

Landslide Risk Management

Partial Risk Analysis for known Landslide Hazard Areas

Public Presentation

June 24, 2009

Michael Porter
BGC Engineering Inc.

1. Landslide Risk Management Program

- Objectives, Overview

2. Partial Risk Analysis Methodology

- Initial Screening
- Landslide Likelihood and Proximity to Homes

3. Results and Recommendations

- Investigation and Risk Assessment
- General Recommendations

Regional Natural Hazards



Source: A City on Edge



- ~ 1 Landslide per year affecting residential development or municipal infrastructure
- Usually occur between November and February
- Consequences have included:
 - Injury, Fatality
 - Damage to Property and Infrastructure
 - Environmental Impacts
 - Increased Development Costs
- Most landslides in the City of North Vancouver involve smaller debris slides from ravine slopes

- Risk = Landslide Probability x Consequence
- Risk = $P_H \times P_{S:H} \times P_{T:S} \times V \times E$:
 - P_H = landslide probability
 - $P_{S:H}$ = spatial probability (likelihood landslide reaches home)
 - $P_{T:S}$ = temporal probability (likelihood people are home)
 - V = vulnerability (degree of loss of impact occurs)
 - E = elements at risk (# of people; structure value)
- Partial Risk = $P_H \times P_{S:H}$

- $FOS = \frac{\text{Forces Resisting Sliding}}{\text{Forces Promoting Sliding}}$
- Landslide occurs if $FOS = 1.0$
 - Steep Slopes
 - Weak Soils
 - High Water Table (natural seepage, rainfall, leaky pools or pipes)
 - External Loads (structures, earthquakes)
- For new development, typical design $FOS > 1.5$; $FOS > 1.1$ (earthquake)



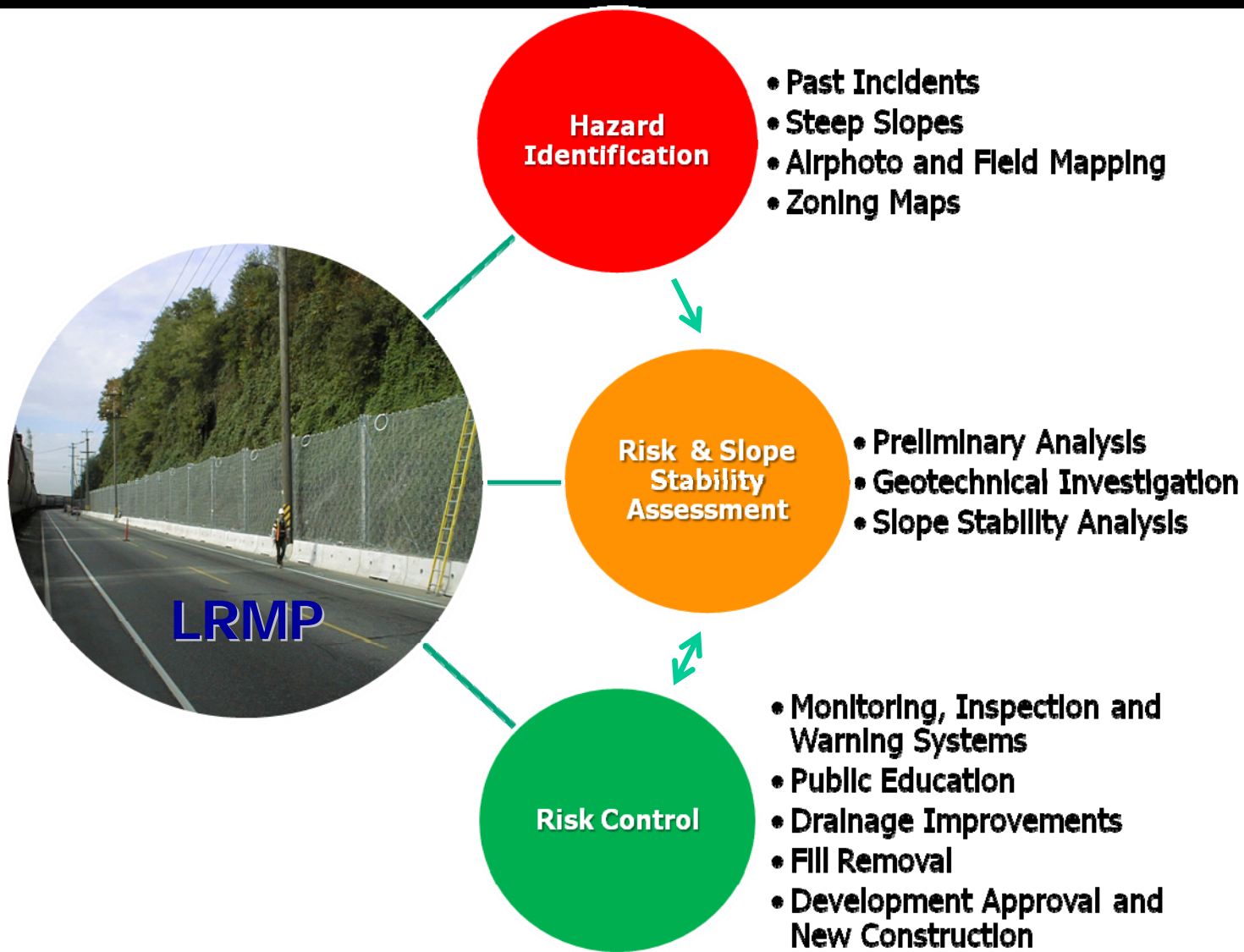
Low Level Road Landslide Protection

**Prevent Injury,
Fatality,
Property Damage**

Began in 1997 with initial assessment of geological hazards
A systematic process to:

