OTTAWA LIGHT RAIL TRANSIT

PROJECT

Track Safety Justification Report

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REVISION HISTORY

Rev	Date	Description	Prepared by	Reviewed by	Approved by	Authorised by	Agreed by
0	17-Apr-2019	Initial Issue	B. Venables	S. Leonard	J. Blowfield	D. Wynne	S. Derry
1	23-May-2019	Update to align with safety docs	B. Venables	S. Leonard	J. Blowfield	D. Wynne	S. Derry
2	14-Aug-2019	Update and prep for RSA - SJR	B. Venables	S. Leonard	J. Blowfield	D. Wynne	S. Derry

EXECUTIVE SUMMARY

This report presents the Primary System Safety Justification for the Ottawa Confederation Line Phase 1 Track System. It has been prepared in accordance with the requirements of the Confederation Line Phase 1 Systems Safety Programme Plan [2] to provide evidence for, and the reasoning behind, the assertion that the Confederation Line Phase 1 Track System is safe for passenger operation and that risks associated with the Stations have been demonstrated to be acceptable.

This has been achieved through hazard identification, analysis and mitigation in line with the requirements of the Confederation Line Phase 1 Hazard Management Procedure [3] as shown in the Track Preliminary Hazard Analysis (PHA) [4] and Track Sub-System Hazard Analysis (SSHA) [5] for the Track System as well as Safety Assessment of the interfaces between Primary systems within the Confederation Line Phase 1 Interface Hazard Analysis [6] and any hazards arising through-life that are assessed within the Confederation Line Phase 1 Operations and Support Hazard Analysis [7]. All hazards are considered to have been reduced to tolerable levels.

Any pertinent hazards have been included in the Project Hazard Log or within the Confederation Line Phase 1 Integrated Hazard Log [9] with Derived Safety Requirements (DSR) placed upon the Owner, Maintainer or Operator agreed at the Hazard Review Panel (HRP) and transferred in line with the processes identified in the Confederation Line Phase 1 Hazard Management Procedure [3].

Evidence of successful completion of System Integration Tests (SIT) and System Acceptance Tests (SAT) is provided in the PA Technical Compliance Matrix [17]. Any residual testing required are identified in the ESAC Outstanding Items [13] but is not considered to have a safety effect.

Correct design, construction and integration has been verified by Engineers of Record within the Design Certification Letters (DCL), Construction Certification Letters (CCL) and Integration Certification Letters (ICL) as evidenced in the PA Technical Compliance Matrix [17].

Confederation Line Phase 1 Reliability Availability and Maintainability Report [54] has been produced for the Track which provides confidence the infrastructure is capable of delivering long term availability, subject to the maintenance regime being carried out.

Based upon the evidence presented, it is considered that Ottawa Confederation Line Phase 1 TSCC is acceptable for revenue services subject to adherence to any Restrictions, Conditions and Limitations identified in the in Confederation Line Phase 1 Operational Restrictions Document [12] and resolution of issues identified in the ESAC Outstanding Items [13].

CONTENTS

1. INTRODUCTION

This document presents the Primary Systems Safety Justification for Track of the Ottawa Confederation Line Phase 1 and support the Confederation Line Phase 1 Case for Safety [1]. The Confederation Line Phase 1 Case for Safety [1] presents a Safety Justification for Revenue Service, subject to stated Restrictions, Conditions and Limitations that can be found in the Confederation Line Phase 1 Operational Restrictions Document [12]. The objective of this Safety Justification Report is to describe the features incorporated into the design and implementation to ensure operational safety and demonstrate that hazards have been identified, assessed and DSR have been agreed and transferred to their respective owners as shown in the Safety Requirements Matrix [55].

Design Certification Letters (DCL), Construction Certification Letters (CCL) and Integration Certification Letters (ICL) have been signed by Engineers of Record. Systems Integration Test (SIT) and Systems Acceptance Test (SAT) Test & Commissioning evidence has been generated for Track System. Any outstanding certification or residual testing required is identified in the ESAC Outstanding Items [13].

Engineering Safety Management has been implemented in accordance with the Confederation Line Phase 1 Systems Safety Programme Plan [2] and assured in line with the Confederation Line Phase 1 Systems Safety Certification Plan [15] in accordance with the requirements of EN 50126 [57], EN 50128 [58] and EN 50129 [59] to ensure safety is inherent in the design and implementation.

All identified hazards have been mitigated to acceptable levels in accordance with the Confederation Line Phase 1 Hazard Management Procedure [3].

Track related safety requirements have been captured from the Project Agreement [16] and are Verified and Validated within the PA Technical Compliance Matrix [17] in accordance with the Confederation Line Phase 1 Systems Engineering Management Plan [19].

Analytical processes have been designed to conform with necessary industrial standards to provide comprehensive Safety Assurance. These have been supplemented by engineering best practice, governance and quality management in line with the Confederation Line Phase 1 Project Quality Plan [21].

1.1 PURPOSE

This report has been prepared to provide a body of evidence supporting the following claims:

- The Confederation Line Phase 1 Track has been demonstrated to be acceptably safe for passenger operations
- All safety risks associated with Track operations have been reduced to an acceptable level as defined in the Confederation Line Phase 1 Hazard Management Procedure [3]
- The Ottawa Confederation Line Phase 1 Track is compliant to the requirements of the Project Agreement [16].

1.2 SCOPE

1.2.1 Specific Inclusions

The following are within the scope of this report:

- Safety assessment conducted in line with the requirements of the Confederation Line Phase 1 Systems Safety Programme Plan [2]
- Hazard analysis conducted in accordance with the Confederation Line Phase 1 Hazard Management Procedure [3]
- Track System defined by the Confederation Line Phase 1 Configurable Items Database [14] and described in section 3.1.1
- All operating modes, lifecycle phases and personnel (including Passengers, Operators and Maintainers)
- Track infrastructure across all Confederation Line Phase 1 geographic locations.

In order to provide a complete safety assessment, this report should be read in conjunction with the following documents:

- Confederation Line Phase 1 Integrated Hazard Log [9]
- Confederation Line Phase 1 Interface Hazard Analysis [6]
- Tunnel Safety Justification Report [26]
- TSCC and BCC Safety Justification Report [27]
- CBTC Systems Safety Hazard Analysis (Thales) [29]
- Rolling Stock Systems Safety Hazard Analysis (Alstom) [30]
- Safety Requirements Matrix [55]
- Technical Compliance Report [32].
- Energy System Safety Justification Report [24]
- Stations Safety Justification Report [28]
- Maintenance & Storage Facilities (MSF) Safety Justification Report [23]

1.2.2 Specific Exclusions

The following are outside of the scope of this report:

- Any systems outside of the Ottawa Confederation Phase 1 interface boundary defined by the Confederation Line Phase 1 System Breakdown Structure [18]
- All turnouts are equipped with electrically operated control switch machines and other associated equipment, provided by Thales and covered in CBTC Systems Safety Hazard Analysis (Thales) [25]
- Emergency Walkway throughout the main 2.5km tunnel, covered in the Tunnel Safety Justification Report [24].

- The provision of Earthing and Bonding of the Track System in relation to the OCS system. This is covered in the Energy Safety Justification Report [22].
- The provision of rail lubrication systems has been excluded from the scope of the Track System. The LRV, provided by Alstom, is fitted with on-board lubricating systems, which are covered in the Rolling Stock Safety File [28].
- Power supplies to switch heaters and buffer stop lighting are excluded.

Safety Assessment for systems covered by the following reports:

- Tunnel Safety Justification Report [26]
- Energy System Safety Justification Report [24]
- Maintenance & Storage Facilities (MSF) Safety Justification Report [23]
- Stations Safety Justification Report [28].

1.3 CONDITIONS

This Safety Justification Report relates to the build standard defined by the Confederation Line Phase 1 Configurable Items Database [14].

The Confederation Line Phase 1 Railway has been correctly maintained throughout the pre-revenue service period.

Further Conditions of operation are identified in section 5.2 and in the Confederation Line Phase 1 Operational Restrictions Document [12].

1.4 DOCUMENT STRUCTURE

This document provides the Systems Safety justification for the Ottawa Confederation Line Phase 1 Track and forms part of the Confederation Line Phase 1 Case for Safety [1], which in turn, forms a major input to the [20].

The Confederation Line Phase 1 Safety and Assurance framework is shown in Figure 1.

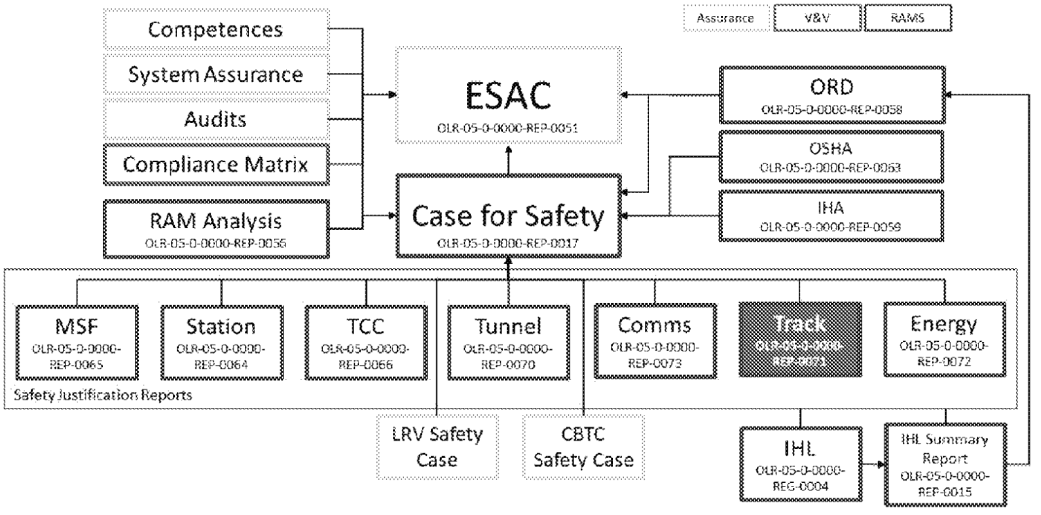

Figure 1: Document Hierarchy

Detailed descriptions of processes implemented as part of the Engineering Safety Management activities are given in the Confederation Line Phase 1 Case for Safety [1] and summarised within this report to avoid duplication.

This Safety Justification is structured as follows:

- Section 1: Defines the purpose, scope and approach to the safety argument together with description of the Confederation Line Phase 1 project
- Section 2: Provides a holistic system description including geographic locations, equipment, key parties, design criteria and environmental and operating context
- Section 3: Description of design characteristics to deliver operational safety and output from hazard analysis and mitigation processes
- Section 4: Overview of quality processes and any deficiencies identified
- Section 5: Identification of any Restrictions, Conditions and Limitations as a result of any design limitations or deficiencies identified
- Sections 6 and 7: Summarising the overall safety argument, claims and body of evidence, and presenting a series of recommendations to mitigate residual risks prior to the onset of revenue service.

