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

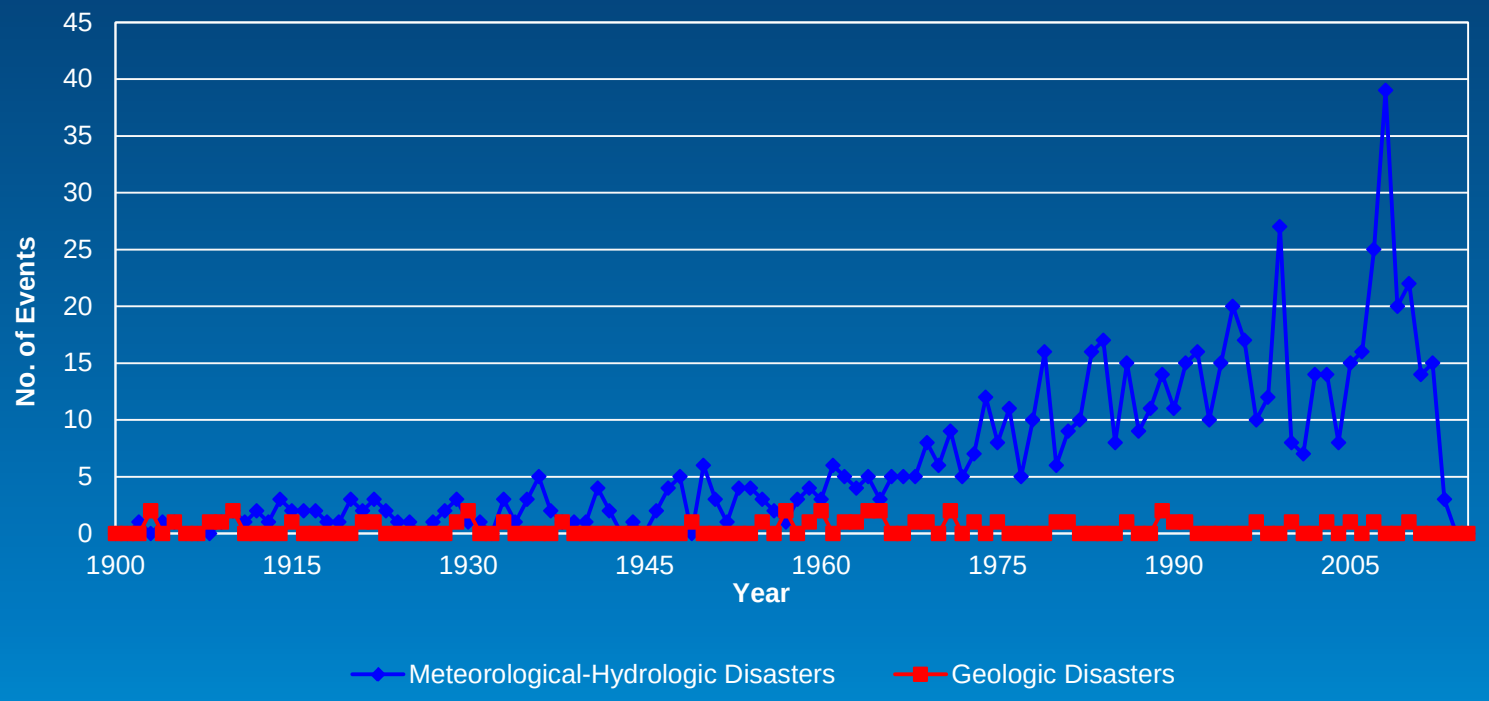
- **Goals in developing the Life Safety Model:**
  - **Remove the need to rely on subjective "*engineering judgment*".**
  - **"*The likelihood of consequences should be estimated using scientific reasoning from data*" (US National Academy of Sciences; NRC 2000).**
  - **Develop a model that produces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

Water and Disasters

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

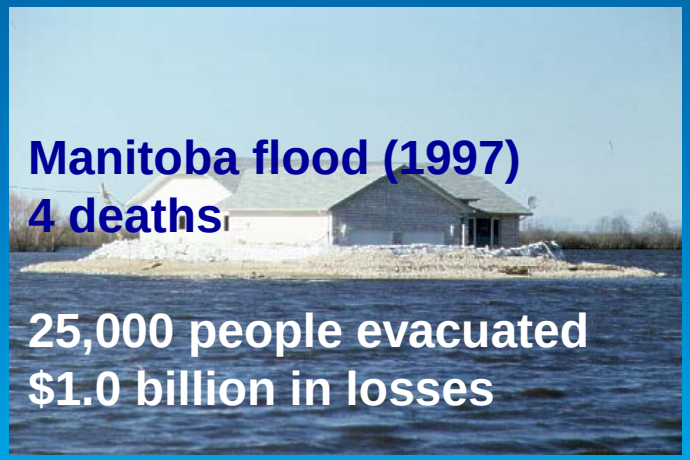
- **Natural disaster, weather related or geophysical (i.e., earthquakes, landslides, tsunamis, volcanic eruptions).**
- **Catastrophic failure of water resources infrastructure.**

Historical Trends of Geologic and Weather Related Disasters in Canada (1900-2015)

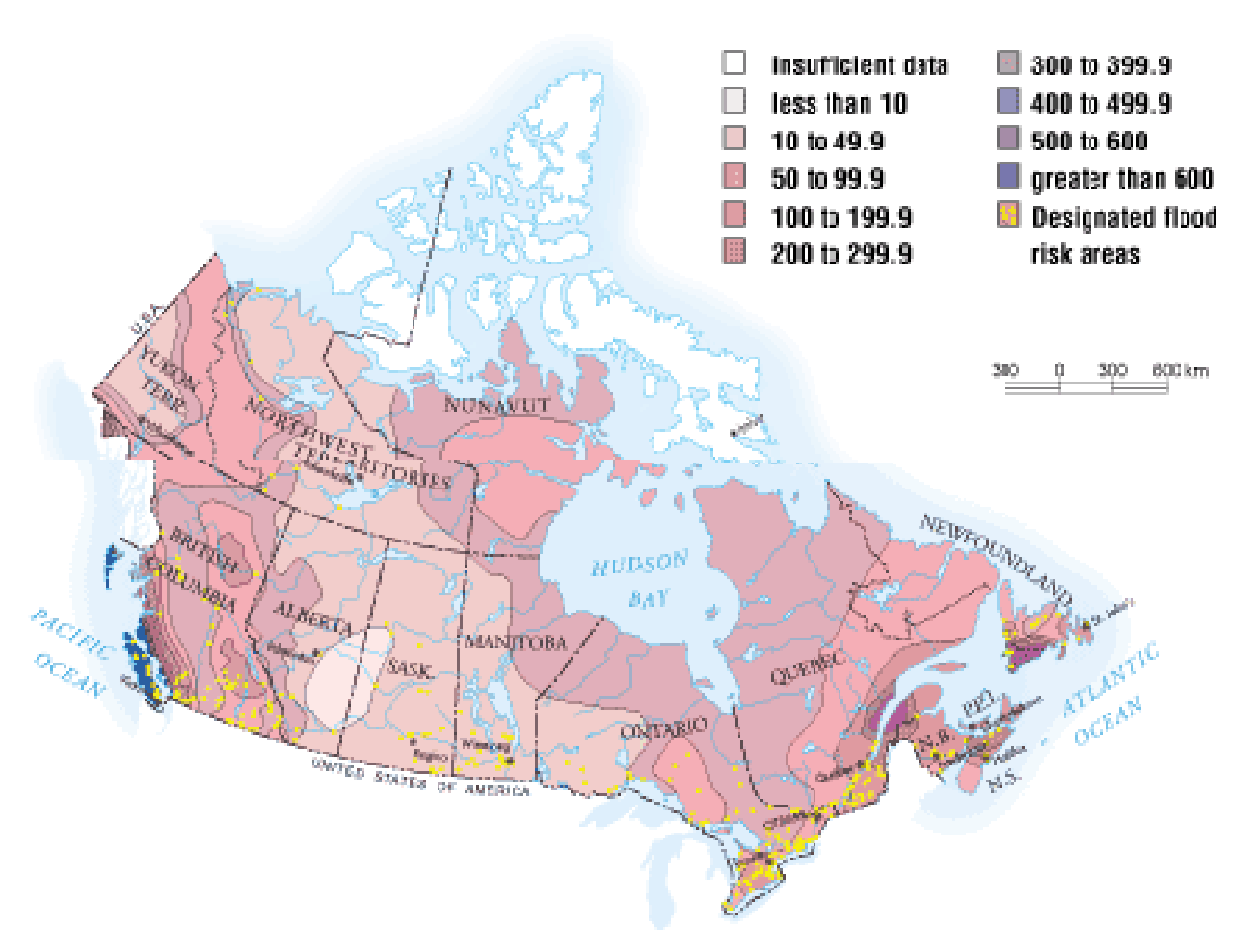


Data Source: Public Safety Canada, Disasters Database

People are vulnerable to water related hazards. Too much water – floods - are a problem

