Soapstone Slide
Risk Exposure & Risk Reduction

A Business Case For Managing Risk by Asset Management

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PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

Soapstone Slide: A Risk Management Business Case

Asset Management was asked to prepare a business case evaluation of the Soapstone Slide area adjacent to the main access road to the Bull Run Watershed and to the Headworks facility. This document summarizes key components of the Bureau's risk methodology and presents its application to quantify the existing risks associated with future slides and the risk mitigation benefits and costs associated with alternatives.

The Soapstone Slide area is prone to exfoliating slides in which soil and substrate come off in sheets with larger slides bringing with them rock, trees and other large amounts of debris. Minor slides, averaging three per year, require a crew of three for an average of one day, plus a dump truck and backhoe, in order to clear the road. Major slides would require an estimated 20 days worth of work to clean and repair the slide area including clearing and repairing the road. Major slides occur on a frequency that the engineers familiar with the situation estimate as a one in 50 year event. During all slides, the access road is closed until cleared and vehicles must use an alternate road that adds on considerable distance and because of tight turns is not accessible for vehicles over 20' in length.

Under existing conditions, there is a very high consequence of fatality or major injury to workers but with a very low probability of occurrence. Nevertheless, analysis shows there to be a very high risk cost associated with the probability of fatality or major injury.

During the last slide of consequence, following a storm event that produced seven inches of rain in seven days in early January 2006, the road drainage system at the site was compromised, allowing runoff to undermine the road surface along a guard rail and crib retaining wall. The subsequent erosion created a void roughly six to eight feet across and approximately six feet deep behind the retaining wall, while the road surface above it remained intact. A Bureau employee assessing the damage stepped onto the unsupported asphalt which then collapsed into the void, causing the employee to fall in as well. The employee was able to catch himself and exit the hole unassisted and without injury. The retaining wall prevented what could have been serious injury or death if the employee had fallen down the near vertical embankment the wall supports above the Bull Run River. This slide would be considered minor for this evaluation.

Two alternative remedies were evaluated: debris clearing and rock scaling (which requires periodic repeating of the procedure every five years); and an engineered tie back wall (which is assumed to be a permanent solution).

The avoided costs of future repairs and additional travel time were about equal to the cost of the clearing / scaling work. If the avoided risk cost of fatality and injuries is factored in, the benefits of the alternative far exceeds the cost (about 10:1).

The engineered tie back wall is a significantly more costly alternative that provides only very minimally greater benefit than clearing / scaling.

Many of the cost and likelihood assumptions were generated with the assistance of Engineering Design Staff Rich Seright and Scott Bryan.

Risk Methodology

The business risk exposure (BRE) is defined by the consequence and likelihood of failure. Table 1 shows the various consequences associated with each of the 9 impact categories in Tier 1 through "Above Tier 5". The approach to quantify the likelihood of failure is outlined in Table 2.

BRE or Criticality ratings can be established by taking the product of consequence and likelihood, or the ratings can be compared using a matrix (shown in Table 3).

Risks of Selected Events and Failure Modes

Five risk events have been considered and evaluated. They are:

- Slide causes a fatality to someone driving through the area (highly unlikely; high consequence)
- Slide causes a fatality to a worker (highly unlikely; high consequence)
- Slide causes a major injury to a worker (moderate likelihood and consequence, 3 on scale of 1-5)
- Major slide causes long term disruption – defined as the road out of service for 3 weeks (low likelihood of once in 50 years and low consequence)
- Frequent minor slides cause short term disruption – defined as the road out of service for 1 day (very likely – occurring an average of 3 times per year, but very low consequence)
- Minor slides still occurring if rock scaling is done but occur once every 3 years with same consequence (road out of service for one day).

Table 4 provides additional details on the risk events, and the basis for their likelihood and consequence rating. The highest rated risk is for a major injury to occur.

Risk Mitigation Alternatives Evaluations

Four risk mitigation alternatives are described and evaluated. They are:

Alternative 1: Do nothing. There are no benefits associated with this alternative. The costs include on-going repair and traffic disruption (leading to extra travel time using the Walker Prairie Road route) costs, and the risk cost of a potential fatality and/or injury occurring. This alternative is the "base" in which other alternatives are compared to.