- Identify hazardous areas
- Assess and evaluate landslide risk
- Prioritize mitigation, monitoring and inspection

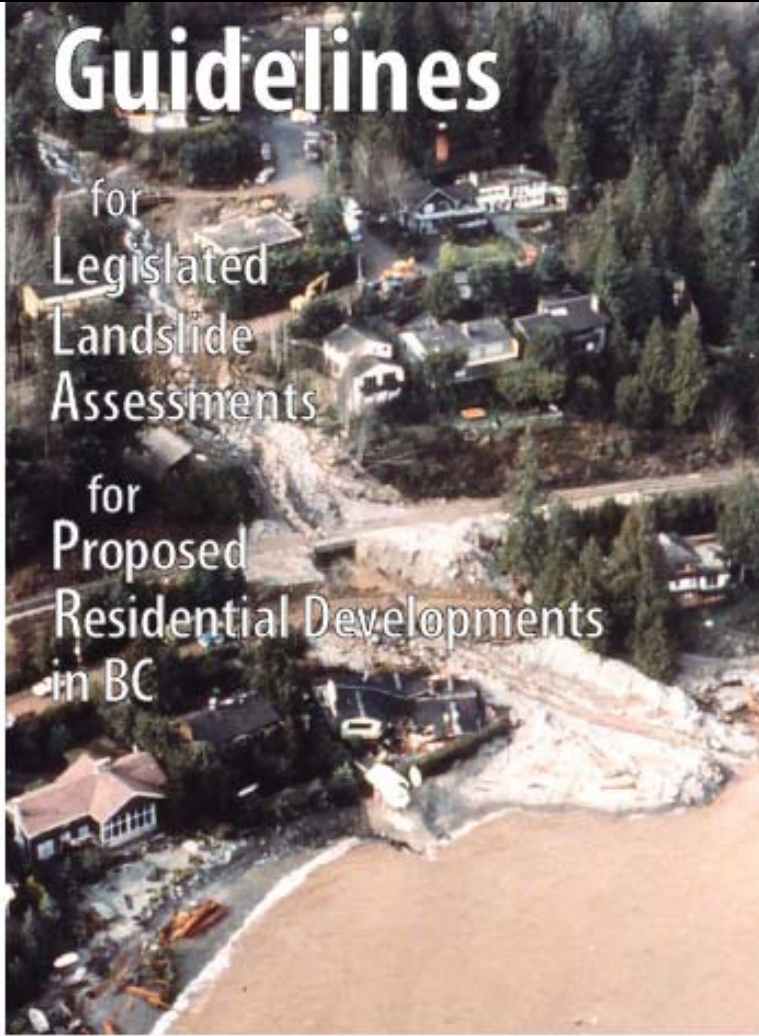
Landslide Risk Management Program



Guidelines

for
Legislated
Landslide
Assessments

for
Proposed
Residential Developments
in BC



- Compliant with:

- CSA Guidelines for Risk Management
- Recommendations in a Coroner's Report prepared following the Berkley Escarpment fatality
- APEGBC Landslide Guidelines
- Methodologies from District of North Vancouver, Seattle, Hong Kong, Australia



Association of Professional Engineers
and Geoscientists of British Columbia

March 2006
Revised May 2008

Previous Studies

Cypress Gardens:

- Channel Reconstruction
- Slope stability monitoring and analysis

Mosquito Creek:

- Preliminary Analysis
- Risk Assessment
- Mitigation Options

Low Level Road:

- Risk Assessment
- Mitigation (catch nets)

Remaining City-Wide Study Areas



- BGC / CNV review of the City to look for potential slide areas
- Focused on:
 - Steep slopes
 - Areas with history of stability problems
 - Residential development
- Review led to the identification of the following key areas:
 - Mackay Creek
 - Thain Creek
 - Mosquito Creek
 - Lower Mission Creek
 - Wagg Creek
 - Low Level Road
 - Grand Boulevard

Preliminary Analysis Methodology

Initial Desk-Study Screening:

- Slopes $>14.5^\circ$ and >3 m high in close proximity to homes



Partial Risk Analysis

$P_{HA} = P_H \times P_{S:H}$ Probability of a specific landslide impacting the identified elements at risk		P_H (Landslide Likelihood)		
		Low	Moderate	High
$P_{S:H}$ (Spatial Probability of Impact – highest risk of either $P_{S:H}$; CREST or BASE)	Low	Very Low	Low	Moderate
	Moderate	Low	Moderate	High
	High	Moderate	High	Very High