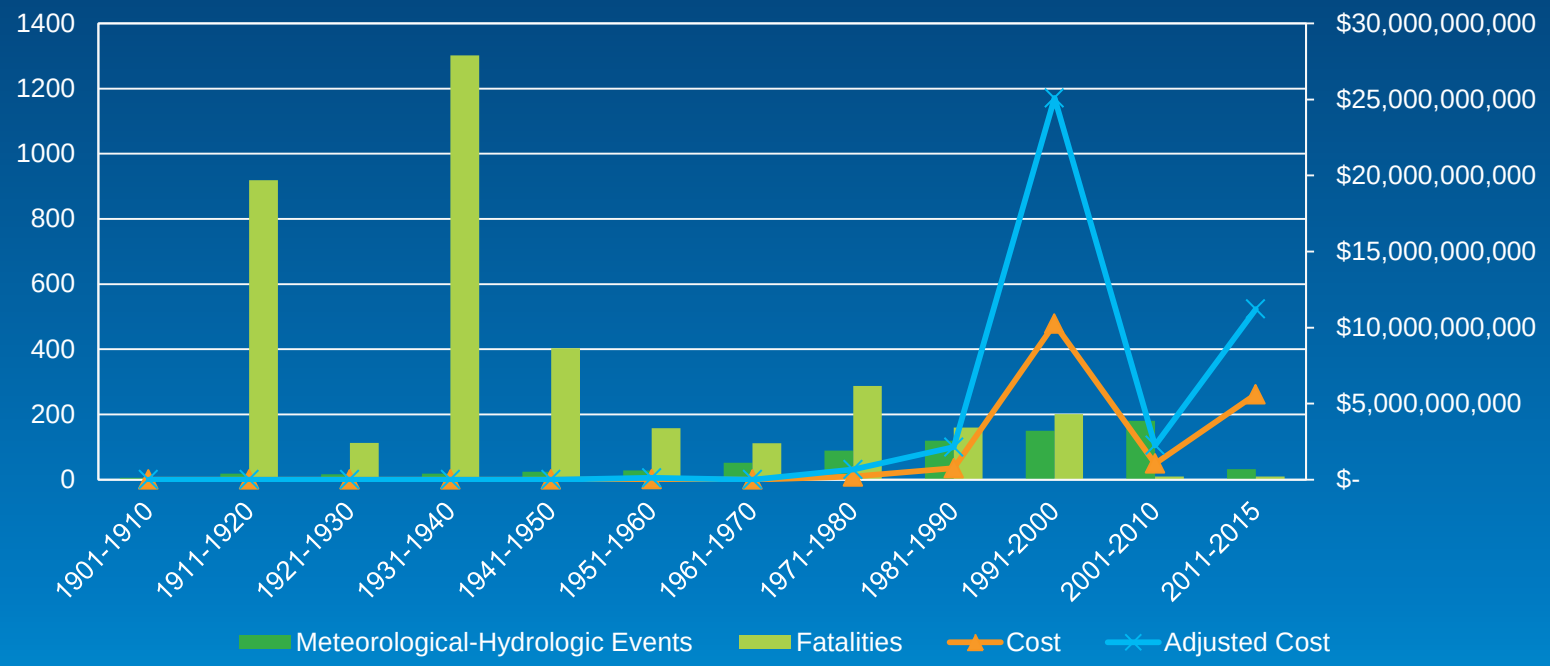


Designated Flood Risk Areas across Canada



Source: Public Safety Canada, Disasters Database

Meteorological – Hydrological Disasters in Canada (1900-2015)

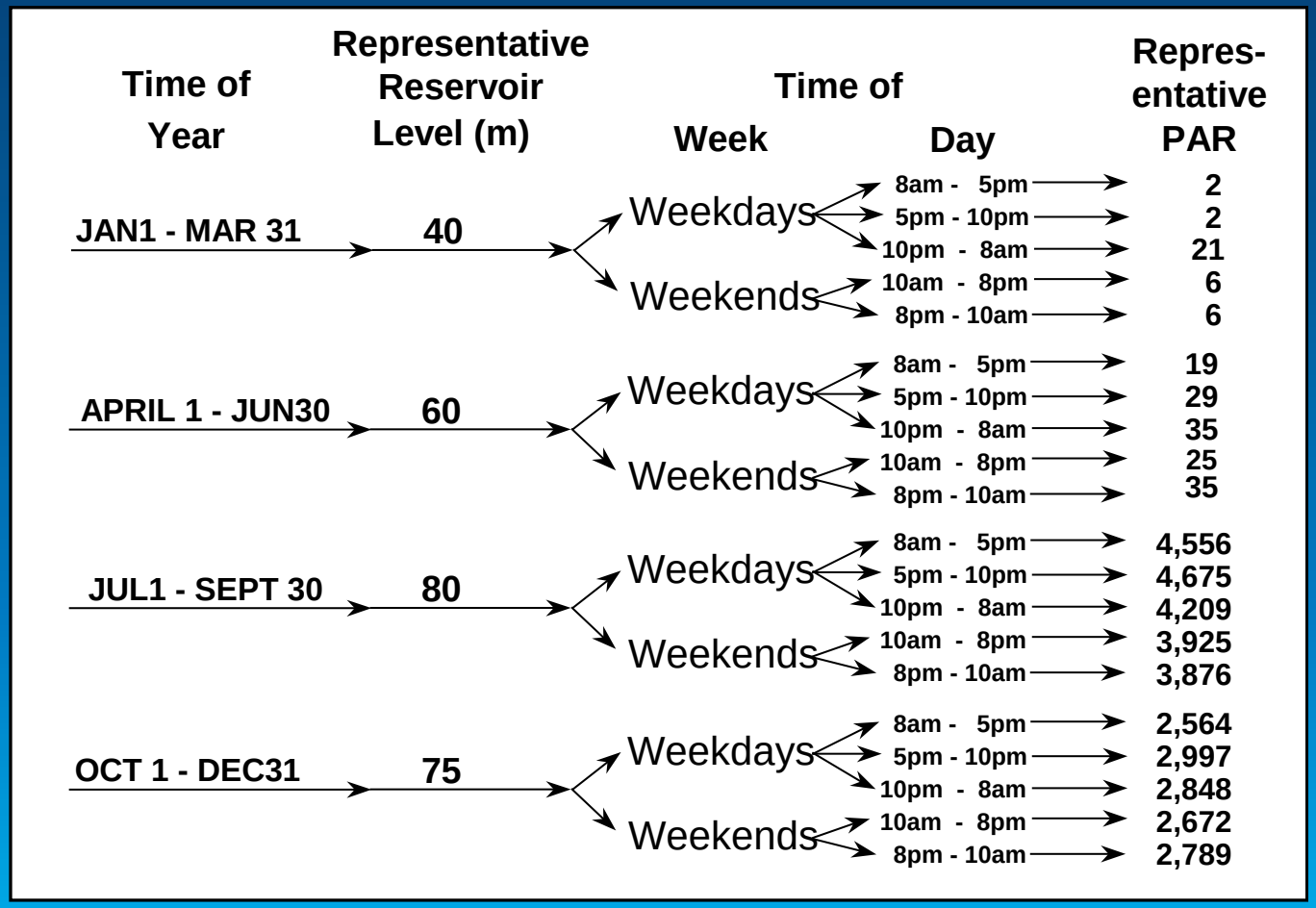


Source: Public Safety Canada, Disasters Database

Challenges in Life Loss Estimation

Arles,
France 2003

Time Domain Concept



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

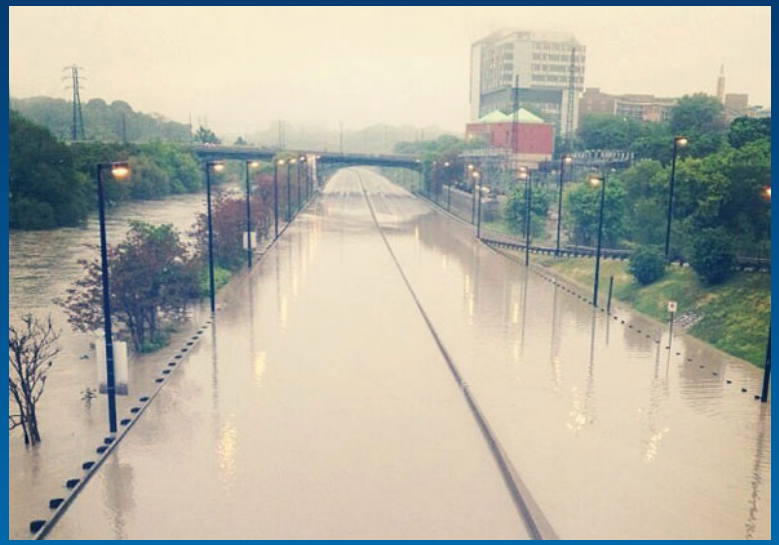
Tropical Storm Allison (2001)

Toronto (2013)