1.5 GLOSSARY

Table 1: Acronyms and Abbreviations

Abbreviation	Meaning
AREMA	American Railway Engineering and Maintenance-of-Way Association
ASTM	American Society for Testing and Materials
BRT	Bus Rapid Transit system
CBTC	Communication Based Train Control
CCL	Construction Certification Letter
CWR	Continuous Welded Rail
DCL	Design Certification Letter
DF	Direct Fixation
DFF	Direct Fixation Fastener
EJV	Engineering Joint Venture
EMC	Electromagnetic Compatibility
FTA	Fault Tree Analysis
HMP	Hazard Management Procedure
HRP	Hazard Review Panel
IHA	Interface Hazard Analysis
IHL	Integrated Hazard Log
LFLRV	Low Floor Light Rail Vehicle
LRT	Light Rail Transit
LRV	Light Rail Vehicle
MSF	Maintenance and Storage Facility
OCS	Overhead Catenary System
OLRT	Ottawa Light Rail Transit
PA	Project Agreement
PHA	Preliminary Hazard Analysis
RAM	Reliability, Availability & Maintainability
RAMS	Reliability, Availability, Maintainability and Safety
RCF	Rolling Contact Fatigue
RTG	Rideau Transit Group

Abbreviation	Meaning
RTM	Rideau Transit Maintenance
SAT	Systems Acceptance Test
SCADA	Supervisory Control & Data Acquisition
SEMP	Systems Engineering Management Plan
SIL	Safety Integrity Level
SIT	Systems Integration Test
SSHA	Sub-Systems Hazard Analysis
T&C	Test and Commissioning
TCRP	Transit Cooperative Research Program
TSCC	Transit Services Control Centre

1.6 REFERENCE DOCUMENTS & GOVERNANCE

1.6.1 Reference Project Documents

Project documents referenced within this report are shown in the Table 2. Reference is made to the latest release unless otherwise stated.

Table 2: Referenced Project Documents

	Title	Document No.
[1]	Confederation Line Phase 1 Case for Safety	OLR-05-0-0000-REP-0017
[2]	Confederation Line Phase 1 Systems Safety Programme Plan	OLR-05-0-0000-MPL-0012
[3]	Confederation Line Phase 1 Hazard Management Procedure	OLR-05-0-0000-PRC-0001
[4]	Track Preliminary Hazard Analysis (PHA)	REJ-05-0-0000-REP-0330
[5]	Track Sub-System Hazard Analysis (SSHA)	REJ-05-0-0000-REP-0357
[6]	Confederation Line Phase 1 Interface Hazard Analysis	OLR-05-0-0000-REP-0014
[7]	Confederation Line Phase 1 Operations and Support Hazard Analysis	OLR-05-0-0000-REP-0063
[8]	EJV Hazard Log	REJ-05-0-0000-REG-0006
[9]	Confederation Line Phase 1 Integrated Hazard Log	OLR-05-0-0000-REG-0004
[10]	Trackwork System RAM Analysis	REJ-05-0-0000-REP-0339
[11]	Design Safety Case	REJ-05-0-0000-REP-0311
[12]	Confederation Line Phase 1 Operational Restrictions Document	OLR-50-0-0000-REP-0058
[13]	Engineering Safety and Assurance Case Outstanding Items	OLR-05-0-0000-REG-0025
[14]	Confederation Line Phase 1 Configurable Items Database	OLR-50-0-0000-REP-0058
[15]	Confederation Line Phase 1 Systems Safety Certification Plan	OLR-05-0-0000-MPL-0003
[16]	Project Agreement	TORO 1; 4868348: v55
[17]	PA Technical Compliance Matrix	OLR-90-0-0000-CMP-0002
[18]	Confederation Line Phase 1 System Breakdown Structure	OLR-09-0-0000-DIA-0001
[19]	Confederation Line Phase 1 Systems Engineering Management Plan	OLR-50-0-0000-MPL-0005
[20]	Confederation Line Phase 1 Engineering Safety and Assurance Case	OLR-05-0-0000-REP-0051

	Title	Document No.
[21]	Confederation Line Phase 1 Project Quality Plan	SEMP-P0050-PLA-0025
[22]	EJV Interface Hazard Analysis	REJ-05-0-0000-REP-0302
[23]	Maintenance & Storage Facilities (MSF) Safety Justification Report	OLR-05-0-0000-REP-0065
[24]	Energy System Safety Justification Report	OLR-05-0-0000-REP-0072
[25]	Communications System Safety Justification Report	OLR-05-0-0000-REP-0073
[26]	Tunnel Safety Justification Report	OLR-05-0-0000-REP-0070
[27]	TSCC and BCC Safety Justification Report	OLR-05-0-0000-REP-0066
[28]	Stations Safety Justification Report	OLR-05-0-0000-REP-0064
[29]	CBTC Systems Safety Hazard Analysis (Thales)	3CU 05018 0247 DUZZA
[30]	Rolling Stock Systems Safety Hazard Analysis (Alstom)	ADD0000939280
[31]	Confederation Line Phase 1 V&V Management Plan	OLR-50-0-0000-MPL-0006
[32]	Technical Compliance Report	OLR-05-0-0000-REP-0054
[33]	Hazard Log Summary Report	OLR-05-0-0000-REP-0015
[34]	Track Failure Modes and Effects Analysis	REJ-05-0-0000-REP-0345
[35]	DCL for Track Alignment	REJ-OLR-21-0-DCL-0025
[36]	DCL for Trackwork Installation	REJ-OLR-22-0-DCL-0026
[37]	Interim CCL for Trackwork Installation	REJ-OLR-22-0-CCL-0177
[38]	CRS for Trackwork Installation – System Wide	REJ-22-0-0000-CRS-0028
[39]	Design Brief Trackwork	RES-22-0-0000-DBC-0003
[40]	Vehicle/Platform relationship report	RES-22-0-0000-DBC-0006
[41]	Design Brief – Rail Break Analysis	RES-22-0-0000-DBC-0007
[42]	Design Brief Vehicle Clearance Analysis	RES-22-0-0000-DBC-0103
[43]	Train to Guideway Clearances – As-Built Condition Assessment	RES-22-0-0000-DBC-0138
[44]	Track Alignment and Geometric design report	RES-22-0-0000-DCI-0001
[45]	Running Rails	RES-22-0-0000-DRD-4001
[46]	Derailment Curb	RES-22-0-0000-DRD-4007
[47]	Confederation Line Trackwork Maintenance Manual	RES-22-0-0000-MAN-0003
[48]	Noise & Vibration Management Plan – Underground Sections	REJ-74-8-0000-REP-0117
[49]	Supplier Tender Quality Management	OLR-04-0-0000-SPE-0001
[50]	Track Assurance Report 1	OLR-22-0-0000-REP-0001
[51]	Track Assurance Report 2	OLR-22-0-0000-REP-0002
[52]	Track Assurance Report – Derailment management	OLR-22-0-0000-REP-0003

	Title	Document No.
[53]	Track Assurance Report 3	OLR-22-0-0000-REP-0004
[54]	Confederation Line Phase 1 Reliability Availability and Maintainability Report	OLR-05-0-0000-REP-0056
[55]	Safety Requirements Matrix	OLR-05-0-0000-REP-0053
[56]	Master Deficiencies List	OLR-90-0-0000-CMP-0004

1.6.2 Referenced Codes and Standards

Confederation Line Phase 1 Track has been designed in accordance with the requirements of the Codes and Standards identified in Table 3. Reference is made to the version in use at the time in which the PA was agreed.

Table 3: Applicable Codes and Standards

	Title	Document No.
[57]	The specification and demonstration of reliability, availability, maintainability and safety (RAMS)	EN50126
[58]	Functional safety of electrical/electronic/programmable electronic safety-related systems	EN50128
[59]	Communication, signalling and processing systems. Safety related electronic systems for signalling	EN50129
[60]	American Railway Engineering and Maintenance-of-Way Association (AREMA) Standards	-
[61]	Transit Cooperative Research Program (TCRP) Report 57 Track Design Handbook for Light Rail Transit;	-
[62]	Transit Cooperative Research Program (TCRP) 155, Track Design Handbook for Light Rail Transit	-
[63]	American Society for Testing and Materials (ASTM) Standards (full suite)	-

2. SYSTEM DESCRIPTION

2.1 PROJECT DESCRIPTION

Ottawa Confederation Line Phase 1 provide a Low Floor Light Rail Vehicle (LFLRV) Light Rail Transit (LRT) service between Tunney's Pasture and Blair stations. The 12.5-kilometre line includes a 2.5km mined tunnel beneath downtown Ottawa and an LRT Maintenance and Storage Facility (MSF) at Belfast Road, shown in Figure 2.

Phase 1 includes thirteen stations, with three considered as Under Ground Stations, one considered as an Enclosed Station, and Blair Station, Hurdman Station and Tunney's Pasture Station integrating with the Bus Rapid Transit system. The Confederation Line links up with the north-south running O-Train at Bayview Station, and with VIA rail at Tremblay.

The Ottawa Confederation Line Phase 1 scope comprises Guideway, Stations and Line of Route systems between Tunney's Pasture and Blair Stations and delivery of the MSF, Yard, TSCC/BCC and LRV Fleet as defined by the RTG - City of Ottawa Project Agreement (PA) [16].

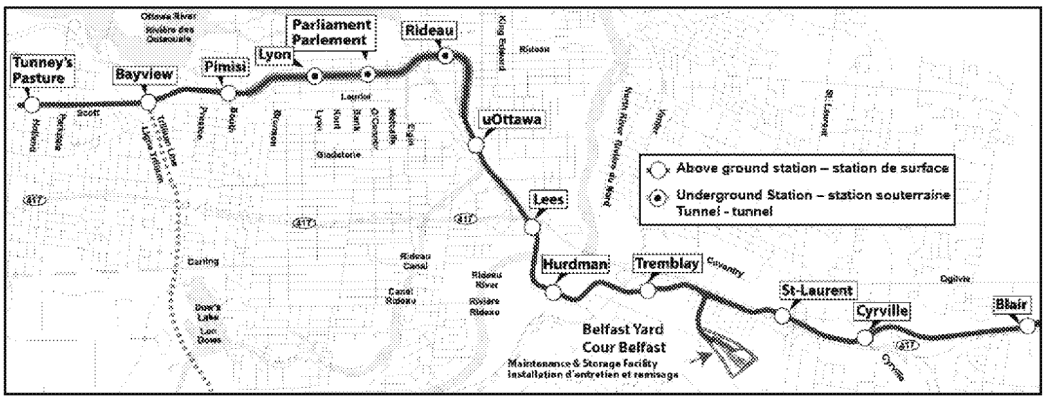

Figure 2: Confederation Line Phase 1 Route Map

2.2 KEY PARTIES

Design of the majority of Ottawa Confederation Line Phase 1 infrastructure has been the responsibility of an Engineering Joint Venture (EJV) partnership between SNC Lavalin, Dragados and EllisDon.

Alstom Citadis Spirit low floor articulated rail vehicles are used to provide up to 300 passengers per LRV unit.

Communications Based Train Control (CBTC) moving block train control systems is provided by Thales.

Transit Services (OC-Transpo) provide all main line control staff, LRV Drivers, transit law and other customer service personnel.

Rideau Transit Maintenance (RTM) are responsible for maintenance of all systems and infrastructure including the LRV fleet.

2.3 ENVIRONMENT

Two and a half kilometres of the Ottawa Confederation Line Phase 1 is underground, passing through the core of Ottawa. Three Stations, Lyon, Parliament and Rideau are in this tunnel section, in addition St Laurent station is an 'Enclosed Station' and considered to be below grade.

In certain areas enhanced track systems have been provided for noise and vibration attenuation.

Part of the railway is under the Ottawa Canal and below the rising water table, requiring appropriate waterproofing and flood protection measures.

The Track System has been designed, and specifically the rail stress management, to the following environmental parameters

- Extremes of heat, cold and relative humidity
  - Average temperature -15°C to +15°C
  - Extreme temperatures - 38°C to +39°C
- Effect of dust (e.g. equipment with appropriate IP protection)
- Snow and ice on exposed sections including tunnel mouths (e.g. point heaters for points in the open areas) and with a risk of build-up of ice on the catenary
- Wind which can deflect the overhead catenary and put sideways forces on the support posts
- Shock and vibration
- Seismic activity
- Electromagnetic Interference.
- In certain areas enhanced Track Systems have been provided for noise and vibration attenuation.

2.4 DESIGN CRITERIA

The Design Brief Trackwork [39] defined the following design criteria:

- Interchangeability
- Modular design
- Standard off the shelf components
- Design for maintainability
- Design for availability and constructability; and
- Design for safety and reliability.

