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EA1415-01-Phase 2 Risk Assessment Technical Report Prairie Creek All Season Road

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Executive summary

The Scope of Work (SoW) for this study, dated January 27th 2016 stated that the Risk Assessment must be based on the evidence on the Review Board's public record for the project and should consider adverse impacts to the environment, people and infrastructure.

It was requested that the Risk Assessment would consider the proposed road as a whole and focus on a series of questions answered one by one at the end of this summary. The replies to the questions of the SoW should be read together with the Report Validity Conditions and Assumptions (Section 11) and the corresponding Appendix 3 (Assumptions).

Extant documents defined environmentally sensitive areas as follows (See Section 6):

- Sundog Creek between km 17-40 and km 25-32;
- Karst Terrain (approximately km 53-64), and
- sensitive drainages at Tetcela (— km 84) and Fishtrap (—km 95).

Based on extant document the traffic structure was modelled as three typical streams (See Fig. 11):

- loaded outbound concentrate trucks,
- inbound empties (with their own fuel and service fluids (hydraulic oil, etc.),
- and inbound environmental sensitive cargo.

Development of the Risk Assessment

The study started by looking at potential consequences of accidents (off-road excursions only, see definition in Section 2). It was assumed that increasingly higher consequences would occur as a result of:

- accidents featuring higher energy,
- larger spread of contaminants,
- increasing difficulties in recovery of pollutants or

any combination thereof, i.e. developing a multidimensional consequence function.

This lead to formulating 9 classes or multidimensional consequences named Consequence Classes (Section 6.5, Table 14). Consequence Class 1 would be characterized by no environmentally sensitive target in potential reach, low energy, easy to contain/retrieve spills, whereas Consequence Class 9 would be characterized by environmental sensitive

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area in immediate reach, highest energy, and extremely difficult to contain/retrieve spills.

Thus the study considered from that point on the 9 classes as follows:

Class 1-2	minor
Class 3	moderate
Class 4-5	significant
Class 6	serious (S)
Class 7-9	very serious (VS).

Extant reports had defined ten Stratification types and a number of Special Sections for specific segments considered by Allnorth to be representative of the rest of the road. Drawing for these covered approx. 20% of the total length (Section 3).

We proceeded (Section 6.5, Table 15, 16) by pairing each of the above with the related Consequences Classes (some Stratifications having more than one Consequence Class) and then applied ORE (Optimum Risk Estimates, ©Riskope, Sections 5, 7, 8) to the set, in order to determine risks (Section 9).

To increase transparency and understanding we decided to transform probabilities of mishaps in expected number of accidents (per year, per service life).

ORE deployment results

1) **ORE pinpointed the Stratifications of high consequences (S-VS accidents)** (Figure 26) as being 1,2,3,4,5,7,8 and Special Sections. The number of high Consequences Classes accidents will be relatively small, but in Stratifications 5 and the Special Sections. **NB:** small does not mean necessarily acceptable, as it will be discussed later.

Stratifications 1,2,3,4 and good number of Special Sections are located in the first 40 km of the road. Stratification 2 (km 6.5-13) corresponds to Funeral Creek and Stratification 3, 4 from km 23.8-39.4km correspond to the Sundog sector.
Six out of the seven Special Sections are located within the first 40kms, the seventh being located at, according to Table 7: Road Summary, km 122.6-122.9, or, following PRAIRIE CREEK MINE GEOMETRIC DESIGN at km 122.7-123.4.
Stratification 5 is located between km 86.3-90.3 in an area where sensitive drainages are present.
Stratification 7 is split in 9 sub-segments from km 39.4-143.1. The length of the sub-segments varies between 0.6km and 21km each. Only 2.5 km of Stratification 7 are drafted with plan view, longitudinal profile, and cross sections.

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Stratification 8 covers a total of 6 km split in three sub-segments as follows:

- Poljie Creek km 50.9-53.9,
- Fishtrap Creek km 94.3-95.3,
- Grainger River km 124.3-126.3km

Due to the small percentage of the project documented with plans and to the highly irregular fragmentation of the Stratifications any attempt to deliver further details in the geographic location of risks along the layout would be fraught with more uncertainties than gained precision, hence be misleading.

2) Since the traffic cargo structure was known (percentage of vehicles with full load of concentrate hazmat, environmental significant cargo and "empties" (with their own fuel and service fluids, like for example hydraulic oil) and an accidental tolerance thresholds had been defined (Section 8), **ORE made it possible to compare the accidental tolerance level** as shown in Figure 27.

ORE showed which type of cargo would generate risks that exceeded accidental tolerance expectation for each Consequence Class. The large exceedance of Consequence Class 1 is not worrisome, as those accidents are minor, whereas the exceedance of Class 4 (significant) has to be discussed.

Class 4 corresponds to areas with fair topography and cross section, but nearby sensitive environment. Consequence Class 4 accidents are indeed located in Stratifications 1,2 predominantly, but also in Stratifications 5,6,7,8 and Special Sections, as shown in Figures 28C, 28B.
Stratification 1,2,3,4,5,7,8 and Specials Sections have been discussed above.
Stratification 6 develops between 40.9-80.0km in 4 segments with one sub-segment covering 20.9km. Only one kilometre layout has been delivered to date, between km 44-45km with the consequences discussed above (hence same note as above re: location).

3) **ORE detected the "black spots (segments)" of the road, i.e. those where the highest accident number will occur.** This information is useful as those accidents will create delays and could be the cause of interdependent accidents. ORE made it possible to show which homogeneous segments would cause the highest number of accidents (of any Consequence Class) as show in figure 28a.

Obviously these results are also influenced by the length of the Stratification varying between 3.8km and 58.7km. This is intuitively correct, as generally the longest distance driven the higher the chances of an accident.

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This being said, Stratification 7 has a large majority of Class 1 (minor) and only a few Class 4 (significant) accidents. The estimated number of Class 1 accidents per year in Stratification 7 is approximately 12. That means that under all the assumptions and conditions made in this report (Section 2, 11, Appendix 3) one truck per month could end-up with at least one wheel off the road in fair topography.

Replies to the questions of the SoW

- **components within the risk assessment:**
  - **what are the risk elements**

The risk elements for this study are:

- the road from the mine to HW7 (at the exclusion of the ice bridge/barge),
- the traffic and
- the environment in general, with particular focus on environmentally sensitive areas pinpointed by Parks Canada and, of course, watercourses.

The traffic includes the loaded concentrate trucks in their outbound trip, the inbound trip, split in environmentally significant cargo and empties (which carry their own fuel and service fluids such as hydraulic oil), as shown in Figure 11 copied below.

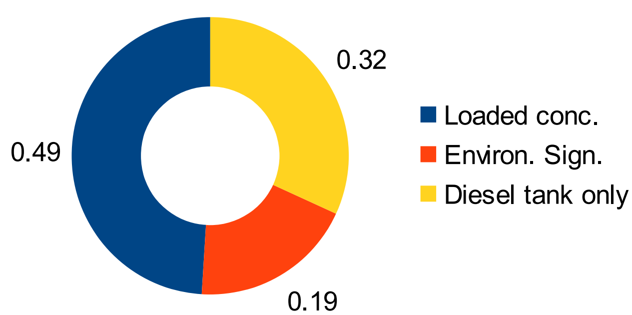

Figure 11 (copy) Traffic share between loaded concentrate truck (outbound) and inbound traffic split between environmental significant loads and truck travelling with their diesel tank only.

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Those elements are exposed directly or indirectly to natural and man-made hazards such as those generated by the road design, the behaviour of drivers, weather conditions, avalanches, avulsions, landslides, etc.

- **what is the probability of an adverse consequence to elements at risk**

The probability of an adverse consequence to elements at risk by various natural or man-made hazards has been converted in a number of accidents (of various types and severity) over the service life of the road. This procedure has two main advantages:

- it allows to state numbers that anyone can understand (example: 3 accidents of type x and severity y are expected over the n years of service of the road INSTEAD of using a "technical" definition like: the probability of accidents of type x and severity y is 10-3/yr).
- It allows to develop a bench marking exercise with other special roads, to ensure the results are "anchored" in reality.

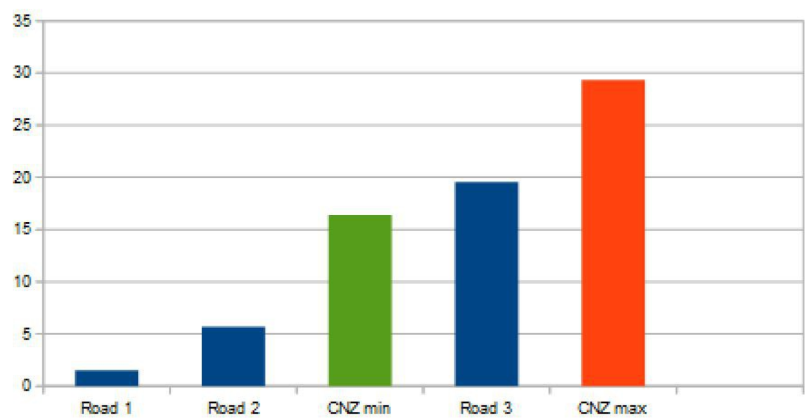

Figure 25 (copy) Bench-marking comparison between the three road examples and Prairie Creek. ORE predicted number of S-VS accidents accidents (See next section for a definition of S-VS accidents).

As it can be seen the minimum, maximum expected number of Serious to Very Serious accidents evaluated for Prairie Creek (respectively green and orange bar) over the service life, compares well with the most similar road example (Road 3, blue bar) we have found in our archives. The definition of Serious to Very Serious accidents is given below.

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- **what are the consequences and severity of each risk**

Based on the paucity of extant data related to highly sensitive potential spill areas this study assumes that higher consequences will occur as a result of accidents featuring at least one of the following characteristics:

a) relative higher energy (careening over higher/ steeper natural or man-made slopes, faster driving, etc.)
b) potential larger spread of contaminants
c) relative increased difficulties in recovery of pollutants.

The consequences are cumulative in the sense that a possible spill at a given location where more than one characteristic is present will lead to higher consequences than another location where only one characteristic is present.
Furthermore, in the absence of detailed and up to date baseline information, extant knowledge base was used to identify four reaches along the all season road reportedly of high biological value and likely highly sensitive to spills:

- The areas of Karst Terrain (approximately km 53-64). Spills in this area could be extremely difficult to contain and clean up due to the extensive underground drainage.
- The Tetcela (— km 84) and Fishtrap (—km 95) drainages. These areas are sensitive due to easy transport of any spill and are also part of a 'Key Migratory Bird Terrestrial Habitat Site'. There is the potential for both Swan breeding and the presence of Yellow Rail, but not surveyed.
- Sundog Creek between km 25 and km 32 has an Arctic Grayling population which is greatly restricted in seasonal movements, as there is a waterfall above, and the creek below flows underground for much of the year. A serious spill in this area could potentially wipe out the entire local population.
- A spill between km17-40 may also have downstream impacts on a resident caribou population.

Concentrate loads, environmental significant loads and empties with diesel tank only were be considered separately, as their consequences are different from an environmental point of view.

Table 14 copied below from the report, shows the Consequences classes adopted for this report.

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Road and Environment features are:		**Comments**
ENVIRONMENTALLY SENSITIVE TARGETS	DOMINANT CROSS SECTION/ TERRAIN (Downhill of road) SLOPE	CARGO OR DIESEL FUEL COULD:
NOT IN POTENTIAL REACH	Fair with fill less than 3m high	be easily contained and recovered **Class 1**
	Moderate with fill less than 2m high	be contained and recovered with some effort **Class 2**
	Significant even if fill height less than 1m	be contained and recovered with greater effort **Class 3**
WITHN REACH Intersect environ-mentally sensitive target Or Contain-ment and recovery require specific salvage equipment	Fair with fill less than 3m high	be contained and recovered **Class 4**
	Moderate with fill less than 2m high	be contained and recovered in difficult conditions **Class 5**
	Significant even if fill height less than 1m	be contained and recovered in very difficult conditions **Class 6**
BRIDGE/WALL PRESENT		
WITHIN IMME DIATE REACH Intersect the environmentally sensitive target. Containment and recovery require specific salvage equipment	Low Bridge/ culvert/wall (less than 2m from bottom)	be contained and recovered **Class 7**
	Moderate high bridge/ culver t/wall (2-3m from bottom)	be contained and recovered in difficult conditions **Class 8**
	Higher bridge/culvert/wall (more than 3m from bottom)	be contained and recovered in very difficult conditions **Class 9**

Table 14 (copy) Consequence classes

This report considers accidents as follows:

Class 1-2	minor
Class 3	moderate
Class 4-5	significant
Class 6	serious (S)
Class 7-9	very serious (VS).

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Driver or "bypassers" could be harmed in all classes of accidents, this not being a specific feature of this road, but a general consideration in accidents involving heavy vehicles. Cargo types will be considered separately.

- ## summary of risk assessment findings:
  - ### where are the highest consequence locations

In the absence of detailed drawing of the entire road, the highest consequences locations have been defined by Stratification type as follows (Table 16 in the report):

Stratification type	Riskope comments	Consequence Class
1	Bridge	4 & 8
2	Bridge, Caribou	4 & 7
3	Bridge, Caribou, Arctic Grayling	2 & 9
4	Bridge, Caribou, Arctic Grayling	1, 2 & 7
5	Creek, Sensitive drainages	1, 4 & 7
6	Karst (53-64)	1 & 4
7	Creeks, Drainages and karst (53-64)	1, 4 & 7
8	Creeks, Drainages and marginally kast	1, 4, 5 & 7
9		1
10	Local high embankments	1 & 2
Special sections	Creeks, slopes etc.	1,4,5,6,7 & 9

Table 16 (copied and simplified)

  - ### where are the riskiest locations and what are the associated consequences

In the absence of detailed drawing of the entire road, the riskiest locations have been defined by Stratification type as shown below.

The highest risk locations are those where Serious to Very Serious accidents could occur. These are a combination of road hazards and natural hazards as shown in the following list and figure 26 from the report (for total traffic):

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Stratification 1-4: bridges, watercourses and caribou & Arctic Grayling population**.**

Special Sections: high embankments, presence of creeks, significant down slopes, caribous and Arctic Grayling population (in the first segments of the road).

Stratification 5: presence of sensitive drainages proximity to creek**.**

Stratification 7-8: water crossings, drainage and karstic environment.

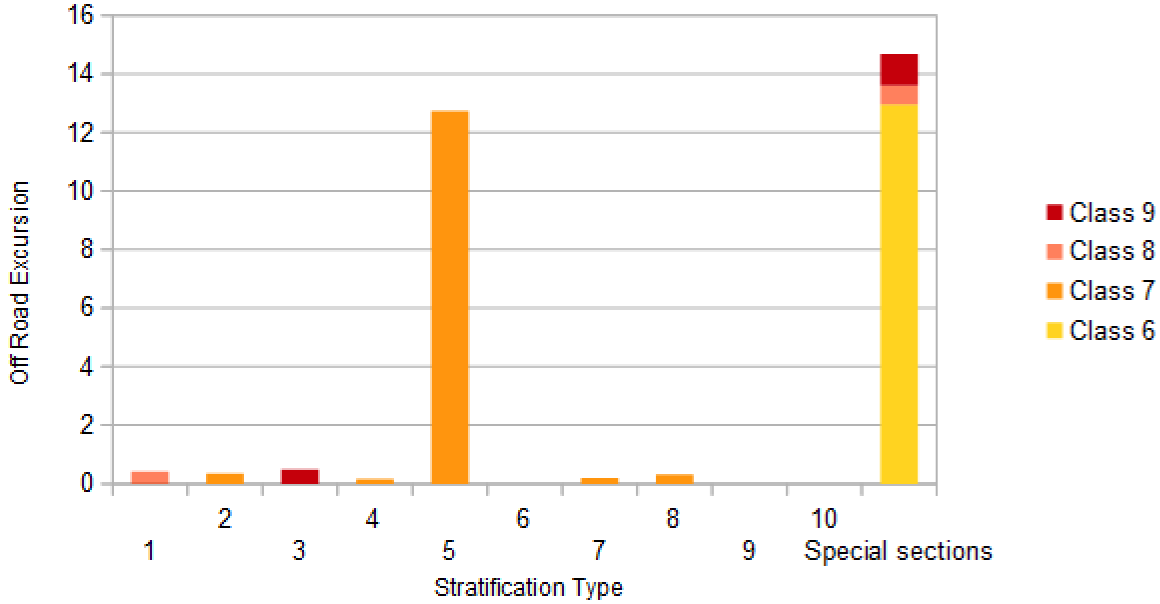

Figure 26 (copied) Off road excursions per Stratification and per Classes 6 or higher.

- **are the risks tolerable and acceptable without mitigations**

During the study an accidental risk tolerance threshold was developed by asking specific questions to CNZ, geared toward understanding their mitigation goal.

It is understood that the definition of the societal tolerance to risk is under the competence of MVEIRB.

In Figure 27 (copied from report) the total number of evaluated off-road excursion accidents (orange bars) is compared to the mitigative goals (blue bars) set by CNZ in their reply to question 8, IR#2. The results are split per type of cargo (loaded concentrate, environmentally significant and empties with their diesel and service fluids).

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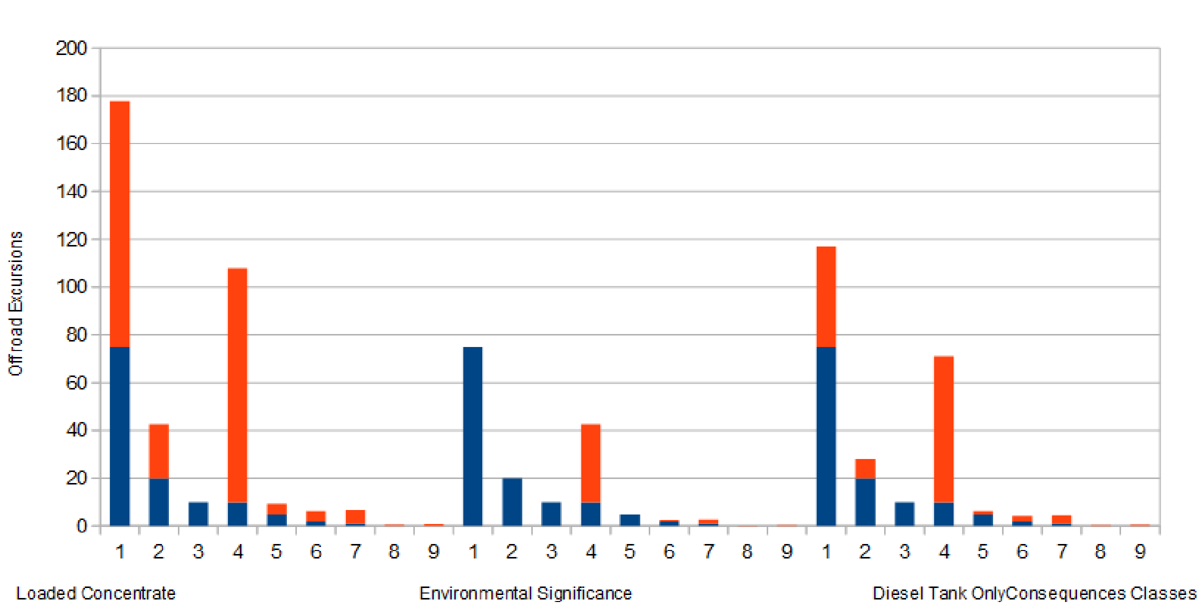

Figure 27 (copied) Off road excursions pert type of cargo (orange bars), compared to the CNZ accidental tolerance (blue bars)

As it can be seen, the risk assessment forecasts a number of:

Class 1-2 **minor**: widely above the CNZ tolerance for loaded and environmentally significant cargo. We note however that the 200 minor accidents (sum of Class 1,2 for loaded concentrate) may not even result in spills, as Class 1,2 topography is very gentle. When looked on a per year basis the number is approximately 12, which is similar to the road 3 (bench marking) result for minor accidents.

Class 3 **moderate**: within CNZ tolerance (due to the fact that the road design carefully avoids Class 3 locations.

Class 4-5 **significant**: here the number of accidents is again widely over the accidental tolerance, because of the presence of sensitive drainages, creeks, crossings, and wildlife.

Class 6-9 **serious to very serious:** Table 26 (in the report, copied below) below summarizes the results which are not visible on the graphic rendering for the classes 6-9:

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Class	Accidental tolerance value	Estimated accident number tolerance exceedance		
		loaded concentrate	environmentally significant cargo	Empties with diesel and service fluids
6	2	4.29	0.49	2.15
7	1	5.68	1.64	3.4
8	0.1	0.42	0.1	0.24
9	0.1	0.65	0.2	0.4

Table 26 (copied) Estimated number of tolerance exceedance with respect to accidental risk tolerance for Consequences classes 6 or higher

Class 6,7 are present when water crossing, karst, sensitive drainages significant cross slopes are present and accordingly the risk estimates for those areas are high, exceeding the somewhat ideal environment considered in the reply to question 8, IR#2.

- **are the risks tolerable and acceptable with mitigations**

The report has examined and considered in the analyses numerous mitigations that have already been proposed by CNZ as defined in Report Validity Conditions and Assumptions (Section 11) and the corresponding Appendix 3 (Assumptions).

The accidental tolerance and comparison to accident forecast have been described in the prior point.

Figures 28A,B,C (copied from report) give a more complete image of where the accidents are predicted to occur (per Stratification), Figure a; which Consequences classes are present in each Stratification, Figure b; and finally the inverse, i.e. which Stratifications are present in each Consequence Class.

Using Figures 28A,B,C it is possible, for example, to see that Stratification 7 & 9, respectively the first and third in terms of overall number of accidents, have a majority of Class 1 (minor) accidents whereas Stratifications 1 & 2, respectively second and fifth in terms of overall number of accidents, have an extreme majority of Class 4 accidents, but also, barely visible Consequence class 7 and 8 present.

Thus these three figures, together with the other diagrams delivered in this study can be used to understand the risk landscape of the project to guide decisions related to future mitigations.

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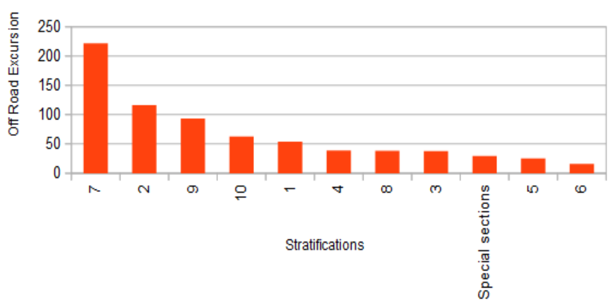
Together the Figures and Tables in this executive summary constitute the ORE (Optimum Risk Estimates, ©Riskope) risk dashboard for this project. The ORE risk dashboard delivers an immediate understanding of the holistic (multi-hazard), scalable, drillable landscape of the project, including accidental risk tolerance, which should be completed, for the ease of use, by a map of the Stratification location by CNZ based on their Table 7: Road Summary from Responses to Information Requests Response to Mackenzie Valley Review Board Response to DAR Addendum of Developer's Assessment Report May 10, 2016.



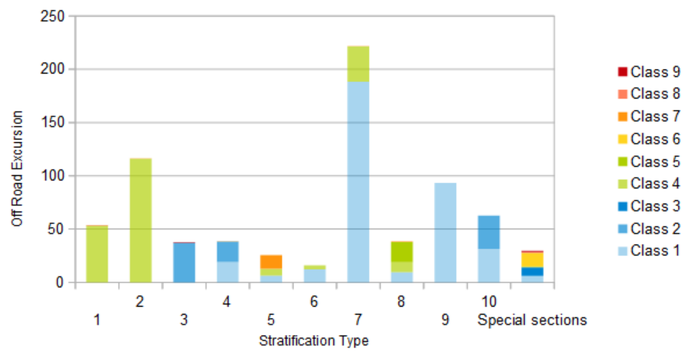


Fig. 28A Off road excursions per Stratification Fig. 28B Consequences classes present per Stratification

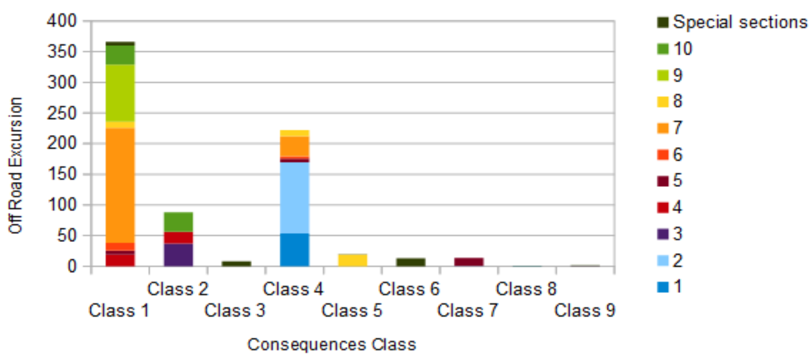


Fig. 28C Stratifications present in each Consequence Class.

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- **what are the residual risks if mitigations are implemented and are the proposed mitigations appropriate and sufficient**

From the two prior points it becomes apparent that mitigations, as proposed to date, are not sufficient to bring the risks within the tolerance levels described by CNZ. The main deviations are mostly due to the environmentally sensitive context of the project. The narrow roadbase, which does not consider any margin for vehicles' slippage, remains a significant point of concern. This, especially as there are doubts related to the feasibility of protective works, such as berms, in many environmentally sensitive locations.

Mitigations of man-made slopes (cuts in the uphill side of the road) has been mentioned in various extant records, but no final plan proposed. In our experience (and also in the experience of any highway department in mountainous/rocky areas (BC, NY, WA, OR, Switzerland just to quote a few; Canadian and US railroads) man-made slopes can generate frequent and damaging slides and rockfalls which at this point have not been evaluated for lack of information.

Thus it can be considered that the presently estimated risks could be reduced in various environmentally sensitive areas with beneficial effects to the overall project. Pending an analysis of man-made slopes, it is foreseeable that residual risks could be brought to accidental tolerance level if detailed analyses of mitigations is carried out and mitigations are then implemented and monitored.

- **how do the risks differ between a winter road versus an all-season road**

Starting with the point of view that the number of concentrate loads to carry out of site is invariant, a winter only road would necessitate a very significant increase of traffic which would then be exposed to avalanches.

Pressure to increase the duration of “winter season” would be great and drivers stress, fatigue would increase. If climate change shortens winters the problems will multiply.

If traffic density increases due to shorter hauling season, accidents that have not been considered in this report will emerge as significant, especially because of the narrow roadbase.

Overall it is our opinion that based on the above, risks would increase in the winter only scenario.

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- **what are the tradeoffs between the proposed alignments from a risk perspective**

The risk assessment has considered the alternative layout as a possible mitigation and come to the conclusion that its implementation would not significantly alter the conclusions, as traffic accidents would be similar, and the avoided natural hazard, using the parameters defined by the extant studies, have a modest influence on the overall results.

- **what are the possible systemic mechanisms that could lead to a failure**

Narrow roadbase could prove too hazardous as it does not leave any margin for error, prevents the installation of safety barriers.

Human factors on drivers, rescue teams and including JSM level may lead to improper reactions if emergency plans have not been developed for all types of accidents.

Normalization of deviance (especially for recurring events, but also for climate change related events) which leads to the classic accumulation of small occurrences that, together, generate catastrophic events. **NB:** Normalization of deviance if defined as the gradual process through which unacceptable practice or standards become acceptable. As the deviant behavior is repeated without catastrophic results, it becomes the social norm for the organization.

Use of codes. More and more industries are becoming aware that the "business like usual", relying on blind compliance, or legalistic approach, to audaciously interpreted codes is not the way of the future. That applies both to the industrialist and the public.

"Generalization" of Stratifications may have lead to miss significant details related to potential consequences.

Rosy scenarios in general, but also, more specifically related to natural geo-hazards and neglecting man-made rockfalls and slides.

- **what are the priority risks to consider / manage overall**

The priority risks to consider/manage are those deriving from the systemic mechanisms described in the prior point.

- The audacious interpretation of codes developed for other traffic (forestry vs. Concentrate cargo) has lead to select a unforgiving roadbase width which

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generates risks that should be considered and managed as a priority, at least in environmentally sensitive areas.

- The generalization of Stratifications may be the cause for over- or under-estimates of risks, as Consequence Classes have been allotted by extending the areas covered by drawings to the entire corresponding Stratification.
- Human factors and normalization of deviance lurk on any long term project (and 16 years service life can be considered long term in this respect) and, again, codes and JMS have proven to be insufficient to ensure optimal risk mitigation.
- Finally, rosy scenario and omission to consider the risks linked to landslides/rockfalls from natural and man-made slopes will generate risks that should be considered and managed with care.

- **what are the major uncertainties in the risk assessment and how were they accounted for.**

There are numerous uncertainties in the study, caused by very different sources.

Climate change is certainly a major one which could alter the number of “slippery road” days, avalanche patterns and drainage, flooding, etc. Given the statements related to JMS, and preventative road closure approach, climate change could, in the negative effect side, cause more closures. The obvious reaction would be to increase traffic to “make-up the missed days” as soon as the conditions allow. There would then be an increase of rotations, but not an increase of the total number of loads. During that period the “one way haul” concept may not work, and colliding trucks accidents, not considered in the study, could occur, on top of low speed off-the-road excursions, if pullouts are not exclusively used. It is hard to see that such conditions would alter in a significant way the results of the study, but should conditions significantly deviate, a reassessment should be performed.

Climate change could also alter the number, volume and frequency of landslides/rockfalls along the road, and thawing of permafrost, where pertinent. Should the conditions change, the hazard study should be updated, new forecast frequencies developed, and then the risk assessment updated. It is expected that landslide/rockfall risks would increase if a negative scenario develops for climate change. If the climate change would develop toward a positive side (less rain, longer dry spells), then visibility reducing dust could become a problem (effects of dust on wildlife are environmental impact issues).

Human factors (fatigue, substance abuse, bravado, etc.) have plagued similar projects and despite the efforts that the proponent intends to apply, the “top shape” of drivers and other personnel is loaded with uncertainties. As the study has been bench marked

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with a road where personnel undergoes similar checks to the ones considered by the proponent, we are relatively confident that these elements have been reflected in the risk results.

General traffic, which remains a major uncertainty pending on the project, has been excluded from the analyses. Should it be included, then the assessment should be updated as it is likely that accidents would significantly increase and include private traffic victims.

The type of trucks, their weight, and the exact cargo containment are not yet (as we understand) definitely been selected. We stress the importance of cargo securing including under severe winter conditions (low temperature brittleness). CNZ spill estimates based on logical intuition constitute a low bound, when considering the type of accidents that could occur on the road. Bulk transportation would generate significant increase of adverse consequences.

- **what are the assumptions for the risk assessment and what are the implications of the assumptions being incorrect.**

As mentioned above, the bench marking exercise “anchors” the overall traffic accident risk study to reality in quite a comforting way.

The study has shown that natural hazards (man/made slopes generated hazards could not be included for lack of information) within the parameters of the SoW (which has an impact on the way avalanches were evaluated) contribute very little to the overall risks. The risk estimates for traffic accidents and natural hazards were developed under a complex set of conditions and assumptions that have to be considered (Report Validity Conditions and Assumptions (Section 11) and the corresponding Appendix 3, Assumptions.

Should any of the conditions and assumptions not be complied with, then the probabilities of occurrence would increase, hence the risks would increase. The same would occur if the “Generalization” of Stratifications may have lead to miss significant details related to potential consequences.

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1. Introduction

Canadian Zinc Corporation (CZN) applied to build an “all season” access road connecting the Prairie Creek Mine to Highway 7 in the NWT. As part of the environmental assessment (EA) process, Allnorth completed for CNZ an evaluation and submitted a report titled “Proposed Prairie Creek Mine Access Road” on February 27, 2015. Following comments from the Mackenzie Valley Environmental Impact Review Board (MVEIRB) on April 23, 2015, Allnorth submitted a supplementary report in September, 2015.

Following this was a round of information requests (IR’s) from all parties, and replies by CZN and their consultants.

MVEIRB contracted Oboni Riskope Associates Inc. (Riskope) on Feb 10th 2016 for the preparation of a Risk Assessment of the project, based on a Scope of Work (SoW) dated January 27th 2016, which does not include the barge/ice bridge operations. Following the prescribed procedures, a Technical Session was completed in Yellowknife, Northwest Territories from June 13 to 16, 2016 involving various government agencies and aboriginal groups supported by their designated consultants and Canadian Zinc supported by their consultants. The session produced a number of “undertakings” for CZN. Subsequent to the undertaking replies, a second round of IR’s occurred.

Allnorth’s responses to information requests were delivered on October 7th and 11th making it possible for Riskope to prepare this Risk Assessment Technical Report, starting on October 20th 2016. In compliance to ISO31000 and Schedule A of EA1415-01 of Riskope Service Agreement, this study follows a stepped approach, slightly adapted to account for this specific project. Risk estimates are developed by deploying Oboni Riskope's ORE (Optimum Risk Estimates, ©Riskope) application, which results in the delivery of a risk dashboard.

ORE deployment and this report are based on information delivered to Oboni Riskope Associates Inc. (Riskope) via the public record and other literature sources, including archival data and past experience (including third parties interviews) on mining access roads and trailers accident analyses. It is Riskope's understanding that delivered data carry inevitable uncertainties due to the varying environmental conditions and geological, geotechnical and hydro-geological intricacies as well as human behaviour. For example: the trip includes the Liard River Crossing (by barge in summer, by ice bridge in winter) and summer/winter duration will obviously be dictated by meteorological conditions and assumptions that have been made by CNZ related to their respective duration. Should climate change severely alter prevailing conditions the risks will have to be reconsidered and updated.

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Riskope's mandate did not include any verification of the delivered data which were taken as based on good engineering concepts and analyses, but discussed when deemed necessary.

The project description and conditions are continuously evolving on various fronts (as the project remains not completed until the design phase) and as such this report may contain, at the time it is delivered, information that is not (any more) up to date or will not be, if compared to the final project version. Thus it will be necessary to check the statements, data and conditions after delivery vs. the latest version of the project. Beyond that, this report expresses technical opinions based on probabilistic concepts and analyses. None of the values contained in this report should be construed as a absolute or general value and users are formally reminded of the uncertainties inevitably remaining in the report.

In this report, texts in *italics font* correspond to statements from the public record.

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2. Report-specific glossary and general limitations

A general risk glossary is delivered in Appendix 1.

2.1 Accidents and Hazards

2.1.1 Hazards

A hazard is a natural or man-made event capable of generating an accident (an event with adverse impacts to the environment, people and infrastructure, see below) within the system while the system is in compliance with all conditions and assumptions described in Section 10, Report Validity Conditions and Assumptions.

