Root-Cause Analysis Report

UNDERGROUND MINING: GROUND CONTROL

Workshop Date: December 7, 2017

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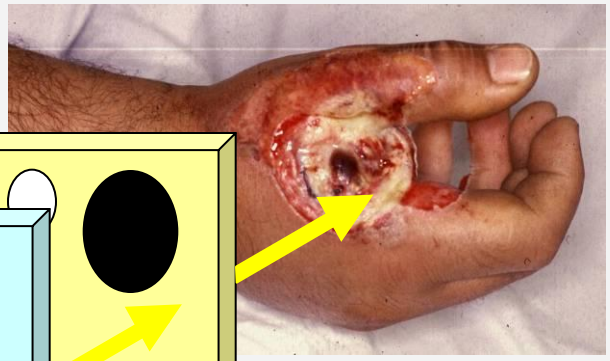
Risk Assessment Project: The Subject Of Inquiry

Examples that could lead to increased risk

Failure/absence of risk controls



ACTIVE FAILURE

LATENT FAILURE

LATENT FAILURE

LATENT FAILURE

LATENT FAILURE

Unsafe act

Shortage of key skillsets

Training material not current

Gaps in Regs.

Design issues

Worker

Simultaneous failure/absence of risk controls could cause a "catastrophic event"

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Revisiting the 2014 Risk Assessment Results: Top 10 Risk Events

Risk Rank	Category	Situation or Condition or Factor that could result in Injury or Illness OR What could keep you up at night?	L		C		Risk
			L	sd-L	C	sd-C	
1	Ground control	Rock bursts underground	4.75	0.66	4.50	0.50	21.38
2	Mobile Equipment	Large vehicle and pedestrian or small vehicle interaction is common and lethal	4.38	0.70	4.75	0.43	20.81
3	Ground control	Loose rock at the face continues to kill and injure workers UG	4.25	0.97	4.63	0.48	19.68
4	Ground Control	Existing underground mines in Ontario are becoming deeper and incurring higher extraction ratios. These situations can result in various forms of ground instability	4.50	0.71	4.25	1.09	19.13
5	Ground control	High faces not scaled and secured to protect workers	4.25	0.97	4.50	0.50	19.13
6	Mobile Equipment	The mobile equipment employed in many underground mines is getting bigger. Bigger equipment can often result in poorer operator visibility (i.e. more and larger blind spots). This can result in collisions with other vehicles or contact with pedestrians.	4.25	0.66	4.38	0.48	18.62
7	Occ. Disease	Exposure to hazardous substances(dusts, materials, metals), gases/ fumes, biological materials or forms, Physical Hazards (vibration, noise, heat/cold stress, light.)	4.63	0.70	4.00	0.71	18.52
8	Fatigue	Working Shiftwork resulting in disrupted sleeping patterns	4.63	0.48	4.00	0.87	18.52
9	Ground control	Fall of ground while installing ground support	4.38	0.86	4.13	0.60	18.09
10	Training	Supervisors in some mines in Ontario lack the proper experience and Training. Inexperienced and improperly trained supervisors pose a threat to themselves and their direct-report workers.	4.38	0.70	4.13	1.05	18.09

Revisiting the 2014 Risk Assessment Results: Top 10 Risk Categories

#	Category	Situation or Condition or Factor that could result in Injury or Illness OR What could keep you up at night?
1	Ground control	Rock bursts underground
2	Mobile Equipment	Large vehicle and pedestrian or small vehicle interaction is common and lethal
3	Occ. Disease	Exposure to hazardous substances(dusts, materials, metals), gases/ fumes, biological materials or forms, Physical Hazards (vibration, noise, heat/cold stress, light.)
4	Fatigue	Working Shiftwork resulting in disrupted sleeping patterns.
5	Training	Supervisors in some mines in Ontario lack the proper experience and Training. Inexperienced and improperly trained supervisors pose a threat to themselves and their direct-report workers.
6	Ventilation	Little in the way of controls on diesel equipment operating in certain areas. No way for workers to know how much equipment is working in any given area. Diesel emissions now a recognized cause of cancer.
7	Lockout/ Guarding	Failure to isolate energy as a result of inappropriate lockout/tagging
8	Mine Services	Working from a scoop-tramp bucket (i.e.. For fan installation and the provision of other services)
9	Water Management	Run of muck due to water in an ore pass
10	Hoisting	Lack of proper signals when hoisting

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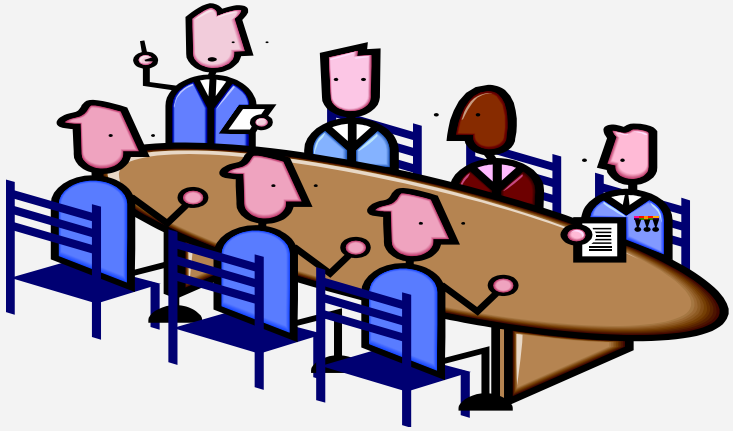
Root-Cause Analysis: Risk Statement

