RAC
Engineers & Economists

2nd International Week on Risk Analysis
as Applied to Dam Safety and Dam Security
Theoretical-Practical Course
Universidad Politecnica de Valencia
Valencia, Spain
27 & 28 February 2008

Utah State University
IDSRM

Complete Dam Risk Analysis & Detailed Applications:

L.7 – LIFESim:

A Simulation Model for Estimating Life Loss from Natural and Dam/Levee Break Floods

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and RAC Engineers & Economists

1) Limitations of empirical approaches

McClelland and Bowles [IWR 2002]

- Based on historical events that are not a "homogeneous statistical population"
  - Like developing a regression equation for factor of safety for seismic stability using dam height and slope for 20 dams around the country but without considering differences in seismic hazard, dam section, materials properties, potential for liquefaction, etc
- Do not distinguish many factors that change with failure mode type vs. natural flooding event
- Travel times, depths, and velocities that affect the fate of people, vehicles, and structures are based on large-scale spatial averages
- PAR is considered for the entire area of inundation or for large subPar
  - Does not distinguish many attributes that are important determinants of life loss
- Warning time is considered as a single variable without taking into account the actual chain of events and many unique factors:
  - Warning system type
  - Rate of mobilization
  - Influence of time of day and population activities
  - Effectiveness of evacuation
  - Benefits of relocation to safer shelters

2) Learning from Case Histories

Phase 1 of Utah State University Project

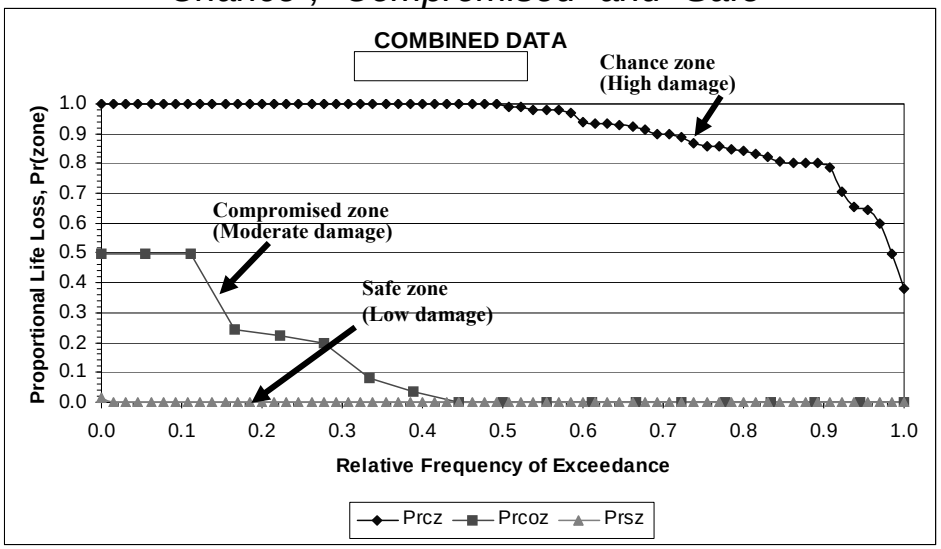
2) Learning from Case Histories

(McClelland & Bowles 1999, 2000 and IWR 2002)

- Approach
  - Collected 180 case histories of flooding events
  - 54 events characterised *(including zero life-loss cases)*
    - 100 *characterising* variables grouped into 16 categories
      - NOT *predictive* variables
  - Identified 250 subPAR with homogeneous (a) flood exposure and (b) flood severity conditions
    - grouped into 3 flood (lethality) zones:
      - *"Chance", "Compromised" and "Safe"*
    - scale-independent approach to estimating fatality rates, which extracts more information from available case histories
- An Important Outcome for Life-Loss Estimation:
  - **Empirically-based fatality-rate probability distributions** for 3 flood zones:
- Then, life loss can be estimated by:
  1) Categorising people in flood events into these 3 flood zones
  2) Applying fatality-rate probability distributions to number of people in each flood zone
- **LIFESim does 1) and 2)**

Fatality Rate Probability Distributions by Flood Zone:

"Chance", "Compromised" and "Safe"