The following are two examples of conditions that do not comply with those described in Section 10:

a) should drivers undergo excessive stress and fatigue, compliance with assumptions and conditions would not be ensured. That type of accident is not studied in this report;
b) should trucks not be maintained and checked properly, compliance would not be ensured. Those accidents are not studied.

A list of the hazards considered in this report, together with their appropriate sections' number, is the following:

- Natural vs traffic hazards (4.1)
- Road and meteorological hazards (4.2)
  - Road features hazards (4.2.1)
  - Weather and snow considerations (4.2.2)
- Avalanche hazard (4.3)
- Creek Avulsion hazard (4.4)
  - Sundog Creek realignment (4.4.1)
  - Other avulsion hazards (4.4.2)
- Landslide Hazards (4.5)
- Man-made cuts related hazards (4.6)
- Seismic hazard (4.7)

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2.1.2 Accidents

An accident occurs when a hazard is present either on the road when the traffic arrives (poor visibility) or when hazards impact people, infrastructure, traffic present/in transit on the road. Given the narrow road, its cross sections types and the uncertainties related to the hazards sources, location, magnitude and resting position, this study considers equally likely an accident in both traffic direction (does not make a distinction based on travel lane).

This report considers three types of traffic accidents.

The first accident type is:

a) a classic loss of control accident due to a set of road characteristics (under the assumption driver and vehicle are in top conditions, road is well maintained).

The second and third accidents types are linked to the potential presence of a hazard above, on or downhill of the road. They correspond respectively to a vehicle:

b) being hit by a hazard as it transits in front of the source, or
c) hitting the hazard already lying on the road (if poor visibility). This type of hazard also applies to the case of damaged bridges, river eroded road fills, etc.

A fourth type of accident which would be:

d) a “traffic” accident between two or more vehicles. This type of accident is not considered in this study for the following reasons: i) trucks leave in convoy or at discrete intervals in the morning, turn around at the end of the road. Thus most heavy vehicles crossings will take place in a relatively easy section of the road. ii) drivers will be in radio contact. iii) pull-outs are rather frequent. Additionally, road intersections (including borrow-pits and other facilities) will be limited, reportedly well marked and speed controlled.

2.2 Probabilities and Consequences

2.2.1 Probability of an accident

The analyses differ substantially for each accident type. As probabilities and frequencies may be difficult to discuss for general public, this report, in an effort to use plain language, converts them into a number of expected accidents of various categories during the service life of the road infrastructure. This enables, the comparison with other existing roads.

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2.2.2 Consequences

Consequences depend on the load (concentrate, environmental significant cargo, diesel and hydraulic fluids of empty trucks) and exclusively, given the paucity of data, on:

- geometric parameters of the potential off-road excursion of the vehicle,
- presence of water bodies and
- sensitive environment.

Off-road excursion means at minimum that a vehicle will quit its normal trajectory with at least one wheel (possibly in the ditch), at maximum that the vehicle will land off-road after sliding, either straight or on its side, or after one or more roll-over.

Accidents involving a loaded concentrate truck, an environmental significant load, or an empty with its diesel fuel (and other fluids like hydraulic and lubricant/hydraulic fluids) will be considered separately from a consequence point of view. Accidents involving empties belong to a significantly lesser consequence provided special measures are taken to prevent spills (anti-puncture tank/anti-spill lids).

In this risk assessment, business consequences (i.e. impacting CNZ only like business interruption, etc.) will not be considered as the scope of work asks us to consider environmental, (public) H&S damages. However, and just for the sake of completeness, scenarios that possibly lead to those damages include (in a very brief preliminary summary): traffic accidents (collisions, loss of control), road defects (collapse, flooding, deformations), and uphill issues (rockfalls, landslides, debris flows, etc.).

2.3 Risk and Risk Tolerance

2.3.1 Risk

In order to define risks, what constitutes a failure has to be explicitly defined. The failure criteria for this access road risk assessment is multifaceted. Any of the following, or a combination, defines a failure in this report:

- an event forbidding a truck, its cargo, or their drivers to reach their destination.
- an event with high potential impact on drivers, vehicles and their cargo, i.e. those with off-road excursions.
- events with various levels of impact on the environment.

Risk is the probability of occurrence of a failure (undesired event, for example a concentrate truck accident) TOGETHER with its potential damages to people (H&S), the

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environment, the business, etc. The undesired event constitutes the hazard situation (example: a truck accident at km xx of the road due to a rock sitting on the road). The combination of the various damages is the consequence of the event.

In this risk assessment, business risks (i.e. impacting CNZ only like business interruption, etc.) will not be considered as the scope of work asks us to consider environmental, (public) H&S damages. However, and just for the sake of completeness, scenarios that possibly lead to those damages include, for example: traffic accidents (collisions, loss of control), road defects (collapse, flooding, deformations), uphill issues (rockfalls, landslides, debris flows, etc.).

2.3.2 Risk tolerance

Risk tolerance is a threshold unique to a project, corporation, an environment, a culture which has to be defined by consultation with all stakeholders. Societal tolerance is the result of MVEIRB deliberations. In this report, in consultation with CNZ through IRs, we define the project's accidental risk tolerance.

2.3.3 Risk Assessment

This risk assessment looks at prioritizing a portfolio of risks (along the road) and the scope of work also asks Riskope to define which accidental risks are intolerable. Our mandate does not include the definition of societal tolerance and acceptability which remain in the hands of MVEIRB.

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3. Project/System Description

During the initial phases of this study there have been discussions bearing on the exact qualification of the proposed road, as the project name (and the title of Allnorth reports) is "access road", but some of the parameters (for example the allowed speeds) correspond to an "haul road".

In their replies to IR#2[1] CNZ clarified that *as defined by the Northern Land Use Guidelines – Access: Roads and Trails under Section 2.1, Table 2.1 the Prairie Creek Access road would be considered an "All Season - Haul Road" as it is designated to carry heavy trucks and support the project beyond initial access. Seasonal limitations due to meteorological and geotechnical considerations are a function of Barge or Ice Bridge availability, Highway 77 seasonal load restrictions, and operational efficiencies, elements that will be discussed later in this report. There will be a winter haul (Ice Bridge) and an 'open water season' haul. The latter would be supported by a barge on the Liard River. The open water season in the north covers parts or all of the spring, summer and fall seasons (the summer season is short). Hence, it is appropriate to consider the road to be an 'all season' road.* Furthermore *based on review of the TAC Document "Primer-Synthesis of Practices of Geometric Design for Special Roads", the Prairie Creek Access road complies*[2] *with the definition of a "Special Road" as a low volume resource access road with an Average Daily Traffic volume of 400 vehicles or less and design speed between 30 to 110 km/h.*

Based on the public records SoW, this report covers the all season Prairie Creek CNZ access road as follows:

a) summer road to be studied:

- locations identified as moderate, high, and very high risk from a geohazards and terrain stability perspective
- the Sundog creek realignment,
- locations with sensitive habitat that would likely result in a high consequence events (this should include areas with karst topography),
- (locations) where the road design increase the likelihood of an accident,
- locations where channel avulsion risks are considered to be likely to effect the road and/or road crossing structures.

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1 Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 1b.

2 Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 1c.

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b) sectors of the winter road that differ from already approved layout.

Reportedly CNZ is actively looking at making the road "private" while recognizing that future road use may evolve.

"*The idea of -- of the road is -- is opening up an area, and also recreational opportunities that could affect people in the region locally, tourism. And you've probably heard it said recently where they've -- the chief here has brought up the fact that we're -- we're planning to -- to take a good -- a good look at setting up the -- a youth -- a youth camp as a start, and maybe even a wellness centre.*"[3]

This report deals with this very significant uncertainty (the opening to free private/ passenger traffic would completely alter the risk study methodology and conclusions) by setting a number of rules and conditions.

3.1 Road design/geometry

3.1.1 Road classification, width, general parameters

As defined by the Northern Land Use Guidelines – Access: Roads and Trails under Section 2.1, Table 2.1 the Prairie Creek Access road would be considered an "All Season - Haul Road". The engineering of the road will be completed so that the road sub-grade, base course and surface course protect or exclude the land surface from traffic damage[4]. After reviewing extant documents the access road would be classified as Type Y[5] [6] following military (US, public) literature[7] or a special road in Canada[8]. The US document

3 http://reviewboard.ca/upload/project_document/EA1415-01_Technical_session_transcripts__14-Jun-2016.PDF page 275

4 Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 1a.

5 **Type Y**--A all-weather route that, with reasonable maintenance, is passable throughout the year but at times having a volume of traffic considerably less than maximum capacity. This type of route is normally formed of roads that do not have waterproof surfaces and are considerably affected by rain, frost, thaw, or heat. This type of route is closed for short periods (up to one day at a time) by adverse weather conditions during which heavy use of the road would probably lead to complete collapse. This risk assessment will consider these operating conditions.

6 To the exception that, following Allnorth statement above, complete collapse seems to be excluded, a point that will be discussed later on in this report.

7 https://sin.thecthulhu.com/library/military/training/US/FM_5-170_Engineer_Reconaissance.pdf Chapter 5

8 http://tac-atc.ca/sites/tac-atc.ca/files/site/doc/resources/primer-gd-special-roads2013.pdf states: "Special roads" is a category for roads that tends not to fit into the standard definition for either urban or rural roadways. In design guidelines and research publications, special roads are often referred to as "low-volume

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defines what military consider route obstructions, i.e. road features which restrict the type, amount, or speed of traffic flow. Obstructions detected in the considered project include:

- Reductions in traveled-way widths that are below the standard minimums prescribed for the type of traffic flow (see Table 1). This includes reductions to "*access roads industry standards" at 4.3m*[9] caused by bridges.

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Vehicles	Limited Access	SingleLane	SingleFlow	DoubleFlow
Wheeled	At least 3.5 m	3.5 to 5.5 m	5.5 to 7.3 m	Over 7.3 m
Tracked and combination vehicles[10]	At least 4.0 m	4.0 to 6.0 m	6.0 to 8.0 m	Over 8 m

Table 1 Traffic-flow capacity based on route width

CNZ apparently recognized the data of Table 1 and includes (at least in the zones for which plans have been made available to date) a high density of passing lanes (pull/outs) and possible turn-around at locations still to be determined to mitigate the obstruction. In particular the proponent stated[11]
they are proposing *at least 1 pullout per kilometre. Pullouts are a cost effective means to ensure efficient and safe transportation of goods on a single lane road. This approach greatly reduces the overall project cost compared to a 2 lane structure while reducing the environmental footprint of the road. This approach would be consistent with comparable resource roads operated in B.C. and other jurisdictions. The application of pullouts could be considered as mitigation to an obstruction such as two vehicles passing in opposite directions, or a vehicle*

roads" (LVR), although volumes are only one criterion for designating a roadway as a special road. Other important criteria related to special roads include function, seasonality, traffic composition and roadway structure. Examples of special roads (besides LVR) include recreational roads (scenic and seasonal, including park, campground, winter lodge, cottage and beach access), resource access roads (including mining, petroleum and logging access) and winter roads (made of ice and snow), amongst others."

9 Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 2b.

10 Combination vehicles include multiple trailers and tractor trucks

11 Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 2a.

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passing another in the event of a slow moving maintenance vehicle. Note that haul operations is the main traffic, and will be essentially one-directional most of the day, and radio-controlled at all times to facilitate passing, when needed. Allnorth added[12] that a *5 m wide running surface is the primary and preferred design specification for the road. A 4 m wide running surface will only be utilized in locations which have terrain limitations, such as excessive rock excavation (blasting) and a few short sections which maybe tight or parallel to a stream channel.* We note that 5m or 4m wide running surface with no shoulders correspond to a narrower effective road, in particular with respect to the selected slopes of the fills. The available drawings[13] display a road width of 5m/4m with no shoulders, Various Typical Cross Sections Associated with Conventional Construction Techniques (Updated), Typical Overland Construction Cross Section (updated) and Non-Typical Overland Construction Cross Section along Lower Sundog Creek (updated) (Figure 1). Allnorth declared[14] that a number of approaches will be applied to mitigate the effects of a 4 m wide running surface:

- ◦ *Opportunity exists in the detailed design stage to reduce the length of the 4 m sections, as proposed in the preliminary designs.*
- ◦ *Any horizontal curves located in 4 m sections will be designed with the required widening as specified in the Engineering Manual, which will override and increase the 4 m wide prescription.*
- ◦ *Speed restrictions will be placed and enforced on all narrower sections, tight corners, or line of sight limitations.*
- ◦ *Appropriate signage will be placed either side.*
- ◦ *Pullouts will be placed in close proximity at either end.*
- ◦ *All mine traffic will follow strict use of radios, specifically important at critical sections such as speed reduced, narrow sections, and bridges.*

- Slopes (gradients) of 7 percent or greater (Most vehicles negotiating slopes of 7 percent or greater for a significant distance will be slowed).
- Curves with a radius of 25 meters and less. Curves with a radius of 25.1 to 45 meters are not considered to be an obstruction.
- Ferries.

12 Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 2b.
13 EA1415-01_Allnorth_Responses_to_Information_Requests.pdf file in Appendix A, Fig. 4,6, 7

14 Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 2b.

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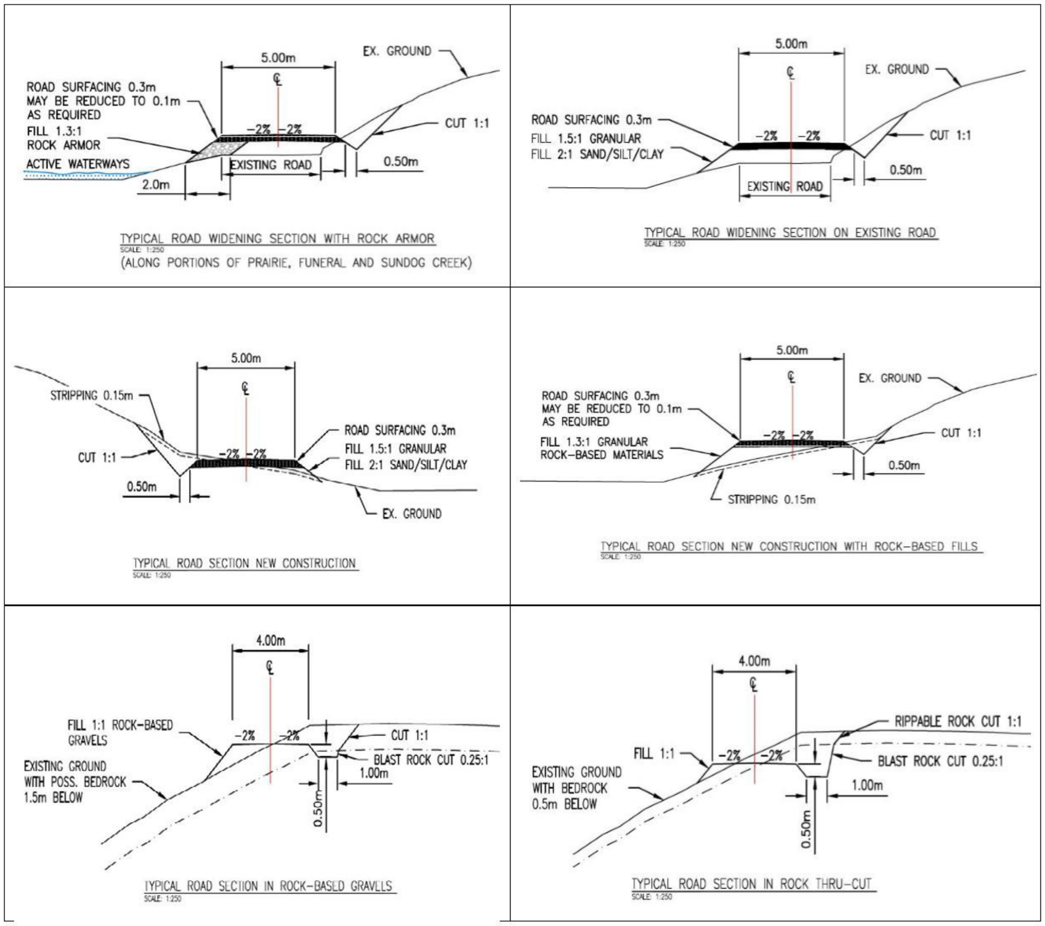

Figure 1 Typical cross sections from EA1415-01_Appendix_1_A.PDF

Road design specifications were also clarified[15] on May 10th 2016 as displayed in Table 2.

The specifications reportedly interpret the B.C. Ministry of Forests, Lands and Natural Resources Operations Engineering Manual which is quoted stating that the controls it defines: "...*are suggested alignment controls for average conditions on forest roads. Variations can be expected, depending on, for example, site conditions and time of use (b) There are no absolute rules for establishing maximum road gradient...".* Thus the

15 EA1415-01_Allnorth_Responses_to_Information_Requests.pdf page 10-13 Section 3.4 PCA #14 Design and Construction Standards summarizes the road design specifications CNZ has proposed for the access road.

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specifications of Table 2 constitute a selection of the flexible rules defined by B.C. Ministry of Forests, Lands and Natural Resources Operations Engineering Manual for average conditions on forest roads where vehicles are generally lighter, not as complex (Super B double trailers, as discussed in Section 1.2.2) and cargo is wood (not concentrate or hazmat) as considered in this project.

Item	Standard
Running Surface Width (primary)	5.0 m
Running Surface Width (secondary)	4.0 m
Design Speed (primary)	40 km/hour
Design Speed (secondary)	20 km/hour
Minimum Curve Radius (primary)	65 m
Minimum Curve Radius (secondary)	25 m
Optimum Maximum Sustained Grade	6 %
Acceptable Maximum Sustained Grade	8 to 10%
Maximum Short pitch Grade (< 250 m)	12 %
Turnouts optimum (minimum)	3(1) per km
Road Life Expectancy	20 years

Table 2 Road Design specifications

3.1.2 Detailed alignment controls and design Stratification

As a reply to a specific question in IR#2[16] the following more detailed alignment control tables (2) were offered. They are published by the B.C. Ministry of Forests, Lands and Natural Resources in the Forest Road Engineering Guidebook, again for forest roads and not concentrate hauling roads (Figures 2,3). **NB:** Tables copied from extant documents are called and numbered as figures in this report, but still show the original numbering for ease of information checking/retrieval.

16 Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 2d.

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Forest Road Engineering Guidebook

Table 2. Summary of alignment controls for forest roads.

Stabilized Road Width (m)	Design Speed (km/h)	Minimum Stopping Sight Distance[a] (m)	Minimum Passing Sight Distance for 2-Lane Roads (m)	Minimum Radius of Curve (m)	Suggested Maximum Road Gradient[b,c]				
					Favourable		Adverse		
					S	P[d]	S	P[e]	Switchbacks
4	20	40		15	16%	18% for distance <150 m	9%	12% for distance <100 m	8%
5–6	30	65		35	12%	14% for distance <150 m	8%	10% for distance <100 m	8%
	40	95		65					
8+	50	135	340	100	8%	10% for distance <200m	6%	8% for distance <100m	6%
	60	175	420	140					
	70	220	480	190					
	80	270	560	250					

NOTE: These are suggested alignment controls for average conditions on forest roads. Variations can be expected, depending on, for example, site conditions and time of use.

[a] For two-lane and single-lane one-way roads, multiply the minimum stopping sight distance by 0.5.

[b] There are no absolute rules for establishing maximum road gradient. Maximum grades cannot generally be established without an analysis to determine the most economical grade for the site-specific conditions encountered. The maximum grade selected for design purposes may also depend on other factors such as: topography and environmental considerations; the resistance to erosion of the road surface material and the soil in the adjacent drainage ditches; the life expectancy and standard of road; periods of use (seasonal or all-weather use); and road surfacing material as it relates to traction, types of vehicles and traffic, and traffic volume. Apply other grade restrictions in special situations. For example:

- On horizontal curves sharper than 80 m radius, reduce the adverse maximum grade by 0.5% for every 10 m reduction in radius.
- As required at bridge approaches, and at highway and railway crossings.

[c] S – sustained grade; P – short pitch

[d] Design maximum short-pitch favourable grades so that they are followed or preceded by a section of slack grade. The average grade over this segment of the road should be less than the specified sustained maximum.

[e] Design maximum short-pitch adverse grades as momentum grades.

Figure 2 Summary of alignment controls for forest roads.

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Forest Road Engineering Guidebook

Table 3. Minimum subgrade widths for roads on curves, for pole and tri-axle trailer configurations, and for lowbed vehicles.

Radius of Curve (m)	Pole and Tri-axle Trailer Configuration: Minimum Subgrade Width (m)	Lowbed Vehicles: Minimum Subgrade Width (m)
180	4.0	4.3
90	4.5	5.3
60	5.0	5.8
45	5.0	6.0
35	5.5	6.5
25	6.0	7.5
20	7.0	8.0
15	8.0	9.0

NOTES:

- The subgrade widths in this table do not allow for the overhang of long logs or any slippage of the truck or trailer due to poor road conditions.
- Apply the widening to the inside of the curve unless the curve has a 60 m long taper section on each end. For widening on the inside, provide a minimum 10 m section on each end of the curve.
- For two-lane roads or turnouts, it is assumed that the second vehicle is a car or single-unit truck. Add 4.0 m for logging trailer configurations and 4.5 m for lowbed vehicles.
- Double-lane any blind curves or provide adequate traffic control devices.

Table 4. Recommended turnout widths, based on stabilized road widths.

Stabilized Road Width[a]	Description	Turnout Width[b] (m)
9+	2-lane off-highway	none
8	2-lane on-highway	none
6	1-lane off-highway	10
5	1-lane on/off-highway	8 to 10
4	1-lane on/off-highway	8

[a] Where no road surfacing is used, the stabilized road width is the width of the road subgrade. Sufficient room should be left on the low side to accommodate debris.
[b] Turnout width includes stabilized road width.

Figure 3 Minimum subgrade widths for roads and curves. The first note indicates the reported widths do not allow for any slippage of the truck or trailer due to poor road conditions.

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To this date, not all road project/layout is known with the same level of detail for the approximate total length of 184km[17]. The total length varies slightly depending on alternatives with Km 0 at the Mine, approximate km 180 at Hwy 7 junction[18].(*We provided preliminary roadway designs for sections of the road that would then be representative of longer sections of the road, and collectively, the entirety of the road. A road alignment was also provided for the entire road. We believe these are a suitable basis for assessing the performance and safety of the road, and environmental effects. It is not necessary, and would be redundant, to provide a preliminary design of the whole road.*)[19].

Allnorth confirmed[20] with reference to their submission "Response to Information Requests" dated May 10, 2016; Appendix E Updated Tables, Table 5 (reproduced below for the original and the alternate alignments, respectively Figure 4,5), *the 170 km plus road was segregated into 10 different construction categories plus six to seven unique individual segments (alternate vs original alignment). Preliminary road designs were completed on 1 to 2 km portions of each of the 10 construction categories and provide a comparable representation of what to expect regarding general ground conditions, earthwork calculations, and construction approach. The majority of the road, roughly 165 km, was classified in this manner. The remaining road length was considered unique for a number of reasons including rock excavation (blasting), stream crossing alignment, and close proximity to stream channel (lower Sundog Creek). A preliminary road design was completed for the entire length of any section considered unique and challenging. This included segment 13.0 to 13.76. Therefore, these sections were not classified into the defined 10 road construction categories due to their unique characteristics.*

As a result, this study bears first on the segments that are best know and gives estimates by analogy to complete the assessment for the rest of the road, using extant documentation, including oblique photos and public records reports.

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17 http://reviewboard.ca/upload/project_document/EA1415-01_Technical_session_transcripts_15-Jun-2016.PDF page 39

18 The project map, updated April 2016, stops at 180 km, 181 km Winter Road Alignment Feb 2013

19 EA1415-01_Allnorth_Responses_to_Information_Requests.pdf page 9-10 Section 3.3 PCA #13 Conceptual Design

20 Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 4a.

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Allnorth

Table 5: Road Construction Types

Type	Length (km)	Description
TYPE I	6.5	UTILIZE EXISTING ROAD GRADE, RE-CONSTRUCTION/WIDENING OF RIGHT OF WAY AND SUBGRADE ON 50% LENGTH, IMPROVE PULLOUTS, DITCH RE-BUILDING AND ESTABLISHMENT, ADDITIONAL CROSS DRAINAGE CULVERTS 3/KM OR AS REQUIRED, MOUNTAIN CONSTRUCTION WITH EXISTING GRANULAR BASE MATERIAL.
TYPE II	16.7	UTILIZE EXISTING ROAD , RE-CONSTRUCTION/WIDENING OF SUBGRADE AND SUBGRADE REQUIRED ON 100% LENGTH, IMPROVED PULLOUTS (AS [ER DESIGN SPECS), DITCH IMPROVE-MENT AND RE-BUILDING ADDITIONAL CROSS DRAINAGE CULVERTS 3/KM OR AS REQUIRED, MOUNTAIN CONSTRUCTION WITH EXISTING GRANULAR BASE MATERIAL
TYPE III	3.8	NEW CONSTRUCTION WITH EXISTING GRANULAR BASE MATERIAL. 15 TO 50 % SIDE SLOPES, EXPECT RIPPABLE ROCK AND SOME MINOR BLASTING
TYPE IV	6.3	EASY UPGRADING EXISTING ROAD ALONG FLOODPLAIN 0 TO 10% SIDE SLOPES, EXSISTING GRAVEL/GRANULAR ROCK BASE MATERIALS.
TYPE V	4.0	NEW CONSTRUCTION WITHIN EXISTING R/W, SAND MINOR SILT SOILS, 0 TO 30% SIDE SLOPES, 50% SECTION LENGTH OVERLAND CONSTRUCTION, BORROW MATERIAL WITHIN 300M OR IDENTIFIED OTHERWISE
TYPE VI	27.2	NEW CONSTRUCTION WITHIN EXISTING R/W, SAND MINOR SILT SOILS, 0 TO 30% SIDE SLOPES, 25% SECTION LENGTH OVERLAND CONSTRUCTION, BORROW MATERIAL WITHIN 300M
TYPE VII	58.7	NEW CONSTRUCTION, SAND MINOR SILT SOILS, 0 TO 30% SIDE SLOPES, 25% SECTION LENGTH OVERLAND CONSTRUCTION, BORROW MATERIAL WITHIN 300M
TYPE VIII	6.0	NEW TYPICAL OVERLAND CONSTRUCTION REQUIRED ON 100% OF THE SECTION. BORROW MATERIAL PROVIDED BY DEFINED BORROW PITS OUTSIDE THE NORMAL RIGHT OF WAY CLEARING WIDTH.
TYPE IX	29.3	NEW CONSTRUCTION, SAND MINOR SILT SOILS, 0 TO 30% SIDE SLOPES, 25% SECTION LENGTH OVERLAND CONSTRUCTION, BORROW MATERIAL WITHIN 300M, SIMILAR TO TYPE VII BUT LARGER RIGHT OF WAY CLEARING THROUGH MATURE TIMBER.
TYPE X	6.2	NEW TYPICAL OVERLAND CONSTRUCTION REQUIRED ON 75% OF THE SECTION. BORROW MATERIAL PROVIDED BY DEFINED BORROW PITS OUTSIDE THE NORMAL RIGHT OF WAY CLEARING WIDTH.
N/A	7.7	SEVEN SECTIONS WHERE TERRAIN OR CONSTRUCTION TECHNIQUES ARE DIVERSE AND UNIQUE. FULL CONCEPT DESIGNS HAVE BEEN CREATED FOR EACH OF THESE SECTIONS.
N/A	10.0	NAHANNI BUTTE ACCESS ROAD. AN EXISTING ALL SEASON SINGLE LANE PUBLIC ACCESS ROAD WHICH WOULD REQUIRE GRAVELLING TO ACCOMODATE ADDITIONAL INDUSTRIAL TRAFFIC. AS THIS ROAD IS CONSIDERED A PUBLIC ROAD, THE PARTY RESPONSIBLE FOR THIS UPGRADE HAS NOT BEEN DETERMINED AND THEREFORE IS EXCLUDED FROM THIS REPORT.
LIARD R.	0.6	
TOTALS	183.0	

Figure 4 Road construction types.

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Prairie Creek Access Road Allnorth

Road Construction Types – Alternate Alignment

Type	Length (km)	Description
TYPE I	6.5	UTILIZE EXISTING ROAD GRADE, RE-CONSTRUCTION/WIDENING OF RIGHT OF WAY AND SUBGRADE ON 50% LENGTH, IMPROVE PULLOUTS, DITCH RE-BUILDING AND ESTABLISHMENT, ADDITIONAL CROSS DRAINAGE CULVERTS 3/KM OR AS REQUIRED, MOUNTAIN CONSTRUCTION WITH EXISTING GRANULAR BASE MATERIAL.
TYPE II	16.7	UTILIZE EXISTING ROAD , RE-CONSTRUCTION/WIDENING OF SUBGRADE AND SUBGRADE REQUIRED ON 100% LENGTH, IMPROVED PULLOUTS (AS [ER DESIGN SPECS), DITCH IMPROVE-MENT AND RE-BUILDING ADDITIONAL CROSS DRAINAGE CULVERTS 3/KM OR AS REQUIRED, MOUNTAIN CONSTRUCTION WITH EXISTING GRANULAR BASE MATERIAL
TYPE III	3.8	NEW CONSTRUCTION WITH EXISTING GRANULAR BASE MATERIAL. 15 TO 50 % SIDE SLOPES, EXPECT RIPPABLE ROCK AND SOME MINOR BLASTING
TYPE IV	5.6	EASY UPGRADING EXISTING ROAD ALONG FLOODPLAIN 0 TO 10% SIDE SLOPES, EXSISTING GRAVEL/GRANULAR ROCK BASE MATERIALS.
TYPE V	4.0	NEW CONSTRUCTION WITHIN EXISTING R/W, SAND MINOR SILT SOILS, 0 TO 30% SIDE SLOPES, 50% SECTION LENGTH OVERLAND CONSTRUCTION, BORROW MATERIAL WITHIN 300M OR IDENTIFIED OTHERWISE
TYPE VI	27.2	NEW CONSTRUCTION WITHIN EXISTING R/W, SAND MINOR SILT SOILS, 0 TO 30% SIDE SLOPES, 25% SECTION LENGTH OVERLAND CONSTRUCTION, BORROW MATERIAL WITHIN 300M
TYPE VII	56.4	NEW CONSTRUCTION, SAND MINOR SILT SOILS, 0 TO 30% SIDE SLOPES, 25% SECTION LENGTH OVERLAND CONSTRUCTION, BORROW MATERIAL WITHIN 300M
TYPE VIII	6.0	NEW TYPICAL OVERLAND CONSTRUCTION REQUIRED ON 100% OF THE SECTION. BORROW MATERIAL PROVIDED BY DEFINED BORROW PITS OUTSIDE THE NORMAL RIGHT OF WAY CLEARING WIDTH.
TYPE IX	29.3	NEW CONSTRUCTION, SAND MINOR SILT SOILS, 0 TO 30% SIDE SLOPES, 25% SECTION LENGTH OVERLAND CONSTRUCTION, BORROW MATERIAL WITHIN 300M, SIMILAR TO TYPE VII BUT LARGER RIGHT OF WAY CLEARING THROUGH MATURE TIMBER.
TYPE X	6.2	NEW TYPICAL OVERLAND CONSTRUCTION REQUIRED ON 75% OF THE SECTION. BORROW MATERIAL PROVIDED BY DEFINED BORROW PITS OUTSIDE THE NORMAL RIGHT OF WAY CLEARING WIDTH.
N/A	7.4	SEVEN SECTIONS WHERE TERRAIN OR CONSTRUCTION TECHNIQUES ARE DIVERSE AND UNIQUE. FULL CONCEPT DESIGNS HAVE BEEN CREATED FOR EACH OF THESE SECTIONS.
N/A	10.0	NAHANNI BUTTE ACCESS ROAD. AN EXISTING ALL SEASON SINGLE LANE PUBLIC ACCESS ROAD WHICH WOULD REQUIRE GRAVELLING TO ACCOMODATE ADDITIONAL INDUSTRIAL TRAFFIC. AS THIS ROAD IS CONSIDERED A PUBLIC ROAD, THE PARTY RESPONSIBLE FOR THIS UPGRADE HAS NOT BEEN DETERMINED AND THEREFORE IS EXCLUDED FROM THIS REPORT.
LIARD R.	0.6	
TOTALS	179.8	

Figure 5 Road construction types- Alternate alignment.

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Table 3 shows[21], the approx. 20km (approx 11%) of the road project which have been delivered in the form of plan view, longitudinal profile and cross sections. In those 20km grades vary between -12% (negative grade means traffic from the mine will descend) and +10% (positive grade means traffic from the mine will ascend).

Construction Stratification Type	from km	to km	Length km
I	**5.14**	**6.2**	1.06
II	**7**	**8**	1
?	**13**	**13.76**	0.76
?	**23**	**23.7**	0.7
III	**25**	**26**	1
IV	**30**	**31**	1
?	**33.2**	**34.2**	1
?	**34.8**	**39**	4.2
VI	**44**	**45**	1
VII	**49**	**51.5**	2.5
VIII	**52**	**53**	1
V	**88**	**89**	1
X	**98.5**	**99.5**	1
?	**122.7**	**123.4**	0.7
IX	**147**	**149**	2
		Total	**19.92**
		% of total length	**10.83**

Table 3 Segments of the road documented by drawings with plan view, longitudinal profile, cross sections, P/O locations.

21 EA1415-01_Allnorth_Responses_to_Information_Requests.pdf Appendix A, Construction Stratification Types.

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3.1.3 Cross sections review

In the Construction Stratification Types narrow stretches featuring cross section width reduced to 4.0m are present as displayed in Table 4 below, confirmed by Allnorth[22] (the segment between km 36.3 and 37.1 displays a reduced width in the cross section, so an uncertainty remains).

Start (approx km)	Finish (approx km)	Approx. Length (km)	Comment
5.4	5.5	0.1	An existing short road section tight to Prairie Creek
6.2			is a bridge location.
23	23.7	0.7	Portions of this section will require significant rock excavation (blasting). Opportunity exists in the detailed road design to reduce the length of the 4 m running surface sections which contain significant rock excavation.
25	26	1	
28	28.6	0.6	Recent realignment to avoid slope stability issues and double crossing of Sundog Creek. The realigned section is located in close proximity to Sundog Creek and potential rock excavation.
36.3?	37.1?	0?	Plan view schematic does not show 4m, but the reduced width is shown in the typical cross sections?
Total at 4m width		2.4km	Over the 19.92km documented with plans
% of 19.92km		12.00%	Of the 19.92km documented with plans

Table 4 Sectors with reduced width and comments. It has been stated by Allnorth that "there will be no other sections that should require a reduced running surface of 4 m."