Based on the results of the Mining Review, the following risk statement was selected by the subject matter expert participants for Root-Cause Analysis using the **"Fishbone"** approach

" A rockburst occurs in an underground mine at a location where workers are normally present"

Workshop: A Bipartite and Collective Process

- Workshop participants were peer-recognized subject matter experts
- Workshop process was open, transparent and collaborative
- Workshop was face-to-face. No teleconferencing
- Any ranking/prioritization of causal factors was done using Employer and Worker input only (MOL & WSN did not vote)



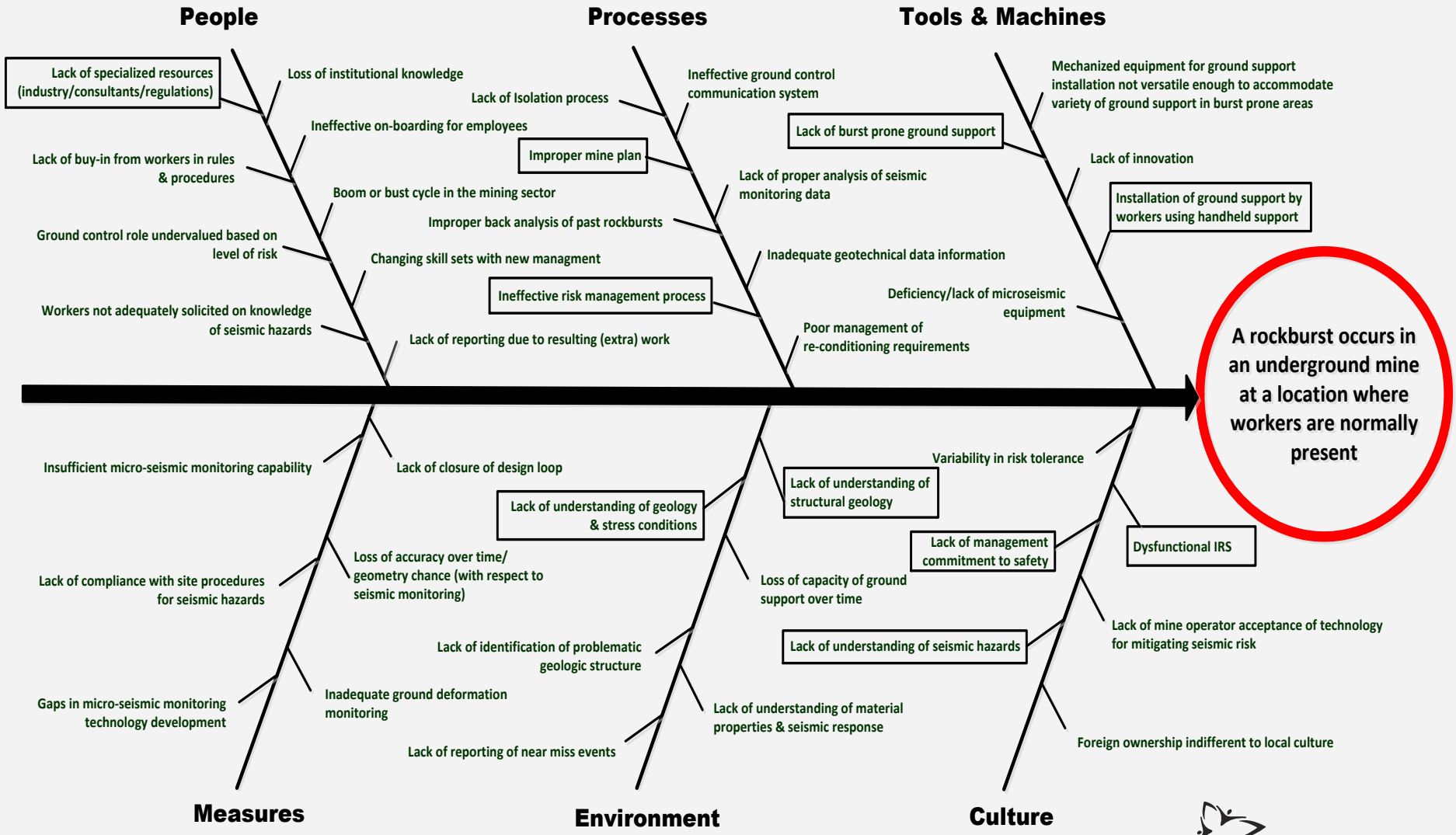
Workshop Participants: Ground Control Subject Matter Experts

#	Name	Company/Representation
1	**Eric Lachance**	USW Local 2020
2	**Al Robb**	UNIFOR, Goderich
3	**Ron Limarilli**	UNIFOR, Sudbury
4	**Anneta Forsythe**	Vale
5	**Brad Simser**	Glencore
6	**Richard Hong**	Kirkland Lake Gold
7	**Philip Dirige**	Workplace Safety North
8	**Ed Pieterse**	Observer, Glencore
9	**Derek Budge**	Observer, Red Path

#	Name	Company/Representation
10	**Robert Barclay**	MOL (Operations)
11	**Jamie Creswell**	MOL (Operations)
12	**Glenn Staskus**	MOL (Operations)
13	**Christine Bibby**	MOL (Corporate Management) - **Workshop Tech Support**
14	**Sujoy Dey**	MOL (Prevention)- **Facilitator**