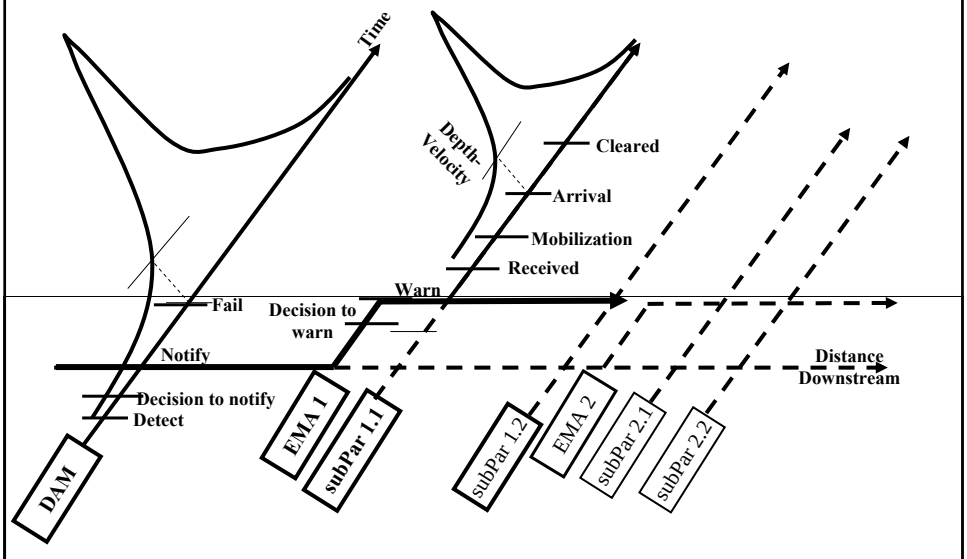


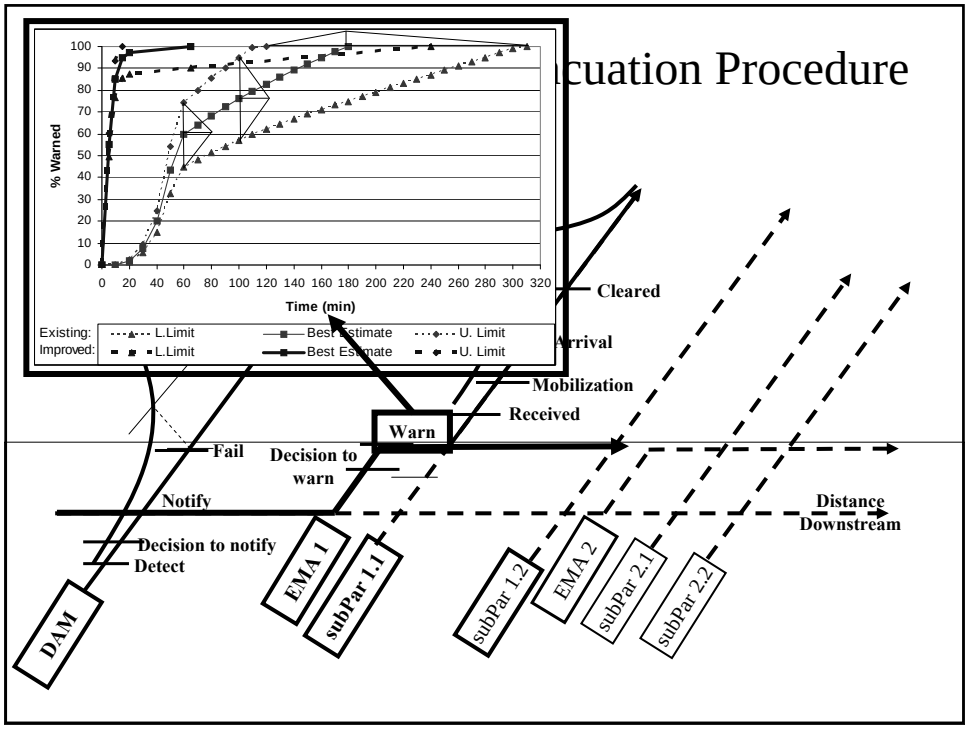
3) LIFESim

LIFESim Overview

- Funded by USACE, ANCOLD, USU & USBR
- Modular, Spatially-distributed, Dynamic Simulation System
- Two Modes:
  - Deterministic Mode
  - Uncertainty Mode
- Development Philosophy:
  - Use readily available data:
    - Census, USGS, HAZUS-MH
  - Categorizes people into 3 homogeneous flood (lethality) zones (*"Chance", "Compromised" and "Safe"*) through simulation using:
    a) Warning and Evacuation Module – redistributes people horizontally and vertically