The DFF system was chosen to control:

- The CWR/Structure interaction forces
- The ability to achieve and maintain desired rail tolerances

- The ability to prevent rail buckling under high temperature
- The ability to permit the structure to move longitudinally owing to structural flexure and thermal expansion or contraction beneath the rail which remains fixed
- The ability to withstand fatigue and wear of fastener components with low maintenance requirements
- The ability to reduce ground borne noise and vibration
- The ability to withstand the local environment without the need to replace major components within the design life
- The ability to withstand longitudinal, lateral, and vertical loading from the vehicle
- The ability to provide adequate electrical isolation between track and ground.

The Track Alignment and Geometric design [44] defines the alignment criteria as being designed for passenger comfort, safety, general accepted light rail engineering principles and the LRV requirements set by the Alstom, especially for the low floor level and gauge clearance.

2.5 OPERATING CONTEXT

Overall performance and cost effectiveness of Ottawa Confederation Line Phase 1 is enhanced by embedding SCADA as the fundamental feature of the design solution and operations concept. This approach automates equipment monitoring, many operating functions and enhances the overall Operator decision-making. SCADA will benefit RAM performance through the provision of an accurate and complete data set relating to the performance and health of equipment that can be used to inform maintenance scheduling.

The Ottawa Confederation Line Phase 1 infrastructure has been designed to minimise the maintenance burden and logistic footprint. Maintenance has been rationalised to repair by LRU replacement at first line as far as is technical feasible, and preventive maintenance minimised by design and widespread implementation of SCADA monitoring capability. This approach is considered to reduce safety risks to on-track personnel by minimizing the time within hazardous environments whilst maximizing benefit to passengers through on-time running and cost effectiveness. Systems have been selected for their inherent ease of maintenance whilst the infrastructure layout has been designed to permit necessary access, walking routes and cater for human factors.

The City of Ottawa will be responsible for ensuring that necessary training and certification has been conducted for all staff required to operate Confederation Line Phase 1.

2.5.1 Operation of the Track System

The Track System has been designed for a maximum operating speed of 100kmph, with localised reductions as appropriate due to the constraints of the previous BRT, or the available land/adjacent buildings.

- Turnout speeds are variable, with two standardised units provided.
- Maximum speed for the MSF connector is 30kmph, and 15kmph for all tracks within the MSF.
- The alignment through all Stations is straight to maximise driver sighting distance.
- Gauge and structural clearances allow for the maximum dynamic effects of the train operating at 100kmph.
- The Track System has excluded any rail lubrication systems. The ability to gain traction on steep gradients, especially during winter conditions, is reliant upon the sanding units fixed to the LRVs.
- Design Brief – Rail Break Analysis [41] has been undertaken and a worst-case gap of 54mm is predicted. This can still be passed safely by an LRV without risk of derailment but may be subjected to a local speed restriction until repaired.

2.5.2 Operation with External Influences

The following areas have dependencies external to the Track sub-system:

- Switch Heaters: Although the Track Design and Build Contractor has installed switch heaters, the supply of power to them and the integration of the remote monitoring equipment to the TCSS/BCC SCADA controls is the responsibility of other asset groups within Confederation Line Phase 1. The provision for the supply of gas to the MSF heaters is through mains supply rather than by locally stored bottle supplies.
- Earthing and Bonding: The Track Systems components have been designed to give electrical separation where practicable. This is through the provision of rail pads and insulators that allow separation of the rails from all other components and asset types. The provision of earthing bonds from the rails is excluded from this Safety Justification Report. Details of earthing and bonding is covered by the Energy Safety Justification Report [24].
- Electromagnetic compatibility: There are no components within the Track System that require specific EMC analysis. The switch motors that connect to the switch rails, are covered by the Communications System Safety Justification Report [25].

2.6 STATIONS

The track design through all platform areas is consistent at all 13 Stations, and includes the following key features:

- All platforms are straight, including a minimum of 15m straight tack at both ends of the platform
- Platform - Rail relationship designed to give level access into the LRV, with a maximum gap of 75mm
- Additional restraining rails provided at key structures to limit LRV derailments due to structural damage.

2.7 TRACK SYSTEM

Technical details for Ottawa Confederation Line Phase 1 can described as follows:

2.7.1.1 Running Rail

- 115RE high strength rail (310 Brinell) Running Rails [45] as per the AREMA standard
- All mainline running rail is Continuous Welded Rail (CWR) compliant to AREMA standards
- All rails within the MSF are 115RE Running Rails [45] in CWR form
- Restraining Rails have been provided on all sharp radius curves below 150m radius and as protection at key structural elements.

2.7.1.2 Fasteners

Direct Fixation Fastener (DFF): by cast, rolled or forged, top and bottom metal plate bonded with rubber, anchored into the slab by anchor bolts with inserts. Rail is secured to DFF fastener by two elastic clips.

Tie and ballast at the MSF: two elastic clips inserted into cast shoulders of a mono-block concrete tie. Two different strength of fasteners have been used. These are 18.5kN/mm for normal track conditions and 9.5kN/mm for the specialist requirements of noise and vibration control in accordance with the Noise & Vibration Management Plan – Underground Sections [48].

2.7.1.3 Supports

- Plinths: cast-in-place reinforced concrete plinths as per the ACI standards are sized to accommodate direct fixation fastener assemblies and reinforcing steel with a minimum cover of 38mm
- Concrete slab in the tunnel and concrete slab in the At Grade reinforced with steel
- Monoblock concrete ties with embedded shoulders, per AREMA standards, on Ballast, sub-ballast, and subgrade: all layers as per the AREMA standards
- A mix of monobloc concrete and timber ties are used in the MSF
- Track gauge is 1,435mm, with the rails inclined at 1 in 40 in towards the each other.

2.7.1.4 Special Trackwork

- Includes turnouts, crossovers, diamond crossings and rail expansion joints
- Turnouts are based on AREMA geometry for all DF mainline tracks and yard lead tracks and will use 115RE rail, with UIC 60E1A1 rail section for the switch blades. Of the 30 main-line turnouts, 12 are installed on concrete slab and the remaining 18 are on concrete ties. However, turnouts at the MSF are installed on timber ties
- Rail expansion joints have been provided at each end of Rideau River Bridge to provide thermal expansion protection to the bridge structure.

2.7.1.5 Track bed

- Direct Fix Track - Direct Fix Track is utilised in locations where for performance, noise and vibration control, existing soil conditions, structural clearances, or dead

load restrictions, it is desirable to have the rail directly fixed to the concrete structure

- Ballasted Track – mainline ballasted track utilises pre-stressed concrete ties that have been designed for electrical isolation and vibration attenuation upon a formation that has been designed to minimise maintenance overhead
- The ballasted track structure is designed to provide a degree of resilience based on the magnitude of load distributed to the rail and track structure. Rail fasteners for ballasted track is of spring clip type for the pre-stressed concrete ties
- The fastening system for the concrete ties consists of:
  - Elastomeric rail pads
  - Spring steel clips
  - Cast-in shoulders and inserts
  - Insulators.

2.7.1.6 End of Line Protection

- The provision of friction control buffer stops at the main-line terminal limits at Tunney's Pasture and Blair
- Fixed buffer stops to all sidings within the MSF.

2.7.2 Supplementary Assets

The core track assets are supplemented by the following assets within this Safety Justification Report.

2.7.2.1 Gauging and Structural Clearance

- The EJV Track work Contractor has taken accountability for demonstrating that safe structural and passing clearances have been achieved. This is based upon an agreed dynamic profile for the Citadis B15 LRV, a maximum line-speed potential of 100Km/ph and the design alignment and geometry
- The track design provides safe clearance to all line-side equipment
- The track design provides safe clearance of emergency walkways within the tunnel sections.

2.7.2.2 Drainage

- Track drainage is a component of track work and is sufficient to remove water from the guideway surface and subsurface
- On the elevated guideway structure and in the tunnel, the track drainage is part of the structural design.

2.7.2.3 Switch Heaters

- All main-line turnouts, except 305-308 points between Lyon and Parliament Stations, are fitted with electric switch heaters. These are linked back to the TSCC/BCC via the

SCADA system. 305-308 points have no heaters as they in a constant environment in the downtown tunnel

- All MSF turnouts have gas supplied switch heaters.

2.7.2.4 Geotechnical Civil Works

- Provision of new embankments to support the track-bed between Rideau River bridge through Hurdman Station towards Tremblay Station.

3. SAFETY JUSTIFICATION

3.1 SAFETY CONSIDERATIONS AND FEATURES

3.1.1 Systems Design

3.1.1.1 Primary Systems

The description and Safety Assessment of Primary Systems covered by other reports are identified in 2.7. These are not discussed below to avoid duplication.

The primary features for safety are:

- Rails – to support and guide the trains
- Slab/ties – to hold the rails are the correct gauge apart and to provide inclination
- Special trackwork – to enable trains to change tracks safely
- Expansion rails – to allow the rail system to have safe movement against induced forces form other structures
- Restraining Rails – to provide additional guidance and protection in sharp curves or at key structural elements and to prevent derailment
- Rail Stress – Rails have an induced stress to control the expansion and contraction forces due to the wide temperature range. This will reduce the risk of misalignment during extreme heat and reduces the likelihood of breaks during extreme cold
- Ballast and Formation – to secure and support the Track asset.

3.2 HAZARD MANAGEMENT

Hazard analysis has been implemented throughout each stage of the project design and implementation lifecycle in line with the Confederation Line Phase 1 Hazard Management Procedure [3]. This has culminated in the preparation of a Track Preliminary Hazard Analysis (PHA) [4] in which initial hazard identification analysis and assessment was undertaken, which was subsequently developed into the Track Sub-System Hazard Analysis (SSHA) [5] to provide detailed risk assessment for Track.

These activities employed a range of analytical techniques including Track Failure Modes and Effects Analysis [34] and Fault Tree Analysis (FTA) to provide confidence in the inherent safety of the designed and implemented solution. Track PHA hazards are shown in Table 4 and discussed in section 3.2.1.2.

The output from these analyses has been recorded in the EJV Hazard Log [8], the Hazard Log Summary Report [33] and the Confederation Line Phase 1 Integrated Hazard Log [9]. The transfer of hazards that require further mitigation by the Operator, Maintainer or City of Ottawa, has been conducted with the oversight and agreement of the Hazard Review Panel (HRP), and in line with the processes defined in the Confederation Line Phase 1 Hazard Management Procedure [3].

Track related hazards have been extracted from the Confederation Line Phase 1 Integrated Hazard Log [9] and are shown together with their corresponding Derived

Safety Requirement (DSR) in the Hazard Log Summary Report [33]. All transferred hazards have been agreed and accepted by the relevant recipient/owner

. Evidence presented in the Confederation Line Phase 1 Integrated Hazard Log [9] supports the assertion that all applicable hazards have been reduced to a tolerable level.

The Railway Level Confederation Line Phase 1 Confederation Line Phase 1 Operations and Support Hazard Analysis [7] has been conducted to identify and assess hazards related to the operations and maintenance of the OLRT Confederation Line Phase 1 infrastructure and identify adequate mitigations required to ensure usage safety.

An EJV Interface Hazard Analysis [22] was developed based upon analysis that had been presented in the Track Preliminary Hazard Analysis (PHA) [4]. This was developed into a more comprehensive Confederation Line Phase 1 Interface Hazard Analysis [6] which took a systematic approach to evaluate each interface with its consequences of failure and mitigations. It is considered that these analyses verified their effective systems integration had been implemented and safety risks had been reduced to a tolerable level.

3.2.1 Primary System Track Hazards

3.2.1.1 Hazard Identification

Hazards obtained from the Track Sub-System Hazard Analysis (SSHA) [5] and identified in Table 4.

