4 \\ 4.537 \end{pmatrix}$$

Fire Life Safety Primary Elements:

$$CS_{weight.FLS.P} := \begin{bmatrix} \frac{\sum\left[\overrightarrow{(El \cdot CS)}^{T}\right]^{\langle 14\rangle^{T}}}{\sum\left[\overrightarrow{(El)}^{T}\right]^{\langle 14\rangle^{T}}} \\ \frac{\sum\left[\overrightarrow{(El \cdot CS)}^{T}\right]^{\langle 15\rangle^{T}}}{\sum\left[\overrightarrow{(El)}^{T}\right]^{\langle 15\rangle^{T}}} \\ \frac{\sum\left[\overrightarrow{(El \cdot CS)}^{T}\right]^{\langle 16\rangle^{T}}}{\sum\left[\overrightarrow{(El)}^{T}\right]^{\langle 16\rangle^{T}}} \end{bmatrix} = \begin{pmatrix} 4 \\ 5 \\ 4.667 \end{pmatrix}$$

The weighted condition states using the NBI scale are calculated in the same fashion as above.

$$NBI_{weight.E.P} = \begin{pmatrix} 7 \\ 7 \\ 7.507 \end{pmatrix}$$

$$NBI_{weight.FLS.P} = \begin{pmatrix} 7 \\ 8 \\ 7.667 \end{pmatrix}$$

Electrical Secondary Elements:

$$CS_{weight.E.S} := \begin{bmatrix} \frac{\sum\left[\overrightarrow{(El \cdot CS)}^{T}\right]^{\langle 12\rangle^{T}}}{\sum\left[\overrightarrow{(El)}^{T}\right]^{\langle 12\rangle^{T}}} \\ \frac{\sum\left[\overrightarrow{(El \cdot CS)}^{T}\right]^{\langle 13\rangle^{T}}}{\sum\left[\overrightarrow{(El)}^{T}\right]^{\langle 13\rangle^{T}}} \end{bmatrix} = \begin{pmatrix} 4 \\ 4.766 \end{pmatrix}$$

Fire Life Safety Secondary Elements:

$$CS_{weight.FLS.S} := \begin{bmatrix} \frac{\sum\left[\overrightarrow{(El \cdot CS)}^{T}\right]^{\langle 17\rangle^{T}}}{\sum\left[\overrightarrow{(El)}^{T}\right]^{\langle 17\rangle^{T}}} \\ \frac{\sum\left[\overrightarrow{(El \cdot CS)}^{T}\right]^{\langle 18\rangle^{T}}}{\sum\left[\overrightarrow{(El)}^{T}\right]^{\langle 18\rangle^{T}}} \end{bmatrix} = \begin{pmatrix} 4.5 \\ 5 \end{pmatrix}$$

The weighted condition states using the NBI scale are calculated in the same fashion as above.

$$NBI_{weight.E.S} = \begin{pmatrix} 7 \\ 7.75 \end{pmatrix}$$

$$NBI_{weight.FLS.S} = \begin{pmatrix} 7.5 \\ 8 \end{pmatrix}$$

Figure 7.3.3-3 Step 1: Weighted Condition States - (E) and (FLS)

Primary & Secondary Element Quantities and Factors

$PE_{qty.S} := 3$ $PE_{qty.M} := 3$ $PE_{qty.E} := 3$ $PE_{qty.FLS} := 3$

$SE_{qty.S} := 2$ $SE_{qty.M} := 1$ $SE_{qty.E} := 2$ $SE_{qty.FLS} := 2$

For this example, there are primary and secondary elements present for every group. Therefore the primary and secondary factors are:

$PE_{factor.S} := 0.8$ $PE_{factor.M} := 0.8$ $PE_{factor.E} := 0.8$ $PE_{factor.FLS} := 0.8$

$SE_{factor.S} := 0.2$ $SE_{factor.M} := 0.2$ $SE_{factor.E} := 0.2$ $SE_{factor.FLS} := 0.2$

Step 2: System Element Ratings

Structural:

$$SE_{rating.S.P} := \sum\left(\frac{PE_{factor.S}}{PE_{qty.S}} \cdot CS_{weight.S.P}\right) = 3.39 \quad \text{(Primary Elements)}$$

$$SE_{rating.S.S} := \sum\left(\frac{SE_{factor.S}}{SE_{qty.S}} \cdot CS_{weight.S.S}\right) = 0.86 \quad \text{(Secondary Elements)}$$

$$SE_{rating.S} := \sum\left(\frac{PE_{factor.S}}{PE_{qty.S}} \cdot CS_{weight.S.P}\right) + \sum\left(\frac{SE_{factor.S}}{SE_{qty.S}} \cdot CS_{weight.S.S}\right) = 4.25$$

$$NBI_{rating.S} := \sum\left(\frac{PE_{factor.S}}{PE_{qty.S}} \cdot NBI_{weight.S.P}\right) + \sum\left(\frac{SE_{factor.S}}{SE_{qty.S}} \cdot NBI_{weight.S.S}\right) = 7.09$$

Mechanical:

$$SE_{rating.M.P} := \sum\left(\frac{PE_{factor.M}}{PE_{qty.M}} \cdot CS_{weight.M.P}\right) = 3.11 \quad \text{(Primary Elements)}$$

$$SE_{rating.M.S} := \sum\left(\frac{SE_{factor.M}}{SE_{qty.M}} \cdot CS_{weight.M.S}\right) = 0.6 \quad \text{(Secondary Elements)}$$

$$SE_{rating.M} := \sum\left(\frac{PE_{factor.M}}{PE_{qty.M}} \cdot CS_{weight.M.P}\right) + \sum\left(\frac{SE_{factor.M}}{SE_{qty.M}} \cdot CS_{weight.M.S}\right) = 3.71$$

$$NBI_{rating.M} := \sum\left(\frac{PE_{factor.M}}{PE_{qty.M}} \cdot NBI_{weight.M.P}\right) + \sum\left(\frac{SE_{factor.M}}{SE_{qty.M}} \cdot NBI_{weight.M.S}\right) = 6.56$$

Electrical:

$$SE_{rating.E.P} := \sum\left(\frac{PE_{factor.E}}{PE_{qty.E}} \cdot CS_{weight.E.P}\right) = 3.34 \quad \text{(Primary Elements)}$$

$$SE_{rating.E.S} := \sum\left(\frac{SE_{factor.E}}{SE_{qty.E}} \cdot CS_{weight.E.S}\right) = 0.88 \quad \text{(Secondary Elements)}$$

$$SE_{rating.E} := \sum\left(\frac{PE_{factor.E}}{PE_{qty.E}} \cdot CS_{weight.E.P}\right) + \sum\left(\frac{SE_{factor.E}}{SE_{qty.E}} \cdot CS_{weight.E.S}\right) = 4.22$$

$$NBI_{rating.E} := \sum\left(\frac{PE_{factor.E}}{PE_{qty.E}} \cdot NBI_{weight.E.P}\right) + \sum\left(\frac{SE_{factor.E}}{SE_{qty.E}} \cdot NBI_{weight.E.S}\right) = 7.21$$

Figure 7.3.3-4 Step 2: System Element Ratings (S), (M) and (E)

Step 2: System Element Ratings

Fire Life Safety:

$$SE_{rating.FLS.P} := \sum\left(\frac{PE_{factor.FLS}}{PE_{qty.FLS}} \cdot CS_{weight.FLS.P}\right) = 3.64 \quad \text{(Primary Elements)}$$

$$SE_{rating.FLS.S} := \sum\left(\frac{SE_{factor.FLS}}{SE_{qty.FLS}} \cdot CS_{weight.FLS.S}\right) = 0.95 \quad \text{(Secondary Elements)}$$

$$SE_{rating.FLS} := \sum\left(\frac{PE_{factor.FLS}}{PE_{qty.FLS}} \cdot CS_{weight.FLS.P}\right) + \sum\left(\frac{SE_{factor.FLS}}{SE_{qty.FLS}} \cdot CS_{weight.FLS.S}\right) = 4.59$$

$$NBI_{rating.FLS} := \sum\left(\frac{PE_{factor.FLS}}{PE_{qty.FLS}} \cdot NBI_{weight.FLS.P}\right) + \sum\left(\frac{SE_{factor.FLS}}{SE_{qty.FLS}} \cdot NBI_{weight.FLS.S}\right) = 7.59$$

Figure 7.3.3-5 Step 2: System Element Ratings (FLS)

Group Presence Factors

Each TIN may have a unique combination of groups present. In this example, all groups are present, so S_{factor}=0.3, M_{factor}=0.2, E_{factor}=0.3, and FLS_{factor}=0.2. Shown below is a matrix which contains the presence factors (PF) for each scenario. If a group is not present, the original factor of that group is distributed equally to the groups that are present.

$S_{PF} := 0.3 \quad M_{PF} := 0.2 \quad E_{PF} := 0.3 \quad FLS_{PF} := 0.2$ (all groups present)

Presence Factor Matrix:

$$PF := \begin{pmatrix} S_{PF} & M_{PF} & E_{PF} & FLS_{PF} \\ S_{PF} + \frac{FLS_{PF}}{3} & M_{PF} + \frac{FLS_{PF}}{3} & E_{PF} + \frac{FLS_{PF}}{3} & 0 \\ S_{PF} + \frac{E_{PF} + FLS_{PF}}{2} & M_{PF} + \frac{E_{PF} + FLS_{PF}}{2} & 0 & 0 \\ S_{PF} + \frac{M_{PF} + FLS_{PF}}{2} & 0 & E_{PF} + \frac{M_{PF} + FLS_{PF}}{2} & 0 \\ S_{PF} + M_{PF} + E_{PF} + FLS_{PF} & 0 & 0 & 0 \\ S_{PF} + \frac{E_{PF}}{3} & M_{PF} + \frac{E_{PF}}{3} & 0 & FLS_{PF} + \frac{E_{PF}}{3} \\ S_{PF} + \frac{E_{PF} + M_{PF}}{2} & 0 & 0 & FLS_{PF} + \frac{E_{PF} + M_{PF}}{2} \\ S_{PF} + \frac{M_{PF}}{3} & 0 & E_{PF} + \frac{M_{PF}}{3} & FLS_{PF} + \frac{M_{PF}}{3} \end{pmatrix}$$

Column 0 1 2 3

$$PF = \begin{array}{c} \begin{matrix} S_{PF} & M_{PF} & E_{PF} & FLS_{PF} \end{matrix} \\ \begin{pmatrix} 0.3 & 0.2 & 0.3 & 0.2 \\ 0.367 & 0.267 & 0.367 & 0 \\ 0.55 & 0.45 & 0 & 0 \\ 0.5 & 0 & 0.5 & 0 \\ 1 & 0 & 0 & 0 \\ 0.4 & 0.3 & 0 & 0.3 \\ 0.55 & 0 & 0 & 0.45 \\ 0.367 & 0 & 0.367 & 0.267 \end{pmatrix} \end{array}$$

Row	Scenario
0	all groups present
1	FLS group missing
2	FLS and E groups missing
3	FLS and M groups missing
4	FLS , E, and M groups missing
5	E group missing
6	E and M groups missing
7	M group missing

Example

row , column

$PF_{2,1} = 0.45$

Figure 7.3.3-6 Group Presence Factors

Step 3: SGR Rating

$S_{factor} := PF_{0,0} = 0.3$ $M_{factor} := PF_{0,1} = 0.2$ $E_{factor} := PF_{0,2} = 0.3$ $FLS_{factor} := PF_{0,3} = 0.2$

$$SGR_{CS.rating} := S_{factor} \cdot SE_{rating.S} + M_{factor} \cdot SE_{rating.M} \cdots + E_{factor} \cdot SE_{rating.E} + FLS_{factor} \cdot SE_{rating.FLS} = 4.2$$

$$SGR_{NBI.rating} := S_{factor} \cdot NBI_{rating.S} + M_{factor} \cdot NBI_{rating.M} \cdots + E_{factor} \cdot NBI_{rating.E} + FLS_{factor} \cdot NBI_{rating.FLS} = 7.12$$

Figure 7.3.3-7 Step 3: SGR Rating

7.3.4 Element Quantity Calculations

See the sample report in the Section 5 attachments for an example of element total quantity calculations.

Figures 4.3.4-1 to 7.3.4-12 provide clarification on what needs to be quantified for certain elements.

Liner: Quantity includes the surface areas of the liner walls and roof (rectangular / box) or the surface area of the liner arc (circular & arch).

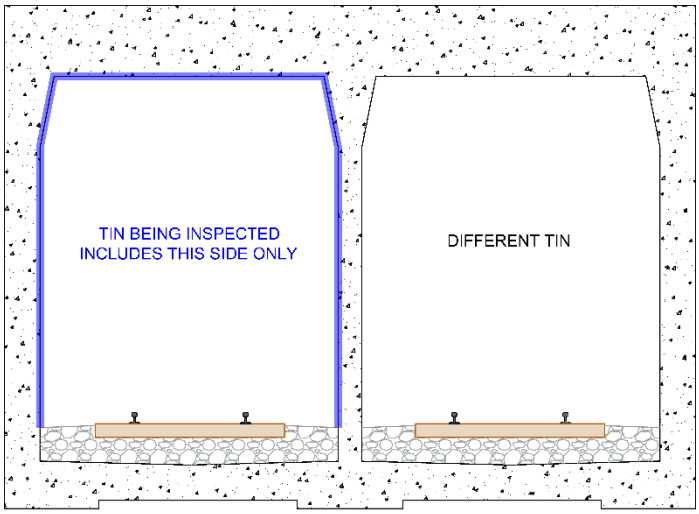


Figure 7.3.4-1 Element Qty Boundary: Liner (SF - Rectangular / Box)

Liner (continued)

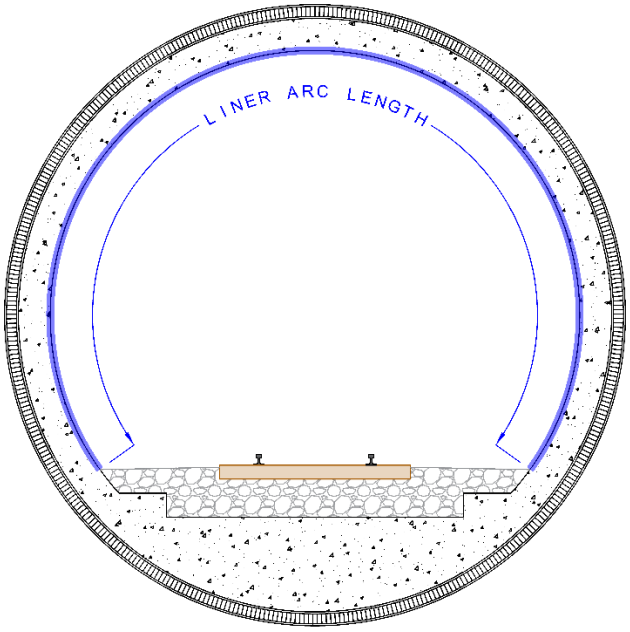


Figure 7.3.4-2 Element Qty Boundary: Liner (SF - Circular & Arch)

Girders: Quantity includes the sum of the individual girder lengths.

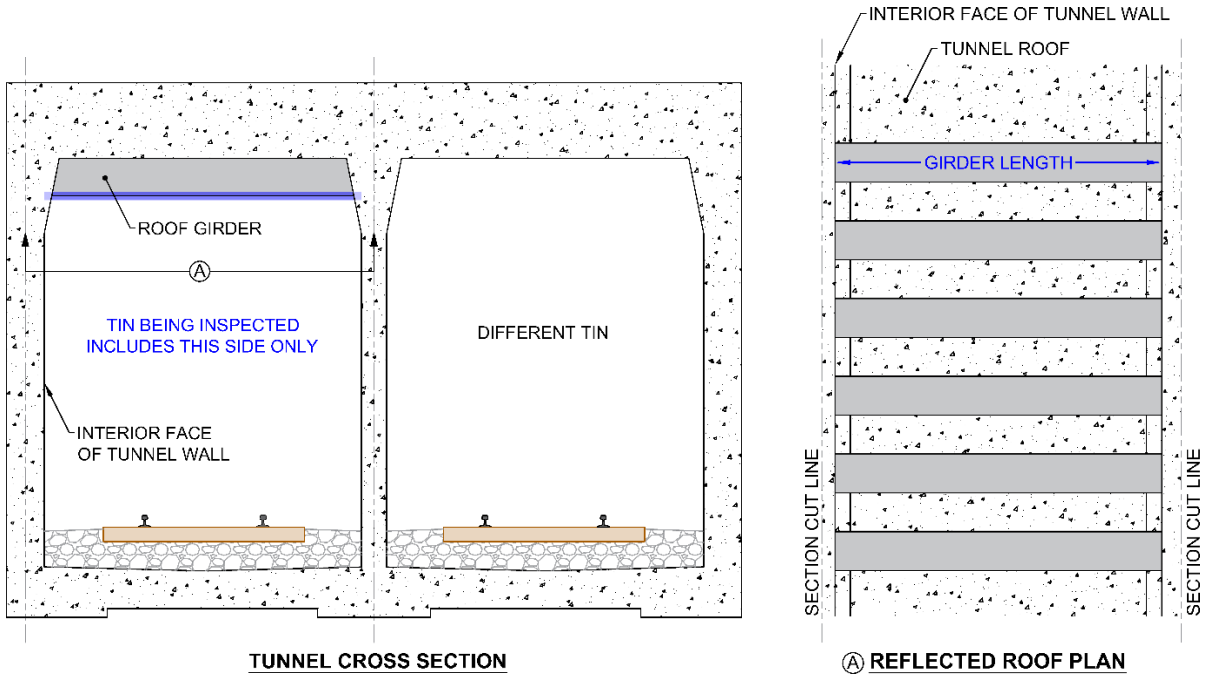


Figure 7.3.4-3 Element Qty Boundary: Girders (LF)

Cross Passage: Quantity includes the sum of the individual cross passage lengths.

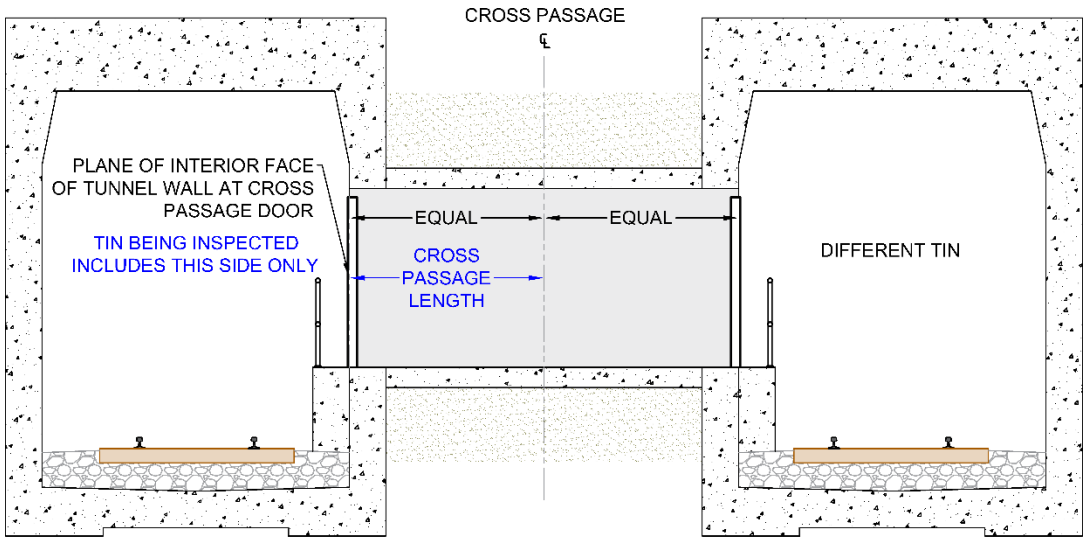


Figure 7.3.4-4 Element Qty Boundary: Cross Passage (LF)

Portal: Quantity includes the sum of the individual portal surface areas. An individual portal area includes the sum of the portal area (shaded in blue) and the wingwall area (shaded in green), if any.