    b) Loss of Shelter Module combined with Flood Severity from an *external Flood Inundation Model* to categorize locations of people (buildings, vehicles, pedestrians) into 3 Flood Zones
    c) Life-loss Module – applies empirically-based fatality-rate probability distributions
  - Reasonable implementation effort

Steps in Warning and Evacuation Procedure





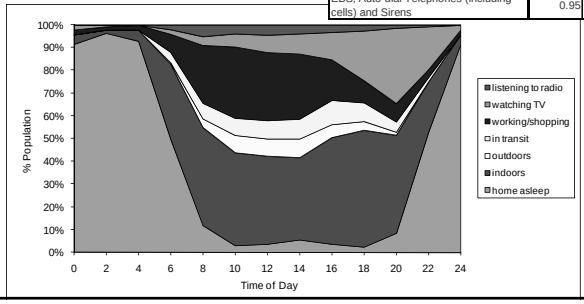
Warning Diffusion

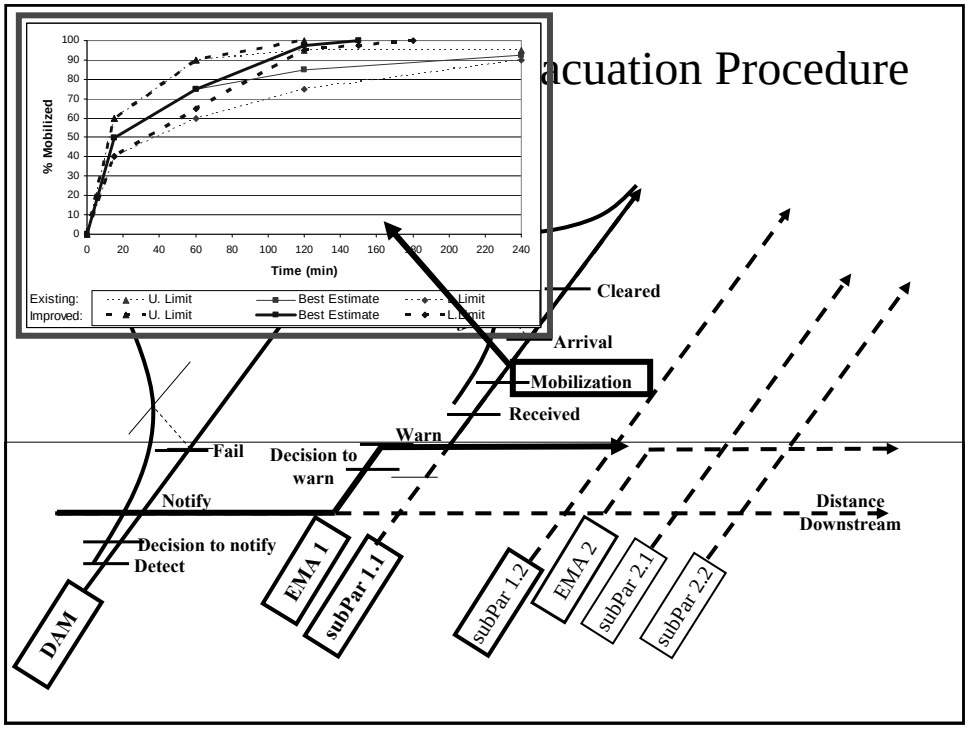
Warning System Type and Population Activities (Rogers et al 1988)

