Life Safety Model for Emergency Planning

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Presentation Outline

• Introduce the Life Safety Model (LSM)
• Describe the development history
• Describe how the LSM works
• Describe how LSM has been tested / validated
• LSM Case Studies
• LSM Applications
• Future development
What is it?

The Life Safety Model (LSM) is a dynamic model that represents people's interactions with a flood and provides estimates of the number of people that are likely to be injured or killed as a result of a flood event, as well as the time that is required for them to evacuate the area at risk.
Life Safety Model Principles

- Goals in developing the Life Safety Model:
  - Remove the need to rely on subjective “engineering judgment”.
  - “The likelihood of consequences should be estimated using scientific reasoning from data” (US National Academy of Sciences; NRC 2000).
  - Develop a model that produces valid, reliable and defensible consequence estimates.
Water and Disasters

There are two types of disasters as it relates to water resources infrastructure:

- Natural disaster, weather related or geophysical (i.e., earthquakes, landslides, tsunamis, volcanic eruptions).
- Catastrophic failure of water resources infrastructure.
Historical Trends of Geologic and Weather Related Disasters in Canada (1900-2015)

Data Source: Public Safety Canada, Disasters Database
People are vulnerable to water related hazards. Too much water – floods - are a problem

**Saguenay Flood (1996)**
- 10 deaths
- 15,000 people evacuated
- $1.5 billion in losses

**Manitoba Flood (1997)**
- 4 deaths
- 25,000 people evacuated
- $1.0 billion in losses
Designated Flood Risk Areas across Canada

Source: Public Safety Canada, Disasters Database
Meteorological – Hydrological Disasters in Canada (1900-2015)

Source: Public Safety Canada, Disasters Database
Challenges in Life Loss Estimation

Arles, France 2003
## Time Domain Concept

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Impact on Individuals and Groups

- Distribution in flood zone
- Movement within, into, out of flood zone
- Interaction with flood wave (escape, toppling and loss)
- Interaction within groups, between groups (awareness, warning)

Tropical Storm Allison (2001)
Impact on Vehicles

Tropical Storm Allison (2001)

Toronto (2013)
Impact on Infrastructure

Natural Flood – Germany. Source: Munich Reinsurance 2002

August 19, 2005 Storm, Toronto, Ontario

June 1, 2012 Storm, Toronto, Ontario

May 2013 Storm, Toronto, Ontario
Impact of Evacuation Routes
Factors that Influence Loss of Life

1. General topography of the impact zone
2. Layout of human settlements & transport infrastructure
3. Time of day, week and year
4. Characteristics of individuals, buildings, vehicles
5. Flood wave characteristics
6. Interaction of objects with the flood wave
7. Location of safe havens and escape routes
8. Detection, Warning and Awareness
9. Decision-Making, Evacuation, & Escape
10. Emergency Planning and Long-Range Mitigation
Scale of Application

- Micro
- Meso
- Macro

Small area/
Detailed study/
High risk?

Regional/
Broad scale study/
Lower risk?
Levels of Modelling -- Macro

One mortality rate applied to the whole area

Evacuation time based on average distance to safety
Levels of Modelling -- Meso

Mortality rates estimated for groups of people or zones

Simplified evacuation routes
Levels of Modelling -- Micros

- The most accurate level of modelling
- Detailed representation of evacuation routes
- Behaviour of each individual is modelled
Life Safety Model Development

- 1990’s - BC Hydro identified concerns regarding Loss of Life estimation methods
- 1997 – BC Hydro simple 1D model
- 2001 – BC Hydro and NRC develop LSMv1
- 2006 – HRW applies LSM to projects
- 2009 – NRC ends collaboration on LSM
- 2011 – HRW begins LSM development
- 2014 – HRW releases LSMv3.0
Empirical Life Loss Estimation Models

- Without sufficient data, empirically based models cannot be applicable to all flood scenarios.
- Consider DSO-99-06 (Graham method):
  - Limited flood data set (40 floods)
  - Very few large dams (only 7 dams larger than 15m /49ft)
  - Mix of cases with and without warning
  - No earthquake induced scenarios
Empirical Life Loss Estimation Models

DSO-99-06 states:

• “The equations may not be applicable for use with dam sizes, dam types, failure causes, flood severity and warning scenarios not reflected in the data set.”
Life Safety Model: What is it?