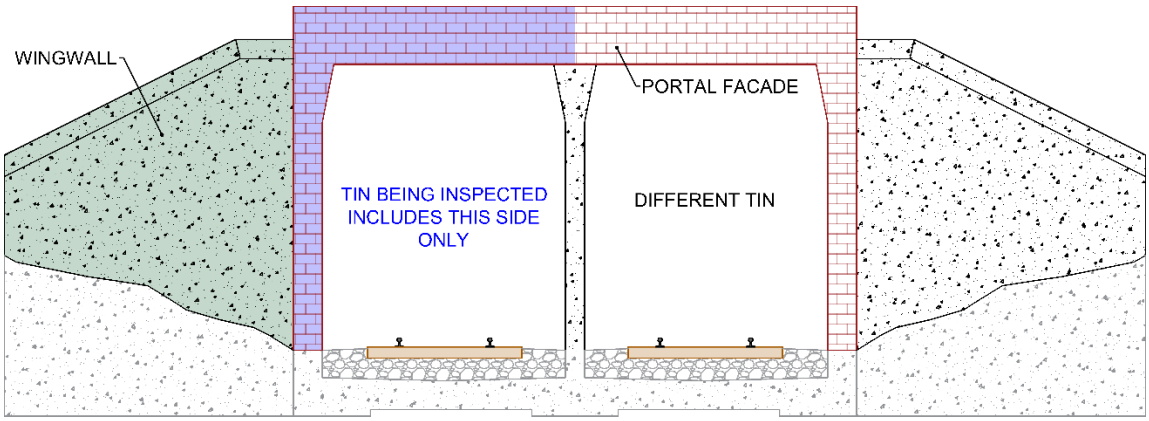


Figure 7.3.4-5 Element Qty Boundary: Portal (SF)

Invert Slab: Quantity includes the surface area of the invert slab projected along the length of the tunnel TIN.

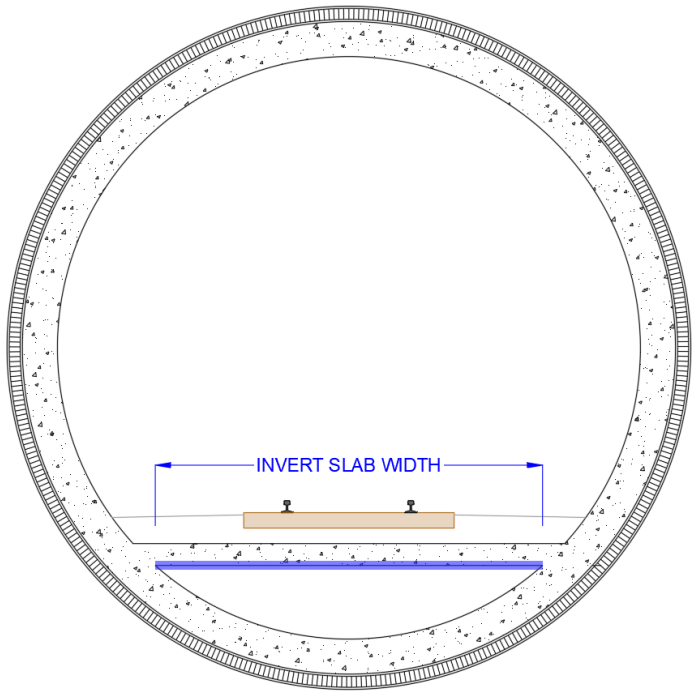


Figure 7.3.4-6 Element Qty Boundary: Invert Slab (SF)

Slab-on-grade: Quantity includes the surface area of the slab-on-grade.

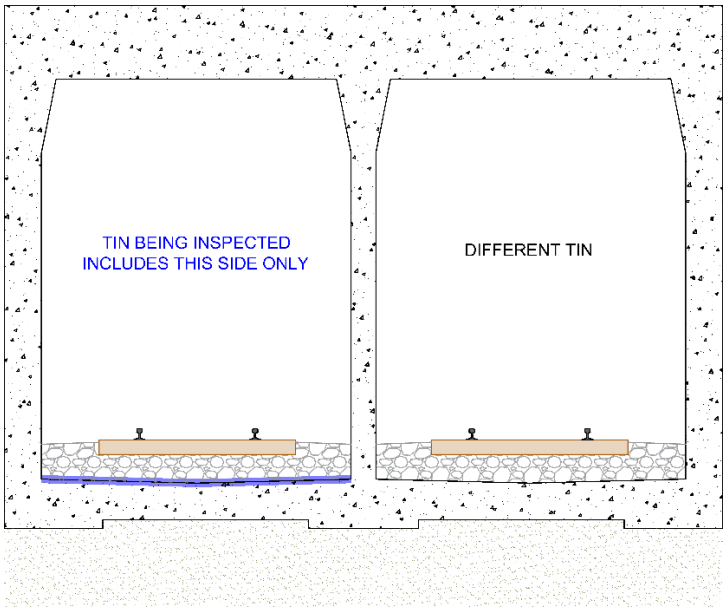


Figure 7.3.4-7 Element Qty Boundary: Slab-on-grade (SF)

Invert Girders: Quantity includes the sum of the individual invert girder lengths.

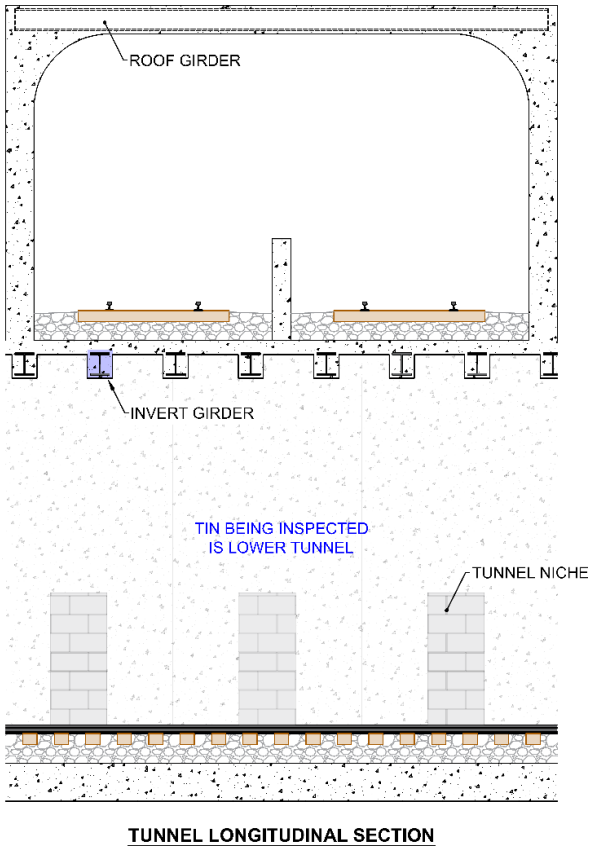


Figure 7.3.4-8 Element Qty Boundary: Invert Girder (LF)

Joint: Quantity includes the sum of lengths (or heights) of joints.

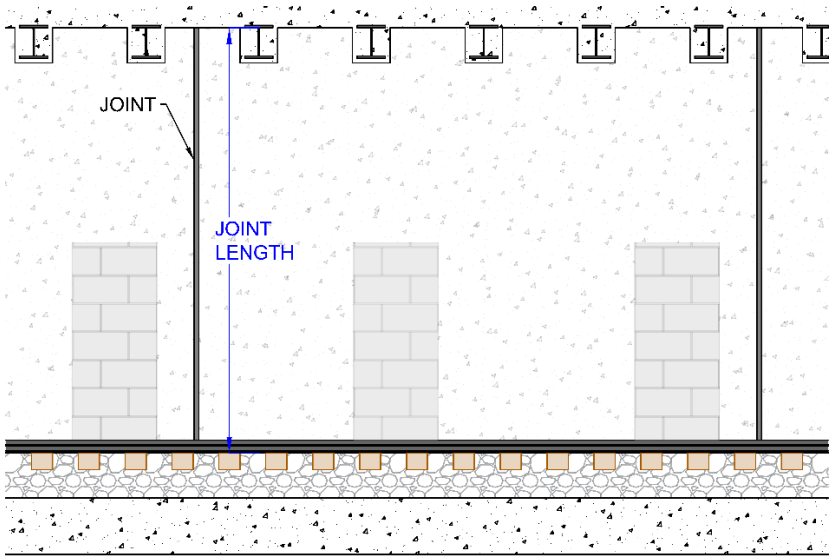


Figure 7.3.4-9 Element Qty Boundary: Joint (LF)

Steel Tie Rod | Tension Member: Quantity includes the total number of steel tie rods or tension members.

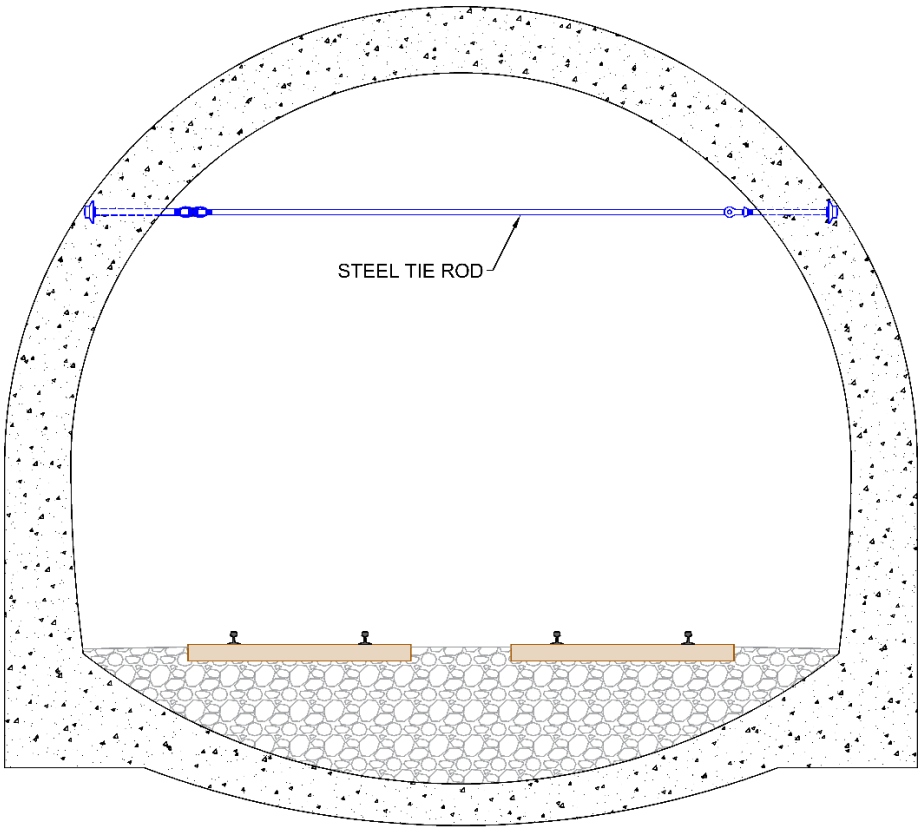


Figure 7.3.4-10 Element Qty Boundary: Steel Tie Rod | Tension Member (EA)

Niches: Quantity includes the total number of niches.

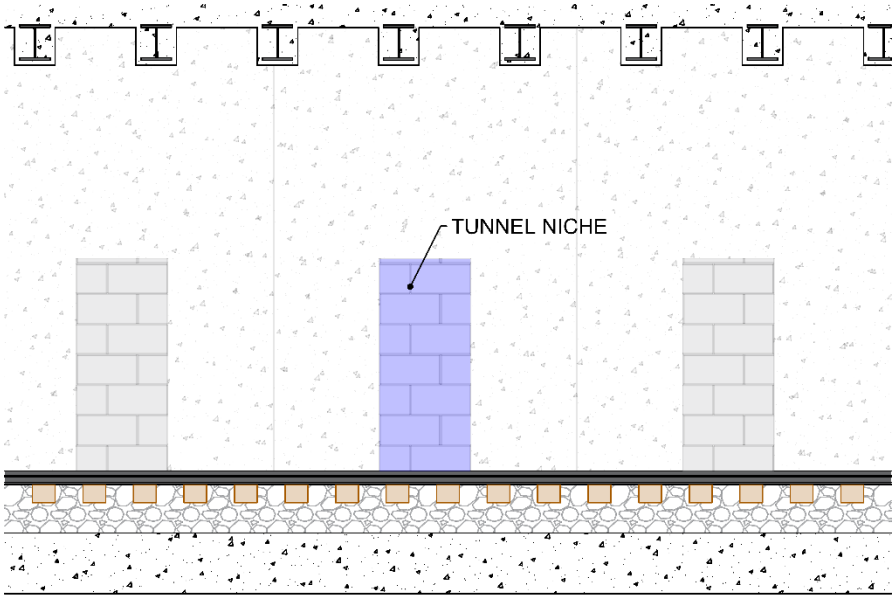


Figure 7.3.4-11 Element Qty Boundary: Niches (EA)

Soil Anchors: Quantity includes the total number of soil anchors.

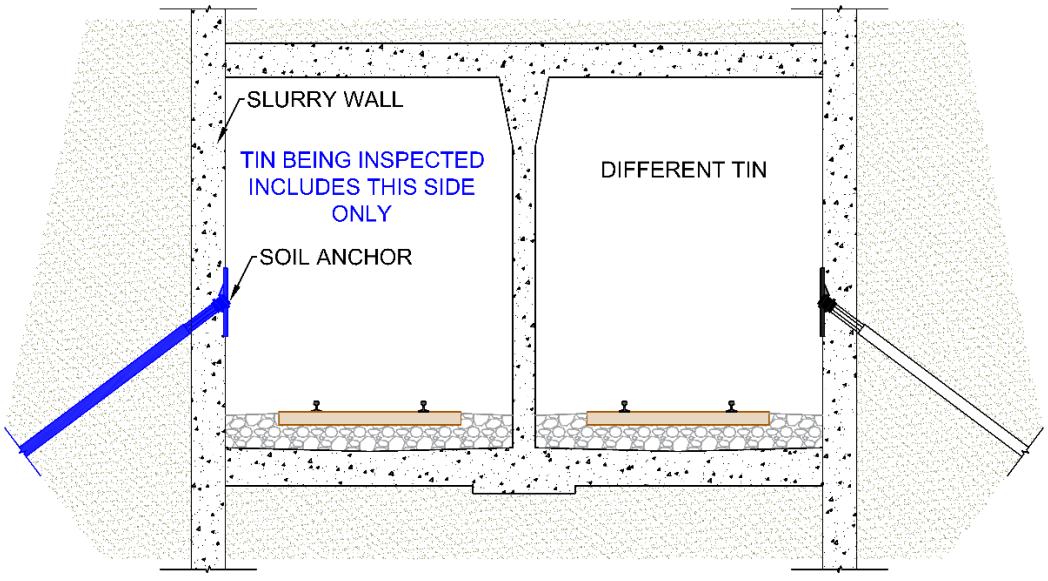


Figure 7.3.4-12 Element Qty Boundary: Soil Anchor (EA)

7.4 Overview of Elements

7.4.1 Parent and Child Elements

Child elements have been developed for some parent elements. The role of a child element is to separate the components of the parent element. This subdivision is performed when the parent element is too large to track as a single element and/or the parent element will have repairs performed to components. The one limitation for creating child elements is that to directly roll up to their parent element, the child elements must have the same defects as the parent element.

7.4.2 List of Elements

Below is a list of all the parent elements for each group. Please refer to individual group sections for a list of child elements associated with each parent element.

Structural/Civil Elements			
10000	Steel Tunnel Liner (SF)	10108	Other Invert Slab (SF)
10001	Cast-In-Place Concrete Tunnel Liner (SF)	10111	Concrete Slab-on-Grade (SF)
10002	Precast Concrete Tunnel Liner (SF)	10119	Other Slab-on-Grade (SF)
10003	Shotcrete Tunnel Liner (SF)	10120	Steel Invert Girder (LF)
10004	Timber Tunnel Liner (SF)	10121	Concrete Invert Girder (LF)
10005	Masonry Tunnel Liner (SF)	10122	Prestressed Concrete Invert Girder (LF)
10010	Steel Tunnel Roof Girders (LF)	10129	Other Invert Girder (LF)
10011	Concrete Tunnel Roof Girders (LF)	10130	Strip Seal Expansion Joint (LF)
10012	Prestressed Concrete Tunnel Roof Girders (LF)	10131	Pourable Joint Seal (LF)
10019	Other Tunnel Roof Girders (LF)	10132	Compression Joint Seal (LF)
10020	Steel Columns | Piles (EA)	10133	Assembly Joint with Seal (LF)
10021	Concrete Columns | Piles (EA)	10134	Open Expansion Joint (LF)
10029	Other Columns | Piles (EA)	10135	Assembly Joint without Seal (LF)
10030	Steel Cross Passageway (LF)	10139	Other Joint (LF)
10031	Concrete Cross Passageway (LF)	10170	Steel Tie | Tension Members (EA)
10034	Timber Cross Passageway (LF)	10180	Tunnel Niches (EA)
10035	Masonry Cross Passageway (LF)	10190	Soil Anchors (EA)
10039	Other Cross Passageway (LF)	10200	Manholes (EA)
10051	Concrete Portal (SF)	10210	Safety Walk (LF)
10055	Masonry Portal (SF)	10220	Fireproofing (SF)
10059	Other Portal (SF)	10230	Ladders (EA)
10101	Concrete Invert Slab (SF)	10240	Concrete Encasement (SF)

Mechanical Elements	
20001	Drainage System (EA)
20002	Pumps (EA)
20102	Flood Gate (EA)
20110	Utility Rooms (EA)

Electrical Elements	
30303	Tunnel Lighting Distribution System (EA)
30304	Tunnel Lighting Fixtures (EA)
30305	Emergency Generator System (EA)
30400	Emergency Lighting Distribution System (EA)
30475	Emergency Lighting Fixtures (EA)
30103	Catenary Support System (EA)

Fire Life Safety Elements	
60650	Fire Detection System (EA)
60750	Emergency Communications System (EA)
60800	Tunnel Operations and Security System (EA)
60805	Emergency Egress (EA)
60809	Cameras (EA)
60810	Portal Alert System (EA)
60601	Ventilation System (EA)
60620	Fans (EA)
60630	Standpipes (EA)

7.5 Structural/Civil Elements

This section defines tunnel structural and civil elements and the methodology for determining total element condition state quantities. The following elements are included.