Table 4: Primary Systems Level Track Hazards

Hazard ID	Hazard Description	Severity
TRK-H-01	Loss of rail structural integrity /distortion of track geometry (broken rail, excessive rail wear, etc.)	Catastrophic
TRK-H-02	Improper rail/wheel interface	Catastrophic
TRK-H-03	Switch in the wrong position	Catastrophic
TRK-H-04	Insufficient train protection at end-of-track	Critical
TRK-H-06	Loss or degradation of the signal transmitted from the trackwork system to the signaling system	Catastrophic
TRK-H-07	Track obstruction	Catastrophic
TRK-H-08	Excessive rail-to-ground potential	Critical
TRK-H-09	Inability to maintain train's dynamic clearance envelope	Critical
TRK-H-10	Improper rail/wheel adhesion	Catastrophic
TRK-H-11	Maintenance staff exposed to burning	Marginal
TRK-H-12	Potential explosion of pressurized equipment	Catastrophic

3.2.1.2 Hazard Analysis

A summary of the hazards, mitigations and overall residual risk associated with hazards identified in Table 4 is provided within this section.

Reference should be made to the Track Sub-System Hazard Analysis (SSHA) [5]for a more detailed assessment.

TRK-H-01: Loss of rail structural integrity /distortion of track geometry (broken rail, excessive rail wear, etc.)

The design and installation of the Track System prevent a loss of rail structural integrity or a distortion of the track geometry as follows:

Design mitigations:

TRK-PHA-07: All rails are ultrasonically tested for internal imperfections.

TRK-PHA-09: The rails/115 lb RE meet the AREMA specifications.

TRK-PHA-18: Rail end faces are smooth and within 0,75mm to ensure proper surface contact for welding.

TRK-PHA-23: The direct fixation fastener system is designed to resist all slip forces.

TRK-PHA-70: Sliding rail expansion joint are provided at required locations to accommodate for differential movements of the structure.

TRK-PHA-21: The ties are designed so that the resulting track gauge is 1435mm +3/-1mm measured at 16mm (0,625") below top of rail.

TRK-PHA-26: The rail fastening system is designed to withstand fatigue and wear of fastener components with low maintenance requirements.

TRK-PHA-24: The direct fixation fasteners provide vertical and lateral stability to the rail.

TRK-PHA-27: CWR are installed in a stress-free temperature, which is the temperature at which the rail theoretically has zero thermal-stress.

TRK-PHA-28: An analysis of rail stresses caused by thermal, wind, vehicular, and structural loads is carried out for the 115 RE running rail in order to confirm the adequacy of the rail steel to perform safely under operating conditions.

TRK-PHA-33: The sub-ballast is designed to comply with mechanical, permeability, chemical, and environmental characteristics as required in the current AREMA.

TRK-IHA-01: All tracks are designed regarding the standard gauge 1435mm, measured at a point 16mm below the top of the running rail.

TRK-IHA-02: The rail is fastened to the structure by resilient bonded fasteners, which will be directly secured to the concrete track bed or plinths using female inserts and bolts.

TRK-IHA-07: Design ensures consistency between the bearing capacity of the civil foundations and track bed: transfer of RS loads.

TRK-IHA-08: Rail 115 lb RE are used for all track construction.

TRK-IHA-09: Running rail are manufactured, fabricated, inspected, and tested in accordance with current requirements of the AREMA Manual for Railway Engineering, Volume 1 for Track.

Operational procedures, maintenance and monitoring mitigations:

TRK-PHA-15: Adequate periodic maintenance of track is carried out to avoid track profile degradation and broken rail.

TRK-PHA-94: Ultrasonic testing is periodically conducted as part of the Maintenance procedures.

Risk assessment performed in this section demonstrates that the likelihood of the accident is "Improbable".

As per the risk matrix, the residual risk resulting from an accident with a severity "Catastrophic" and a frequency "Improbable" is "Acceptable with review".

Based upon the detailed review of the evidence presented, it is considered that this hazard has been reduced to an acceptable level and the infrastructure is acceptable for operation of live services.

TRK-H-02: Improper rail/wheel interface

The design and installation of the Track System prevent an improper wheel/rail interface as follows:

Design mitigations:

TRK-PHA-09: The rails/115 lb RE meet the AREMA specifications.

TRK-PHA-31: Proper vehicle-track interface is provided, including, but not limited to, alignment constraints and critical tolerances, track equipment static loads, mounting details and interfaces, special provisions for switches and running rails, rail forces and track bed drainage.

TRK-PHA-86: RS wheel and rail grade characteristics (geometrical and mechanical) are consistent as defined in specifications.

TRK-PHA-87: Non-revenue vehicles are chosen compatible to the track design.

TRK-IHA-26: CWR are chosen to minimize long term maintenance, provide smoother and better ride quality, and reduce wear and tear on train equipment including wheel wear.

Operational procedures, maintenance and monitoring mitigations:

TRK-PHA-15: Adequate periodic maintenance of track is carried out to avoid track profile degradation and broken rail.

TRK-PHA-85: Preventive maintenance tasks are foreseen, well defined and respected to check wheels and bogies equipment.

Risk assessment performed in this section demonstrates that the likelihood of the accident is "Improbable".

As per the risk matrix, residual risk resulting from an accident with a severity "Catastrophic" and a frequency "Improbable" is "Acceptable with review".

Based upon the detailed review of the evidence presented, it is considered that this hazard has been reduced to an acceptable level and the infrastructure is acceptable for operation of live services.

TRK-H-03: Switch in the wrong position

The design and installation of the Track System prevent any wrong switch's position as follows:

Design mitigations:

TRK-PHA-03: Electric hot air blowers are provided at all turnout and crossover locations on the Mainline, with the exception of any special track located within tunnels, where heaters will not be required.

TRK-PHA-04: Gas powered switch heaters are provided at all turnout and crossover locations in the MSF Yard.

TRK-PHA-90: Switch machines are able to be manually operated with minimal physical effort, as back-up to powered operation.

TRK-PHA-91: Special track components are based on AREMA specifications

TRK-PHA-92: Train control system closes the track upon detection of a failure of a switch heater.

TRK-IHA-24: Switch machines are equipped with sensors to detect if the switch cannot throw in the requested position.

Operational procedures, maintenance and monitoring mitigations:

TRK-PHA-55: Periodic inspection of the track heaters (gas and electric) is performed.

TRK-PHA-58: Periodic inspection of the switch machines is performed.

TRK-PHA-72: Position of the switch machine is monitored.

Risk assessment performed in this section demonstrates that the likelihood of the accident is "Improbable".

As per the risk matrix, the residual risk resulting from an accident with a severity "Catastrophic" and a frequency "Improbable" is "Acceptable with review".

Based upon the detailed review of the evidence presented, it is considered that this hazard has been reduced to an acceptable level and the infrastructure is acceptable for operation of live services.

TRK-H-04: Insufficient train protection at end-of-track

The design and installation of the Track System take into account an insufficient train protection at end-of-track as follows:

Design mitigations:

TRK-PHA-08: End-of-Track shock-absorbing devices (bumpers) for use at terminal station Tracks are installed as a back-up for manual operation.

TRK-PHA-11: Buffer stop (or wheel stop) are designed to reduce the effect of a train collision within a specified speed range.

TRK-PHA-16: Sliding wheel stops are provided in the MSF yard tracks as required.
Operational procedures, maintenance and monitoring mitigations:

TRK-PHA-12: Buffer stop are regularly checked as described in Maintenance Manual.

TRK-PHA-56: CBTC system over-run protection is provided.

Risk assessment performed in this section demonstrates that the likelihood of the accident is "Improbable".

As per the risk matrix, the residual risk resulting from an accident with a severity "Catastrophic" and a frequency "Improbable" is "Acceptable with review".

Based upon the detailed review of the evidence presented, it is considered that this hazard has been reduced to an acceptable level and the infrastructure is acceptable for operation of live services.

TRK-H-06: Loss or degradation of the signal transmitted from the track system to the signalling system

The design and installation of the Track System prevent any track obstruction as follows:

Design mitigations:

TRK-PHA-65: Signal and track equipment mounted on track slab along the alignment are kept clear of the under-car clearance envelop of the vehicle.

Operational procedures, maintenance and monitoring mitigations:

TRK-PHA-50: Guideway is visually verified in order to detect track obstruction before starting the revenue service after a maintenance task.

TRK-PHA-66: Guideway is periodically inspected in order to detect any track obstruction.

Risk assessment performed in this section demonstrates that the likelihood of the accident is "Improbable".

As per the risk matrix, residual risk resulting from an accident with a severity "Catastrophic" and a frequency "Improbable" is "Acceptable with review".

Based upon the detailed review of the evidence presented, it is considered that this hazard has been reduced to an acceptable level and the infrastructure is acceptable for operation of live services.

TRK-H-08: Excessive rail-to-ground potential

The design and installation of the Track System prevent any excessive rail-to-ground potential as follows:

Design mitigations:

TRK-PHA-82: The rail grounding switch (RGS) is designed to withstand voltage during a specified period without breakdown.

TRK-PHA-76: Rail to ground sensing devices (NGD) are implemented to monitor the negative voltage to ground and "clamp" the rails to ground upon exceeding pre-set limits.

TRK-PHA-80: Negative cables between the running rails and the TPSS are appropriately sized.

TRK-PHA-83: The running rails are electrically continuous, and each TPSS has an NGD. One NGD in failure does not affect the protection from other NGDs.

Operational procedures, maintenance and monitoring mitigations:

TRK-PHA-81: Periodic inspection, testing, and maintenance of the TPS System and its components are performed.

TRK-PHA-84: Maximum number of trains traveling on the mainline are determined regarding EJV subsystems characteristics.

Risk assessment performed in this section demonstrates that the likelihood of the accident is "Improbable".

As per the risk matrix, the residual risk resulting from an accident with a severity "Critical" and a frequency "Improbable" is "Acceptable with review".

Based upon the detailed review of the evidence presented, it is considered that this hazard has been reduced to an acceptable level and the infrastructure is acceptable for operation of live services.

TRK-H-09: Inability to maintain train's dynamic clearance envelope

The design and installation of the Track System take into consideration the possible inability to maintain the train's dynamic clearance envelope as follows:

Design mitigations:

TRK-PHA-24: The direct fixation fasteners provide vertical and lateral stability to the rail.

TRK-PHA-65: Signal and track equipment mounted on track slab along the alignment are kept clear of the under-car clearance envelope of the Vehicle.

TRK-PHA-68: Vehicle clearances are analysed along the entire length of the guideway to ensure there is a safe space allowance between the running LRV and structures and wayside equipment.

TRK-PHA-69: Track alignment and geometric design principles are developed regarding passenger comfort, safety and clearances.

TRK-PHA-88: Non-Revenue Vehicle dynamic and static envelopes for Guideway clearances are coordinated with the Guideway Design selected Non-Revenue Vehicle type.

Operational procedures, maintenance and monitoring mitigations:

TRK-PHA-63: Sufficient running clearances and tolerances under all operating conditions are maintained as per project agreement.

Risk assessment performed in this section demonstrates that the likelihood of the accident is "Improbable".

The installation of Datum Plates to ensure correct track positioning is recommended as shown in Table 9.

As per the risk matrix, the residual risk resulting from an accident with a severity "Critical" and a frequency "Improbable" is "Acceptable with review".

Based upon the detailed review of the evidence presented, it is considered that this hazard has been reduced to an acceptable level and the infrastructure is acceptable for operation of live services.

TRK-H-10: Improper rail/wheel adhesion

The design and installation of the Track System prevent an improper rail/wheel adhesion as follows:

Design mitigations:

TRK-PHA-19: Rails are produced as specified with minimum surface hardness limit of Brinell 310.