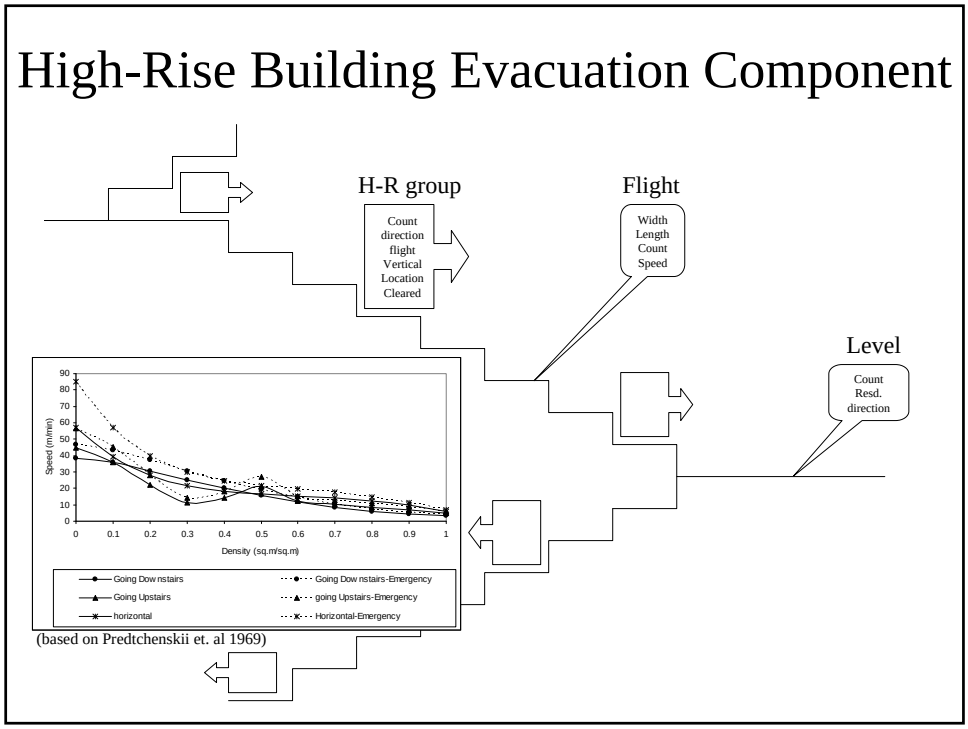
Type of warning system	k	a1	a2	30-min limit	release rate
Sirens	0.2	0.2	0.3	0.75	0.3
tone-alert radios	0.4	0.3	0.2	0.9	0.1
Auto-dial telephones	0.3	0.2	0.25	0.5	0.5
EBS	0.4	0.35	0.2	0.93	0.1
Sirens and tone alert radios	0.4	0.3	0.3	0.95	0.1
sirens and auto-dial telephones	0.4	0.35	0.3	0.95	0.1

Warning system Effectiveness (a,f) Our modifications in red

Warning System Type	Home Asleep	Indoors	Outdoors	In Transit	Working/ Shopping	Watching TV	Listening to Radio
Sirens	0.691	0.8	0.9	0.9	0.6	0.7	0.7
Tone-alert Radios	0.85	0.9	0	0	0.7	0.8	0.8
Auto-dial Telephones - land lines only	0.933	0.95	0	0	0.8	0.95	0.95
Auto-dial Telephones - adjusted for cell phones	0.95	0.97	0.85	0.85	0.85	0.95	0.95
Emergency Broadcast System (EBS)	0	0.4	0.2	0.2	0.1	1	1
Sirens and Tone Alert Radios	0.9	0.9	0.9	0.9	0.7	0.8	0.8
Sirens and Auto-dial Telephones	0.933	0.85	0.9	0.9	0.8	0.95	0.95
EBS and Auto-dial Telephones (including cells)	0.95	0.97	0.85	0.85	0.85	1	1
EBS, Auto-dial Telephones (including cells) and Sirens	0.95	0.97	0.9	0.9	0.85	1	1




acuation Procedure
% Mobilized
Time (min)
Existing:
Improved:
U. Limit
Best Estimate
Limit
Cleared
Arrival
Mobilization
Received
Warn
Fail
Decision to warn
Notify
Distance Downstream
Decision to notify
Detect
DAM
EMA 1
subPar 1.1
subPar 1.2
EMA 2
subPar 2.1
subPar 2.2