Element Number	Element Name	Unit of Measurement
10000	Steel Tunnel Liner	SF
Child Elements: 10000.1 - Right Wall, 10000.2 - Left Wall, 10000.3 - Roof, 10000.4 - Interior Wall		
10001	Cast-In-Place Concrete Tunnel Liner	SF
Child Elements: 10001.1 - Right Wall, 10001.2 - Left Wall, 10001.3 - Roof, 10001.4 - Interior Wall		
10002	Precast Concrete Tunnel Liner	SF
Child Elements: 10002.1 - Right Wall, 10002.2 - Left Wall, 10002.3 - Roof, 10002.4 - Interior Wall		
10003	Shotcrete Tunnel Liner	SF
Child Elements: 10003.1 - Right Wall, 10003.2 - Left Wall, 10003.3 - Roof, 10003.4 - Interior Wall		
10004	Timber Tunnel Liner	SF
Child Elements: 10004.1 - Right Wall, 10004.2 - Left Wall, 10004.3 - Roof, 10004.4 - Interior Wall		
10005	Masonry Tunnel Liner	SF
Child Elements: 10005.1 - Right Wall, 10005.2 - Left Wall, 10005.3 - Roof, 10005.4 - Interior Wall		
10010	Steel Tunnel Roof Girders	LF
10011	Concrete Tunnel Roof Girders	LF
10012	Prestressed Concrete Tunnel Roof Girders	LF
10019	Other Tunnel Roof Girders	LF
10020	Steel Columns | Piles	EA
10021	Concrete Columns | Piles	EA
10029	Other Columns | Piles	EA
10030	Steel Cross Passageway	LF
10031	Concrete Cross Passageway	LF
10034	Timber Cross Passageway	LF
10035	Masonry Cross Passageway	LF
10039	Other Cross Passageway	LF
10051	Concrete Portal	SF
10055	Masonry Portal	SF
10059	Other Portal	SF
10101	Concrete Invert Slab	SF
10108	Other Invert Slab	SF
10111	Concrete Slab-on-Grade	SF

Element Number	Element Name	Unit of Measurement
10119	Other Slab-on-Grade	SF
10120	Steel Invert Girder	LF
10121	Concrete Invert Girder	LF
10122	Prestressed Concrete Invert Girder	LF
10129	Other Invert Girder	LF
10130	Strip Seal Expansion Joint	LF
10131	Pourable Joint Seal	LF
10132	Compression Joint Seal	LF
10133	Assembly Joint with Seal	LF
10134	Open Expansion Joint	LF
10135	Assembly Joint without Seal	LF
10139	Other Joint	LF
10170	Steel Tie | Tension Members	EA
10180	Tunnel Niches	EA
10190	Soil Anchors	EA
10200	Manholes	EA
10210	Safety Walk	LF
10220	Fireproofing	SF
Child Elements: 10220.1 - Liner, 10220.2 - Girder, 10220.3 - Other		
10230	Ladders	EA
10240	Concrete Encasement	SF
Child Elements: 10240.1 - Girder, 10240.2 - Column/Piles, 10240.3 - Other		

7.5.1 Steel Tunnel Liner

10000 Steel Tunnel Liner			
Child Element Numbers/Names			
10000.1 - Right Wall	10000.2 - Left Wall	10000.3 - Roof	10000.4 - Interior

Specification	Commentary
Record this element for all steel tunnel liners. Steel tunnel liners function as a shell for the exterior of the tunnel and as a divider between different bores of the tunnel. The area of a tunnel liner is the product of the length (along the centerline) of the tunnel and the perimeter of the liner.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure SF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Corrosion (1001)	No deficiencies	Freckled rust. Corrosion of the steel has initiated.	Surface rust is evident with no section loss.	Section loss is evident, or pack rust is present but does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR structural review has been completed and the defects impact strength and/or serviceability of the element or tunnel.
Cracking (1002)	No deficiencies	Crack that has stopped propagating or has been arrested with an effective retrofit.	Identified crack exists that is continuing to propagate more than 0.250 inches since last inspection.	Identified crack exists that is continuing to propagate more than 0.50 inches since last inspection but does not warrant structural review.	
Connection (1003)	Connection is in place and functioning as intended.	Loose fasteners or pack rust without distortion is present but the connection is in place and functioning as intended.	Loose fasteners or pack rust with minor distortion present but the connection is in place and is functioning mostly as intended.	Missing bolts, rivets or fasteners; broken welds; or pack rust with significant distortion but does not warrant a structural review.	
Distortion (1004)	No deficiencies	Distortion is minor or has been mitigated.	Distortion is moderate and recommend monitoring.	Distortion is significant; however, structural review does not require mitigation.	
Leakage (1007)	No deficiencies	Surface indicating evidence of past seepage.	Damp or partially saturated surface indicating active seepage.	Fully saturated surface with leakage.	Seepage could range from dripping to flowing.

7.5.2 Cast-In-Place Concrete Liner

10001 Cast-in-Place Concrete Tunnel Liner			
Child Element Numbers/Names			
10001.1 - Right Wall	10001.2 - Left Wall	10001.3 - Roof	10001.4 - Interior

Specification	Commentary
Record this element for cast-in-place concrete tunnel liners. Cast-in place concrete tunnel liners function as a shell for the exterior of the tunnel and as divider between different bores of the tunnel. The area of a tunnel liner is the product of the length (along the centerline) of the tunnel and the perimeter of the liner.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure SF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Spall, Honeycombing, Scale (1101)	No deficiencies	Scale, spall, honeycombing with depth less than concrete cover (no reinforcing exposed).	Scale, spall, honeycombing with depth equal to concrete cover (reinforcing exposed).	Scale, spall, honeycombing with depth greater than concrete cover (minor section loss to reinforcing). Does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR structural review has been completed and the defects impact strength and/or serviceability of the element or tunnel.
Delamination, Patched Area (1111)	No deficiencies	Delaminated area present individual areas less than 1SF that is sound. Patched area that is sound.	Delaminated area present individual areas greater than 1SF and less than 3SF that is sound. Patched area that is unsound or showing signs of distress.	Delaminated area present individual areas greater than 3SF and unsound. If delamination or patch area is unsound and showing signs of severe distress/ loose, refer to critical finding protocol.	
Exposed Rebar (1102)	No deficiencies	Present with no or light rust.	Present with heavy rust, but insignificant section loss <10%.	Present with measurable section loss >10%, but does not warrant structural review.	
Efflorescence, Rust Staining (1103)	No deficiencies	Surface white without build up or leaching without rust staining.	Slight build up with minor rust staining.	Heavy build up with significant rust staining.	
Cracking (1104)	Width less than 0.012 in. or spacing greater than 5 ft.	Width between 0.012 - 0.06 in. below spring line or spacing of 3.0 - 5.0 ft.	Width between 0.06 - 0.10 in. below spring line or less than 0.030 in. above spring line or spacing of 1.0 - 3.0 ft.	Width greater than 0.10 in. below spring line or greater than 0.030 in. above spring line or spacing of less than 1 ft.	

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Distortion (1105)	No deficiencies	Distortion is minor or has been mitigated.	Distortion is moderate and monitoring is recommended.	Distortion is significant; however, structural review does not require mitigation.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR structural review has been completed and the defects impact strength and/or serviceability of the element or tunnel.
Leakage (1109)	No deficiencies	Surface indicating evidence of past seepage.	Damp or partially saturated surface indicating active seepage.	Fully saturated surface with leakage.	Seepage could range from dripping to flowing.

7.5.3 Precast Concrete Tunnel Liner

10002 Precast Concrete Tunnel Liner			
Child Element Numbers/Names			
10002.1 - Right Wall	10002.2 - Left Wall	10002.3 - Roof	10002.4 - Interior

Specification	Commentary
Record this element for precast concrete tunnel liners. Precast concrete tunnel liners function as a shell for the exterior of the tunnel and as divider between different bores of the tunnel. The area of a tunnel liner is the product of the length (along the centerline) of the tunnel and the perimeter of the liner.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure SF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Spall, Honeycombing, Scale (1101)	No deficiencies	Scale, spall, honeycombing with depth less than concrete cover (no reinforcing exposed).	Scale, spall, honeycombing with depth equal to concrete cover (reinforcing exposed).	Scale, spall, honeycombing with depth greater than concrete cover (minor section loss to reinforcing). Does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR structural review has been completed and the defects impact strength and/or serviceability of the element or tunnel.
Delamination, Patched Area (1111)	No deficiencies	Delaminated area present individual areas less than 1SF that is sound. Patched area that is sound.	Delaminated area present individual areas greater than 1SF and less than 3SF that is sound. Patched area that is unsound or showing signs of distress.	Delaminated area present individual areas greater than 3SF and unsound. If delamination or patch area is unsound and showing signs of severe distress/ loose, refer to critical finding protocol.	
Exposed Rebar (1102)	No deficiencies	Present with no or light rust.	Present with heavy rust, but insignificant section loss <10%.	Present with measurable section loss >10%, but does not warrant structural review.	
Efflorescence, Rust Staining (1103)	No deficiencies	Surface white without build up or leaching without rust staining.	Slight build up with minor rust staining.	Heavy build up with significant rust staining.	
Cracking (1104)	Width less than 0.012 in. or spacing greater than 5 ft.	Width between 0.012 - 0.06 in. below spring line or spacing of 3.0 - 5.0 ft.	Width between 0.06 - 0.10 in. below spring line or less than 0.030 in. above spring line or spacing of 1.0 - 3.0 ft.	Width greater than 0.10 in. below spring line or greater than 0.030 in. above spring line or spacing of less than 1 ft.	

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Distortion (1105)	No deficiencies	Distortion is minor or has been mitigated.	Distortion is moderate and monitoring is recommended.	Distortion is significant; however, structural review does not require mitigation.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR structural review has been completed and the defects impact strength and/or serviceability of the element or tunnel.
Leakage (1109)	No deficiencies	Surface indicating evidence of past seepage.	Damp or partially saturated surface indicating active seepage.	Fully saturated surface with leakage.	Seepage could range from dripping to flowing.

7.5.4 Shotcrete Tunnel Liner

10003 Shotcrete Tunnel Liner			
Child Element Numbers/Names			
10003.1 - Right Wall	10003.2 - Left Wall	10003.3 - Roof	10003.4 - Interior

Specification	Commentary
Record this element for all shotcrete tunnel liners. Shotcrete tunnel liners function as a shell for the exterior of the tunnel and as divider between different bores of the tunnel. The area of a tunnel liner is the product of the length (along the centerline) of the tunnel and the perimeter of the liner.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure SF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Spall, Honeycombing, Scale (1101)	No deficiencies	Scale, spall, honeycombing with depth less than concrete cover (no reinforcing exposed).	Scale, spall, honeycombing with depth equal to concrete cover (reinforcing exposed).	Scale, spall, honeycombing with depth greater than concrete cover (minor section loss to reinforcing). Does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR structural review has been completed and the defects impact strength and/or serviceability of the element or tunnel.
Delamination, Patched Area (1111)	No deficiencies	Delaminated area present individual areas less than 1SF that is sound. Patched area that is sound.	Delaminated area present individual areas greater than 1SF and less than 3SF that is sound. Patched area that is unsound or showing signs of distress.	Delaminated area present individual areas greater than 3SF and unsound. If delamination or patch area is unsound and showing signs of severe distress/ loose, refer to critical finding protocol.	
Exposed Rebar (1102)	No deficiencies	Present with no or light rust.	Present with heavy rust, but insignificant section loss <10%.	Present with measurable section loss >10%, but does not warrant structural review.	
Efflorescence, Rust Staining (1103)	No deficiencies	Surface white without build up or leaching without rust staining.	Slight build up with minor rust staining.	Heavy build up with significant rust staining.	
Cracking (1104)	Width less than 0.012 in. or spacing greater than 5 ft.	Width between 0.012 - 0.06 in. below spring line or spacing of 3.0 - 5.0 ft.	Width between 0.06 - 0.10 in. below spring line or less than 0.030 in. above spring line or spacing of 1.0 - 3.0 ft.	Width greater than 0.10 in. below spring line or greater than 0.030 in. above spring line or spacing of less than 1 ft.	

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Distortion (1105)	No deficiencies	Distortion is minor or has been mitigated.	Distortion is moderate and monitoring is recommended.	Distortion is significant; however, structural review does not require mitigation.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR structural review has been completed and the defects impact strength and/or serviceability of the element or tunnel.
Leakage (1109)	No deficiencies	Surface indicating evidence of past seepage.	Damp or partially saturated surface indicating active seepage.	Fully saturated surface with leakage.	Seepage could range from dripping to flowing.

7.5.5 Timber Tunnel Liner

10004 Timber Tunnel Liner			
Child Element Numbers/Names			
10004.1 - Right Wall	10004.2 - Left Wall	10004.3 - Roof	10004.4 - Interior

Specification	Commentary
Record this element for all timber tunnel liners consisting of timber sets with or without timber lagging. Timber tunnel liners function as a shell for the exterior of the tunnel and as divider between different bores of the tunnel. The area of a tunnel liner is the product of the length (along the centerline) of the tunnel and the perimeter of the liner.	Timber tunnel liners consist of timber sets spaced along the length of the tunnel. Typically, the space between sets is fitted with timber lagging. In the case where the area between the timber set is not timber lagging also record a linear type, i.e. Unlined Rock, Shotcrete Linear, etc., to identify the area between the timber sets. Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure SF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Decay or Rot (1201)	No deficiencies	Decay has started in the timber sets or lagging. No fungus growth or discoloration is present.	Decay has progressed in the timber sets or lagging. Fungus growth or discoloration is present. There is no loss of strength, deflection or crushing.	Decay has resulted in loss of strength, deflection, or crushing of the element but not of a sufficient magnitude to affect the strength and serviceability of the tunnel. Fungus growth and discoloration is present.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR structural review has been completed and the defects impact strength and/or serviceability of the element or tunnel.
Voids (1202)	No deficiencies	Small voids may exist in the annular space behind the lagging.	Medium voids may exist in the annular space behind the lagging.	Large voids may exist in the annular space behind the lagging.	
Cracks, Splits, Checks (1203)	No deficiencies	Cracks, splits or checks exist in the timber sets or lagging.	Medium cracks, splits or checks exist in the timber sets or lagging and has not impacted strength and/or serviceability.	Large cracks, splits or checks exist in the timber sets or lagging and has impacted strength and/or serviceability but does not warrant a structural review.	
Timber Distortion (1204)	No off-set or misalignment between the timber members (good compression fit).	Off-set or misalignment between timber members may exist but is 1/8 in. or less.	Off-set or misalignment between timber members may exist and is between 1/8 in and 1/2 in.	Off-set or misalignment between timber members may exist and is more than 1/2 in.	

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Insect Infestation (1205)	No deficiencies	Infestation has started in the timber sets or lagging.	Infestation exists in the timber sets or lagging resulting in minor loss of section.	Infestation exists in the timber sets or lagging and has produced loss of strength or deflection of the element but not of a sufficient magnitude to affect the strength and/or serviceability of the tunnel.	
Loose or Missing Connectors (1206)	No deficiencies	Loose bolts, or fasteners are present but the connection is in place and functioning as intended.	Loose bolts, or fasteners are present but the connection is functioning mostly as intended.	Missing bolts or fasteners but does not warrant a structural review.	
Leakage (1208)	No deficiencies	Surface indicating evidence of past seepage.	Damp or partially saturated surface indicating seepage present.	Fully saturated surface with leakage.	Seepage could range from dripping to flowing.

7.5.6 Masonry Tunnel Liner

10005 Masonry Tunnel Liner			
Child Element Numbers/Names			
10005.1 - Right Wall	10005.2 - Left Wall	10005.3 - Roof	10005.4 - Interior

Specification	Commentary
Record this element for all masonry tunnel liners. Masonry tunnel liners function as a shell for the exterior of the tunnel and as divider between different bores of the tunnel. The area of a tunnel liner is the product of the length (along the centerline) of the tunnel and the perimeter of the liner.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure SF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Efflorescence, Rust Staining (1401)	No deficiencies	Surface white without build up or leaching without rust staining.	Surface white with build up or leaching with minor rust staining.	Heavy build up or with heavy rust staining.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR a structural review has been completed and the defects impact strength or serviceability of the element or tunnel.
Mortar Breakdown (1402)	No deficiencies	Cracking or voids in less than 10% of joints.	Cracking or voids between 10% and 15% of joints.	Cracking or voids in 15% or more of the joints.	
Split, Spall (1403)	No deficiencies	Block or stone has minor split or spall with no shifting.	Block or stone has splits or spalls with minor shifting.	Block or stone has splits or spalls with significant shifting but does not warrant a structural review.	
Patched Area (1404)	No deficiencies	Sound patch.	Unsound patch.	Loose or broken patch.	
Masonry Displacement (1405)	No deficiencies	Block or stone has shifted slightly out of alignment.	Block or stone has shifted out of alignment and requires mitigation or monitoring.	Block or stone has shifted significantly out of alignment or is missing but does not warrant structural review.	
Distortion (1406)	No deficiencies	Distortion is minor or has been mitigated.	Distortion is moderate and recommend monitoring.	Distortion is significant; however, structural review does not require mitigation.	
Leakage (1407)	No deficiencies	Surface indicating evidence of past seepage.	Damp or partially saturated surface indicating seepage present	Fully saturated surface with leakage.	Seepage could range from dripping to flowing.

7.5.7 Steel Tunnel Roof Girders

10010 Steel Tunnel Roof Girders	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all steel tunnel roof girders. Tunnel roof girders support the tunnel roof liner or exposed rock which constitutes the tunnel roof. The total length of the tunnel roof girder is the sum of all the lengths of each tunnel roof girder.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure LF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Corrosion (1001)	No deficiencies	Freckled rust. Corrosion of the steel has initiated.	Surface rust is evident with no section loss.	Section loss is evident, or pack rust is present but does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR structural review has been completed and the defects impact strength and/or serviceability of the element or tunnel.
Cracking (1002)	No deficiencies	Crack that has stopped propagating or has been arrested with an effective retrofit.	Identified crack exists that is continuing to propagate more than 0.250 inches since last inspection.	Identified crack exists that is continuing to propagate more than 0.50 inches since last inspection but does not warrant structural review.	
Connection (1003)	Connection is in place and functioning as intended.	Loose fasteners or pack rust without distortion is present but the connection is in place and functioning as intended.	Loose fasteners or pack rust with minor distortion present but the connection is in place and is functioning mostly as intended.	Missing bolts, rivets or fasteners; broken welds; or pack rust with significant distortion but does not warrant a structural review.	
Distortion (1004)	No deficiencies	Distortion is minor or has been mitigated.	Distortion is moderate and recommend monitoring.	Distortion is significant; however, structural review does not require mitigation.	
Leakage (1007)	No deficiencies	Surface indicating evidence of past seepage.	Damp or partially saturated surface indicating active seepage.	Fully saturated surface with leakage.	Seepage could range from dripping to flowing.

7.5.8 Concrete Tunnel Roof Girders

10011 Concrete Tunnel Roof Girders	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all concrete tunnel roof girders. Tunnel roof girders support the tunnel roof liner or exposed rock which constitutes the tunnel roof. The total length of the tunnel roof girder is the sum of all the lengths of each tunnel roof girder.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure LF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Spall, Honeycombing, Scale (1101)	No deficiencies	Scale, spall, honeycombing with depth less than concrete cover (no reinforcing exposed).	Scale, spall, honeycombing with depth equal to concrete cover (reinforcing exposed).	Scale, spall, honeycombing with depth greater than concrete cover (minor section loss to reinforcing). Does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR structural review has been completed and the defects impact strength and/or serviceability of the element or tunnel.
Delamination, Patched Area (1111)	No deficiencies	Delaminated area present individual areas less than 1SF that is sound. Patched area that is sound.	Delaminated area present individual areas greater than 1SF and less than 3SF that is sound. Patched area that is unsound or showing signs of distress.	Delaminated area present individual areas greater than 3SF and unsound. If delamination or patch area is unsound and showing signs of severe distress/ loose, refer to critical finding protocol.	
Exposed Rebar (1102)	No deficiencies	Present with no or light rust.	Present with heavy rust, but insignificant section loss <10%.	Present with measurable section loss >10%, but does not warrant structural review.	
Efflorescence, Rust Staining (1103)	No deficiencies	Surface white without build up or leaching without rust staining.	Slight build up with minor rust staining.	Heavy build up with significant rust staining.	
Cracking (1104)	Width less than 0.012 in. or spacing greater than 5 ft.	Width between 0.012 - 0.06 in. below spring line or spacing of 3.0 - 5.0 ft.	Width between 0.06 - 0.10 in. below spring line or less than 0.030 in. above spring line or spacing of 1.0 - 3.0 ft.	Width greater than 0.10 in. below spring line or greater than 0.030 in. above spring line or spacing of less than 1 ft.	