In the extant plans 31 pullouts (P/O, meaning a wider stretch of road, i.e. a easier passing location) were counted, yielding a density of 31/19.92= 1.56 P/O per km (one P/O every 640m) which lies between the values (3 min 1 PO/km) indicated earlier. Reportedly CNZ foresees larger pullouts where concentrate vehicles can be turned

22 Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 2c.

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around[23] every ~10 km at presently unspecified locations. In the same discussions CNZ has also mentioned the possibility for a driver to drop the trailers and bring back to the mine the rig in case of extreme adverse conditions.

It has been specified that selected "low risks" locations would be defined ahead, special SoPs prepared and drivers would receive specific instructions. In case of adverse all season conditions or a hazard/accident blocking the road, or in relations to the ice bridge load bearing capacity both tactics (turn-around and P/O waiting) may be used. In all cases prolonged stops on the road will result in increased exposure to natural and man-made hazards. Below (Fig. 6,7,8) we display a selection of cross sections to illustrate the diversity of conditions along the 20km for which plans have been made available. Cross sections vary from 100% fill to 100% excavation in various configurations depending on the terrain dominant cross slope.

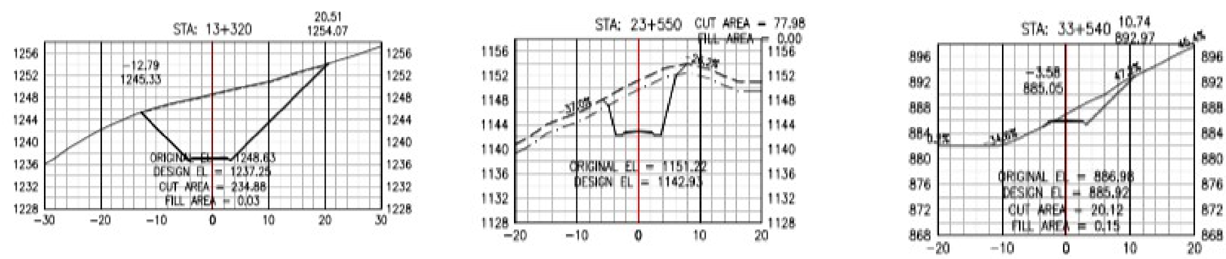

Figure 6 Three cross sections featuring cut profiles in moderate cross slopes.

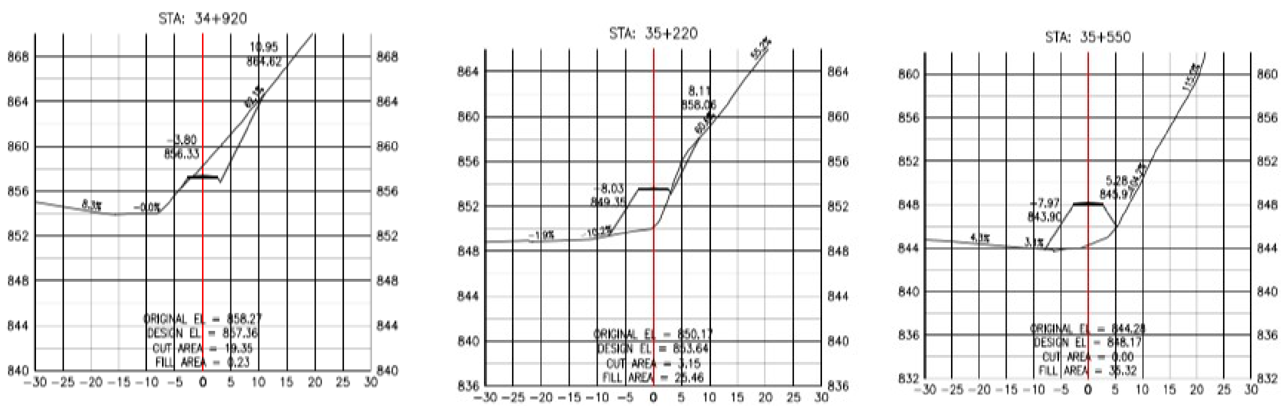

Figure 7 Three sections in steep terrain: cut (left), cut and fill (centre), fill (right).

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23 http://reviewboard.ca/upload/project_document/EA1415-01_Technical_session_transcripts_16-Jun-2016.PDF page 127 to 135

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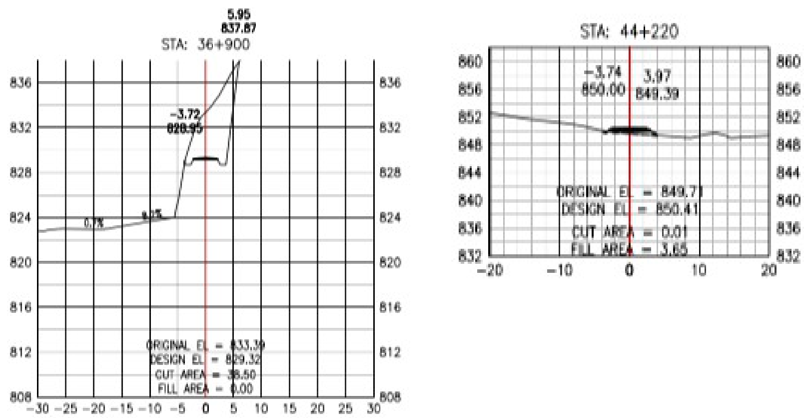

Figure 8 Extreme cut in near vertical slope (left), small fill on fair terrain.

3.1.4 Characterization of man-made, cross slopes & consequence parameters

Table 5 shows cross slope characterization of natural or man-made slopes based on various publicly available sources as accepted[24] by Allnorth. Table 6 displays a categorization of cross sections based on road and environmental features. The slopes characterization of Table 5 is used.

Slope degrees	Slope Characterization	OSHA (indoor)[25]	YDS class for hiking/climbing (outdoor)[26]
Less than 15 degrees[27]	Fair	Limit of ramp for humans in dry, non slippery conditions	Class I
Between 15 and	Moderate	Lower end of stair use for	Class 2

24 Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 7.

25 https://www.ccohs.ca/oshanswers/safety_haz/stairs_fallprevention.html

26 https://en.wikipedia.org/wiki/Yosemite_Decimal_System

27 TransColorado_Gas_Pipeline_Transmission.pdf

28 *https://www.worksafebc.com/en/law-policy/occupational-health-safety/searchable-ohs-regulation/ohs-guidelines/guidelines-part-26: G26.16 Slope limitations - Safe work procedures*
(b) a crawler tractor, feller buncher, excavator and other similar equipment must not be operated on a slope which exceeds 40% (22 degrees);

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		slippery conditions	
Over 25 degrees	Significant	Slope of stairs for humans in dry, non slippery conditions	Class 3

Table 5 Slope characterization vs. slope degrees and two literature based ratings.

ENVIRONMENTALLY SENSITIVE TARGETS[29]	**DOMINANT CROSS SECTION/TERRAIN SLOPE[30] (Downhill of road)**
NOT IN POTENTIAL REACH	Fair with fill less than 3m high
	Moderate with fill less than 2m high
	Significant even if fill height <1m
WITHN REACH (intersect environmentally sensitive target.) or Containment and recovery require specific salvage equipment	Fair with fill less than 3m high
	Moderate with fill less than 2m high
	Significant even if fill height <1m
BRIDGE PRESENT	
WITHN **IMMEDIATE** REACH (intersect the environmentally sensitive target. Containment and recovery require specific salvage equipment	Low Bridge/culvert (less than 2m from bottom) .
	Moderate high bridge (2-3m from bottom)
	Higher bridge (more than 3m from bottom)

Table 6 categorization of cross sections based on road and environmental features

29 Environmentally sensitive targets can be water courses, water bodies, karst, habitats and others as defined by parks Canada
30 As specified in table 5

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3.2 Project life, traffic and vehicles

3.2.1 Project life

Reportedly the service concentrate hauling life will be 16 years preceded by one year of implementation. Concentrate trucks traffic will only occur during the project life of 16 years. During the one year implementation potential accidents will involve unloaded trucks and/or trucks loaded with equipment.

During implementation it has been reported[31] that "*this is basically a tote road to get the material in. We can envisage maybe something like a hundred loads in total over a space of perhaps two (2) or three (3) weeks, once in, once out. So that gives you an idea of the traffic volume.*"

During that period inspection and maintenance/repair will already be in full activity as stated during the technical sessions: "*During road construction, operations and reclamation, there will be regular inspections by supervisory, maintenance and environmental staff, as well as community monitors. Any evidence of impacts, or conditions that might lead to impacts, will be immediately brought to the attention of the transportation manager. Any obvious problems, such as sediment dispersal, will be rectified immediately by construction/maintenance crews.*

A short and long term road maintenance program would be developed at the detailed road design stage."[32]

3.2.2 Considered traffic

For this study traffic is considered to be concentrate trucks, heavy CNZ traffic (hazardous matters, fuel). Trucks per day in a given year could be as low as 5, and as high as 20 (with a nearly fixed total number of truck over the service life of the mine/road). As the quantity of concentrate cargo is known a good estimate of how many trucks will have to travel in a given year can be delivered.

Concentrate trucks will leave in the morning at discrete intervals to reduce staggering at the barge, then they turn around and back to the mine. In winter concentrate trucks will leave as a convoy, as the ice bridge replace the barge. The vast majority of deliveries will

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31 http://reviewboard.ca/upload/project_document/EA1415-01_Technical_session_transcripts_16-Jun-2016.PDF page 80 81

32 EA1415-01_EA1415-01_Developer_s_Assessment_Report.pdf page 90 of SHORT AND LONG TERM ROAD MAINTENANCE EA1415-01_Appendix_1_A.pdf

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be by back-haul on the concentrate trucks. Considering the convoy and the interval departures Allnorth delivered the following details[33]:
If we assume there are 15 concentrate trucks travelling daily, we can envisage the trucks departing in clusters of three or more vehicles at a time in winter, up to the total 15 vehicles in a single cluster. Vehicle separation would likely be in the order of 50-100 m. The convoy concept will apply to returning vehicles in winter. It would not apply to special deliveries, such as explosives, unless more then (one?) vehicle is involved for that delivery. However, for such deliveries, road monitors and maintenance crews will be alerted and the progress of the delivery tracked. It may also be possible to time the delivery so that it occurs in convoy with the concentrate trucks.
In summer, concentrate trucks will travel individually, spaced approximately 30 mins apart, in order to avoid delay crossing the Liard River.

Trucks will be retained at camp if weather is bad (trucks might be loaded) and: "*You know, and you have to bear in mind that -- that there isn't just one (1) person on the road at a given time. There's -- there's -- there are people throughout the road. We -- we are in radio communication constantly, as well as the maintenance crews. So as wea -- bad weather develops, people will be informed accordingly and -- and respond accordingly.*"[34]

As already mentioned, two periods are available for hauling, summer and winter. The summer haul period is after spring break-up and before fall freeze-up on the Liard River crossing. The start of the haul period is delayed by load restrictions on the Liard Highway. The winter haul period is governed by the Liard River ice bridge. Current data indicates that such a bridge cannot accommodate loads greater than 60 tonnes until after January 15. The 'conservative dates' in Figure 9 below reflect these limitations, and include allowance for lost days due to poor weather or road conditions.

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33 Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 9a,b,c of Oct 7th and 11th.

34 http://reviewboard.ca/upload/project_document/EA1415-01_Technical_session_transcripts_16-Jun-2016.PDF page 133

TABLE 1: CONCETRATE PRODUCTION AND HAUL TRUCK NUMBERS

Conservative Dates				Projected Dates			
	From	To	Number		From	To	Number
Summer haul period	Jul 1	Nov 4	127	Summer haul period	Jun 15	Nov 4	142
Summer lost days			5	Summer lost days			5
Winter haul period	Jan 15	Mar 31	75	Winter haul period	Jan 1	Mar 31	89
Winter lost days			5	Winter lost days			5
Total No. Haul Days			192	Total No. Haul Days			221

Year	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9
Concentrate t.p.a.	112,357	154,634	138,799	139,947	146,636	154,120	139,492	161,679
Conservative								
No. trucks/day - 42.5 t	13.8	19.0	17.0	17.2	18.0	18.9	17.1	19.8
No. trucks/day - 50.3 t	11.6	16.0	14.4	14.5	15.2	16.0	14.4	16.7
Projected								
No. trucks/day - 42.5 t	12.0	16.5	14.8	14.9	15.6	16.4	14.9	17.2
No. trucks/day - 50.3 t	10.1	13.9	12.5	12.6	13.2	13.9	12.5	14.5
Year	**Y10**	**Y11**	**Y12**	**Y13**	**Y14**	**Y15**	**Y16**	**Y17**
Concentrate t.p.a.	127,567	119,221	117,000	118,248	116,924	86,161	77,097	59,808
Conservative								
No. trucks/day - 42.5 t	15.6	14.6	14.3	14.5	14.3	10.6	9.4	7.3
No. trucks/day - 50.3 t	13.2	12.3	12.1	12.2	12.1	8.9	8.0	6.2
Projected								
No. trucks/day - 42.5 t	13.6	12.7	12.5	12.6	12.4	9.2	8.2	6.4
No. trucks/day - 50.3 t	11.5	10.7	10.5	10.6	10.5	7.8	6.9	5.4

Figure 9 Concentrate production and haul truck numbers.

As stated[35] trucks will be carrying concentrates, fuel, reagents and chemicals, including acid. Diesel fuel will be brought to site in the winter on the back-haul by concentrate trucks, each carrying a dedicated tank as discussed later. Figure 10 (Table 9-1 in the original from the source document) shows the detail of such traffic for a "average" year.

In the first round of IR we were informed that there will be a very limited number of special deliveries, such as explosives. (Assume 1 trip/quarter).

35 EA0809-002_Developer_s_Assessment_Report__Vol_1_of_4_.PDF

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TABLE 9-1: MATERIALS OF ENVIRONMENTAL SIGNIFICANCE TO BE HAULED

Material	Form	Package	Contents	Tonnes per load	Units per load (max)	No. loads	Total loads
Outbound							3,082
Mineral concentrates	Solid	Bag/bulk (kg)	3,000	39	13	3,077	
Hazardous waste	Various	Drum (litres)	205	10	49	5	
Inbound							1,133
Fuel and Oil							
Diesel	Liquid	Tanker (litres)	10,000		1	800	
Mineral Oil (Explosives)	Liquid	Tanker (litres)	10,000		1	3.5	
Petroleum fluids	Liquid	drum (litres)	205	20	98	4	807
Mill Supplies and Reagents							
Jaw Crusher Liners	Solid	Pallets (Kg)	250	15	60	0.6	
Cone Crusher Liners	Solid	Pallets (Kg)	250	15	60	1.2	
Ball Mill Liners	Solid	Pallets (Kg)	250	15	60	0.9	
Grinding Balls	Solid	drum (litres)	250	15	60	6.9	
Ferro Silicon	Solid	bag (kg)	1000	20	20	7.2	
Glycol	Liquid	drum (litres)	205	20	98	1.0	
Flocculant	Solid	bag (kg)	200	10	50	0.1	
DF067	Liquid	drum (litres)	205	20	98	0.4	
SIBX	Solid	bag (kg)	1000	20	20	1.6	
MIBC	Liquid	drum (litres)	205	20	98	0.0	
Soda ash	Solid	bag (kg)	1000	20	20	21.1	
P82	Solid	bag (kg)	1000	20	20	1.9	
AQ4	Solid	bag (kg)	1000	20	20	7.3	
Copper sulphate	Solid	bag (kg)	1000	20	20	19.0	
3894	Liquid	drum (litres)	205	20	98	0.2	
RTR3	Solid	bag (kg)	1000	20	20	0.2	
SIL N	Solid	bag (kg)	1000	20	20	5.0	
Sodium sulphide	Solid	bag (kg)	1000	20	20	8.7	
Backfill Cement	Solid	bag (kg)	1000	30	30	170.7	254
Water Treatment Reagents							
Sulphuric acid	Liquid	Tote (litres)	1,400	20	14	21.6	
Sodium sulphide	Solid	bag (kg)	1000	20	20	2	
Ferric sulphate (Ferix 3)	Solid	bag (kg)	1000	20	20	3	
Lime	Solid	bag (kg)	1000	20	20	12	39
Mine Supplies							
Mine operating supplies	Solid	Pallets (Kg)	500	15	30	33.3	33
Explosives Components							
Sensitizer	Solid	boxes (Kg)	152	10	66	6	
Sodium nitrate	Solid	bag (kg)	25	15	600	6	
Ammonium nitrate	Solid	bag (kg)	1000	30	30	10.5	23

Figure 10 Materials of environmental significance to be hauled.

Using Figure 10 we can estimate the following:

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The Mine will require approximately ~8,000,000 litres of diesel fuel per year. With fuel brought in on concentrate truck back-hauls, this equates to approximately 2,700 L/trip. The trucks will likely have dedicated tanks installed behind the cab or on the trailers for the fuel haul, with a maximum capacity of 10,000 L. (EA1415-01_EA1415-01_Developer_s_Assessment_Report)

Outbound traffic: 5/3082= +0.16% (1.6/1000) increase of average traffic due to hazardous waste. This increase is negligible compared to other uncertainties. Passenger traffic negligible (fly-in, fly-out except rare occurrences, see Section 1.2 Condition 1).

Inbound traffic:

Fuel & oil	807
Mill supplies & reagents approx.	254
Water treatment reagents	39
Mine supplies	33
Explosive components	23
Total environmental significant loads	1156

Thus it can be inferred that 1156/3077=37.5% of the concentrate trucks will travel back to the mine with environmental significant loads, whereas 62.5% will travel back to the mine with their respective diesel tanks only. Figure 11 displays the traffic share.

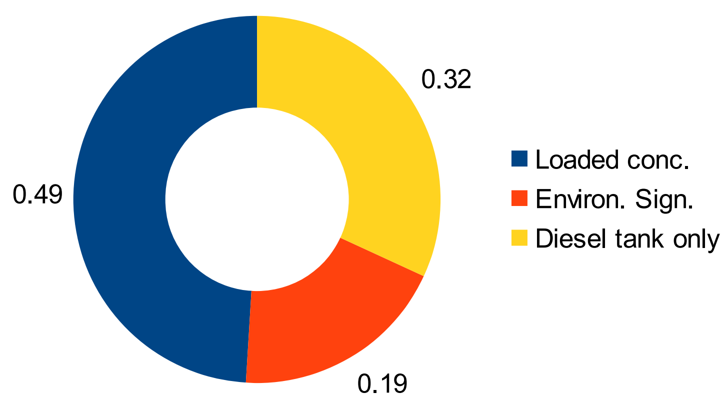

Figure 11 Traffic share between loaded concentrate truck (outbound) and inbound traffic split between environmental significant loads and truck travelling with their diesel tank only.

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In summary the "average" outbound traffic considered in the risk assessment will be constituted by 100% concentrate trucks, whereas the inbound traffic will be 37.5% environmental significant loads, 62.5% empties with diesel tanks only.
Based on the extant traffic forecast is it possible to evaluate that approximately 1.2Mkm (million kilometres) will be driven per year, respectively 20Mkm for the service life of the road.

3.2.3 Project speed

CNZ stated[36] during the Technical Sessions the following regarding concentrate trucks speed: *"So what I'm hearing from my colleague is that the traffic estimates contemplated a typical speed in the forty (40) to fifty (50) range, maybe with a top speed of sixty (60) in certain locations, and then lower than -- obviously lower than forty (40) and fifty (50) at certain spots that have got issues. So I think we're comfortable then that an average of thirty (30) is a conservative assumption.*
We did quite an extensive study analysis on -- on this in terms of determining cycle times. Cycle times is not just travel speeds, but it takes in account road conditions, winter and summer operations, chaining up, fuelling. All these things are -- are integral to determining what the cycle time is. And then, in the case of operating the -- the barge, there's -- there's a lot of time to -- to compensate for that. So that's how we determine our -- our cycles times. And this is a very common thing that we do in the industry to determine costs and what have you, so."
In the IR#2 replies[37] CNZ delivered a somewhat different opinion related to the speed limit for haul trucks as follows: *The design speed limit of the Prairie Creek Access Road for haul trucks is 40km/h, unless specific alignment curves, grades or narrow section warrant a speed reduction.* Thus, for the sake of this study we will consider the following "general" speeds:

- 30km/h on average with
- typical speed of 40~50 km/h and
- max of 60km/h in some sections for the concentrate and other heavy traffic. NB: the 60km/h derives from the public record and comes as an exception to the road design specifications shown earlier, declared by Allnorth and delivered in tabular form in Sections 3.1.1 and 3.1.2 (Table 2, Figures 2, 3), when considering the maximum width of 5m.

36 http://reviewboard.ca/upload/project_document/EA1415-01_Technical_session_transcripts_16-Jun-2016.PDF page 123
37 Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 3b.

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3.2.4 Concentrate vehicles

In the DAR[38], there are two truck configuration options for the haul.

1) An 8 axle tandem drive tractor with Super B-train concentrate trailers in a train configuration has a payload of 42.5 tonnes, with a gross vehicle weight (GVW) of 63.5 tonnes (Fig. 12). Length of the 8 axle configuration: 23.79m.

2) A 9 axle configuration consisting of a tridem tractor with Super B-train[39] concentrate trailers has a payload of 50.3 tonnes, with a GVW of 72.3 tonnes (Fig. 13). Length of the 9 axle configuration is 24.79m. The GNWT Department of Transportation stipulates a 63.5 tonne GVW maximum for B–train truck and trailer combinations, unless a variance is provided by special permit. It is our understanding that the 63.5 tonne maximum is based on limiting the scale of the required maintenance on territorial roads.

CZN intends to apply for a special permit to haul the 50.3 tonne loads, which we assume the GNWT will consider in connection with upgrades to the Liard Highway.

A 50.3 tonne payload is preferred by CNZ because it is cheaper, safer and results in less traffic and the associated effects, while however increasing the kinetic energy and potential spills consequences in an accident. Both payload options were included in the calculations[40].

38 Environmental Assessment EA1415-001, Prairie Creek Mine Concentrate Haul.pdf

39 "Tridem axle group" means an axle group of three equally spaced axles that: (i) has an axle spread of not less than 2.4 metres and not more than 3.7 metres; and (ii) is not part of a multiple axle group; "tridem drive axle group" means a tridem axle group in which all axles in the group are connected to a power source that transmits tractive power to all wheels on those axles.

40 EA1415-01_CanZinc_letter_to_MVEIRB_re_Concentrate_Haul_.pdf

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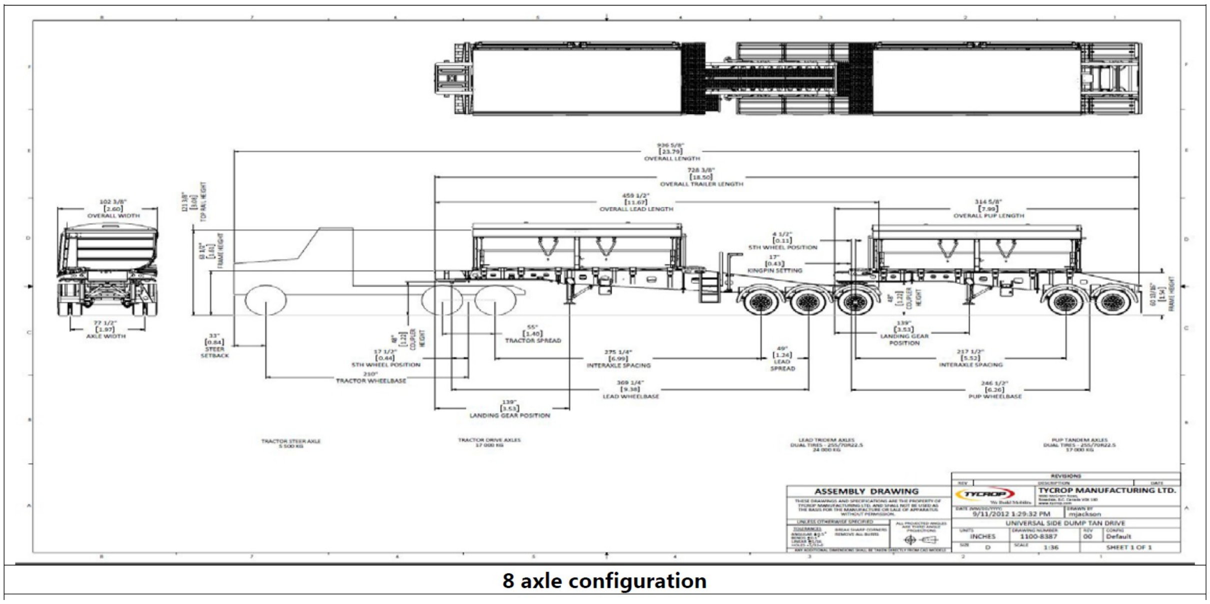

Figure 12 8 axle configuration.

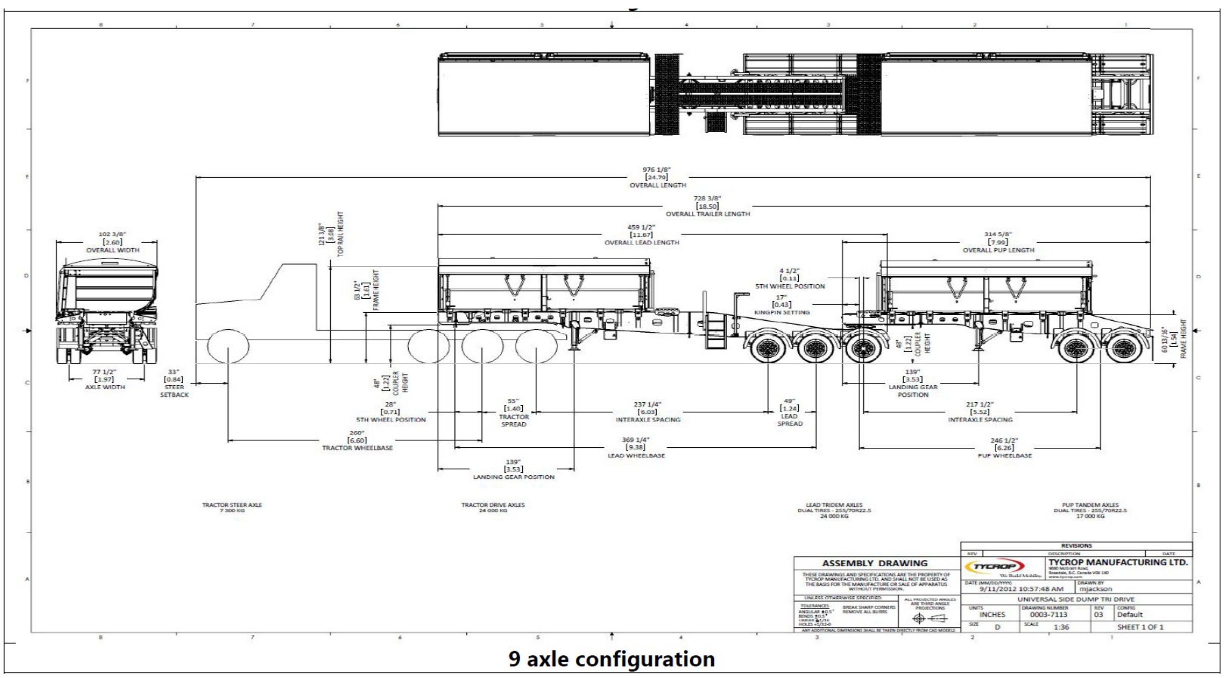

Figure 13 9 axle configuration.

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Allnorth provided in prior reports (Figure 14) which displays a flatbed 9 axle configuration loaded with concentrate bags travelling on a wide and flat two lanes highway. This image is not pertinent with the "special road" environment in which the CNZ vehicles will operate and the securing of the cargo, based exclusively on transverse span sets with no longitudinal links has to be considered as inefficient in case of an accident (sliding, rolling off a road embankment), especially considering the environmentally harmful content of the bags in case they split. The situation would be somewhat mitigated if the flatbeds would be equipped with load stoppers in addition to the cross span-sets.

Figure 14 A prior version of the highway concentrate haul truck.

Allnorth has since confirmed in Undertaking #35, 46[41] that the trucks will either be similar to those used at the Red Dog Mine (Figure 15) for bulk hauling or, *if concentrates are hauled in bags, they will be 3 tonne bags tied-down inside a truck box which will have a lockable solid lid. In the event of an accident and truck overturn, the bags are likely to remain attached within the trailers.* The spilled volume potential will be discussed later on in this report.

CNZ has confirmed that *since concentrates will have an 8% moisture content, dust generation should not be an issue* even in case of bulk haulage. They also stated that *given the concentrate trucks will have sealed lids, if a dust issue occurs, it can only be*

41 EA1415-01_Letter_to_MVEIRB_re_Undertakings_from_Technical_Session_Aug_11__2016.PDF

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from dust that has settled on the exterior of the trucks while on site, and is subsequently lost from the trucks as they depart site. Therefore, if no dust issue is detected proximal to the site, it is very unlikely that one would be detected further from site.

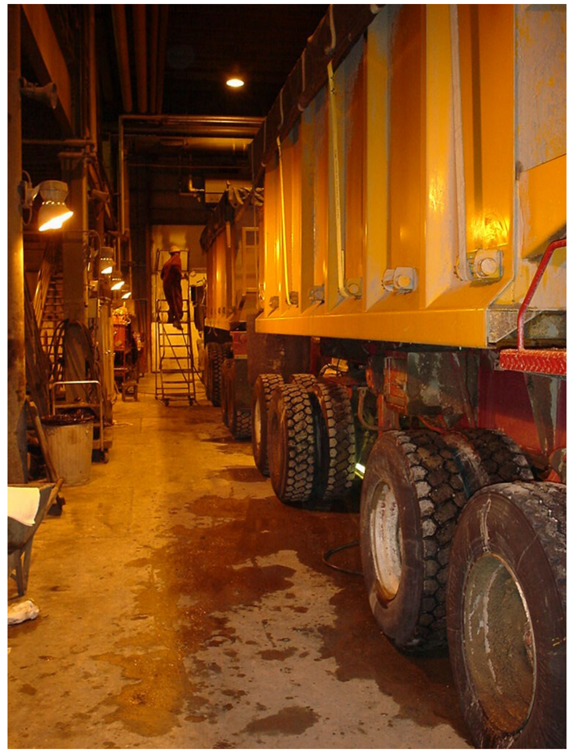

Figure 15 Concentrate truck on haulage road in the Arctic and in the shop for maintenance. Notice the tarp roof and the spansets securing it. In this particular case concentrate is loaded in bulk. The road is mostly flat with very moderate cross slopes.

In addition Allnorth stated[42] that:

all haul trucks will carry concentrate and fuel. It should also be noted that cargo risks were reduced by reducing the fuel tank size from 10,000 L to 5,100 L, and specifying that the tanks will be double-walled with a secondary containment capacity greater than the inner tank.

42 Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 3b.

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When asking about vehicles certification and braking capabilities, the following was delivered[43]:*Various government agencies, federal, provincial and state, both in the U.S. and Canada and other world jurisdictions, collectively work with engineers and institutions to study and analyze braking systems, materials, statistical braking data based on truck configurations and weights, and braking system failures due to heat (fading). This information is then used to develop industry standards and laws which are under the jurisdiction of provincial and territorial Ministry of Transportation. All vehicles, including commercial vehicles, sold and operating on public roads must meet these minimum standards. All commercial vehicles are required to complete annual certifications to ensure they conform to the standards. The stopping distance and brake fade data for the specific haul truck is not available. These units will be manufactured to the current government standard which includes the Canadian Motor Vehicle Safety Standard (CMVSS). The braking systems will be designed and tested to CMVSS 121 Air Brake Systems.* In addition[44]: *Braking tests will be performed to the standard required by CMVSS 121. This does not include testing the units on slippery surfaces or grades. These units will be equipped with an anti-lock braking system that is compliant with the CMVSS 121. The Anti-lock system is to reduce the potential for a loss of control during a stopping situation. In addition to this, the units will be required to have a parking brake that is capable of holding the entire unit on a 20% grade facing uphill and facing downhill on a smooth, dry, Portland cement concrete roadway. We recognize that braking is more difficult on slippery surfaces. This will be taken into account in the setting of speed limits. Also, during less than optimum haul conditions, the Road Supervisor always has the option to implement further specific or road-wide speed reductions by notification to haul drivers.*

The concentrate transport and resupply haulage fleet will comprise a fleet of 13 operating tractor/trailer units owned and operated by CZN and a Contractor fleet of 13 similar units. The CZN fleet will be stranded at the Mine site during the summer in order to be available to haul concentrate to the TTF early in the winter.

43 Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 6a.

44 Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 6b.

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4. Hazards

This section reviews natural and man-made hazards potentially impinging on the system as described in Section 3.

Due to the scope of work, we will look at environmental and “public” H&S only accidents involving concentrate and other environmental significant loads traffic.
However, our mandate includes, for summer road and sectors of the winter road that differ from already approved layout:

- locations identified as moderate, high, and very high risk from a geohazards and terrain stability perspective
- the Sundog creek realignment and other potential avulsion areas
- locations with sensitive habitat that would likely result in a high consequence events (this should include areas with karst topography)[45],
- (locations) where the road design increase the likelihood of an accident, locations where channel avulsion risks are considered to be likely to effect the road and/or road crossing structures.

The following sections on Hazard Identification are structured to cover the points above.

The issues related to permafrost (and its future behaviour due to climate change) are an engineering/environmental issue that transcends this risk assessment report and are therefore not included. Should climate change generate new geohazards, the report will be due for an update.

4.1 Natural vs traffic hazards

A multitude of hazards (above, on, downhill of the road, and meteorological) can affect the likelihood of a truck losing control on the road. We consider that whiteouts and other extreme meteorological conditions will lead to precautionary road closure (as described by CNZ) thus can be neglected in the risk assessment. We also consider that mud-ice-snow conditions are “business as usual” for this type of road. Professional drivers will adapt speed and behaviour (including chaining up) to those conditions, but will be exposed, nevertheless to more hazardous conditions. Allnorth[46] have confirmed those conditions alter stopping distance and other parameters.