Alternative 2: Do nothing at the Soapstone Slide area, but improve the Walker Prairie Road route. There are no quantified benefits (improvements to the road might make it easier for a chlorine truck to use the road but, if chlorine is not available – after 3 weeks – groundwater supply can be used until the Walker Prairie or main roads become available). Groundwater operation costs depend on the magnitude and duration of use. The cost of road improvements is estimated at $1 million.

Alternative 3: Debris clearing and rock scaling of the slide area. This is expected to cost $75,000 the first time, and require $50,000 repeated "treatments" every 5 years. After clearing/scaling, slides are expected to occur much less frequently, once every 4 years on average. The benefits are having much less frequent repair and traffic routing costs. This approach has been used successfully by ODOT (according to Scott Bryan)

Alternative 4: An engineered solution involving a rock bolt tie back wall and application of shotcrete (similar to what was used on a road slope at Bull Run Lake). This is a significantly more costly alternative, $2.5M, with only very minimal additional benefits than Alternative 3. A rock bolt tie back wall would not have the recurring minor slides every four years and thus greater benefits of $1,000 per year over Alternative 3.

Table 5 provides additional details on the alternatives, and the relative benefits and costs. Key cost and probability assumptions are outlined below:

Benefits of avoiding repairs and additional travel time during slides:

- Minor slide repair cost = $2,000 (one Sandy River crew, one day)
- Major slide repair cost = $50,000
- Minor slide extra travel time cost = 20 hours X 50/hour = $1,000
- Major slide extra travel time cost = 20 days X ($1,000/day) = $20,000

Cost of fatality, injury and engineering work:

- Cost of fatality = $25 million (see Table 4 for an explanation of the dollar amount)
- Cost of injury = $7.5 million (see Table 4 for an explanation of the dollar amount)
- Cost of clearing / scaling work: $75,000, plus $50,000 every 5 years
- Cost of engineered tie back wall: $2.5 million.

Probabilities of fatality/injury:

- Frequency of minor slides – three times per year
- Frequency of major slide – 50 year event (0.02 per year event)
- Probability of fatality – 10% during a major slide, 1% during a minor slide (these were "judgment values" agreed to by Asset Management, Engineering Design and Safety representatives)
- Probability of injury – 20% during a major slide, 5% during a minor
- Probability of fatality/injury during construction – 0.003 for fatality, 0.015 for injury (equal to 1/10 the probability of a fatality or injury during a minor slide, construction is once in 5 years).

The alternatives are compared over a 50 year period, in terms of annual equivalent costs.

Risk exposure can be defined as the consequence of an event occurring times the likelihood of the event.

$$\textit{Risk Exposure} = \textit{Consequence} \quad X \quad \textit{Likelihood}$$

Investments that are aimed at reducing risk should be valued such that each dollar invested reduces the risk exposure by a value greater than or equal to the dollar invested. Since most investments intended to reduce risk are single value projects we can write the investment equation as:

$$\textit{Investment} \leq \textit{Risk Exposure}$$

The Risk Exposure calculations for our examples can be written as:

Risk Exposure (Fatality/major slide) = .02 X .1 X $25 million = $50,000 per year
Risk Exposure (Fatality/minor slide) = 3.0 X .01 X $25 million = $750,000 per year

Risk Exposure (Injury/major slide) = .02 X .2 X $7.5 million = $30,000 per year
Risk Exposure (Injury/minor slide) = 3.0 X .05 X $7.5 million = $1,125,000 per year

Risk Cost (Fatality/cleaning & scaling) = 0.015 X .2 X $7.5 million = $112,500 per year
Risk Cost (Injury/ cleaning & scaling) = 0.003 X .2 X $25 million = $75,000 per year

The annual risk exposure is the sum of fatality and injury risks during minor and major slides, or $1,955,000 per year. Therefore, any investment less than this amount that could reduce the risk exposure to, or close to, zero would have a positive benefit/cost ratio (i.e. > 1) and would reduce the risk exposure by more than the cost of the investment.

