Landslide occurrence, operational response and strategic risk management

A case study of Hurricane Tomas in St Lucia

Chris Arnold – Principal Engineering Geologist
Contents

Introduction
Impact of Hurricane Tomas
Operational Response
Risk assessment
Strategic risk management and preparedness
Introduction
### Primary road network

<table>
<thead>
<tr>
<th>Road</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main line</td>
<td>136km</td>
</tr>
<tr>
<td>Bois Cachet</td>
<td>0.6km</td>
</tr>
<tr>
<td>La Toc</td>
<td>3.6km</td>
</tr>
<tr>
<td>Millennium Highway</td>
<td>6.2km</td>
</tr>
</tbody>
</table>
Hurricane Tomas

[Map of Hurricane Tomas from 29 Oct - 7 Nov 2010 showing the path and impact areas.]

[Image of the hurricane as of 30/10/2010 showing sustained winds and pressure.]

[Graph showing wind speed and pressure for Hurricane Tomas from 29 October to 7 November 2010, with various data points indicating observations from different sources.]
Hurricane Tomas

Bar chart showing the 3-day rainfall (mm) for various storms:

- Tropical Storm Ella
- Hurricane Abby
- Tropical Storm Edith
- Tropical Storm Judith
- Tropical Storm Beulah
- Tropical Storm Edith
- Tropical Storm Dorothy
- Hurricane Ana
- Tropical Storm Allen
- Tropical Storm Gilbert
- Tropical Storm Cindy
- Tropical Storm Debby
- Tropical Storm Iris
- Hurricane Jerry
- Hurricane Dean
- Hurricane Tomas
Impact of Hurricane Tomas
Seven dead / missing as a result of landsliding

Major sections of primary road network impassable

Several communities completely isolated

US$45M damage to road transport sector (ECLAC, 2011)
Seven dead / missing as a result of landsliding

Major sections of primary road network impassable

Several communities completely isolated

US$45M damage to road transport sector (ECLAC, 2011)
Seven dead / missing as a result of landsliding

Major sections of primary road network impassable

Several communities completely isolated

US$45M damage to road transport sector (ECLAC, 2011)
Seven dead / missing as a result of landsliding

Major sections of primary road network impassable

Several communities completely isolated

US$45M damage to road transport sector (ECLAC, 2011)
Hurricane Tomas
Impact on Primary Road Network

Cul de Sac – Ravine Poisson

Barre de Lisle – Hill top Dennery

Anse La Raye - Canaries

Quart Chemin – Soufriere

Myers Bridge - Soufriere

Choisel Village Bridge – Myers Bridge
Response
Immediate response

Landslide Response Plan

National Emergency Management Organisation

Zone Engineers
Immediate response

Landslide Response Plan

National Emergency Management Organisation

Zone Engineers
Long-term response

Reconstruction
Revegetation
Landslide risk assessment
Long-term response

Reconstruction
Revegetation
Landslide risk assessment
Landslide risk assessment
Hurricane Tomas
Landslide risk assessment

• Analyse and assess slope stability, drainage and geotechnical conditions
• Map levels of risk
• Identify primary and secondary causal factors of slope movement
• Suggest cost effective slope stabilisation, protection and landslide remediation measures
• Enhance the capacity of the GoSL to manage landslide hazards
# Hurricane Tomas
## Landslide risk assessment

### Increasing frequency / decreasing condition

<table>
<thead>
<tr>
<th>LANDSLIDE RISK MATRIX FOR SAINT LUCIA'S PRIMARY ROAD NETWORK</th>
<th>FREQUENCY</th>
<th>RAINFALL AND/OR HURRICANE TRIGGERING EVENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Event considered possible, but has no precedent in the historical record</td>
<td>Event likely to occur in a prolonged, near-stationary Hurricane event (e.g. Tomas), once every 100+ years</td>
<td>Event likely to occur during &quot;normal&quot; rain storm event, possibly in combination with earthquake</td>
</tr>
<tr>
<td>Slope in good condition. Failure might occur in exceptional circumstances e.g. landside is conditional on failure of a man-made structure</td>
<td>Event likely to occur in next 10-50 years. Slope in moderately poor condition and expected to deteriorate</td>
<td>Event likely to occur in next 5-10 years. Slope in poor condition and expected to deteriorate</td>
</tr>
<tr>
<td>Mature trees present. Signs of slope distress, but landslide is conditional on failure of a man-made structure (e.g. retaining wall)</td>
<td>Event likely to occur in next 5-10 years. Slope in very poor condition and expected to deteriorate</td>
<td>Slope condition assessment</td>
</tr>
<tr>
<td>A. Complete loss of road. Road not serviceable.</td>
<td>11</td>
<td>16</td>
</tr>
<tr>
<td>B. Loss of outer carriageway fill or deformation/settlement of road surface. Road serviceable, but one-lane traffic flows.</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>C. Partial loss of outer carriageway fill. Temporary blockage of 1 carriageway, road out-of-service.</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>D. Temporary blockage of inner carriageway. One-lane traffic flows.</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>E. Debris on road e.g. rocks or soil. Damage to inner carriageway road drain. Road remains usable.</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>P &lt; 0.002 (&lt; 1 in 500 years)</th>
<th>P = 0.02 - 0.002 (1 in 50 to 1 in 500 years)</th>
<th>P = 0.1 - 0.02 (1 in 10 to 1 in 50 years)</th>
<th>P = 0.2 - 0.1 (1 in 5 to 1 in 10 years)</th>
<th>P = 1 (1 in 1 year)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ANNUAL PROBABILITY</strong></td>
<td>Indicative Annual Probability of Event</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **High Risk**
- **Medium Risk**
- **Low Risk**
- **Very Low Risk**

- **Hatched fill signifies risk level considered 'as low as reasonably practicable'**
Landslide risk assessment
Hurricane Tomas
Landslide risk assessment
Hurricane Tomas
Landslide risk assessment
Hurricane Tomas
Landslide risk assessment
Strategic risk management and preparedness
Hurricane Tomas

Outcomes of risk assessment and strategic risk management

≥Hurricane Tomas event to cause landslide

ALARP – accept the risk
Reassess risk following large storm events
Regularly inspect structures and drainage, and maintain as required
Respond to events as they occur
40km

5-50 year storm
Not complete loss of road

Accept the risk
Reassess risk following large storm events
Regularly inspect structures and drainage, and maintain as required
Respond to events as the occur
1km

Normal rainfall → Tropical Storm
Partial to significant loss of serviceability

Respond to events as they occur
Mitigation/remedial works in selected cases

0km

Complete loss of serviceability

High priority remedial works / preventative measures required
Hurricane Tomas
Outcomes of risk assessment and strategic risk management

- Research and set rainfall monitoring triggers to predict when events are more likely to occur and potentially restrict access to parts of the network under such storm conditions.
Conclusions
Ministry and zone engineers responded admirably

Lessons are not always being learnt or passed on

Data management and landslide inventory required

Drainage
Acknowledgements

• Ministry of Infrastructure, Port Services and Transport - Jude Regis, Nicholas Johnny

• Strata Engineering Consultants Ltd - Roosevelt Issacs

• Mark Lee, Prof. Norbert Morgenstern, Fred Matich

• Colleagues at Mott MacDonald especially Peter Phipps & Elizabeth Ward
Thank you