45 These areas are discussed in the Consequences Section
46 Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 6b.

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Source	Natural Hazard
Above road	Small Rock
	Rock/ avalanche
	Landslide/ avalanche
	Mud flow/ avalanche
On road	Sinkhole
	Water
Down of road	(Riverbank) Erosion
	Slide
Atmospheric	Wind

Table 7 Potential Hazards above, on and below (downslope) of the road.

Mechanical failure are left out of the analysis because with proper maintenance and regular check, the rates of potential accidents specifically due to mechanical failures is extremely low (beyond present credibility).

4.2 Road and meteorological hazards

Many Road features (such as sighting distance) and meteorological events are a factor to determine to understand if corrective reactions can be attempted by the driver in a hazardous situation. Hazardous situations may arise from road features under certain conditions reviewed below. Most accidents will be generated by human error, poor judgment, fatigue, compounded with meteorological (adverse) conditions, possible distractions and, of course road and vehicles characteristics.

4.2.1 Road features hazards

To prepare this section we studied the Information Circular 8758 Design of Surface Mine Haulage Roads - A Manual by Walter W. Kaufman and James C. Ault, UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF MINES and interviewed heavy articulated vehicles drivers accustomed to four season unpaved roads of similar design and conditions to the one under examination.

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Sight distance: From Circular 8758 we read: "as far as is economically feasible, all geometric elements of-haulage roads should be designed to provide safe, efficient travel at normal operating speeds. The ability of the vehicle operator to see ahead a distance equal to or greater than the stopping distance required is the primary consideration". As already stated earlier, Allnorth is aware that sight conditions may not be respected and will mitigate these by reducing posted speed and introducing signals. Furthermore in IR#2 they specified the following[47]: *Refer to Allnorth's submission "Response to Information Requests" dated May 10, 2016; Section 3.4 PCA #14 Design and Construction Standards, Item 1. MOFLNR Table 3-2. The B.C. Ministry of Forests, Lands and Natural Resources Operations Engineering Manual provides the primary design and construction standards which will govern the final road location and design. Line of sight distance is a combination of horizontal and vertical alignment. A safe line of sight distance also considers such things as speed, field conditions, road standards, and weather. Horizontal line of sight can be improved by increasing right of way clearing widths on the inside of a corner. The "minimum" line of sight (or stopping) distance is the shortest distance required to stop (which includes operator reaction time) a designated vehicle (in this case a heavy commercial truck) in a safe manner under typical operating conditions (in this case, gravel road). This distance would be considered a minimum requirement and it would be preferred to exceed this value. Maximum line of sight is not considered because the greater line of sight, the safer it is. MOFLNR provides the "Minimum Stopping Sight Distance" prescribed for a designated speed. A 20 km/hr speed requires a minimum 40 m, 30 km/hr requires 65 m, and 40km/hr requires 95 m. It is Allnorth's professional opinion that these values are attainable throughout the length of the road and speed will be restricted by other design factors such as alignment and road widths. It is a normal process in the design process of the road to incorporate line of sight. At the detailed design stage, using the MOFLNR Engineering Manual standards, sections with restricted line of sight will be speed reduced accordingly and posted.*

"From a safety standpoint, haulage road grades must be designed to accommodate the braking capabilities of those vehicles... The design of routes that accommodate the braking systems of haulage trucks should leave a sufficient margin of safety for other equipment less frequently used, such as dozers, loaders, scrapers, graders, etc." Such vehicles will be present on the road at all time as lately once more confirmed by Allnorth[48].

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47 Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 5a,5b.

48 Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 14b.

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Superelevation: There is a practical limit to the rate of superelevation of the road surface. In regions subject to snow and ice, slow travelling vehicles could slide down the cross slope. When ice or mud are constant problems, excessive cross sloping can cause vehicles to slide. This possibility is especially pronounced at slow operating speeds on grades of more than 5%. Therefore cross slopes should be limited to the minimum value. In the typical cross sections delivered date, 2% superelevation of the road is indicated as standard, presumably in straight lines (to allow for proper drainage). We did not see any information on superelevation in curves. Road maintenance should insure that the road surface is kept smooth and drains properly under the final design conditions/parameters that will be selected.

Sharp Curve Design: Widening on Curves. Switchbacks or other areas requiring sharp curves must be designed to take into consideration the minimum turning path capability of the vehicles. Allnorth has confirmed this in IR#2 replies and the Stratification drawing report widening in sharp curves.

Bridges: The designs of the bridges is coherent with common practice rules.

A total of 18 major stream crossings were identified[49] in the original report. A "revised" preliminary design was completed on 7 of the major crossings considered more hazardous related to infrastructure, channel, morphology, high water flows, and general stream integrity. These revised designs were reportedly updated with calculated Q100 flow elevations and site specific measures to be applied to ensure long term protection of stream integrity and road infrastructure. 3 of the original preliminary bridge designs (KP 39.8, 53.7, and 89.8) were considered under-designed for sufficient freeboard, and were therefore raised in elevation, necessitating increased span lengths. Bridges are reported in Appendix 2.

In the Alps accidents have occurred, dues to climate change, where bridges have been blown away, during flash floods, by the air pressure-wave preceding the flood wave. If the bridge deck does not leave enough free cross section above the flood, the air pressure-wave cannot dissipate under the deck and the deck is blown away. As it has been specified that traffic would not be running during severe weather, hence flooding events, it is considered that bridges will be present at all time vehicles have to cross them. Business interruption is not part of the scope of this study.

Culverts: As above for bridges, but in the case of culvert it's a plugging, pressurizing issue.

Crossings and junctions: Due to the overall limited volume of traffic, low speeds and the stated ongoing radioing, crossings and junctions are not considered to represent a noteworthy hazard. Should traffic volume and speed increase, use of the area, including borrow pits change, then a revision would be warranted. It is also understood that

49 EA1415-01_App_A_-_Allnorth_Road_Eng.PDF Appendix A

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particular care will be taken in ensuring good visibility in all directions and crossings. Should 3rd party users access the road, a revision should be considered.

Retaining walls and shoulders: There are none in the extant designs of the various Stratifications. It is unclear how certain road prisms will be built, as they display near vertical slopes, although the use of rock gabions has been cited.

Dust: dust represents a major safety hazard to the vehicle operator in that it can become so dense that visibility is severely reduced. Eliminating the dust problem requires continual wetting of the surface, which represents yet another maintenance expenditure. When subjected to heavy wetting, non stabilized earthen roads become extremely slick and may be severely defaced by erosion. Thus, reduced vehicular controllability from a slippery surface creates a safety hazard, and maintenance must be increased to eliminate erosion gullies. At this time the issue does not seem to have been addressed in one way or another (effect on wildlife is an environmental impact issue).

4.2.2 Weather and snow hazards

Collision chances usually increases during precipitations, from negligible amounts to reportedly several hundred percent, although the typical estimate in more rigorous studies is 50 to 100 percent. Variations are due in part to differences in methods and weather conditions, but may also reflect urban/rural or regional/contextual differences in sensitivity. There is considerable evidence that snowfall has a greater effect than rainfall on collision occurrence.

Because of the road width (not allowing much margin of error or slippage as noted in Figure 3) this report adopts a 100% value for the snow/ice conditions accident increase while recognizing that drivers will be skilled professionals. It is also considered that raining events during summer may increase slippage, leading to a 45/55 share of hauling days with dry/slippery conditions on average during the service life.

4.3 Avalanche hazard

CNZ[50] stated that: *The Alpine Solutions report* (2012) *confirms that the scope of the avalanche assessment was the whole road. Alpine Solutions identified avalanche paths between Km 4-35, and provided frequency and magnitude projections.*

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50 http://reviewboard.ca/upload/project_document/EA1415-01_CanZinc_responses_to_outstanding_adequacy_items.PDF

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The 2012 Alpine solutions report[51] states: *Twenty seven avalanche paths (or hazard areas) over an accumulated distance of approximately 17 km along the road were identified, and they are distributed from approximately 4 km to 35 km from the mine site (Drawings 1 through 6, Appendix A). Due to estimated shallow snowpack depths most winters, frequency of avalanches reaching the road is not high (annual or less frequent). Large avalanches (Size 3 and 4) would only be expected with frequency on the order of once every 3 years or less often, and would typically only be expected in the spring when the snowpack is near its maximum depth.*

Potential consequences of avalanches reaching the winter road include traffic delays due to road blockage, potential vehicle damage, occupant injury or fatality, and mine concentrate spillage. In addition any fixed infrastructure (such as bridges) located in avalanche areas may be at risk if they are not designed to withstand the effects of avalanches. Associated consequences may include economic losses resulting from the above, and impact to company reputation. A complete risk assessment for each individual scenario involving avalanches cannot be undertaken without further details regarding traffic frequency, and location of fixed infrastructure (bridges). However, considering the preliminary details which include: ☐ proposed active winter road use schedule, and ☐ extended length of road affected by avalanche paths, the risk from avalanches to the winter road is estimated to vary between low and high, depending on annual snowpack and climate conditions.

Alpine solutions recommendations for the road avalanche risk analysis and mitigations included the following:

- *Road layout on attached avalanche hazard maps should be reviewed and confirmed once the road alignment is finalized.*
- *...*
- *...*
- *An avalanche hazard management plan should be prepared for the Prairie Creek winter road. The plan should specify all measures employed to reduce risk to vehicles and occupants. In addition the plan should include an emergency response plan.*
- *If structures such as bridges are to be installed at creek and river crossings near avalanche paths along the mountain segment of the road, an assessment of potential avalanche impact should be undertaken.*
- *...*

51 In http://reviewboard.ca/upload/project_document/EA1415-01_CanZinc_responses_to_outstanding_adequacy_items.PDF

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In the Alpine report a Summary of Avalanche Paths affecting the winter road was delivered. We note from the report that: *In general avalanches of Size 2 or greater are expected to pose a risk to a person, and avalanches of Size 3 and greater will pose a risk to medium to large size vehicles. This does not take into account the effect of terrain features which may augment the effect of an avalanche (eg. a vehicle being pushed into a river by a Size 2 avalanche). Occupants will be partially protected from avalanche impact if they are in a vehicle; however if the vehicle becomes stuck, and the occupants choose to go outside to shovel, their vulnerability increases substantially.*
Bridges or stationary vehicles and equipment may also be at risk, depending on their vulnerability.

As the exposure time of maintenance workers and light vehicles is not known, it is assumed that Size 2 avalanches (which could reportedly impact heavy trucks only in particular topographic situations) will be dealt by CNZ by implementing Alpine recommendations and mitigations. Thus this report only looks at risks linked to known traffic (concentrate trucks accidents, environmental significant cargo, empties) potentially generating spills (business interruption and safety of the workers are and remain under the exclusive responsibility of the owner of the road (avalanche hazard management plan, as advised by Alpine) and private traffic is a priori excluded), the considered events are summarized in Table 8.

Path ID	***Approx. location***	***Affected segment (m)***	***Aspect***	***Magnitude-frequency estimate events:years***		
				Size 2	***Size 3***	***Size 4***
4	*Prairie Creek 4 km along road*	*600*	*West*	*1:1*	*1:10*	
9	*Funeral Creek 8 to 9 km along road*	*1700*	*South*		*1:10*	
11	*Funeral Creek 11 km along road*	*250*	*South*		*1:10*	
12	*Funeral Creek 12.5 km along road*	*250*	*North*	*1:1*	*1:3*	
12.5	*Funeral Creek 12.5 km along road*	*250*	*East*		*1:10*	
15	*Funeral Creek 15 km along road*	*1200*	*NW*	*1:1*	*1:1*	
16	*Funeral Creek 16 km along road*	*200*	*South*		*1:10*	
16.5	*Funeral Creek 16.5 k along road*	*50*	*North*		*1:10*	

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17	*Sundog Tributary just east of Pass*	*700*	*South*	*1:1*	*1:3*	
18	*Sundog Tributary just east of Pass*	*700*	*South*	*1:1*	*1:3*	
20	*4 km east of Funeral/Sundog Pass*	*800*	*NE*		*1:3*	
22	*6 km east of Funeral/Sundog Pass*	*1000*	*NE*	*1:1*	*1:3*	
25	*Sundog Trib 15 km west of Cat Camp*	*200*	*SW*		*1:10*	
25.5	*Sundog Trib 14.5 km west of Cat Camp*	*500*	*SW*		*1:3*	
26	*Sundog Trib 14 km west of Cat Camp*	*200*	*SW*		*1:3*	*1:30*
27	*Sundog Trib 13 km west of Cat Camp*	*400*	*SW*	*1:1*	*1:3*	
28	*Sundog Trib 12 km west of Cat Camp*	*200*	*SW*	*1:1*	*1:3*	
28.5	*Sundog Trib 11.5 km west of Cat Camp*	*200*	*SW*	*1:1*	*1:3*	
29	*Sundog Trib 11 km west of Cat Camp*	*200*	*SW*		*1:10*	
30	*Sundog Trib 10 km west of Cat Camp*	*500*	*SW*		*1:10*	
31	*Sundog Creek 9 km west of Cat Camp*	*2000*	*South*		*1:10*	
33	*Sundog Creek 7 km west of Cat Camp*	*1400*	*NW*	*1:1*	*1:10*	
34	*Sundog Creek 6 km west of Cat Camp*	*1200*	*NW*	*1:1*	*1:10*	
35	*Sundog Creek 5 km west of Cat Camp*	*800*	*NW*	*1:1*	*1:10*	

Table 8 list of Size 3 avalanche hazards, which can reportedly push a vehicle off road.

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Riskope's SoW specifically requires to only evaluate risks in areas where the all season road differs from the winter road. Hence Table 9 shows these areas, under the assumption that minimal layout differences are insignificant.

Path ID	***Approx. location***	***Affected segment (m)***	***Aspect***	***Magnitude-frequency estimate events:years***		
				Size 2	***Size 3***	***Size 4***
16	*Funeral Creek 16 km along road*	*200*	*South*		*1:10*	
20	*4 km east of Funeral/Sundog Pass*[52]	*800*	*NE*		*1:3*	
25	*Sundog Trib 15 km west of Cat Camp (same note as above, but apparently in a milder topography)*	*200*	*SW*		*1:10*	
25.5	*Sundog Trib 14.5 km west of Cat Camp (same note as above)*	*500*	*SW*		*1:3*	
26	*Sundog Trib 14 km west of Cat Camp (same note as above)*	*200*	*SW*		*1:3*	*01:30:00*
27	*Sundog Trib 13 km west of Cat Camp (same note as above)*	*400*	*SW*	*1:1*	*1:3*	
28	*Sundog Trib 12 km west of Cat Camp (same note as above, apparently equivalent topography)*	*200*	*SW*	*1:1*	*1:3*	
28.5	*Sundog Trib 11.5 km west of Cat Camp (same note as above)*	*200*	*SW*	*1:1*	*1:3*	
33	*Sundog Creek 7 km west of Cat Camp*	*1400*	*NW*	*1:1*	*1:10*	
34	*Sundog Creek 6 km west of Cat Camp*	*1200*	*NW*	*1:1*	*1:10*	
35	*Sundog Creek 5 km west of Cat Camp*	*800*	*NW*	*1:1*	*1:10*	

Table 9 List of the Size 3 avalanche hazards that have to be covered under Riskope's SoW.

52 In this segment the all season road is on the opposite side of the valley. Possible avalanche areas could be in this section as well, thus we keep it in consideration.

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NB: the all season road may be exposed to avalanches that were not noted in Alpine's report, due to layout changes.

4.4 Creek Avulsion hazard

4.4.1 Sundog Creek realignment

CNZ stated[53] that: *from Km 33 to 38, portions of an active creek channel are to be occupied by the road. In some places, the active channel will be moved over in equal part to the road encroachment. From Km 35.5 to 36.9, the road will occupy portion of the current main channel. We propose to deepen an adjacent channel, in use relatively recently, as necessary to recreate the original channel, and the adjacent channel will thus become the main or re-aligned channel. All channels in the area are relatively shallow (less than 40 cm), punctuated with occasional pools in proximity to rock abutments. In the absence of detailed site survey, which would be completed during the final design phase, it is difficult to estimate the quantity of material that would be excavated from the re-aligned channel and placed in the existing with any degree of accuracy. The excavated material would be incorporated into the road prism. If there is a material deficit, fill would be sourced from the borrow sources that have been defined, or the considerable number of reserve borrow sources.*

...Regarding environmental risks to project components, and risks to the road segment in the absence of channel re-alignment, Tetra Tech EBA's proposals are provided in their report. It is important to understand here that the risks CNZ is discussing are those that would provoke damage to the road and related business interruptions with only in extreme cases loss of fill materials (mostly autochtonous, following their statements) in the creek current, as noted by CNZ, if the creek was not realigned.

Without the creek re-alignment, creek flows would directly abut the road, and the road would be prone to erosion. Further, since the road would occupy a portion of the channel, hydraulic capacity would be diminished. By re-aligning the creek into a previously used channel, risks to the road can be substantially reduced and channel capacity maintained. Once the channel has been re-aligned, there may be local thalweg shifting and channel infill. This is of no concern provided it does not lead to channel movement south to the original alignment. The potential for this occurrence is considered to be low, since partially vegetated islands exist between the two channels. There are a few low spots between islands that will need to be filled to ensure the re-aligned channel does not 'short-circuit' to the south. Channel location and bedload accumulation will be monitored. Bedload accumulation could force the channel to avulse in a direction not

53 http://reviewboard.ca/upload/project_document/EA1415-01_CanZinc_responses_to_outstanding_adequacy_items.PDF

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preferred. Therefore, if problematic bedload accumulation is noted, maintenance dredging may be considered. This would occur in the absence of channel flow in the late fall/early winter period, or later in winter if necessary. The re-aligned channel will not be allowed to move back to original location during the life of the road, and so the road prism and protection is not expected to change over the life of the project. Allnorth have reviewed the preliminary road design for Km 33-38.1. Details are provided in their letter attached. The letter includes definition of the spatial footprint of the road on the floodplain and channels. The spatial footprint of the channel re-alignment, and the hydraulics of it, is described in the above noted Tetra Tech EBA report. That report also describes channel changes, other than the channel re-alignment, that will be required to maintain channel hydraulics and stability where the road bed will impinge on existing channels.

It is extremely unlikely (beyond present credibility) that under these conditions, the presence of maintenance crews, proper monitoring and a Journey Management System (JMS) a concentrate truck would be involved in an accident due to creek avulsion unless "normalization of deviance" (See Appendix 1 for a definition) would occur over time.

In areas of similar topography, climate and environment around the world (but also reportedly along the Dodo Creek (Canol Heritage Trail)- NEWS/NORTH NWT, Monday July 25th 2016), page A3) potential for local channel avulsion and the possibility of the development of debris dams resulting from landslides on the side slopes exist.

Reportedly CNZ/Tetra Tech did not identify any evidence of previous landslides blocking the valley. This is a natural terrain hazard (i.e. a potential environmental effect on the project as opposed to a potential effect of the project on the environment). The annual probability of such an event would be very low and would reduce further in the realignment section where the valley floor is wider (approximately 350 m-wide) meaning it would take a very large magnitude/extremely low frequency landslide to 'dam' the valley. A partial damming occurring on the slope opposite to the road may create difficulties, but again it is difficult to believe a concentrate truck may be involved. A partial damming would cover the road. Tetra Tech reportedly identified that a channel avulsion occurred in the 1940's in the vicinity of KP 36 within the Sun Dog Creek re-alignment section as a result of landslides on the south side slopes of the canyon. That means no events in 76 years to date, and thus, based on extant evidence and data, negligible hazard to concentrate traffic.

4.4.2 Other potential avulsions

As per avulsion hazards at other locations than Sundog Creek, Allnorth in their Responses to Technical Review Undertakings (Aug. 10Th 2016), delivered Figures 16, 17A,

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B (NB: we note to avoid confusion that the term “risk” should be replaced by “hazard”).

The Figures show respectively three decreasing qualitative categories of likelihood of occurrence of potential events generating environmental consequences. The events are described at specific kilometres of the road and include:

- avulsions,
- ice jams,
- woody logs debris.

The Description/Mitigation column in the same figure describes the measures that will be taken, including monitoring after intense events or seasonally.

Table 3: List of Major Stream Crossings Ranked by Risk

Major Crossing Location	Structure Type	Associated Risk	Description/Mitigation:
KP 6.2 (existing structures to be upgraded)	bridge	Avulsion	• Crossing over an active floodplain. • Thoroughly armor foundations • Train existing main channel to manage and contain flows • Installation of overflow culverts as required. • Design final road elevation to avoid large damming/back-up of head water • Monitoring annually and following unseasonal heavy rainfall periods
KP 39.8	bridge	Avulsion	• Crossing over an active floodplain. • Thoroughly armor foundations • Armor existing main channel to manage and contain flows • Installation of overflow culverts as required. • Design final road elevation to avoid large damming/back-up of head water • Monitoring annually and following unseasonal heavy rainfall periods
KP 124.8	bridge	Avulsion	• Crossing over an active floodplain. Large, single span bridge over single, defined channel • Thoroughly armor foundations • Armor existing main channel to manage and contain flows • Installation of overflow culverts as required. • Design final road elevation to avoid large damming/back-up of head water • Monitoring annually and following unseasonal heavy rainfall periods
KP 89.8	bridge	Avulsion Woody Log Debris	• Large, single span bridge over single, defined channel. May experience high water levels during spring runoff, flooding larger footprint. • Thoroughly armor foundations • Armor existing main channel to manage and contain flows • Installation of overflow culverts as required. • Design final road elevation to avoid large damming/back-up of head water • Monitoring annually and following unseasonal heavy rainfall periods
KP 118.1*	large	Avulsion	• Braided, multiple channels on 70 m floodplain only active during heavy runoff periods.

Figure 16 Moderate probability avulsions and low to moderate probability avulsions and woody log debris.

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Major Crossing Location	Structure Type	Associated Risk	Description/Mitigation:
	multiple culverts	Ice Jams	• Armor existing braided channel and direct waterflows into selected, defined channels • Thoroughly armor/rip rap inlet/outlets • Design final road elevation to avoid large damming/back-up of head water • Monitoring annually and following unseasonal heavy rainfall periods • Periodic maintenance of road structure
KP 53.7	bridge	Avulsion	• Structure to span active, defined channel. High water levels possible during heavy runoff, flooding larger footprint • Thoroughly armor foundations • Armor existing main channel to manage and contain flows • Installation of overflow culverts as required. • Monitoring annually and following unseasonal heavy rainfall periods
KP 20.3*	Large multiple culverts	Avulsion	• Stable channel. • Thoroughly armor/rip rap inlet/outlets • Armor existing main channel to manage and contain flows • Monitoring annually and following unseasonal heavy rainfall periods
KP 43.4*	Large multiple culverts	Avulsion	• Stable channel. • Thoroughly armor/rip rap inlet/outlets • Armor existing main channel to manage and contain flows • Monitoring annually and following unseasonal heavy rainfall periods
KP 87.4	bridge	Avulsion	• Structure to span active, defined channel. High water levels outside active channel possible but low probability • Thoroughly armor foundations • Armor existing main channel to manage and contain flows • Installation of overflow culverts as required. • Monitoring annually and following unseasonal heavy rainfall periods
KP 151.3	large culvert	Avulsion	• Single, defined and contained channel which experiences significant water flow during spring thaw and unseasonal heavy rainfall periods. • Thoroughly armor inlet/outlets • Armor existing main channel • Monitoring annually and following unseasonal heavy rainfall periods
KP 123.3	bridge	Avulsion	• Shallow gradient, slow moving, stable channel. • Thoroughly armor foundations • Armor existing main channel to manage and contain flows • Monitoring annually and following unseasonal heavy rainfall periods
KP 122.3	bridge		• Shallow gradient, slow moving, stable channel. • Thoroughly armor inlet/outlets • Monitoring annually and following unseasonal heavy rainfall

Figure 17A Low to moderate probability ice jams and avulsions and low probability avulsions.

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Major Crossing Location	Structure Type	Associated Risk	Description/Mitigation:
			periods
KP 95.0*	large multiple culverts		• Shallow gradient, slow moving, stable channel. • Thoroughly armor inlet/outlets • Monitoring annually and following unseasonal heavy rainfall periods
KP 111.7*	large multiple culverts		• Shallow gradient, slow moving, stable channel. • Thoroughly armor inlet/outlets • Monitoring annually and following unseasonal heavy rainfall periods
KP 23.5*	bridge		• Structure and foundation located above/outside deep canyon stream channel on suspected bedrock. • Monitoring annually and following unseasonal heavy rainfall periods
KP 25.3*	bridge		• Structure and foundation located above/outside deep canyon stream channel on suspected bedrock. • Monitoring annually and following unseasonal heavy rainfall periods
Moderate		Moderate probability of risk related to environmental factors such as avulsion occurring on road structure which will require additional road or structural maintenance to ensure safe and reliable operations. An increased frequency of monitoring will be implemented.	
Low to Moderate		Low to moderate probability of risk related to environmental factors such as avulsion occurring on road structure. May require additional road or structural maintenance to ensure safe and reliable operations.	
Low		Low probability of risk related to environmental factors such as avulsion occurring on road structure. Expect standard road or structural maintenance to ensure safe and reliable operations.	

* Not fish-bearing

Figure 17B Low probability avulsions and bridge/culverts.

Given the traffic assumptions described earlier, the proposed measures and proposed monitoring we consider extremely unlikely (beyond present credibility) that under these conditions, any of the heavy traffic considered in this report would be involved in an accident due to creek avulsion. Maintenance workers, lighter vehicles may be exposed, especially in case of bravado (based on several experiences world-wide). Of course if "normalization of deviance" (See Appendix 1 for a definition) would occur over time, then the situation could be different. Avulsions could also trigger geohazards that have not been detected to date.

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4.5 Landslides Hazard

4.5.1 Review

This study scope covers moderate, high, very high rated landslide hazards as defined in extant documents[54] plus a series of potentially accident generating natural and road (man-made) hazards that will be discussed in later sections.

The Mackenzie Valley Review Board (MVRB) requested[55] a desktop magnitude/ frequency assessment for landslides along the proposed alignment. The purpose of the magnitude/ frequency analysis was to provide a preliminary assessment of the susceptibility of the proposed road to landslides hazards along the proposed route alignment, including one alternate route alignment.

A previous qualitative risk analysis for landslides and ground movement was presented as part of Table 7.2.2-1 in the geotechnical report for the route[56] which defined the following classes of probability that at least one landslide event will occur within the assumed 20-year design life of the road (Table 10).

Classes of probability that at least one landslide event will occur within the assumed 20-year design life of the road (following references above).		
> 33%	8% to 33%	< 8%

Table 10 extracted from Table 7.2.2-1 in the geotechnical report for the route.

It is important to understand that the numbers in Table 10 give the probability of at least one event, but 2,3,...n events would also be possible. It is a common misunderstanding to think that this type of definition leads to only one possible occurrence[57].

After adjusting the life to 17 years and using appropriate mathematics (Poisson function) for "potentially recurring" natural hazards, we can evaluate the following:

54 TetraTech_Risk analysis -landslide hazards_4May2016.pdf, Table y

55 Section 5.3 of the December 21, 2015 document titled "Reasons for Decision of the Adequacy of the Developer's Assessment Report

56 Geotechnical Evaluation and Developer's Assessment Report Sections for Proposed Prairie Creek All-Season Road, Near Nahanni Butte, Northwest Territories. Prepared for Canadian Zinc Corporation. March 2015. Tetra Tech EBA File: Y14103320.01-001

57 For example a flood return time of 100 years does not mean at all that one event will occur every hundred years, but that the flooding will occur on average every hundred years. Two or more floodings could occur "next year"!

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probability to see at least 1 event at 8% over 17 years means approximately:

P of 1 event = 0.077

P of 2 events =0.003

Thus, over 17 years, the probability to see up to 2 events is indeed 8%.

Probability to see at least 1 event at 33% over 17 years means approximately:

P of 1 event = 0.26

P of 2 events =0.05

P of 3 events =0.007

P of 4 events =0.0007

Thus, over 17 years, the probability to see up to 2 events is 31% and the probability to see up to 4 events is (sum of the probabilities) 32%.

Table 11 from the same referenced document deliver other parameters of the studied hazards

Magnitude Rating	Area affected (ha)	Minimum volume involved (m3)
Very Large	> 2.5	> 25,000
Large	0.5 to 2.5	5,000 – 25,000
Medium	0.05 to 0.5	500 – 5,000
Small	< 0.05	<500

Velocity Proxy[58] Classes		
< 1.5 m/year	1.5 m/year to 2 m/h	> 2 m/h

Deposition vs. Scouring Proxy		
Low	Medium	High

Table 11 other parameters used in extant geohazards studies. We note that small volume (say 1m^3), high energy rockfall events (say 60km/h or more) cannot be properly accounted for because of the volume/velocity threshold values adopted.

58 Definition of proxy in the extant report: a figure (combining, for example various parameters) that can be used to represent the value of another parameter in a "proxy based" calculation.

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The referenced documents also mention other slope-hydro-related hazards, such as:

- Debris flows
- Minor rockfalls
- Debris slides
- Thaw flow slides
- Large rotational to translational slides or slumps in bedrock
- Earth slump/flows
- Three colluvial cones with potential for rock slide and debris flow material

The description of some of the phenomena follows in this sections (Table 12, 13) and more details are displayed in Appendix 2 in the column "Notes".

Start	Finish	Rating
0	0.4	Moderate
16.3	17	Moderate
25.5	26.6	Moderate
26.2	26.3	High
27.2	27.4	Very High
28.1	28.4	High
29	29.2	Moderate
30.6	30.8	Moderate
30.8	31.2	Moderate
31.2	31.8	Moderate
32.5	36.2	Moderate
42.9	43.3	Moderate
46.8	48.4	Moderate
49.7	50	Very High
53.7	54.2	High
54.5	57.6	Moderate
59.7	60.4	High
61.4	61.5	Moderate
83.5	85.5	High
?	?	Moderate
95.5	101.7	High
Alt	route	
111.8	113.1	Moderate
Original	route	
110.2	115.1	Moderate
136.4	137.3	High
154.5	155.3	High
155.9	159.3	Very High

Table 12 List of Moderate, High, Very High natural hazard road segments as defined in TetraTech_Risk analysis -landslide hazards_4May2016.pdf

We noted in Table 11 that the thresholds adopted in the study do not explicitly cover potentially extremely disruptive events characterized by small volume, high velocity

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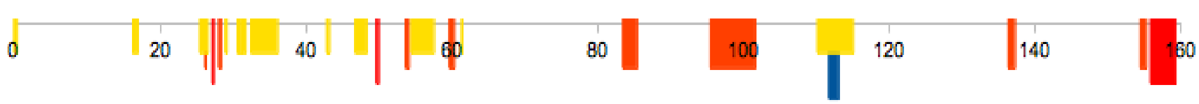
(hence high energy), capable of severely damaging the road surface or push a concentrate truck off road (or generating highly undesirable effects on the drivers).

Table 12 can be summarized graphically as in the Figure 18 below.



Legend:

- Yellow: segments ranked as moderate risk
- Orange: segment ranked as high risk
- Red: segment ranked as very high risk
- Blue: segment of the alternative road ranked as moderate risk

Figure 18 Graphic summary of the landslide hazardous sectors described in Table 12.

4.5.2 Summary of landslides hazard

Finally, after reviewing the oblique photos, extant information Table 13 was compiled. The large majority of the Moderate, High, Very high landslide hazards are located outside of segments documented with Stratification drawings (on a total of 26 considered hazards only 10 fall within Stratification drawings). Using extant documents[59] it was possible to allot a Stratification type to each hazard in Table 13.

Construction Stratification Type	Extant Landslide Hazard list			Notes from cross sections and oblique photos
	km Start	km Finish	Rating	
I	0	0.4	Moderate	
II	16.3	17	Moderate	
III	25.5	26.6	Moderate	Below road
III	25.5	26.6	Moderate	

59 EA1415-01_Appendix_1_A.PDF

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Construction Stratification Type	Extant Landslide Hazard list			Notes from cross sections and oblique photos
	km Start	km Finish	Rating	
III	26.2	26.3	High	
III	27.2	27.4	Very High	
N/A	28.1	28.4	High	
II	29	29.2	Moderate	
IV	30.6	30.8	Moderate	Debris fan
IV	30.8	31.2	Moderate	
IV, N/A	32.5	36.2	Moderate	Scree face
IV, N/A	32.5	36.2	Moderate	High cuts slopes
VI	42.9	43.3	Moderate	Cliffs...
VI	46.8	48.4	Moderate	
VII	49.7	50	Very High	Debris slide
VII, VIII	53.7	54.2	High	
VII	54.5	57.6	Moderate	
VI	59.7	60.4	High	
VI	61.4	61.5	Moderate	
VII	83.5	85.5	High	Debris slide
VII	83.5	85.5	High	
	?	?	Moderate	
X	95.5	101.7	High	Slump in bedrock
X	95.5	101.7	High	
	Alt	route		
VII	111.8	113.1	Moderate	
	Original	route		
VII	110.2	115.1	Moderate	
	Original	route		

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Construction Stratification Type	Extant Landslide Hazard list			Notes from cross sections and oblique photos
	km Start	km Finish	Rating	
VII	136.4	137.3	High	
	Original	route		
IX	154.5	155.3	High	
IX	155.9	159.3	Very High	

Table 13 Merger of extant data displaying the Construction Stratification Type and the extant record of Moderate, High, Very high landslide hazards.

The latest version of the hazard mapping (October 24th) has added some details, but reportedly does not alter the conclusions reached by CNZ in prior studies.

4.6 Man-made cuts related hazards

The Stratifications drawing display areas where man-made cuts will be necessary to allow for the road passage. Extant documents[60] also show that gabions are considered as stabilizing elements for areas where their construction is feasible.

Based on experience on this type of roads and mountainous terrain, the occurrence of rockfall (relatively small volumes), possibly high velocity from man-made cuts of a variety of heights is possible and rather frequent.

Rockfalls of this type can provoke accidents. That is the reason why many roads have uphill cuts protected by nets and in some cases rockfall fences.

It is our understanding that CNZ will ensure safety by designing the appropriate protections and monitoring them, having skilled personnel perform inspections prior to concentrate shipments and, in particular, after severe meteorological events.

60 project_document/EA1415-01_CanZinc_responses_to_outstanding_adequacy_items.PDF, figure 1

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4.7 Seismic hazard

The 1985 Nahanni earthquakes is the name for a continuous sequence of earthquakes that began in 1985 in the Nahanni region of the Northwest Territories, Canada. The largest of these earthquakes occurred on December 23, reaching 6.9 magnitude. It was one of the most significant earthquakes in Canada during the 20th century.

The earthquakes had a long succession of aftershocks and jolts. The earthquakes amazed both the general public and the earth science community as they were felt in the Yukon, Alberta, Saskatchewan, British Columbia, and southeastern Alaska.