"Fishbone" Diagram: Primary Causal Factors

Mining Root Cause Analysis for Ground Control



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December 2017

Created by: Christine Bibby, Risk Assessment Team, Ministry of Labour

Ground Control RCA: Top 10 (out of 40) Primary Causal Factors

1. **Lack of burst-prone ground support**
2. **Lack of understanding of geology and stress conditions**
3. **Lack of management commitment to safety**
4. **Ineffective risk management process**
5. **Improper mine plan**
6. **Lack of understanding of seismic hazards**
7. **Dysfunctional IRS**
8. **Installation of ground support by workers using handheld support**
9. **Lack of understanding of structural geology**
10. **Lack of specialized resources (industry/consultants/regulators)**

1. Lack of Burst-Prone Ground Support - Controls

a. Improve cost effectiveness, efficiency
b. Excavation Design for potential installation of burst prone support
c. Understand lifecycle of excavation
d. Be proactive in your mining planning to accommodate future burst prone GS design
e. Anticipation process for installation of burst prone support
f. Improve installation equipment availability
g. Predetermine areas for burst prone support (pre-hab)
h. Operations acceptance of ground control recommendations for burst prone support
i. Incorporate burst prone support into the cycle (consider it single pass installation – not primary/secondary)
j. Prioritize secondary support. Link to mining plan schedule
k. Improve the ability to measure the residual capacity of the support
l. Equal importance to production bonus system for pre-hab and rehab
m. Quality control of surface support (need for continuous improvement)
n. Continuous improvement of the design of the composite burst prone support system
o. Better clarity on the specs of the various dynamic supports
p. Better understanding of the interaction between individual components of burst prone system (e.g. not always numerically driven)

Note: Control list not in any order of priority

2. Lack of Understanding of Geology & Stress Conditions - Controls

a. Optimize use of diamond drill information (analysis of borehole breakouts using Acoustic televiewer)
b. Increased use of cutting-edge technology, but due diligence required before use. Currently using mechanical engineering software (finite element software)
c. Need people at the mine site with the ability to use the technology

Note: Control list not in any order of priority

3. Lack of Management Commitment to Safety- Controls

a. Define seismic risk management plan in corporate health and safety policy
b. Formal audits and reviews to ensure operational execution is aligned with corporate expectations
c. JHSC vigilance and participation
d. Effective IRS

Note: Control list not in any order of priority

4. Ineffective Risk Management Process- Controls

a. Educate and involve all workplace parties in the power of risk assessment and management
b. Report near-miss data to incorporate into risk assessment analysis
c. Business analytics to feed into risk assessments
d. Better data and analysis to reduce subjectivity
e. Train people on risk assessment facilitation
f. Provide risk assessment guidelines
g. Better capability of HSAs to provide support on risk assessments
h. Tangible results on operations based on risk assessment (closing the loop on the risk management cycle)
i. Formalized risk assessment program to comply with sections 5.1, 5.2, 5.3 of the mining Reg.

Note: Control list not in any order of priority

5. Improper Mine Plan - Controls

a. Pre-mine geo-mechanical/stability analysis
b. Deliberate effort to get strategic geotechnical information as early as possible
c. Flexibility in mine plan to accommodate changes in ore reserves
d. Capable planning personnel
e. Mindful of engineering fundamentals while meeting economic targets

Note: Control list not in any order of priority

6. Lack of Understanding of Seismic Hazards - Controls

a. Educate on and keep workplace parties aware of seismic hazards
b. Ensure conversation at the face (muck-pile discussion)
c. Foster awareness of the triggers/causes of seismic hazards
d. Communicate any seismic concerns at crew lineup meetings and continue the discussion underground at the face
e. Basic level of training for supervisor on the seismic viewer
f. Formal ground control training and review

Note: Control list not in any order of priority

7. Dysfunctional IRS - Controls

a. Clear definition of IRS
b. Management commitment to IRS
c. Every supervisor having the same understanding of IRS
d. Implement improvement strategies based on IRS survey results
e. Continuous improvement of the system
f. KPIs on closure of workers' concerns

Note: Control list not in any order of priority

8. Installation of Ground Support by Workers Using Handheld Support- Controls

a. Proper blasting controls
b. Scaling before installing ground support
c. On-going scaling
d. Proper training for application (bolting off a muckpile vs platform: ground support type)
e. Consideration given to modified leading edge support (e.g. stiffer bolts or zero gauge screen straps)
f. Ensuring capability & capacity of the tools (e.g. sufficient air pressure for handheld tools, rebar pushers, drill bits)
g. Ensure proper housekeeping for retreat purposes
h. Adequate re-entry protocol & monitoring (for large blasts or seismic events)
i. Proper ground support selection & installation procedure (taking into consideration burst prone walls and face)
j. Proper ground support design (engineered)
k. Clear communication of ground support requirements for site specific conditions
l. Proper workplace inspections

Note: Control list not in any order of priority

9. Lack of Understanding of Structural Geology- Controls

a. Having processes to collect geotechnical information (geophysics: Acoustical Televiewer (ATV), Optical Televiewer (OTV), diamond drilling, mapping)
b. Better classification of structures/faults with regards to seismic risk
c. Better use of pilot/reconnaissance holes
d. Having a robust design to capture uncertainties
e. Understanding local geology (utilizing diamond drill and previous cut mapping information)
f. Understanding of lithology, ore type and structure
g. Understanding of location and condition (ore contact, abutment, sill pillar, proximity to faults/structures)
h. Making good use of the data analysis
i. Better resources (structural geologists), skillsets to analyze the geotechnical information
j. Retraining program