Impact on Infrastructure

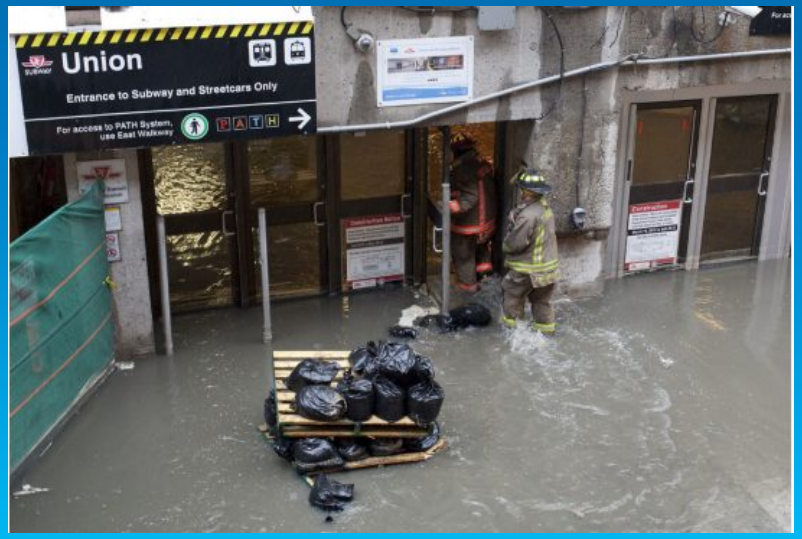
Natural Flood – Germany. Source: Munich Reinsurance 2002