- Life Safety Model (LSM) is simulation model
- It combines 2\textsuperscript{nd} party hydrodynamic representation of a flood with an evacuation and life loss model using geo-spatial data
- Determines potential loss of life based on physical characteristics of objects in the flood.
Life Safety Model Concept

- 2D "People Flow"
- 2D Water Flow
- Normal water extent
- Flood extent at time “x”
- Infrastructure: Buildings & Road Network

Loss of Life Estimation
- Damage and Loss Functions

Loss of Life Mitigation
- Emergency Planning Support Functions

Dam

Infrastructure: Buildings & Road Network
High Level Architecture

- Life Safety Simulator (physical equations and logic)
- Flood Wave (each scenario)
- Initial States of World (each scenario)
- Virtual World:
  - Natural Environment
  - Socio-Economic Environment (all time, all scenarios)
- Weights
- Outputs Summary:
  - Weighted Loss of Life
  - Event Visualization

LSM Simulator: “single scenario”

GIS tools: “analyze outputs, estimate losses”
Object Damage and Loss Function

- Safe/No Damage
- Injury/Building Damage/Floating Vehicle
- Fatality/Building Loss/Toppled Vehicle

Depth vs. Velocity diagram with color-coded regions for different levels of damage and loss.
Building Loss Algorithm

- Determine D, V, DV at building for current timestep
- Update BSS, BCDVM, BDVC

```
Building (Status = 0 = Standing)
```

```
BSS < BSSC?
```

```
BDVC < DV?
```

```
Building (Status = 0 = Standing)
```

```
Flood Wave
```

```
Destroy Building
```

```
Set Status of PARUs within building to DECEASED
```

```
Building (Status = 1 = Destroyed)
```
Building Damage & Loss Curves

Figure 21 – Building Damage in Dale Dyke Flood
Adapted from Clausen & Clark 1990
Human Stability Data

Figure 23 – Human Stability Test Data
Vehicle Stability Data

**Figure 25 – Vehicle Stability Diagram**
(after Keller, 1992)
Physical Interaction of Objects in Flood
Testing and Validation of LSM

- LSM was tested and validated for the 1953 storm surge at Canvey Island.
  - 58 people had died in the event
  - Model results agreed “well” with the historical data
  - Model indicates that between 55 and 150 people died
  - Sensitivity to model assumptions indicate that 55 people died as a result of drowning and 150 people died as a result of buildings collapsing.
**Case Study – Windsor NSW Australia**

- **Windsor NSW Australia**
  - Town of Windsor becomes an island in flood events with a single high bridge connection to evacuation route
  - In very large floods (PMF) the town would be completely inundated
  - LSM model for State Emergency Services (SES) to understand time taken for evacuation and assessment of options to reduce evacuation time:
    - Phase evacuation
    - Defined evacuation route
    - Doubling the number of lanes on the evacuation route
Case Study – Emergency Planning

• Emergency Planning in Humberside
  - LSM used as part of a tiered study to investigate options for mass evacuation in Humberside for a major storm surge.
  - Evacuation times for LSM compared well with traffic models
  - LSM identified a key issue of congestion on local road network.
LSM Applications

Additional applications of LSM:

- BC Hydro has applied LSM as part of its own dam risk studies, presented at ASDSO conference 2014

- Application by KCL to tsunami in New Zealand

- US Bureau of Reclamation is currently using LSM for its own dam risk studies (presented at ASDSO, 2012)
Potential Future Developments

• Model processes
  - Further improvements to traffic model component
  - Including emergency responders

• Coding
  - 64-bit version for stability with larger datasets
  - Parallel processing or multi-threading for faster simulation with larger models

• Alternative applications
  - Application of the model to wildfires and CBRNE events as well as flooding

• Improved graphical displays
The End

Questions?