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Distortion (1105)	No deficiencies	Distortion is minor or has been mitigated.	Distortion is moderate and monitoring is recommended.	Distortion is significant; however, structural review does not require mitigation.	
Leakage (1109)	No deficiencies	Surface indicating evidence of past seepage.	Damp or partially saturated surface indicating active seepage.	Fully saturated surface with leakage.	Seepage could range from dripping to flowing.

7.5.9 Prestressed Concrete Tunnel Roof Girders

10012 Prestressed Concrete Tunnel Roof Girders

Child Element Numbers/Names
None

Specification	Commentary
Record this element for all prestressed concrete tunnel roof girders. Tunnel roof girders support the tunnel roof liner or exposed rock which constitutes the tunnel roof. The total length of the tunnel roof girder is the sum of all the lengths of each tunnel roof girder.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure LF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Spall, Honeycombing, Scale (1101)	No deficiencies	Scale, spall, honeycombing with depth less than concrete cover (no reinforcing exposed).	Scale, spall, honeycombing with depth equal to concrete cover (reinforcing exposed).	Scale, spall, honeycombing with depth greater than concrete cover (minor section loss to reinforcing). Does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR structural review has been completed and the defects impact strength and/or serviceability of the element or tunnel.
Delamination, Patched Area (1111)	No deficiencies	Delaminated area present individual areas less than 1SF that is sound. Patched area that is sound.	Delaminated area present individual areas greater than 1SF and less than 3SF that is sound. Patched area that is unsound or showing signs of distress.	Delaminated area present individual areas greater than 3SF and unsound. If delamination or patch area is unsound and showing signs of severe distress/ loose, refer to critical finding protocol.	

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Exposed Rebar (1102)	No deficiencies	Present with no or light rust.	Present with heavy rust, but insignificant section loss <10%.	Present with measurable section loss >10%, but does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR structural review has been completed and the defects impact strength and/or serviceability of the element or tunnel.
Efflorescence, Rust Staining (1103)	No deficiencies	Surface white without build up or leaching without rust staining.	Slight build up with minor rust staining.	Heavy build up with significant rust staining.	
Cracking (1104)	Width less than 0.012 in. or spacing greater than 5 ft.	Width between 0.012 - 0.06 in. below spring line or spacing of 3.0 - 5.0 ft.	Width between 0.06 - 0.10 in. below spring line or less than 0.030 in. above spring line or spacing of 1.0 - 3.0 ft.	Width greater than 0.10 in. below spring line or greater than 0.030 in. above spring line or spacing of less than 1 ft.	
Exposed Prestressing (1106)	No deficiencies	Present with no or light rust.	Present with heavy rust, but insignificant section loss <10%.	Present with measurable section loss >10%, but does not warrant structural review.	

7.5.10 Other Tunnel Roof Girders

10019 Other Tunnel Roof Girders	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all tunnel roof girders composed of other materials. Tunnel roof girders support the tunnel roof liner or exposed rock which constitutes the tunnel roof. The total length of the tunnel roof girder is the sum of all the lengths of each tunnel roof girder.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure LF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
General Condition (1301)	Excellent condition - no notable distress.	Good condition - isolated breakdowns or deterioration.	Adequate condition - occasional breakdowns or deterioration.	Marginal condition - widespread deterioration or breakdowns without reducing load capacity.	Poor condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR a structural review has been completed and the defects impact strength or serviceability of the element or tunnel.

7.5.11 Steel Column/Piles

10020 Steel Column/Piles

Child Element Numbers/Names
None

Specification	Commentary
Record this element for all steel columns/piles. Tunnel columns support the tunnel roof girders and tunnel invert girders. Tunnel piles provide support for the tunnel columns. The total number of columns/piles is the sum of all the number of columns and piles.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. The majority of the columns/piles will be below grade and therefore not visible for inspection. Unit of Measure EA

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Corrosion (1001)	No deficiencies	Freckled rust. Corrosion of the steel has initiated.	Surface rust is evident with no section loss.	Section loss is evident, or pack rust is present but does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR structural review has been completed and the defects impact strength and/or serviceability of the element or tunnel.
Cracking (1002)	No deficiencies	Crack that has stopped propagating or has been arrested with an effective retrofit.	Identified crack exists that is continuing to propagate more than 0.250 inches since last inspection.	Identified crack exists that is continuing to propagate more than 0.50 inches since last inspection but does not warrant structural review.	
Connection (1003)	Connection is in place and functioning as intended.	Loose fasteners or pack rust without distortion is present but the connection is in place and functioning as intended.	Loose fasteners or pack rust with minor distortion present but the connection is in place and is functioning mostly as intended.	Missing bolts, rivets or fasteners; broken welds; or pack rust with significant distortion but does not warrant a structural review.	
Distortion (1004)	No deficiencies	Distortion is minor or has been mitigated.	Distortion is moderate and recommend monitoring.	Distortion is significant; however, structural review does not require mitigation.	

7.5.12 Concrete Column/Piles

10021 Concrete Column/Piles	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all concrete columns/piles. Tunnel columns support the tunnel roof girders and tunnel invert girders. Tunnel piles provide support for the tunnel columns. The total number of columns/piles is the sum of all the number of columns and piles.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. The majority of the columns/piles will be below grade and therefore not visible for inspection. Unit of Measure EA

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Spall, Honeycombing, Scale (1101)	No deficiencies	Scale, spall, honeycombing with depth less than concrete cover (no reinforcing exposed).	Scale, spall, honeycombing with depth equal to concrete cover (reinforcing exposed).	Scale, spall, honeycombing with depth greater than concrete cover (minor section loss to reinforcing). Does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR structural review has been completed and the defects impact strength and/or serviceability of the element or tunnel.
Delamination, Patched Area (1111)	No deficiencies	Delaminated area present individual areas less than 1SF that is sound. Patched area that is sound.	Delaminated area present individual areas greater than 1SF and less than 3SF that is sound. Patched area that is unsound or showing signs of distress.	Delaminated area present individual areas greater than 3SF and unsound. If delamination or patch area is unsound and showing signs of severe distress/ loose, refer to critical finding protocol.	

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Exposed Rebar (1102)	No deficiencies	Present with no or light rust.	Present with heavy rust, but insignificant section loss <10%.	Present with measurable section loss >10%, but does not warrant structural review.	
Efflorescence, Rust Staining (1103)	No deficiencies	Surface white without build up or leaching without rust staining.	Slight build up with minor rust staining.	Heavy build up with significant rust staining.	
Cracking (1104)	Width less than 0.012 in. or spacing greater than 5 ft.	Width between 0.012 - 0.06 in. below spring line or spacing of 3.0 - 5.0 ft.	Width between 0.06 - 0.10 in. below spring line or less than 0.030 in. above spring line or spacing of 1.0 - 3.0 ft.	Width greater than 0.10 in. below spring line or greater than 0.030 in. above spring line or spacing of less than 1 ft.	

7.5.13 Other Column/Piles

10029 Other Column/Piles

Child Element Numbers/Names
None

Specification	Commentary
Record this element for all columns/piles composed of other material. Tunnel columns support the tunnel roof girders and tunnel invert girders. Tunnel piles provide support for the tunnel columns. The total number of columns/piles is the sum of all the number of columns and piles.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. The majority of the columns/piles will be below grade and therefore not visible for inspection. Unit of Measure EA

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
General Condition (1301)	Excellent condition - no notable distress.	Good condition - isolated breakdowns or deterioration.	Adequate condition - occasional breakdowns or deterioration.	Marginal condition - widespread deterioration or breakdowns without reducing load capacity.	Poor condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR a structural review has been completed and the defects impact strength or serviceability of the element or tunnel.

7.5.14 Steel Cross Passageway

10030 Steel Cross Passageway	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all steel cross passageways. Cross passageways are typically oriented transverse to the tunnel bores and are comprised of doors to allow egress between separated tunnel bores. The total length of the cross passageway is the sum of all the lengths of each cross passageway.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure LF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Corrosion (1001)	No deficiencies	Freckled rust. Corrosion of the steel has initiated.	Surface rust is evident with no section loss.	Section loss is evident, or pack rust is present but does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR structural review has been completed and the defects impact strength and/or serviceability of the element or tunnel.
Cracking (1002)	No deficiencies	Crack that has stopped propagating or has been arrested with an effective retrofit.	Identified crack exists that is continuing to propagate more than 0.250 inches since last inspection.	Identified crack exists that is continuing to propagate more than 0.50 inches since last inspection but does not warrant structural review.	
Connection (1003)	Connection is in place and functioning as intended.	Loose fasteners or pack rust without distortion is present but the connection is in place and functioning as intended.	Loose fasteners or pack rust with minor distortion present but the connection is in place and is functioning mostly as intended.	Missing bolts, rivets or fasteners; broken welds; or pack rust with significant distortion but does not warrant a structural review.	
Distortion (1004)	No deficiencies	Distortion is minor or has been mitigated.	Distortion is moderate and recommend monitoring.	Distortion is significant; however, structural review does not require mitigation.	
Leakage (1007)	No deficiencies	Surface indicating evidence of past seepage.	Damp or partially saturated surface indicating active seepage.	Fully saturated surface with leakage.	Seepage could range from dripping to flowing.

7.5.15 Concrete Cross Passageway

10031 Concrete Cross Passageway	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all concrete cross passageways. Cross passageways are typically oriented transverse to the tunnel bores and are comprised of doors to allow egress between separated tunnel bores. The total length of the cross passageway is the sum of all the lengths of each cross passageway.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure LF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Spall, Honeycombing, Scale (1101)	No deficiencies	Scale, spall, honeycombing with depth less than concrete cover (no reinforcing exposed).	Scale, spall, honeycombing with depth equal to concrete cover (reinforcing exposed).	Scale, spall, honeycombing with depth greater than concrete cover (minor section loss to reinforcing). Does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR structural review has been completed and the defects impact strength and/or serviceability of the element or tunnel.
Delamination, Patched Area (1111)	No deficiencies	Delaminated area present individual areas less than 1SF that is sound. Patched area that is sound.	Delaminated area present individual areas greater than 1SF and less than 3SF that is sound. Patched area that is unsound or showing signs of distress.	Delaminated area present individual areas greater than 3SF and unsound. If delamination or patch area is unsound and showing signs of severe distress/ loose, refer to critical finding protocol.	
Exposed Rebar (1102)	No deficiencies	Present with no or light rust.	Present with heavy rust, but insignificant section loss <10%.	Present with measurable section loss >10%, but does not warrant structural review.	
Efflorescence, Rust Staining (1103)	No deficiencies	Surface white without build up or leaching without rust staining.	Slight build up with minor rust staining.	Heavy build up with significant rust staining.	
Cracking (1104)	Width less than 0.012 in. or spacing greater than 5 ft.	Width between 0.012 - 0.06 in. below spring line or spacing of 3.0 - 5.0 ft.	Width between 0.06 - 0.10 in. below spring line or less than 0.030 in. above spring line or spacing of 1.0 - 3.0 ft.	Width greater than 0.10 in. below spring line or greater than 0.030 in. above spring line or spacing of less than 1 ft.	

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Distortion (1105)	No deficiencies	Distortion is minor or has been mitigated.	Distortion is moderate and monitoring is recommended.	Distortion is significant; however, structural review does not require mitigation.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR structural review has been completed and the defects impact strength and/or serviceability of the element or tunnel.
Leakage (1109)	No deficiencies	Surface indicating evidence of past seepage.	Damp or partially saturated surface indicating active seepage.	Fully saturated surface with leakage.	Seepage could range from dripping to flowing.

7.5.16 Timber Cross Passageway

10034 Timber Cross Passageway	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all timber cross passageways. Cross passageways are typically oriented transverse to the tunnel bores and are comprised of doors to allow egress between separated tunnel bores. The total length of the cross passageway is the sum of all the lengths of each cross passageway.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure LF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Decay or Rot (1201)	No deficiencies	Decay has started in the timber sets or lagging. No fungus growth or discoloration is present.	Decay has progressed in the timber sets or lagging. Fungus growth or discoloration is present. There is no loss of strength, deflection or crushing.	Decay has resulted in loss of strength, deflection, or crushing of the element but not of a sufficient magnitude to affect the strength and serviceability of the tunnel. Fungus growth and discoloration is present.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR structural review has been completed and the defects impact strength and/or serviceability of the element or tunnel.
Voids (1202)	No deficiencies	Small voids may exist in the annular space behind the lagging.	Medium voids may exist in the annular space behind the lagging.	Large voids may exist in the annular space behind the lagging.	
Cracks, Splits, Checks (1203)	No deficiencies	Cracks, splits or checks exist in the timber sets or lagging.	Medium cracks, splits or checks exist in the timber sets or lagging and has not impacted strength and/or serviceability.	Large cracks, splits or checks exist in the timber sets or lagging and has impacted strength and/or serviceability but does not warrant a structural review.	
Timber Distortion (1204)	No off-set or misalignment between the timber members (good compression fit).	Off-set or misalignment between timber members may exist but is 1/8 in. or less.	Off-set or misalignment between timber members may exist and is between 1/8 in and 1/2 in.	Off-set or misalignment between timber members may exist and is more than 1/2 in.	

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Insect Infestation (1205)	No deficiencies	Infestation has started in the timber sets or lagging.	Infestation exists in the timber sets or lagging resulting in minor loss of section.	Infestation exists in the timber sets or lagging and has produced loss of strength or deflection of the element but not of a sufficient magnitude to affect the strength and/or serviceability of the tunnel.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR structural review has been completed and the defects impact strength and/or serviceability of the element or tunnel.
Loose or Missing Connectors (1206)	No deficiencies	Loose bolts, or fasteners are present but the connection is in place and functioning as intended.	Loose bolts, or fasteners are present but the connection is functioning mostly as intended.	Missing bolts or fasteners but does not warrant a structural review.	
Leakage (1208)	No deficiencies	Surface indicating evidence of past seepage.	Damp or partially saturated surface indicating seepage present.	Fully saturated surface with leakage.	Seepage could range from dripping to flowing.

7.5.17 Masonry Cross Passageway

10035 Masonry Cross Passageway	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all masonry cross passageways. Cross passageways are typically oriented transverse to the tunnel bores and are comprised of doors to allow egress between separated tunnel bores. The total length of the cross passageway is the sum of all the lengths of each cross passageway.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure LF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Efflorescence, Rust Staining (1401)	No deficiencies	Surface white without build up or leaching without rust staining.	Surface white with build up or leaching with minor rust staining.	Heavy build up or with heavy rust staining.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR a structural review has been completed and the defects impact strength or serviceability of the element or tunnel.
Mortar Breakdown (1402)	No deficiencies	Cracking or voids in less than 10% of joints.	Cracking or voids between 10% and 15% of joints.	Cracking or voids in 15% or more of the joints.	
Split, Spall (1403)	No deficiencies	Block or stone has minor split or spall with no shifting.	Block or stone has splits or spalls with minor shifting.	Block or stone has splits or spalls with significant shifting but does not warrant a structural review.	
Patched Area (1404)	No deficiencies	Patched area that is sound.	Patched area that is unsound or showing distress.	Unsound patch.	
Masonry Displacement (1405)	No deficiencies	Block or stone has shifted slightly out of alignment.	Block or stone has shifted out of alignment and requires mitigation or monitoring.	Block or stone has shifted significantly out of alignment or is missing but does not warrant structural review.	
Distortion (1406)	No deficiencies	Distortion is minor or has been mitigated.	Distortion is moderate and recommend monitoring.	Distortion is significant; however, structural review does not require mitigation.	
Leakage (1407)	No deficiencies	Surface indicating evidence of past seepage.	Damp or partially saturated surface indicating seepage present	Fully saturated surface with leakage.	Seepage could range from dripping to flowing.

7.5.18 Other Cross Passageway

10039 Other Cross Passageway	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all other cross passageways. Cross passageways are typically oriented transverse to the tunnel bores and are comprised of doors to allow egress between separated tunnel bores. The total length of the cross passageway is the sum of all the lengths of each cross passageway.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure LF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
General Condition (1301)	Excellent condition - no notable distress.	Good condition - isolated breakdowns or deterioration.	Adequate condition - occasional breakdowns or deterioration.	Marginal condition - widespread deterioration or breakdowns without reducing load capacity.	Poor condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR a structural review has been completed and the defects impact strength or serviceability of the element or tunnel.

7.5.19 Concrete Portal

10051 Concrete Portal	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all concrete portals. This element defines the portal facade, which comprise the architectural/ structural elements that are above the roadway at the opening of the tunnel. The area of the portal is the product of the width and height of the portal minus the area of the track opening. The area may include wingwalls which retain soils and rock near the portal but does not include walls leading up to the portal.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure SF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Spall, Honeycombing, Scale (1101)	No deficiencies	Scale, spall, honeycombing with depth less than concrete cover (no reinforcing exposed).	Scale, spall, honeycombing with depth equal to concrete cover (reinforcing exposed).	Scale, spall, honeycombing with depth greater than concrete cover (minor section loss to reinforcing). Does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR structural review has been completed and the defects impact strength and/or serviceability of the element or tunnel.

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Delamination, Patched Area (1111)	No deficiencies	Delaminated area present individual areas less than 1SF that is sound. Patched area that is sound.	Delaminated area present individual areas greater than 1SF and less than 3SF that is sound. Patched area that is unsound or showing signs of distress.	Delaminated area present individual areas greater than 3SF and unsound. If delamination or patch area is unsound and showing signs of severe distress/ loose, refer to critical finding protocol.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR structural review has been completed and the defects impact strength and/or serviceability of the element or tunnel.
Exposed Rebar (1102)	No deficiencies	Present with no or light rust.	Present with heavy rust, but insignificant section loss <10%.	Present with measurable section loss >10%, but does not warrant structural review.	
Efflorescence, Rust Staining (1103)	No deficiencies	Surface white without build up or leaching without rust staining.	Slight build up with minor rust staining.	Heavy build up with significant rust staining.	
Cracking (1104)	Width less than 0.012 in. or spacing greater than 5 ft.	Width between 0.012 - 0.06 in. below spring line or spacing of 3.0 - 5.0 ft.	Width between 0.06 - 0.10 in. below spring line or less than 0.030 in. above spring line or spacing of 1.0 - 3.0 ft.	Width greater than 0.10 in. below spring line or greater than 0.030 in. above spring line or spacing of less than 1 ft.	
Settlement (1110)	No deficiencies	Exists within tolerable limits or arrested with no observed structural distress.	Exists with minor signs of structural distress.	Exceeds tolerable limits but does not warrant structural review.	

7.5.20 Masonry Portal

10055 Masonry Portal	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all masonry portals. This element defines the portal facade, which comprise the architectural/ structural elements that are above the roadway at the opening of the tunnel. The area of the portal is the product of the width and height of the portal minus the area of the track opening. The track may include wingwalls which retain soils and rock near the portal but does not include walls leading up to the portal.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure SF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Efflorescence, Rust Staining (1401)	No deficiencies	Surface white without build up or leaching without rust staining.	Surface white with build up or leaching with minor rust staining.	Heavy build up or with heavy rust staining.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR a structural review has been completed and the defects impact strength or serviceability of the element or tunnel.
Mortar Breakdown (1402)	No deficiencies	Cracking or voids in less than 10% of joints.	Cracking or voids between 10% and 15% of joints.	Cracking or voids in 15% or more of the joints.	
Split, Spall (1403)	No deficiencies	Block or stone has minor split or spall with no shifting.	Block or stone has splits or spalls with minor shifting.	Block or stone has splits or spalls with significant shifting but does not warrant a structural review.	
Patched Area (1404)	No deficiencies	Patched area that is sound.	Patched area that is unsound or showing distress.	Unsound patch.	
Masonry Displacement (1405)	No deficiencies	Block or stone has shifted slightly out of alignment.	Block or stone has shifted out of alignment and requires mitigation or monitoring.	Block or stone has shifted significantly out of alignment or is missing but does not warrant structural review.	
Distortion (1408)	No deficiencies	Exists within tolerable limits or arrested with no observed structural distress.	Exists with minor signs of structural distress.	Exceeds tolerable limits but does not warrant structural review.	