Just for the sake of comparison, the recent quake swarm in Italy, which started with a 6.6 event, has damaged roads (in some cases with full width loss), power towers, earth retaining and rockfall protection structures, water distribution lines, and a major dormant landslide has been reactivated.

However no vehicle has performed any off road excursion due to the quake(s), in the densely trafficked mountainous areas.

Undertaking #43 from the tech sessions asked for return periods of earthquakes of similar magnitude to 1985 and 1987. The July 3 response listed the events but did not provide the return period. In Undertaking #42 Canzinc stated that a *total of 12 events of 4.0 magnitude or higher have occurred within a 200 kilometer radius of the Prairie Creek Mine site at 61°.33 latitude, 124°.48 longitude. This data is generated from the Natural Resources Earthquake Database (http://www.earthquakescanada.nrcan.gc.ca/). Most events occurred north of the Prairie Creek Mine and access road*

CanZinc confirmed (Oct.24th) that *in the region of the project, earthquakes with a magnitude of 6 to 7 have a return frequency of approximately 10 years. It is therefore conceivable that a large landslide could be triggered by an earthquake in the project area during its design-life.*

Canzinc also expressed the opinion (October 24th) that *the above has already essentially been addressed in the Road Operations Plan (Section 6) and Road Construction and Maintenance Plan (Section 8) (which can be found in PR#101 Appendix C) with respect to rockfall and avalanches, which by extension covers earthquake - triggered landslides, but we will make this clearer in subsequent drafts of these plans.*

It is our understanding that in case of a seismic event careful inspection of the slopes and infrastructure will be undertaken before traffic is restored.

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5. Risk Analysis

A systematic approach to risk considerations in decision-making and management support is paramount especially when various layers of uncertainties surround alternatives, projects, operations, because decision-makers need to understand the:

- assumptions made, so that evaluations can be discussed, audited,
- uncertainties surrounding the decision/project including systemic failures,
- probabilistic future behaviour (evolution)
- benefits of updating risk information during the life cycle of the system,
- benefits of a scalable (from "high level" to detailed operational, no information wasted) risk analysis system.

In general approaches should cover:

- physical losses (human and assets)
- business interruption (BI)
- environmental damages
- reputational damages and crisis potential.

In order to carry out this study, in compliance with the SoW, Riskope developed a Step by Step Quantitative Risk Assessment Framework (QRAF) approach which lead to the deployment of a customized deployment of ORE (Optimum Risk Estimates ©Oboni Riskope Associates Inc.).

The results covering the SoW requirements are delivered as series of graphic representation (dashboards) and related verbiage.

Consequences were analyzed using a multidimensional rule:

- cargo type,
- likely energy (is the vehicle undergoing an off road excursion going to gain energy due to slope/free-fall),
- Sensitive environment,
- Difficult recovery conditions.

This lead to the definition of 9 Consequences classes in Section 6. These are applicable to any type of accident, whether a traffic mishap (accident type a), or generated by a hazard (accident type b,c).

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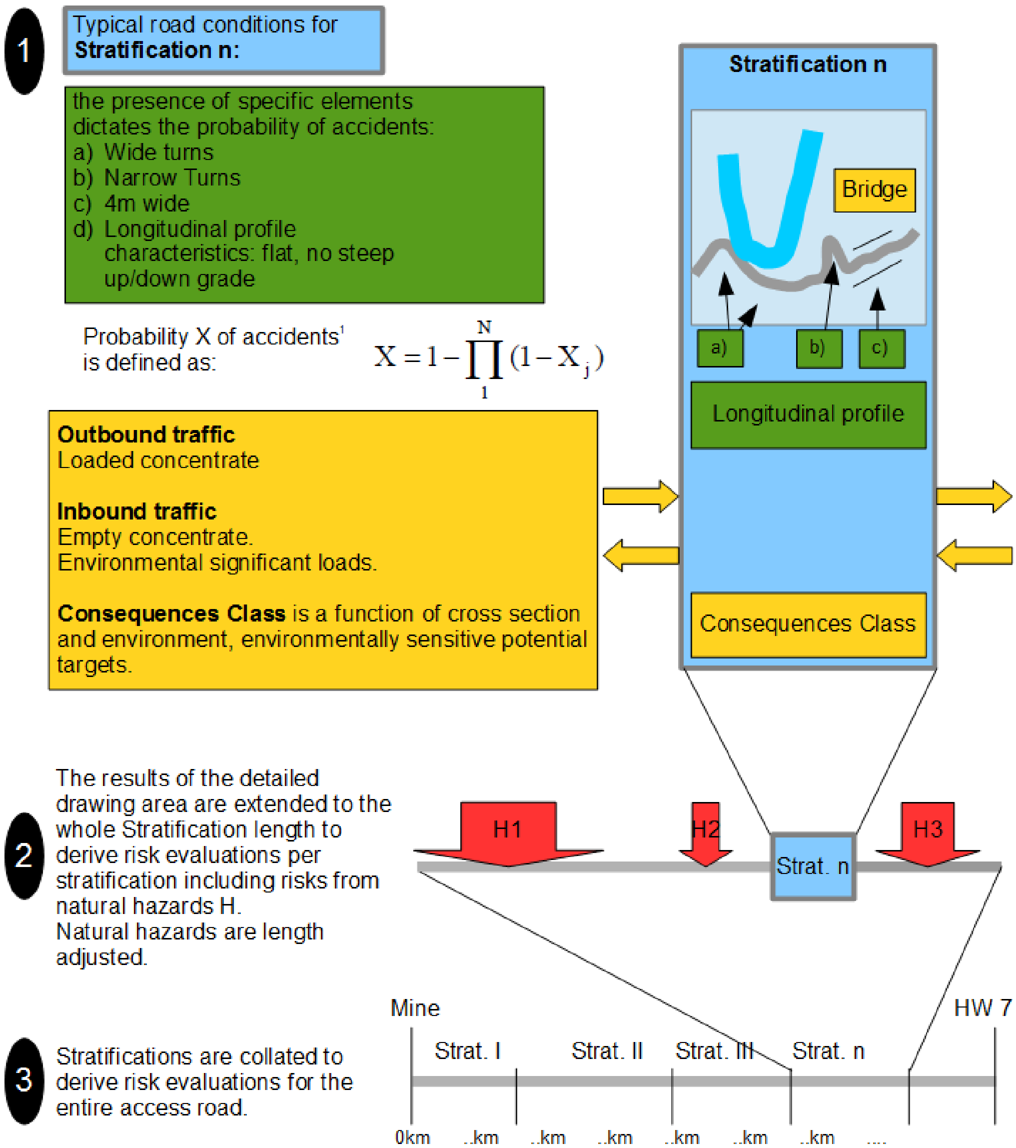

Probability of accidents[1]:
Ang, A. H-S., Tang, W. H., Probability Concepts in Engineering Planning and Design, 34 Vol. I, Wiley, United States, 1975.
Ang, A. H-S., Tang, W. H., Probability Concepts in Engineering Planning and Design, 2 Vol. II, Wiley, United States, 1984.
Oboni, F.,Ten Years Experience in Linear Facilities Risk Assessment (LFRA), San Francisco ICASP9, 2003

Figure 19 The three phases used to derive risk evaluations for the entire road.

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Probabilities were derived using extant documents (for hazards like avalanches, landslides) and experience (for traffic), as shown in Section 7. In order enhance understanding of the report by non technical readers, probabilities have been converted in number of accidents of the service life of the road.

Natural hazards have been studied using their length, as the length influences the expected exposure in case of type b accidents.

Customization included developing a project-specific accident tolerance proposal that was used to understand CNZ accident tolerance goals and expectations (Question 8 of IR#2). This development is reported in Section 8.

Under those conditions risk is expressed by “number of accidents (off road)” of a “certain type of cargo” in an area with “certain Consequences class” as shown in Section 9.

Figure 19 shows diagrammatically how the risk evaluations were carried out, from the detailed Stratification drawing (Phase 1), to the entire extent of each Stratification (Phase 2), and then, by collating the Stratifications, extended to the entire road (Phase 3).

This procedure is justified by the assertion made by CNZ that the Stratification drawings are representative of the entire length of each Stratification as we will discuss in Section and later.

6. Consequence analysis

6.1 CNZ spill evaluations discussion

As mentioned earlier in Undertaking 46 CNZ[61] stated that *if concentrates are hauled in bags, they will be 3 tonne bags tied-down inside a truck box which will have a lockable solid lid. In the event of an accident and truck overturn, the bags are likely to remain attached within the trailers. However, one may become detached and split, and in a worst case, several could split. Reasonable and worst case spilled quantities are assumed to be 2 and 8 tonnes, respectively. If concentrates are hauled in bulk, they will be in containerized trailers, two per vehicle, also with lockable lids. Each truck load would be approximately 40 tonnes. In the event of a spill, reasonable and worst case spilled quantities are assumed to be 5 and 20 tonnes, respectively.* When asked about the

61 EA1415-01_Letter_to_MVEIRB_re_Undertakings_from_Technical_Session_Aug_11__2016.PDF

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rationale behind such estimates Allnorth[62] replied that *the estimated spill volumes provided in our reply to Undertaking 46 were based on logical intuition***.** *In the case of bulk concentrate transport and a 40 tonne load, in the event of over-turn, it is considered unlikely that the full load would be spilt. More likely the spill would be small (5t) or up to half of the load (20t). Similarly, with bagged concentrate, it is considered more likely that detached bags would not split, but if they did, they would likely only loose a portion of the contents, hence the 2-8t range to account for a varying number of split bags and portion of contents spilt.*

Due to the road topographic environment, concentrate trucks will assume, even if travelling at the speed indicated by CNZ, high kinetic energy, especially if they undergo off-road excursions. Based on Alberta's statistics 1/3 of trucks accidents include such an excursion, and considering the narrow roadbase, that estimate may be low. Nevertheless we will use that value in this report. “Logical intuition” generally falters under dynamic conditions and extreme cold temperatures, when any material becomes stiffer and brittle. The presence of numerous watercourses, environmentally sensitive areas, together with the time (and difficulties) required for retrieving any spilled material should incite prudence and discourage “rosy scenarios”.

The same applies to other cargo of environmental significance and even to the diesel tank and other service fluids (e.g. Hydraulic oil) on empty concentrate trucks in the inbound trip, in case of an accident. CNZ stated: *Spill quantities were provided for those cargos of environmental significance with a sizable number of loads and relatively large container size (see Table 9-1 in the DAR). Lubricating oils and greases will also be transported, but these will be in small containers (50-200L) and the loads will be few. Mill and water treatment reagents (soda ash, copper sulphate, sodium sulphide, ferric sulphate, lime) and ammonium nitrate will be transported in 1t sacks. The number of loads/annum will be small (21 or less). These sacks, like those for concentrate (*assumption again*), are unlikely to split in the event of a roll-over. However, in the event they did split, a spill range of 1-3t could be an appropriate assumption (*assumption again*) to cover the number of bags and proportion of contents spilt.*

Nevertheless CNZ also stated that *the evaluations are considered valid for fair to moderate slopes below the road, and irrespective of the length a truck may slide downslope* (this seems again a very rosy assumption, disproved by many road accidents in mountainous terrain observed by Riskope*).*
One section of the road has slightly steeper slopes, from Km 13.4 to 14.9. The Km 13.4-13.6 section has a steep slope below, and a truck leaving the road here would likely rollover. The Km 13.6-14.9 section has a slope of about 25%, right at the boundary

62 Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 10a,b,c of October 7th and 11th.

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between a moderate and steep slope. A rollover here is considered unlikely, although a truck may slide further downslope. However, note that this road section is essentially straight, and therefore departure from the road is unlikely.

In this study we will consider CNZ spill estimates as a lower bound, especially in areas along watercourses, creek beds, and other sensitive environmental areas where retrieval of any spilled material, and the vehicle, may be difficult (cross slope, vertical drop-off) and containment may be problematic.

6.2 Operational experience

6.2.1 Wolverine Mine

During the preparation of the study we were able to consult the Wolverine Mine 2014 report. Wolverine is a similar size to CanZinc, produces Pb/Zn concentrate and transports it through mountains (mine is presently closed).

In the report's “Chapter 6 Environmental Incidents” we noticed four reportable spills (defined by the Yukon Spills Regulations as “a release of a hazardous substance to the environment in quantities above the spill reporting thresholds, or any amount of spill onto a watercourse”) and one unauthorized discharges in 2014 (Table 6-1). Of those two had to do with concentrate haul trucks as follows:

14-May-14 ~4.04 wmt of Cu Concentrate Haul truck fell off road losing 2 bags of concentrate Initial Report: 25-May-14 Follow-up Report: 30-Jun-14

10-Oct-14 ~7.3 wmt of Zn Concentrate Haul truck fell off road decanting Zn concentrate went tipped over on side Initial Report: 13-Oct-14

The term “fell off the road” does not allow any precise understanding of the dynamic of the accidents or the resting position of the vehicle, no details were given on the state of the bags or their retrieval. We do not know anything about the topography at the accident scene, or the causes of these accidents that occurred mid May and mid October. The same applies to the phrase “Zn concentrate went tipped over on side”.

These accidents seem however to correspond to CNZ ideas of what typical accidents would be along the road (See Section 6.1). If two occurrences of this type would occur on average (there is no way to state with any certainty that this would be the case) then Prairie Creek road could see 32 such accidents over its the service life. These accidents were certainly not the worst case scenario, and, at the other end of the spectrum, it is reasonable to believe that many more accidents occurred of lesser consequence (non reportable accidents in the Yukon).

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6.2.2 Canadian North

Highly experienced personnel who have overseen transportation on haulage roads in Northern Canada were interviewed. They highlighted the fact that with the foreseen road width and the lack of berms, any driver error, sudden trajectory alteration, even at low speeds would result in a vehicle off-road excursion.

Provided the embankment slope is sufficient roll-overs are possible. They stressed the scenarios of vehicles losing traction while driving uphill and backing in an uncontrollable way leading, in the case of bi-articulated 8-9 axle configuration to possible “pile-up”on but more likely partially or entirely out of the road.

6.2.3 Other mountainous access roads

Figures 20, 21 display pictures from an accident involving a 40tonnes Sulphuric acid tanker.

Figure 20 This acid tanker (only the tractor is visible) overturned (a few minutes before the picture) against the uphill slope. Notice that traffic is possible before removal because the road is wide enough. The spill in front is from the fuel tank that did not rupture but started leaking immediately. No acid was spilled (this time) because the tank featured a last generation protected dome.

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Figure 21 This full acid tanker overturned against the hill. Driver was killed on the spot in the crushed cabin.

It is remarkable to notice the vehicle overturned against the uphill side of the road, likely because of fatigue and human error, in a relatively easy stretch of the road in terms of width (over 6 m), longitudinal profile, curves and atmospheric conditions. Vehicles do not need extreme topographic features to overturn or roll-over.

6.3 Environmental consequences

Park Canada[63] stated that without the appropriate level of baseline information on wildlife and vegetation it is impossible for Parks Canada to identify all areas adjacent to the all season road that would be most sensitive to a spill. In the absence of detailed and up to date baseline information, extant knowledge base was used to identify four reaches along the all season road reportedly of high biological value and likely highly sensitive to spills:

- The areas of Karst Terrain (approximately km 53-64). Spills in this area could be extremely difficult to contain and clean up due to the extensive underground drainage.

63 Park canada answered # 16 http://reviewboard.ca/upload/project_document/EA1415-01_GoC_Undertakings_Responses_-_tech_session.PDF

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- The Tetcela (— km 84) and Fishtrap (—km 95) drainages. These areas are sensitive due to easy transport of any spill and are also part of a 'Key Migratory Bird Terrestrial Habitat Site'. There is the potential for both Swan breeding and the presence of Yellow Rail, but not surveyed.
- Sundog Creek between km 25 and km 32 has an Arctic Grayling population which is greatly restricted in seasonal movements, as there is a waterfall above, and the creek below flows underground for much of the year. A serious spill in this area could potentially wipe out the entire local population.
- A spill between km17-40 may also have downstream impacts on a resident caribou population.

Based on the paucity of extant data related to highly sensitive potential spill areas this study assumes that higher consequences will occur as a result of accidents featuring at least one of the following characteristics:

a) relative higher energy (careening over higher/ steeper natural or man-made slopes, faster driving, etc. as defined below)
b) potential larger spread of contaminants
c) relative increased difficulties in recovery of pollutants.

The consequences will be cumulative in the sense that a possible spill at a given location where more than one characteristic is present will lead to higher consequences than another location where only one characteristic is present.

Concentrate loads, environmental significant loads and empties with diesel tank only will be considered separately, as their consequences are different from an environmental point of view.

Because of Parks Canada statement and the point b,c above, we assume the difficulty to clean up a potential spill being equal for water bodies and karst.

In the definition of the spill magnitude, the time necessary to react, contain and return to prior conditions should be considered, as a relatively small spill in a remote section of the road would have larger environmental consequences than the same spill occurring nearby a rescue/emergency station because of the time required to react; a relatively small spill in a water course will also have relative higher consequences etc. CNZ have stated and explained that the “reaction time” would be identical at any road location, due to the presence of numerous maintenance crews and other vehicles. In their October 7th/11th reply to questions 14a,14b they stated: ***14a:*** *If a truck has a problem, the next truck arriving at the location immediately becomes a responder, as does the next truck, as necessary. A response would be mounted immediately, as well as notifying 'Control' of*

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the event. If a response team is needed, they will immediately depart. Control will then direct trucks on the road to proceed to a turn-out, or advance beyond the incident location, so as not to block the response team. We believe a 40 km/hr response team speed is more than realistic because they will be in a medium duty truck with a limited payload.
14b: *Given other truck traffic on the road, including maintenance crews and monitors, response time will likely be much less than 2h15. For the arrival of a response team, we would expect this to occur within 3 hours, likely much less, because an incident is more likely to occur closer to a team location than the 90 km maximum. A response vehicle and equipment would be ready, and the team would depart minutes after receiving notice by radio to do so. If haul operations were occurring, it is safe to assume that conditions are suitable for a response team to respond in a timely manner. Note, the declared average speed is for laden trucks, not a response team in a lighter vehicle.*

Some accidental scenarios, especially in difficult cross sections, under adverse conditions and with the road occupied by other vehicles may require means and actions that overcome the capabilities of a rescue team in a medium duty truck with a limited payload. This will be included in the definition of the consequences that will be developed later in this section.

6.4 Vehicle consequences

As mentioned earlier, trucks' mass is so significant that even at low speed (30km/hr) the kinetic energy is comparable to very damaging rockfalls or higher than, for example, the high energy levels used in cars' crash tests. A truck "falling" (sliding or rolling) on the downstream slope of the road or off an almost vertical slope, or off a bridge will acquire even further energy. These three scenarios are present along the proposed road.

Three tons concentrate bags inside a box would receive very significant dynamic stresses and we have seen to date no proof that they would actually resist, also considering the brittle conditions due to below freezing conditions. There is no proof that their attachments would resist either. Bulk transport covered with a tarp (reportedly Red Dog style) would also be subject to those energies and accelerations.

Of course there will also be less critical accidents, on flat terrain, hopefully at low speed. However, skilled truck drivers interviewed during the development of this study have confirmed it is rare to see a truck accident where the truck does not turn on its side or capsizes. Drivers with no belts are most likely ejected even if the truck turns sideways at minimal speed. Depending on the dynamic of the accident drivers are often hurt in this type of accident, or killed (Figures 20,21).

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If traction is insufficient in a grade, an ascending truck can slide back, trailers going sideways, thus it is likely cargo will be lost/spilled. The same concept applies to driving downhill.

Unchained vehicles and trailers can slide sideways simply because of road transversal slope, as mentioned earlier.

Finally, because of the narrow road base, it is likely the vehicle will experience a total or partial off road excursion and its damaging results described above.

6.5 Consequences classes

Table 14 below discusses classes of consequences (not the probability) of accidents based on geometric criteria (at a given location consequences will also be a function of the hauled material, but that dimension will be considered later). Thus road curvature, longitudinal convexity & concavity, visibility, rockfalls, landslides and other hazards which contribute to the probability of accident are not included. All that matters is:

- how far the vehicles may “fall”,
- if there is water/sensitive areas nearby in compliance to the a,b,c criteria described above and
- how difficult it may be to retrieve the spilled material due to the cross slope.

Given the descriptions in Table 14, this report considers accidents of Class 1-2 as minor, Class 3 as moderate, Class 4-5 as significant, Class 6 as serious and Class 7-9 as very serious. Driver or “bypassers” could be harmed in all classes of accidents, this not being a specific feature of this road, but a general consideration in accidents involving heavy vehicles. Cargo types will be considered separately.

Based on the data described earlier in this report and in Table 14, Table 15 and 16 link the consequence classes to the design Stratifications and the geographic areas (location) they cross.

When preparing Table 15 it was possible to match the Stratification drawings with the Consequences Classes for those specific segments of the alignment. The column Comments of Table 15 gives the main elements which were considered in the Consequences allotment, including the considerations of Section 6.3.

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Road and Environment features are:		Comments
ENVIRONMENTALLY SENSITIVE TARGETS	DOMINANT CROSS SECTION/ TERRAIN (Downhill of road) SLOPE	CARGO OR DIESEL FUEL COULD:
NOT IN POTENTIAL REACH	Fair with fill less than 3m high	be easily contained and recovered **Class 1**
	Moderate with fill less than 2m high	be contained and recovered with some effort **Class 2**
	Significant even if fill height less than 1m	be contained and recovered with greater effort **Class 3**
WITHN REACH Intersect environ-mentally sensitive target Or Contain-ment and recovery require specific salvage equipment	Fair with fill less than 3m high	be contained and recovered **Class 4**
	Moderate with fill less than 2m high	be contained and recovered in difficult conditions **Class 5**
	Significant even if fill height less than 1m	be contained and recovered in very difficult conditions **Class 6**
BRIDGE/WALL PRESENT		
WITHIN IMME DIATE REACH Intersect the environmentally sensitive target. Containment and recovery require specific salvage equipment	Low Bridge/ culvert/wall (less than 2m from bottom)	be contained and recovered **Class 7**
	Moderate high bridge/culver t/wall (2-3m from bottom)	be contained and recovered in difficult conditions **Class 8**
	Higher bridge/culver t/wall (more than 3m from bottom)	be contained and recovered in very difficult conditions **Class 9**

Table 14 Consequence classes.

Among the elements noted in the Comments the following are particularly interesting:

- adjacent creeks, creek beds,
- bridges and culverts,
- possible presence of wildlife (Caribou)
- karst terrain,
- sensitive drainages

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as they cover specific requests formulated in Riskope's SoW.

Construction Stratification Type	from km	to km	Length km	Comments	Consequence Class
I	**5.14**	**6.26**	1.12	Embankment typical <2m locally 4m Prairie Creek in locally in close proximity, but terrain is fair	Class 4
II	**7**	**8**	1	Embankment typical <2m Prairie & Funeral Creek adjacent to the road	Class 4
?	**13**	**13.76**	0.76	Embankment locally at 6m Significant down slopes Small creek is present	Class 6 & 7 at culvert
?	**23**	**23.7**	0.7	Locally "U" section Significant down slopes River and bridge, Caribou & Arctic Grayling	Class 6 & 9 at bridge
III	**25**	**26**	1	Significant down slopes Creek and bridge, Caribou & Arctic Grayling	Class 2 & 9 at bridge
IV	**30**	**31**	1	Fair terrain and minimal embankment watercourse is distant, Caribou & Arctic Grayling	Class 1 Class 2
?	**33.2**	**34.2**	1	2-4m embankment fair terrain, Sundog plain, Caribou	Class 4
?	**34.8**	**39**	4.2	2-4m embankments or even less, moderate down slopes, Sundog Creek, Caribou	Class 4, 5 & 9
VI	**44**	**45**	1	Fair conditions	Class 1
VII	**49**	**51.5**	2.5	Locally 3-5m embankments fair down slopes small creek, sensitive drainages & wildlife	Class 1 & 4 (nearby the creek)
VIII	**52**	**53**	1	Fair down slopes	Class 1 & 4

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Construction Stratification Type	from km	to km	Length km	Comments	Consequence Class
				small creeks some Karst terrain (53-64)	(nearby the creek) Class 5
V	**88**	**89**	1	84 -95 sensitive drainages & wildlife Embankments <2m fair down slopes creek nearby	Class 7 Class 1 & 4 (nearby the creek)
X	**98.5**	**99.5**	1		Class 1 & 2
?	**122.7**	**123.4**	0.7		Class 1 & 7 at the bridge
IX	**147**	**149**	2		Class 1

Table 15 This table links the Stratifications the Consequence classes

In order to allow for the extension of the areas discussed in Table 15 to the respective entire Stratification length (Phase 2 of Figure 19), as displayed in Table 16, the fragmentation of the Stratifications has to be considered.

Some Stratifications (for example 5-8) are indeed fragmented in segments that are sometimes less than one kilometre long and span over karst and other environmentally sensitive areas.

This leads to the need to carefully compare the segments with the sensitive areas locations prior to allotting Consequences Classes.

The results are displayed in Table 16.

Stratification type	Length (km)	Length (alt) (km))	Allnorth comments on down slopes	Riskope comments	Consequence Class
1	6.5	6.5		Bridge	4 & 8
2	16.7	16.7		Bridge, Caribou	4 & 7
3	3.8	3.8	Up to 50%	Bridge, Caribou,	2 & 9

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Stratification type	Length (km)	Length (alt) (km))	Allnorth comments on down slopes	Riskope comments	Consequence Class
				Arctic Grayling	
4	6.3	5.6	Up to 10%	Bridge, Caribou, Arctic Grayling	1, 2 & 7
5	4.0	4.0	Up to 30%	Creek, sensitive drainages, etc.	1, 4 & 7
6	27.2	27.2	Up to 30%	Karst (53-64)	1 & 4
7	58.7	56.4	Up to 30%	Creeks, drainages and karst (53-64)	1, 4 & 7
8	6.0	6.0		Creeks, drainages and marginally kast	1, 4, 5 & 7
9	29.3	29.3	Up to 30%		1
10	6.2	6.2		Local high embankments	1 & 2
N/A	7.7	7.4		Creeks	1,4,5,6,7 & 9
N/A	10.0	10.0			
Liard R.	0.6	0.6			N/A

Table 16 Allotment of lengths to the various Stratifications (Allnorth Table 5) and their relationship with consequences classes.

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7. Probability analysis

7.1 Operational experience

During the development of this study we interviewed highly experienced personnel with a professional life devoted to mining transportation of concentrate, encompassing, of course the Canadian North.

The following is a summary of the statements offered by these individuals:

- Traction is a major problem: contrary to common belief heavy concentrate vehicles can slide, U-turn, slip backward on hazardous surfaces, which may lead to off-road excursions or collisions (Figure 22). The problem is more acute in winter and at high speed (above 40km/hr). On Alberta Hy63 (Supercast hill) “every winter, numerous trucks” slip backward on a 7% grade when temperatures are low.
- Low temperatures tend to annihilate the effect of any tire (as they harden at low temperatures).
- Chaining up can somewhat mitigate the situation but it can create ruts on the road surface which create the need for additional maintenance to avoid scouring.

Figure 22 Trailer tanker lost adherence and started slipping back on access road. Grader came in to help as it was performing maintenance. Road was blocked for more than one hour. Note the road width (approx. 8 m). Left side is indicated by a red/white vertical signal, a small protective berm is present on the shoulders, both sides.

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- At the end the root causes of accidents are most often fatigue & human error, inexperience, bravado (incidentally, more in men than women) and "poor judgment calls" (Fig. 23).
- Fatigue generally hits drivers after a challenging section, when driver can "relax", especially after a number of hours. NB: this corresponds to an accident Riskope studied years ago, where after a steep and challenging climb, where the access road became flat and wider, driver fell asleep and truck overturned.
- Various fleets (corresponds to Riskope's experience as well) adopt now collision avoidance sensors and eye movement sensors on their trucks as rather inexpensive ways to somewhat prevent accidents.

Figure 23 A classic driver's fatigue accident, likely paired to high speed (estimated over 60km/hr). Notice the trailer truck rolled over at least twice on a flat terrain.

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7.2 Road generated mishap (accident type A)

There is no available statistical source defining rates of accidents per Mkm on roads similar to the one considered in this report, with similar traffic. The project being a “special road” extreme care has to be used in comparing different projects. Anecdotal reports (like the Wolverine mine, discussed in Section 6.2.1) are generally incomplete, biased or censored.

Nevertheless, in order to check the results of this risk assessment were reflecting “reality” we decided to prepare a bench-marking exercise before competing the risk assessment. We found in Riskope's files three examples of “serious to very serious” (S (Class 6) to VS (Class 7-9)) accidents histories on roads with comparable passage of specialty vehicles, driven by certified and tested drivers. These are reported in Table 17 with omitted names to preserve clients' confidentiality. Serious to very serious accidents would generally see vehicles at least turned on their side, most often rolling over a slope/ravine, as it would occur in any of Consequence Categories and 6 to 9 or 7 to 9 defined in the Consequence section of this report (Table 14).

The number of expected trips also remains an approximation (there is still an uncertainty related to the number of trips due to the type of truck -40tonnes vs. 50 tonnes-, but that uncertainty bears no significance when compared to the other uncertainties still bearing on the project). As already stated, no private traffic is considered in the analyses and mine passenger traffic is insignificant compared to concentrate and hazmat traffic.

Road	Road conditions	Traffic	Natural hazards	Days of closure to trucks, buses per yr	Reported causes of full loss accidents
1 Saint Bernard, Switzerland	Slopes up to 6% two/three lanes, paved, guard rails, wide bridges mountainous	Public	Avalanches, flash floods, rains, snow and ice	4 to 5	Failure to break, human error
2 Mine access road, Americas	Slopes up to 8% two lanes, paved, no bridges,	Private road with tolerated private	Rockfalls, mud flows, flash floods, heavy rain, rare snow	2 to 3	Fatigue, human error

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Road	Road conditions	Traffic	Natural hazards	Days of closure to trucks, buses per yr	Reported causes of full loss accidents
	culverts, mountainous	vehicle traffic, contractors.	on the passes		
3 Mine access road, Americas	Slopes up to 10% two narrow lanes, dirt/gravel, no bridges, culverts, mountainous yearly snow	Private road with tolerated private vehicle traffic, contractors.	Mud flows, flash floods, rain, snow on on 30% of the length	2 to 4	Fatigue, human error, distraction

Table 17 the three types of roads used as examples. No full loss accident was caused by natural or man-made hazards.

As none of the accidents on the three example roads were due to natural hazards it can be inferred the three examples correspond to “road only” accidents.

Let's note that the Wolverine mine report which stated that 2 trucks “fell off” the road is of difficult interpretation, but points to serious events. Let's also note that reportedly the Red Dog mine access road does not have any comparable feature to Prairie Creek access road (flatter, less turns, wider) and could not be used as a comparison.

The number of expected S-VS accidents was derived from the simple statistics of the three selected example roads after adapting to the mileage, traffic and lifespan to Prairie Creek, as displayed in Table 18.

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Road/ length	Accidents (full loss)	Million km driven	Approx. Passages/day	Expected accidents using Prairie Creek road mileage, traffic, lifespan	Multiplier using the Saint Bernard road as basis
1 Saint Bernard, Switzerland	2 in 44 years	26	20	1.5	1
2 Mine access road, Americas	1 in 10 years	7	12	5.7	3.8
3 Mine access road, Americas	4 over 16 less critical reported accidents in two years.	2	20	19.6	12

Table 18 number of expected full loss accidents has been derived from the simple statistics of the three roads after adapting to Prairie Creek mileage, traffic and lifespan.

We note that all these cases were deemed unacceptable after the occurrence of the S-VS accidents (most included one to multiple fatalities), and significant mitigations were implemented in the aftermath of the accidents.

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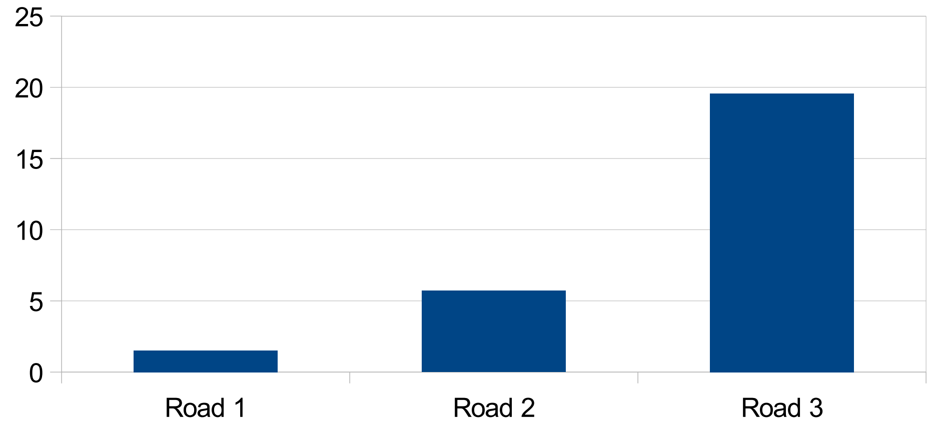

Figure 24 For the three type of roads (as described in Table 18) the bars show the expected number of S-VS accidents evaluated by applying Prairie Creek access road mileage, traffic and lifespan.

Figure 24 displays graphically the expected number of S-VS accidents evaluated by applying Prairie Creek access road mileage, traffic and lifespan to the example roads.

We will return to Figure 24 below, once the type A accidents are determined and it will be possible to compare the projected number of accidents on the Prairie Creek road to the three road examples discussed in Table 17, 18.

The elements of the analysis of type A accidents have already been laid out earlier in this report:

- Traffic share among concentrate, environmentally sensitive loads and empties has been developed earlier (Figure 11), as well as
- the share between "slippery/dry" days and the increase of hazard due to ice and snow , section 3.2.2).
- Chances that an accident results in a off road excursion (and it is not just a fender bender) is considered equal to 1/3 (33% approx). This corresponds to the ratio of vehicles that run out of the road (statistics from HW 63 881 in Alberta).
- The ORE procedure has been explained diagrammatically in Figure 19.
- The Consequences Classes have been allotted to the various Stratification types, including due consideration to the fragmentation of the Stratifications over a number of sub-segments.

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It is now time to develop the probability of Type A accidents (Phase 1 of the ORE procedure, Figure 19).

At each Stratification type sample drawing we have a number (to be selected in the list, as a function of the road layout, Table 19) of characteristics which contribute to the probability of generating an accident in that Stratification.