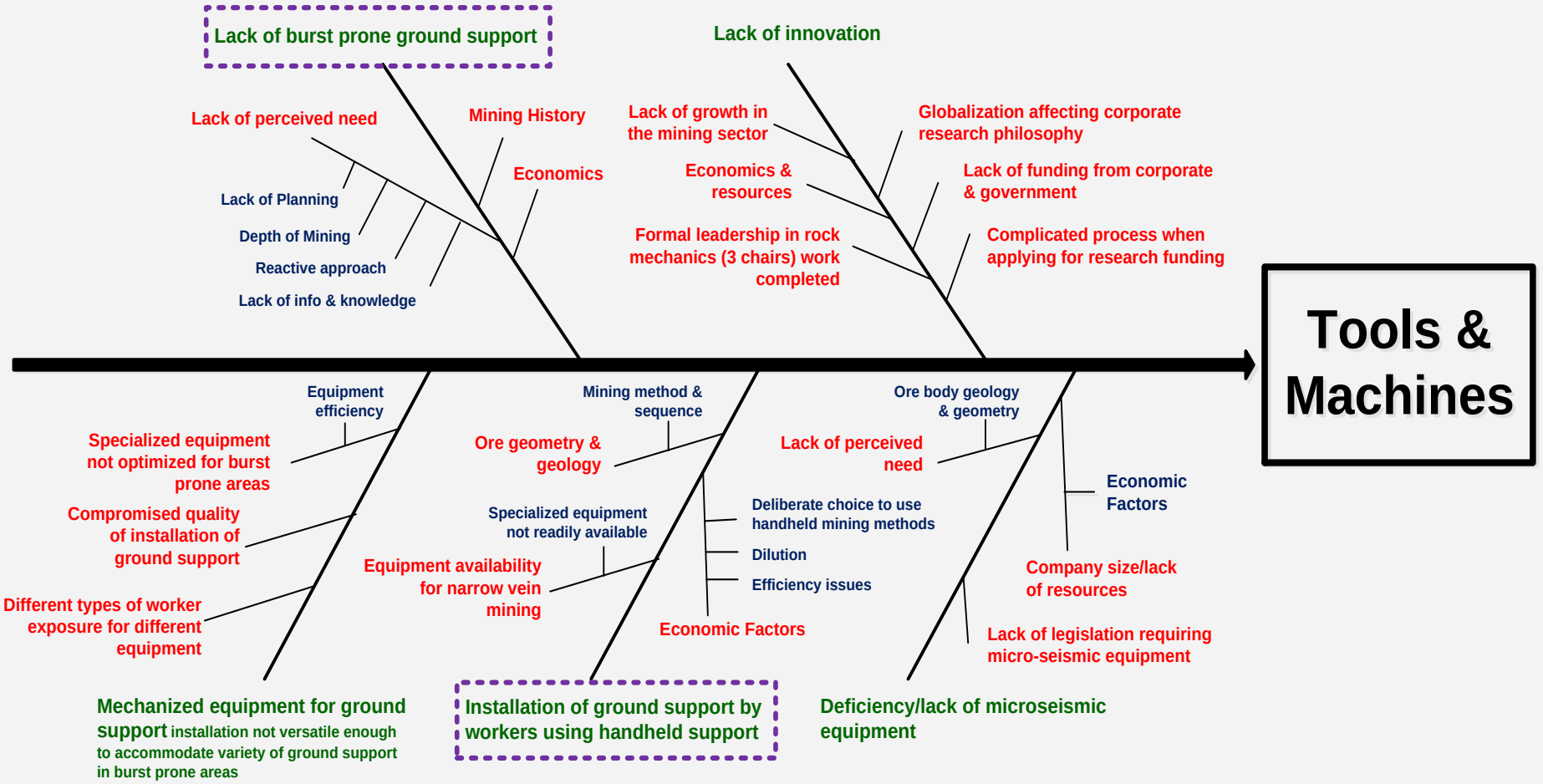
Note: Control list not in any order of priority

10. Lack of Specialized Resources (industry/ consultants/ regulators) - Controls

a. Better collaboration with universities, colleges and industry towards providing programs that have better emphasis on geology and ground control
b. Setting up an environment for better collaboration between geology and mining programs
c. More organized, structured and formalized training program for new recruits
d. Refresher training
e. Define the desired requirements of a ground control engineer/specialist
f. Elevate the profile of a ground control engineer/specialist
g. Incentivize (E.g. Payscale)
h. Create opportunities for others who are interested to get into ground control
i. Regulation considerations for a ground control specialist (having a ground control specialist for every mine site)
j. Consult with HSA for the optimum qualification for a ground control specialist

