WEST CORRIDOR LRT PROJECT
FINAL ENGINEERING DESIGN PHASE

Preliminary Hazard Analysis

DRAFT

Revision 0

June 15, 2006

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RECORD OF REVISIONS

Revision Number	Date	Reason for Revision	Authorization
0	6-15-06	Initial Draft	IEI/DEA

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West Corridor Preliminary Hazard Analysis for Final Design

ACRONYMS

CCTV	Closed Circuit Television
CoPUC	Colorado Public Utilities Commission
CPTED	Crime Prevention Through Environmental Design
FLSC	Fire/Life Safety Committee
FRI	Final Risk Index
FTA	Federal Transit Administration
HRI	Hazard Risk Index
IRI	Initial Risk Index
LR	Light Rail
LRT	Light Rail Transit
LRV	Light Rail Vehicle
MPS	Manager of Public Safety
MUTCD	Manual on Uniform Traffic Control Devices
OCS	Overhead Contact (or Catenary) System
PHA	Preliminary Hazard Analysis
PRO	Pre-Revenue Operations
QA	Quality Assurance
QC	Quality Control
ROW	Right of Way
RRI	Residual Risk Index
RTD	Regional Transportation District (Denver)
SCADA	Supervisory Control and Data Acquisition
SIT	System Integration Testing
SSPP	System Safety Program Plan
SSWG	Safety and Security Working Group
TPP	Test Program Plan
TPSS	Traction Power Substations
TVM	Ticket Vending Machines

1.0 INTRODUCTION

The identification, assessment, and resolution of potential hazards has been, and remains, the prime means of assuring the highest practical level of safety in any system. The approach now almost exclusively used for light rail transit systems follows the *Hazard Analysis Guidelines for Transit Projects* published by the Federal Transit Administration (FTA) in January 2000. The process that the David Evans & Associates (DEA)/Interactive Elements Inc.(IEI) Team will use for the West Corridor complies with these Guidelines, but with effort concentrated on system differences from existing RTD LRT operational and pre-operational segments.

The start of the Preliminary Hazard Analysis process, the identification and analysis of hazards, calls for a rational application of knowledge, past experience, and judgment on the part of those performing the tasks. Experienced personnel performing hazard identification and analysis may sometimes differ on the assessment of the probability or severity of a particular hazard, but usually to a minor degree. Given this, the results of the process for one LRT system segment would be largely applicable to another LRT system segment designed and constructed to the same criteria. No two systems are identical, however, and it is necessary to verify the similarities, and apply the full hazard identification, analysis, and resolution process to the differences.

1.1 WEST CORRIDOR CONSIDERATIONS

Most of the Facilities to be installed on the West Corridor (Track, Pedestrian Bridges, Tunnels, Stations) are known quantities that have been in use for several years both at RTD and in the Light Rail Transit industry at large. These systems designs have been refined with each expansion of the RTD Light Rail Transit system.

The design and construction of the West Corridor project will, however, pose new challenges to RTD, the Design Consultant, and Construction Contractors. Previous LRT project alignments have been, for the most part, at grade, running generally North-South along existing railroad/highway rights-of-way, outside of urban areas, and generally not subject to close interaction with civilian communities located immediately adjacent to the alignment.

The West Corridor, although following the trace of an existing single track railroad alignment, traverses known flood plains, areas of steeply sloped terrain along the North and South sides of the alignment and locations where the alignment narrows, and passes through “Open Cut” type sections closely bound on one, or both, sides by homes and/or light industry sites and schools. In addition there are several locations where steeply sloping roadways approach rail crossings, primarily from the North.

West Corridor System Map

Rude Park steep sloped terrain (looking west)

Perry Street – (looking west)

Flood plains will pose challenges with respect to track integrity during periods of high water; the steeply sloped terrain in the initial portions of the alignment will present water control issues and concerns with respect to lateral and vertical separation of the catenary system from adjacent park lands and homes; the open cut locations will pose similar concerns with respect to vertical and horizontal catenary clearance from homes and businesses located close by. The steeply sloped terrain to the South of the initial portions of the alignment and the “berm” located further to the Southwest, will have an effect on track design. Here the concern is to ensure that the LRVs operating on these portions of the alignment do not leave the track-way, in the event of a derailment.

13th & Garrison

The "Berm" – steep slope

The East-West direction of the alignment could have an adverse effect on the Train Operator's ability to observe the alignment and signal indications (illuminated and fixed) during the early morning and late afternoon periods when the bright sun is low in the sky.

All road crossings and closures will present challenges with respect to the control of pedestrian/vehicular traffic and emergency response vehicles to incidents in the civilian communities. Those crossings where the highway approaches are steep (primarily from the North) will require particular attention in order to devise cost effective, safe, solutions to the control of vehicular traffic during both normal and adverse weather conditions. Road closures must be selected in a manner that will accomplish the safety requirements of the West Corridor while providing the access into and across the Right-of-Way (ROW) required by emergency responders to the civilian community and to any LRV incidents that may occur.

2.0 APPROACH

For the West Corridor, DEA/IEI Team resources and effort have concentrated on those elements of the West Corridor that exhibit differences from other RTD segments. Initially, the DEA/IEI Team reviewed the Preliminary Hazard Analyses prepared for previous segments, compared their design criteria to the West Corridor design criteria, and compared alignment characteristics among all the segments. These comparisons not only include the LRT vehicle, civil, systems, and operational elements, but also passenger, public, traffic, and environmental differences along the corridors.

These comparisons reveal some new hazards on the West Corridor that had not been considered on previous corridors, but most often they reveal some differing probabilities – and severities – for hazards that were identified on the other corridors. As an example, the pedestrian patterns prior to introduction of LRT may make trespass more

likely on the West Corridor than on previous RTD alignments. This difference could warrant assignment of a higher risk category, and, possibly, a different resolution than used on the lower risk alignments.

A large majority of hazards identified on the previous corridors is similar to those identified on the West Corridor. While they will, of course, all be verified, the risks associated with them and the resolutions applied on previous corridors will likely be the same. The prime effort for these hazards, therefore, is to verify, with RTD, satisfaction with the resolutions applied on the previous corridors.

For those hazards that are unique to the West Corridor, or for similar hazards with a differing risk factor on the West Corridor, the DEA/IEI Team will identify resolutions in the priority hierarchy identified in the FTA Guidelines. These will be specifically identified in the PHA. Where appropriate, alternate means of resolution may be presented, along with risk factor reduction and cost differences.

3.0 SAFETY AND SECURITY COORDINATION

Although security issues are not normally considered part of a PHA, today's environment demands that the safety and security aspects of a project be closely coordinated. Hazard management and threat and vulnerability management are addressed through separate processes, looking at safety and security issues, respectively. The process to be used by the DEA/IEI for Threat and Vulnerability Analysis (TVA) is described in a separate document. Often, however, when identifying a hazard, a vulnerability may also be recognized; the reverse may also be true. As an example, inadequate stairway lighting may be recognized as a hazard that could lead to injury due to a fall; it may also be recognized as a vulnerability posing a threat of injury due to mugging. The hazard resolution and threat remediation may both be, at least partly, the same; such as an increase in lighting levels.

The DEA/IEI team recognizes the need to identify, assess, and resolve hazards or mitigate threats through separate processes. The Team also recognizes the advantages of coordinating the application of the two processes, and their proposed resolutions and countermeasures, to assure the most effective use of West Corridor resources. Towards that end, personnel pursuing system safety issues and those pursuing system security issues will exchange gathered data and meet frequently during the design effort to get the greatest return possible on the project's investment in safety and security.