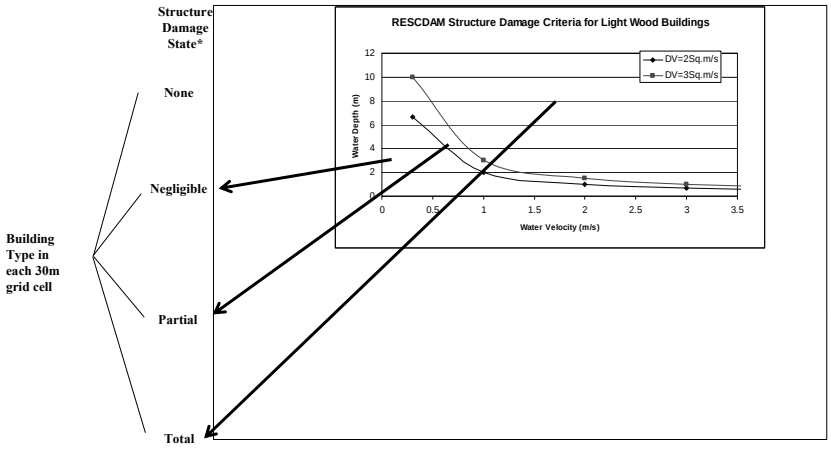

High-Rise Building Evacuation Component
H-R group
Flight
Count direction flight Vertical Location Cleared
Width Length Count Speed
Level
Count Resd. direction
Speed (m/mn)
Density (sq.m/sq.m)
Going Dow nstairs
Going Upstairs
horizontal
Going Dow nstairs-Emergency
going Upstairs-Emergency
Horizontal-Emergency
(based on Predtchenskii et. al 1969)

Modified Greenshield's Transportation Component (Based on Greenshield 1935)

- Road network - GIS
  - Road category
  - Segment lengths
  - Number of lanes
  - Interconnectivity
- Modal split: cars and SUVs
- Speed a function of traffic density
  - Free flow speed - TRB (2000) Highway Capacity Manual
- Traffic Jams - Minimum "Stop-and-go speed" when Jam Density exceeded
- Road Segment Blocking in Flooding
  - Car stability criteria exceeded

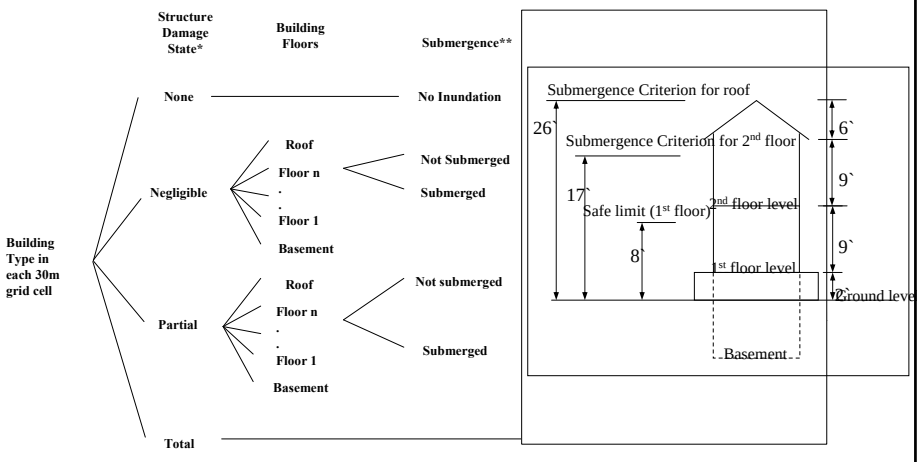
b) Loss-of-Shelter Categories/Flood Zones for Buildings