Note: Control list not in any order of priority

Appendix I: Tools & Machines



Top 10 Primary Root-Cause

Primary Root-Cause

Secondary Root-Cause

Tertiary Root-Cause

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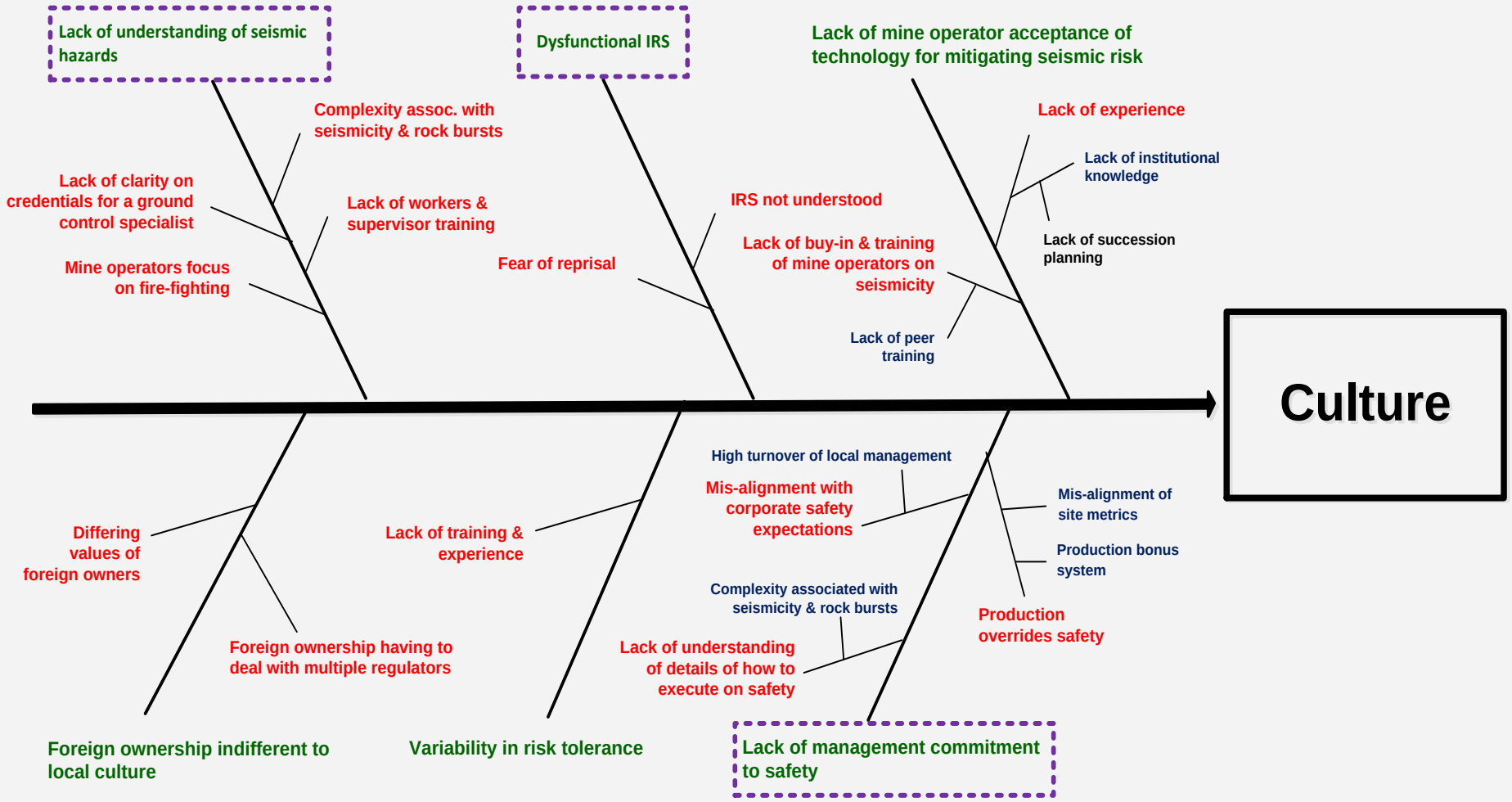
Appendix II: Culture



Top 10 Primary Root-Cause

Primary Root-Cause

Secondary Root-Cause

Tertiary Root-Cause

Quaternary Root-Cause

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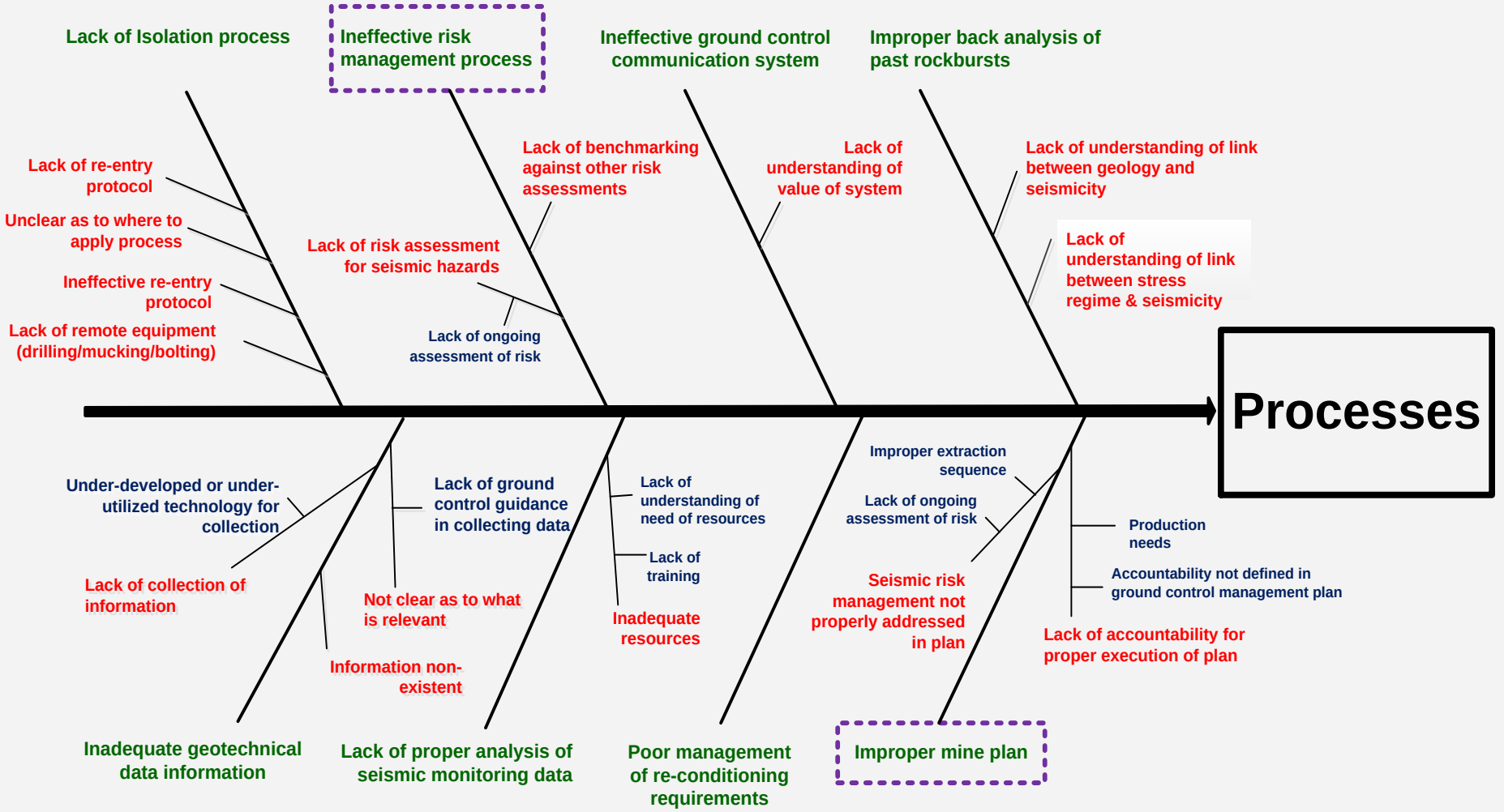
Appendix III: Processes