May 2013 Storm, Toronto, Ontario

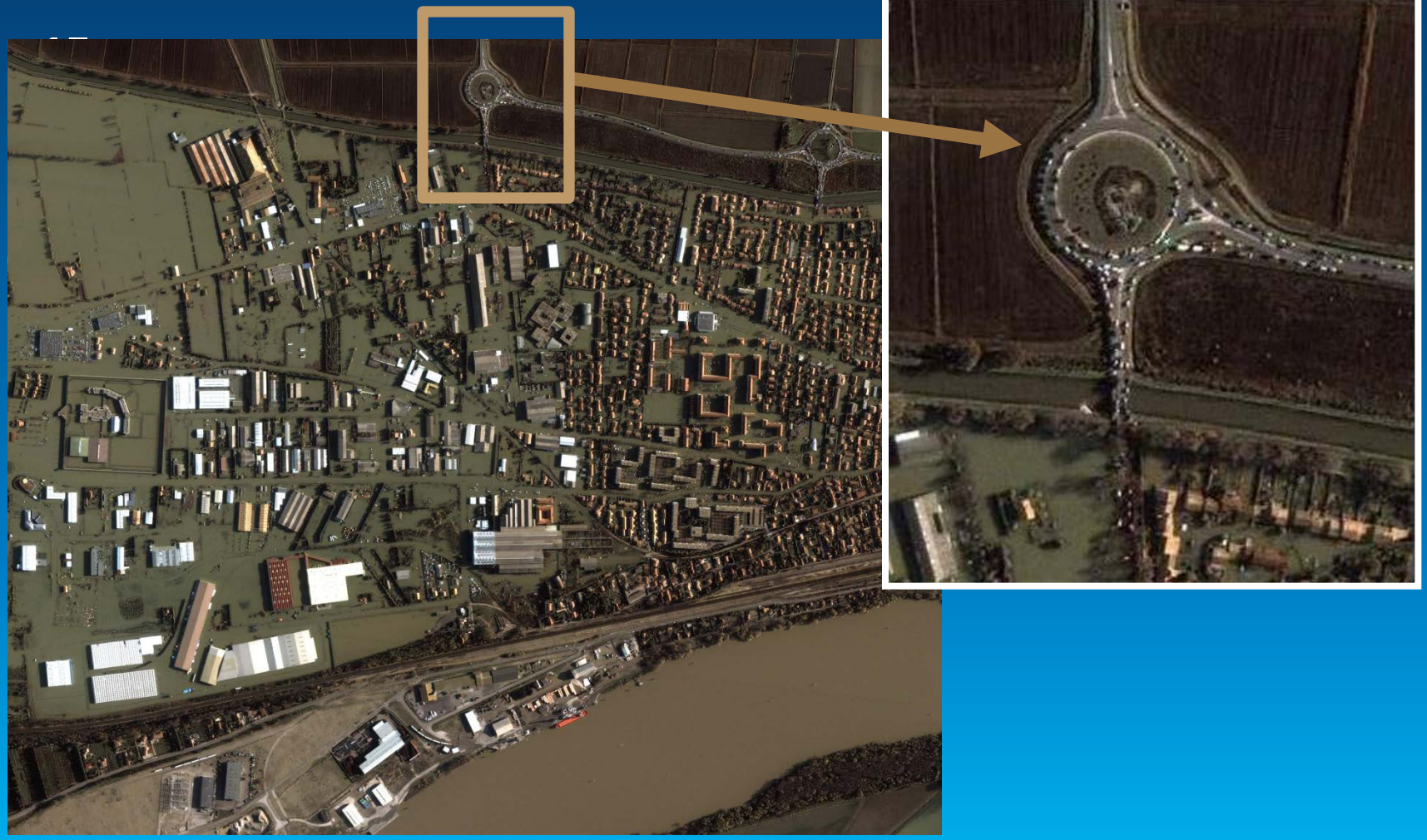


August 19, 2005 Storm, Toronto, Ontario

June 1, 2012 Storm, Toronto, Ontario



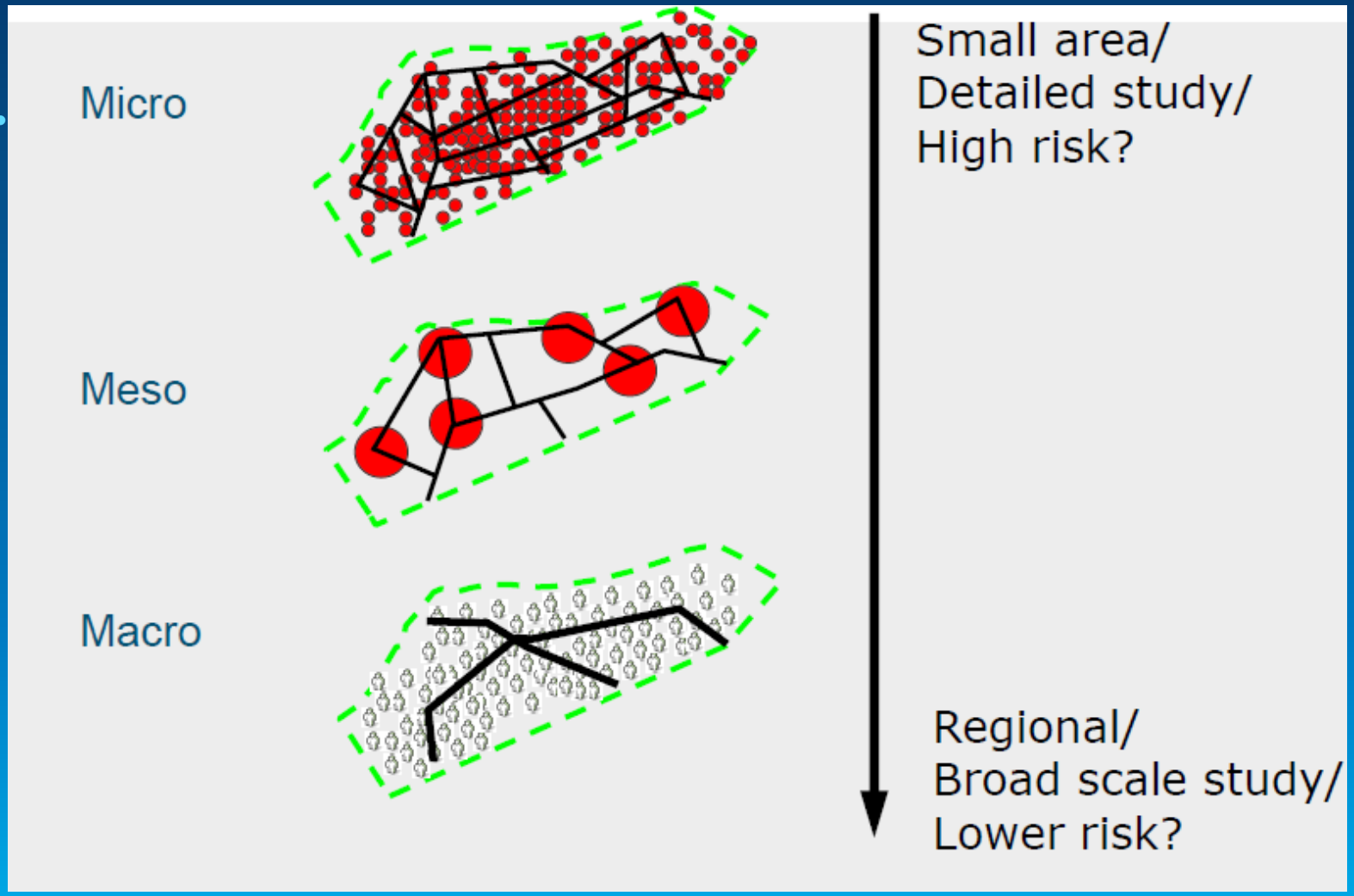
Impact of Evacuation Routes



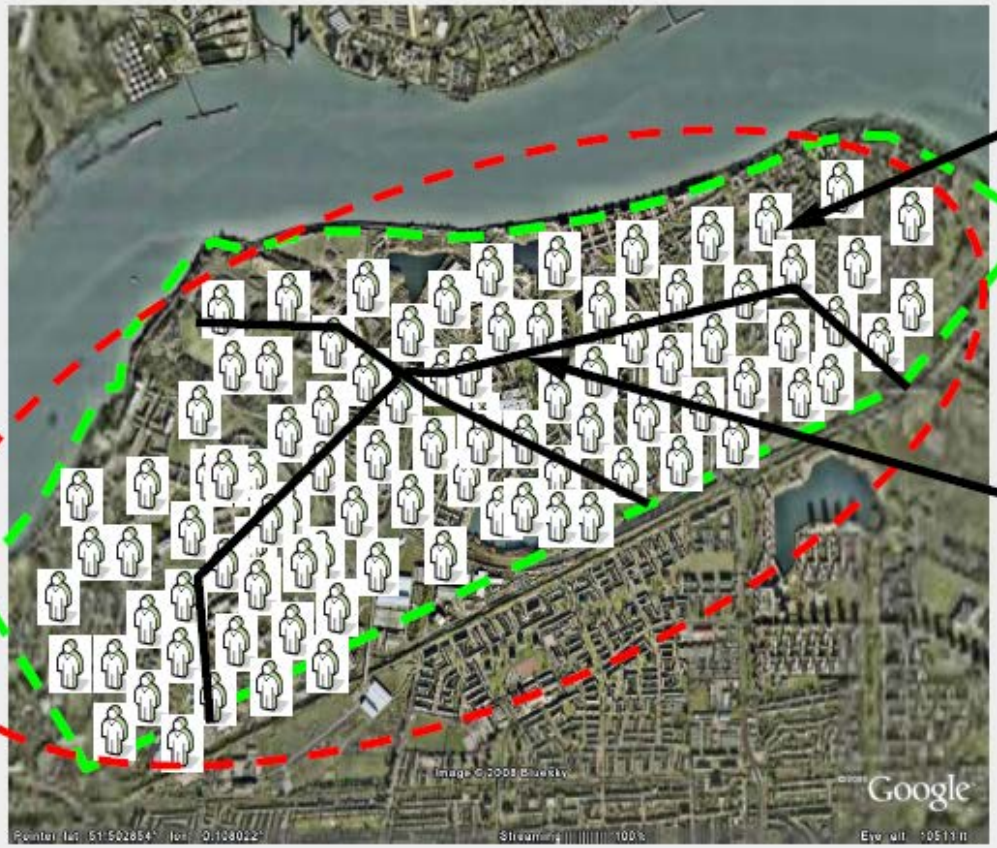
Factors that Influence Loss of Life

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