Road Characteristics	P (dry)
Straight	1/100,000
Steep grade up	1/100,000
Steep grade down	1/10,000
Wide turn (>40km/hr)	1/10,000
Narrow/hairpin (<30km/hr)	1/100,000
Narrow section	1/10,000

Table 19 List of characteristics linked to their elemental probability of generating an accident.

The contribution of each characteristic is measured by the probability of the characteristic to generate an accident (of any type and consequences) at each vehicle passage in dry road conditions: P (dry) in Table 19. The values used (1/100,000 and 1/10,000) are drawn from experience. For example:

- 1/100,000 is considered to be at the limit of credibility, as indeed one would consider "incredible" that a truck travelling in dry conditions would go out of the road in a straight segment.
- Wide turns are considered one order of magnitude higher (1/10,000), as many accidents actually do happen in wide turns where, in general drivers tend to speed.
- Etc.

ORE uses the data described above and usual probabilistic mathematics to derive the probability of accidents for each segment belonging to a specific Stratification, in Phase 1.

In Phase 2 (Figure 19) the results of type A accidents are extended to the entire related Stratification, and finally, in Phase 3 the Stratifications are collated to obtain a risk estimate for the whole road. In Phase 2 the natural hazards are studied and added to the Stratifications they impinge over, as explained in Section 7.3 below.

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At this point however, we are going to examine how the global results brought by the ORE deployment for type A accidents can be compared to the three road histories (Table 18 and Fig. 24) as shown in Figure 25. As it can be seen, Prairie Creek access road total service life V-VS accident number could be lower or higher than the one of Road 3, based on optimistic/pessimistic assumptions. Given the nature of Road 3 this result is comforting and lead to consider that the model is reasonable.

As it can be seen in Figure 25, the S-VS forecast results for type A accidents for Prairie Creek access road frame the statistically derived value for Road 3 (Table 17,18) and can be easily justified considering the narrow roadbase, the topography, bridges, and slippery conditions.

Given expected precipitation distribution, the likely need to maintain the road wet (to avoid dust), the early and late “summer” driving, an analysis of “summer only” accident , although feasible, seems inappropriate at this time considering the uncertainties that remain on 80% of the road alignment not documented with Stratification drawings to date.

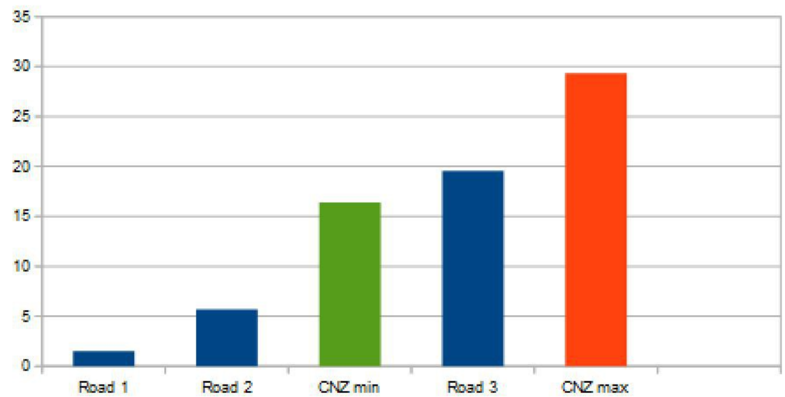

Figure 25 Bench-marking comparison between the three road examples and Prairie Creek ORE ORE predicted number of S-VS accidents. The bars show the expected number of S-VS accidents evaluated by applying Prairie Creek access road mileage, traffic and lifespan.

During the course of the study we reviewed two alternative alignments (one, abandoned, in the Sundog Creek area (34.480-35.00 and 36.3-36.856, the other, still considered , at the 103-123km).
The first alternative alignment, as pointed out by Allnorth in their Responses to Technical Review Undertakings (Aug. 10[Th] 2016), includes two river crossings (with massive and

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vulnerable abutments) and runs in the floodplain. Applying the ORE procedure this alignment generates higher type A risks than the one considered above.
The second alternative alignment, produces, as far as the approximate information available allows to understand, similar type A risks than the one considered above.

7.3 Moving trucks accidents (type B,C)

As mentioned above, in Phase 2 the natural hazards are studied and added to the Stratifications they impinge over.

Natural hazards can provoke accident type B, when a passing vehicle is hit by the hazard (or pushed over, or deviated by driver's reaction into an off-road excursion). The analysis evaluates the exposure of vehicles to each natural hazard (considering vehicle length, average speed and hazard length) and, from that value, estimates the number of accidents.

Accidents type C are analyzed following a different logic. It is extremely unlikely that a hazard would occur between vehicles and not be detected before the next vehicle arrives at the location, since vehicles will travel in convoys, or in clusters. Thus the analysis considers only the “first vehicle” of any given day as the one that could hit a hazard present on the road (eg. Occurred during the “non-traffic hours”, when it is assumed no or very little control will be present).

In the sections below all the hazards discussed in Section 4.3 to 4.7 have their probabilities for type B,C accidents evaluated using the procedure described above.

7.3.1 Avalanches

We use Table 9 in Section 4.4.2 noting that extant documents do not allow to precisely pinpoint avalanches locations with respect to the Stratifications. As stated in extant reports avalanches *would typically only be expected in the spring when the snowpack is near its maximum depth...*so their impact will be considered on winter traffic only.

Table 20 delivers a list of the Size 3 avalanche hazards that have to be covered under our SoW sorted by expected frequency (only areas where the all seasons road differs from the presently permitted winter road). From Table 20 it can be derived that 3800+2300= 6.1km (approx. 20%) of considered road are exposed to avalanches Size 3 with a return

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(average frequency) between 1:3 and 1:10 (only one case of Size 4, with a frequency of 1/30).

The Stratifications drawings present between km 4 and 35 are shown in Table 21.

As it can be seen, approximately 20% of the road is "precisely known" through plans covering 6 segments of an average length of 0.95km each. There no other Stratifications present in the road segment exposed to avalanches.
Based on the limited knowledge of the final design of the road we will compute the expected avalanche accidents and split it uniformly among the 6 segments to evaluate risks.

For the 1:3 avalanches 2.27 accidents (types B,C) for both directions over the service life were computed. For the 1:10 avalanches 0.79 accidents (types B,C) for both directions over the service life were computed.

Path ID	***Approx. Location***	***Affected segment (m)***	***Aspect***	***Magnitude-frequency estimate events:years***		
				Size 2	***Size 3***	***Size 4***
16	*Funeral Creek 16 km along road*	*200*	*South*		*1:10*	
25	*Sundog Trib 15 km west of Cat Camp (same note as above, but apparently in a milder topography)*	*200*	*SW*		*1:10*	
33	*Sundog Creek 7 km west of Cat Camp*	*1400*	*NW*	*1:1*	*1:10*	
34	*Sundog Creek 6 km west of Cat Camp*	*1200*	*NW*	*1:1*	*1:10*	
35	*Sundog Creek 5 km west of Cat Camp*	*800*	*NW*	*1:1*	*1:10*	
	TOTAL	***3800***				
20	*4 km east of Funeral/Sundog Pass*[64]	*800*	*NE*		*1:3*	
25.5	*Sundog Trib 14.5 km west of*	*500*	*SW*		*1:3*	

64 In this segment the all season road is on the opposite side of the valley. Possible avalanche areas could be in this section as well, thus we keep it in consideration.

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Path ID	*Approx. Location*	*Affected segment (m)*	*Aspect*	*Magnitude-frequency estimate events:years*		
				Size 2	*Size 3*	*Size 4*
	Cat Camp (same note as above)					
26	*Sundog Trib 14 km west of Cat Camp (same note as above)*	*200*	*SW*		*1:3*	*'1:30*
27	*Sundog Trib 13 km west of Cat Camp (same note as above)*	*400*	*SW*	*1:1*	*1:3*	
28	*Sundog Trib 12 km west of Cat Camp (same note as above, apparently equivalent topography)*	*200*	*SW*	*1:1*	*1:3*	
28.5	*Sundog Trib 11.5 km west of Cat Camp (same note as above)*	*200*	*SW*	*1:1*	*1:3*	
	TOTAL	***2300***				

Table 20 List of the Size 3 avalanche hazards that have to be covered under our SoW sorted by expected frequency.

Strat. #	**km**	**km**	**L (km)**
2	7	8	1
?	13	13.76	0.76
?	23	23.7	0.7
3	25	26	1
4	30	31	1
?	33	34.2	1.2
		Tot.	5.66

Table 21 Stratifications potentially exposed to avalanches that have to be studied based on SoW.

Thus for accident type B,C potentially generated by avalanches a total of 2.27+0.79= 3.06 accidents can be computed over the life of the road. This estimate covers only the avalanches to be studied following the SoW. Table 22 displays the results split per Stratification present on the exposed stretch.

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Strat. #	L (km)
2	0.51
3	0.51
4	0.51
?	1.53
Total	**3.06**

Table 22 SoW required avalanches split among the exposed Stratifications.

These 3.06 accidents have varied consequences (as a function of their location), which will be considered in Section 9, risk assessment.

7.3.2 Avulsions

As concluded in Section 4.4.2, given the traffic assumptions described earlier, the proposed measures and proposed monitoring we consider extremely unlikely (beyond present credibility) that under these conditions, any of the heavy traffic considered in this report would be involved in an accident due to creek avulsion. Maintenance workers, lighter vehicles may be exposed, especially in case of bravado (based on several experiences world-wide). Of course if "normalization of deviance" (See Appendix 1 for a definition) would occur over time, then the situation could be different. Avulsions could also trigger geohazards that have not been detected to date.

Thus there will be no numerical analysis for avulsions risks (accidents type B,C) at this time.

7.3.3 Landslides

As discussed earlier, we noted during our review several locations where high energy, possibly small volume, events are to be expected. However only a detailed study (not on the SoW scope) would allow to perform those analyses.

Table 23 adds to information contained in Table 13 the evaluated accidents (type B,C) for each moderate, high, very high hazard, using frequencies delivered in extant studies (in the column titled Rating).

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Construction Stratification Type and km		Extant Landslide Hazard list			Notes from cross sections and oblique photos and extant hazard assessment[65]	Accidents during service life
from km	to km	Km Start	Km Finish	Rating		
	I	0	0.4	Moderate with M=Medium L=High 400m	Several older rockfalls, three small 2012 rockfalls	0.17
5.14				M=medium/ small L=moderate (mostly) 9,500m	very steep up slopes: rockfalls (See original table)	0.12
	6.2					
II						
7					Locally very steep upslopes: rockfalls (See original table)	
	8				Low visibility due to rockface (See original table)	
N/A						
13					Mostly excavated upslopes	
	13.76					
	II	16.3	17	Moderate with M=Medium L=High 700m	4 from 1949 and 1 from 1994, all of which cross the road; apparently little obvious effect on road as only occasional boulders seen in recent	0.17

65 EA1415-01_CanZinc_responses_to_outstanding_adequacy_items.PDF; Table 1: Magnitude and Frequency Ratings along the Proposed Prairie Creek All Season Road, NT

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Construction Stratification Type and km		Extant Landslide Hazard list			Notes from cross sections and oblique photos and extant hazard assessment	Accidents during service life
from km	to km	Km Start	Km Finish	Rating		
					time (D. Harpley, pers. comm. Apr. 8, 2016)	
N/A						
23				M=large to small L=moderate (mostly) 6,200m	(See original table)	0.11
	23.7					
III						
25						
	III	25.5	26.6	Moderate with M=small/ med. L=moderate 1,000m	Below road	0.09
	26	I	I			
	III	25.5	26.6			
	III	26.2	26.3	High	M=M, L=M; 100m	0.08
	III	27.2	27.4	Very High	M=M, L=H; 200m	0.17
	N/A	28.1	28.4	High	M=M, L=H; 300m	0.17
	II	29	29.2	Moderate	M=M, L=H; 200m	0.17
IV						
30						
	IV	30.6	30.8	Moderate	Debris fan M=M, L=H; 200m	0.17
	IV	30.8	31.2	Moderate	M=M, L=H; 400m	0.17
	31					
	IV	31.2	31.8	Moderate	M=L, L=H; 600m	0.17
N/A				M=L, L=H; 300m		0.17

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Construction Stratification Type and km		Extant Landslide Hazard list			Notes from cross sections and oblique photos and extant hazard assessment	Accidents during service life
from km	to km	Km Start	Km Finish	Rating		
	IV, N/A	32.5	36.2	Moderate	Scree face	
33.2		I	I	M=M to L, L=H 3,700m	Upslopes at natural angle	
	34.2	I	I			
N/A	Sundog Creek sector	I I I	I I I			0.19
34.8		I	I		Very steep upslopes	
	IV, N/A	32.5	36.2	Moderate	High cuts slopes	
	39			M=S to VL, L=L 6,700m		0.04
	VI	42.9	43.3	Moderate M=L, L=L 400m	Cliffs...	0.03
VI				M=L L=L 400m		
44						
	45					
	VI	46.8	48.4	Moderate	M=VL, L=L; 1,600m	0.04
VII						
49						
	VII	49.7	50	Very High M=L, L=M; 300m	Debris slide	0.09
	51.5					

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Construction Stratification Type and km		Extant Landslide Hazard list			Notes from cross sections and oblique photos and extant hazard assessment	Accidents during service life
from km	to km	Km Start	Km Finish	Rating		
VIII						
52						
	53					
	VII, VIII	53.7	54.2	High M=m, L=H; 500m		0.17
	VII	54.5	57.6	Moderate M=VL, L=M; 3,100m		0.09
	VI	59.7	60.4	High M=M, L=M; 700m		0.09
	VI	61.4	61.5	Moderate M=M, L=M; 100m		0.08
	VII	83.5	85.5	High	Debris slide	
V		I	I	M=S, L=M; 2,000m		
88		I	I			0.09
	VII	83.5	85.5	High		
	89					
		?	?	Moderate M=S to L, L=M; 3,200m		0.1
	X	95.5	101.7	High	Slump in bedrock	
X		I	I	M=VL, L=L;		

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Construction Stratification Type and km		Extant Landslide Hazard list			Notes from cross sections and oblique photos and extant hazard assessment	Accidents during service life
from km	to km	Km Start	Km Finish	Rating		
98.5	X	I	I			0.04
	99.5	I	I	3,200m		
	X	95.5	101.7	High		
		101.7	102	M=M, L=M; 300m		0.09
					SUBTOTAL	3.07
		Alt	route			
	VII	111.8	113.1	Moderate M=L, L=M; 1,300m		0.09
		Orig.	route			
	VII	110.2	115.1	Moderate M=S, L=M; 4,900m		0.1
122.7						
	123.4	Orig.	route			
	VII	136.4	137.3	High M=L, L=M; 900m		0.09
IX						
147						
	149	Orig.	route			
	IX	154.5	155.3	High M=VL, L=L; 800m		0.03
	IX	155.9	159.3	Very High M=M, L=H;		0.19

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Construction Stratification Type and km		Extant Landslide Hazard list			Notes from cross sections and oblique photos and extant hazard assessment	Accidents during service life
from km	to km	Km Start	Km Finish	Rating		
				3,400m		

Table 23 Type B,C landslides accidents evaluations.

Total accidents, for both directions over service life on the original alignment: subtotal 3.07+0.09+0.03+0.19= 3.38. Accidents for both directions over service life on the alternative route sum up at 0.19 and are therefore negligible (around km111).
These 3.38 accidents have varied consequences (as a function of their location), which will be considered in Section 9, risk assessment.

Stratification	Accidents due to landslides	Accidents due to avalanches	Accidents following SoW
1	0.22		0.22
2	0.47	0.51	0.98
3	0.39	0.51	0.9
4	0.58	0.51	1.09
5	0.09		0.09
6	0.16		0.16
7	0.46		0.46
8	0.12		0.12
9	0.23		0.23
10	0.13		0.13
?	0.53	1.53	2.06
TOTAL	**3.38**	**3.06**	**6.44**

Table 24 total type B,C accidents, for both directions, during service life, due to the hazards mentioned in the columns header.

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Table 24 delivers the total accidents type B,C per Stratification and avalanches, following SoW instructions, and landslides (following extant hazard analyses).

In section 9 these accidents will be combined with the Consequence Classes to derive a risk estimate for the whole road.

7.3.4 Man-made cuts

As mentioned earlier, man-made slopes generate risks, but at this time it is impossible to deliver an estimate due to lack of information. The care that CNZ will take in designing and performing the cuts, together with possible mitigations will dictate the level of added exposure leading to risk.

7.3.5 Seismic

As discussed earlier, seismic events with an evaluated return of 10 years will have definite impacts on the infrastructure (bridges, culverts, armoured slopes) and possibly deform/collapse stretches of the road while reactivating ancient landslides or triggering new ones.

During such an event traffic tends to stop and traffic accidents due to earthquake are rare. At this time it is not possible to deliver an estimate of the risks, given the paucity of detailed data on the road and bridge construction which would anyways demand detailed analyses not included in the SoW.

8. Accidental tolerance

Any human endeavour can lead to accidents (possibly with unpleasant consequences). Hunting, fishing, driving a heavy truck, cooking in one's house are typical human endeavours which can generate accidents: encountering an aggressive bear, capsizing the boat, veering off road, burning the house.

Over the life of the considered access road it is inevitable that some accidents will occur, as shown by the road used as examples in the prior section. Some will be benign, some might be more significant as described in the Consequence section of this report.

Zero risk is not achievable, not even in highly controlled industries like nuclear, civil aviation and certainly not in traffic mishaps. Also, of course, neither in traditional life,

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including hunting, fishing, simply living in a house. Anyone of us, every-day makes a decision to undertake some activity and consciously or unconsciously assumes a risk that is considered acceptable/tolerable.

In order to complete our scope of work which demands "*are the risks tolerable and acceptable without mitigations, are the risks tolerable and acceptable with mitigations, and what are the residual risks if mitigations are implemented and are the proposed mitigations appropriate and sufficient* " a accident risk tolerance threshold has to be selected. Literature does not help as published thresholds address generic large scale societal tolerance which are very different from accidental tolerance and will remain the responsibility of MVEIRB.

Accidental tolerance thresholds are indeed always project/corporate specific and therefore a specific threshold had to be defined by probing the perception of CNZ.
In IR#2 a question addressed specifically this point. As there are no right or wrong answers in this field, CNZ was asked to express their opinion on what is the number (over the service life) of corporately tolerable accidents of each consequence class for the specific project.

Values from Riskope's experience were proposed to facilitate the replies and CNZ replied (Table 25) with values that indicate their accident tolerance, which can also be interpreted as their mitigative objective for this project. CNZ displayed a higher accidental tolerance for lower classes of consequences (hence for less critical accidents than Riskope), but a lower tolerance for higher consequence classes.

FAILURE CLASS	TOLERABLE NUMBER OF ACCIDENTS DURING SERVICE LIFE by Riskope	Do you agree with the tolera-ble number Reply below YES or NO at each line	propose your values (one per line)	Allnorth[66] comments
Class 1	32	No	75	*These incidents are common and would be consistent with a truck having one wheel off the road, or have driven into a low slope ditch. The dominant cross section slope being fair would reduce the probability of a release of fluid or material. Have increased the occurrence of these as they are by far the most likely to occur.*

66 Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 8.

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FAILURE CLASS	TOLERABLE NUMBER OF ACCIDENTS DURING SERVICE LIFE by Riskope	Do you agree with the tolerable number Reply below YES or NO at each line	propose your values (one per line)	Allnorth comments
Class 2	30	No	20	*I would equate this to an incident where the vehicle has ended up on an angle or on its side due to the dominant cross section. Although not common, it can be expected to occur once per year based on professional experience.*
Class 3	28	No	10	*I would equate this to an incident where the vehicle rolled over due to the dominant cross section. My experience hauling in similar situations is this may occur once every couple of years, but is not common.*
Class 4	16	No	10	*These incidents are not as common as class 1 due to the required proximity to a sensitive target. It is reasonable to assume that this could happen once every two years.*
Class 5	9	No	5	*These incidents are not as common as class 2 due to the required proximity to a sensitive target. It is reasonable to assume that this could happen once every four years.*
Class 6	5	No	2	*These incidents are not as common as class 3 due to the proximity to a sensitive target. It is reasonable to assume that this could happen twice in the project life.*
Class 7	2	No	1	*My experience operating a large commercial transport company would suggest that these are very uncommon. There is an opportunity for this to occur but it is estimated to only be once for the duration of the project. Moderate*
Class 8	0.5	No	0.1	*There is a possibility of this occurring, but the probability is*

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FAILURE CLASS	TOLERABLE NUMBER OF ACCIDENTS DURING SERVICE LIFE by Riskope	Do you agree with the tolera-ble number Reply below YES or NO at each line	propose your values (one per line)	Allnorth comments
				extremely low.
Class 9	0.1	No	0.1	*There is a possibility of this occurring, but the probability is extremely low.*

Table 25 Initially proposed tolerance threshold expressing the tolerated number of accidents per accident class over the service life.

9. Risk Assessment results

As discussed earlier, the risk elements for this study are:

- the road from the mine to HW7 (at the exclusion of the ice bridge/barge),
- the traffic and
- the environment in general, with particular focus on environmentally sensitive areas pinpointed by Parks Canada and, of course, watercourses.

The traffic includes the loaded concentrate trucks in their outbound trip, the inbound trip, split in environmentally significant cargo and empties (which carry their own fuel and service fluids such as hydraulic oil), as shown in Figure 11.

Those elements are exposed directly or indirectly to natural and man-made hazards such as those generated by the road design, the behaviour of drivers, weather conditions, avalanches, avulsions, landslides, etc.

In this risk assessment, the probability of an adverse consequence to elements at risk by various natural or man-made hazards has been converted in a number of accidents (of various types and severity) over the service life of the road. This procedure has two main advantages:

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- it allows to state numbers that anyone can understand (example: 3 accidents of type x and severity y are expected over the n years of service of the road INSTEAD of using a "technical" definition like: the probability of accidents of type x and severity y is 10-3/yr).
- It allows to develop a bench marking exercise with other special roads, to ensure the results are "anchored" in reality thanks to a bench-marking exercise which delivered good results.

Based on the paucity of extant data related to highly sensitive potential spill areas this study assumes that higher consequences will occur as a result of accidents featuring at least one of the following characteristics:

a) relative higher energy (careening over higher/ steeper natural or man-made slopes, faster driving, etc.)
b) potential larger spread of contaminants
c) relative increased difficulties in recovery of pollutants.

The consequences are cumulative in the sense that a possible spill at a given location where more than one characteristic is present will lead to higher consequences than another location where only one characteristic is present.
Furthermore, in the absence of detailed and up to date baseline information, extant knowledge base was used to identify four reaches along the all season road reportedly of high biological value and likely highly sensitive to spills: karst terrain, sensitive drainage, water courses, and wildlife (Caribous and Arctic Grayling).

Concentrate loads, environmental significant loads and empties with diesel tank only have been considered separately, as their consequences are different from an environmental point of view.
Table 14 shows the Consequences classes (1-9) adopted for this report. This report considers accidents as follows:

Class 1-2	minor
Class 3	moderate
Class 4-5	significant
Class 6	serious (S)
Class 7-9	very serious (VS).

Driver or "bypassers" could be harmed in all classes of accidents, this not being a specific feature of this road, but a general consideration in accidents involving heavy vehicles. Cargo types will be considered separately.

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In the absence of detailed drawings of the entire road, the highest consequences locations have been defined by Stratification type as shown in Table 16. Also, the riskiest locations have been defined by Stratification type as shown below.

The highest risk locations are those where Serious to Very Serious accidents could occur. These are a combination of road hazards and natural hazards as shown in the following list and Figure 26 (for total traffic):

Stratification 1-4: bridges, watercourses and caribou & Arctic Grayling population**.**

Special Sections: high embankments, presence of creeks, significant down slopes, caribous and Arctic Grayling population (in the first segments of the road).

Stratification 5: presence of sensitive drainages proximity to creek**.**

Stratification 7-8: water crossings, drainage and karstic environment.

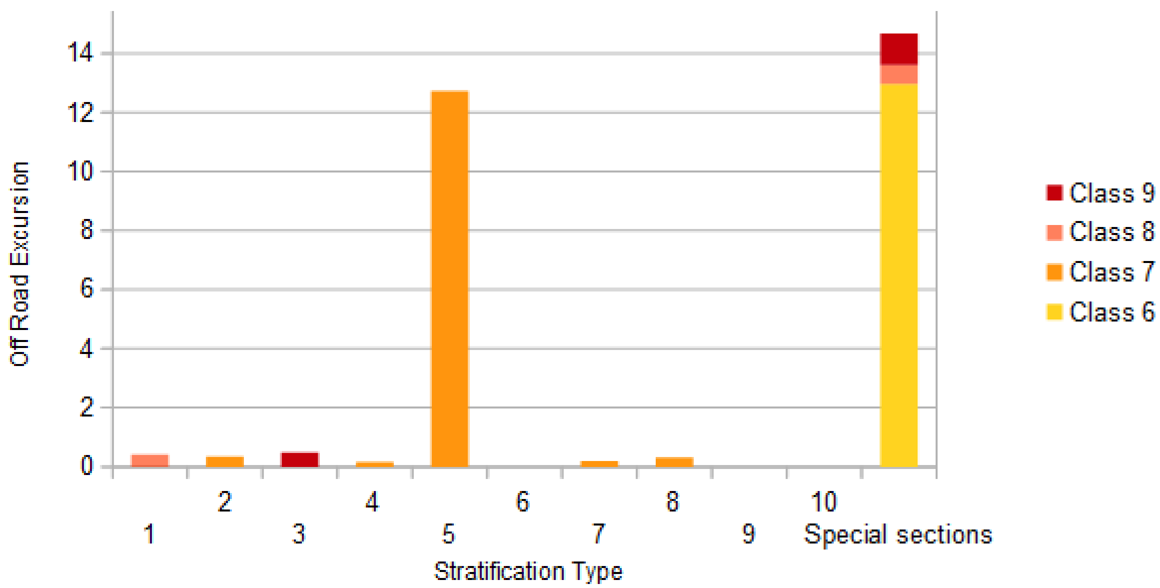

Figure 26 Off road excursions per Stratification and per Classes 6 or higher.

An accidental risk tolerance threshold was developed by asking specific questions to CNZ, geared toward understanding their mitigation goal (Section 8).

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It is understood that the definition of the societal tolerance to risk is under the competence of MVEIRB.

In Figure 27 the total number of evaluated off-road excursion accidents (orange bars) is compared to the mitigative goals (blue bars) set by CNZ in their reply to question 8, IR#2. The results are split per type of cargo (loaded concentrate, environmentally significant and empties with their diesel and service fluids).

As it can be seen in Figure 27, the risk assessment forecasts a number of :

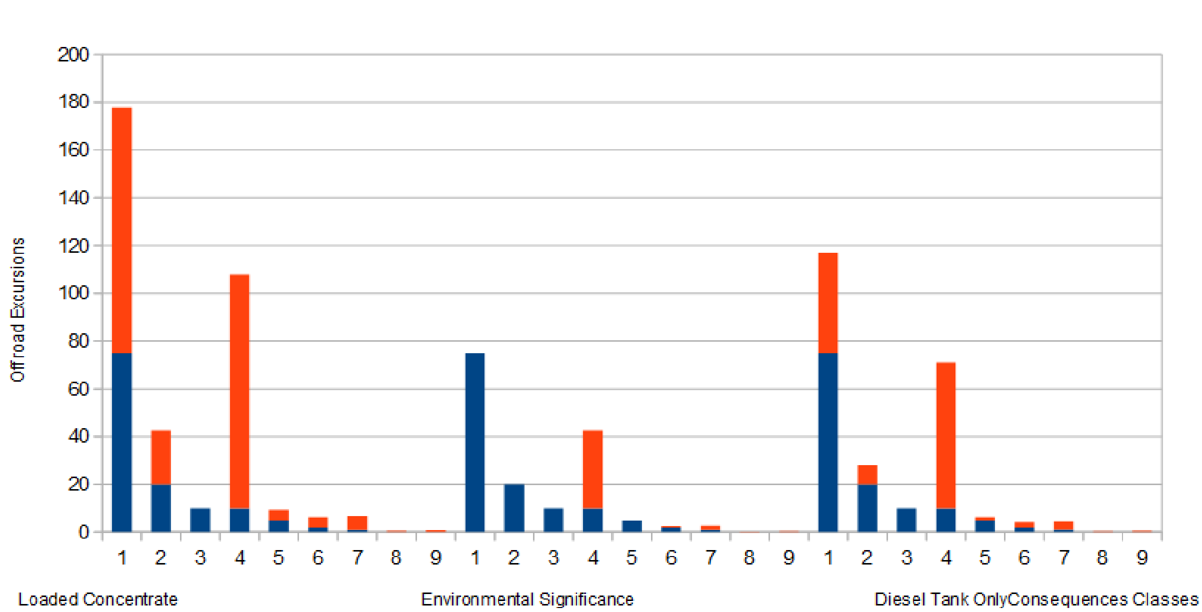

Figure 27 Off road excursions pert type of cargo (orange bars), compared to the CNZ accidental tolerance (blue bars)

Class 1-2 **minor**: widely above the CNZ tolerance for loaded and environmentally significant cargo. We note however that the 200 minor accidents (sum of Class 1,2 for loaded concentrate) may not even result in spills, as Class 1,2 topography is very gentle. When looked on a per year basis the number is approximately 12, which is similar to the road 3 (bench marking) result for minor accidents.

Class 3 **moderate**: within CNZ tolerance (due to the fact that the road design carefully avoids Class 3 locations.

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Class 4-5 **significant:** here the number of accidents is again widely over the accidental tolerance, because of the presence of sensitive drainages, creeks, crossings, and wildlife.

Class 6-9 **serious to very serious:** Table 26 summarizes the results which are not visible on the graphic rendering for the classes 6-9:

Class	Accidental tolerance value	Estimated accident number of tolerance exceedance		
		loaded concentrate	environmentally significant cargo	Empties with diesel and service fluids
6	2	4.29	0.49	2.15
7	1	5.68	1.64	3.4
8	0.1	0.42	0.1	0.24
9	0.1	0.65	0.2	0.4

Table 26 Estimated number of tolerance exceedance with respect to accidental risk tolerance for Consequences classes 6 or higher

Class 6,7 are present when water crossing, karst, sensitive drainages significant cross slopes are present and accordingly the risk estimates for those areas are high, exceeding the somewhat ideal environment considered in the reply to question 8, IR#2.

The risk assessment has examined and considered in the analyses numerous mitigations that have already been proposed by CNZ as defined in Report Validity Conditions and Assumptions (Section 11) and the corresponding Appendix 3 (Assumptions).

Figures 28 A,B,C give a more complete image of where the accidents are predicted to occur: Figure 28A per Stratification,; Figure 28B which Consequences classes are present in each Stratification,; and finally Figure 28C the inverse, i.e. which Stratifications are present in each Consequence Class.

Using Figures 28A,B,C it is possible, for example, to see that Stratification 7 & 9, respectively the first and third in terms of overall number of accidents, have a majority of Class 1 (minor) accidents whereas Stratifications 1 & 2, respectively second and fifth in terms of overall number of accidents, have an extreme majority of Class 4 accidents, but also, barely visible Consequence class 7 and 8 present.

Thus these three figures, together with the other diagrams delivered in this study can be used to understand the risk landscape of the project to guide decisions related to future mitigations.

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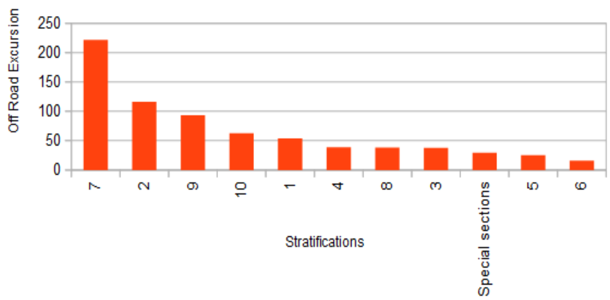
Together the Figures and Tables in this Section constitute the ORE (Optimum Risk Estimates, ©Riskope) risk dashboard for this project. The ORE risk dashboard delivers an immediate understanding of the holistic (multi-hazard), scalable, drillable landscape of the project, including accidental risk tolerance, which should be completed, for the ease of use, by a map of the Stratification location by CNZ based on their Table 7: Road Summary from Responses to Information Requests Response to Mackenzie Valley Review Board Response to DAR Addendum of Developer's Assessment Report May 10, 2016.



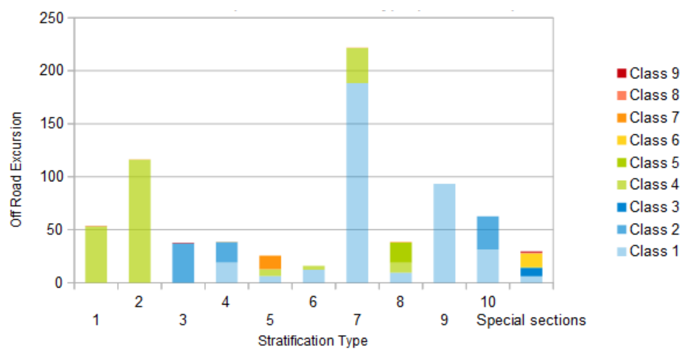


Fig. 28A Off road excursions per Stratification Fig. 28B Consequences classes present per Stratification

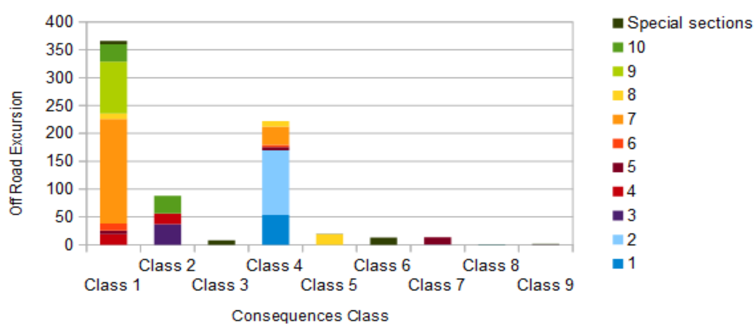


Fig. 28C Stratifications present in each Consequence Class.

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10. Mitigations

We note that this stage no mitigations have been yet designed (albeit some suggestions have been formulated) for rockfalls and/or landslides and/or avalanches, so all the slopes are completely unmitigated.