TRK-PHA-20: A Brinell Hardness Test in accordance with the ASTM E10 (or latest version approved) is performed on a rail or a piece of rail at least 155 mm long cut from a rail of each heat of steel.

TRK-PHA-35: OLRT planting along the alignment is realized in such a way that the accumulation of leaf materials on the Guideway is minimized and that operations and maintenance are not negatively affected by leaves accumulation on the alignment.

TRK-PHA-73: The train is equipped with a sanding system to reduce slippery conditions.
Operational procedures, maintenance and monitoring mitigations:

TRK-PHA-95: Guideway shall be visually verified in order to detect any accumulation of dust/slippery material before starting the revenue service after a maintenance task.

Risk assessment performed in this section demonstrates that the likelihood of the accident is “Improbable”.

As per the risk matrix, the residual risk resulting from an accident with a severity “Catastrophic” and a frequency “Improbable” is “Acceptable with review”.

Based upon the detailed review of the evidence presented, it is considered that this hazard has been reduced to an acceptable level and the infrastructure is acceptable for operation of live services.

TRK-H-11: Maintenance staff exposed to burning

The design and installation of the Track System prevent any exposure to burning by maintenance staff as follows:

Operational procedures, maintenance and monitoring mitigations:

TRK-PHA-79: Maintenance Staff wear personal protection equipment (PPE) during any intervention on electric or hot air switch heater to protect against burns.

TRK-PHA-93: Only qualified and trained operators can perform maintenance tasks on switch heaters.

Risk assessment performed in this section demonstrates that the likelihood of the accident is “Remote”.

As per the risk matrix, the residual risk resulting from an accident with a severity “Marginal” and a frequency “Remote” is “Acceptable with review”.

Based upon the detailed review of the evidence presented, it is considered that this hazard has been reduced to an acceptable level and the infrastructure is acceptable for operation of live services.

TRK-H-12: Potential explosion of pressurized equipment

The design and installation of the Track System take into consideration the potential explosion of pressurized equipment as follows:

Design Mitigations:

TRK-PHA-77: Failure of switch heaters status to correspond to command status causes an alarm indication.

TRK-PHA-78: Switch heaters include an output to SCADA to indicate whether the track switch is in Local, Remote, or OFF position and whether the switch heater is on OFF, ON or in remote mode status.

Risk assessment performed in this section demonstrates that the likelihood of the accident is "Improbable".

As per the risk matrix, residual risk resulting from an accident with a severity "Catastrophic" and a frequency "Improbable" is "Acceptable with review".

Based upon the detailed review of the evidence presented, it is considered that this hazard has been reduced to an acceptable level and the infrastructure is acceptable for operation of live services.

TRK-H-13: Electrical Hazard

The design and installation of the Track System prevent any electrical hazards as follows:

Design mitigations:

TRK-PHA-67: All switch heater ducts are electrically isolated from the tracks.

Risk assessment performed in this section demonstrates that the likelihood of the accident is "Improbable".

As per the risk matrix, the residual risk resulting from an accident with a severity "Critical" and a frequency "Improbable" is "Acceptable with review".

Based upon the detailed review of the evidence presented, it is considered that this hazard has been reduced to an acceptable level and the infrastructure is acceptable for operation of live services.

TRK-H-14: Excessive corrosion

The design and installation of the Track System prevent any electrical hazards as follows:

Design mitigations:

TRK-PHA-76: Rail to ground sensing devices (NGD) are implemented to monitor the negative voltage to ground and "clamp" the rails to ground upon exceeding pre-set limits.

Operational procedures, maintenance and monitoring mitigations:

TRK-PHA-81: Periodic inspection, testing, and maintenance of the TPS System and its components are performed.

Risk assessment performed in this section demonstrates that the likelihood of the accident is "Remote".

As per the risk matrix, the residual risk resulting from an accident with a severity "Marginal" and a frequency "Remote" is "Acceptable with review".

Based upon the detailed review of the evidence presented, it is considered that this hazard has been reduced to an acceptable level and the infrastructure is acceptable for operation of live services.

3.2.2 Railway Level Hazard Analysis

3.2.2.1 Integrated Hazard Analysis

Railway Level Hazards relating to the Track System are identified in Confederation Line Phase 1 Integrated Hazard Log [9] and are summarised in Appendix A.

Hazards can have a number of mitigations expressed as DSR's.

A DSR associated with a single hazard has been satisfied before the Hazard has been referred to the HRP for closure.

Any DSR that is reliant upon design evidence is controlled via the processes identified in the Confederation Line Phase 1 V&V Management Plan [31] using defined definition of acceptance criteria. Typical information used to verify a DSR has been satisfied includes DCLs, CCLs, ICLs, T&C Reports, Design Reports, OBC Building Occupancy Certificates, OFS Fire Service Certificates, etc.

An individual DSR's status can be found in the Safety Requirements Matrix [55] and the details supporting the status can be found in the Technical Compliance Report [32].

3.2.2.2 Hazard Transfer

Responsibility for reviewing and authorising proposed mitigations to deem a hazard as 'closed' resided with the Hazard Review Panel (HRP).

Derived Safety Requirements identified in the Confederation Line Phase 1 Integrated Hazard Log [9] have been designated as being either 'DC' (Design and Construction) or 'OM' (Operations and Maintenance).

'DC' or design measures were the responsibility of either OLRT-C, Alstom, Thales or EJV.

DSR designated as being 'OM' have been addressed by Operational Processes (by OC Transpo) and/or by Maintenance Processes (by RTM).

3.2.3 Hazard Transfer

3.2.3.1 Track System Railway Level Hazards Mitigated by Design

The distribution of owners for Track System related Railway Level hazards that have been mitigated by design are shown in Figure 3.

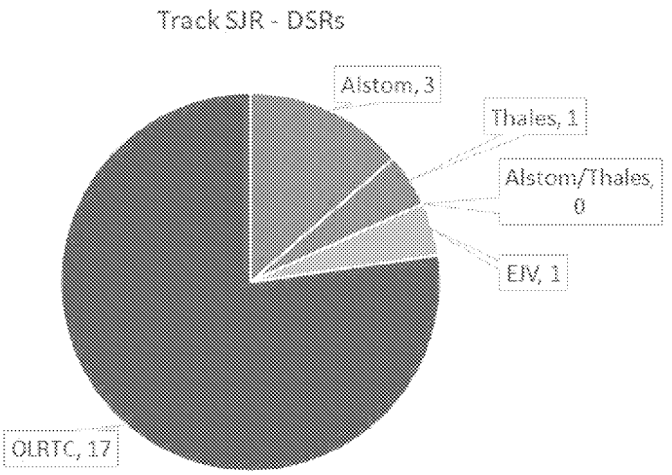

Figure 3: Design Mitigation Owners

3.2.3.2 Track System IHL Hazards Mitigated by Operations and/or Maintenance

Each DSR identified as 'OM' (Operations and Maintenance) in the Confederation Line Phase 1 Integrated Hazard Log [9] are detailed and justified in a 'Hazard Mitigation Form' for review and acceptance by HRP.

The distribution of owners for OM DSRs are shown in Figure 4.

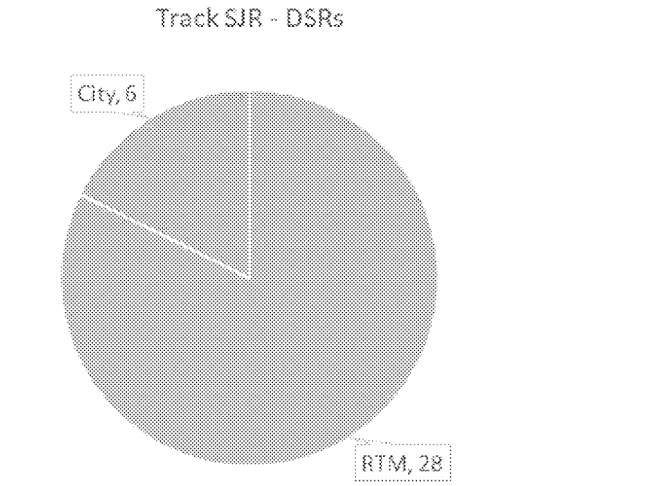

Figure 4: Process Mitigation Owners

Transfer of hazards to their respective owners is evidenced by Hazard Transfer registers shown in Table 5.

Table 5: Hazard Transfer Registers

No.	Origin	To	Document Number	Title
1	IHL	RTM	OLR-05-0-0000-REG-0017	Hazard Transfer Log - IHL to RTM
2	IHL	City	OLR-05-0-0000-REG-0018	Hazard Transfer Log - IHL to City
3	EJV	RTM	OLR-05-0-0000-REG-0019	Hazard Transfer Log - EJV Haz Log to RTM
4	EJV	City	OLR-05-0-0000-REG-0020	Hazard Transfer Log - EJV Haz Log to City
5	Thales	RTM	OLR-05-0-0000-REG-0021	Hazard Transfer Log - Thales Haz Log to RTM
6	Thales	City	OLR-05-0-0000-REG-0022	Hazard Transfer Log - Thales Haz Log to City
7	Alstom	RTM	OLR-05-0-0000-REG-0023	Hazard Transfer Log - Alstom Haz Log to RTM
8	Alstom	City	OLR-05-0-0000-REG-0024	Hazard Transfer Log - Alstom Haz Log to City

3.2.4 Hazard Management Summary

It is considered that all hazards have been managed to an acceptable level. There are no Track System related hazards with a post assessment risk classification of Undesirable (Un) or Unacceptable (Ac).

3.2.4.1 Hazard Pre and Post-Mitigation

The hazard identification process resulted in 30 hazards associated with Track being identified. The initial risk assessment ranked the Track hazards as follows:

Table 6: Track Original Risk

		Pre-mitigation
Unacceptable	Un	5
Undesirable	Ud	12
Acceptable with Review	A/R	13
Acceptable	Ac	0
	Total	30

Upon completion of the identification and evaluation of the proposed mitigations, the risk assessment ranked the Track hazards as follows:

Table 7: Track Residual Risk

		Post-mitigation
Unacceptable	Un	0
Undesirable	Ud	0
Acceptable with Review	A/R	29
Acceptable	Ac	1
	Total	30

Hazards assigned as Acceptable with Review have undergone further assessment within the oversighted of HRP and are deemed to be acceptable as evidenced within the Confederation Line Phase 1 IHL [9] subject to implementation of the DSRs identified in the Safety Requirements Matrix [55] and Restrictions, Conditions and Limitations shown in the Confederation Line Phase 1 Operational Restrictions Document [12].

3.2.5 Summary of Undesirable Hazards

There are no Undesirable hazards post implementation of mitigating control measures.

3.3 SAFETY CERTIFICATION

Assurance of correct design has been provided by in the form of DCLs by Engineers of Record that confirm the structural and mechanical design.

Assurance of correct construction has been provided in the form of CCLs by Engineers of Record that underwrite the general conformity of construction to the DCL. The following documents have been issued:

- DCL for Track Alignment [35]
- DCL for Trackwork Installation [36]
- Interim CCL for Trackwork Installation [37]

3.4 ASSURANCE OF CORRECT FUNCTIONAL OPERATION

The Track design has been subjected to system safety assurance process throughout the project life cycle in line with the Confederation Line Phase 1 Systems Safety Programme Plan [2].

Correct functional operation is assured through compliance with standards and the requirements of the Project Agreement [16] as detailed within DOORS modules in which verification and validation evidence is presented.

The Confederation Line Phase 1 Confederation Line Phase 1 Reliability Availability and Maintainability Report [54] was compiled to provide confidence that the infrastructure can deliver long, term cost effective and safe service delivery performance.

Reliability predictions have utilised asset populations, configurations and reliability data obtained from a series of Primary System RAM analyses including the Trackwork System

RAM Analysis [10]. Trackwork System RAM Analysis [10] presented a parts-count RAM assessment using empirical failure rate data. This was integrated with the Track Failure Modes and Effects Analysis [34] and similar reports for other Ottawa Confederation Line Phase 1 Primary Systems to derive a Railway Level RAM analysis that considered the consequences of failure upon service perturbation given the timetable identified in the Project Agreement [16].