7.5.21 Other Portal

10059 Other Portal	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all portals composed of other materials. This element defines the portal facade, which comprise the architectural/structural elements that are above the roadway at the opening of the tunnel bore. The area of the portal is the product of the width and height of the portal minus the area of the roadway opening. The area may include wingwalls which retain soils and rock near the portal but does not include walls leading up to the portal.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure SF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
General Condition (1301)	Excellent condition - no notable distress.	Good condition - isolated breakdowns or deterioration.	Adequate condition - occasional breakdowns or deterioration.	Marginal condition - widespread deterioration or breakdowns without reducing load capacity.	Poor condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR a structural review has been completed and the defects impact strength or serviceability of the element or tunnel.
Settlement (1110)	No deficiencies	Exists within tolerable limits or arrested with no observed structural distress.	Exists with minor signs of structural distress.	Exceeds tolerable limits but does not warrant structural review.	

7.5.22 Concrete Invert Slab

10101 Concrete Invert Slab	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all concrete invert slabs. This element defines those structural slabs which support the roadway and traffic loads. The total area of the invert slab is the product of the width and length of the slab.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. The slab evaluation is three dimensional with the defects observed on the top surface, bottom surface, or both, and being captured using the defined condition states. Slab top or bottom surfaces that are not visible for inspection shall be assessed based on the available visible surface. If both top and bottom surfaces are not visible, the condition shall be assessed based on destructive and nondestructive testing or indicators in the materials covering the surfaces. Unit of Measure SF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Spall, Honeycombing, Scale (1101)	No deficiencies	Scale, spall, honeycombing with depth less than concrete cover (no reinforcing exposed).	Scale, spall, honeycombing with depth equal to concrete cover (reinforcing exposed).	Scale, spall, honeycombing with depth greater than concrete cover (minor section loss to reinforcing). Does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR structural review has been completed and the defects impact strength and/or serviceability of the element or tunnel.

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Delamination, Patched Area (1111)	No deficiencies	Delaminated area present individual areas less than 1SF that is sound. Patched area that is sound.	Delaminated area present individual areas greater than 1SF and less than 3SF that is sound. Patched area that is unsound or showing signs of distress.	Delaminated area present individual areas greater than 3SF and unsound. If delamination or patch area is unsound and showing signs of severe distress/ loose, refer to critical finding protocol.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR structural review has been completed and the defects impact strength and/or serviceability of the element or tunnel.
Exposed Rebar (1102)	No deficiencies	Present with no or light rust.	Present with heavy rust, but insignificant section loss <10%.	Present with measurable section loss >10%, but does not warrant structural review.	
Efflorescence, Rust Staining (1103)	No deficiencies	Surface white without build up or leaching without rust staining.	Slight build up with minor rust staining.	Heavy build up with significant rust staining.	
Cracking (1104)	Width less than 0.012 in. or spacing greater than 5 ft.	Width between 0.012 - 0.06 in. below spring line or spacing of 3.0 - 5.0 ft.	Width between 0.06 - 0.10 in. below spring line or less than 0.030 in. above spring line or spacing of 1.0 - 3.0 ft.	Width greater than 0.10 in. below spring line or greater than 0.030 in. above spring line or spacing of less than 1 ft.	

7.5.23 Other Invert Slab

10108 Other Invert Slab	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all invert slabs composed of other materials. This element defines those structural slabs which support the train loading. The total area of the invert slab is the product of the width and length of the slab.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. The slab evaluation is three dimensional with the defects observed on the top surface, bottom surface, or both, and being captured using the defined condition states. Slab top or bottom surfaces that are not visible for inspection shall be assessed based on the available visible surface. If both top and bottom surfaces are not visible, the condition shall be assessed based on destructive and nondestructive testing or indicators in the materials covering the surfaces. Unit of Measure SF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
General Condition (1301)	Excellent condition - no notable distress.	Good condition - isolated breakdowns or deterioration.	Adequate condition - occasional breakdowns or deterioration.	Marginal condition - widespread deterioration or breakdowns without reducing load capacity.	Poor condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR a structural review has been completed and the defects impact strength or serviceability of the element or tunnel.

7.5.24 Concrete Slab-on-Grade

10111 Concrete Slab-on-Grade	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all concrete slabs-on-grade. This element defines a slab that is supported continuously on a subbase material. The area of the slab-on-grade is the product of the width and length of the slab.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure SF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Spall, Honeycombing, Scale (1101)	No deficiencies	Scale, spall, honeycombing with depth less than concrete cover (no reinforcing exposed).	Scale, spall, honeycombing with depth equal to concrete cover (reinforcing exposed).	Scale, spall, honeycombing with depth greater than concrete cover (minor section loss to reinforcing). Does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR structural review has been completed and the defects impact strength and/or serviceability of the element or tunnel.
Delamination, Patched Area (1111)	No deficiencies	Delaminated area present individual areas less than 1SF that is sound. Patched area that is sound.	Delaminated area present individual areas greater than 1SF and less than 3SF that is sound. Patched area that is unsound or showing signs of distress.	Delaminated area present individual areas greater than 3SF and unsound. If delamination or patch area is unsound and showing signs of severe distress/ loose, refer to critical finding protocol.	

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Exposed Rebar (1102)	No deficiencies	Present with no or light rust.	Present with heavy rust, but insignificant section loss <10%.	Present with measurable section loss >10%, but does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR structural review has been completed and the defects impact strength and/or serviceability of the element or tunnel.
Cracking (1104)	Width less than 0.012 in. or spacing greater than 5 ft.	Width between 0.012 - 0.06 in. below spring line or spacing of 3.0 - 5.0 ft.	Width between 0.06 - 0.10 in. below spring line or less than 0.030 in. above spring line or spacing of 1.0 - 3.0 ft.	Width greater than 0.10 in. below spring line or greater than 0.030 in. above spring line or spacing of less than 1 ft.	
Settlement (1110)	No deficiencies	Exists within tolerable limits or arrested with no observed structural distress.	Exists with minor signs of structural distress.	Exceeds tolerable limits but does not warrant structural review.	

7.5.25 Other Slab-on-Grade

10119 Other Slab-on-Grade	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all slabs-on-grade composed of other materials. This element defines a slab that is supported continuously on a subbase material. The area of the slab-on-grade is the product of the width and length of the slab.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure SF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
General Condition (1301)	Excellent condition - no notable distress.	Good condition - isolated breakdowns or deterioration.	Adequate condition - occasional breakdowns or deterioration.	Marginal condition - widespread deterioration or breakdowns without reducing load capacity.	Poor condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR a structural review has been completed and the defects impact strength or serviceability of the element or tunnel.
Settlement (1110)	No deficiencies	Exists within tolerable limits or arrested with no observed structural distress.	Exists with minor signs of structural distress.	Exceeds tolerable limits but does not warrant structural review.	

7.5.26 Steel Invert Girder

10120 Steel Invert Girder	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all steel invert girders. This element defines the invert girders which support the invert slabs. The total quantity for invert girder is the sum of all the lengths of each invert girder.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure LF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Corrosion (1001)	No deficiencies	Freckled rust. Corrosion of the steel has initiated.	Surface rust is evident with no section loss.	Section loss is evident, or pack rust is present but does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR structural review has been completed and the defects impact strength and/or serviceability of the element or tunnel.
Cracking (1002)	No deficiencies	Crack that has stopped propagating or has been arrested with an effective retrofit.	Identified crack exists that is continuing to propagate more than 0.250 inches since last inspection.	Identified crack exists that is continuing to propagate more than 0.50 inches since last inspection but does not warrant structural review.	
Connection (1003)	Connection is in place and functioning as intended.	Loose fasteners or pack rust without distortion is present but the connection is in place and functioning as intended.	Loose fasteners or pack rust with minor distortion present but the connection is in place and is functioning mostly as intended.	Missing bolts, rivets or fasteners; broken welds; or pack rust with significant distortion but does not warrant a structural review.	
Distortion (1004)	No deficiencies	Distortion is minor or has been mitigated.	Distortion is moderate and recommend monitoring.	Distortion is significant; however, structural review does not require mitigation.	

7.5.27 Concrete Invert Girder

10121 Concrete Invert Girder	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all concrete invert girders. This element defines the invert girders which support the invert slabs. The total quantity for invert girder is the sum of all the lengths of each invert girder.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure LF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Spall, Honeycombing, Scale (1101)	No deficiencies	Scale, spall, honeycombing with depth less than concrete cover (no reinforcing exposed).	Scale, spall, honeycombing with depth equal to concrete cover (reinforcing exposed).	Scale, spall, honeycombing with depth greater than concrete cover (minor section loss to reinforcing). Does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR structural review has been completed and the defects impact strength and/or serviceability of the element or tunnel.
Delamination, Patched Area (1111)	No deficiencies	Delaminated area present individual areas less than 1SF that is sound. Patched area that is sound.	Delaminated area present individual areas greater than 1SF and less than 3SF that is sound. Patched area that is unsound or showing signs of distress.	Delaminated area present individual areas greater than 3SF and unsound. If delamination or patch area is unsound and showing signs of severe distress/ loose, refer to critical finding protocol.	

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Exposed Rebar (1102)	No deficiencies	Present with no or light rust.	Present with heavy rust, but insignificant section loss <10%.	Present with measurable section loss >10%, but does not warrant structural review.	
Efflorescence, Rust Staining (1103)	No deficiencies	Surface white without build up or leaching without rust staining.	Slight build up with minor rust staining.	Heavy build up with significant rust staining.	
Cracking (1104)	Width less than 0.012 in. or spacing greater than 5 ft.	Width between 0.012 - 0.06 in. below spring line or spacing of 3.0 - 5.0 ft.	Width between 0.06 - 0.10 in. below spring line or less than 0.030 in. above spring line or spacing of 1.0 - 3.0 ft.	Width greater than 0.10 in. below spring line or greater than 0.030 in. above spring line or spacing of less than 1 ft.	

7.5.28 Prestressed Concrete Invert Girder

10122 Prestressed Concrete Invert Girder	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all prestressed concrete invert girders. This element defines the invert girders which support the invert slabs. The total quantity for invert girder is the sum of all the lengths of each invert girder.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure LF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Spall, Honeycombing, Scale (1101)	No deficiencies	Scale, spall, honeycombing with depth less than concrete cover (no reinforcing exposed).	Scale, spall, honeycombing with depth equal to concrete cover (reinforcing exposed).	Scale, spall, honeycombing with depth greater than concrete cover (minor section loss to reinforcing). Does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR structural review has been completed and the defects impact strength and/or serviceability of the element or tunnel.
Delamination, Patched Area (1111)	No deficiencies	Delaminated area present individual areas less than 1SF that is sound. Patched area that is sound.	Delaminated area present individual areas greater than 1SF and less than 3SF that is sound. Patched area that is unsound or showing signs of distress.	Delaminated area present individual areas greater than 3SF and unsound. If delamination or patch area is unsound and showing signs of severe distress/ loose, refer to critical finding protocol.	
Exposed Rebar (1102)	No deficiencies	Present with no or light rust.	Present with heavy rust, but insignificant section loss <10%.	Present with measurable section loss >10%, but does not warrant structural review.	
Efflorescence, Rust Staining (1103)	No deficiencies	Surface white without build up or leaching without rust staining.	Slight build up with minor rust staining.	Heavy build up with significant rust staining.	
Cracking (1104)	Width less than 0.012 in. or spacing greater than 5 ft.	Width between 0.012 - 0.06 in. below spring line or spacing of 3.0 - 5.0 ft.	Width between 0.06 - 0.10 in. below spring line or less than 0.030 in. above spring line or spacing of 1.0 - 3.0 ft.	Width greater than 0.10 in. below spring line or greater than 0.030 in. above spring line or spacing of less than 1 ft.	

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Exposed Prestressing (1106)	No deficiencies	Present with no or light rust.	Present with heavy rust, but insignificant section loss <10%.	Present with measurable section loss >10%, but does not warrant structural review.	

7.5.29 Other Invert Girder

10129 Other Invert Girder	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all prestressed concrete invert girders. This element defines the invert girders which support the invert slabs. The total quantity for invert girder is the sum of all the lengths of each invert girder.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure LF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
General Condition (1301)	Excellent condition - no notable distress.	Good condition - isolated breakdowns or deterioration.	Adequate condition - occasional breakdowns or deterioration.	Marginal condition - widespread deterioration or breakdowns without reducing load capacity.	Poor condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR a structural review has been completed and the defects impact strength or serviceability of the element or tunnel.

7.5.30 Strip Seal Expansion Joint

10130 Strip Seal Expansion Joint	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all strip seal expansion joints. This element defines those tunnel expansion joint devices which utilize a neoprene type waterproof gland with some type of metal extrusion or other system to anchor the gland. The total quantity for expansion joints is the sum of all the lengths of each joint.	Unit of Measure LF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Leakage (1501)	No deficiencies	Minimal. Minor dripping through the joint.	Moderate dripping through the joint.	Significant. More than moderate dripping but less than free flow of water.	Free flow of water through the joint.
Seal Adhesion (1502)	Fully adhered	Unadhered for more than 25% of the joint.	Unadhered between 25% and 50% of the joint.	Unadhered 50% or less of the joint but still some adhesion.	Complete loss of adhesion.
Seal Damage (1503)	No deficiencies	Seal abrasion without punctures.	Seal abrasion with moderate punctures.	Punctured or ripped or partially pulled out.	Punctured completely through, pulled out, or missing.
Seal Cracking (1504)	No deficiencies	Surface crack.	Crack that partly penetrates the seal.	Crack that penetrates the seal greater than 50% of the seal thickness.	Crack that fully penetrates the seal.
Debris Impaction (1505)	No debris to a shallow cover of loose debris may be evident but does not affect the performance of the joint.	Partially filled with hard-packed material, but still allowing free movement.	Partially filled with very hard-packed material, possibly impacting free movement.	Completely filled and impacts joint movement.	Completely filled and prevents joint movement.
Adjacent Deck or Header (1506)	Sound. No spall, no delamination or no patch.	Delamination. Patched area that is sound.	Spall less than 2 inches deep. No exposed rebar. Patched area that is unsound. Joint is not loose.	Spall greater than 2 inches deep and/or exposed rebar. Delamination or unsound patched area that makes the joint loose.	Spall, delamination, unsound patched area or loose joint anchor that prevents the joint from functioning as intended.
Metal Deterioration or Damage (1507)	No deficiencies	Freckled rust, metal has no cracks, or impact damage.	Moderate surface rust or cracks, or impact damage. Connections may be loose but functioning as intended.	Section loss, missing or broken fasteners, cracking of the metal or impact damage but joint is still functioning.	Metal cracking, section loss, damage or connection failure that prevents the joint from functioning as intended.

7.5.31 Pourable Joint Seal

10131 Pourable Joint Seal	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all pourable joint seals. This element defines those tunnel joints filled with a pourable seal with or without a backer. The total quantity for expansion joints is the sum of all the lengths of each joint.	Unit of Measure LF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Leakage (1501)	No deficiencies	Minimal. Minor dripping through the joint.	Moderate dripping through the joint.	Significant. More than moderate dripping but less than free flow of water.	Free flow of water through the joint.
Seal Adhesion (1502)	Fully adhered	Unadhered for more than 25% of the joint.	Unadhered between 25% and 50% of the joint.	Unadhered 50% or less of the joint but still some adhesion.	Complete loss of adhesion.
Seal Damage (1503)	No deficiencies	Seal abrasion without punctures.	Seal abrasion with moderate punctures.	Punctured or ripped or partially pulled out.	Punctured completely through, pulled out, or missing.
Seal Cracking (1504)	No deficiencies	Surface crack.	Crack that partly penetrates the seal.	Crack that penetrates the seal greater than 50% of the seal thickness.	Crack that fully penetrates the seal.
Debris Impaction (1505)	No debris to a shallow cover of loose debris may be evident but does not affect the performance of the joint.	Partially filled with hard-packed material, but still allowing free movement.	Partially filled with very hard-packed material, possibly impacting free movement.	Completely filled and impacts joint movement.	Completely filled and prevents joint movement.
Adjacent Deck or Header (1506)	Sound. No spall, no delamination or no patch.	Delamination. Patched area that is sound.	Spall less than 2 inches deep. No exposed rebar. Patched area that is unsound. Joint is not loose.	Spall greater than 2 inches deep and/or exposed rebar. Delamination or unsound patched area that makes the joint loose.	Spall, delamination, unsound patched area or loose joint anchor that prevents the joint from functioning as intended.

7.5.32 Compression Joint Seal

10132 Compression Joint Seal	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all compression joint seals. This element defines those tunnel joints filled with a preformed compression type seal. This joint does not have an anchor system to confine the seal. The total quantity for expansion joints is the sum of all the lengths of each joint.	Unit of Measure LF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Leakage (1501)	No deficiencies	Minimal. Minor dripping through the joint.	Moderate dripping through the joint.	Significant. More than moderate dripping but less than free flow of water.	Free flow of water through the joint.
Seal Adhesion (1502)	Fully adhered	Unadhered for more than 25% of the joint.	Unadhered between 25% and 50% of the joint.	Unadhered 50% or less of the joint but still some adhesion.	Complete loss of adhesion.
Seal Damage (1503)	No deficiencies	Seal abrasion without punctures.	Seal abrasion with moderate punctures.	Punctured or ripped or partially pulled out.	Punctured completely through, pulled out, or missing.
Seal Cracking (1504)	No deficiencies	Surface crack.	Crack that partly penetrates the seal.	Crack that penetrates the seal greater than 50% of the seal thickness.	Crack that fully penetrates the seal.
Debris Impaction (1505)	No debris to a shallow cover of loose debris may be evident but does not affect the performance of the joint.	Partially filled with hard-packed material, but still allowing free movement.	Partially filled with very hard-packed material, possibly impacting free movement.	Completely filled and impacts joint movement.	Completely filled and prevents joint movement.
Adjacent Deck or Header (1506)	Sound. No spall, no delamination or no patch.	Delamination. Patched area that is sound.	Spall less than 2 inches deep. No exposed rebar. Patched area that is unsound. Joint is not loose.	Spall greater than 2 inches deep and/or exposed rebar. Delamination or unsound patched area that makes the joint loose.	Spall, delamination, unsound patched area or loose joint anchor that prevents the joint from functioning as intended.