4.0 RISK MANAGEMENT

Simply stated, safety is "freedom from unintentional harm." Absolute safety cannot be guaranteed in any real system. The best that may be achieved is a probability of occurrence so low, or consequence so negligible, that the resultant risk from hazard or threat activation can be considered to have no detrimental effect on any person,

equipment, or system. For most hazards, this low level of risk is not achievable with the limited resources available for any transit project. The object of the PHA process, therefore, is to effectively use available resources to design, build, and operate a transit system with the risk level from every identified hazard lowered to an acceptable limit.

5.0 SYSTEM DEFINITION

Defining all elements of the West Corridor LRT system, and their differences with other RTD segments, is necessary for the identification of all significant hazards. As indicated earlier, the elements and differences to be defined are not only the physical and operational elements, but also the interface with the operating environment. This definition will be a concentrated initial focus of the process, but it will also be revisited on a continuing basis to assure that any design or environmental changes that may occur over the duration of the design process are appropriately assessed for hazards.

6.0 HAZARD IDENTIFICATION

It is understood that we cannot assess and resolve hazards that have not been identified. Hazard identification, therefore, can be considered the most critical step in the process. The process utilizes:

- Data from previous accidents (case studies) or operating experience
- Scenario Development and judgment of knowledgeable individuals
- Generic hazard checklists
- Formal hazard analysis techniques
- Design data and drawings

During the PHA development, and after, as design progresses, the DEA/IEI Safety Team will frequently meet with the design Team to review the design and make a determination if any system element requires a Failure Modes and Effects Analysis (FMEA) to identify potential hazards. Similarly, the Team will use the operating information available to it to perform any Operating Hazard Analysis (OHA) that may be warranted. If the Team continues past the end of Final Design, it will monitor the operating plan development and perform additional OHAs if warranted by changes to the plan.

7.0 HAZARD ANALYSIS

Each identified hazard must be analyzed to determine its consequences (severities). For severities other than negligible, analysis must continue to determine probability (frequency) of occurrence.

Occurrence of a single hazard may result in more than one consequence, with each consequence possibly having a different severity or frequency. For example, a moveable track switch point represents a single-point hazard with at least three possible consequences: 1) a train moving over it while it is unlocked can result in a derailment; 2) a train "picking" an unlocked switch point can be diverted to an unintended route leading to a possible collision; 3) a moveable point of a remotely operated track switch can crush the foot of an employee or trespasser. Each of these consequences must be separately evaluated for severity and frequency.

8.0 HAZARD SEVERITY

Hazard severity will be assessed to place the consequences of hazards in one of the four traditional categories:

Severity Category	Consequences of Occurrence
I Catastrophic	Death; system loss
II Critical	Severe injury or illness; major system damage
III Marginal	Minor injury or illness; minor system damage
IV Negligible	Trivial injury or illness; trivial system damage

In the descriptions of specific occurrences, individual evaluators can differ between two adjacent categories, but it is unlikely that they would differ over three categories. The DEA/IEI Team is comprised of experienced safety professionals who will reach consensus on the most likely severity of each possible consequence of a hazard activation.

9.0 HAZARD PROBABILITY

Hazard probability will be assessed to place the frequency of hazard activation in one of the five traditional categories:

Probability Level	Individual Item Probability	System-wide Probability
A Frequent	Likely to occur frequently	Continuously experienced
B Probable	Occurs several times in item's life	Likely to occur frequently
C Occasional	Likely at least once in item's life	Occurs several times
D Remote	Unlikely, but possible to occur	Can be expected to occur
E Improbable	Assume no occurrence	Unlikely, but possible

As was the case with hazard severity, individual evaluators can differ between two adjacent probability categories, but it is unlikely that they would differ over three categories, which would be separated by at least one order of magnitude (a factor of ten in frequency). As with the assessment of severity, the DEA/IEI Team will reach consensus on the most likely probability level for each possible consequence of a hazard's activation.

10.0 RISK DETERMINATION

Once assigned a severity (I, II, III, or IV) and a probability (A, B, C, D, or E), each hazard consequence is defined by one of 20 risk indices. The highest Hazard Risk Index (HRI), IA, would be for a catastrophic severity and a frequent occurrence; the lowest, IVE, would be for a negligible severity with an improbable occurrence. Dealing with 20 different HRIs is cumbersome and unnecessary, considering the similarities in consequence of adjacent HRIs. Recognizing this, the FTA Guidelines allocate these 20 HRIs over four defined risk categories, and assigns acceptance criteria for risks in each category:

Risk Category	**HRIs in Risk Category**	**Acceptance Criteria**
High	IA, IB, IC, IIA, IIB, IIIA	Unacceptable
Moderate	ID, IIC, IID, IIIB, IIIC	Undesirable
Low	IE, IIE, IIID, IIIE, IVA, IVB	Acceptable with review
Trivial	IVC, IVD, IVE	Acceptable

It should be noted that the FTA Guideline does not name the risk categories; the DEA/IEI Team has provided the four Risk Category definitions above for ease in describing and managing the PHA process.

11.0 HAZARD RESOLUTION

The priorities for hazard resolution are:

►All High risks are unacceptable and options for elimination, or reductions in risk category, have been developed by the DEA/IEI Team and presented in the PHA, or will be in subsequent hazard analyses.

►Moderate risks are undesirable and the Team provides options for reductions in risk, wherever possible.

►Low risks are reviewed and, with input from RTD, recommendations will either be that the hazards be left as is or be acted on to reduce risk.

►All Trivial risks are acceptable and the DEA/IEI Team will recommend that no action be taken by RTD to address them.

In evaluating resolution options, the standard priority order of resolution possibilities will be followed:

►Design to eliminate the hazard
►Design Safety Device(s) to control the hazard
►Design Warning Device(s) for the hazard
►Develop Procedures and Provide Training to better manage the hazard

In cases where it is warranted, more than one of these options may be used to bring a hazard to an acceptable risk level. The hazard resolution process is described in detail in the relevant portion of the PHA Table.

12.0 THE WEST CORRIDOR PHA

The DEA/IEI team's application of the PHA process to the West Corridor seeks to assure that hazards are identified, fully assessed, and resolved to the satisfaction of RTD. Where alternative means of resolution exist, options will be evaluated with the designers and RTD to arrive at the most effective resolution.

The DEA/IEI Safety and Security Teams will continue to work cooperatively with each other, the designers, and RTD, to assure that designs, and non-design solutions, addressing project's safety and security requirements are coordinated.

The form being used for the West Corridor PHA is shown in Appendix A, Instructions for Completing the PHA Form. The instructions are informative as to the content of each element shown on the form.