This predicted that the Track System is capable of supporting 99.01% operational availability for the Confederation Line Phase 1, subject to the maintenance regime being carried out.

3.5 DERAILMENT MANAGEMENT

To mitigate this hazard, EJV has applied AREMA engineering manual principles, as required by the Project Agreement, and has included:

- 310 Brinell grade 115RE rails throughout
- Concrete ties from a proven supplier
- Concrete plinth and slab design principles in line with recognised world-wide methodologies
- Rail fasteners from proven suppliers
- The provision of an alignment design that has evaluated the derailment potential caused by combining of vertical and horizontal curves and short elements
- The provision of restraining rails for all sharp radius curves below 150m
- The provision of restraining rails for high risk structures within Station limits
- The provision of Jordan rails (4-ft guard rails) as derailment guidance at high risk structures
- The provision of robust kerb structures within the tunnel emergency walkway to prevent overturning
- The provision of derailment containment curb/rails for Rideau River Bridge [46]
- The application of mobile flash-butt welding methods to reduce the risk of weld failure
- Detailed rail break impact analysis for the environmental extreme limits that the system must tolerate [41]
- Undertaken rail stressing requirements, as defined in the rail break analysis above
- The provision of a maintenance inspection regime that has appropriate focus on the key asset failures that contribute to derailments [47].

3.6 RELIABILITY, AVAILABILITY AND MAINTAINABILITY

The Confederation Line Phase 1 Reliability Availability and Maintainability Report [54] was compiled to provide confidence that the infrastructure can deliver long term, cost effective and safe service delivery performance.

Reliability predictions have utilised asset populations, configurations and reliability data obtained from a series of RAM analyses including the Track Confederation Line Phase 1 Reliability Availability and Maintainability Report [54].

This has identified the following predicted targets:

- Reliability = MTBSF of 4,297hrs (approx. 180 days)
- Availability = 99.88%
- Maintainability = Average corrective time of 4.42 hours.

The projected reliability value is considered low. This is influenced by the harsh winter conditions affecting switch performance, and the lack of general line-side access during operational hours to fix minor failures. This Safety Justification Report accepts that reliability should exceed the predicted target based upon the installation of approved components that have a proven history of reliable functionality in the railway environment and meet the good practice principles defined in AREMA standards and TCRP guidance.

The provision of strategic spares has considered the lead time for key parts, such as cast crossings and switch blades, and has made adequate provision to support the required availability targets. The EoR has confirmed that all agreed strategic spares have been provided.

Possession access will be critical for all track maintenance corrective works.

4. QUALITY AND SYSTEMS ASSURANCE

4.1 SYSTEMS ASSURANCE

The Confederation Line Phase 1 Engineering Safety and Assurance Case [20] details the work carried out by the System Assurance team in support of the Ottawa Confederation Line Phase 1 project. This includes detail of process reviews, competency management and audit.

Details of the Quality and System Assurance activities are shown in the Confederation Line Phase 1 Engineering Safety and Assurance Case [20].

The assurance function has compiled all Non-Conformance Reports in a Deficiencies List. Any NCRs and Deficiencies that may have an impact on safety have been assessed and recommendations are made in section 6, where applicable.

4.2 DEFICIENCIES

Safety related deficiencies are listed in the Master Deficiencies List [56].

4.3 TRACK SYSTEM ASSURANCE

The Track Systems design has been developed to fulfil the Project Agreement [16] to meet the Design Safety Case [11] and compliance to AREMA standards by the scope of works provided in the Design Brief Trackwork [39]. This has been approved by the City within CRS for Trackwork Installation – System Wide [38].

The Track Systems design has been subjected to the System Safety Assurance process and the design Confederation Line Phase 1 Project Quality Plan [21] throughout the project life cycle. The assessment for safety at interfaces was incorporated into the Preliminary Hazard Analysis work, as shown in section 4.1.

Correct functional operation is assured through:

1. Compliance with standards, as stated in the Design Brief Trackwork [39], and the Project Agreement [16].
2. The PA Technical Compliance Matrix [17] confirms all track work is compliant, except for any variations identified that have been submitted and approved.
3. The hazard analysis shown in section 3.2 provides evidence that hazards have been reduced to acceptable levels.
4. Structural and gauging assessments have been conducted and provide evidence that the correct Citadis B15 LRV profile provides level access requirements at all Stations, as shown in Vehicle/Platform relationship report [40] and the Design Brief Vehicle Clearance Analysis [42]. This is supplemented by a Train to Guideway Clearances – As-Built Condition Assessment [43].
5. Compliance with Confederation Line Phase 1 Quality and Safety Plan principles is evidenced within the DCL for Track Alignment [35] and DCL for Trackwork Installation [36].

6. Detailed FMEA has been undertaken in the Track Failure Modes and Effects Analysis [34]. This has applied appropriate analysis of potential failure modes of the Track System and has identified how the failure methods link to the Sub-System Hazard Analysis outputs. The FMEA identifies that each sub-component can be repaired in-situ. The ability to repair in the given times of the FMEA is dependent upon appropriate track access being granted. The Track Failure Modes and Effects Analysis [34] and the Confederation Line Trackwork Maintenance Manual [47] identify visual inspection as the principle control method, other than those parts of the system that are linked to the SCADA system.
7. Detailed Trackwork System RAM Analysis [10] analysis has been undertaken and provides evidence that the Track is capable of supporting long term service provision, as is discussed in section 3.6.
8. An indicative maintenance regime for the Track System [47] demonstrates how each component can be maintained. Independent assurance reports [50], [51], [52] and [53] of the Track System identified various inspection frequencies that need to be changed for the initial operating life. This is to enable the specific rail to wheel interface to be monitored until exact wear data is established, and grinding regimes defined and is discussed in section 5.

4.4 PRODUCT ACCEPTANCE

Within the design brief report, there are specific product supply requirements defined. This includes the appropriate quality assurances and control tests, in-line with AREMA mandated processes the product must meet. All product suppliers were required to comply with the OLRT-C Suppliers General tender document: Supplier Tender Quality Management [49]. All products were to be supplied with appropriate quality control/assurance documentation and were subject to sampling acceptance by OLRT-C.

Approval of suppliers was by the Construction Contractor, with endorsement by OLRT-C.

Identification of any new and novel components was the responsibility of the Construction Contractor, based upon any technical requirements defined by EJV in the Design Brief Trackwork [39].

No new or novel components have been identified within this Safety Justification Report.

4.5 SAFETY QUALITY TESTS

The Design and Build Contractor has issued a Train to Guideway Clearances – As-Built Condition Assessment [43]. This report confirms that the final as-built structural clearances provide the design safety minimum clearance of 100mm across the whole system, except at eight locations that where designed to a minimum of 50mm+ on the principle that the track was direct fixation on slab, thus reducing the risk of track position movement.

All the locations are within the Stations of the downtown tunnel section.

In-situ testing of all bumper stops (mainline and MSF) has been carried out by the manufacturer, and conformance certificates issued.

In-situ testing of the mainline electrical switch heaters has been carried out by the supplier, and conformance certificates issued, and site surveillance inspections have witnessed them working.

4.6 DEFICIENCIES

4.6.1 V&V Non-Compliances

OLRT-C has produced a detailed report of compliance in accordance with the Confederation Line Phase 1 V&V Management Plan [31] to the requirements of the Project Agreement [16]. This report documents the following areas of non-compliance or variation:

Table 8: Track Design Requirement Variation or Non-Compliances

Requirement Identity	Requirement		Non-Compliance or Variation	Safety Justification Report Acceptance
93625	(i)	The typical Track centre spacing is 4500mm. The mainline Track centre spacing may be reduced to an absolute minimum based on the selected LRV dynamic envelope and provided sufficient running clearances and tolerances under all operating conditions are maintained.	1) Except where locally widened to accommodate site-specific geometry or centre platforms, mainline track centres are nominally 4.0 m on open guideway. Within the tunnels and Under Ground Stations, where OCS poles are not required, track centres are nominally 3.6 m. This reduction is based upon the agreed kinematic envelope profile of the Citadis B15 LRV, as defined in gauging report RES-22-0-0000-DBC-0103.	Rationale accepted as the reduction in track centre dimension only impacts on the proximity between LRV's in a derailment situation. Day to Day safe operation is accepted by this variation.
93662	(d)	A minimum tangent length of 20m shall be inserted between the back to back switch points where the turnout arrangement may entail a reverse movement through turnouts.	TRACKWORK NON-COMPLIANT. Constrained condition for Crossover no. 328 & 329, see drawing RES-21-5-0000-DRD-1022_0; (Less than 20 m)	Location is constrained by the existing position of Blair Station and the alignment towards Cyrville. The reduced length will not impact on safe day to day operation, but the location will need to be monitored for unusual wear of components during maintenance inspections.
93671	(iii)	Where no walkway is present, a typical minimum side clearance of 1890mm from Track centreline to any physical feature shall be maintained on tangent	Note DDO: Horizontal clearance: Not compliant. the values indicated in the Report-S are different from the values indicated in this section of P.A.	Gauging report declares minimum lateral clearance to be 1496mm + 100mm +50mm (construction tolerance) giving 1646mm as a safe minimum lateral

Requirement Identity	Requirement		Non-Compliance or Variation	Safety Justification Report Acceptance
		at-grade and retained cut Track. The mainline Track side clearance may be reduced to an absolute minimum based on the selected LRV dynamic envelope and provided sufficient running clearances and tolerances under all operating conditions are maintained.		clearance for the Citadis B15 train. Original PA requirement was defined on an assumed LRV width. This Safety Justification Report accepts that this reduced value is safe for day to day operations.
93675	(vii)	The typical horizontal clearance distance from the centreline of Track to the finished edge of Station Platform shall be 1405mm, or as otherwise required for the selected LRV such that a gap no greater than 75mm is maintained.	1); 3) Track compliant; 2) Track compliant except art.4.0. See comment resolution of 'REJ-22-0-0000-CRS-0277': This matter has been resolved through operation procedure 4) Track not compliant for Rideau Station, East side	Known clearance variation at Rideau Station has been accepted by the Client through CRS acceptance. This Safety Justification Report accepts that there is no risk to day to day safe operations.
93727	B.	Restrain the rail movement during rail break incidents limiting the rail break gap to 50mm;	2)DDO: Non-compliant. Rail break maximum gap calculated in Table-2 has values over 50 mm for 3 scenarios.	EJV detailed rail break report [RES-22-0-0000-DBC-0007] has been reviewed by independent Track assurance engineer and conclusions accepted [OLR-22-0-0000-REP-0003], as safe to operate. EJV has made formal application to OLRT for non-compliance to be accepted.
93743	(iii)	No gas-powered switch heaters shall be permitted in tunnels or enclosed areas.	DDO: 1) Non-compliance: Electric hot air blowers shall be provided at all turnout and crossover locations, with the exception of any special trackwork located within tunnels.	Not seen as a non-compliance. Provision of electric heaters is seen as a safer solution than gas. This Safety Justification Report accepts as no risk to day to day operations.
93749	(i)	End-of-Track shock-absorbing devices for use at terminal Station Tracks shall be included in the Trackwork Design Report and be which shall be submitted as	Track: Non-complaint based on agreed PA variance as per RFI-0271.	Independent track assurance review has accepted the positioning and type of buffer stops as fit for purpose. See Track Assurance Report 1 [50] and

Requirement Identity	Requirement	Non-Compliance or Variation	Safety Justification Report Acceptance
	part of the Works Submittals according to Schedule 10 – Review Procedure. These devices shall be mounted near the end of Track on both Station Platform Tracks. Project Co shall procure and install the approved end-of-Track devices as part of the Works.		Track Assurance Report 3 [53]. This Safety Justification Report accepts as no risk to safe day to day operations.