7.5.33 Assembly Joint with Seal

10133 Assembly Joint with Seal

Child Element Numbers/Names
None

Specification	Commentary
Record this element for all assembly joints with seals. This element defines only those tunnel joints with an assembly mechanism that have a seal. The total quantity for expansion joints is the sum of all the lengths of each joint.	Unit of Measure LF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Leakage (1501)	No deficiencies	Minimal. Minor dripping through the joint.	Moderate dripping through the joint.	Significant. More than moderate dripping but less than free flow of water.	Free flow of water through the joint.
Seal Adhesion (1502)	Fully adhered	Unadhered for more than 25% of the joint.	Unadhered between 25% and 50% of the joint.	Unadhered 50% or less of the joint but still some adhesion.	Complete loss of adhesion.
Seal Damage (1503)	No deficiencies	Seal abrasion without punctures.	Seal abrasion with moderate punctures.	Punctured or ripped or partially pulled out.	Punctured completely through, pulled out, or missing.
Seal Cracking (1504)	No deficiencies	Surface crack.	Crack that partly penetrates the seal.	Crack that penetrates the seal greater than 50% of the seal thickness.	Crack that fully penetrates the seal.
Debris Impaction (1505)	No debris to a shallow cover of loose debris may be evident but does not affect the performance of the joint.	Partially filled with hard- packed material, but still allowing free movement.	Partially filled with very hard- packed material, possibly impacting free movement.	Completely filled and impacts joint movement.	Completely filled and prevents joint movement.
Adjacent Deck or Header (1506)	Sound. No spall, no delamination or no patch.	Delamination. Patched area that is sound.	Spall less than 2 inches deep. No exposed rebar. Patched area that is unsound. Joint is not loose.	Spall greater than 2 inches deep and/or exposed rebar. Delamination or unsound patched area that makes the joint loose.	Spall, delamination, unsound patched area or loose joint anchor that prevents the joint from functioning as intended.
Metal Deterioration or Damage (1507)	No deficiencies	Freckled rust, metal has no cracks, or impact damage.	Moderate surface rust or cracks, or impact damage. Connections may be loose but functioning as intended.	Section loss, missing or broken fasteners, cracking of the metal or impact damage but joint is still functioning.	Metal cracking, section loss, damage or connection failure that prevents the joint from functioning as intended.

7.5.34 Open Expansion Joint

10134 Open Expansion Joint	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all open expansion joints. This element defines only those tunnel joints that are open and not sealed. The total quantity for expansion joints is the sum of all the lengths of each joint.	Unit of Measure LF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Debris Impaction (1505)	No debris to a shallow cover of loose debris may be evident but does not affect the performance of the joint.	Partially filled with hard-packed material, but still allowing free movement.	Partially filled with very hard-packed material, possibly impacting free movement.	Completely filled and impacts joint movement.	Completely filled and prevents joint movement.
Adjacent Deck or Header (1506)	Sound. No spall, no delamination or no patch.	Delamination. Patched area that is sound.	Spall less than 2 inches deep. No exposed rebar. Patched area that is unsound. Joint is not loose.	Spall greater than 2 inches deep and/or exposed rebar. Delamination or unsound patched area that makes the joint loose.	Spall, delamination, unsound patched area or loose joint anchor that prevents the joint from functioning as intended.

7.5.35 Assembly Joint without Seal

10135 Assembly Joint without Seal	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all assembly joints without seals. This element defines only those tunnel assembly joints that are open and not sealed. These joints include finger and sliding plate joints. The total quantity for expansion joints is the sum of all the lengths of each joint.	Unit of Measure LF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Debris Impaction (1505)	No debris to a shallow cover of loose debris may be evident but does not affect the performance of the joint.	Partially filled with hard-packed material, but still allowing free movement.	Partially filled with very hard-packed material, possibly impacting free movement.	Completely filled and impacts joint movement.	Completely filled and prevents joint movement.
Adjacent Deck or Header (1506)	Sound. No spall, no delamination or no patch.	Delamination. Patched area that is sound.	Spall less than 2 inches deep. No exposed rebar. Patched area that is unsound. Joint is not loose.	Spall greater than 2 inches deep and/or exposed rebar. Delamination or unsound patched area that makes the joint loose.	Spall, delamination, unsound patched area or loose joint anchor that prevents the joint from functioning as intended.
Metal Deterioration or Damage (1507)	No deficiencies	Freckled rust, metal has no cracks, or impact damage.	Moderate surface rust or cracks, or impact damage. Connections may be loose but functioning as intended.	Section loss, missing or broken fasteners, cracking of the metal or impact damage but joint is still functioning.	Metal cracking, section loss, damage or connection failure that prevents the joint from functioning as intended.

7.5.36 Other Joint

10139 Other Joint	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all other expansion joints. This element defines only those tunnel expansion joint devices which utilize a neoprene type waterproof gland with some type of metal extrusion or other system to anchor the gland. The total quantity for expansion joints is the sum of all the lengths of each joint.	Unit of Measure LF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Leakage (1501)	No deficiencies	Minimal. Minor dripping through the joint.	Moderate dripping through the joint.	Significant. More than moderate dripping but less than free flow of water.	Free flow of water through the joint.
Debris Impaction (1505)	No debris to a shallow cover of loose debris may be evident but does not affect the performance of the joint.	Partially filled with hard-packed material, but still allowing free movement.	Partially filled with very hard-packed material, possibly impacting free movement.	Completely filled and impacts joint movement.	Completely filled and prevents joint movement.
Adjacent Deck or Header (1506)	Sound. No spall, no delamination or no patch.	Delamination. Patched area that is sound.	Spall less than 2 inches deep. No exposed rebar. Patched area that is unsound. Joint is not loose.	Spall greater than 2 inches deep and/or exposed rebar. Delamination or unsound patched area that makes the joint loose.	Spall, delamination, unsound patched area or loose joint anchor that prevents the joint from functioning as intended.
Metal Deterioration or Damage (1507)	No deficiencies	Freckled rust, metal has no cracks, or impact damage.	Moderate surface rust or cracks, or impact damage. Connections may be loose but functioning as intended.	Section loss, missing or broken fasteners, cracking of the metal or impact damage but joint is still functioning.	Metal cracking, section loss, damage or connection failure that prevents the joint from functioning as intended.

7.5.37 Steel Tie/Tension Member

10170 Steel Tie/Tension Members

Child Element Numbers/Names
None

Specification	Commentary
Record this element for all primary structural steel members acting in tension to provide for load support. This would include horizontal ties within a tied arch system. It could also be used for steel hangers used to support ceilings. The anchorages for these tension members may or may not be visible. The total quantity for Steel Tie / Tension Members (including their anchorages) is the sum of all the number of individual tension members.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Distress observed on either the tension member or anchorages should be considered in the condition assessment. This does not apply to steel struts or bracing members. It also does not apply to hangers or horizontal members designed solely to support utilities. The condition of those should be considered when condition rating those utilities/ systems. Note that primary structural tension/tie members are sometimes also used to support utilities. Unit of Measure EA

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Corrosion (1001)	No deficiencies	Freckled rust. Corrosion of the steel has initiated.	Heavy surface rust, but no notable loss of section.	Section loss is evident, or pack rust is present but does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR a structural review has been completed and the defects impact strength or serviceability of the element or tunnel.
Cracking (1008)	No deficiencies	Crack that is longitudinal and has self-arrested or has been arrested with effective arrest holes, doubling plates or similar.	Crack that is longitudinal and has not self-arrested or has not been arrested with effective arrest holes, doubling plates or similar.	Identified transverse crack exists that is not arrested but does not warrant structural review.	
Connection (1003)	Connection is in place and functioning as intended.	One loose fastener or light pack rust without distortion is present and the connection is in place and functioning as intended.	More than 1 loose fastener or heavy pack rust without distortion is present and the connection is in place and functioning as intended.	Missing bolts, rivets or fasteners; broken welds; or pack rust with significant distortion but does not warrant a structural review.	
Bowing and Elongation (1009)	No deficiencies	Displacement is minor but visible and anchorage has received structural review and has been mitigated.	Displacement is visible and anchorage has received structural review and has been mitigated.	Displacement is visible and anchorage has received structural review and does not require mitigation.	
Creep (1010)	No deficiencies	Displacement is minor but visible and anchorage has received structural review and has been mitigated.	Displacement is visible and anchorage has received structural review and has been mitigated.	Displacement is visible and anchorage has received structural review and does not require mitigation.	
Anchorage Area (1011)	Sound anchorage.	Hairline cracking around anchorage areas, but concrete is sound.	Cracking around surface anchorage or spalls less than 2" deep around embedded members, but remaining concrete is sound.	Significant cracking or any spalling around surface anchorage or spalls more than 2" deep around embedded members or concrete is not sound.	

7.5.38 Tunnel Niches

10180 Tunnel Niches	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all tunnel Niches. This element defines those tunnel niches within the tunnel. The total quantity for tunnel niches is the sum of all the number of tunnel niches.	The tunnel niche condition is based on if it is functional or not. If the tunnel niche can adequately contain railroad personnel and equipment within the tunnel. It does not depend on the material deficiencies that the Niche is made of, this will be included with the corresponding element condition state. Unit of Measure EA

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Functions Adequately (1601)	No notable deficiencies	Some have functionality issues but niches still functions appropriately	Equipment or utilities are stored in niche restricting room but can still accommodate personnel	Niche cannot accommodate any personnel due to structural condition or occupied by equipment or utilities	The number of niches in a row that cannot accommodate personnel extends for a distance that is a safety concern. When the distance of available niches extends beyond 50 feet the niches within that range shall be code as CS1 until the length between available niches is reduced to less than 50 feet.

7.5.39 Soil Anchors

10190 Soil Anchors

Child Element Numbers/Names
None

Specification	Commentary
Record this element for soil anchors. In general, the only visible components of the soil anchors will be the anchorage assembly and/or steel plates on the interior side of the tunnel liner wall; therefore, the defects recorded for this element will pertain to the soil anchorage assemblies. The total quantity of the soil anchors is the sum of the soil anchors located along the tunnel liner walls.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure EA

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Corrosion (1001)	No deficiencies	Freckled rust. Corrosion of steel has initiated.	Surface rust is evident with no section loss.	Section loss is evident, or pack rust is present but does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR a structural review has been completed and the defects impact strength or serviceability of the element or tunnel.
Nut/Chuck (1900)	No deficiencies	Nut is secure with light surface rust.	Nut has moderate surface rust, minor section loss, and/ or minor gap at nut and plate interface but nut is tight.	Nut has significant surface rust, moderate section loss, and/or moderate gap at nut and plate interface with a hand loose nut.	
Bearing Plate and Bevel (1901)	No deficiencies	Loose connection assemblies or pack rust without distortion is present but the connection is in place and functioning as intended.	Loose connection assemblies or pack rust with minor distortion but the connection is in palace and functioning mostly as intended.	Missing connection assemblies which does not result in an unstable situation.	
Wall (1902)	No deficiencies	The wall at the bearing plate has minor deterioration.	The wall at the bearing plate has moderate deterioration.	The wall at the bearing plate has severe deterioration.	

7.5.40 Manholes

10200 Manholes	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for manholes. In general, the manholes will have covers; therefore, the defects recorded for this element will pertain to the covers, frame, and encasement. The total quantity of the manholes is the sum of the manholes located along the surface of the track.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure EA

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Cover (2000)	No deficiencies	Cover is intact, has minor rust.	Cover has moderate rust and minor section loss.	Cover has severe rust with moderate section loss.	Cover is missing or has a hole in the cover greater than 8" diameter with severe section loss.
Frame (2001)	No deficiencies	Frame is intact with minor rust.	Frame has moderate rust with minor section loss but still has enough section to securely support the cover.	Frame has severe rust with moderate section loss but cover is still fully supported.	Frame support has corroded to the point that the cover is unsupported and/or unstable.
Encasement (2002)	No deficiencies	Encasement is stable, but has minor erosion and/or minor deterioration.	Encasement has minor loss of stability, moderate erosion, and/ or moderate deterioration.	Encasement is severely eroded and/or has deteriorations that have created voids that affect the stability of manhole.	Encasement has voids around the entire perimeter of the manhole, has caused instability, and could potentially affect the stability of the track and ballast.

7.5.41 Safety Walk

10210 Safety Walk	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for safety walks. In general, safety walks are narrow elevated walkways with safety railings along the walls of the tunnel liner. The total quantity of the safety walk is the sum of all the lengths of each safety walk.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure LF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Spall, Honeycombing, Scale (1101)	No deficiencies	Scale, spall, honeycombing with depth less than concrete cover (no reinforcing exposed).	Scale, spall, honeycombing with depth equal to concrete cover (reinforcing exposed).	Scale, spall, honeycombing with depth greater than concrete over (minor section loss to reinforcing). Does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR a structural review has been completed and the defects impact strength or serviceability of the element or tunnel.
Exposed Rebar (1102)	No deficiencies	Present with no or light rust.	Present with heavy rust, but insignificant section loss <10%.	Present with measurable section loss >10%, but does not warrant structural review.	
Efflorescence, Rust Staining (1103)	No deficiencies	Surface white without build up or leaching without rust staining.	Slight build up with minor rust staining.	Heavy build up with significant rust staining.	
Delamination, Patched Area (1111)	No deficiencies	Delaminated area present individual areas less than 1 SF that is sound. Patched area is sound.	Delaminated area present individual areas greater than 1 SF and less than 3 SF that is sound. Patched area is unsound or showing signs of distress.	Delaminated area present individual areas greater than 3 SF and unsound. If delamination or patch area is unsound and showing signs of severe distress / loose, refer to critical finding protocol.	
Cracking (1104)	Width less than 0.012 in. or spacing greater than 5 ft.	Width between 0.012 - 0.06 in. below spring line or spacing of 3.0 - 5.0 ft.	Width between 0.06 - 0.10 in. below spring line or less than 0.030 in. above spring line or spacing of 1.0 - 3.0 ft.	Width greater than 0.10 in. below spring line or greater than 0.030 in. above spring line or spacing of less than 1 ft.	
Misalignment (2100)	No deficiencies	Minor vertical misalignment between portions less than 1/4 in.	Moderate vertical misalignment between portions 1/4 in. to 5/8 in.	Significant vertical misalignment between portions 5/8 in. and 1 in.	Vertical misalignment greater than 1 in.
Cover (2101)	No deficiencies	Portion of safety walk is void due to drainage components or utilities, but cover is present.	Cover is partially deteriorated but still stable.	Cover is misaligned, has minor movement when walking on but is stable.	Cover is unstable, missing, or has severely deteriorated.

7.5.42 Fireproofing

10220 Fireproofing		
Child Element Numbers/Names 10220.1 - Liner	10220.2 - Girder	10220.3 - Other

Specification	Commentary
Record this element for fireproofing. In general, fireproofing will be a relatively thin layer of material that coats and adheres to the entire surface of the element it is protecting. The total quantity of the fireproofing is the sum of the area of fireproofing on the element.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure SF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Effectiveness (2200)	No deficiencies	Minor signs of wear to material, but is fully effective.	Moderate signs of wear to material, but is mostly effective.	Limited effectiveness with some significant signs of wear such as areas with cracks, wetness, loose sections, and loss of material thickness.	Failed -no protection of underlying element.

7.5.43 Ladders

10230 Ladders	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for ladders. The total quantity of ladders is the sum of all the ladders.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure EA

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Anchorage (2300)	No deficiencies	Anchorage has minor movement and play.	Anchorage has moderate movement and play.	Anchorage has severe movement and play, but is still stable enough to be utilized.	The condition is unstable and the ladder is unable to be utilized.
Concrete Deterioration (2301)	No deficiencies	Concrete components have minor deteriorations.	Concrete components have moderate deteriorations.	Concrete components have severe deteriorations.	
Steel Deterioration (2302)	No deficiencies	Steel components have minor rust and/ or section loss.	Steel components have moderate rust and/or section loss.	Steel components have severe rust and/ or section loss.	

7.5.44 Concrete Encasement

10240 Concrete Encasement		
Child Element Numbers/Names 10240.1 - Girder	10240.2 - Column/Piles	10240.3 - Other

Specification	Commentary
Record this element for concrete encased elements. The total quantity of concrete encasement is the sum the area of concrete encasement on the element.	Visual assessments may be supplemented with non-destructive or destructive testing results for all elements. Unit of Measure SF

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Delamination, Patched Area (1111)	No deficiencies	Delaminated area present individual areas less than 1SF that is sound. Patched area that is sound.	Delaminated area present individual areas greater than 1SF and less than 3SF that is sound. Patched area that is unsound or showing signs of distress.	Delaminated area present individual areas greater than 3SF and unsound. If delamination or patch area is unsound and showing signs of severe distress/ loose, refer to critical finding protocol.	Delaminated area present individual areas greater than 3 SF and unsound. If delamination or patch area is unsound and showing signs of severe distress / loose, refer to critical finding protocol.
Effectiveness (2200)	No deficiencies	Minor signs of wear to material, but is fully effective.	Moderate signs of wear to material, but is mostly effective.	Limited effectiveness with some significant signs of wear such as areas with cracks, wetness, loose sections, and loss of material thickness.	Failed -no protection of underlying element.

7.6 Mechanical Elements

This section defines tunnel mechanical elements and the methodology for determining total element condition state quantities. The following elements are included.

Element Number	Element Name	Unit of Measurement
20001	Drainage System	EA
20002	Pumps	EA
20102	Flood Gate	EA
20110	Utility Rooms	EA

7.6.1 Drainage System

20001 Drainage System	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all drainage and pumping systems. This element includes storm drains, piping, pumps and water treatment equipment for the removal of water that may enter the tunnel from the portals, vent shafts, cracks in the tunnel lining or thru the ballast. Drainage at the tunnel facility also handles the drippings from vehicles traversing the tunnel and potential spills from trains hauling liquid materials. The total quantity for drainage and pumping system is the sum of all the draining and pumping systems.	The drainage and pumping system may include the following subcomponents: Pumps - Sump Pumps, Pump Motors, Pump Controller, Piping Drains and Water Treatment Equipment. For this element, a separate drainage and pumping system is considered to be one system. Tunnels with twin bores may have separate draining and pumping systems and would be considered as two. Some tunnels may have a draining and pumping system at each portal that work independently and would also be considered as two. Unit of Measure EA

Condition State Definitions

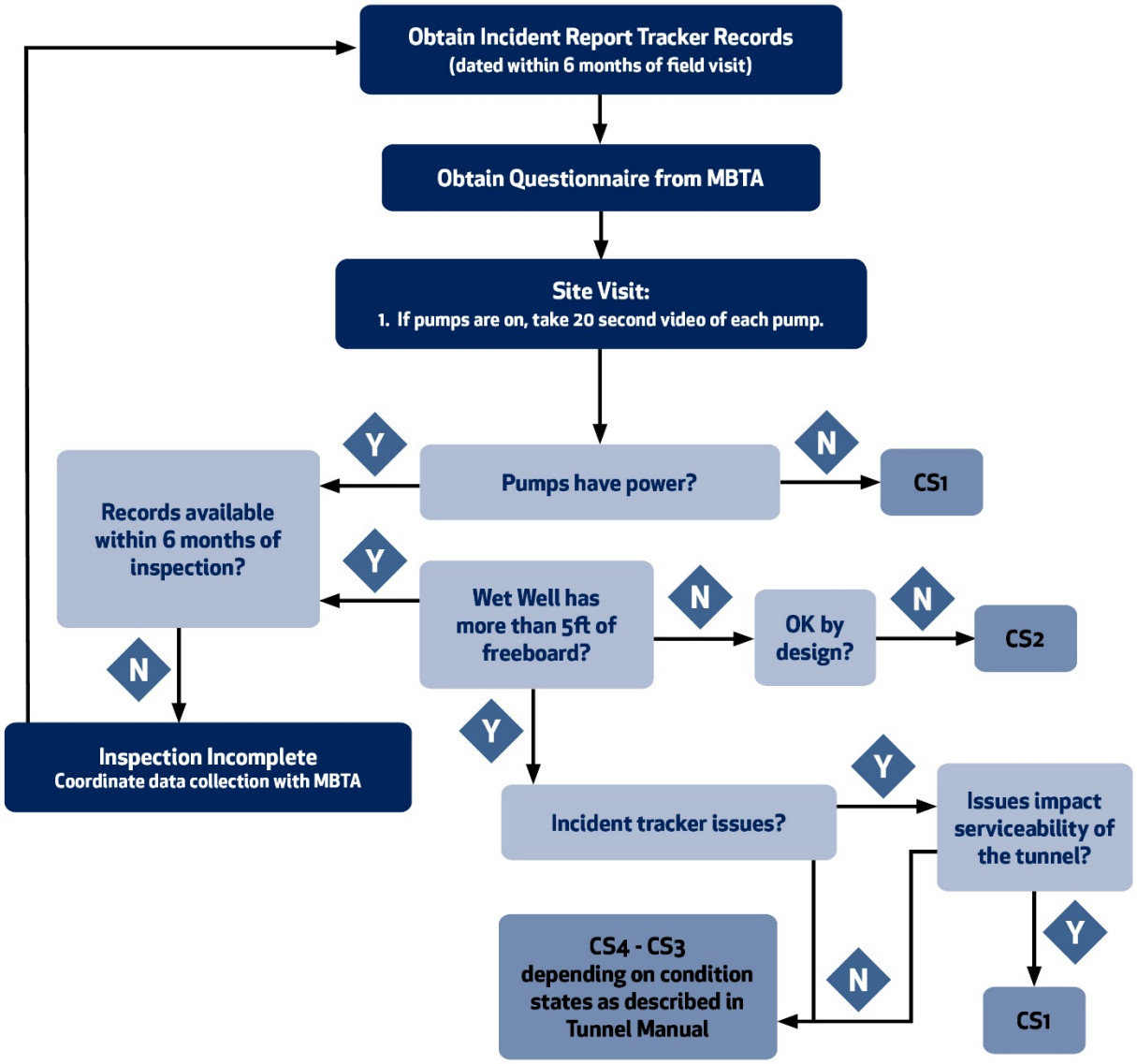
Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
System Condition (1701)	The system is in excellent condition- no notable distress.	The system is in good condition with some deterioration.	The system is in adequate condition- isolated breakdowns or widespread deterioration.	The system is in marginal condition- widespread deterioration or breakdowns reducing operational capacity, without impacting the serviceability of the element or tunnel.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR a structural review has been completed and the defects impact strength or serviceability of the element or tunnel.