The risk cost during cleaning and scaling is the sum of fatality and injury risks during the operations. This is equal to $187,500 per year.

The average yearly cost of Alternative 3 is the sum of the original investment plus the 5 year recurring investments plus the cleaning costs (much reduced because of cleaning/scaling). The average yearly cost = ($75,000 + (9 X $50,000)) / 50 = $10,500 per year.

Alternative 4 is a $2.5 million investment that will last at least 50 years. If the tie back is financed at 5% interest rate then the annualized cost of the investment is $136,942. If the benefits are the roughly the same, i.e. if risk exposure is eliminated or reduced significantly by equal amounts, then Alternative 3 is the more cost effective option.

Benefit / Cost Analysis:

Costs for the engineering operations are known and listed above. Risk cost is the cost of the exposure to a fatality or an injury during the construction (for this exercise we are only estimating risk cost on cleaning / scaling). Benefits are defined as the reduction in costs (forgone work in cleaning/repair and time not spent waiting or driving alternate routes) and a reduction in risk exposure. Benefit cost ratios are given below with the calculations for each component annualized:

Alternative 3 (*without risk cost; i.e., not including avoided injury and fatality*):

Benefit 1: Reduction in repairs and lost time during minor slides.
Original cost = 3 times/yr X ($1,000 + $2,000) = $9,000/year.
New cost = once in 4 years (0.25) X ($1,000 + $2,000) = $750.
Net cost reduction is $8,250 per year.

Benefit 2: reduction in repairs and lost time during major slides
Once per 50 years (.02) X ($50,000 + $20,000) = $1,400.

Cost: $10,500 per year average

B/C = ($8,250 + $1,400) / $10,500 = 0.92

Alternative 3 (*including risk cost*):

Risk Cost: $1, 955,000 per year as defined above

B/C = ($8,250 + $1,400 + $1, 955,000) / ($10,500 + $187,500) = 9.9:1

Alternative 4 provides only very minimal benefits over Alternative 3; the recurring minor slides at once every 4 years at an average annual cost of $750 would be avoided but at a cost of $136,942 per year vs. $10,500 per year for the clearing / scaling. This makes Alternative 3 the more desirable option.

With a B/C ratio of less than one, the investment in clearing/scaling has higher costs than the direct benefits received from the investment. Based on the direct benefits alone without risk cost, the benefits derived from clearing/scaling is not justified by the investment (i.e. benefits are less than costs). However, if risk reduction is valued then the investment in clearing / scaling has benefits that are ten times greater than the investment costs.

Risk Avoidance Analysis:

An alternative methodology can be used in risk cost on the B/C ratio. If we do not initially quantify the value of a fatality or injury, we can easily estimate its minimum value that would generate a B/C value greater than one based on the estimated probabilities of slide occurrences and injury/fatality from above. These estimates for injury and fatality can then be used to answer the question that if the PWB would place a value on injury/fatality at this level or greater, then the risk exposure to injury or fatality would justify investment in a project that would eliminate or reduce that risk.

Our risk cost equations that will be used to put a value on fatality or injury that would drive the B/C to a ratio of 1:1 is estimated below:

B/C = (Benefit 1 + Benefit 2 + Avoided Risk Exposure) / (Cost + Risk Cost) = 1:1

= ($8,250 + $1,400 + *Avoided Risk Exposure*) / ($10,500 + $187,500) = 1:1

Change in Risk Exposure to get B/C of 1:1 = $10,500 + $187,500 - $8,250 - $1,400 = $188,350

Remembering that our risk exposure (or risk cost) is equal to the consequence times the likelihood of the event. The equation, as previously presented, is

Risk Exposure = Consequence X Likelihood

Consequence = Risk Exposure / Likelihood

We can put this into the above formula with the probabilities of a fatality and/or injury during a major and minor slide, and we can calculate that consequence value that would drive the B/C to 1:1.