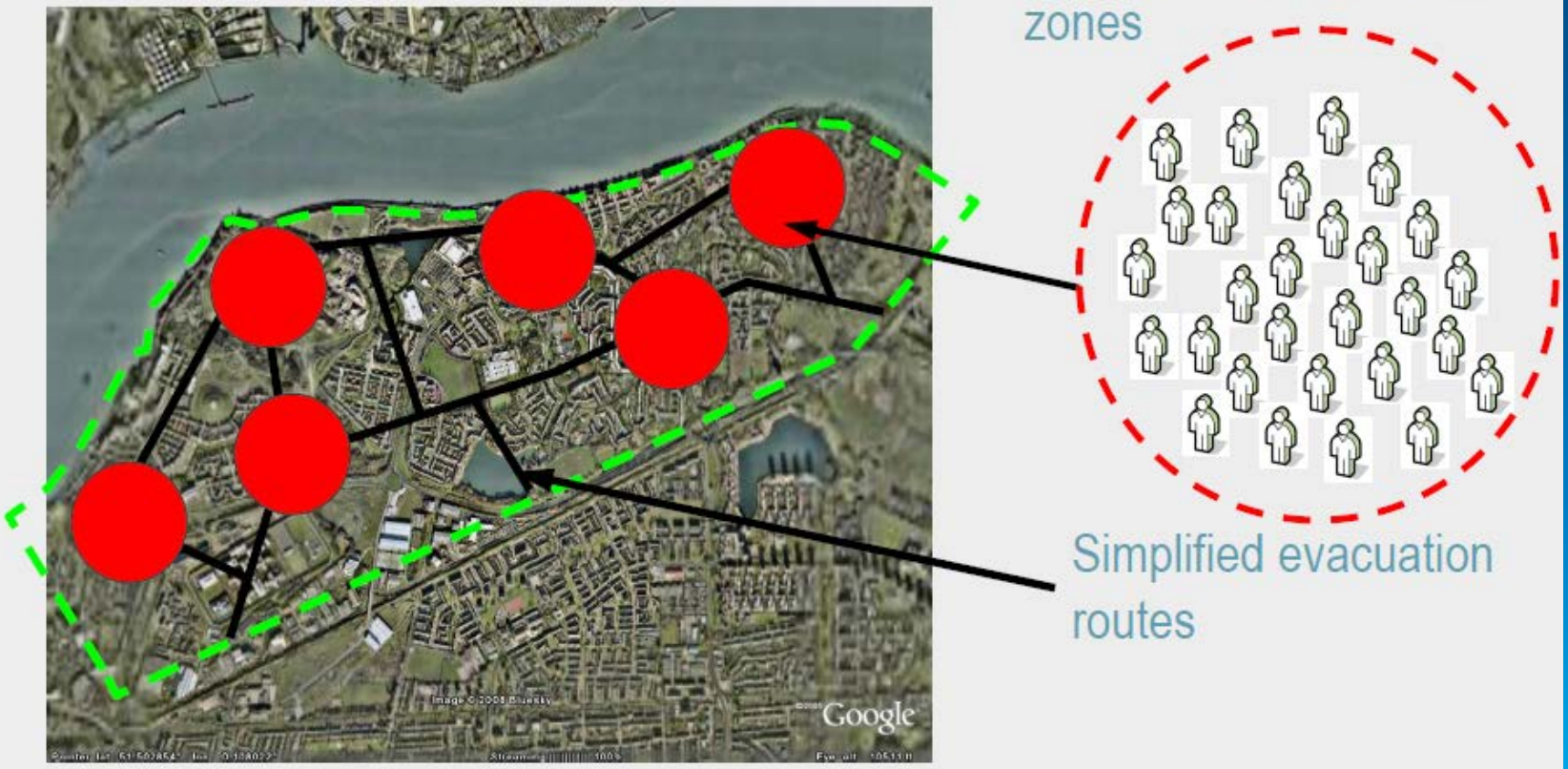
Levels of Modelling -- Macro



One mortality rate applied to the whole area

Evacuation time based on average distance to safety

Levels of Modelling -- Meso

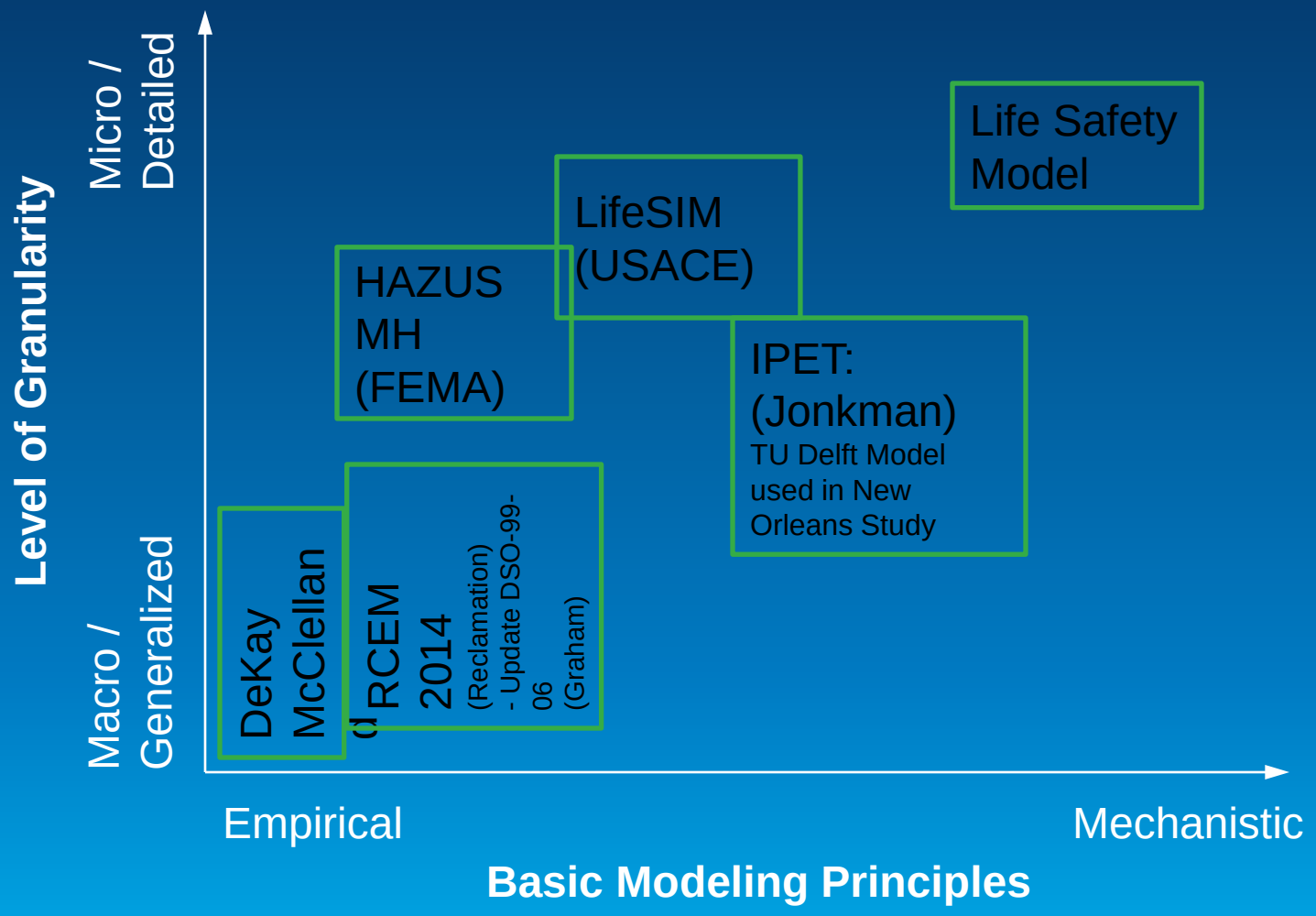


Levels of Modelling -- Micros

Behaviour of each individual is modelled