10.1 Signs and posts

Following Allnorth indications signage will be extensively used along the road. In IR#2[67][68] it was specified *that a detailed catalogue of typical signs that may be applied to this project can be found at the Ministry website[69].*

They declared: *For maximum effectiveness, signage along the Prairie Creek Access Road will be standardized as per the Province of BC, Ministry of Transportation and Infrastructure to ensure consistency in application and driver understanding. Typical signs may include some of the following:*

Figures 29, 30 are "traffic oriented" delivered by Allnorth and do not include any signs related to natural hazards common in mountainous roads such as, for example:

- "Rockfall, do not stop.... xxx m",
- "slide area- proceed with caution",
- "wild animals", etc.

Sign W7.6 in Figure 30 relates to poor visibility, but "hill blocks view" is certainly not the only poor visibility type along the foreseen project.

67 Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 3b.

68 Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 13a.

69 *http://www.th.gov.bc.ca/publications/eng_publications/geomet/geometsigns.htm.*

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Figure 29 examples of signage

Professionals with decades long experience in the North interviewed during the development of this study have stated the need for winter/summer changes in the posted speed (in each direction).

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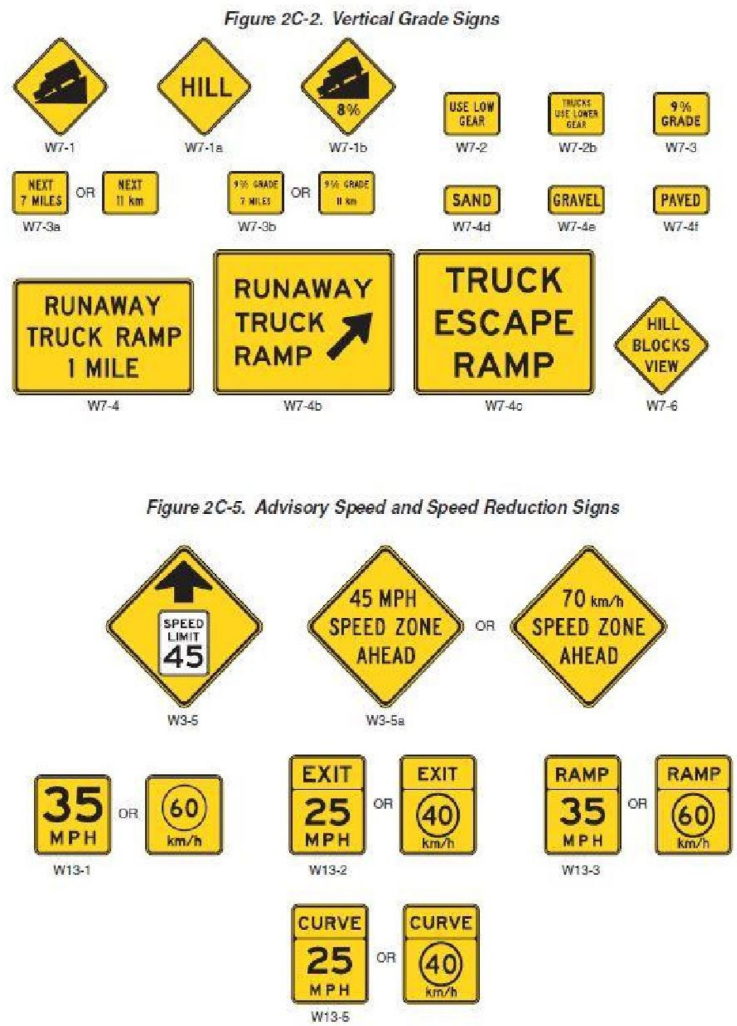

Figure 30 examples of signage.

10.2 Barriers berms and runaway lanes

Allnorth has stated all along the discussions and lately their position[70] on runaway lanes as follows: *As presented in CZN's response to Undertaking 20, 4 different public reference manuals and guidebook publications were used including:*

70 Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 3a.

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- *B.C.FLRO Engineering Manual*
- *Health, Safety, and Reclamation Code for Mines in British Columbia*
- *Geometric Design Guide for Canadian Roads (TAC) (used by MOT)*
- *Northern Land use Guidelines.*

As previously discussed, all four publications do not provide specific standards related to when and where runaway lanes and/or safety railings are to be applied and utilized.

In addition, review of the TAC Document "Primer-Synthesis of Practices of Geometric Design for Special Roads shows the inconsistency and lack of jurisdictional guidelines with respect to "Special Road" Design and recommends that "Design guides must be non-prescriptive, as the needs of each Special Road are unique. These roads must be designed and treated holistically, on a project-by-project basis, using engineering judgment".

Within the Undertaking 20 response, Table 1 was provided describing three major sections of the Prairie Creek Access road alignment, where use of runaway lanes or barriers may be warranted due to alignment considerations, and indicated that further review and design would be required at the detailed design stage.
CZN has committed to reviewing these sections in detail at the detailed design stage and if required and feasible, will include runaway lanes and barriers into the design. As previously stated, based on our review of the above documents, field investigations, completed road designs and road profiles, at this stage of the design, it is our professional opinion that runaway lanes are not required. CZN has not refined it's analysis to specific types of cargo types or energy considerations as eliminating the hazard of errant vehicles is equivalent despite cargo type and energy rating.

From the Stratification drawing we have seen to date, we would tend to agree with CNZ position at this point, noting however that further review is necessary. The following are general comments on runaway lanes offered as a complement of information.

The large size of haulage vehicles precludes use of conventional vehicle arresting or impact attenuation devices to stop a runaway. In haulage operations with adverse grades, retarder failure has reportedly resulted in loss of life and substantial property damage. We note however that as stated by Allnorth that the Prairie Creek road should not have long descents to be travelled by loaded concentrate vehicles which, by far, would be the heavier to transit the road and CNZ has committed to maintain the vehicles to the highest standards.

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Furthermore Allnorth also indicated[71] that f*or the purpose of the Prairie Creek Access Road, the two barrier types that will be considered during detailed design are earthen berms and precast concrete barriers.*

Here we note that the area that probably would require the most robust barriers are those along the creeks and other sensitive environments. Given the cross section of the road placing any barrier seems impossible, both from an available space and foundation point of view. Thus, it may well be that, if the road is permitted as proposed, no barriers will be implemented for reasons that are already evident today. Snow removal will only complicate matters further.

There are two principal berm designs that are in common use. One is the typical triangular or trapezoidal berm formed typically from unconsolidated, relatively homogeneous material obtained during overburden removal or from material obtained as a result of the haulage road construction itself. Berms of this type require a wide space to be installed.

The other most common berm consists of large boulders lining the haulage road with an earthen backing material. The basic limitations imposed by this configuration are (1) substantial damage to the vehicle can result from its use, (2) the vehicle would tend to impact the berm at sharp angles of incidence (possibly injuring the driver), and (3) the local geologic and topographic characteristics of the area must accommodate construction of the berm.

Height is the main factor to be considered in designing berms. For conventional berms, the rule of thumb regarding height is that for a berm to possess any measurable tendency to redirect a haulage vehicle, its height must be equal to or greater than the rolling radius of the vehicle's tire. At moderate vehicle speeds, this height allows sufficient time for the driver of the vehicle to apply corrective measures before the truck either overturns or mounts the berm.

10.3 Rescue and salvage operations

When asked about rescue and salvage operations, the following has been delivered by Allnorth[72]: *If a truck has a problem, the next truck arriving at the location immediately becomes a responder, as does the next truck, as necessary. A response would be*

71 Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 3b.

72 Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 14a,b Oct. 7th and 11th

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mounted immediately, as well as notifying 'Control' of the event. If a response team is needed, they will immediately depart. Control will then direct trucks on the road to proceed to a turn-out, or advance beyond the incident location, so as not to block the response team. We believe a 40 km/hr response team speed is more than realistic because they will be in a medium duty truck with a limited payload.

Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 14b., October 7th and 11th. *Given other truck traffic on the road, including maintenance crews and monitors, response time will likely be much less than 2h15. For the arrival of a response team, we would expect this to occur within 3 hours, likely much less, because an incident is more likely to occur closer to a team location than the 90 km maximum. A response vehicle and equipment would be ready, and the team would depart minutes after receiving notice by radio to do so. If haul operations were occurring, it is safe to assume that conditions are suitable for a response team to respond in a timely manner. Note, the declared average speed is for laden trucks, not a response team in a lighter vehicle.*

As already mentioned this scenario works for a minor accidents where the vehicle does not obstruct the road and havoc occurs behind it. Furthermore, if the truck victim of an accident is at the bottom of a slope or in a river and bags are scattered downhill this type of response is not sufficient. A crane or a heavy winched vehicle will be necessary, and the response time will significantly expand.

10.4 Journey Management System

CZN previously described a JMS that will be implemented to manage and control transport operations on the road (see Appendix I, 2nd IR round, EA0809-002, http://www.reviewboard.ca/upload/project_document/EA0809-002_Canadian_Zinc_2nd_round_Information_Request_Responses.PDF).
In addition, Allnorth indicated[73] that *there will be a Road Operations Superintendent, responsible for overseeing road maintenance, transport operations and making decisions with respect to safety. The JMS already includes provision for ensuring vehicles are properly maintained and suitable for use. We will add provisions for checking on the condition of drivers before they start their shift, specifically, are they sufficiently rested and not sick. We will also make provision for driver relief during their journey if they do not feel fully able to drive safely for any reason. During orientation, all drivers will be warned about the dangers of distraction and not being alert. This will be reinforced in*

73 Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 12.

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morning meetings prior to initiation of the days' transport activities. Drug and alcohol screening is a standard procedure for all employees and contractors, and will be rigourously enforced and monitored. Any suspicion of impairment noted in morning meetings prior to initiation of the days' transport activities will result in the driver being withdrawn from work that day and subject to testing.

Mining operations in the Canadian North, especially those of major companies, reportedly have JMS implemented and active. JMS is not immune to human error and does not entirely preclude drivers bravado. Anecdotal evidence exist of numerous cases where, for example, the decision to chain-up trucks was delayed or postponed for various reasons, leading to mishaps.

10.5 Cargo safety

Allnorth stated[74] the Cargo safety will be the responsibility of the motor carrier. Since the trucks fleet will be partially owned by CNZ, we assume this responsibility will be in the hands of CNZ and of third party carriers. *Cargo safety is regulated by both Transport Canada (Transportation of Dangerous Goods) and the provincial commercial transport regulations. As this haul will be transcending the border into British Columbia, the BC commercial transport act and regulations would be the dominant authority with respect to cargo securement. CZN will ensure that all carriers (including its own) that are transporting dangerous good will provide proof of Transportation of Dangerous training and certification of the drivers. In addition, it will be confirmed that the operators of the unit possesses appropriate TDG containment and response equipment. For the non-categorized dangerous good, CZN will ensure that all carriers are operating to the minimum standard of the National Safety Code Cargo Containment, Standard 10.*

In our experience accidents occur also when standards and business like usual concepts are applied. Prairie Creek is a “special road” and it has a number of special features.

We discussed earlier the blind use of Forestry road standards applied to a Concentrate road project and the use of a width standard, while ignoring an important note related to the lack of margin of error. Likewise we urge the proponent to review the cargo safety rules and adapt them to a road that will carry environmentally sensitive cargo through environmentally sensitive areas with no barriers.

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74 Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 11b.

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10.6 Man made cuts and slopes

We noted earlier that at this stage no mitigations have been yet designed (albeit some suggestions have been formulated) for rockfalls and/or landslides and/or avalanches, so all the slopes are completely unmitigated.

Man made cuts and slopes will generate rockfalls and possibly slides (including snow/ice slides) which will have to be mitigated as they can be the cause to additional accidents of type B,C. In our experience the frequency of these is actually higher than the frequency of natural hazards.

11. Report Validity Conditions and Assumptions

This Section states the conditions necessary to ensure the risk assessment assumptions and related results reflect future operating conditions.

The assumptions formulated for this report are stated in Appendix 3.

The conditions do not mean that all uncertainties have been reduced, but describe a reasonably safe operating environment. Of course, should the project or its operating conditions (including of course climate change related events) diverge from what is described in this report, then analyses should be updated and conclusions may be altered.

11.1 Passengers Traffic

1) Crew changes will be by air, on average one flight per week. Weather delays will usually mean only flight delays. Occasionally, a flight may be diverted to Nahanni Butte, followed by personnel busing to the Mine. There may also be very occasional Mine tours via mini-bus. Assume an average of 1 trip/month. Thus it is considered the added risk to buses is negligible. However, as flight diversion will occur in periods of adverse meteorology, buses escorted by a light vehicle preceding at no more than 200m and in constant radio contact should be used. Mines using this system have seen their rate of accident reduced below credibility. Should this system not be implemented the probability of having an accident should increase significantly.
2) Subcontractor, private traffic will be regulated. The road will be accessed at specific times and weather dependent. Safety briefing will be compulsory before entering, a registry of entering/existing vehicles will be kept and destination declared.
3) Road operations and road maintenance supervisors will make periodic inspection

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trips. There will also be environmental monitors. Assume an average of 1.5 vehicles per day.

11.2 Vehicle Maintenance and Drivers Fitness

Allnorth[75] stated the following: *CZN will rely on the systems which have been established by the federal and provincial authorities to regulate the safety and performance of the commercial transport industry. In Canada all commercial motor vehicle carriers are required to have National Safety Code Registrations. Part of the requirements of the National Safety code is to ensure the minimum requirements are met with respect to:*

- *Driver qualifications and regular certification,*
- *Hours of Service Operations,*
- *Vehicle Inspections (Daily and semi-annually),*
- *Pre-trip Assessments*
- *Maintenance Records and reporting.*

The status of an operator can be measured by their National Safety Code Standing. The National Safety Code registration is required to register and insure a commercial vehicle. The status of this is automatically verified when the unit is insured or reinsured on an annual basis. In addition to this, as the status of a carrier changes due to poor performance, accidents or incidents the Commercial Vehicle Safety and Enforcement team will commence with various disciplinary tools available to them including:

- *Audits*
- *Suspensions*
- *Removal of National Safety Code Registration.*

CZN is committed to ensuring the safe transportation of personnel and goods. CZN would adopt, at a minimum, and under the responsibility of a Road Operations Manager, standard industry operating procedures for all vehicles supporting the mine operation. These standards would include:

- *Daily tailboard meetings with operators to review any specific or unique road conditions which can impact the safe and efficient operation of the transportation fleet.*
- *Weekly safety meetings of all personnel utilizing the road regularly*
- *Radio call procedures*

75 Allnorth, Information Request Round 2, Responses to Oboni Riskope Information Requests dated September 23, 2016, October 7, 2016, reply to question 11a.

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- *Daily pre and post trip inspections of all commercial vehicles, which would include brake checks, and inspection reports, completed by the operator*
- *Reporting procedures for all near misses and incidents and the appropriate actions to follow.*
- *Procedures for routine inspections of cargo and general truck conditions to be completed during the daily transportation cycle.*

4) Vehicles maintenance will follow a regular, extensive maintenance inspections. System pressures and integrity, tire pressure, fluid levels, electrical system continuity, belt tension, etc. may require daily inspection. Periodic maintenance (daily, weekly, or by hours of operation) will be performed to replace filters, change oil, grease fittings, clean air filters and breathers, clean and fill batteries, etc. Chains and cargo retaining devices, bags should be included in these checks. Periodic inspection is required for brake systems pressure, brake linings, wheel bearings, cab controls and accessories, etc. Repair and replacement of components such as engine, transmission, rear end, axle, etc., will be performed as required. Many companies require the truck drivers to file daily reports on vehicle condition and this should be enforced on this project as a overall risk mitigation.

5) During maintenance checks, special attention will be given to all brake system components to see that they are properly adjusted to manufacturer's specifications. A vehicle with improperly maintained service brakes, or pressure leakage in the brake components, which causes activation of the emergency brake system, could result in unequal brake application and excessive heating of one drum. Because ignition of brake system components and flame propagation to other truck areas is not uncommon, fire extinguishers have become standard equipment. In addition, improper adjustment of one or more brake linings places total dependence on the others. If uncorrected, the brakes that are functioning properly will experience excessive and unnecessary wear.

6) CNZ and subcontractor's drivers have to be fit to work with alcohol and substance enforced control criteria. Distractions during driving shall be maintained to a minimum as experience in mining access road has shown that stress, fatigue and distractions (telecom with family, for example) are an extremely hazardous mix.

7) Any driver on the road (CNZ, subcontractors, private) will have to undergo a safety briefing, including special instruction in case of accident, hazardous conditions, need to stop on a pull out, etc.

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11.3 Meteorological conditions

8) Since Canzinc recognized whiteout and other extreme meteorological conditions would increase the likelihood of an accident, those extreme conditions will lead to precautionary road closure thus can be neglected in the risk assessment.
9) Mud-ice-snow conditions are considered "business as usual" and professional drivers will adapt speed and behaviour to those conditions.

11.4 Road safety, driving rules

10) Accordingly to road morphology and conditions, speed limits will be strictly enforced and signalled.
11) This study takes into consideration that SoP conditions in case of an accident/extreme weather blocking the road will be clearly explained to each driver and a safety sheet will be visible in each vehicle (stop where you are, do not "pack up" stopped trucks, allow as much place as possible to rescue vehicles...etc.), including "plan B" and possibly "plan C".
12) Private/subcontractors traffic to be controlled (time of the day, volume of traffic, etc...) and adequately trained to behave correctly on a mining access road.

11.5 Accidents Response and Road and Infrastructure

13) Response times will be within an hour for first responders, and approximately two hours for a larger crew with equipment, in all seasons. Very little hauling is likely to occur at night, and if it does, spill responders will be on call with the same expected performance.

14) The placement of a road surface over any material that cannot adequately support the weight of traversing traffic will severely hamper vehicular mobility and controllability, thus increasing probability of accidents. Moreover, lack of a sufficiently rigid bearing material beneath the road surface will permit excessive rutting, sinking, and overall deterioration of the travelled way. Thus, we assume that adequate maintenance will be implemented to keep the road free of erosion gullies, ruts, potholes etc.

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12. Conclusions

Extant documents defined environmentally sensitive areas as follows (See Section 6):

- Sundog Creek between km17-40 and km 25-32;
- Karst Terrain (approximately km 53-64), and
- sensitive drainages at Tetcela (— km 84) and Fishtrap (—km 95).

Based on extant document the traffic structure was modelled as three typical streams (See Fig. 11):

- loaded outbound concentrate trucks,
- inbound empties (with their own fuel and service fluids (hydraulic oil, etc.),
- and inbound environmental sensitive cargo.

The study started by looking at potential consequences of accidents (off-road excursions only, see definition in Section 2). It was assumed that increasingly higher consequences would occur as a result of:

- accidents featuring higher energy,
- larger spread of contaminants,
- increasing difficulties in recovery of pollutants or

any combination thereof, i.e. developing a multidimensional consequence function.

This lead to formulating 9 classes or multidimensional consequences named Consequence Classes (Section 6.5, Table 14). Consequence Class 1 would be characterized by no environmentally sensitive target in potential reach, low energy, easy to contain/retrieve spills, whereas Consequence Class 9 would be characterized by environmental sensitive area in immediate reach, highest energy, and extremely difficult to contain/retrieve spills.

Thus the study considered from that point on the 9 classes as follows:

Class 1-2	minor
Class 3	moderate
Class 4-5	significant
Class 6	serious (S)
Class 7-9	very serious (VS).

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Extant reports had defined ten Stratification types and a number of Special Sections for specific segments considered by Allnorth to be representative of the rest of the road. Drawing for these covered approx. 20% of the total length (Section 3).

We proceeded (Section 6.5, Table 15, 16) by pairing each of the above with the related Consequences Classes (some Stratifications having more than one Consequence Class) and then applied ORE (Optimum Risk Estimates, ©Riskope, Sections 5, 7, 8) to the set, in order to determine risks (Section 9).

To increase transparency and understanding we decided to transform probabilities of mishaps in expected number of accidents (per year, per service life).

1) **ORE pinpointed the Stratifications of high consequences (S-VS accidents)** (Figure 26) as being 1,2,3,4,5,7,8 and Special Sections. The number of high Consequences Classes accidents will be relatively small, but in Stratifications 5 and the Special Sections. **NB:** small does not mean necessarily acceptable, as it will be discussed later.

Stratifications 1,2,3,4 and good number of special sections are located in the first 40 km of the road. Stratification 2 (km6.5-13) correspond to Funeral Creek and Stratification 3, 4 from km 23.8-39.4km correspond to the Sundog sector.
Six out of the seven special sections are located within the first 40kms, the seventh being located at, according to Table 7: Road Summary, km 122.6-122.9, or, following PRAIRIE CREEK MINE GEOMETRIC DESIGN at km 122.7-123.4.
Stratification 5 is located between km 86.3-90.3 in an area where sensitive drainages are present.
Stratification 7 is split in 9 sub-segments from km 39.4-143.1. The length of the sub-segments varies between 0.6km and 21km each. Only 2.5 km of Stratification 7 are drafted with plan view, longitudinal profile, and cross sections.
Stratification 8 covers a total of 6 km split in three sub-segments as follows:

- Poljie Creek km 50.9-53.9,
- Fishtrap Creek km 94.3-95.3,
- Grainger River km 124.3-126.3km

Due to the small percentage of the project documented with plans and to the highly irregular fragmentation of the Stratifications any attempt to deliver further details in the geographic location of risks along the layout would be fraught with more uncertainties than gained precision, hence be misleading.

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2) Since the traffic cargo structure was known (percentage of vehicles with full load of concentrate hazmat, environmental significant cargo and "empties" (with their own fuel and service fluids, like for example hydraulic oil) and an accidental tolerance thresholds had been defined (Section 8), **ORE made it possible to compare the accidental tolerance level** as shown in Figure 27.

ORE showed which type of cargo would generate risks that exceeded accidental tolerance expectation for each Consequence Class. The large exceedance of Consequence Class 1 is not worrisome, as those accidents are minor, whereas the exceedance of Class 4 (significant) has to be discussed.
Class 4 corresponds to areas with fair topography and cross section, but nearby sensitive environment. Consequence Class 4 accidents are indeed located in Stratifications 1,2 predominantly, but also in Stratifications 5,6,7,8 and Special Sections, as shown in Figures 28C, 28B.
Stratification 1,2,3,4,5,7,8 and Specials Sections have been discussed above.
Stratification 6 develops between km 40.9-80.0 in 4 segments with one sub-segment covering 20.9 km. Only one kilometre layout has been delivered to date, between km 44-45 with the consequences discussed above (same remark re: location as above).

3) **ORE detected the "black spots (segments)" of the road, i.e. those where the highest accident number will occur.** This information is useful as those accidents will create delays and could be the cause of interdependent accidents. ORE made it possible to show which homogeneous segments would cause the highest number of accidents (of any Consequence Class) as show in figure 28a.

Obviously these results are also influenced by the length of the Stratification varying between 3.8 km and 58.7 km. This is intuitively correct, as generally the longest distance driven the higher the chances of an accident.

This being said, Stratification 7 has a large majority of Class 1 (minor) and only a few Class 4 (significant) accidents. The estimated number of Class 1 accidents per year in Stratification 7 is approximately 12. That means that under all the assumptions and conditions made in this report (Section 2, 11, Appendix 3) one truck per month could end-up with at least one wheel off the road in fair topography.
From the results of the risk assessment (Section 9) and the review of the mitigations (Section 10) it becomes apparent that mitigations, as proposed to date, are not sufficient to bring the risks within the tolerance levels described by CNZ.

The main deviations from tolerance are mostly due to the environmentally sensitive context of the project. The narrow roadbase, which does not consider any margin for vehicles' slippage, also remains a significant point of concern. This, especially as there

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are doubts related to the feasibility of protective works, such as berms, in many environmentally sensitive locations.

While developing the study it was noted that mitigations of man-made slopes (cuts in the uphill side of the road) had been mentioned in various extant records, but no final plan proposed. In our experience (and also in the experience of any highway department in mountainous/rocky areas (BC, NY, WA, OR, Switzerland just to quote a few; Canadian and US railroads) man-made slopes can generate frequent and damaging slides and rockfalls which, at this point, have not been evaluated for lack of information.

Thus it can be considered that the presently estimated risks could be reduced in various environmentally sensitive areas with beneficial effects to the overall project. Pending an analysis of man-made slopes, it is foreseeable that residual risks could be brought to accidental tolerance level if detailed analyses of mitigations is carried out and mitigations are then implemented and monitored.

Starting with the point of view that the number of concentrate loads to carry out of site is invariant, a winter only road would necessitate a very significant increase of winter traffic which would then be exposed to avalanches.

Pressure to increase the duration of "winter season" would be great and drivers stress, fatigue would increase. If climate change shortens winters the problems will multiply.

If traffic density increases due to shorter hauling season, accidents that have not been considered in this report will emerge as significant, especially because of the narrow roadbase.

Overall it is our opinion that, based on the above, risks would increase in the winter-only scenario.

The risk assessment has considered the alternative layout as a possible mitigation and showed that its implementation would not significantly alter the risk landscape, as traffic accidents would be similar, and the avoided natural hazard, using the parameters defined by the extant studies, have a modest influence on the overall results.

The possible systemic mechanisms that could lead to a failure are the following:

Narrow roadbase could prove too hazardous as it does not leave any margin for error, prevents the installation of safety barriers.

Human factors on drivers, rescue teams and including JSM level may lead to improper reactions if emergency plans have not been developed for all types of accidents.

Normalization of deviance (especially for recurring events, but also for climate change related events) which leads to the classic accumulation of small occurrences that, together, generate catastrophic events. **NB:** Normalization of deviance if defined as the

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gradual process through which unacceptable practice or standards become acceptable. As the deviant behavior is repeated without catastrophic results, it becomes the social norm for the organization.

Use of codes. More and more industries are becoming aware that the "business like usual", relying on blind compliance, or legalistic approach, to audaciously interpreted codes is not the way of the future. That applies both to the industrialist and the public.

"Generalization" of Stratifications may have lead to miss significant details related to potential consequences.

Rosy scenarios in general, but also, more specifically related to natural geo-hazards and neglecting man-made rockfalls and slides.

The priority risks to consider/manage are those deriving from the systemic mechanisms just described.

- The audacious interpretation of codes developed for other traffic (forestry vs. Concentrate cargo) has lead to select a unforgiving roadbase width which generates risks that should be considered and managed as a priority, at least in environmentally sensitive areas.
- The generalization of Stratifications may be the cause for over- or under-estimates of risks, as Consequence Classes have been allotted by extending the areas covered by drawings to the entire corresponding Stratification.
- Human factors and normalization of deviance lurk on any long term project (and 16 years service life can be considered long term in this respect) and, again, codes and JMS have proven to be insufficient to ensure optimal risk mitigation.
- Finally, rosy scenario and omission to consider the risks linked to landslides/rockfalls from natural and man-made slopes will generate risks that should be considered and managed with care.

There are numerous uncertainties in the study, caused by very different sources.

Climate change is certainly a major one which could alter the number of "slippery road" days, avalanche patterns and drainage, flooding, etc. Given the statements related to JMS, and preventative road closure approach, climate change could, in the negative effect side, cause more closures. The obvious reaction would be to increase traffic to "make-up the missed days" as soon as the conditions allow. There would then be an increase of rotations, but not an increase of the total number of loads. During that period the "one way haul" concept may not work, and colliding trucks accidents, not considered

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in the study, could occur, on top of off-road excursions, if pullouts are not exclusively used for crossing/passing. It is hard to see that such conditions would alter in a significant way the results of the study, but should conditions significantly deviate, a reassessment should be performed.

Climate change could also alter the number, volume and frequency of landslides/rockfalls along the road, and thawing of permafrost, where pertinent. Should the conditions change, the hazard study should be updated, new forecast frequencies developed, and then the risk assessment updated. It is expected that landslide/rockfall risks would increase if a negative scenario develops for climate change. If the climate change would develop toward a positive side (less rain, longer dry spells), then visibility reducing dust could become a problem.

Human factors (fatigue, substance abuse, bravado, etc.) have plagued similar projects and despite the efforts that the proponent intends to apply, the “top shape” of drivers and other personnel is loaded with uncertainties. As the study has been bench marked with a road where personnel undergoes similar checks to the ones considered by the proponent, we are relatively confident that these elements have been reflected in the risk results.

General traffic, which remains a major uncertainty pending on the project, has been excluded from the analyses. Should it be included, then the assessment should be updated as it is likely that accidents would significantly increase and include private traffic victims.

The type of trucks, their weight, and the exact cargo containment are not yet (as we understand) definitely been selected. We stress the importance of cargo securing including under severe winter conditions (low temperature brittleness). CNZ spill estimates based on logical intuition constitute a low bound, when considering the type of accidents that could occur on the road. Bulk transportation would generate significant increase of adverse consequences.

As mentioned in Section 8, the bench marking exercise “anchors” the overall traffic accident risk study to reality in quite a comforting way.

The study has shown that natural hazards (man/made slopes generated hazards could not be included for lack of information) within the parameters of the SoW (which has an impact on the way avalanches were evaluated) contribute very little to the overall risks. The risk estimates for traffic accidents and natural hazards were developed under a complex set of conditions and assumptions that have to be considered (Report Validity Conditions and Assumptions (Section 11) and the corresponding Appendix 3, Assumptions.

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Should any of the conditions and assumptions not be complied with, then the probabilities of occurrence would increase, hence the risks would increase. The same would occur if the "Generalization" of Stratifications may have lead to miss significant details related to potential consequences.

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Appendix 1 Glossary

Acronyms	
ANCOLD	Australian National Committee on Large Dams
BCP	Business Continuity Planning. It identifies an organization's exposure to internal and external threats, synthesizes hard and soft assets to provide effective prevention and recovery for the organization, while maintaining competitive advantage and value system integrity. BCPs are also called Business Continuity and Resiliency Planning (BCRP). A BCP is a roadmap for continuing operations under adverse conditions such as a extreme storms or a cyber attacks. In the US, governmental entities refer to the process as Continuity of Operations Planning (COOP). Business continuity planning is often used to refer to those activities associated with preparing documentation to assist in the continuing availability of property, people and information and processes
BI	Business Interruption whcih can be valuated in duration (days, week, months) or monetary terms (M$)
BI	Business Intelligence (should be used carefully in order to avoid confusion with the prior one)
BIA	Business Impact Analysis
CCTV	Closed Circuit Television
DRP & BRP	Disaster Recovery & Business Resumption Planning (DRP) Let's start with a definition: a disaster is any nefarious event that will significantly affect a business' operations: "Traditional" disasters include fires, floods, hurricanes and earthquakes. "Non-traditional" disasters may include terrorist strikes, toxic waste dispersions, computer system crashes and labor strikes. A DRP consist of two parts: "Disaster recovery", i.e. the process of restoring the ability to operate; and "Business resumption", i.e. the process of re-opening each of the facility components.
QRTC	Quantitative Risk Tolerance (tolerability) Curves. Interested readers can refer to: • Improving Sustainability through Reasonable Risk and Crisis Management, by Franco & César Oboni, ISBN 978-0-9784462-0-8, 2007, • C. Oboni, F. Oboni, Aspects of Risk Tolerability, Manageable vs. Unmanageable Risks in Relation to Governance and Effective Leadership, Geohazards 6 (2014), Kingston (ON), Canada, June 15 – 18, 2014., • Oboni, F., Oboni, C., Is it true that PIGs fly when evaluating risks of tailings management systems? Short Course and paper, Tailings and Mine Waste ’12, Keystone Colorado
WTP	Willigness To Pay. The amont of money a society is agreeable to pay to save a life. Interested readers can refer to: • Marin, A., Costs and Benefits of Risk Reduction. Appendix in Risk: Analysis, Perception and Management, Report of a Royal Society Study Group, London, 1992;

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General Terminology	
Cost of Consequences	A measure of the impact of a hazard on potential receptors, obtained as a sum of various components such as direct costs, replacement costs, indirect costs (loss of business etc.), social costs, political costs, public reaction costs etc.
Consequence function	A holistic consequence function integrating all health and safety, environmental, economic and financial direct and indirect effects.
Public Relations (PR)	A management function that helps to define organizational objectives and philosophies, and facilitates organizational change Public relations practitioners communicate with all relevant internal and external public in an effort to create consistency between organizational goals and societal expectations. More specifically, PR can be used in risk communication and crisis management.
Problem	A doubtful or difficult matter requiring a solution; sudden deviation from an expected performance or the existence of a permanent deviation from an expected performance.
Accident	An event that is without apparent causes or is unexpected. Generally an unfortunate event, possibly causing physical harm or damage brought about unintentionally.
Incident	An event or occurrence that attracts general attention or that is otherwise noteworthy in some way.
Emergency	An unforeseen combination of circumstances or the resulting state that calls for immediate action. An urgent need for assistance or relief "the governor declared a state of emergency after the flood".
Catastrophe or Disaster	A great and usually sudden disruption of the human ecology which exceeds the capacity of the community to function normally, unless disaster preparedness and mitigatory measures are in place.
Mitigation	Measures and activities implemented with the goal of reducing the hazard (probability of occurrence).
Force Majeure Clauses	A term used in contracts to define events which are considered an Act of God. An event at or below human credibility (less than 1/100,000 to 1/1,000,000)
Resilience	The capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure.
Interdependen-	A chain reaction that occurs when a small change causes a change nearby, which

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cies and domino effects	then causes another change, and so on in linear sequence. It typically refers to a linked sequence of events where the time between successive events is relatively small. It can be used literally (an observed series of actual collisions) or metaphorically (causal linkages within systems such as global finance or politics).
Normalization of deviance	The gradual process through which unacceptable practice or standards become acceptable. As the deviant behavior is repeated without catastrophic results, it becomes the social norm for the organization.
Risk-related Terminology	
Risk (Downside)	The product (multiplication) of the probability of occurrence of a hazard by the cost of the undesirable consequences resulting from the occurrence of the hazard. In some cases, the product is not expressed, and probability of occurrence p and cost of consequences C may be plotted as points on a p-C graph.
Risk Management (RM)	The complete process of risk assessment and risk control, i.e. the result of a rational approach to risk analysis and evaluation, and the periodic monitoring of its effectiveness using the results of Risk Assessments (RA) as one input.
Risk Estimation	May be based on historical data, logical models (fault and event trees), or mathematical models. Probabilities can be assigned subjectively or objectively if an historical database is available. Risk estimation helps answer the questions, What is the likelihood of the hazard, what will happen, and what areas will be affected?
Risk Evaluation	The process of determining acceptable risk. There are upper and lower limits (or thresholds) to risk that need to be defined before risk control can take place. These thresholds are often influenced by society's level of accepted risk.
Risk Control	The process of deciding on measures to control risks and monitoring the results of implementation. Decision theory can be used as a tool here. Risk control can answer the question, what can be done to reduce the risk?
Risk Communi-cation	The US National Research Council defines risk communication as “an interactive process of exchange of information and opinion among individuals, groups, and institutions”. Risk Communication is part of the RM/CM process and, in a way, risk mitigation at the non-technical level. Stakeholder analysis has to be performed to prepare a risk communication campaign.
Hazard-related Terminology	
Hazard	A condition with the potential to cause undesirable consequences. The term hazard is often used to mean source of a given magnitude (for example, volume of sliding mass).
Hazard Management (HM)	The set of techniques used to define hazards and to rate them in terms of likelihood or magnitude.
Hazard	Identifies the hazards and potential damages. Hazard identification answers the