4.6.2 Concerns raised through Site Inspections

4.6.2.1 Rail Management and Hardness

The onward safe management of rails is dependent upon many criteria, and there is no perfect answer. It will always be a combination of rail hardness, geometric design features, rolling stock bogie performance features and the ultrasonic testing and rail grinding regimes. This hazard is discussed in completeness in this section.

The Design has not carried out any specific rail wear or Rolling Contact Fatigue (RCF) analysis against the track alignment, the railhead profile and metallurgic properties, and the LRV characteristics of suspension and braking. There is an assumption that the provision of AREMA compliant 115RE CWR will give adequate wear and RCF control against the Citadis B15 wheel profile. Rail hardness is defined at 310 Brinell, wheel hardness is defined as 310-350 Brinell. This should lead to a balance wear rate but can lead to brittleness if the surfaces are not kept work hardened through wheel loading forces or through regular rail grinding works.

The proposed 1:40 rail inclination is not fully matched by the wheel profile (1:60 variable), as shown below by the extracts from Running Rails [45]. This variance of profiles may result in unusual wear patterns as the wheel forces are transferred into the railhead. This has the potential to increase the development of localised soft spots, i.e. areas that are not work hardened by the wheel.

Rail wear has been seen on site during track surveillance inspections, that indicate unusual wear patterns on all No. 8 switches, especially in the turnout direction, and one cast crossing (frog) at Lyon has had shards of metal, circa 20-50mm long cut from the nose. The photos below in Figure 7, Figure 8 and Figure 9 that demonstrate these concerns are taken at 316pts (switch wear) and 306pts (crossing wear).

The design geometry of the Track System has not utilised high cant deficiency values to increase the curving forces on the rail, which would help with the hardening of the railhead. This means that additional rail gridning will be required throughout the life of the system to prevent the build of of RCF type defects, and additional ultrasonic and visual inspection made to obsevre for the tell-tale sign fo RCF development.

Where there is a risk of hardned rails becoming brittle, the only remedial options are to either replace the rail with a softer hardness (260 Brinell) or to increase the visual inspections and ultrasonic testing regimes to identify the potential areas of RCF growth and to undertake remedial grinding/rail replacements before failure occurs.

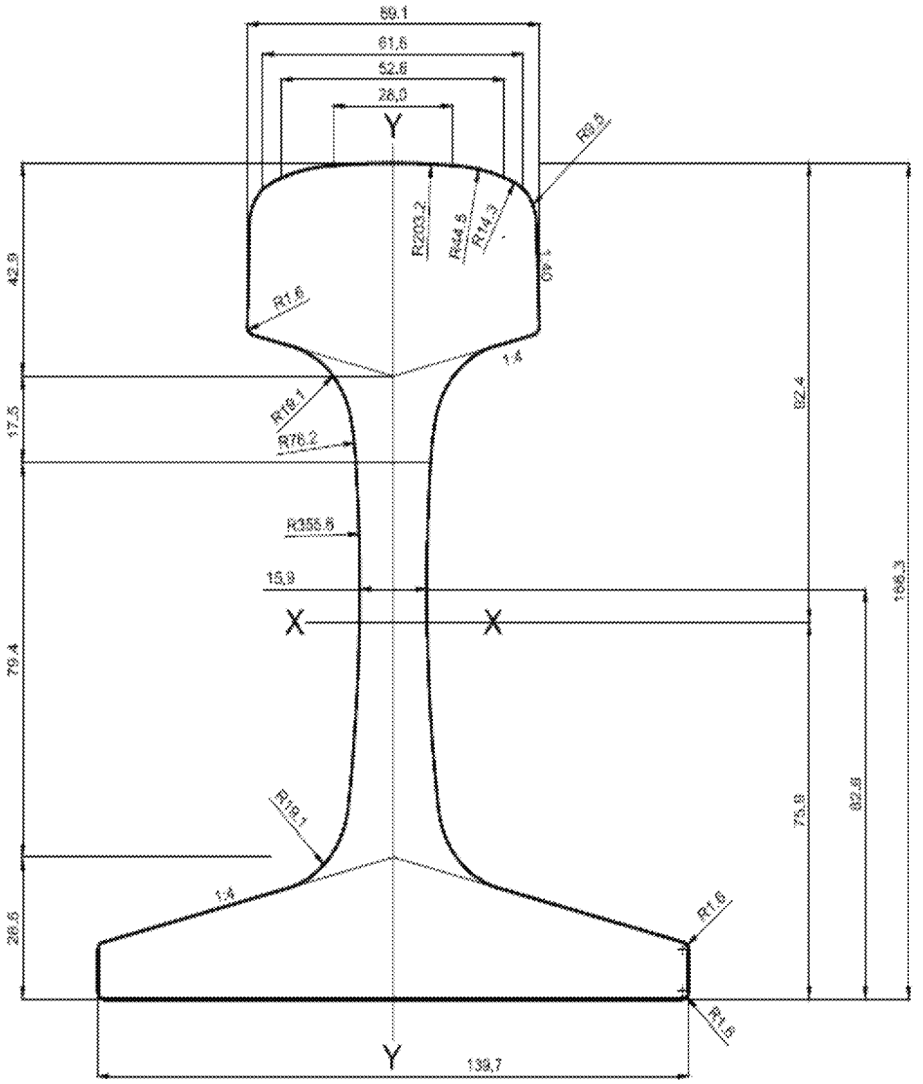

Figure 5: Rail Profile

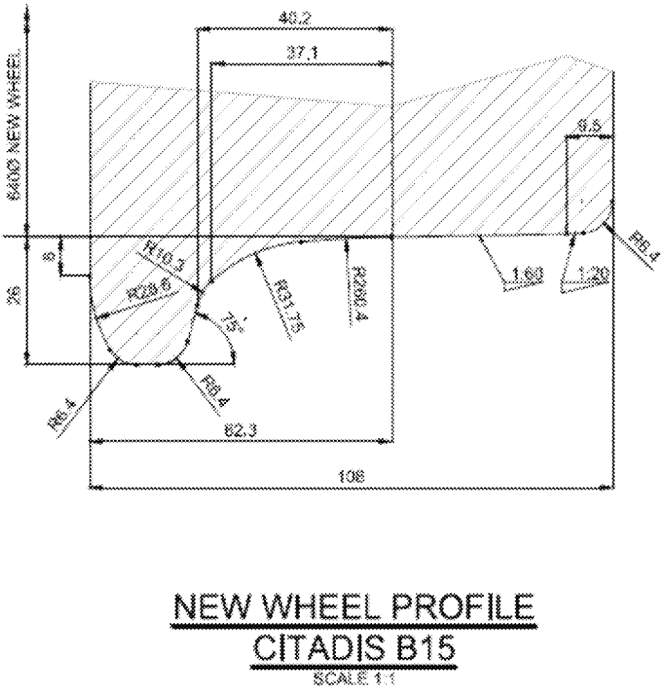

Figure 6: Train Wheel Profile

This is a safety concern raised, in the independent Track Assurance Report – Derailment [52], about the lack of conicity between the wheel and rail profiles. Observation of the initial operation of trains during the testing and commissioning period has indicated some unusual rail wear patterns. The photo shown in Figure 7, Figure 8 and Figure 9 were taken during track surveillance inspections on 2nd and 3rd March 2019.

Figure 7: Rail Wear

Figure 8: Switch Wear

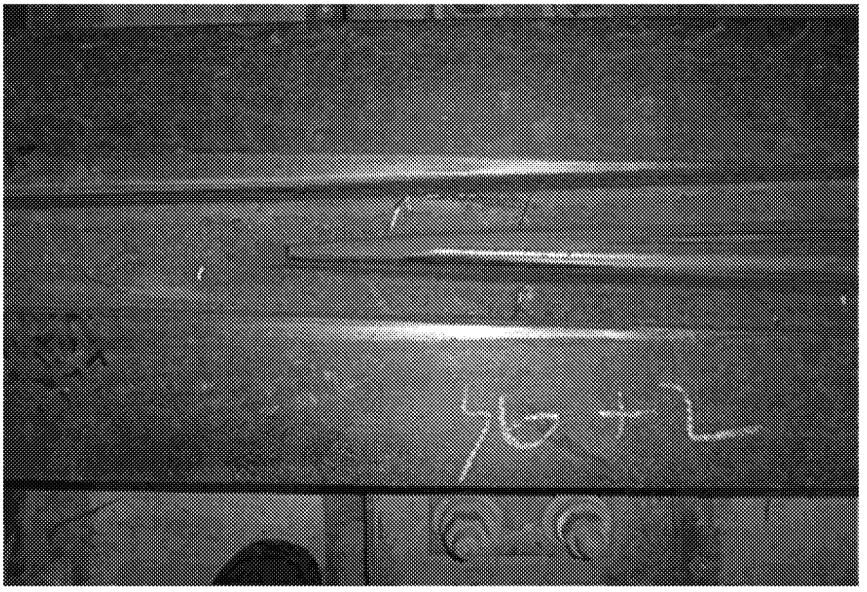

Figure 9: Crossing Wear

To reduce any potential risks that could arise from a variance between the wheel profile and the rail profile, this Safety Justification Report recommends that post commissioning monitoring of the issue is established as discussed in section 6 of this Safety Justification Report.

There are no track circuits within the signalling system, so tack circuits will not contribute to the detection of broken rails. Detection is only available through visual inspection methods or by report from a train driver.

Other key derailment causes, such as over-speeding of the train and failure of the points machine system, are captured in other supporting system Safety Justification Reports.

4.6.2.2 Installation of OCS structure to Rail Bonds

The installation of OCS structure to rail bonds, from the TPS connect boxes located in the six-foot area, are buried in the track ballast. The bond cables are unprotected and are at risk of being damaged during track tamping maintenance activities as discussed in section 6 of this Safety Justification Report.

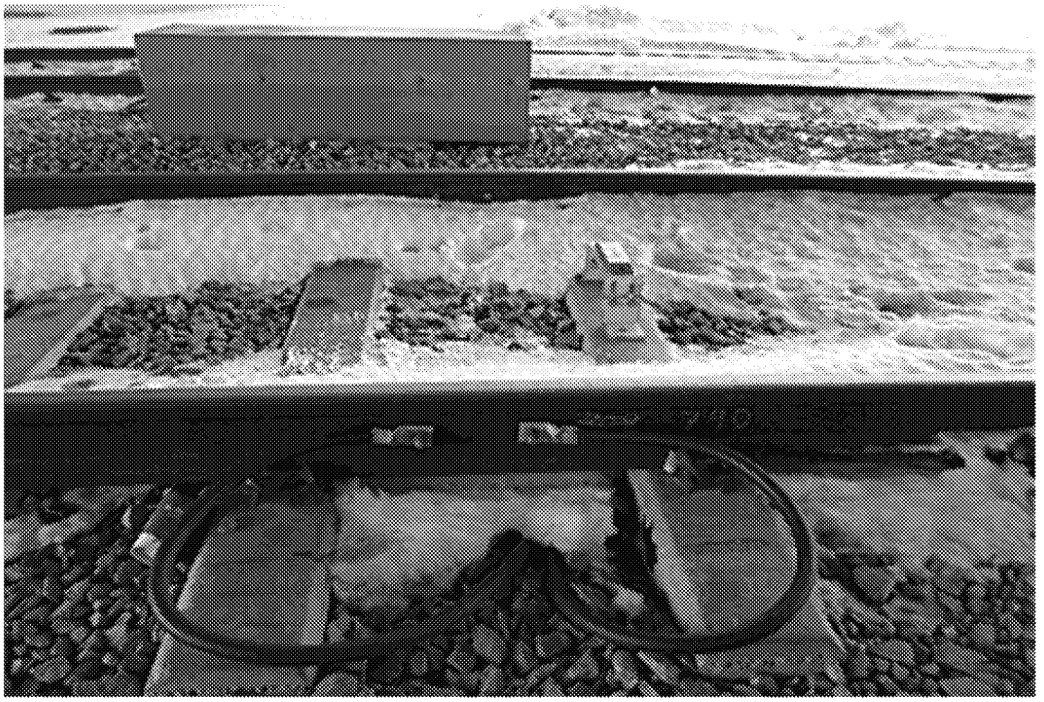

Figure 10: Photo of Buried OCS Rail Bonds at Tremblay

4.6.2.3 Track Alignment Datums

The track alignment has no specific on-site datum referencing system to enable the routine checking of the kinematic envelope as discussed in section 6 of this Safety Justification Report.