Top 10 Primary Root-Cause

Primary Root-Cause

Secondary Root-Cause

Tertiary Root-Cause

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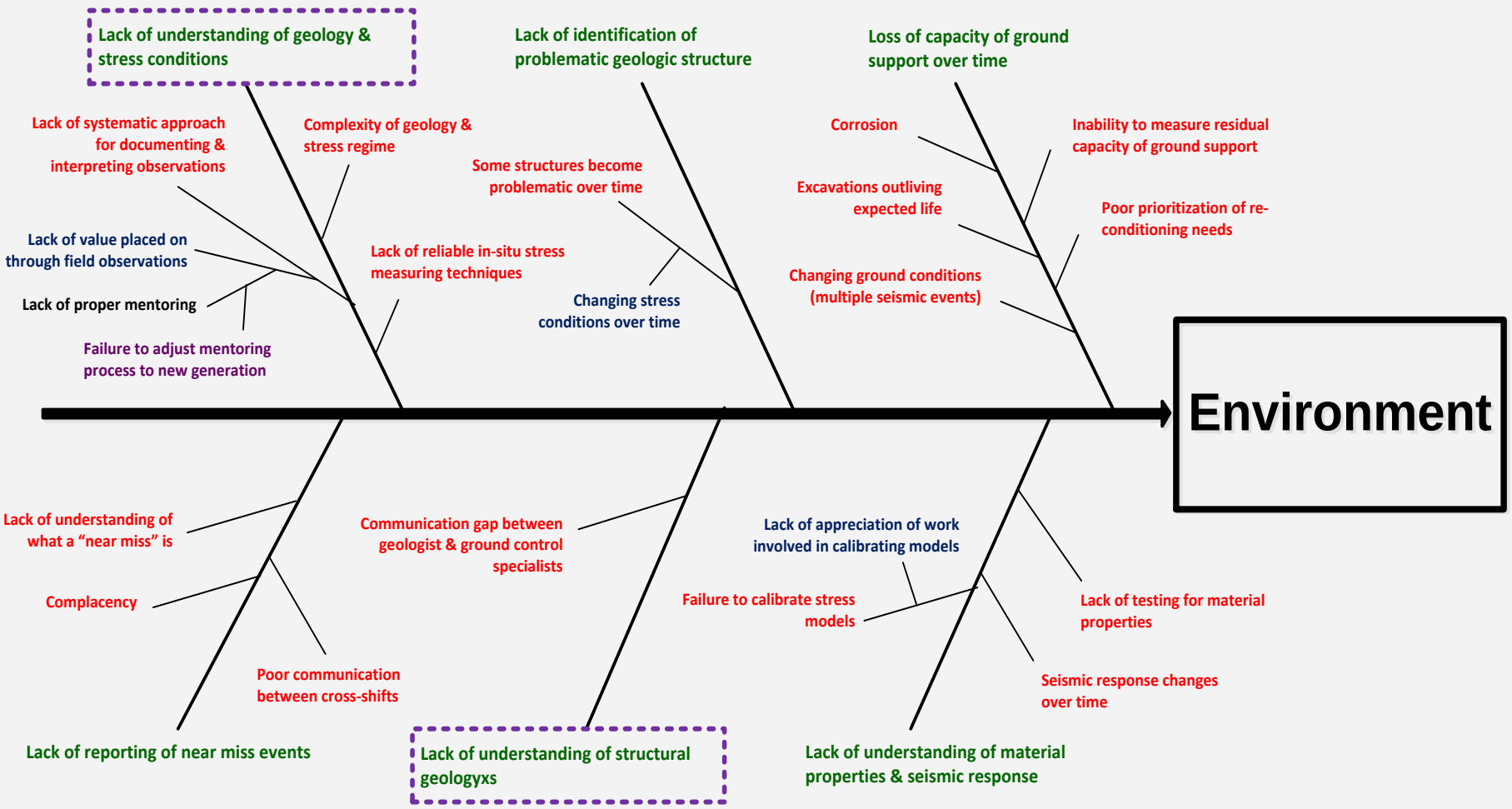
Appendix IV: Environment