Detailed representation of evacuation routes

Life Loss Estimation Models



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

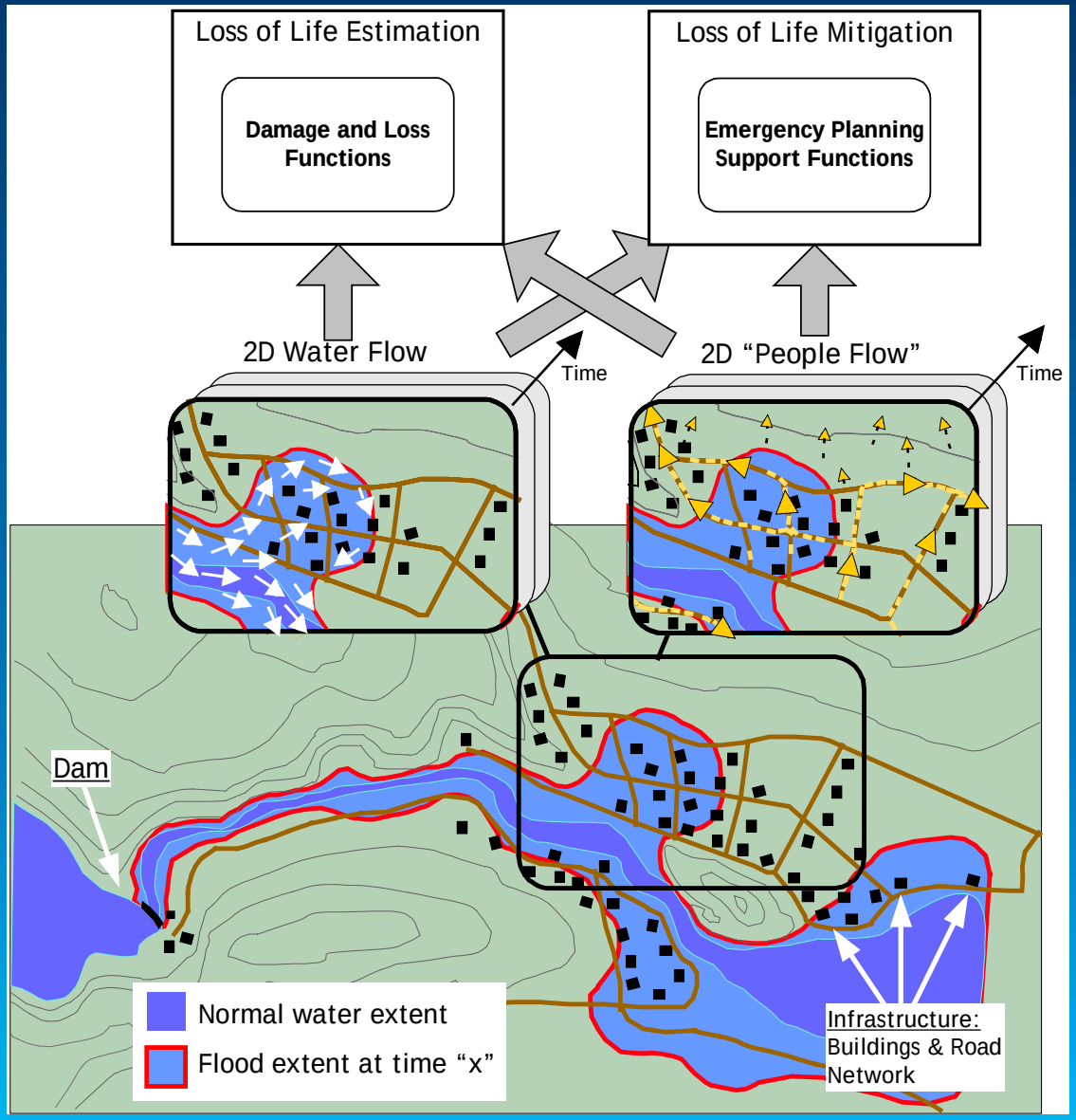
DSO-99-06 states:

- **“*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.*”**

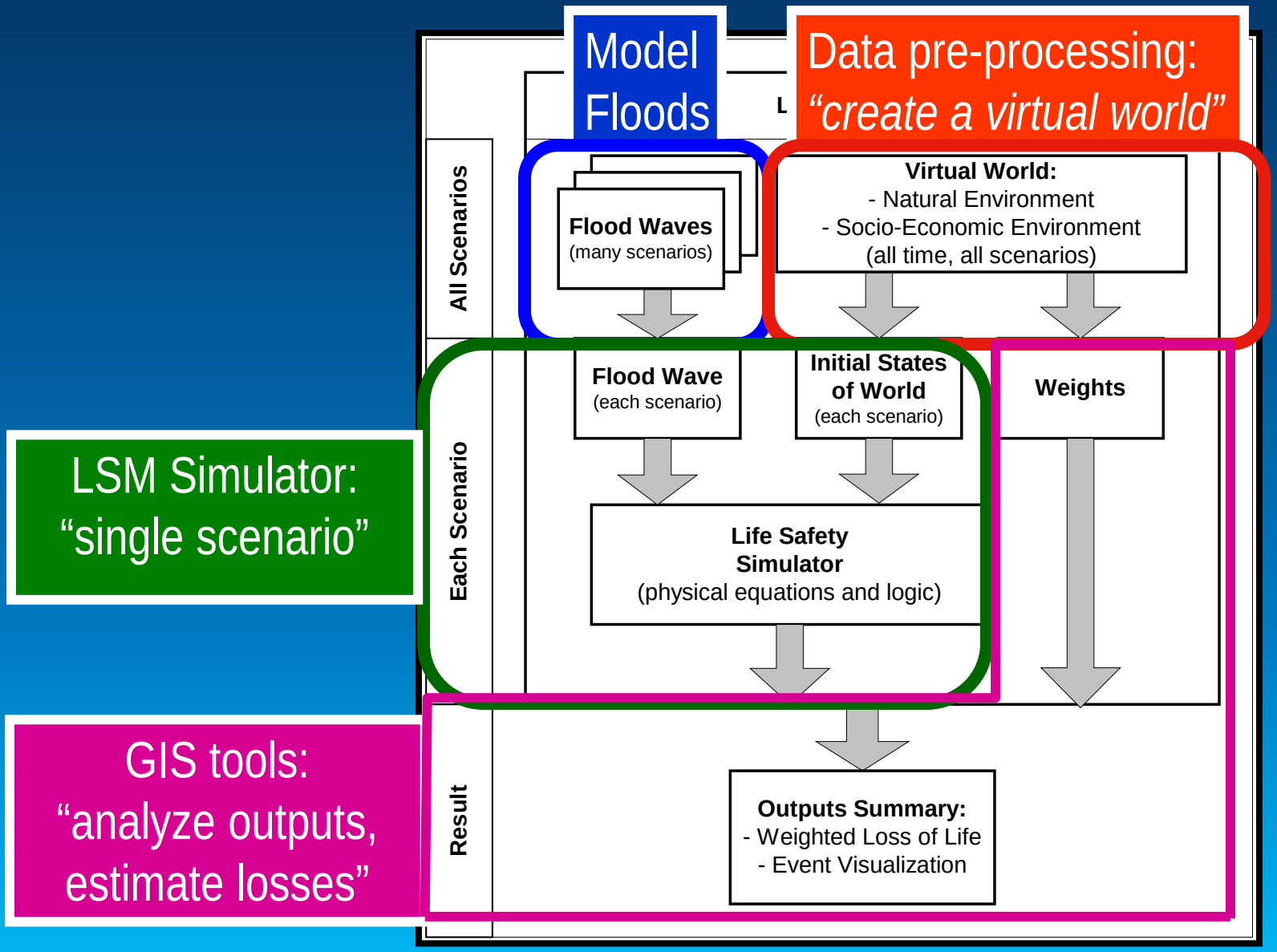
Life Safety Model: What is it?