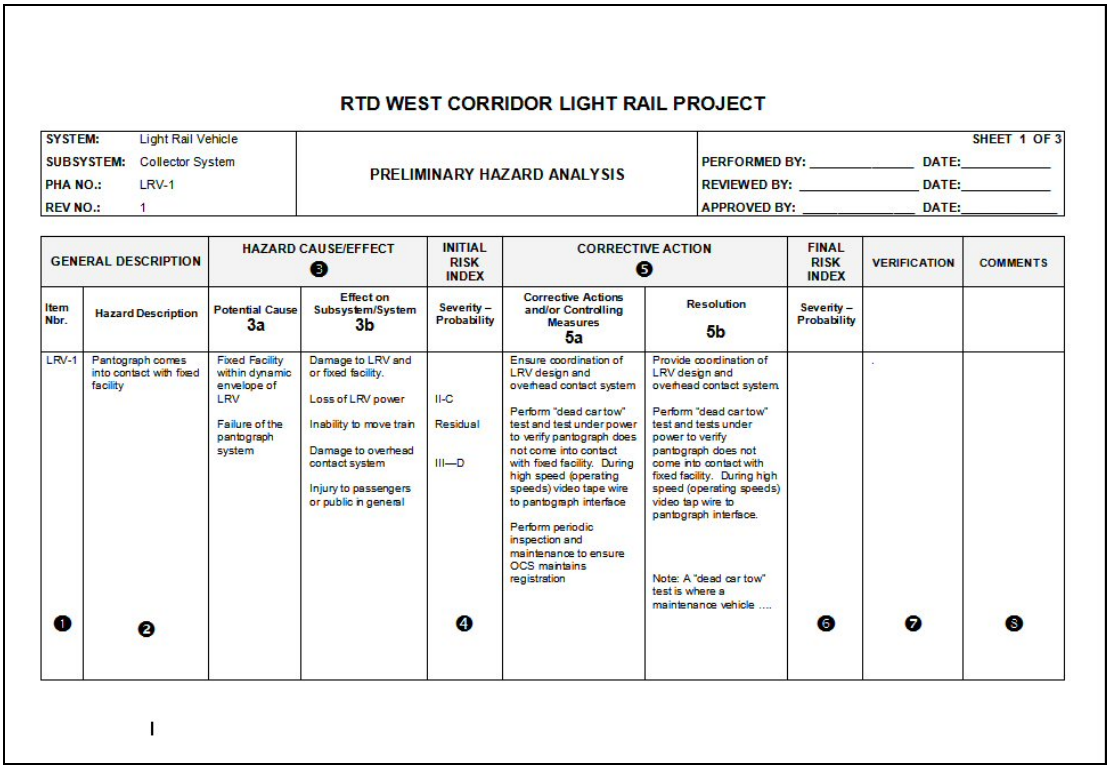
The completed draft West Corridor PHA for Final Design follows Appendix A. This PHA is a working document and will be revised and expanded as warranted during FD. As individual hazards are satisfactorily resolved, they will be appropriately signed and forwarded to the SSWG for review and appropriate action.

DAVID EVANS AND ASSOCIATES INC.

APPENDIX A

INSTRUCTIONS FOR COMPLETING THE PHA FORM

The Preliminary Hazard Analyses (PHA) Form is to be completed as indicated below (refer to sample shown):



RTD WEST CORRIDOR LIGHT RAIL PROJECT

SYSTEM: Light Rail Vehicle SUBSYSTEM: Collector System PHA NO.: LRV-1 REV NO.: 1	PRELIMINARY HAZARD ANALYSIS	SHEET 1 OF 3 PERFORMED BY: _____ DATE: _____ REVIEWED BY: _____ DATE: _____ APPROVED BY: _____ DATE: _____	

GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT ❸		INITIAL RISK INDEX	CORRECTIVE ACTION ❺		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item Nbr.	Hazard Description	Potential Cause 3a	Effect on Subsystem/System 3b	Severity – Probability	Corrective Actions and/or Controlling Measures 5a	Resolution 5b	Severity – Probability		
LRV-1 ❶	Pantograph comes into contact with fixed facility ❷	Fixed Facility within dynamic envelope of LRV Failure of the pantograph system	Damage to LRV and or fixed facility. Loss of LRV power Inability to move train Damage to overhead contact system Injury to passengers or public in general	II-C Residual III—D ❹	Ensure coordination of LRV design and overhead contact system Perform "dead car tow" test and test under power to verify pantograph does not come into contact with fixed facility. During high speed (operating speeds) video tape wire to pantograph interface Perform periodic inspection and maintenance to ensure OCS maintains registration	Provide coordination of LRV design and overhead contact system Perform "dead car tow" test and tests under power to verify pantograph does not come into contact with fixed facility. During high speed (operating speeds) video tap wire to pantograph interface. Note: A "dead car tow" test is where a maintenance vehicle	❻	❼	❽

SYSTEM - Element of the West Corridor.
SUBSYSTEM - Sub element of a system or component.
PHA NO. - PHA identification number.
REV NO. - Revision number of the identified PHA.

PERFORMED BY and **DATE –** Name of Individual performing the assessment through Column 5a and date of assessment completion.
REVIEWED BY and **DATE -** Name of Individual confirming correct completion of Columns 5b through 8 and date of review completion.
APPROVED BY and **DATE -** Name of Individual approving the design resolution of the hazard and date of approval.

GENERAL DESCRIPTION

Column 1. Item Number: A unique consecutive number assigned to each identified hazard.
Column 2. Hazard Description: Concise, but adequate, description of the hazard.

HAZARD CAUSE /EFFECT
Column 3a. Potential Cause: Concise, but adequate, description of the potential cause(s) of the hazard.
Column 3b. Effect on Subsystem/System: Concise, but adequate, description of the effect(s) of the hazard on the subsystem, or system, or individuals.

INITIAL RISK INDEX
Column 4. Assigned Initial Risk Index (IRI) number and letter to the identified hazard based on best judgment of severity and probability, followed by the word "Residual," followed by an assigned Residual Risk Index (RRI) number and letter to the identified hazard based on best judgment of severity and probability assuming that corrective actions identified in Column 5a will be implemented.

CORRECTIVE ACTION
Column 5a. Possible Corrective Actions and/or Controlling Measures: Concise, but adequate, design solutions or other actions that may be employed to reduce the severity, probability of occurrence, or both, of the Identified hazard.
Column 5b. Resolution. Concise, but adequate description of the actual measures taken to address the identified hazard.

FINAL RISK INDEX
Column 6. Assigned Final Risk Index (FRI) number and letter to the identified hazard based on best judgment of severity and probability based on the actual design or other measures taken, as identified in Column 5b.

VERIFICATION
Column 7. Concise, but adequate, description of the method(s) used to verify that the measures shown in Column 5b have actually been put in place.

COMMENTS:
Column 8. Explanatory or other information that may be entered by any signatory for use by future reviewers/approvers in reaching a conclusion as to the acceptability of the assessment, or its resolution, or its risk.

DAVID EVANS AND ASSOCIATES INC.

West Corridor Preliminary Hazard Analysis for Final Design

RTD WEST CORRIDOR LIGHT RAIL PROJECT

SYSTEM: Alignment **SUBSYSTEM:** **PHA NO.:** A-0 **REV NO.:** 0	**PRELIMINARY HAZARD ANALYSIS**	**SHEET 1 of 11** **PERFORMED BY:** C. Yongue **DATE:** June 15, 2006 **REVIEWED BY:** _____ **DATE:** _____ **APPROVED BY:** _____ **DATE:** _____	

GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
A-1	LRV Fire.	Electrical short circuit igniting flammable materials. Human action igniting flammable materials. Ignition of flammable liquids on-board, beneath, or on top of vehicle. LRV stopped adjacent to a wayside fire.	Injury, death, equipment damage, service disruption.	I-C Residual 1-D	Design LRV in accordance with IEEE, NFPA, NEMA standards. Provide portable fire extinguishers in LRV. Inspection and Maintenance procedures designed to assure wiring integrity and proper containment of lubricants and flammable liquids. SOPS to prohibit LRV from operating through wayside fire/smoke without OCC authorization. Develop emergency procedures for fire incidents. Provide manual opening of LRV doors, intercoms, and radio for emergency notification. Provide signage, tunnel walkways and lighting for				Verification will likely be by design reviews and testing and by review of Rulebook, SOPs, and emergency procedures.