Fatality:

Consequence of Fatality = *Risk Exposure / Likelihood*

= $188,350 / ((0.10 X .02) + (0.01 X 3.0))

= $5,885,938 per event = $5.9 million

Injury:

Consequence of Injury = *Risk Exposure / Likelihood*

= $188,350 / ((0.20 X .02) + (0.05 X 3.0))

= $1,223,052 per event = $1.2 million

In summary, if we work the Risk Cost equations backward we find the minimum values of a fatality or an injury that would justify the $10,500 average yearly cost of debris clearing and rock scaling of the slide area. The minimum value of a major injury (more than 30 days off work) is $1.2 million and the minimum value of a fatality would be $5.9 million. If the Bureau deemed that the value of avoiding an injury or fatality less than the estimated values, then the risk cost approach would not support the investment. Conversely, if the injury or fatality were valued at more than the estimated amount then it would make the B/C a ratio ≥ 1:1 and would lend support to the investment that would eliminate, or substantially reduce, the risk exposure.

Final note is that since we do not know if or when an injury or fatality would occur, all values were kept in today's dollars and were not discounted. To pick a time an injury might occur, for example at the midpoint in the years of recurrence of an event, and then discount it would presume an injury or fatality in the future is worth less than one today may also raise questions of validity.

Conclusions

Two alternatives were evaluated to address the recurring slides at the Soapstone section of the main access road to Headworks: 1) rock scaling and debris clearing (Alternative 3) and 2) an engineered tie back wall (Alternative 4). The conclusions of the analysis are:

- The engineered tie back wall is much more expensive, and with little additional beneficial compared to the rock scaling and debris clearing.
- Excluding consideration of injury and fatality avoidance, the rock scaling and debris clearing alternative has a benefit cost ratio of less than one (0.92).
- Using injury and fatality cost avoidance values from earlier Bureau risk analysis work, the rock scaling and debris clearing alternative has benefits far exceeding costs to the ratio of 9.9:1.
- If the value of a major injury exceeds $1.2 million, or the value of a fatality exceeds $5.9 million, then the rock scaling and debris clearing alternative would be supported by a reduction in risk exposure.

Bibliography

CLEM Committee Work Product. Portland Water System Assets, Business Risk Exposure (Criticality) and Risk Mitigation (Business Case) Evaluation. December 2007.

Table 1. Consequences of Failures

Category	Subcategory	Above Tier 5	Tier 5	Tier 4	Tier 3	Tier 2	Tier 1
Water Quality							
		Large scale water system contamination that leads to multiple loss of life	Large scale water system contamination, causing a single fatality	Widespread sickness	Exceeding water quality MCL's, minor health issues, such as turbidity event	Localized WQ issues such as turbidity from main break etc..	Localized WQ issue (Non-health - fall color, taste, localized turbidity problem
Illness							
				More than 100 hospitalized due to confirmed water-borne disease	More than 10 confirmed cases of water-borne disease; Unconfirmed reports of minor illness with symptoms related to water-borne disease		
Regulations							
			Revocation of PWS certification	Tier 1 Violation (acute), e.g. Consent Order to treat	Tier 2 Notification (includes nitrates, etc.)	Monitoring/Reporting Req't	No Violation
				Boil water, half of city or more	Secondary MCL problem, e.g., manganese problems		Approaching violation
				Event triggers loss of the filtration exemption	Sampling violations		Detects requiring notification
Supply Continuity							
	Supply Outage	Much of City out of water for longer than 72 hours	"Major" or "Large" service area out of water for longer than 72 hours	"Major" or "Large" service area out of water for 24-72 hours; 250 - 1000 Services out of water for longer than 72 hours; WCSL out of service for longer than 72 hours	*250 - 1000 Services out of water for 24 - 72 hours; WCSL out of service for 24 - 72 hours*; 50 - 250 Services out of water for longer than 72 hours	50 - 250 Services out of water for 24 - 72 hours; Up to 50 Services out of water for longer than 72 hours	