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Identification (HI)	question, "What can go wrong?"
Crisis-related Terminology	
Crisis	A decisive moment, particularly in times of danger or difficulty.
Crisis Management (CM)	A set of techniques that manage the public relations and media relations implications of crisis situations that have the potential to damage or destroy the image and/or function of an organization. Crisis management is also an organizational discipline involving logistics experts, security managers and technical communications experts.
Issue Management (IM)	A relatively new discipline that identifies and manages issues related to an organization. The tools are research (issue identification phase) and a variety of techniques designed to develop effective communication channels between the organization and its stakeholders. Issue management manages issues that are potentially detrimental to an organization's reputation or operations in such a way that the issues do not lead to crises.
Crisis Management Plan	A CM Plan is the compass in the middle of the fog, i.e. a crisis. A CM Plan encompasses several components.
Media Training	The media are an important stakeholder in a crisis and are often a key link to the public and other stakeholders. The development of key messages that reflect the knowledge that is acquired in the RM process and other important factors in a crisis (for example, compassion) is an important step in media training.
Probability- and statistics-related Terminology	
Statistics	The set of mathematical interpretative techniques to be applied to phenomena that cannot be studied deterministically because of the number and complexity of their parameters. An example of such a phenomenon would be the duration of a flu-related sick leave. There are dozens of driving parameters, including physical and mental fitness of the sick person, the environment and so on. There is certainly no deterministic magic formula to determine the duration of the required leave. As a result, it is possible to say only that a flu-related sick leave lasts from three to ten days, with an average of five and a standard deviation of one.
Probabilities (concept)	The set of mathematical rules used to evaluate the stochastic (uncertain, possible) character of an occurrence by evaluating the number of chances of the occurrence of the phenomenon over a total number of possible occurrences. In De Natura Deorum, Cicero wrote that probabilities direct the conduct of the wise man. Evaluating chances, studying their consequences and opting for various courses of conduct are indeed the basic steps of modern Risk Management and risk-based decision making. As such, statistics are a descriptive discipline whereas probabilities are an evaluative discipline. If the flu example given above is addressed in terms of probabilities, for example, it may be seen that probabilities can be used to evaluate the chances that an ill person will still be on leave in two days time.
Probabilities	A measure of the likelihood of an event, expressed with numerical values ranging

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(numerical)	from 0 to 1, where 0 represents impossibility and 1 certainty. Probability is often interpreted as a subjective degree of belief (opinion, subjective interpretation). Many assessment methods rely on subjective probabilities. These probabilities are determined by employing the expert opinion of an individual or a consensus of highly qualified professionals. The personalist (subjectivist) or Bayesian view considers the probability of a phenomenon's occurrence as the degree of belief that the event will occur, given the level of knowledge presently available. In this view, estimates are considered "first or a priori" estimates, to be perfected with updates whenever further information becomes available. This vision of probability is generally used throughout this book's examples, even though in some cases an alternative approach based on observed information is presented. The reason for this apparent break in logic is that often times observed information is generally incomplete or deficient, and, therefore, probabilities estimated in this manner remain "a priori" estimates. The frequency interpretation of probability, in which probabilities are understood as mathematically convenient approximations of long-run relative frequencies, can also be used. In the frequentist view of probabilities, the probability of an event is defined as the frequency with which it occurs in a long sequence of similar trials. For example, in the toss of a coin, the frequentist approach says that the probability of a head is 0.5, i.e. that the long run frequency converges towards 0.5 when the number of tosses increases. In the case of a coin toss, few would question this definition, but if the analysis focuses on, for example, estimation of the occurrence of a unique event (a terrorist attack against a facility), the long-run aspect of this approach is clearly non-applicable.
Frequency	Frequency or relative frequency is a proportion measuring how often or how frequently something occurs in a sequence of observations. This concept can better be explained with an example related to railroad Track Occupancy Frequencies (TOF): these can be defined for various types of traffic on a given stretch of track. Required data are: a) daily number of trains of a given type, b) train speed, and, c) train length. TOF are defined as the time during which any portion of a train is physically present in the considered sector. Let's assume traffic of 25 freight-trains of 100 cars per day, at 20Mph (32kph) speed for a one-mile (1.6km) stretch of track. One hundred cars cover a length of appx. 1.61km, thus: time of occupancy per train tt: (1.61+1.6)/32 = 0.10hrs/train track occupancy per day to: 0.10*25 = 2.51hrs/day track occupancy frequency TOF: 2.51/24 = 0.10/d
Monte-Carlo Method	The Monte Carlo method is a way of solving problems using statistical methods; stochastic technique (which means using random numbers) and probability. It is generally applied using commercial soft wares. One of the major limitations of the Monte Carlo method is that it requires the user to define the probability distribution for each variable: as most users either do not know how or do not have enough data to reliably define the distributions, it can be shown that the methods generates more uncertainty than other simpler "distribution free" methods such as for example the Rosenblueth Point Estimate Method.
Root Cause	Encompasses methods aimed at identifying the root causes of problems or events.

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Analysis	RCA users believe that problems are best solved by attempting to correct or eliminate root causes, as opposed to addressing the symptoms. By directing corrective measures at root causes, it is hoped that the likelihood of problem recurrence will be minimized. RCA is often considered to be an iterative process, and is frequently viewed as a tool of continuous improvement.
Entreprise Risk Management (ERM)	Enterprise risk management (ERM) includes the methods and processes used by organizations to manage upside or downside risks. ERM provides a framework for risk management, which typically involves identifying particular events or circumstances relevant to the organization's objectives (risks and opportunities), assessing them in terms of likelihood and cost of consequences, determining a response strategy, and monitoring progress. By identifying and proactively addressing risks and opportunities, business enterprises protect and create value for all their stakeholders.
Decision Trees, Event Trees	(or tree diagram) is a decision support tool that uses a graph or model of decisions and their possible consequences, including chance event outcomes, resource costs, and utility. A decision tree is used to prioritize strategies. A common use of trees is for calculating conditional probabilities.

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Appendix 2 Landslide hazards and road summary

The notes in the table are end-notes, so they are found at the end, after Appendix 3.

Constr. Strat. Type (from Appendix A[76])		Extant Landslide Hazard list			Major stream crossing /parallel	4m Width Sections	SteepGrades	Radii (m)	Notes
from km	**to km**	**From km**	**To km**	**Rating**					**NB:** Notes with roman numerals (Ex. See [n]) are at the end of the Document
		0	0.4	Mod.					
I									
5.14					Prairie C.				Not continuously
					I	5.4-5.5			Prairie Creek
							6.0-6.1		Short +8%
					I I			6.125- 6.250	S turn 45m, then 30m
	6.2				6.2				Clear-Span Bridge 15.3 meters (dar appendix b page 12 du pdf)
II									
7					Prairies C.				Varying degree of proximity
					I			7.4-7.45	30m
	8				Funeral C.				
?									
13					13-13.4		13.0- 13.76		Water course along road. Mostly 8-10%
					13.4		I I I		Multi large diam. Metal culvert
							I	13.4-	27m. No steep grade

76 EA1415-01_Allnorth_Responses_to_Information_Requests.pdf Appendix A, Construction Stratification Types.

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							I	13.5	in turn.
	13.76						13.0-13.76		
		16.3	17	Mod.					
					20.5				Multiple Large Culverts
?									
23							23.0-23.7		Mostly -9 to -12%
					23.4		I I		Clear-Span Bridge (58m) grade nil.
						23-23.7	I		Short +10%
	23.7						23.0-23.7		
III									
25						25-26			
					25.3	I I I I			Clear-Span Bridge L>40m (64m) rock blasting
								25.45	20m
		25.5	26.6	Mod.		I			
	26	I	I	I		25-26			
		25.5	26.6	Mod.					
		26.2	26.3	High					See [i]
		27.2	27.4	Very High					See [ii]
		28.1	28.4	High					Rock blasting around 28.4 See [iii]
					28.6				Clear-Span Bridge
		29	29.2	Mod.					
IV									
30							30.0-31.0		Two very short -10% stretches
		30.6	30.8	Mod.			I		

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		30.8	31.2	Mod.			I		See [iv]
	31						30.0-31.0		
		31.2	31.8	Mod.					See note above
?									
		32.5	36.2	Mod.					
33.2		I	I	I					
	34.2	I	I	I					
?	Sundog Creek sector	I I I	I I I	I I I					
34.8		I	I	I	Sundog C.				
		32.5	36.2	Mod.	I				
					I I I I I I	36.3-37.1	36.8		Width not shown in plans, but mentioned in cross sections. Short -10.8%
					37.7-37.9				Partially in river bed
	39								
					39.2 (39.4 original)				Clear-Span Bridge
					42.8 (43.15 original)				Multiple Large Culverts
		42.9	43.3	Mod.					
VI									
44							44		Short +8%
	45								
		46.8	48.4	Mod.					
VII									
49							49.6-50.0		10.00%
		49.7	50	Very			49.6-		See [v]

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				High			50.0		
							50.2-50.6		-9.90%
	51.5						51.6		9.00%
VII									
52									
	53								
					53.2 (53.55 original)				Clear-Span Bridge
		53.7	54.2	High					See [vi]
		54.5	57.6	Mod.					
		59.7	60.4	High					See [vii]
		61.4	61.5	Mod.					
		83.5	85.5	High					
					87.1(87.25 original)				Clear-Span Bridge
V									
88		I	I	I			88.0-88.5		Short +10, -10%
		83.5	85.5	High					See [viii]
	89								
					89.5 (89.8 original)				Clear-Span Bridge L>40m
					94.6 (95.0 original)				Large diam. Culvert
		?	?	Mod.					
		95.5	101.7	High					See [ix]
X									
98.5		I	I	I			98.5-99.1		7% -9%
		I	I	I				99.15-99.25	30m, grade 4%
	99.5	I	I	I					

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		95.5	101.7	High					See note above
		Alt.	route						
					111.7 (122.1 original)				Large diam. Culvert
		111.8	113.1	Mod.					See [x]
		Orig.	route						
		110.2	115.1	Mod.					
					118.1				Multiple Large diam. culverts
					121.8 (122.1 original)				Clear-Span Bridge
?									
122.7									
					122.8 (123.1 original)				Clear-Span Bridge (30.52m), grade -4%. Before bridge grade is briefly -8%
	123.4	Orig.	route						Rock blasting
					124.2 (124.5 original)				Clear-Span Bridge
		136.4	137.3	High					See [xi]
IX									
147							147.9		Short -8%
	149	Orig.	route						
					150.8 (151.1 original)				Large diam. culvert
		154.5	155.3	High					See [xii]
		155.9	159.3	Very High					See [xiii]
					158.9 (159.4 original)				Ice Bridge (winter) or Barge (summer)

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Appendix 3 Assumptions

In this appendix assumptions are gathered by theme, for example, Road Design and Maintenance, Road width, etc. Each assumption is preceded by a statement that causes/justifies that assumption. Like in the body of the report *italic characters* denote texts from CNZ and their consultants.
These assumptions and the conditions stated in Section 11 (Report Validity Conditions and Assumptions) have to be considered simultaneously. As stated in Section 11, if any of the conditions & assumptions is not complied with an update of the risk evaluation should be performed.

Road design & Maintenance

We provided preliminary roadway designs for sections of the road that would then be representative of longer sections of the road, and collectively, the entirety of the road. A road alignment was also provided for the entire road. We believe these are a suitable basis for assessing the performance and safety of the road, and environmental effects. It is not necessary, and would be redundant, to provide a preliminary design of the whole road.

Assumption 1: this study bears first on the segments that are best know and gives estimates by analogy to complete the assessment for the rest of the road, using extant documentation, including oblique photos and public records reports. Figure 19 shows diagrammatically how the risk evaluations were carried out, from the detailed Stratification drawing (Phase 1), to the entire extent of each Stratification (Phase 2), and then, by collating the Stratifications, extended to the entire road (Phase 3).

Assumption 2: Road maintenance will insure that the road surface is kept smooth and drains properly under the final design conditions/parameters that will be selected.

B.C. Ministry of Forests, Lands and Natural Resources Operations Engineering Manual which was quoted stating that the controls it defines: "...*are suggested alignment controls for average conditions on forest roads. Variations can be expected, depending on, for example, site conditions and time of use (b) There are no absolute rules for establishing maximum road gradient...".* Thus the specifications of Table 2 constitute a selection of the flexible rules defined by B.C. Ministry of Forests, Lands and Natural Resources Operations Engineering Manual for average conditions on forest roads where vehicles are generally lighter, not as complex (Super B double trailers, as discussed in Section 1.2.2) and cargo is wood (not concentrate or hazmat) as considered in this project. Furthermore in Figure 3 the first note indicates the reported widths do not allow for any slippage of the truck or trailer due to poor road conditions.

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Assumption 3: There will be no other sections that should require a reduced running surface of 4 m other than those marked in Table 4, as confirmed by Allnorth.

Assumption 4: Given the narrow road, its cross sections types and the uncertainties related to the hazards sources, location, magnitude and resting position, this study considers equally likely an accident in both traffic direction (does not make a distinction based on travel lane).

Assumption 5: The pullout frequency of 1/km will strictly be complied to, in particular at both ends of narrower segments. Generous widening will be provided in sharp curves, possibly exceeding the code to take into account the lack of forgiveness due to the 5m width.

Traffic

During implementation it has been reported[77] *that "this is basically a tote road to get the material in. We can envisage maybe something like a hundred loads in total over a space of perhaps two (2) or three (3) weeks, once in, once out. So that gives you an idea of the traffic volume."*

Assumption 6: construction time accidents are considered negligible compared to the service life of the road. Nevertheless, "hot spots" highlighted by this study will exists during the construction time. Extreme care will have to be exerted, especially with possible oversized cargo, in particular in the environmentally sensitive areas.

Assumption 7: Concentrate traffic and environmentally significant loads will be those defined in Figures 9,10.

Allnorth has since confirmed in Undertaking #35, 46[78] that the *trucks will either be similar to those used at the Red Dog Mine (Figure 15) for bulk hauling or, if concentrates are hauled in bags, they will be 3 tonne bags tied-down inside a truck box which will have a lockable solid lid*

Assumption 8: This report considers the CNZ evaluated spills for the bags alternative as a minimum spill in case of an offroad excursion accident. Should the "Red Dog" solution be adopted the minimum spill will be significantly larger.

77 http://reviewboard.ca/upload/project_document/EA1415-01_Technical_session_transcripts_16-Jun-2016.PDF page 80 81

78 EA1415-01_Letter_to_MVEIRB_re_Undertakings_from_Technical_Session_Aug_11__2016.PDF

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Assumption 9: Proposed speed

- 30km/h on average with
- typical speed of 40~50 km/h and
- max of 60km/h in some sections for the concentrate and other heavy traffic. NB: the 60km/h derives from the public record and comes as an exception to the road design specifications shown earlier, declared by Allnorth and delivered in tabular form in Sections 3.1.1 and 3.1.2 (Table 2, Figures 2, 3), when considering the maximum width of 5m.

These speeds are to be considered as absolute maximums and will have to be strictly enforced. *At the detailed design stage, using the MOFLNR Engineering Manual standards, sections with restricted line of sight will be speed reduced accordingly and posted.* Assumption 9 and possible reductions to lower speeds apply of course to those locations, narrow spots, sharp curves, intersections, and other specific locations that will be noted during the design phase. As concentrate transport will partly be contracted, all rules apply to subcontractors as well.

Traffic accidents

Assumption 10: traffic accidents between two or more vehicles are not considered in this study for the following reasons: i) trucks leave in convoy or at discrete intervals in the morning, turn around at the end of the road. Thus most heavy vehicles crossings will take place in a relatively easy section of the road. ii) drivers will be in radio contact. iii) pull-outs are rather frequent. Additionally, road intersections (including borrow-pits and other facilities) will be limited, reportedly well marked and speed controlled.

Assumption 11: This report considers the road as open to mine traffic only. The opening to free private/ passenger traffic would completely alter the risk study methodology and conclusions, thus requiring a revision of the analyses. The hot spots highlighted by this study would probably remain unaltered, but the number of accidents would increase.

Assumption 12: Accidents involving empties belong to a significantly lesser consequence provided special measures are taken to prevent spills (anti-puncture tank/anti-spill lids).

Reportedly CNZ foresees larger pullouts where concentrate vehicles can be turned around[79] every ~10 km at presently unspecified locations. In the same discussions CNZ has also mentioned the possibility for a driver to drop the trailers and bring back to the

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79 http://reviewboard.ca/upload/project_document/EA1415-01_Technical_session_transcripts_16-Jun-2016.PDF page 127 to 135

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mine the rig in case of extreme adverse conditions.

Assumption 13: In all cases prolonged stops on the road will result in increased exposure to natural and man-made hazards, especially in adverse conditions. This practice cannot be considered as a valid risk management practice.

Road features hazards

Assumption 14: Bridges and culverts. As it has been specified that traffic would not be running during severe weather, hence flooding events, it is considered that bridges will be present at all time vehicles have to cross them. Business interruption is not part of the scope of this study.

Assumption 15: Crossings and junctions. Due to the overall limited volume of traffic, low speeds and the stated ongoing radioing, crossings and junctions are not considered to represent a noteworthy hazard. Should traffic volume and speed increase, use of the area, including borrow pits change, then a revision would be warranted. It is also understood that particular care will be taken in ensuring good visibility in all directions and crossings. Maintaining vegetation and ensuring no visual obstacles are preset is part of this assumption. Should 3rd party users access the road, a revision should be considered.

Assumption 16: Retaining walls and shoulders. There are none in the extant designs of the various Stratifications. It is unclear how certain road prisms will be built, as they display near vertical slopes, although the use of rock blocks and gabions has been cited. The areas that probably would require the most robust barriers are those along the creeks and other sensitive environments. Given the cross section of the road placing any barrier seems impossible, both from an available space and foundation point of view. Thus, it may well be that, if the road is permitted as proposed, no barriers will be implemented for reasons that are already evident today. Snow removal will only complicate matters further.

Traffic Hazards

Assumption 17: Mechanical failure are left out of the analysis because with proper maintenance and regular check, the rates of potential accidents specifically due to mechanical failures is extremely low (beyond present credibility).

Assumption 18: Most accidents will be generated by human error, poor judgment, fatigue, compounded with meteorological (adverse) conditions, possible distractions and, of course road and vehicles characteristics.

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Assumption 19: Because of the road width (not allowing much margin of error or slippage as noted in Figure 3) this report adopts a 100% value for the snow/ice conditions accident increase while recognizing that drivers will be skilled professionals. It is also considered that raining events during summer may increase slippage, leading to a 45/55 share of hauling days with dry/slippery conditions on average during the service life.

Assumption 20: Based on Alberta's statistics 1/3 of trucks accidents include such an excursion, and considering the narrow roadbase, that estimate may be low. Nevertheless we will use that value in this report.

CNZ has confirmed that *since concentrates will have an 8% moisture content, dust generation should not be an issue even in case of bulk haulage.* They also stated that *given the concentrate trucks will have sealed lids, if a dust issue occurs, it can only be from dust that has settled on the exterior of the trucks while on site, and is subsequently lost from the trucks as they depart site. Therefore, if no dust issue is detected proximal to the site, it is very unlikely that one would be detected further from site.*

Of course, in case of dry spells, the road traffic will produce dust from the road itself, which could produce visibility problems. Dust reduces visibility and may require wetting of the roadbase. When subjected to heavy wetting, non stabilized earthen roads become extremely slick and may be severely defaced by erosion. Thus, reduced vehicular controllability from a slippery surface creates a safety hazard, and maintenance must be increased to eliminate erosion gullies. At this time the issue does not seem to have been addressed in one way or another.

Assumption 21: Dust of any kind will be controlled so that it does not become a visibility hazard and the road is not damaged or becomes excessively slippery.

Avalanches

In general avalanches of Size 2 or greater are expected to pose a risk to a person, and avalanches of Size 3 and greater will pose a risk to medium to large size vehicles. This does not take into account the effect of terrain features which may augment the effect of an avalanche (eg. a vehicle being pushed into a river by a Size 2 avalanche). Occupants will be partially protected from avalanche impact if they are in a vehicle; however if the vehicle becomes stuck, and the occupants choose to go outside to shovel, their vulnerability increases substantially. Bridges or stationary vehicles and equipment may also be at risk, depending on their vulnerability.

Assumption 22: Our SoW specifically requires to only evaluate risks in areas where the all season road differs from the winter road. Hence Table 9 shows these areas, under the

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assumption that minimal layout differences are insignificant. **NB:** the all season road may be exposed to avalanches that were not noted in Alpine's report, due to layout changes.

Assumption 23: As the exposure time of maintenance workers and light vehicles is not known, it is assumed that Size 2 avalanches (which could reportedly impact heavy trucks only in particular topographic situations) will be dealt by CNZ by implementing Alpine recommendations and mitigations. Thus this report only looks at risks linked to known traffic (concentrate trucks accidents, environmental significant cargo, empties) potentially generating spills (business interruption and safety of the workers are and remain under the exclusive responsibility of the owner of the road (avalanche hazard management plan, as advised by Alpine) and private traffic is a priori excluded), The considered events are summarized in Table 8.

Avulsions

Assumption 24: Sundog & other avulsions. It is extremely unlikely (beyond present credibility) that under the conditions presented by CNZ, the presence of maintenance crews, proper monitoring and a Journey Management System (JMS) a concentrate truck would be involved in an accident due to creek avulsion unless "normalization of deviance" (See Appendix 1 for a definition) would occur over time. Avulsions could also trigger geohazards that have not been detected to date and only a detailed study could lead to evaluate their risks.

Landslides & rockfalls

Assumption 25: Table 11 shows parameters used in extant geohazards studies. We note that small volume (say $1m^3$), high energy rockfall events (say 60km/h or more) cannot be properly accounted for because of the volume/velocity threshold values adopted.

Assumption 26: the thresholds adopted in the study do not explicitly cover potentially extremely disruptive events characterized by small volume, high velocity (hence high energy), capable of severely damaging the road surface (leave a crater) or push a concentrate truck off road (or generating highly undesirable effects on the drivers).

Assumption 27: frequencies defined by prior studies have been used although we are inclined to believe they have very significant uncertainties, especially for locations where the road is at the toe of scree generated by up slope rock faces and cliffs.

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Man made slopes

Based on experience on this type of roads and mountainous terrain, the occurrence of rockfall (relatively small volumes), possibly high velocity from man-made cuts of a variety of heights is possible and rather frequent.

Rockfalls of this type can provoke accidents. That is the reason why many roads have uphill cuts protected by nets and in some cases rockfall fences.

Assumption 28: It is our understanding that CNZ will ensure safety by designing the appropriate protections and monitoring them, having skilled personnel perform inspections prior to concentrate shipments and, in particular, after severe meteorological events. Only a detailed study of man-made cuts could deliver an estimate of future behavior and risk potential.

Earthquakes

CanZinc confirmed (Oct.24th) that *in the region of the project, earthquakes with a magnitude of 6 to 7 have a return frequency of approximately 10 years. It is therefore conceivable that a large landslide could be triggered by an earthquake in the project area during its design-life.*

Canzinc also expressed the opinion (October 24th) that *the above has already essentially been addressed in the Road Operations Plan (Section 6) and Road Construction and Maintenance Plan (Section 8) (which can be found in PR#101 Appendix C) with respect to rockfall and avalanches, which by extension covers earthquake - triggered landlsides, but we will make this clearer in subsequent drafts of these plans.*

Assumption 29: It is our understanding that in case of a seismic event careful inspection of the slopes and infrastructure will be undertaken before traffic is restored. Clarification in the emergency plan and stranded cargo retrieval in the post event phase will be welcome.

Spill volumes & consequences

Assumption 30: In this study we will consider CNZ spill estimates as a lower bound, especially in areas along watercourses, creek beds, and other sensitive environmental areas where retrieval of any spilled material, and the vehicle, may be difficult (cross slope, vertical drop-off) and containment may be problematic.

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Assumption 31: this study assumes that higher consequences will occur as a result of accidents featuring at least one of the following characteristics:

a) relative higher energy (careening over higher/ steeper natural or man-made slopes, faster driving, etc. as defined below)
b) potential larger spread of contaminants
c) relative increased difficulties in recovery of pollutants.

The consequences will be cumulative in the sense that a possible spill at a given location where more than one characteristic is present will lead to higher consequences than another location where only one characteristic is present.

Assumption 32: Because of Parks Canada statement and the point b,c in Assumption 31, we assume the difficulty to clean up a potential spill being equal for water bodies and karst.

Assumption 33: Given the descriptions in Table 14, this report considers accidents of Class 1-2 as minor, Class 3 as moderate, Class 4-5 as significant, Class 6 as serious and Class 7-9 as very serious. Driver or "bypassers" could be harmed in all classes of accidents, this not being a specific feature of this road, but a general consideration in accidents involving heavy vehicles.

Systemic failure review

Narrow roadbase could prove too hazardous as it does not leave any margin for error, prevents the installation of safety barriers.

"Generalization" of Stratifications may have lead to miss significant details related to potential consequences.

Human factors on drivers, rescue teams and including JSM level may lead to improper reactions if emergency plans have not been developed for all types of accidents.

Use of codes: More and more industries are becoming aware that the "business like usual", relying on blind compliance, or legalistic approach, to audaciously interpreted codes is not the way of the future. That applies both to the industrialist and the public.

Normalization of deviance (See Appendix 1 for a definition) (especially for recurring events, but also for climate change related events) which leads to the classic accumulation of small occurrences that, together, generate catastrophic events.

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Rosy scenarios in general, but also, more specifically related to natural geo-hazards and neglecting man-made rockfalls and slides.

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[i] **KP026.2 to KP026.3 – Debris flow of moderate likelihood and high consequence** (defined in TetraTech_Risk analysis -landslide hazards_4May2016.pdf). A sinuous ridge of debris above the road is of unknown origin. It appears to have directed water flow across the proposed road alignment in the past, scouring out the area below and forming a small depositional fan adjacent to the creek. Uncertain if debris flows have formed above road or not. Mapped as debris flow to be conservative. Culvert mitigation to be considered as described below for KP155.9 to KP159.3.

[ii] **KP027.2 to KP027.4 – Debris slide or flow** (defined in TetraTech_Risk analysis -landslide hazards_4May2016.pdf) with high likelihood and consequence, resulting in very high risk. This feature is to be spanned with a bridge. Regular monitoring is advisable in case additional mitigations are required in the future.

[iii] **KP028.2 to KP028.4 – Part of re-route to south side of valley: Minor rockfall activity in limited areas in 1994 and 2012 with high likelihood but moderate consequence** (defined in TetraTech_Risk analysis -landslide hazards_4May2016.pdf)**;** shaded in 1949, so unable to determine activity level at that time. Activity should be monitored and mitigation considered, if necessary.

[iv] **KP030.8 to KP031.8 – Three colluvial cones with potential for rock slide and debris flow materia**l (defined in TetraTech_Risk analysis -landslide hazards_4May2016.pdf) originating upslope to cross road. These hazards have a high hazard likelihood rating and a low consequence rating, resulting in a moderate risk rating. Wide dispersion of rockslide debris evident on 1949 and 1994 photos shows that up to 90 m of road alignment on each fan was affected prior to 1949, possibly by single events. Recent debris flow activity (visible on 2012 LiDAR image) is much smaller and crosses about 50 m of road. Culverts will be used in mitigation, but may not capture all debris if new debris flows occur on other parts of fans. Armouring between culverts to be considered. Some possible culvert mitigations are as described above for KP155.9 to KP159.3.

[v] **KP049.7 to KP050.0 – The realignment was adjusted after Terrain Stability Mapping to shift the road back from potentially retrogressive slides** (defined in TetraTech_Risk analysis -landslide hazards_4May2016.pdf); the road is already well back from slide areas that are being eroded by the creek. The likelihood of ongoing movements is considered moderate and the consequence is very high (the latter areas would have a high frequency). Further shifting of the road upslope is not practical in this section due to steeper side-slopes and road grades, and another proposed stream crossing further upstream was determined to be less amenable to development due to slope stability issues. The current road location is therefore likely to receive fewer impacts from possible future slope movements than the adjacent routes that were considered. Should movement resume along existing slide paths in this section, it may be necessary to consider additional mitigations including possible erosion protection at the creek, retaining or buttressing parts of the slope, and/or implementing additional water drainage measures. Appropriate mitigations will be considered at the time of detailed design, and would include monitoring and/or specific measures. The latter would be determined in accordance with the likely contributors to, and types of, movement considered to be likely.

[vi] **KP053.7 to KP054.2 – A thaw flow slide** (defined in TetraTech_Risk analysis -landslide hazards_4May2016.pdf) visible on 2012 LiDAR image nearby, but offset 100 m from the road alignment at the closest point, and set back 125 m from road route upslope. Although the likelihood of continued climate change means that the thaw flow slide might continue to retrogress, the route is now located outside of the apparent near-surface permafrost area, and the increased setback compared to the originally proposed route

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has reduced the likelihood that possible future movements will affect the road. However, monitoring is required, to keep track of slope movements that might require future mitigation.

[vii]**KP059.7 to KP60.4 – Route crosses a few older slides** (defined in TetraTech_Risk analysis -landslide hazards_4May2016.pdf) visible in 1949 photos. Debris slide of moderate likelihood and high consequence because part of feature is below road and potentially could cut into road. Monitoring is warranted, in case slope mitigations are needed in the future.

[viii]**KP083.5 to KP085.5 – Debris slides on slope above river and below alignment** (defined in TetraTech_Risk analysis -landslide hazards_4May2016.pdf) have moderate likelihood but high consequence. Road is well back from older and younger debris slides and tension cracks. Regular monitoring of the slope below this road section is advisable, to keep track of slope movements that might require additional mitigation.

[ix]**KP095.5 to KP101.7 – Large rotational to translational slide or slump in bedrock that likely occurred quite some time ago** (defined in TetraTech_Risk analysis -landslide hazards_4May2016.pdf)**.** Although this location has a low hazard likelihood, due to its size and potentially low to high velocity, it has a very high consequence and therefore a "high" risk rating. Because of its very large size, mitigation requirements could be considerable if movement renews. In particular, the large amount of gullying indicates that there is abundant water movement on this slope. Drainage planning will be very important here to prevent lubrication of old slide planes during exceptional rain or rain-on-snow events. As noted in the geotechnical report (Tetra Tech EBA 2015a), the goal is to have sufficient drainage measures such that surface water does not flow in channels in locations where water would naturally flow as sheet flow. The design of appropriate drainage measures is especially important at switchback locations. Also on this slope are some newer soil debris slides that have occurred in the colluvial soils overlying the bedrock slide, as well as some larger debris slides/flows to the south and north of the alignment in similar terrain.While such slides/flows are likely to continue, the soil debris slides tend to be small, and appropriate drainage measures will also help to reduce the possibility of the road contributing to local debris slides or flows. While no significant changes have occurred affecting the former winter road, this is not necessarily a reliable predictor of future performance.

[x]**KP111.8 to KP113.1 (Alternative route) – Road alignment crosses a debris flow area** (defined in TetraTech_Risk analysis -landslide hazards_4May2016.pdf) with recent activity, but it has been adjusted to the lowest possible location on the fans to avoid flows/slides that do not extend to the edge of the fan. The flows visible on the 2012 imagery are 20 to 40 m wide. Appropriate culvert locations and mitigations as described above will help protect the road in these locations; however, it is possible that new debris flows may occur elsewhere on the fans. Although this location has a "moderate" rating, considerable mitigation may be required if a substantial debris flow event occurs.

[xi]**KP136.4 to KP137.3 – Large debris slides** (defined in TetraTech_Risk analysis -landslide hazards_4May2016.pdf) in this section have been assigned a low likelihood and very high consequence. Potentially, a moderate likelihood exists but these features are difficult to discern on both sets of photos. One feature at KP136.4 may be a debris flow, but the feature is rather indistinct – may have a low frequency and/or may be intermixed with fluvial sediment. Monitoring is needed to track slope movements.

[xii]**KP0154.5 to KP155.3 – Earth slump/flow assumed to be old** (defined in TetraTech_Risk analysis -landslide hazards_4May2016.pdf)**,** as it was inactive in 1949, but could have up to moderate likelihood; road alignment has been moved upslope to avoid this area. In the analysis, this hazard was given a low likelihood of affecting the road, but it has a very high consequence due to being about 800 m long. If the slide moves again, it could be a very large event, entailing a lot of work to repair. The adjacent section of slope (KP155.9 to 159.3), with tension cracks above a similar slope failure in similar terrain, indicates that the possibility of renewed movement should not be disregarded in this section. Although the road has been moved upslope, it is not at low risk: the risk is simply reduced from what it would be if the road was immediately above the scarp. Regular monitoring of the slope below this road section is advisable, to keep track of slope movements

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that might require additional mitigation.

[xiii]**KP155.9 to KP159.3 – Recently-developed debris flows** (defined in TetraTech_Risk analysis -landslide hazards_4May2016.pdf), visible only on the 2012 LiDAR images, cross the route at KP158.4 to KP158.5. These flows are presently narrow (each about 25 m wide for the two that cross the road), but the source area for the debris is large. The debris flows have a high hazard likelihood rating and a high consequence rating, resulting in a very high risk rating. Culvert mitigation including larger culverts, strategic placement of back-up culverts, and channel armouring should be considered in the detailed design for this area. Culverts may still plug if debris flows occur, so culverts at staggered locations and elevations may be beneficial in case the lower culverts become plugged with debris. Additional mitigations may be needed if debris flow activity grows in magnitude due to increased water flow from thawing rock glaciers upslope, with possibilities including additional armouring, barriers, nets, and/or catch-basins. The road must cross the eastern portion of the same earth slump-flow that affects KP0154.5 to KP155.3 in order to reach the Liard River crossing. This part of the slide does not exhibit tension cracks and the slide frequency is low. However, if a slide occurs (or reactivates) in this road section, the consequence would be very high, due to the potentially very large earth volume that could move, resulting in a high risk rating. Below the alignment, seepage appears to be occurring; drainage planning will be important in this location. Regular monitoring of slopes and drainage provisions is advisable to keep track of events that might require additional mitigation in this section.