RTD WEST CORRIDOR LIGHT RAIL PROJECT

SYSTEM: Alignment	**PRELIMINARY HAZARD ANALYSIS**	**SHEET 2 of 11**	
SUBSYSTEM:		**PERFORMED BY:** C. Yongue	**DATE:** June 15, 2006
PHA NO.: A-0		**REVIEWED BY:** _____	**DATE:** _____
REV NO.: 0		**APPROVED BY:** _____	**DATE:** _____

GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
					patron evacuation.				
A-2	Fire/smoke on alignment.	Fire at station, wayside building, or brush. Motor vehicle fire at crossing or adjacent to ROW. Wood tie fire at special work. Ignition of flammable materials being used for maintenance or stored near alignment.	Injury to passengers, employees, or the public, equipment damage, service disruption.	II-C Residual II-D	Design to eliminate or minimize flammable materials on alignment and at stations. Inspection and maintenance procedures to assure clearance of excessive debris and brush on alignment and prohibit storage of flammable materials. SOPs to provide early warning of smoke/fire to LRV operations and prevent operation into area without OCC approval. Develop emergency procedures for alignment fire incidents.				Verification will likely be by design reviews and testing and by review of Rulebook, SOPs, and emergency procedures.
A-3	Fire/smoke in tunnel.	LRV disabled in underpass with fire (see A-1). Alignment fire/smoke	injury, death, equipment or system damage, service disruption.	I-D Residual II-D	Design tunnel structures and equipment and systems in tunnel to eliminate flammable materials and in compliance with NFPA				Verification will likely be by design reviews and testing and by review of Rulebook, SOPs,

RTD WEST CORRIDOR LIGHT RAIL PROJECT

SYSTEM: Alignment	**PRELIMINARY HAZARD ANALYSIS**	**SHEET 3 of 11**	
SUBSYSTEM:		**PERFORMED BY:** C. Yongue	**DATE:** June 15, 2006
PHA NO.: A-0		**REVIEWED BY:** _____	**DATE:** _____
REV NO.: 0		**APPROVED BY:** _____	**DATE:** _____

GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
		spreads to tunnel (see A-2) Ignition of flammable materials in tunnel structure or systems. Ignition of flammable materials stored in tunnel. Ignition of debris in tunnel.			130. Inspection and maintenance procedures to assure frequent clearance of debris from tunnels and prohibit storage of flammable materials within tunnel. SOPs to provide early warning of smoke/fire to LRV operations and prohibit entry into a tunnel if fire/smoke is observed. Develop emergency procedures for tunnel fire incidents. Provide emergency walkways, lighting, and signage to speed evacuation.				and emergency procedures.
A-4	Toxic Gases In Tunnel (See STA-12 for Toxic Gases on Alignment)	Toxic gases enter tunnel from alignment or station.	Injury, death, service disruption.	I-D Residual I-D	Identify pipelines or storage tanks in the vicinity of tunnels carrying toxic substances and relocate away from				Verification will likely be by design reviews and testing and by review of SOPs

RTD WEST CORRIDOR LIGHT RAIL PROJECT

SYSTEM: Alignment	**PRELIMINARY HAZARD ANALYSIS**	**SHEET 4 of 11**	
SUBSYSTEM:		**PERFORMED BY:** C. Yongue	**DATE:** June 15, 2006
PHA NO.: A-0		**REVIEWED BY:** _____	**DATE:** _____
REV NO.: 0		**APPROVED BY:** _____	**DATE:** _____

GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
		Gas or other toxic agent pipeline adjacent to tunnel fails Natural toxic gas seeps through tunnel walls. Maintenance personnel release toxic gas while performing work.			tunnels. Do geological search for natural gas pockets and if any are present, line tunnel to prevent seepage and design gas detection system with indication to OCC.. Inspection and maintenance procedures to prohibit use of toxic gases in tunnels during service hours and prohibit storage of toxic/flammable materials within tunnel. Develop and coordinate emergency procedures with local emergency response agencies.				and emergency procedures.
A-5	Pedestrian on restricted alignment.	Unfenced alignment. Inadequate signage. Lack of public	Injury, death, service disruption.	I-C Residual I-D	Design fencing and warning signs in alignment areas where intrusion is likely (schools, playgrounds) and pedestrian bridges where crossing of the				Verification will likely be by design reviews and testing and by review of Rulebook.

RTD WEST CORRIDOR LIGHT RAIL PROJECT

SYSTEM: Alignment **SUBSYSTEM:** **PHA NO.:** A-0 **REV NO.:** 0	**PRELIMINARY HAZARD ANALYSIS**	**SHEET 5 of 11** **PERFORMED BY:** C. Yongue **DATE:** June 15, 2006 **REVIEWED BY:** _____ **DATE:** _____ **APPROVED BY:** _____ **DATE:** _____	

GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
		education on dangers of entering alignment.			alignment by residents is highly likely (parks, long runs between intersections through residential neighborhoods) Rulebook to require LRV operators to continuously observe alignment and stop short of person or object observed. Implement rail safety education programs for schools, community groups, local radio and TV.				
A-6	Motor vehicle on alignment.	Stalled vehicle on alignment at crossing. Vehicle drives onto alignment at crossing. Off-road vehicle drives onto or across restricted alignment in park or other area.	Collision causing Injury, death, derailment, equipment damage, or service disruption	I-C Residual I-D	Design fencing and warning signs in restricted alignment areas where vehicle intrusion is likely. Design warning signs and Install CCTV to monitor grade crossings. Rulebook to require LRV operators to continuously observe alignment and				Verification will likely be by design reviews and testing and by review of Rulebook.

RTD WEST CORRIDOR LIGHT RAIL PROJECT

SYSTEM: Alignment **SUBSYSTEM:** **PHA NO.:** A-0 **REV NO.:** 0	**PRELIMINARY HAZARD ANALYSIS**	**SHEET 6 of 11** **PERFORMED BY:** C. Yongue **DATE:** June 15, 2006 **REVIEWED BY:** _____ **DATE:** _____ **APPROVED BY:** _____ **DATE:** _____	

GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
					stop short of person or object observed. Implement rail safety education programs for schools, community groups, and local media.				
A-7	Flood on Alignment.	Heavy rain. Water main break.	Track system damage, derailment, loss of power, injury, death, equipment damage, service disruption.	I-C Residual II-C	Design for adequate drainage, water diversion, or raised track in flood prone alignment areas. Inspection and maintenance procedures to assure all drainage water diversion systems are operational. SOPs and Rulebook to require reduced speed operation during heavy rain with reduced visibility and not to enter any areas where water is above top of rail without OCC permission. Operation with OCC permission not to exceed 5 mph.				Verification will likely be by design reviews and testing and by review of Rulebook, SOPs, and maintenance procedures.

RTD WEST CORRIDOR LIGHT RAIL PROJECT

SYSTEM: Alignment	**PRELIMINARY HAZARD ANALYSIS**	**SHEET 7 of 11**	
SUBSYSTEM:		**PERFORMED BY:** C. Yongue	**DATE:** June 15, 2006
PHA NO.: A-0		**REVIEWED BY:** _____	**DATE:** _____
REV NO.: 0		**APPROVED BY:** _____	**DATE:** _____

GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
A-8	Object on Alignment.	Dropped LRV equipment, rockslide, fallen tree, thrown debris, structural failure of bridge.	Derailment, injury, death, equipment damage, service disruption.	I-D Residual II-D	Design to provide clearance from trees and rockslide areas and fencing where appropriate. Inspection and maintenance procedures to verify structural integrity of structures above and adjacent to alignment and the integrity of LRV truck and undercar equipment Rulebook to require LRV operators to continuously observe alignment and stop short of person or object observed and report observation to OCC				Verification will likely be by design reviews and testing and by review of Rulebook, SOPs, and maintenance procedures.
A-9	Maintenance workers on alignment in location unknown to train operators.	Poor procedures, poor communication, mis-filed work plan, train operator failure	Injury, death, derailment, equipment damage, service disruption.	I-D Residual II-D	Design to provide clearance areas along entire alignment or posting of continuous “no clearance” signage in areas where clearance				Verification will likely be by design reviews and testing and by review of Rulebook, SOPs,

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SYSTEM:	Alignment		**SHEET 8 of 11**
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GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
		to obey rules, maintenance supervisor failure to obey rules.			cannot be provided. Develop operating procedures to require request and approval process for work on ROW and bulletin notification to train operators. OCC to maintain constant control over worker location and use radio to remind operators and notify of gang movement. SOPs, Rulebook, and Inspection and maintenance procedures to require flagging protection for all workers other than lone trackwalker. Rulebook to require LRV operators to continuously observe alignment and stop short of workers unless given permission to proceed by flag person.				and maintenance procedures.