Top 10 Primary Root-Cause

Primary Root-Cause

Secondary Root-Cause

Tertiary Root-Cause

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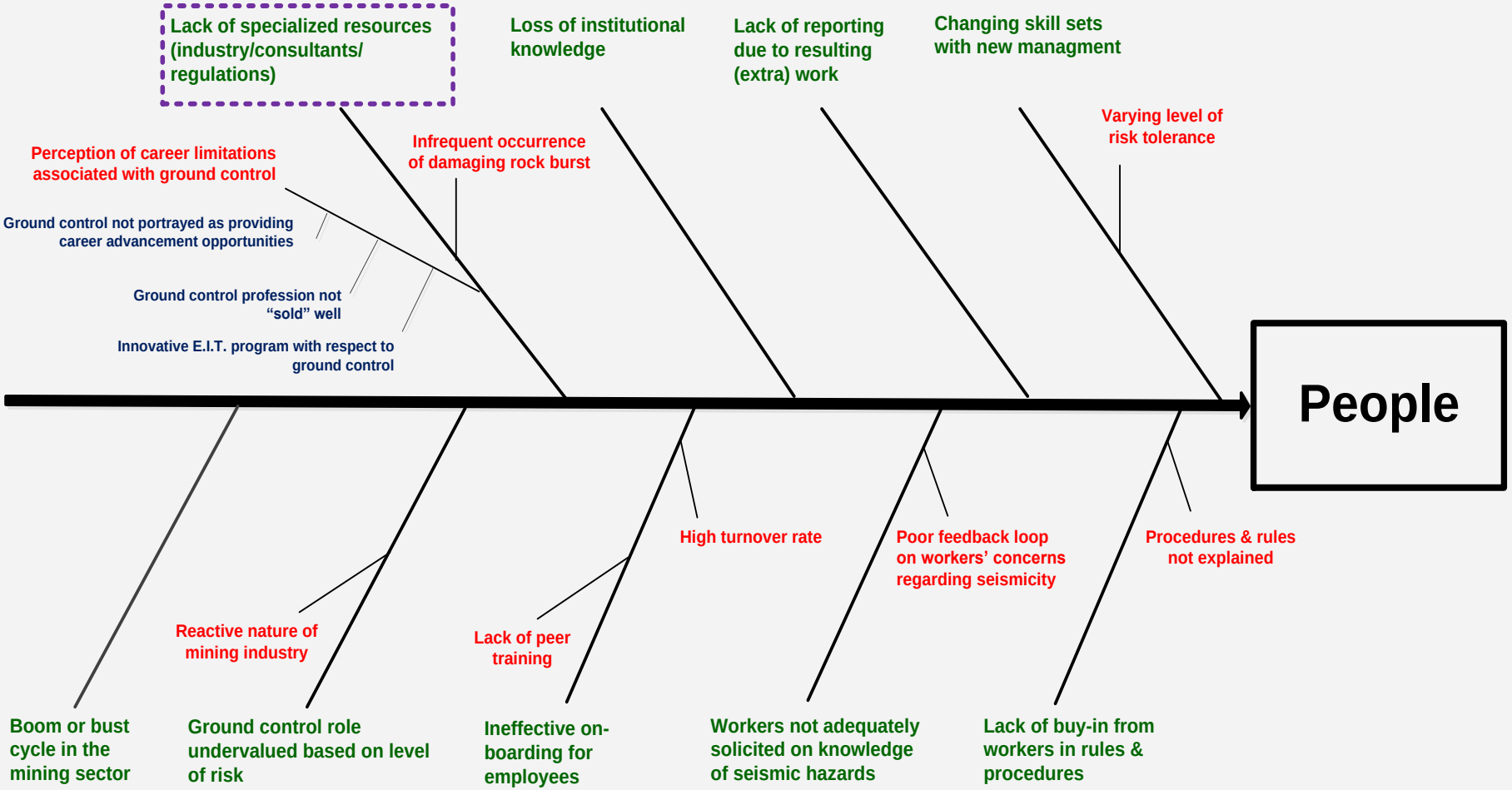
Appendix V: People



Top 10 Primary Root-Cause
Primary Root-Cause
Secondary Root-Cause
Tertiary Root-Cause