Simulated up to Flood Peak



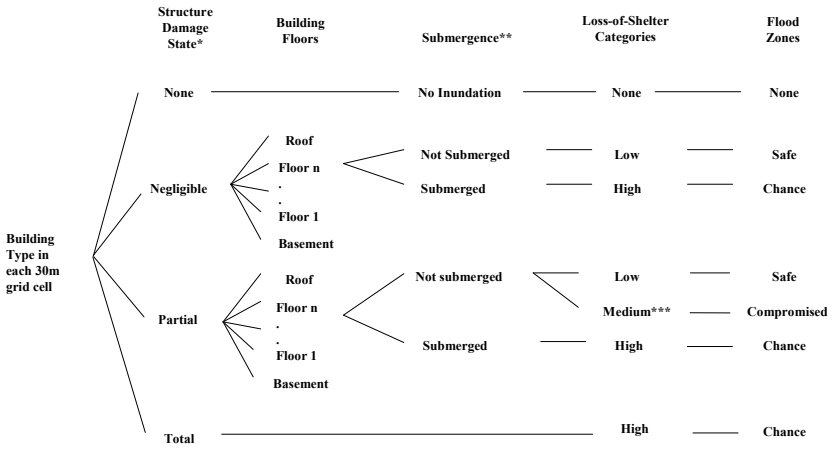
* Use building performance criteria

Loss-of-Shelter Categories/Flood Zones for Buildings
Simulated up to Flood Peak



* Use building performance criteria
** Use loss of shelter by submergence criteria

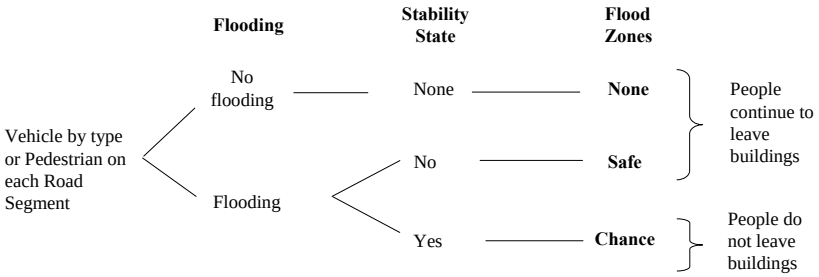
Loss-of-Shelter Categories/Flood Zones for Buildings
Simulated up to Flood Peak



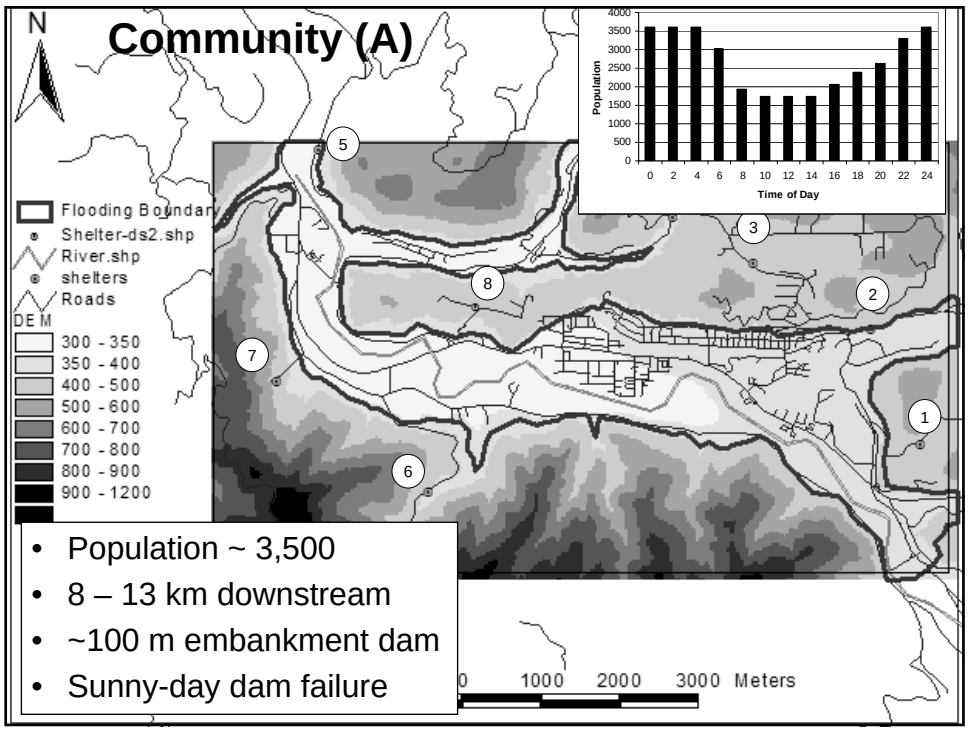
* Use building performance criteria
** Use loss of shelter by submergence criteria
*** Use human stability criteria