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SYSTEM: Alignment	**PRELIMINARY HAZARD ANALYSIS**	**SHEET 9 of 11**
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GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
A-10	Snow or Ice.	Inadequate removal of heavy snow fall or ice build-up	Injury, equipment damage, service disruption.	II-C Residual III-C	Design to eliminate or minimize areas where snow can build-up into drifts blocking alignment or passenger travel. Develop procedures and maintenance agreements with CDOT/cities for snow/ice removal at all crossings and areas adjacent to stations. SOPs and EOPs to provide for effective snow/ice removal. Inspection and maintenance procedures to require snow/ice removal from special work and crossing equipment. SOPs and Rulebook to require train operation at reduced speed when weather hampers visibility and train braking performance.				Verification will likely be by design reviews and testing and by review of Rulebook, SOPs, and maintenance procedures.

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SYSTEM: Alignment	**PRELIMINARY HAZARD ANALYSIS**	**SHEET 10 of 11**	
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GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
A-11	Poor Visibility on restricted alignment.	Glare due to low sun on east-west alignment. Plant growth blocks view of signal or crossing. Heavy rain or snow.	Collision, injury, death, equipment damage, service disruption.	I-B Residual III-C	Vehicle design to Install sun visors, shades, and screens in LRV operating cabs. Design to provide for removal of trees, shrubs, and brush from signal and grade crossing sight lines; integration testing to verify adequate sight lines. Inspection and maintenance procedures to require vegetation control. SOPs and Rulebook to require train operation at reduced speed (within half their range of vision) when weather hampers visibility and train braking performance or alignment configuration reduces forward sight distance.				Verification will likely be by design reviews and testing and by review of Rulebook, SOPs, and maintenance procedures.
A-12	Inadequate distance between track centers.	Design error. Construction	Sideswipe collision, derailment, injury, death, equipment	I-D Residual	Verify vehicle dynamic envelope and design track spacing to industry				Verification will likely be by design reviews and

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SYSTEM:	Alignment		**SHEET 11 of 11**
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GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
		error. LRV design dynamic envelope incorrect.	damage, service disruption.	I-E	standards. Verify construction to design requirements; perform dynamic clearance tests, including passing trains at speed at closest track centers, during integration testing. Inspection and maintenance procedures to assure cross-level remains at design parameters. Speed signs to be posted where required to advise operators of maximum civil speed. SOPS and Rulebook to require operators not to exceed speed for which track is safe.				testing and by review of Rulebook, SOPs, and maintenance procedures.

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SYSTEM: Track **SUBSYSTEM:** **PHA NO.:** T-0 **REV NO.:** 0	**PRELIMINARY HAZARD ANALYSIS**	**SHEET 1 of 8** **PERFORMED BY:** C. Yongue **DATE:** June 15, 2006 **REVIEWED BY:** _____ **DATE:** _____ **APPROVED BY:** _____ **DATE:** _____

GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
T-1	Pumping (unstable) Track.	Improper Track bed design. Poor installation. Poor maintenance. Track bed undermined by water.	Derailment, Injury, death, equipment damage, service disruption.	I-D Residual II-E	Design and test in accordance with AISC, AREMA and ASTM criteria. Inspection and maintenance procedures to include assurance of track system stability, use of track geometry car on regular basis, and pre-service start-up inspections after events with track system damage potential. Rulebook and SOPs to require operator notification to OCC or any perceived change in ride quality. Bi-weekly walking inspections of entire track system.				Verification will likely be by design reviews and testing and by review of Rulebook, SOPs, and maintenance procedures.

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SYSTEM: Track **SUBSYSTEM:** **PHA NO.:** T-0 **REV NO.:** 0	**PRELIMINARY HAZARD ANALYSIS**	**SHEET 2 of 8** **PERFORMED BY:** C. Yongue **DATE:** June 15, 2006 **REVIEWED BY:** _____ **DATE:** _____ **APPROVED BY:** _____ **DATE:** _____	

GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
T-2	Spread Rail (overgauge).	Poorly designed, defective, or improperly installed rail fasteners. Poor inspection and maintenance. Stresses due to excessive speed or LRV weight. Rail expansion (kink) due to prolonged periods of high temperature.	Derailment, Injury, death, equipment damage, service disruption.	I-D Residual II-E	Design rail fastening system in accordance with industry standard, including heat stressing welded rail strings and utilizing QA/QC procedures to assure fastening system meets specifications. Test and certify completed rail fastening system to assure compliance with design. Inspection and maintenance procedures to include assurance of rail fastener integrity, use of track geometry car on regular basis. Rulebook and SOPs to require operator notification to OCC or any perceived change in ride quality				Verification will likely be by design reviews and testing and by review of Rulebook, SOPs, and maintenance procedures.

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SYSTEM: Track	**PRELIMINARY HAZARD ANALYSIS**	**SHEET 3 of 8**	
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GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
					and maintenance of speeds not exceeding track design limitations. Speed limit signs to be posted on curves and other areas of civil speed restriction. Use restraining rails on curves. Bi-weekly walking inspections of entire track system; daily inspections during high heat periods.				
T-3	Broken rail.	Rail defect. Bad weld. Improper heat treating. Wheel loads too high. Rail overstressed	Derailment, Injury, death, equipment damage, service disruption.	I-C Residual I-D	Design rail system in accordance with industry standard for wheel loads, welding, heat stressing, and broken rail detection; utilize QA/QC procedures to assure rail and welds meet specifications. Test and certify				Verification will likely be by design reviews and testing and by review of Rulebook, SOPs, and maintenance procedures.

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SYSTEM: Track	**PRELIMINARY HAZARD ANALYSIS**	**SHEET 4 of 8**	
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GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
		on curve. Rail contraction (pull-apart) due to prolonged periods of extremely cold temperature.			completed rail installation to assure compliance with design. Inspection and maintenance procedures to include assurance of rail integrity, use track geometry car, with ultra sonic testing or rail integrity, on regular basis. Rulebook and SOPs to require operator notification to OCC or any perceived change in ride quality and maintenance of speeds not exceeding track design limitations. Speed limit signs to be posted on curves and other areas of civil speed restriction. Use retraining rails				

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SYSTEM: Track	**PRELIMINARY HAZARD ANALYSIS**	**SHEET 5 of 8**	
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GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
					on curves. Bi-weekly walking inspections of entire track system; daily inspections during period of extreme cold weather.				
T-4	Worn Rail.	Rail hardness less than required. Poor inspection and maintenance. Inadequate super elevation on curves. Poor wheel/rail interface.	Derailment, Injury, death, equipment damage, service disruption.	I-C Residual I-D	Design to assure proper rail hardness, wheel rail interface, and super elevation and restraining rails on curves to prevent excessive rail wear; QA/QC inspections to assure rail hardness and profile meets specifications Construction oversight and testing to assure super elevation and guardrails are installed as designed Inspection and maintenance procedures to include				Verification will likely be by design reviews and testing and by review of Rulebook, SOPs, and maintenance procedures.