Table 1. Consequences of Failures, Continued

Category	Subcategory	Above Tier 5	Tier 5	Tier 4	Tier 3	Tier 2	Tier 1
	Service Pressures				Half or more of City receiving pressure < 20 psi for 2-4 hours; "Major" or "Large" service area receiving pressure < 20 psi for 72 hours or more	"Major" or "Large" service area receiving pressure < 20 psi for 2-4 hours or more; Up to 250 services receiving pressure < 20 psi for 72 hours or more	50 to 250 services receiving pressure < 20 psi for 2-4 hours or more
	Fire Flows			Supplying less than minimal fire flow to a commercial/industrial fire	Supplying less than minimal fire flow to a residential fire; Supplying minimal fire flow to a commercial/industrial fire	Supplying less than reduced fire flow to a residential fire; Supplying reducedl fire flow to a commercial/industrial fire	Supplying reduced fire flow to a residential fire
Public Confidence							
	Supply Outage		Half the city out of water for 8 hours or more		*Major or large service area out of water for 8 hours*	*250 to 1000 services out of water for 8 hours or more*	Up to 250 services out of water for 8 hours or more
	Water Quality Issue		Single Loss of life	Boil Water Order or other public warning to half of City or more	Boil water order to smaller service area	Discolored water	Potential news report on water quality issue
	Use restrictions			Mandatory Curtailment Measures	Request for Voluntary reduction in water use; interruption of supply to wholesalers		
	Security Breach		Successful / proven contamination action		News report on contamination attempt		
	Customer Billing			Equity: 30% or more of bills/accounts not paying their fair share; Accuracy: miscalculation of large number of bills, 25% error	Equity: 10% or more of bills/accounts not paying their fair share; Accuracy: miscalculation of large number of bills, 10% error		

Table 1. Consequences of Failures, Continued

Category	Subcategory	Above Tier 5	Tier 5	Tier 4	Tier 3	Tier 2	Tier 1
Social Consequences / Health and Safety							
		Multiple loss of life	Single Loss of life	Permanent disability	Major injury, >30 days off work; life-safety issues	Work time injury	Inconvenience only
	Community financial impact (excluding BWW direct cost)		>$20 million of losses	>$10 million of losses	>$5 million of losses	>$1 million of losses	
Environmental							
		Severe degradation of Bull Run watershed / loss of habitat	Release of a volume of chlorinated water that results in a major fish kill of ESA-listed species	Release of chlorinated water that results in visible die off of aquatic life in a river or stream	Release of chlorinated water that results in moderate damage to aquatic habitat	Release of chlorinated water that results in minor damage to aquatic habitat	
				Erosion causes major damage to sensitive aquatic or terrestrial habitats	Erosion causes moderate damage to sensitive aquatic or terrestrial habitats	Erosion causes minor damage to sensitive aquatic or terrestrial	Erosion causes mud to track into street and silt up catch basins
	Energy Use				Increases energy use significantly	Increases energy use moderately	Increases energy use
Loss of Revenue / Expenditures							
	Weather impact on water supply			water shortage - mandatory curtailment	Voluntary Curtailment	Strong conservation message	conservation message
	Wholesale customer agreement			Bureau does not deliver guarantee > 30 days twice in 10 years- wholesalers can reduce future demand 10%	Customer dispute or ligation more than $XX - OR customers with 10 year agreement do not renew	Bureau does not deliver guarantee > 5 days - wholesalers does not have to pay	

Table 1. Consequences of Failures, Continued

Category	*Subcategory*	*Above Tier 5*	Tier 5	Tier 4	Tier 3	Tier 2	Tier 1
	Large expenditures		Additional expenditures/loss greater than $20 million	Additional expenditures/loss greater than $10 million	Additional expenditures/loss greater than $5 million	Additional expenditures/loss greater than $1 million	
	Billing and collection issues		bills not generated (or $$ not collected) for 60 days	bills not generated (or $$ not collected) for 30 days	bills not generated (or $$ not collected) for 15 days		
	Bond - Rating downgrade	Bonds not marketable	Moody's Rating C		Moody's Rating B	Moody's Rating A	
	Excessive pressure				250 services provided water at higher of 150 psi or 50 psi over normal for 1 hour	50 services provided water at higher of 150 psi or 50 psi over normal for 1 hour	
	Liability Insurance Coverage Thresholds		>$30 million of damages	$10-30 million of damages	$1-10 million of damages	$0.5-1 million of damages	
Customer Service							
	Customer response		No contact or unable to respond to Customers adequately, 30 days	No contact or unable to respond to Customers adequately, 20 days	No contact or unable to respond to Customers adequately, 7 days		
	Bill / revenue generation		bills not generated (or $$ not collected) for 60 days	bills not generated (or $$ not collected) for 30 days	bills not generated (or $$ not collected) for 15 days		