7.6.2 Pumps

20002 Pumps	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all pumps. This element includes the component that moves water that may enter the tunnel from the portals, vent shafts, and crack in the tunnel lining. The total quantity for pumps is the sum of all the pumps.	The pumps may include the following subcomponents: Sump Pumps, Pump Motors, Pump Controller, etc. Unit of Measure EA

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Pump Operation (Includes Sump Pump, Pump Motor, Pump Controller, Pump Control Panel, Oil Leakage, Pump Leakage, Noise and Vibration and Temperature) (1702)	Operates at all speeds and in all modes. Shut-off valves operate freely and without binding. Fair amount of noise and vibration velocity of 100 in./s or less. No oil leakage observed. No leakage observed at pump seal. No water leakage noted in immediate piping and valves. Motor temperature is within expected limits.	Operates at all speeds and in all modes in a reduced capacity. Shut-off valves operate with some resistance and binding but do appear to fully open/ seal. Slightly rough noise and vibration velocity between 100 and 300 in./s. Limited exterior staining from oil seepage at seals. Limited exterior water seepage from seals with seals appearing wet. Motor temperature is slightly increased during motor operation.	Operates at some speeds and in all modes in a reduced capacity. Shut-off valves operate, but with significant resistance and binding, but do appear to fully open/ seal. Moderate rough noise and vibration velocity between 200 and 300 in/s. Moderate exterior staining from oil seepage at seals. Moderate exterior water seepage from seals. Motor temperature is noticeably increased during motor operation.	Operates intermittently or haltingly. Shut-off valves difficult or impossible to operate. Rough noise and vibration velocity in excess of 300 in./s. Extensive exterior staining from oil seepage around seals. Measurable water seepage around seals that can be quantified in drips per minute. Motor temperature is moderately above what is expected and/ or hot spots of temperature exist.	Pump will not operate. Pooling of oil on exterior surfaces of seals or significant reduction of interior lubricant level. A visible stream of water on exterior surfaces of seals or significant reduction of pump performance. Motor temperature is drastically increased and motor function is influenced.


Obtain Incident Report Tracker Records
(dated within 6 months of field visit)
Obtain Questionnaire from MBTA
Site Visit:
1. If pumps are on, take 20 second video of each pump.
Pumps have power?
Y
N
CS1
Records available within 6 months of inspection?
Y
N
Wet Well has more than 5ft of freeboard?
N
OK by design?
N
CS2
Y
Inspection Incomplete
Coordinate data collection with MBTA
Incident tracker issues?
Y
Issues impact serviceability of the tunnel?
Y
CS1
N
CS4 - CS3 depending on condition states as described in Tunnel Manual

7.6.3 Flood Gate

20102 Flood Gate	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all flood gates. These elements are the actual gates, seals, mechanical components, and power supply of a flood gate system. The flood gates are typically located at each portal for each bore. The flood gates are usually used when the tunnel is closed and the bores are threatened with taking on water at the portals. The total quantity for flood gate is the sum of all the flood gates.	For this element, a separate flood gate is considered to be one gate. Some tunnels may have a flood gate at each portal that work independently and would be considered as two. Unit of Measure EA

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
System Condition (1701)	The system is in excellent condition- no notable distress.	The system is in good condition with some deterioration.	The system is in adequate condition- isolated breakdowns or widespread deterioration.	The system is in marginal condition- widespread deterioration or breakdowns reducing operational capacity, without impacting the serviceability of the element or tunnel.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR a structural review has been completed and the defects impact strength or serviceability of the element or tunnel.

7.6.4 Utility Rooms

20110 Utility Rooms

Child Element Numbers/Names
None

Specification	Commentary
Record this element for each individual utility room. The total quantity of utility rooms is the sum of all the utility rooms which are connected to or associated with the TIN, and regardless of the utilities in the room.	The utility rooms includes the following subcomponents: structural box (walls, ceiling, and floor), floor drains, and doors. Inspections shall be conducted as follows: • Check the structural box for cracks, leaks, spalls, exposed & corroding rebar or soldier piles. • Check the floor drain for debris clogging the grate and/ or pipe. • Check the door and make sure it can open, close, and lock properly. Code the General Condition State as follows: • CS5 = no comments. • CS4 =structural box has scattered non-structural cracks, areas of exposed rebar or soldier piles with dampness, no section loss; floor drain partially clogged with minor debris; door has some difficulty opening or closing. • CS3 = structural box has heavy non-structural cracking, areas of glistening, exposed rebar or soldier piles with minor section loss, floor drain partially clogged with debris, door has difficulty opening or closing. • CS2 = structural box has heavy cracking or structural cracks, areas of active leakage, exposed rebar or soldier piles with measurable section loss but does not warrant a structural review; floor drain partially clogged with debris with water pooling. • CS1 = structural box is in a severe condition and warrants a structural review; floor drain fully clogged; door unable to open or lock. Unit of Measure EA

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
General Condition (1301)	Excellent condition - no notable distress.	Good condition - isolated breakdowns or deterioration.	Adequate condition - occasional breakdowns or deterioration.	Marginal condition - widespread deterioration or breakdowns without reducing load capacity.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR a structural review has been completed and the defects impact strength or serviceability of the element or tunnel.

7.7 Electrical Elements

This section defines tunnel electrical elements and the methodology for determining total element condition state quantities. The following elements are included.

Element Number	Element Name	Unit of Measurement
30303	Tunnel Lighting Distribution Systems	EA
30304	Tunnel Lighting Fixtures	EA
30305	Emergency Generator System	EA
30400	Emergency Lighting Distribution System	EA
30475	Emergency Lighting Fixtures	EA
30103	Catenary Support System	EA

7.7.1 Tunnel Lighting Distribution Systems

30303 Tunnel Lighting Distribution Systems	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all tunnel lighting systems. These systems consist of the light fixtures, supports, bulb housings, lenses, light switches, junction boxes, wiring, conduit, cable, sensors, and controllers used to provide lighting for the tunnel. The total quantity for tunnel lighting system is the sum of all the tunnel lighting systems.	The tunnel lighting system may also include the following subcomponents: photo controls, and remote ballasts. For this element, a separate tunnel lighting system is considered to be one system. Tunnels with twin bores may have separate tunnel lighting systems and would be considered as two. Unit of Measure EA

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
System Condition (1701)	The system is in excellent condition- no notable distress.	The system is in good condition with some deterioration.	The system is in adequate condition- isolated breakdowns or widespread deterioration.	The system is in marginal condition- widespread deterioration or breakdowns reducing operational capacity, without impacting the serviceability of the element or tunnel.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR a structural review has been completed and the defects impact strength or serviceability of the element or tunnel.

7.7.2 Tunnel Lighting Fixtures

30304 Tunnel Lighting Fixtures	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all tunnel lighting fixtures. This element includes the physical housing of the tunnel lights and their connections to the tunnel. The total quantity for tunnel lighting fixture is the sum of all the tunnel lighting fixtures.	Component supports include anchorage to the supporting member and connecting hardware for the component housing. When a lighting fixture serves the dual purpose of general tunnel lighting and emergency tunnel lighting, it is only counted under the tunnel lighting fixture element. However, those fixtures will have an impact on both tunnel lighting system and emergency lighting system elements. Unit of Measure EA

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Component Supports (1703)	No deficiencies	Minor defects.	Loose anchorage or component housing connection hardware.	Missing anchorage or component housing connection hardware which does not result in an unstable situation.	Failed anchorage or component connection hardware which results in an unstable situation.
Corrosion (1704)	No deficiencies	Freckled rust. Corrosion of the steel has initiated.	Heavy corrosion, but no section loss is evident.	Section loss is evident or pack rust is present but does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR a structural review has been completed and the defects impact strength or serviceability of the element or tunnel.
Component Housing or Enclosure (1705)	No deficiencies	Minor defects.	Single crack.	Multiple cracks.	Holes are present.

7.7.3 Emergency Generator System

30305 Emergency Generator System	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all emergency generator systems. These elements are the mechanical components of an emergency generator and power system which consist of fuel delivery, fuel storage, an engine cooling and exhaust systems. The emergency generator provides a back-up power source in the event of utility service failure to the tunnel. The mechanical systems support the proper operation of the generator to provide back-up power. The total quantity for emergency generator is the sum of all the emergency generator systems.	The emergency generator system may include the following subcomponents: fuel main storage tank, fuel day tanks, circulating fuel pumps, fuel tank venting, fuel tank sensors, coolant systems, exhaust manifold insulation and lagging, exhaust air louver and damper actuator, supply air louver and damper actuator, generator, generator control equipment, control panels and conduit. For this element, a separate emergency generator system is considered to be one system. Tunnels with twin bores may have separate emergency generator systems and would be considered as two. Unit of Measure EA

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
System Condition (1701)	The system is in excellent condition- no notable distress.	The system is in good condition with some deterioration.	The system is in adequate condition- isolated breakdowns or widespread deterioration.	The system is in marginal condition- widespread deterioration or breakdowns reducing operational capacity, without impacting the serviceability of the element or tunnel.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR a structural review has been completed and the defects impact strength or serviceability of the element or tunnel.

7.7.4 Emergency Lighting Distribution System

30400 Emergency Lighting Distribution System	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all emergency lighting systems. These systems consist of the light fixtures, supports, bulb housings, lenses, light switches, junction boxes, wiring, conduit, cable, sensors, and controllers used to provide emergency lighting for the facility. The total quantity for emergency lighting system is the sum of all the emergency lighting systems.	The emergency lighting system may also include the following subcomponents: exit signs, batteries; and support space sighting, and remote ballasts. For this element, a separate emergency lighting system is considered to be one system. Tunnels with twin bores may have separate emergency lighting systems and would be considered as two. Unit of Measure EA

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
System Condition (1701)	The system is in excellent condition- no notable distress.	The system is in good condition with some deterioration.	The system is in adequate condition- isolated breakdowns or widespread deterioration.	The system is in marginal condition- widespread deterioration or breakdowns reducing operational capacity, without impacting the serviceability of the element or tunnel.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR a structural review has been completed and the defects impact strength or serviceability of the element or tunnel.

7.7.5 Emergency Lighting Fixtures

30475 Emergency Lighting Fixtures

Child Element Numbers/Names
None

Specification	Commentary
Record this element for all emergency lighting fixtures. This element includes the physical housing of the emergency lights and their connections to the tunnel. The total quantity for emergency lighting fixture is the sum of all the emergency lighting fixtures.	Component supports include anchorage to the supporting member and connecting hardware for the component housing. When a lighting fixture serves the dual purpose of general tunnel lighting and emergency tunnel lighting, it is only counted under the tunnel lighting fixture element. However, those fixtures will have an impact on both tunnel lighting system and emergency lighting system elements. Unit of Measure EA

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Component Supports (1703)	No deficiencies	Minor defects.	Loose anchorage or component housing connection hardware.	Missing anchorage or component housing connection hardware which does not result in an unstable situation.	Failed anchorage or component connection hardware which results in an unstable situation.
Corrosion (1704)	No deficiencies	Freckled rust. Corrosion of the steel has initiated.	Heavy corrosion, but no section loss is evident.	Section loss is evident or pack rust is present but does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR a structural review has been completed and the defects impact strength or serviceability of the element or tunnel.
Component Housing or Enclosure (1705)	No deficiencies	Minor defects.	Single crack.	Multiple cracks.	Holes are present.

7.7.6 Catenary Support System

30103 Catenary Support System

Child Element Numbers/Names
None

Specification	Commentary
Record this element for catenary support systems. Catenary support function as the structural support of the catenary system. The total quantity for the catenary supports Is the sum of all of the catenary supports.	Visual assessments and non-destructive assessment shall be made of the catenary support system that attaches to the structural linear of the tunnel. Unit of Measure EA

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Registration Arm Failure (1706)	No deficiencies	Arm is showing signs of flexing.	Arm is showing signs of cracking or distortion.	Failed arm which does not result in an unstable situation.	Failed arm or component connection hardware which results in an unstable situation.
Registration Connection Failure (1707)	No deficiencies	Loose connection hardware or pack rust without distortion is present but the connection is in place and functioning as intended.	Loose connection hardware or pack rust with minor distortion but the connection is in palace and functioning mostly as intended.	Missing connection hardware which does not result in an unstable situation.	Failed connection hardware which results in an unstable situation.
Support Anchor Failure (1708)	No deficiencies	Loose anchorage or component housing connection hardware.	Missing anchorage or component housing connection hardware which does not result in an unstable situation.	Failed anchorage or component connection hardware which results in an unstable situation.	The condition warrants a structural review to determine the effect on strength or serviceability.
Broken or Dirty Insulators (1712)	No deficiencies	Surface is showing signs of collecting dirt.	Surface indicating evidence of past arcing.	Surface is cracked or damaged but does not result in an unstable situation.	Failed insulator which results in an unstable situation.

7.8 Fire Life Safety Security Elements

This section defines tunnel fire, life safety, and security elements and the methodology for determining total element condition state quantities. The following elements are included.

Element Number	Element Name	Unit of Measurement
60650	Fire Detection System	EA
60750	Emergency Communications System	EA
60800	Tunnel Operations and Security System	EA
60805	Emergency Egress	EA
60809	Cameras	EA
60810	Portal Alert System	EA
60601	Ventilation System	EA
60620	Fans	EA
60630	Standpipes	EA

7.8.1 Fire Detection System

60650 Fire Detection System	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all fire detection systems. These systems consist of control panels, initiating devices (heat and smoke detectors, pull-stations, etc.), notification appliances (strobes, horns, etc.), wiring, conduit, and cable used to detect a fire in the tunnel. The total quantity for fire detection system is the sum of all the fire detection systems.	The fire detection system may also include the following subcomponents: sensors, controls, and alarms. For this element, a separate fire detection system is considered to be one system. Tunnels with twin bores may have separate fire detection systems and would be considered as two. Unit of Measure EA

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
System Condition (1701)	The system is in excellent condition- no notable distress.	The system is in good condition with some deterioration.	The system is in adequate condition- isolated breakdowns or widespread deterioration.	The system is in marginal condition- widespread deterioration or breakdowns reducing operational capacity, without impacting the serviceability of the element or tunnel.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR a structural review has been completed and the defects impact strength or serviceability of the element or tunnel.

7.8.2 Emergency Communications System

60750 Emergency Communications System	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all emergency communication systems. The components of the emergency communication system include the communication device itself (i.e. intercom, radios, cell-phone), receivers, wiring, exchange devices, etc. The total quantity for emergency communication system is the sum of all the emergency communication systems.	The emergency communications system may also include the following subcomponents: signs, controllers, speakers and audio input equipment. For this element, a separate emergency communication system is considered to be one system. Tunnels with twin bores may have separate emergency communication systems and would be considered as two. Unit of Measure EA

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
System Condition (1701)	The system is in excellent condition- no notable distress.	The system is in good condition with some deterioration.	The system is in adequate condition- isolated breakdowns or widespread deterioration.	The system is in marginal condition- widespread deterioration or breakdowns reducing operational capacity, without impacting the serviceability of the element or tunnel.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR a structural review has been completed and the defects impact strength or serviceability of the element or tunnel.

7.8.3 Tunnel Operations and Security System

60800 Tunnel Operations and Security System	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for all tunnel operations and security systems. These systems consist of the communication equipment (CCTV cameras, telephones, radios, etc.) used to provide communication within and from the tunnel. The total quantity for tunnel operations and security system is the sum of all the tunnel operations and security systems.	The tunnel operations and security system may also include the following subcomponents: closed-circuit camera system, cell phone antennas, door access, controller and radio. For this element, a separate tunnel operation and security system is considered to be one system. Tunnels with twin bores may have separate tunnel operations and security systems and would be considered as two. Unit of Measure EA

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
System Condition (1701)	The system is in excellent condition- no notable distress.	The system is in good condition with some deterioration.	The system is in adequate condition- isolated breakdowns or widespread deterioration.	The system is in marginal condition- widespread deterioration or breakdowns reducing operational capacity, without impacting the serviceability of the element or tunnel.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR a structural review has been completed and the defects impact strength or serviceability of the element or tunnel.

7.8.4 Emergency Egress

60805 Emergency Egress

Child Element Numbers/Names
None

Specification	Commentary
Record this element for each individual tunnel emergency egress. For locations where multiple TINS utilize the same tunnel egress, the quantity and corresponding defect condition states shall be within the TIN that has the lowest most egress entrance from the roadway. For TINS that utilize the same tunnel egress and have the same lowest egress entrance, the tunnel egress quantity and corresponding defect condition states shall be within the TIN carrying Northbound or Eastbound traffic. The total quantity of emergency egresses is the sum of all emergency egresses in the tunnel.	The tunnel egress includes the following subcomponents: Structural box (walls, ceiling, floor, and stairs), floor drains, doors, railing, lights, way finding signage and debris. Inspections should be conducted as followed: • Check the structural box for cracks, leaks, spalls, exposed & corroding rebar or soldier piles. • Check the floor drain for debris clogging drain and/or pipe. • Check the doors and make sure they can open and close properly. • Check the railing for defects along the rails, posts and connections. • Check the lights for visibility. • Check all way finding signage for clarity, condition and visibility. • Check for debris to make sure nothing is blocking the egress path. Unit of Measure EA

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Structural Box (1801)	No deficiencies	Scattered cracks or shallow spalls.	Moderate cracking, signs of water intrusion, spalls exposing rebar or soldier piles with negligible section loss.	Heavy cracking, areas of active leakage, exposed rebar or soldier piles with measurable section loss but does not warrant a structural review.	Warrants a structural review.
Floor Drain (1802)	No deficiencies	Partially clogged with debris.	Mostly clogged with debris, but no signs of water pooling.	Mostly clogged with debris with signs of water pooling.	Floor drain fully clogged.
Doors/Hatches (1803)	No deficiencies	Good, minor defects, but functional.	Adequate, moderate defects within useful life.	Marginal, defective components, difficult to open or cannot open fully.	Locked or unable to open or close.
Railing (1804)	No deficiencies	Surface corrosion or missing fastener, but stable.	Areas of heavy rust or slight looseness.	Section loss, moderate looseness.	Holes present, sections detached or very loose.
Lights (1805)	No deficiencies	Random light(s) out but egress path still fully visible.	Adjacent lights out but egress path visible.	Numerous light(s) out but egress path still partially visible.	Egress path not visible for stretches.
Debris (1806)	No deficiencies	Minor does not impact egress path.	Moderate, but does not impact egress path.	Substantial enough to partially limit egress path.	Egress path blocked.
Signage (1807)	No deficiencies	Good, minor defects.	Adequate, moderate defects or dirty.	Marginal, loose support or heavy dirt.	Failed, fallen, illegible or misleading signage.