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SYSTEM: Track **SUBSYSTEM:** **PHA NO.:** T-0 **REV NO.:** 0	**PRELIMINARY HAZARD ANALYSIS**	**SHEET 6 of 8** **PERFORMED BY:** C. Yongue **DATE:** June 15, 2006 **REVIEWED BY:** _____ **DATE:** _____ **APPROVED BY:** _____ **DATE:** _____	

GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
					assurance of minimum acceptable rail profile, use track geometry car to measure rail profile on regular basis. Rulebook and SOPs to require operator notification to OCC or any perceived change in ride quality and maintenance of speeds not exceeding track design limitations. Speed limit signs to be posted on curves and other areas of civil speed restriction. Bi-weekly walking inspections of entire track system.				
T-5	Inadequate Wheel/Rail Adhesion.	Wet leaves on rail. Oil/grease on rail.	Design braking distance cannot be achieved, collision, derailment, injury, death, equipment damage, service disruption.	1-B Residual II-C	Design rail greasing systems to minimize grease spread on rails; design alignment to				Verification will likely be by design reviews and testing and by review of

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SYSTEM: Track	**PRELIMINARY HAZARD ANALYSIS**	**SHEET 7 of 8**	
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GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
					minimize adjacent trees Inspection and maintenance procedures to keep trees and brush cut back and to remove leaves from rail. SOPs and Rulebook to require operators report leaves or contaminants on rail or any abnormal traction conditions and for operators to operate at reduced speed when they are present. Track inspectors are to report leaves or foreign substances on rail.				Rulebook, SOPs, and maintenance procedures.
T-6	Unobserved track switch operation.	Remote operation from location without visual of switch or	Derailment, injury, death, equipment damage, service disruption.	I-C Residual II-D	Design train control system to prevent switch movement when train is in approach to a track				Verification will likely be by design reviews and testing and by review of

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SYSTEM: Track **SUBSYSTEM:** **PHA NO.:** T-0 **REV NO.:** 0	**PRELIMINARY HAZARD ANALYSIS**	**SHEET 8 of 8** **PERFORMED BY:** C. Yongue **DATE:** June 15, 2006 **REVIEWED BY:** _____ **DATE:** _____ **APPROVED BY:** _____ **DATE:** _____

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Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
		track conditions.			switch. Provide OCC with CCTV coverage of track switch and its approach or use train operator push button control instead of remote operation. Training and public education programs to warn that switch movement can be expected at any time. Inspection and maintenance procedures to require blocking and clamping switches when working in their vicinity.				Rulebook, SOPs, and maintenance procedures.

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SYSTEM: Stations **SUBSYSTEM:** **PHA NO.:** STA-0 **REV NO.:** 0	**PRELIMINARY HAZARD ANALYSIS**	**SHEET 1 of 7** **PERFORMED BY:** C. Yongue **DATE:** June 15, 2006 **REVIEWED BY:** _____ **DATE:** _____ **APPROVED BY:** _____ **DATE:** _____	

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Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
STA-1	Fire/smoke on station platform.	Electrical wiring fault. Ignition of flammable gas/liquid. Vandalism. Human error. Fire on adjacent property.	Injury, death, equipment damage/loss, or service disruption.	I-D Residual II-C	Design stations to meet existing electrical codes (NEC and UL) and applicable NFPA guidelines. Prohibit use and handling of hazardous and/or flammable materials at station. Add necessary signage, Fire Management Panels, and fire detection and alarm systems. Prohibit patrons from carrying flammable substances on trains and in stations. Use non-flammable solvent and cleaners in stations. Evaluate fire threat from adjacent property during design and provide necessary safeguards.				Verification will likely be by design reviews and testing and by review of SOPs and maintenance procedures.

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SYSTEM: Stations	**PRELIMINARY HAZARD ANALYSIS**	**SHEET 2 of 7**	
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GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
STA-2	Platform/LRV gap is too large.	Inadequate design, Construction error. LRV load leveling failure.	Injury, loss of wheelchair access, service disruption.	II-D Residual II-E	Ensure platform to car distance is designed to meet ADA requirements. Confirm proper distances during construction and integration testing. Design LRV car load-leveling systems with secondary metal springs that support the car body should the air spring or compressed air supply fail. Develop procedures to aid disabled passengers if load leveling fails. Institute maintenance and inspection program.				Verification will likely be by design reviews and testing and by review of SOPs and maintenance procedures.
STA-3	Damaged equipment or facility.	Vandalism. Poor materials or workmanship.	Injuries to patrons due tripping or contact with sharp edges, protrusions, broken glass.	III-C Residual II-D	Design vandal resistant with hardened walking and other surfaces. Provide adequate lighting and CCTV coverage. Institute maintenance and inspection program.				Verification will likely be by design reviews and testing and by review of maintenance procedures.

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Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
STA-4	Exposed electrical wiring or equipment.	Improper design, installation, or maintenance. Vandalism.	Injury to patrons and employees due to electric shock.	II-D Residual II-E	Design electrical system in accordance with federal, state and local codes and ordinances; use vandal resistant materials. Enclose electrical wiring and equipment in conduit, chases, or cabinets. Provide adequate lighting and CCTV coverage at stations. Develop maintenance and inspection procedures.				Verification will likely be by design reviews and testing and by review of maintenance procedures.
STA-5	Obstacles or sharp edges.	Improper design, poor construction, defective equipment, or Inadequate maintenance.	Injury to patrons or employees.	III-D Residual Iv-D	Design for elimination of tripping, impalement or cutting hazards, including in artwork. Verify constructed system and artwork meets design. Develop maintenance and inspection procedures.		IV-D		Verification will likely be by design reviews and testing and by review of maintenance procedures.

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SYSTEM: Stations	**PRELIMINARY HAZARD ANALYSIS**	**SHEET 4 of 7**	
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GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
STA-6	Platform edge not discernable.	Improper design, improper construction, inadequate maintenance.	Injury or death from entering track way and tripping or being struck by train.	I-C Residual I-D	Use ADA compliant platform edge design. Construct and inspect to design requirements. Sound LRV bell when entering station. Inspect and maintain to design standards.				Verification will likely be by design reviews and testing and by review of SOPS, Rulebook and maintenance procedures.
STA-7	Slippery or uneven station walking surfaces.	Improper design, or Improper construction, or Inadequate maintenance. Wet surfaces.	Injury patrons or employees from falls.	III-C Residual III-D	Design slip resistant walking surfaces that will remain even over their useful life. Provide adequate lighting and signage. Provide adequate station drainage. Develop inspection and maintenance procedures.				Verification will likely be by design reviews and testing and by review of maintenance procedures.
STA-8	Uncontrolled motor vehicle movement at drop-off and parking areas.	Improper design. Inadequate signage.	Injury, death, or vehicle damage.	I-D Residual III-D	Design marked pedestrian and vehicular crossings, entrance and exit and motor vehicle right of way for single direction, low				Verification will likely be by design reviews and testing and by review of

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SYSTEM: Stations **SUBSYSTEM:** **PHA NO.:** STA-0 **REV NO.:** 0	**PRELIMINARY HAZARD ANALYSIS**	**SHEET 5 of 7** **PERFORMED BY:** C. Yongue **DATE:** June 15, 2006 **REVIEWED BY:** _____ **DATE:** _____ **APPROVED BY:** _____ **DATE:** _____	

GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
					speed movement. Provide adequate signage, lighting, surveillance, and speed limit enforcement.				maintenance procedures.
STA-9	Platform overcrowding.	Inadequate Platform design. Inadequate crowd control. Delayed train service. Inadequate exiting capacity.	Injury to patrons or employees.	II-C Residual II-D	Design platforms to handle expected peak loading and means to close platforms if overcrowded. Design queuing areas adjacent to stations serving special events and exiting capacity to effectively empty platform. Develop operations procedures for crown control. Use stand-by trains. Provide adequate lighting and CCTV coverage at stations. Provide public education on dangers of overcrowding.		III-D		Verification will likely be by design reviews and testing and by review of operating and maintenance procedures.