Table 2. Likelihood of Failure Proposed for Portland

Likelihood Rating	**Recurrence Interval for a single asset failure (years)**	**Failure Rate of a Population**
5	<= 5	0.3
4	5-20	0.1
3	20-50	0.03
2	50-100+	0.013
1	>> 100	<.01

Table 3. Criticality Matrix

	Consequence of Failure					
Likelihood of Failure		**1**	**2**	**3**	**4**	**5**
	1	Very Low	Very Low	Low	Medium	Medium
	2	Very Low	Very Low	Medium	Medium	High
	3	Low	Low	High	High	Very High
	4	Low	Medium	High	Very High	Very High
	5	Low	Medium	High	Very High	Very High

Table 4. Risk Events and Likelihood and Consequence Ratings

Event	Failure Mode	Likelihood Rating	Consequence Rating	Risk Rating
1	Slide occurs and driver who encounters the slide, drives off the road	1 (1 in 1000+ year event; occurs during annual event, but <0.1% chance it occurs	4 ($25,000,000 equivalent financial cost to fatality; off Table 1, tier 5 for health and safety is made equal to tier 5 for community financial impact, as agreed to by Bureau CLEM Committee)	4
2	Slide occurs, leading to fatality of worker	1 (1 in 200 year event; could occur during annual event, during major slide, or during geotechnical assessment - annual event; 0.5% chance (1 in 200); - major repair activity occurs once in 50 years, we are more careful, but it is more dangerous; 1% chance (1 in 5000); - geotechnical assessment, happens one time in next 10 years, agitating slope, 1% chance (1in 1000 ?)	4 ($25,000,000 equivalent financial cost to fatality)	4
3	Slide occurs, leading to major injury to worker (> 30 days off work)	3 (1 in 20 year event; could occur during annual event, during major slide, or during geotechnical assessment - annual event; <5% chance (< 1 in 20); - major repair activity occurs once in 50 years, we are more careful, but it is more dangerous; 5% chance (1 in 250); - geotechnical assessment, happens one time (in next 10 years), agitating slope, 10% chance	3 ($7.5 million equivalent financial cost to major injury; tier 3 for health and safety and tier 3 for community financial impact are made equivalent)	9
4	Major slide occurs, causing long term disruption	2 (Event occurs once in 50 years that takes out road for at least three weeks) Has not happened since road was constructed (in the 1950s, when conduit 4 was built), but conditions are getting worse	1 Repair cost = $50,000 (no discount) Added travel time cost = $20,000 (no discount) No supply disruption cost (if chlorine is not delivered in time, groundwater is used)	4
5	Minor slide occurs, requiring repairs	5 (Every year, events occur that takes road out of service for average 1 day – occurs 3 to 4 times each year)	1 Repair and traffic cost = $9000/year for 50 years = $450K	5

Table 5 . Critical Asset Benefits and Costs Summary

Alternative	Description	Benefits ("Avoided costs")	Costs (in 50 years)
1	Do nothing – clean up of slides as they occur, rely on Walker Prairie Road entrance, as needed		Repair = $350K Routing = $170K Risk cost = $25M !
2	No action on Soapstone Slide area; clean up of slides as they occur, continues. Improvements to Walker Prairie Road entrance	"More stable alternate route", but no quantifiable benefit	Same cost as #1, plus $1M
3	Debris clearing and rock scaling of Soapstone Slide area (Assume that slides will no longer occur; solution repeated on 5 year cycle)	- Avoided repair cost: $350K - Avoided routing cost: $170K (does not account for re-routing during planned slope work) - Avoided risk cost: $25M - Safer working conditions for geotechnical survey of the slide	Cost of clearing/scaling work $575K in 50 years
4	Shot crete, rock bolt tie back wall	Same quantified benefits as #3	Cost of engineered solution / wall $2.5M