4.6.2.4 Platform Edge Gates

The installation of all platform end gates was completed after the gauging test train trials. Although the gates are clear of the train bodies (as proven by the test running and commissioning of trains progressing without any gates being struck), the positioning of the gates close to the platform edge has not been fully validated as safe. This concern also applies to walkway protection glazing off the platform ends at Hurdman Station, towards the bus station access stairs. See Figure 11 and Figure 12.

Figure 11: Platform Glazing Panels at Hurdman

Figure 12: Platform End Gate at Hurdman

4.6.2.5 Rail Head Condition

The condition of the rail head, through the core tunnel between Parliament Station on the East portal, has been contaminated by work site debris, water ingress and tunnel lining remedial products, as witnessed during surveillance inspection on 2nd March 2019 and shown in Figure 13 and Figure 14.

Not removing this detritus from the rail head can affect the functionality of rail ultrasonic testing equipment and could prevent the detection of rail defects. This would increase the potential for a rail break to occur. Recommendations to manage and mitigate this issue are given in section 6 of this Safety Justification Report.

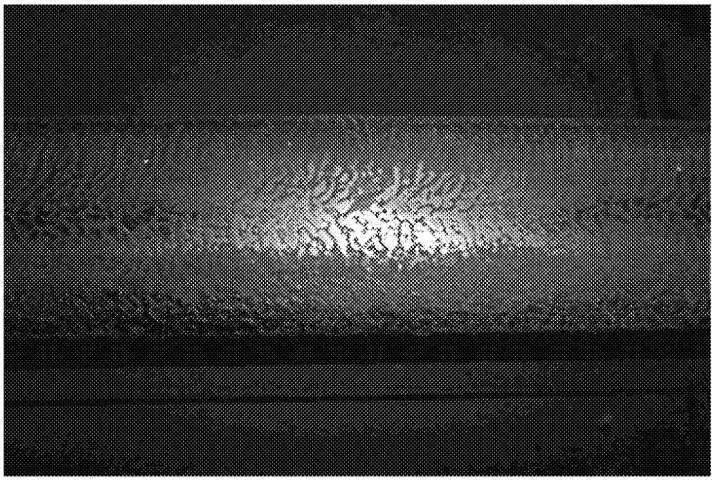

Figure 13: Rail Head Contamination in Main Tunnel (Image 1)

Figure 14: Rail Head Contamination in Main Tunnel (Image 2)

4.7 OPERATION AND MAINTENANCE

The Design and Build Contractor has provided a Confederation Line Trackwork Maintenance Manual [47]. This documents the core inspection activities and periodicity requirements across all the individual components of the system.

This manual also includes preventative and corrective maintenance tasks that are required.

Where specific manufacturer inspection and corrective activities are essential to the onward safe management, the manufacturer's documentation has been included to define the specific actions required.

This Safety Justification Report has considered which switches will be operated most frequently and would benefit from supplementary inspections. These are as follows:

- 301, 302, 303 and 304pts at Tunney's Pasture
- 319, 320, 321, 322, 323 and 324pts entry to the MSF
- 327, 328, 329 and 330pts at Blair.

Independent reviews of the Track System [50], [51] and [53] have identified that the proposed maintenance manual periodicity for inspection and preventative activities does not recognise the initial "bedding-in" period that occurs during the opening of a new railway system. The reports make recommendations that some key activities should have amended periodicity for the initial two years, such that key data trends for wear or failure are established. See section 4.6.2.1 for details.

The amount of specialist rail mounted equipment that supports maintenance activities, such as tamping machines, grinding trains and rail delivery vehicles, has not been defined in the maintenance manual.

The maintenance organisation will need to determine the amount of equipment required to undertake all preventative and corrective activities in view of the recommendations relating to ultrasonic testing and rail grinding, including recommendations made in section 6 of this Safety Justification Report.

Section 13 of the Confederation Line Trackwork Maintenance Manual [47] defines how much small plant is to be provided at hand-over to support the start of service.

The Confederation Line Trackwork Maintenance Manual [47] does not define any special requirements for seasonal readiness checks, such as inspecting ballast shoulders prior to the summer months, or clearing of drainage culverts etc prior to the winter months. There is also no mention of any technical inspections annually to monitor structural and platform clearances.

There will be a reliance upon Hi-Rail based equipment to undertake track corrective works, and therefore the utilisation of the three install access mats (Bayview, Lees and Blair) will be critical to the effective delivery of planned works.

There are limited walkways alongside the guideway, so safety of track workers during inspection walks will need to be regularly evaluated.

5. RESTRICTIONS, CONDITIONS AND LIMITATIONS

5.1 RESTRICTIONS

This Safety Justification Report has no recorded restrictions upon the Track System, and it is fit to operate at design line-speed in revenue service.

5.2 CONDITIONS

5.2.1 Ultrasonic Testing Frequency

Due to the concerns about rail hardness raised in section 4.6.2.1 and the lack of any technical methods of detecting rail breaks, this Safety Justification Report raises a condition on the approval of the system that the ultrasonic testing regime is amended to once every 3 months for the first 2 years. The MSF connector and yard should be tested every 6 months for the initial two years. The frequency of all ultrasonic testing may then be changed based on findings and a risk-based approach.

This will aid the identification of rail defects when they are embryonic, such that their propagation rates can be monitored, and rail replacements planned prior to total failure. This is the only mitigation that can be applied to reduce the risk of broken rails.

Ultrasonic Testing will not be effective if the Track is contaminated. Therefore, this condition must be carried out in conjunction with the conditions stipulated in Section 5.2.2 for the geographic area in question.

5.2.2 Grinding of Rails in Downtown Tunnel

The condition of all the railheads in the Downtown Tunnel between Parliament Station and the East portal are contaminated. This contamination has the potential to mask the effectiveness of ultrasonic testing equipment, as the signals will either fail to return or will give false indications.

This Safety Justification Report raises a condition on the approval of the system that rail grinding is undertaken within two months of the commencement of 0evenue Service.

5.3 LIMITATIONS

There are no identified limitations on the Track System, and it is fit to operate at design line-speed in revenue service.

6. RECOMMENDATIONS

These recommendations made as a result of the Safety Management activities recorded in this Track Safety Justification Report are detailed in Table 7.

The following recommendations are made as a result of the Safety Management activities recorded in this Ottawa Confederation Line Phase 1 Track Safety Justification. The recommendations are also recorded in the Confederation Line Phase 1 Operational Restrictions Document [12].

Table 9: Track System Recommendations

Item	Recommendation	Accountability
1.	**See section 4.6.2.1** - Establish a working group to monitor wheel and rail wear data. From this, specific remedial actions can be identified and agreed, such that they do not cause any worsening to one asset of the other.	RTM to establish working group prior to start of passenger operations
2.	**See section 4.6.2.1** - Remit of wheel-rail working group to cover: Increasing rail wear visual inspections on all sharp curves to measure side wear rates. Ultrasonic testing and visual rail inspection results. Monitor wheel profile wear rates through increased visual and NDT inspections. Monitor effectiveness of LRV mounted lubricator performance, linked to rail wear locations, and evaluate the potential to install rail mounted lubricators and friction modifiers. Increase the preventative rail grinding frequency across the whole system to reduce the risk of RCF growth in the harder 310 Brinell rail. Review the switch blade profile of No.8 switches to reduce the wear rate.	RTM working group
3.	**See section 4.6.2.2 -** The installation of protective troughing to all main line OCS bonds, to prevent damage during tamping operations.	RTM
4.	Review how much equipment is required to undertake all preventative and corrective activities.	RTM
5.	**See section 4.6.2.3 -** Provision of structural clearance datum plates, including the OCS masts, to enable monitoring of track position.	
6.	**See section 4.6.2.4 -** Provision of annual checks of structural and platform clearances to ensure safe operation of LRV.	RTM to add to maintenance regime
8.	**See section 4.6.2.3 -** Validation of gauge clearance acceptance for all platform end gates and any secondary glazing systems installed along the platform edge needs to be demonstrated.	RTGEJV
9.	Provision of sufficient track possession access to allow effective preventative and corrective maintenance works is essential to support the required RAM targets.	RTM/OC Transpo

7. CONCLUSIONS

The following conclusions are made as a consequence of this Safety Assessment:

- A body of evidence exists that hazards associated with the Confederation Line Phase 1 Track have been assessed and mitigated to acceptable levels.
- All DSRs have been accepted by and transferred to their respective owners and agreed by HRP as evidenced in Table 5 and the Safety Requirements Matrix [55].
- The design of the Track System has met the requirements of the Project Agreement, whilst mitigating the hazards raised during the safety analysis of the works. Where the design did not initial meet the PA requirements, derogations or variations have been sought and accepted by the City.
- The installation of the Track System has been independently inspected by an internationally experienced track expert. This review has endorsed the opening of the track to operational passenger service, subject to minor deficiencies being addressed.
- The identification and mitigation of hazards has been undertaken, as stated in section 3.2 of this Safety Justification Report and all maintenance hazards have been transferred to the Maintenance Team responsible for the onward safe operation of the Ottawa Confederation Line Phase 1 system.
- The establishing of RAM targets has been undertaken, as stated in section 3.6 of this Safety Justification Report. The design of the Track System ensures that these RAM targets can be achieved, through the provision of proven rail system components and the application of robust maintenance procedures.
- Detailed analysis of rail break factors has been undertaken to ensure that the Track System will cope with the range of temperature extremes that occur in Ottawa. This analysis has been independently reviewed by an international track expert and the conclusion supported.
- The track design has excluded any rail lubrication or friction modifier equipment. This is to be provided as on-board equipment on the LRV.
- The track design has not undertaken any specific wheel-rail interface analysis and has not declared any specific rail-head profile modifications are to be implemented to aid the conicity management. The specification of the rail was defined by the Client, based upon the principles of the AREMA engineering manual. The profile of Citadis B15 wheel profile was proposed by Alstom, as part of their LRV specifications. This Safety Justification Report has made recommendations to establish a wheel-rail interface working group to monitor all parameters that could affect wheel and rail interface performance and prevent accelerated failure of the track.
- The Confederation Line Trackwork Maintenance Manual [47] does not define an enhanced maintenance and inspection regime for the initial bedding period following the onset of revenue service. This might include an increased periodicity of inspection, ultrasonic testing and rail grinding. Accordingly, recommendations to ensure long-term safety are presented in section 6 of this report.

- The Confederation Line Trackwork Maintenance Manual [47] does not define any specific activities relating to seasonal readiness, or the need for periodic structure/platform gauge monitoring tasks. Accordingly, recommendations to ensure long-term safety are presented in section 6 of this report.
- Provision of sufficient track possession access to allow effective preventative and corrective maintenance works is essential to support the required RAM targets.
- Ottawa Confederation Line Phase 1 Track is considered to be acceptably safe and suitable for the onset of Revenue Service subject to the conditions identified in section 1.3, section 5.2 and in the Confederation Line Phase 1 Operational Restrictions Document [12].