7.8.5 Cameras

60809 Cameras	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for each individual camera. The total of all cameras is the sum of all cameras.	The camera inspections are limited to cameras within the tunnels only. Inspections should be conducted as follows: • Check the physical condition of the camera and its supports (i.e. General Condition). • Check the functionality of the camera. Unit of Measure EA

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
General Condition (1301)	Excellent condition - no notable distress.	Good condition - isolated breakdowns or deterioration.	Adequate condition - occasional breakdowns or deterioration.	Marginal condition - widespread deterioration or breakdowns without reducing functionality	Severe condition - element has failed and is no longer effective.
Camera Operation (1709)	Camera is operational.	—	—	—	Camera is not operational (no power or no visible image).

7.8.6 Portal Alert System

60810 Portal Alert System	
Child Element Numbers/Names None	
Specification	**Commentary**
Record this element for each portal alert system. The total quantity of portal alert systems is the sum of all portal alert systems.	Unit of Measure EA

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
General Condition (1301)	Excellent condition - no notable distress.	Good condition - isolated breakdowns or deterioration.	Adequate condition - occasional breakdowns or deterioration.	Marginal condition - widespread deterioration or breakdowns without reducing functionality	Severe condition - element has failed and is no longer effective.

7.8.7 Ventilation System

60601 Ventilation System

Child Element Numbers/Names
None

Specification	Commentary
Record this element for all ventilation systems. This element describes the components that provide the supply of fresh air to the tunnel while removing stale air and contaminants. The total quantity for ventilation system is the sum of all the ventilation systems servicing the TIN. For a ventilation system which services multiple TINS, it should be associated with the TIN that it is closest to.	The ventilation system may include the following subcomponents: Fans - Fan Motors, Fan Controller, Airways, Sound Attenuators, Dampers, Damper Motor, Damper Controller, Air Quality Monitoring Equipment (CO), Control Panels and Conduit. Damper inspection should also include a review of the maintenance records for each piece of equipment and note any special or frequent maintenance problems. For this element, a separate ventilation system is considered to be one system. Tunnels with twin bores may have separate ventilation systems and would be considered as two. Some tunnels may have a ventilation system at each portal that work independently and would also be considered as two. Unit of Measure EA

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
System Condition(1701)	The system is in excellent condition- no notable distress.	The system is in good condition with some deterioration.	The system is in adequate condition- isolated breakdowns or widespread deterioration.	The system is in marginal condition- widespread deterioration or breakdowns reducing operational capacity, without impacting the serviceability of the element or tunnel.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or tunnel, OR a structural review has been completed and the defects impact strength or serviceability of the element or tunnel.

7.8.8 Fans

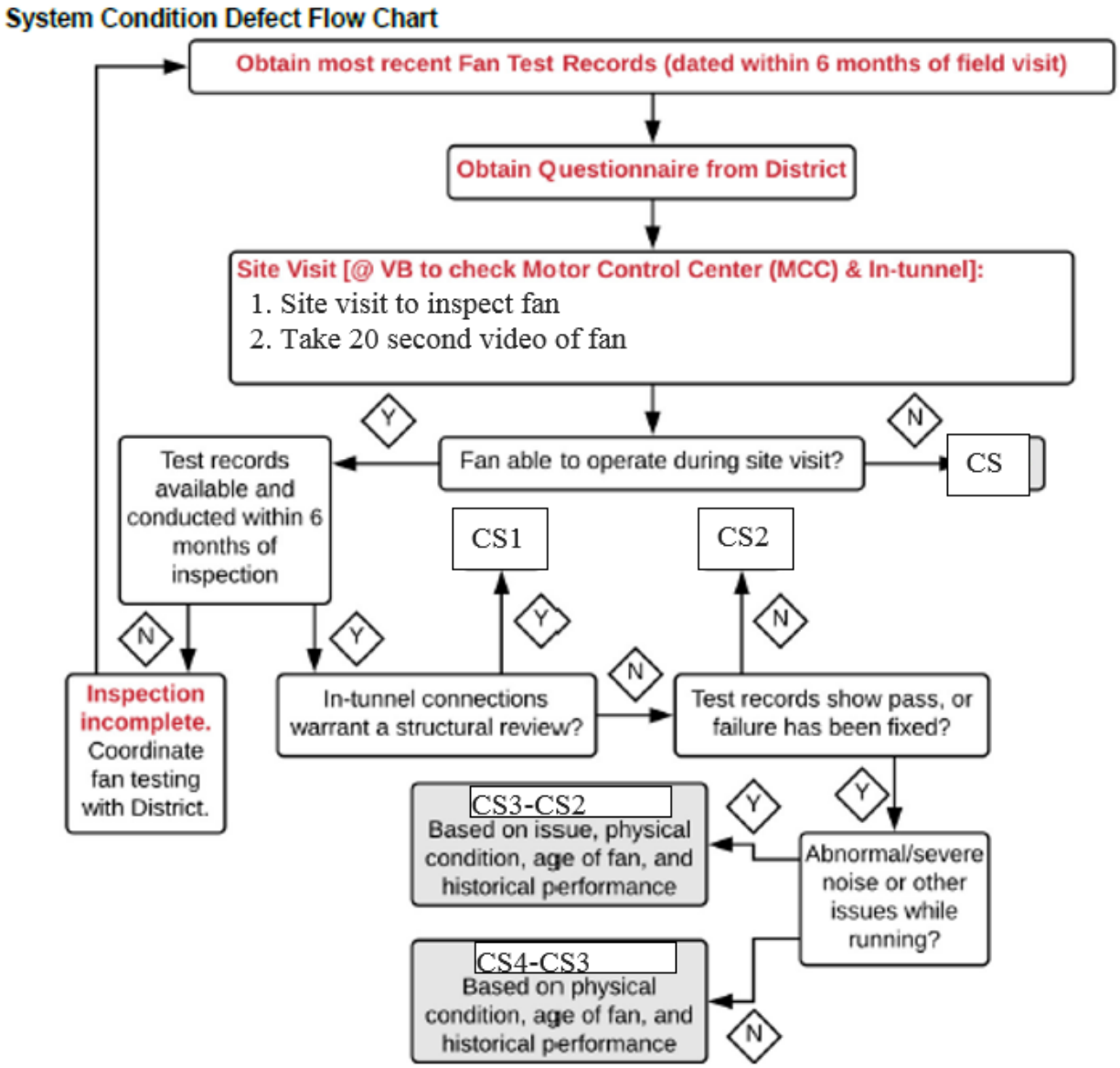
60620 Fans

Child Element Numbers/Names
None

Specification	Commentary
Record this element for all fans. This element describes the components that produce a current of air which provides the supply of fresh air to the tunnel while removing stale air and contaminants. The total quantity for fans is the sum of all the fans.	The fans may include the following subcomponents: Fan Motors, Fan Controller, Fan Belt, etc. Unit of Measure EA

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
Fan Operation (1710)	No deficiencies	Operates on all speeds and in all modes. Requires manual restart or manual control to achieve this. Drive(s) require some adjustment. More than normal play observed. (If belt - minor wear/ deterioration to belt.) Less than 40 ° F temperature rise form ambient temperatures during operation.	Operates on most speeds and in all modes. Requires manual restart or manual control to achieve this. Drive(s) require some adjustment. Significant play observed. (If belt - moderate wear/ deterioration to belt.) Between 40 - 60 ° F temperature rise from ambient temperatures during operation.	Fan operates on at least one speed or only operates in manual mode. Drive(s) require major adjustment. Severe play and/or belt/ chain noise is observed. (If belt- moderate wear/ deterioration to belt.) Between 40 ° F and 80 ° F temperature rise form ambient temperatures during operation.	Fan will not operate on any speed. Over 80 ° F temperature rise for ambient temperatures during operation.
Fan Condition (1711)	No deficiencies	Isolated breakdowns or deterioration.	Moderate deterioration, wear or minor oil staining.	The system is in poor condition — widespread deterioration or breakdowns reducing operational capacity, without impacting the serviceability of the element or tunnel.	The fan warrants evaluation to determine the effect on serviceability of the element or tunnel or the evaluation has determined there is an impact on the serviceability of the element or tunnel.


System Condition Defect Flow Chart
Obtain most recent Fan Test Records (dated within 6 months of field visit)
Obtain Questionnaire from District
Site Visit [@ VB to check Motor Control Center (MCC) & In-tunnel]:
1. Site visit to inspect fan
2. Take 20 second video of fan
Fan able to operate during site visit?
Y
N
CS
Test records available and conducted within 6 months of inspection
N
Y
Inspection incomplete. Coordinate fan testing with District.
In-tunnel connections warrant a structural review?
Y
CS1
N
Test records show pass, or failure has been fixed?
N
CS2
Y
Abnormal/severe noise or other issues while running?
Y
CS3-CS2
Based on issue, physical condition, age of fan, and historical performance
N
CS4-CS3
Based on physical condition, age of fan, and historical performance

Fan Inspection Questionnaire

(to be filled out/delegated by MBTA personnel)

MBTA Personnel: _____ Date: _____

(Electrical, Mechanical, etc.)

Inspection Team: _____ Inspection Date: _____

The following questions pertain to the following fan: _____

1. Have there been any recent repairs to the fan or any existing deficiencies/issues that should be noted?

2. Are there any on going repairs?

3. Is there any scheduled repairs/replacements to the fan?

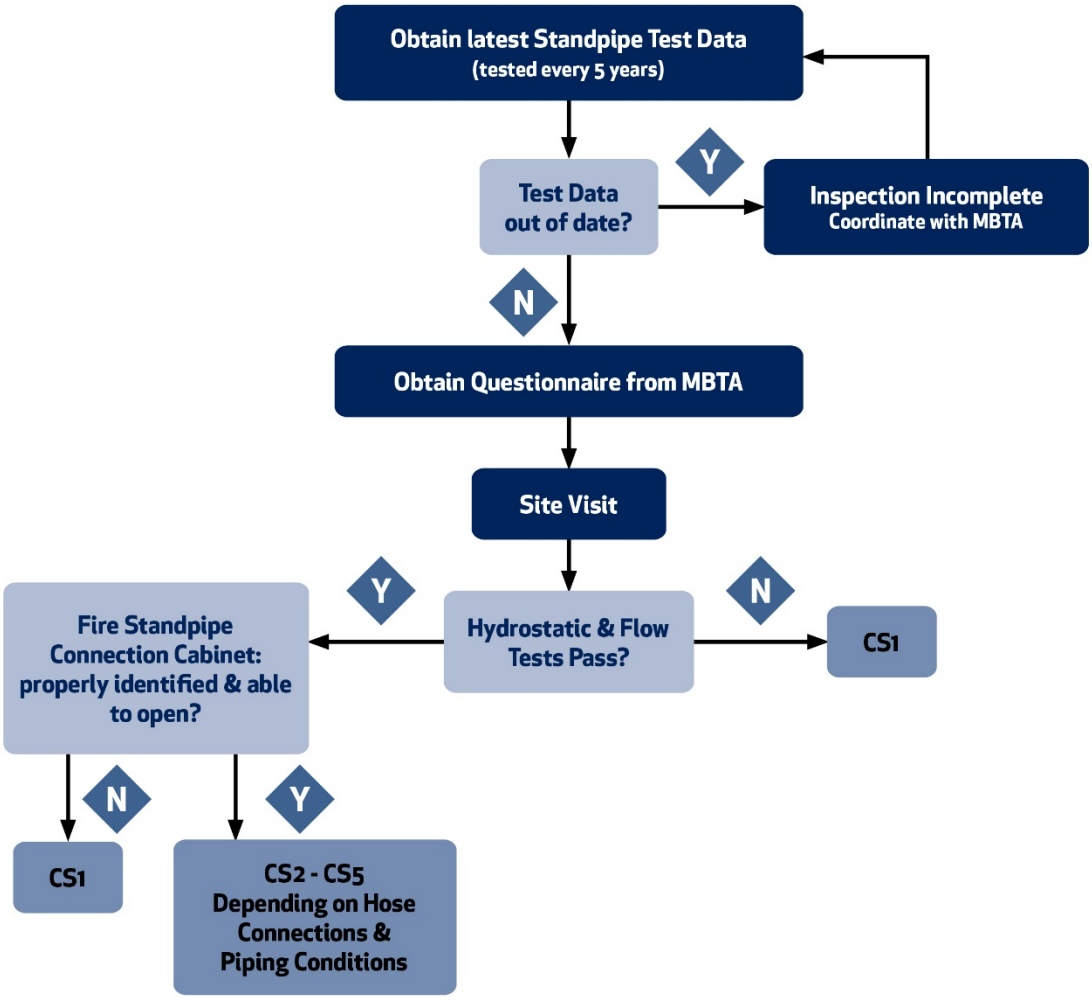
4. Are there any recent (within the last 6 months) testing information provided by an outside agency for the fans?

7.8.9 Standpipes

60630 Standpipes	
Child Element Numbers/Names None	
Specification	**Commentary**
The total quantity for stand pipes shall be total number of standpipes located within the tunnel. See flowchart and inspection questionnaire.	The fire standpipe includes the following subcomponents: • Tests: flow test, hydrostatic test, main drain test • Hose and connections: valve caps, cap gaskets, fire hose connections, valve handles, obstructions to connections, pressure restricting device • Piping: pipes, control valves, gauges, pipe support devices, water flow alarm • Cabinets: doors, handles, nameplates Due to the fact that a standpipe is an interdependent system, an isolated deficiency may impact the serviceability Unit of Measure EA

Condition State Definitions

Defect	Condition State 5	Condition State 4	Condition State 3	Condition State 2	Condition State 1
General Condition (1301)	Excellent condition - no notable distress.	Good condition - isolated breakdowns or deterioration.	Adequate condition - occasional breakdowns or deterioration.	Marginal condition - widespread deterioration or breakdowns without reducing functionality	Severe condition - element has failed and is no longer effective.


Obtain latest Standpipe Test Data
(tested every 5 years)
Test Data out of date?
Y
Inspection Incomplete
Coordinate with MBTA
N
Obtain Questionnaire from MBTA
Site Visit
Hydrostatic & Flow Tests Pass?
Y
N
CS1
Fire Standpipe Connection Cabinet: properly identified & able to open?
N
Y
CS1
CS2 - CS5
Depending on Hose Connections & Piping Conditions

Standpipe Inspection Questionnaire

(to be filled out/delegated by MBTA personnel)

MBTA Personnel: _____ Date: _____

(Electrical, Mechanical, etc.)

Inspection Team: _____ Inspection Date: _____

The following questions pertain to the following standpipe sections: _____

1. Have there been any recent repairs to the standpipe or any existing deficiencies/issues that should be noted?

2. Are there any on going repairs to the standpipes?

3. Are there any scheduled repairs/replacements to the standpipe?

4. Is there any recent (within the last 2 years) testing information provided by an outside agency for the standpipe?

7.9 Attachments

7.9.1 ..... NTIED Sheet Blank

7.9.2 ..... NTIED Sheet Example

Rail Transit Tunnel Inventory Items

Date:

7.2.2: Identification Items			
I.1	Tunnel ID Number		
I.2	Line code		
I.3	Branch Code		
I.4	Stationing Direction		
I.5	Transit Station - Start		
I.6	Transit Station - End		
I.7	Stationing - Start		
I.8	Stationing - End		
I.9	Latitude		
I.10	Longitude		
I.11	Portal-to-Portal Name		
7.2.3: Age and Service Items			
A.1	Year Built		
A.2	Year Rehabilitated		
A.3	Total Number of Tracks		
A.4	Average Number of Trains per Day		
A.5	Year of Average Number of Trains per Day		
A.6	Power Section		
A.7	Service in Tunnel		
7.2.4: Classification Items			
C.1	Owner		
C.2	Operator		
C.3	Users		
C.4	On a Revenue Line		
7.2.5: Geometric Data Items			
G.1	Tunnel Length		
G.2	Minimum Vertical Clearance above Track		
G.3	Minimum Total Lateral Clearance		
G.4	Minimum Left Clearance		
G.5	Minimum Right Clearance		
7.2.6: Inspection Items			
D.1	Routine Inspection Target Date		
D.2	Actual Routine Inspection Start Date		
D.3	Actual Routine Inspection End Date		
D.4	Routine Inspection Interval		
D.5	Damage Inspection Date		
D.6	Special Inspection Date		
7.2.7: Structure Type and Materials Items			
S.1	Number of Bores		
S.2	Tunnel Shape		
S.3	Ground Conditions		

Rail Transit Tunnel Inventory Items

Date: 12/07/2018

7.2.2: Identification Items			
I.1	Tunnel ID Number	BLW-EB-MP-104	
I.2	Line code	Blue	
I.3	Branch Code	Main	
I.4	Stationing Direction	WE	
I.5	Transit Station - Start	Maverick	
I.6	Transit Station - End	Portal	
I.7	Stationing - Start	134+50	
I.8	Stationing - End	164+20	
I.9	Latitude	42.36791	42° 22' 4"
I.10	Longitude	71.04049	71° 2' 26"
I.11	Portal-to-Portal Name	East Boston Tunnel	
7.2.3: Age and Service Items			
A.1	Year Built		1903
A.2	Year Rehabilitated		1997
A.3	Total Number of Tracks		1
A.4	Average Number of Trains per Day		2160
A.5	Year of Average Number of Trains per Day		2018
A.6	Power Section		T-2B/T-4
A.7	Service in Tunnel		Heavy Rail
7.2.4: Classification Items			
C.1	Owner	01	
C.2	Operator	02	
C.3	Users	01	
C.4	On a Revenue Line	01	
7.2.5: Geometric Data Items			
G.1	Tunnel Length		2970 Ft
G.2	Minimum Vertical Clearance above Track		16.5 Ft
G.3	Minimum Total Lateral Clearance		18.4 Ft
G.4	Minimum Left Clearance		09.2 Ft
G.5	Minimum Right Clearance		09.2 Ft
7.2.6: Inspection Items			
D.1	Routine Inspection Target Date		03082019
D.2	Actual Routine Inspection Start Date		03152019
D.3	Actual Routine Inspection End Date		03212019
D.4	Routine Inspection Interval		24
D.5	Damage Inspection Date		06082019
D.6	Special Inspection Date		12082019
7.2.7: Structure Type and Materials Items			
S.1	Number of Bores		1
S.2	Tunnel Shape		2
S.3	Ground Conditions		4

Appendices

Appendices have not been included in this external version.

Appendix A

Routine All-Item Inspection Report Sample

Special Member /Overhead Inspection Report Sample

Damage/Emergency Inspection Report Sample

Element Total Quantity Calculation Example

Report Condition Summary Sheet

Reporting Charts

Appendix B

Element/Defect Codes List