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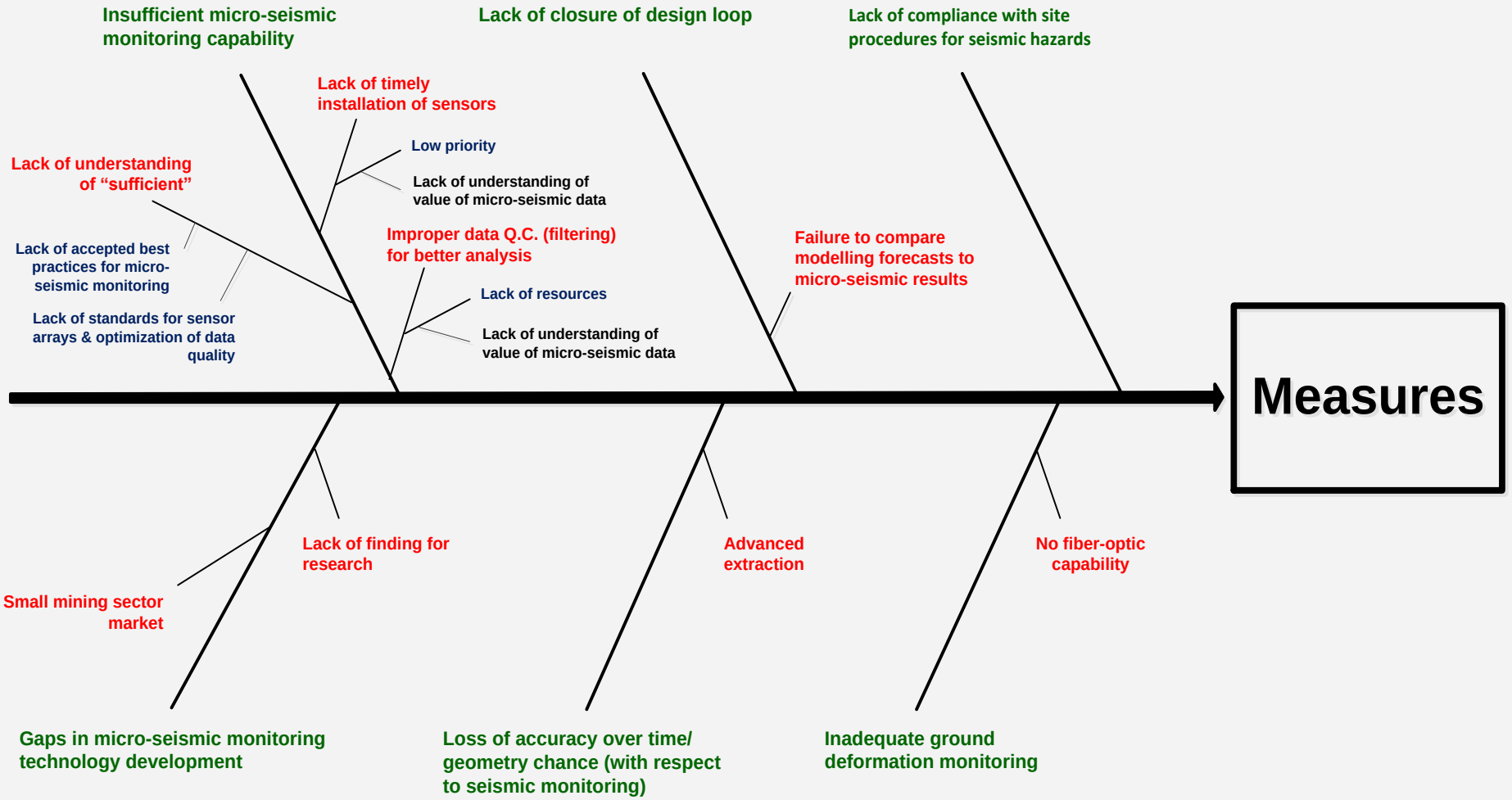
Appendix VI: Measures



Top 10 Primary Root-Cause

Primary Root-Cause

Secondary Root-Cause

Tertiary Root-Cause

Quaternary Root-Cause

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Appendix A: Risk Assessment Methods/Standards*

1. Bayesian Analysis
2. Bow tie analysis
3. Brainstorming (e.g. what-if)
4. Business impact analysis
5. Cause and effect analysis
6. Checklists
7. Computer Hazard and Operability Studies (CHAZOP)
8. Consequence Analysis (also called Cause-Consequence Analysis)
9. Likelihood/Consequence matrix
10. Construction Hazard Assessment and Implication Review (CHAIR)
11. Decision tree
12. Delphi technique
13. Energy Barrier Analysis (or Energy Trace Barrier Analysis)
14. Environmental risk assessment
15. Event tree analysis
16. Failure Mode and Effect Analysis (FMEA)
17. Failure mode, effect and criticality analysis
18. Fault Tree Analysis
19. Fishbone (Ishikawa) Analysis
20. Hazard analysis and critical control points
21. Hazard and Operability studies (HAZOP)
22. Human reliability analysis
23. Job Safety Analysis (JSA)
24. Level of Protection Analysis (LOPA)
25. Markov analysis
26. Monte Carlo
27. Preliminary Hazard Analysis (PHA)
28. Reliability centered maintenance
29. Scenario analysis
30. Sneak circuit analysis
31. Structured/semi-structured interviews
32. SWIFT (i.e. structured what-if)
33. Systemic Cause Analysis Technique (SCAT)
34. Human Error Analysis (HEA)
35. Workplace Risk Assessment and Control (WRAC)

Risk Management Standards:

1. Risk Management Principles and Guidelines (ISO 31000:2009)
2. Risk Assessment Techniques (ISO/IEC 31010:2009)
3. OH&S Hazard Identification and Elimination and Risk Assessment and Control (CSA Z1002)
4. Process Safety Management (CSA Z767-17)
5. Enterprise Risk Management (COSO 2004)
6. Global Minerals Industry Risk Management (GMIRM)
7. International Council on Mining & Metals (ICMM)

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*** Not an exhaustive list**

Appendix B: Ministry of Labour Contacts

- For additional information or questions, please contact:

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