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SYSTEM: Stations	**PRELIMINARY HAZARD ANALYSIS**	**SHEET 6 of 7**	
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GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
STA-10	Passenger track crossings.	Design element of system. Poor or incorrect signage. Passenger inattention. LRV operator fails to warn of approach.	Injury or death, service disruption.	I-C Residual I-D	Design pedestrian walkways in accordance with MUTCD, ADA and other relevant codes and standards. Install appropriate warning signage. Include gates or barriers at dedicated pedestrian crossings at stations. Rulebook to require sounding bell when entering station. Provide rail safety education program.				Verification will likely be by design reviews and testing and by review of Rulebook, SOPs and maintenance procedures.
STA- 11	Obstructed sightlines.	Station design prevents clear view of approaching train unless at platform edge. Equipment stored on station blocks sight lines.	Injury or death if struck while leaning over platform edge.	I-C Residual I-E	Design for clear sightlines to approaching train from at least four feet from platform edge. SOPs should prohibit equipment/material storage within six feet of platform edge.				Verification will likely be by design reviews and testing and by review of SOPs and maintenance procedures.

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SYSTEM: Stations	**PRELIMINARY HAZARD ANALYSIS**	**SHEET 7 of 7**	
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Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
STA-12	Toxic gases.	Failure at Industrial facility or pipeline adjacent to the station. Crash/Fire involving tanker truck carry toxic material near station.	Injury, death, or system loss.	I-D Residual I-D	Identify facilities, pipelines, truck routes in the vicinity of stations, whose operations involve toxic or flammable substances that have the potential release of toxic materials. Relocate pipelines that transport toxic/flammable materials/gases. Develop and coordinate emergency procedures with local emergency response agencies.				Verification will likely be by design reviews and testing and by review of SOPs and emergency procedures.

RTD WEST CORRIDOR LIGHT RAIL PROJECT

SYSTEM: Train Control **SUBSYSTEM:** **PHA NO.:** TC-0 **REV NO.:** 0	**PRELIMINARY HAZARD ANALYSIS**	**SHEET 1 of 7** **PERFORMED BY:** C. Yongue **DATE:** June 15, 2006 **REVIEWED BY:** _____ **DATE:** _____ **APPROVED BY:** _____ **DATE:** _____	

GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
TC-1	Gate fails to operate when train present.	System fails to detect train. Mechanical or electrical problem with gate control and/or mechanism.	Potential collision with road vehicle or pedestrian. Injury or death.	I-C Residual 1-D	Design gate and gate control circuits to fail safe in compliance with MUTCD and AREMA recommended practices. Minimum shunting sensitivity should be 0.2 ohms. Install gate down indication (or Operator's indication) on crossing gate or wayside. Rule book must require train operators to view gate down indication and other conditions around gate prior to entering the crossing and report failures.				Verification will likely be by design reviews and testing and by review of Rulebook and Operating SOPs.
TC-2	Broken Gate Arm.	Arm struck by motor vehicle. Arm broken by wind or other causes.	Gate arm no longer provides barrier to traffic lane. Road Vehicle or pedestrian enters crossing causing collision. Injury or death.	I-C Residual 1-D	Design gate with gate positive down indication (Grade Crossing Indicator). Design Gate mechanism to follow MUTCD so that counter weight will not permit a gate down indication with a broken		I-D		Verification will likely be by design reviews and testing and by review of Rulebook and Operating SOPs.

RTD WEST CORRIDOR LIGHT RAIL PROJECT

SYSTEM: Train Control **SUBSYSTEM:** **PHA NO.:** TC-0 **REV NO.:** 0	**PRELIMINARY HAZARD ANALYSIS**	**SHEET 2 of 7** **PERFORMED BY:** C. Yongue **DATE:** June 15, 2006 **REVIEWED BY:** _____ **DATE:** _____ **APPROVED BY:** _____ **DATE:** _____	

GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
					arm. Rule Book must require train operator to preview gate down indication and crossing condition prior to entering the crossing and report failures. Stencil emergency phone numbers on crossing gate equipment. Coordinate crossing design with CoPUC. At crossings with steep approaches, primarily from the north, install LRV activated caution light and fixed sign between the last entry onto the main road and the rail crossing.				
TC-3	Gate preview time is less than 20 seconds.	Train approach circuit not long enough for train speeds. Coordination with traffic signals and or railway signal system does not	Road Vehicle or pedestrian enters crossing resulting in collision, Injury or death.	I-C Residual 1-D	Design approach circuits of appropriate length (25 seconds). Coordinate traffic control/caution system and railway signaling system to ensure proper approach time.				Verification will likely be by design reviews and testing and by review of Rulebook and Operating SOPs

RTD WEST CORRIDOR LIGHT RAIL PROJECT

SYSTEM:	Train Control		**SHEET 3 of 7**
SUBSYSTEM:		**PRELIMINARY HAZARD ANALYSIS**	**PERFORMED BY:** C. Yongue **DATE:** June 15, 2006
PHA NO.:	TC-0		**REVIEWED BY:** _____ **DATE:** _____
REV NO.:	0		**APPROVED BY:** _____ **DATE:** _____

GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
		provide timely advance warning.			Rulebook must require train operator to preview gate down indication and crossing condition prior to entering the crossing and report failures. Perform system integration tests to verify proper gate time per design. Educate public using Operation Life Saver or similar campaign.				

RTD WEST CORRIDOR LIGHT RAIL PROJECT

SYSTEM:	Train Control		**SHEET 4 of 7**
SUBSYSTEM:		**PRELIMINARY HAZARD ANALYSIS**	**PERFORMED BY:** C. Yongue **DATE:** June 15, 2006
PHA NO.:	TC-0		**REVIEWED BY:** _____ **DATE:** _____
REV NO.:	0		**APPROVED BY:** _____ **DATE:** _____

GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
TC-4	Gate preview time greater than 30 seconds.	Train approach circuit too long for train speeds. Traffic signals/caution signal and or TCl system delays train.	Road Vehicle drives around gate causing collision, Injury, or death.	I-C Residual 1-D	Design approach circuits of appropriate length (25 seconds). Coordinate traffic control system and railway signaling system to ensure proper approach time. Rulebook require train operator to preview gate down indication and crossing condition prior to entering intersection. Perform system integration tests to verify proper gate time. Educate public using Operation Life Saver or other similar campaign.				Verification will likely be by design reviews and testing and by review of Rulebook and Operating SOPs.

RTD WEST CORRIDOR LIGHT RAIL PROJECT

SYSTEM:	Train Control		**SHEET 5 of 7**
SUBSYSTEM:		**PRELIMINARY HAZARD ANALYSIS**	**PERFORMED BY:** C. Yongue **DATE:** June 15, 2006
PHA NO.:	TC-0		**REVIEWED BY:** _____ **DATE:** _____
REV NO.:	0		**APPROVED BY:** _____ **DATE:** _____

GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
TC-5	Side and tip lights not illuminating or visible.	Improper circuitry. Equipment malfunction. Sight lines not maintained. Lights not visible from all approach angles. Burned lamp bulb. Inactive warning sign blocked, missing, or covered with graffiti.	Road Vehicle or pedestrian not alerted to gate activation resulting in collision, injury, or death.	I-C Residual I-D	Verify visual warning devices can be seen from all angles of access as designed. Perform routine maintenance and inspection. Educate public using Operation Life Saver or similar campaign. Design rail crossing(s) to conform to MUTCD standards. Coordinate grade crossing design with CoPUC.			.	Verification will likely be by design reviews and testing and by review of SOPs and maintenance procedures.