Periodic Inspection Recommended

Detailed Assessment Recommended

Preliminary Analysis Methodology

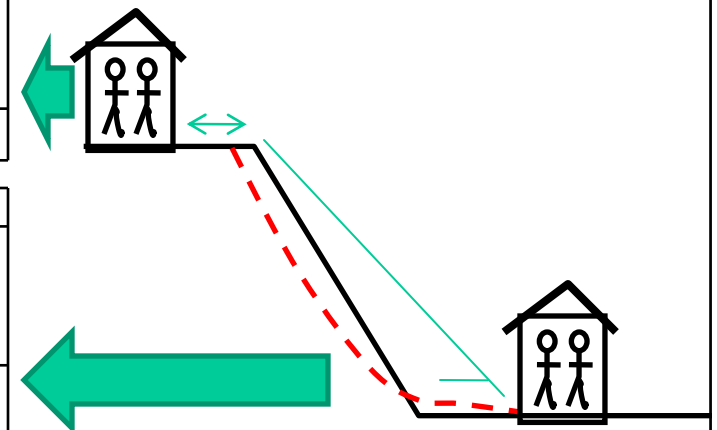


Factor	Rating	Criteria
Hazard Likelihood (P _H)	High	Evidence of active or historical landslides or slope deformation, regardless of slope angle or height -landslide scarps containing exposed soil or re-vegetated with deciduous trees or young conifers -visible settlement in fills, retaining walls
	Moderate	Adverse slope conditions, but no evidence of historical landslides or slope deformation -slopes steeper than 35° and more than 3 m high -presence of random fills or yard waste -presence of un-engineered retaining walls -abundant seepage or surface erosion
	Low	Favourable slope conditions and no evidence of historical landslides or slope deformation -slopes less steep than 35° -slopes less than 3 m high -engineered fills or retaining walls (if present)
	Not Rated	Slopes less steep than 25° with no evidence of historical landslides, slope deformation or adverse ground conditions

Preliminary Analysis Methodology

Factor	Rating	Criteria
Spatial Probability for Homes At or Near Crest of Slope (P _{S:H; CREST})	High	Home or attached deck < 3 m from crest of slope. High likelihood of initial landslide impacting the element(s) at risk.
	Moderate	Home or attached deck 3 to 6 m from crest of slope. Initial landslide or subsequent erosion or landslide retrogression could impact the element(s) at risk.
	Low	Home or attached deck 6 to 10 m from crest of slope. Initial landslide or subsequent erosion or landslide retrogression unlikely to impact the element(s) at risk.
	Not Rated	Home or attached deck > 10 m from crest of slope.

Factor	Rating	Criteria
Spatial Probability for Homes At or Near the Base of Slopes (P _{S:H; BASE})	High	Angle between home/habitable structure and crest of slope or source area > 23°. High likelihood of landslide debris impacting the element(s) at risk.
	Moderate	Angle between home/habitable structure and crest of slope or source area between 21° and 23°. Moderate likelihood of landslide debris impacting the element(s) at risk.
	Low	Angle between home/habitable structure and crest of slope or source area between 19° and 21°. Highly unlikely that landslide debris would impact the element(s) at risk.
	Not Rated	Angle between home/habitable structure and crest of slope or source area < 19°. Landslide impact on the element(s) at risk does not warrant analysis.



Results and Recommendations

Partial Risk Rating	Very High	High	Moderate	Very Low & Low
<i>Typical FOS (at nearest Structure)</i>	<1.1	1.1 to 1.3	1.3 to 1.5	>1.5
Mackay Creek	1	4	4	5
Mosquito Creek	0	0	1	0
Thain Creek	0	3	3	0
Lower Mission Creek	0	3	4	2
Wagg Creek	0	2	6	5
Low Level Road	0	1	4	0
Grand Blvd	0	2	4	3
<i>Total All Areas</i>	<i>1</i>	<i>15</i>	<i>26</i>	<i>15</i>
<i>Recommended Action</i>	<i>Assessment within 1 yr</i>	<i>Assessment within 3 yrs</i>	<i>Inspect every 1-5 yrs</i>	<i>No further action</i>

Example: Structures at Crest of Slope





- **Storm water management**
 - Most effective means of reducing landslide risk
 - Connect roof drains to storm sewer system
- **Fill and lawn cuttings**
 - Oversteepens slopes
 - Damages natural vegetation
 - Retains moisture
- **Awareness and Inspection**
 - Cracks, settlement, exposed soil, leaning trees
 - Contact the City

- **Follow-up Assessment (fall 2009)**
 - Retain geotechnical consultant
 - Obtain permission to enter properties
 - Commence detailed assessment of High, Very High sites
 - Geotechnical investigations, slope stability analyses
 - Conducted at City's expense
- **Mitigation (if required)**
 - Fill removal
 - Drainage improvement
 - Conducted at Owner's expense

Thank You



Questions?