- Life Safety Model (LSM) is simulation model
- It combines 2nd 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.

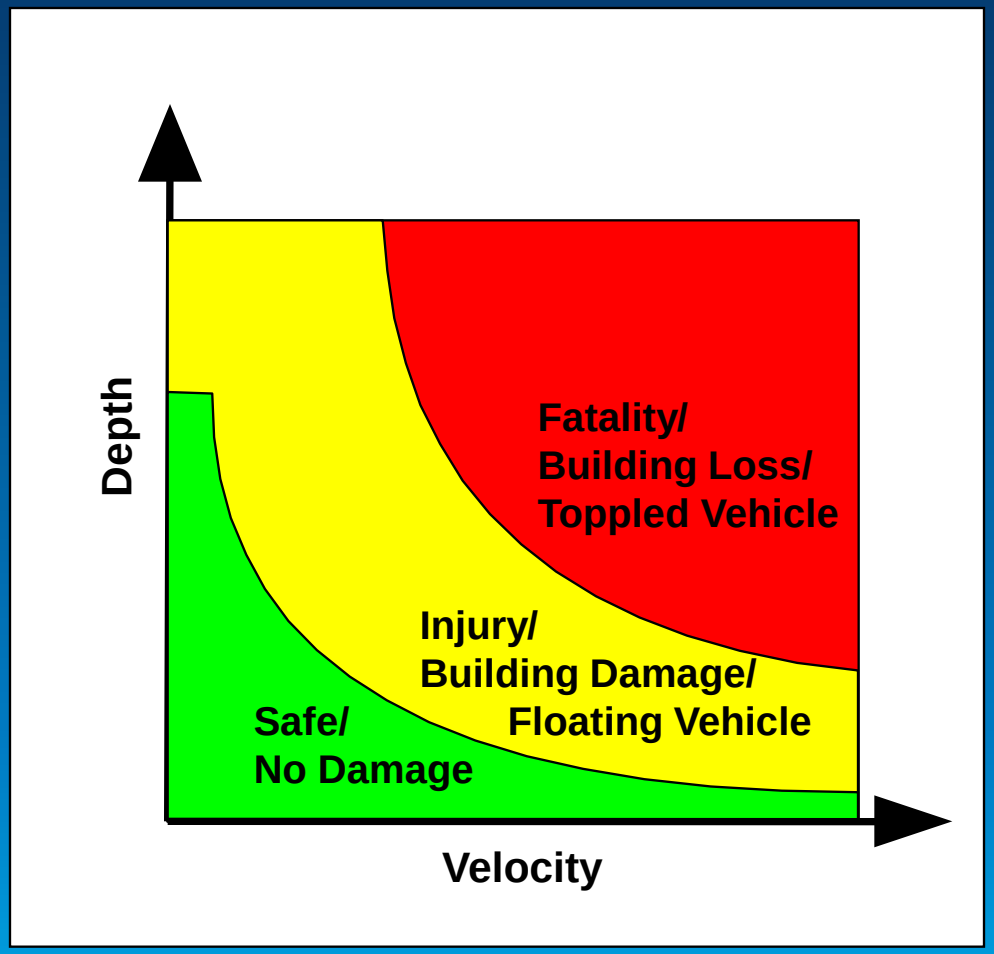
Life Safety Model Concept



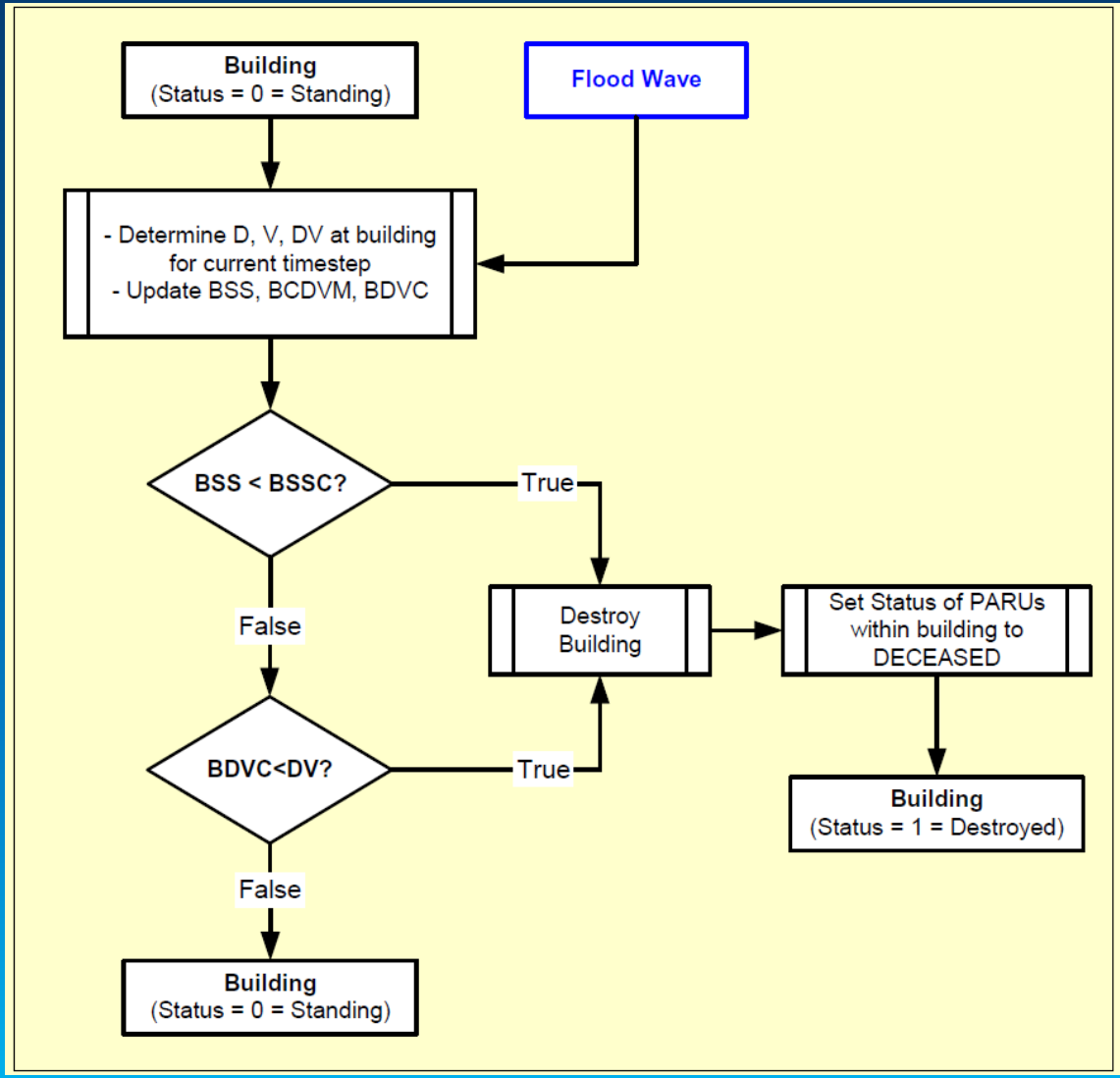
High Level Architecture



Object Damage and Loss Function



Building Loss Algorithm



Building Damage & Loss Curves

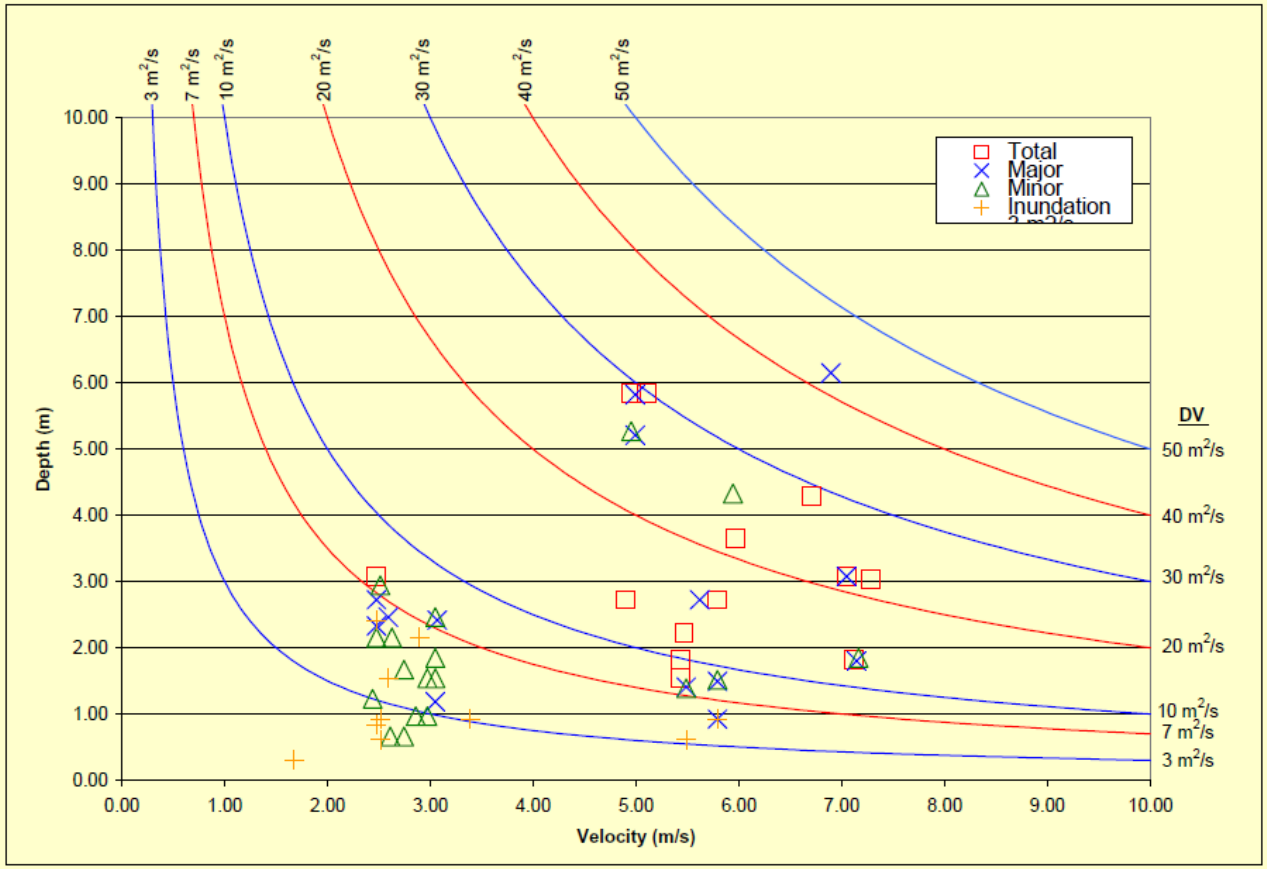


Figure 21 – Building Damage in Dale Dyke Flood

Adapted from Clausen & Clark 1990

Human Stability Data

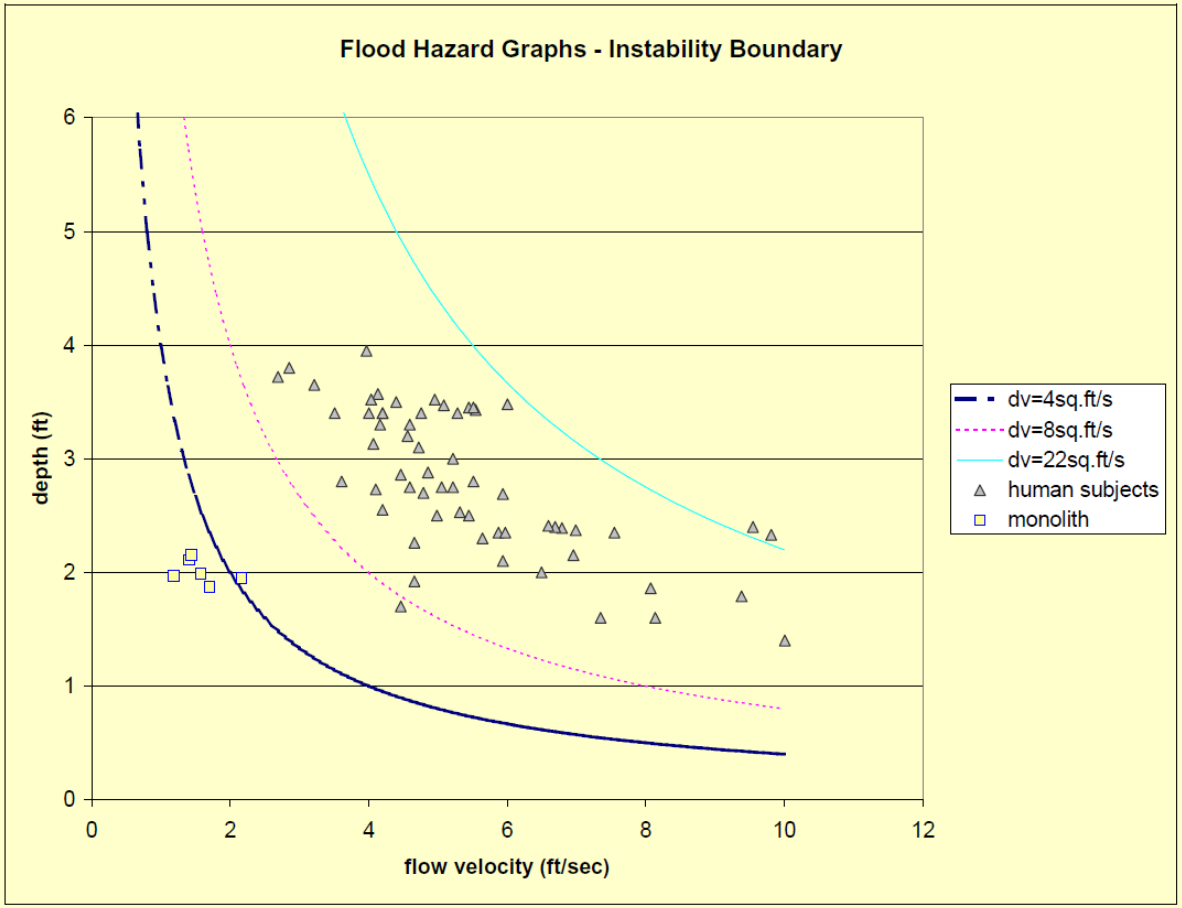


Figure 23 – Human Stability Test Data

(After Abt, Wittler, et al, 1989)