Loss-of-Shelter Categories/Flood Zones for Vehicles and Pedestrians

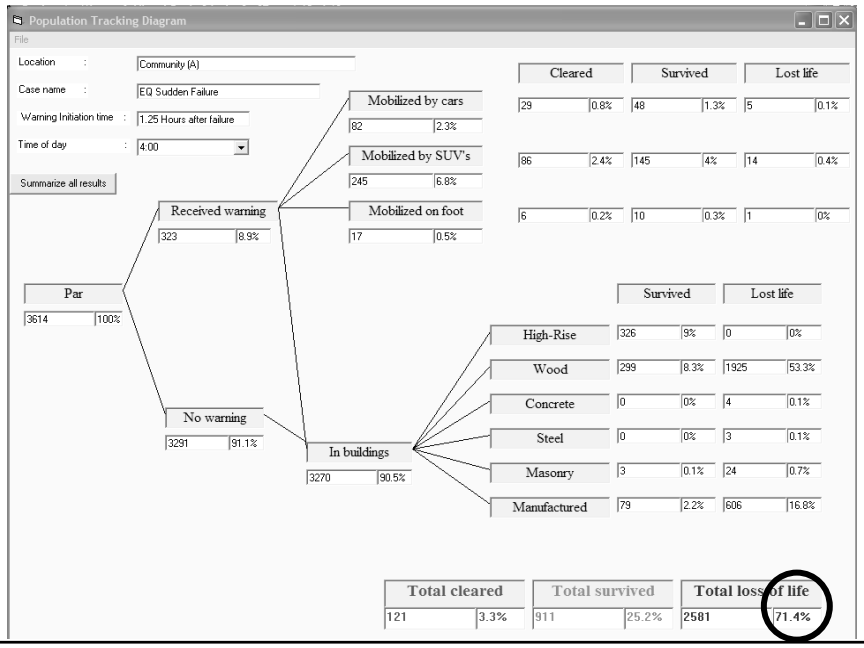
Simulated up to Flood Peak



4) LIFESim Case Studies

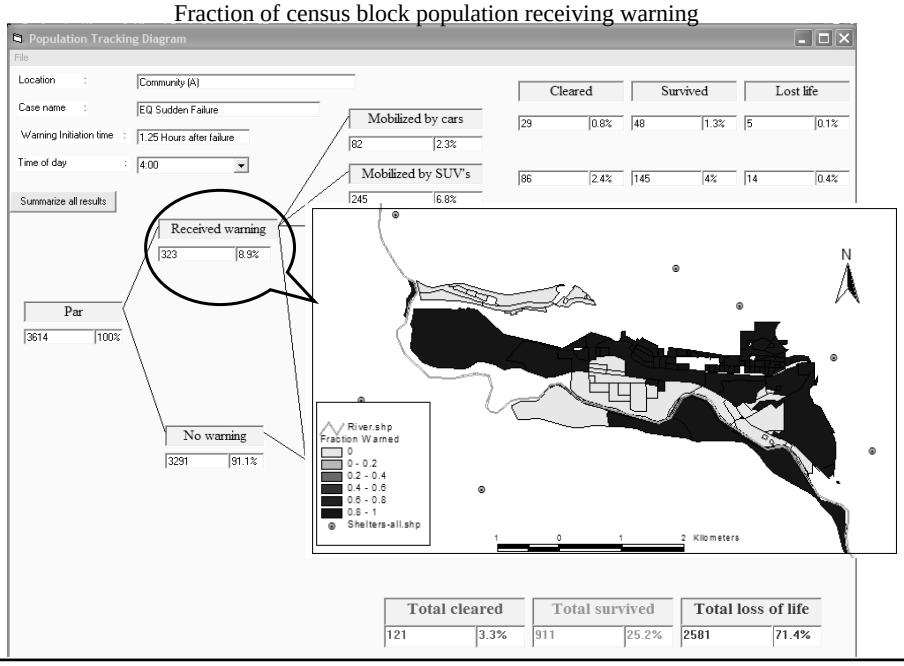


Community (A) – Population Tracking Diagram