RTD WEST CORRIDOR LIGHT RAIL PROJECT

SYSTEM: Train Control	**PRELIMINARY HAZARD ANALYSIS**	**SHEET 6 of 7**	
SUBSYSTEM:		**PERFORMED BY:** C. Yongue	**DATE:** June 15, 2006
PHA NO.: TC-0		**REVIEWED BY:** _____	**DATE:** _____
REV NO.: 0		**APPROVED BY:** _____	**DATE:** _____

GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
TC-6	Grade crossing Warning System failed or not visible or audible.	Improperly wired. Equipment malfunction. Sight lines not maintained. Lights not visible from all approach angles. Burned light bulb. Warning sign Inactive, blocked, missing, or covered with graffiti.	Road Vehicle or pedestrian not alerted to gate activation resulting in collision, injury, or death.	I-C Residual I-D	Ensure visual warning devices can be seen from all angles of access. Perform routine maintenance and inspection. Design Crossing to MUTCD standards to include warning devices. Educate public using Operation Life Saver or similar campaign.				Verification will likely be by design reviews and testing and by review of SOPs and maintenance procedures.
TC-7	Road Vehicle drives around crossing gate.	Driver tries to beat the train. Gate comes down too early and driver and becomes impatient. Open area allows Road Vehicle to drive around gate.	Collision. Injury or loss of life.	I-B 1-C	Use concrete barriers, raised curbs, multiple gates, or other types of barriers to close off all entry routes. Maintain minimum safe gate down times. Install automatic camera surveillance. Work with FLSC to increase enforcement of				Verification will likely be by design reviews and testing and by review of SOPs and maintenance procedures.

RTD WEST CORRIDOR LIGHT RAIL PROJECT

SYSTEM: Train Control **SUBSYSTEM:** **PHA NO.:** TC-0 **REV NO.:** 0	**PRELIMINARY HAZARD ANALYSIS**	**SHEET 7 of 7** **PERFORMED BY:** C. Yongue **DATE:** June 15, 2006 **REVIEWED BY:** _____ **DATE:** _____ **APPROVED BY:** _____ **DATE:** _____	

GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
					traffic laws. Provide public education such as Operation Lifesaver. Establish a media campaign warning public of hazard of train moving in traffic lane.				
TC-8	Road Vehicle breaks gate arm and fouls track.	Driver approaches crossing too fast. Insufficient warning before gates descend.	Collision, injury, or loss of life.	I-B Residual 1-C	Coordinate with the FLSC to increase enforcement of traffic laws. At crossings with steep approaches, primarily from the north, install LRV activated caution light and fixed sign between the last entry onto the main road and the rail crossing. Ensure visual warning devices can be seen from all angles of access. Provide public education such as Operation Lifesaver.			.	Verification will likely be by design reviews and testing and by review of SOPs.

RTD WEST CORRIDOR LIGHT RAIL PROJECT

SYSTEM:	Overhead Contact System	**PRELIMINARY HAZARD ANALYSIS**	**SHEET 1 of 4**
SUBSYSTEM:			**PERFORMED BY:** C. Yongue **DATE:** June 15, 2006
PHA NO.:	OCS-0		**REVIEWED BY:** _____ **DATE:** _____
REV NO.:	0		**APPROVED BY:** _____ **DATE:** _____

GENERAL DESCRIPTION		**HAZARD CAUSE/EFFECT**		**INITIAL RISK INDEX**	**CORRECTIVE ACTION**		**FINAL RISK INDEX**	**VERIFICATION**	**COMMENTS**
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
OCS-1	Access to energized catenary.	Passenger or trespasser contact with exposed energized catenary at stations, ROW, bridges. Contact by maintenance personnel performing duties. Energized catenary falls on LRV causing shock potential for passenger boarding or alighting or being evacuated from LRV during an emergency.	Serious injuries or death, equipment damage, or service disruption.	I-D Residual II-C	Use fences, signage, and security forces to prevent access by unauthorized persons to dedicated right of way sections. Provide shields over catenaries that pass below bridges. Provide proper training and procedures for maintenance personnel working near catenaries. De-energize and lock out power when working on or near power lines. Provide emergency trip capability at substations. Develop maintenance and emergency procedures. Coordinate evacuation with Central Control to have power removed.				Verification will likely be by design reviews and testing and by review of SOPs and maintenance procedures.

RTD WEST CORRIDOR LIGHT RAIL PROJECT

SYSTEM:	Overhead Contact System		**SHEET 2 of 4**
SUBSYSTEM:		**PRELIMINARY HAZARD ANALYSIS**	**PERFORMED BY:** C. Yongue **DATE:** June 15, 2006
PHA NO.:	OCS-0		**REVIEWED BY:** _____ **DATE:** _____
REV NO.:	0		**APPROVED BY:** _____ **DATE:** _____

GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
OCS-2	Energized catenary falls on LRV.	Catenary support system fails due to mechanical or material failure. Catenary breaks due to ice build-up or tree falling.	Injury, death, equipment damage, or service disruption.	I-D Residual I-C	Design catenary support system to withstand heavy ice loads and with necessary mechanical integrity. Incorporate appropriate maintenance procedures to ensure integrity of the OCS at all times. Incorporate protective devices in substations to monitor OCS and trip out circuits in the event of accidental grounding. Initiate tree control along ROW.				Verification will likely be by design reviews and testing and by review of SOPs and maintenance procedures.
OCS-3	Power surge.	Lighting strike.	Injury, death, equipment damage, fire, or service disruption.	I-D Residual II-C	Provide a lightning protection system, including lightning arrestors on line and surge protection to power and other circuits that are subject to lightning induced surges. Provide maintenance procedures requiring				Verification will likely be by design reviews and testing and by review of SOPs and maintenance procedures.

RTD WEST CORRIDOR LIGHT RAIL PROJECT

SYSTEM:	Overhead Contact System		**SHEET 3 of 4**
SUBSYSTEM:		**PRELIMINARY HAZARD ANALYSIS**	**PERFORMED BY:** C. Yongue **DATE:** June 15, 2006
PHA NO.:	OCS-0		**REVIEWED BY:** _____ **DATE:** _____
REV NO.:	0		**APPROVED BY:** _____ **DATE:** _____

GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
					inspection of surge protection system.				
OCS-4	Catenary pole failure	Improper design or installation. Strike by LRV. Strike by Motor Vehicle.	Injury, death, derailment, equipment damage, or service disruption.	II-D Residual III-D	Use proven pole design and installation techniques; inspect installation. Place catenary poles within right of way outside vehicle dynamic envelope and design barriers to protect poles where exposure to motor vehicle hits is high. Include inspection of poles in maintenance procedures.				Verification will likely be by design reviews and testing and by review of SOPs and maintenance procedures.
OCS-5	Induced current in denergized catenary.	High voltage AC line running parallel to OCS.	High voltage (low current) shock to maintenance personnel.	II-D Residual IV-D	Maintenance procedures to include detection of stray currents and grounding of de-energized wires before working on them.				Verification will likely be by review of SOPs and maintenance procedures.
OCS-6	Catenary damaged by falling trees or by vandalism.	Catenary system too close to adjacent property. Inadequate vertical and horizontal	Loss of motive power, service disruption, injury, death, system damage.	II-C Residual III-D	Remove trees too close to catenary and ensure adequate horizontal and vertical clearance between the catenary system and adjacent terrain. Install barriers to deter		III-D		Verification will likely be by design reviews and testing and by review of SOPs and maintenance procedures.

RTD WEST CORRIDOR LIGHT RAIL PROJECT

SYSTEM:	Overhead Contact System	**PRELIMINARY HAZARD ANALYSIS**	**SHEET 4 of 4**
SUBSYSTEM:			**PERFORMED BY:** C. Yongue **DATE:** June 15, 2006
PHA NO.:	OCS-0		**REVIEWED BY:** _____ **DATE:** _____
REV NO.:	0		**APPROVED BY:** _____ **DATE:** _____

GENERAL DESCRIPTION		HAZARD CAUSE/EFFECT		INITIAL RISK INDEX	CORRECTIVE ACTION		FINAL RISK INDEX	VERIFICATION	COMMENTS
Item No.	**Hazard Description**	**Potential Cause**	**Effect on Subsystem/System**	**Severity – Probability**	**Corrective Actions and/or Controlling Measures**	**Resolution**	**Severity – Probability**		
		clearance between open cut terrain and catenary. (Rude /Sanchez Parks and Pike view).			vandalism.				