Vehicle Stability Data

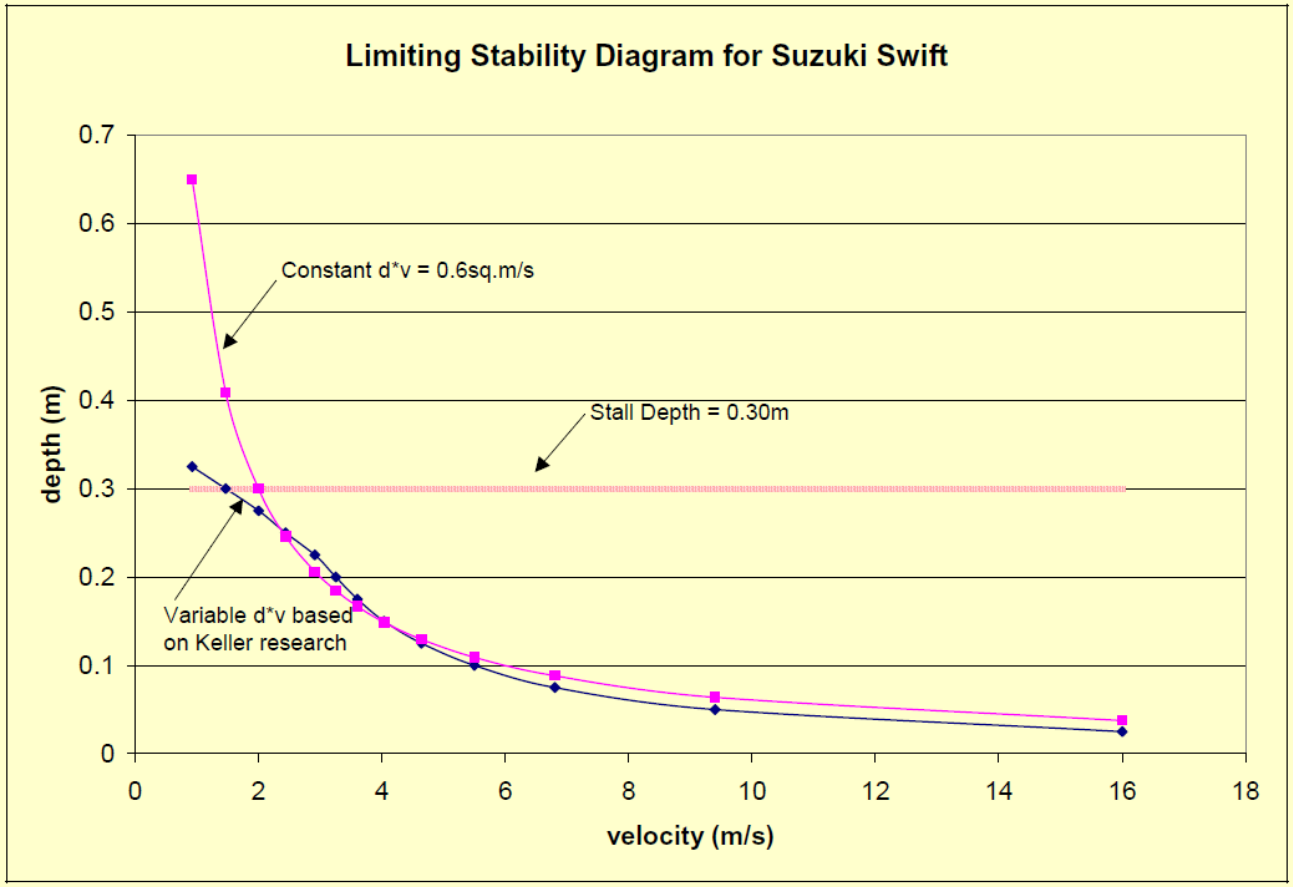
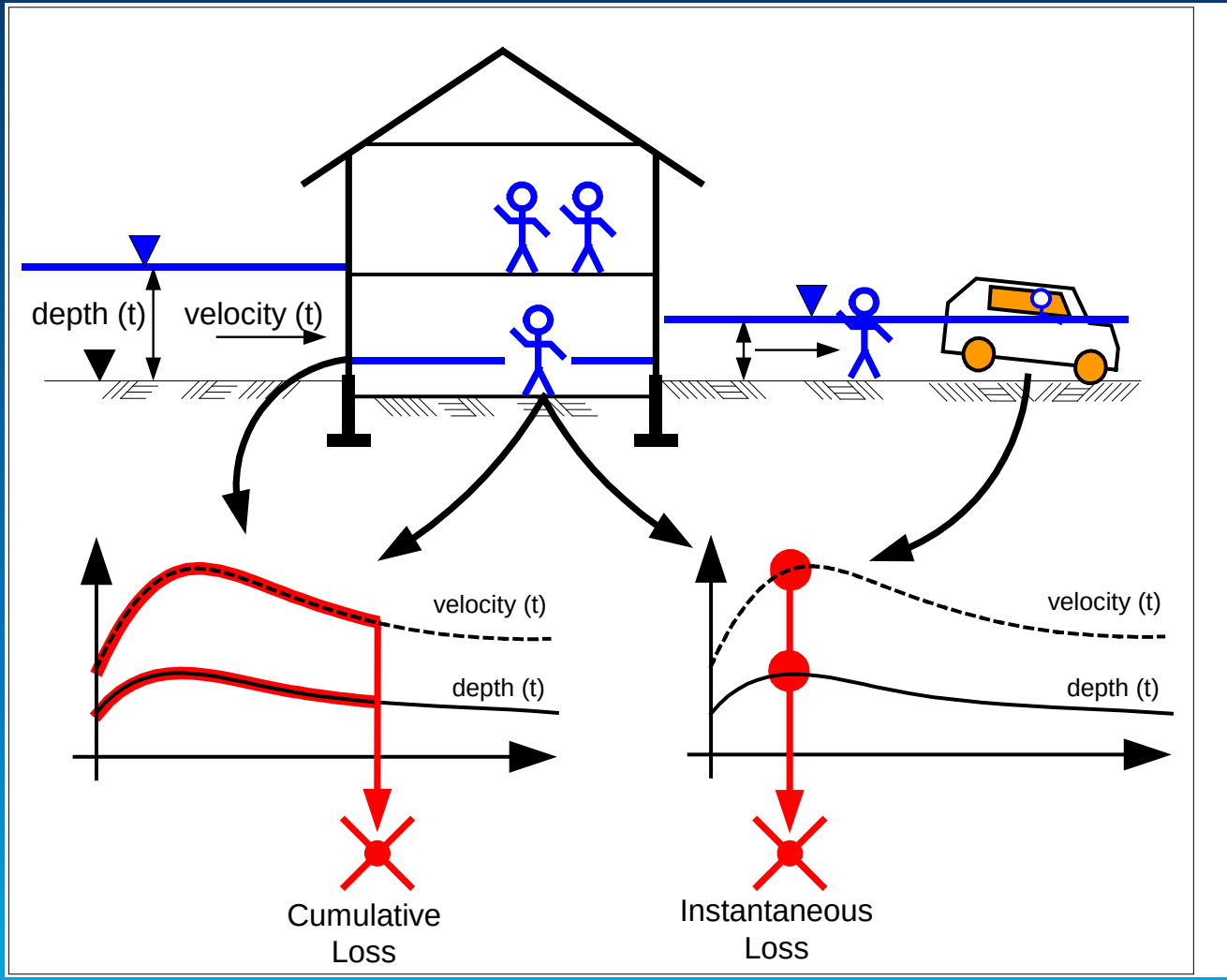


Figure 25 – Vehicle Stability Diagram

(after Keller, 1992)

Physical Interaction of Objects in Flood

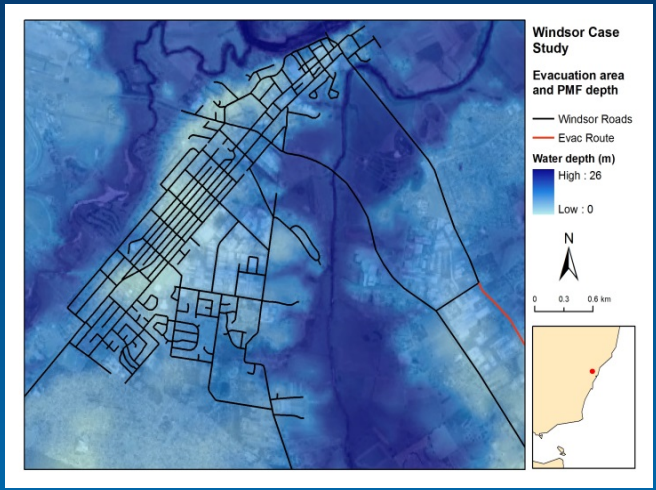


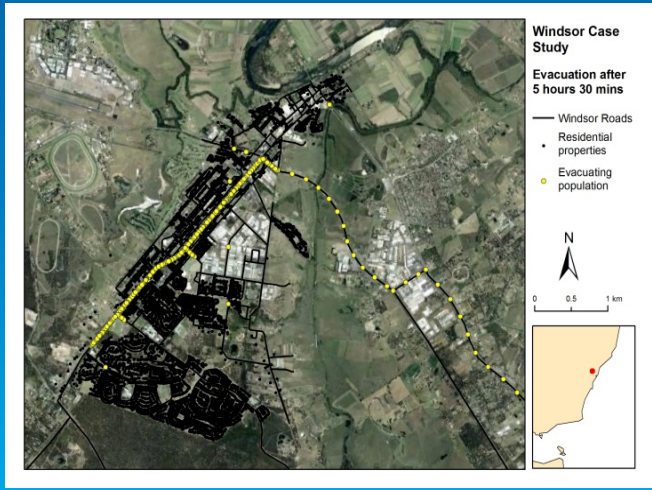
Testing and Validation of LSM

- 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

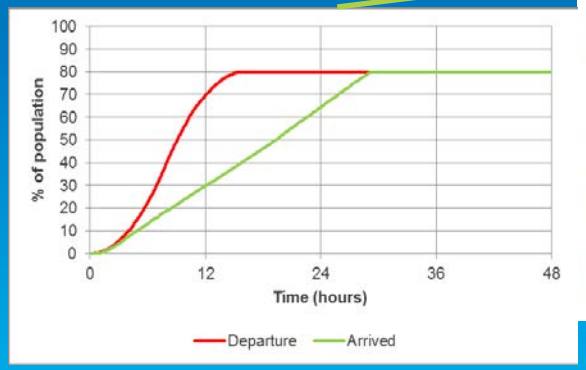
- Windsor NSW Australia
  - Town of Windsor becomes an island in flood events with a single high bridge connection to evacuation route
  - In very large floods (PMF) the town would be completely inundated
  - LSM model for State Emergency Services (SES) to understand time taken for evacuation and assessment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

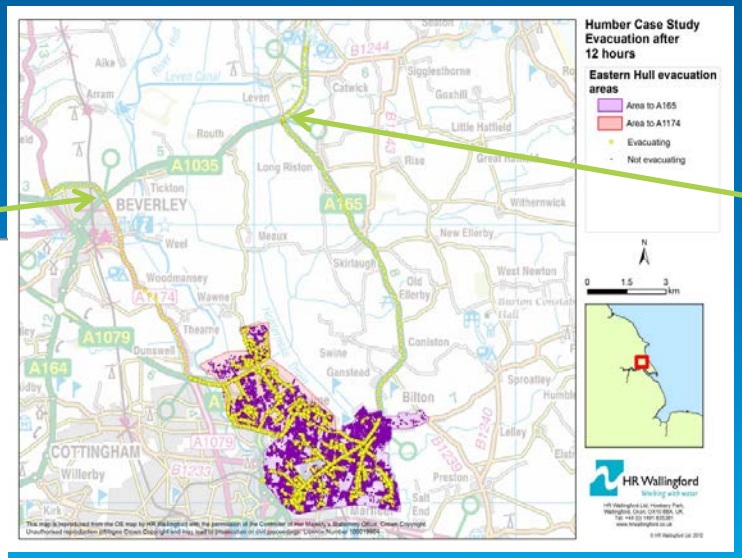


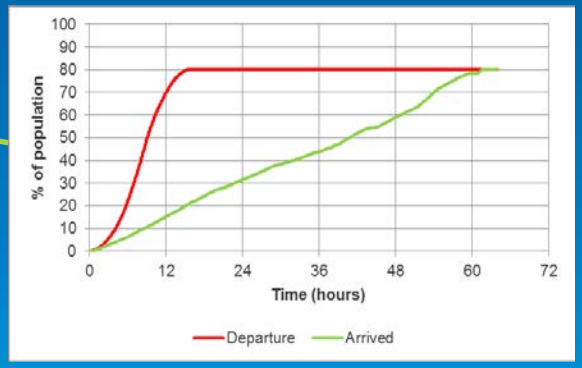


Case Study – Emergency Planning

- **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?