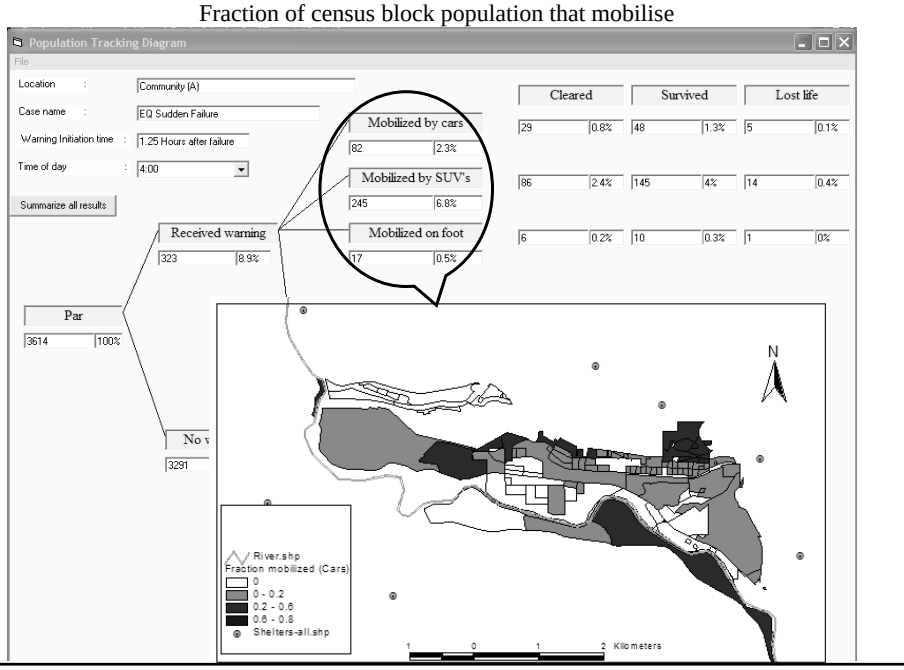
Community (A) – Warning

Fraction of census block population receiving warning



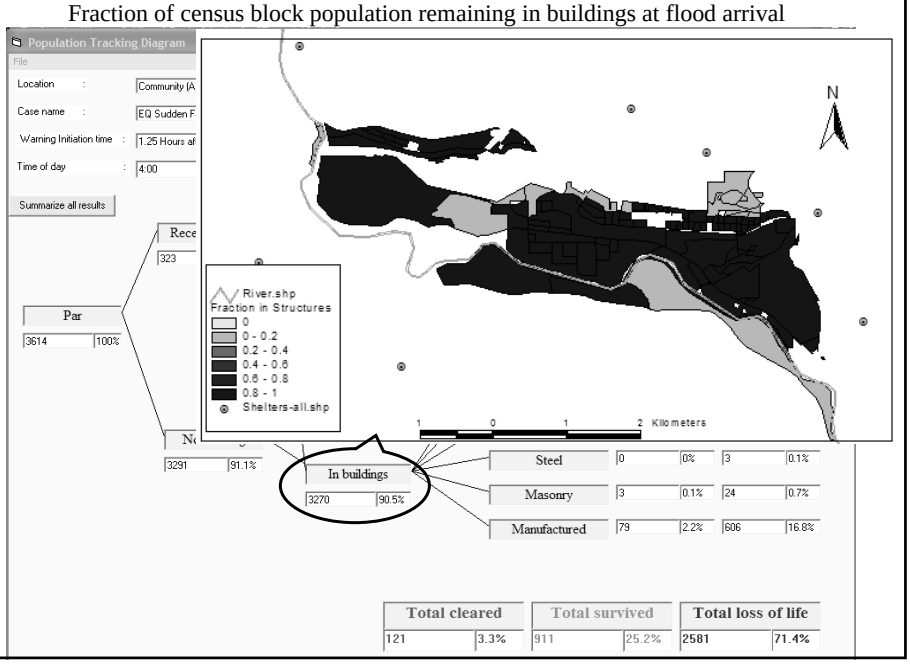
Community (A) – Mobilization

Fraction of census block population that mobilise



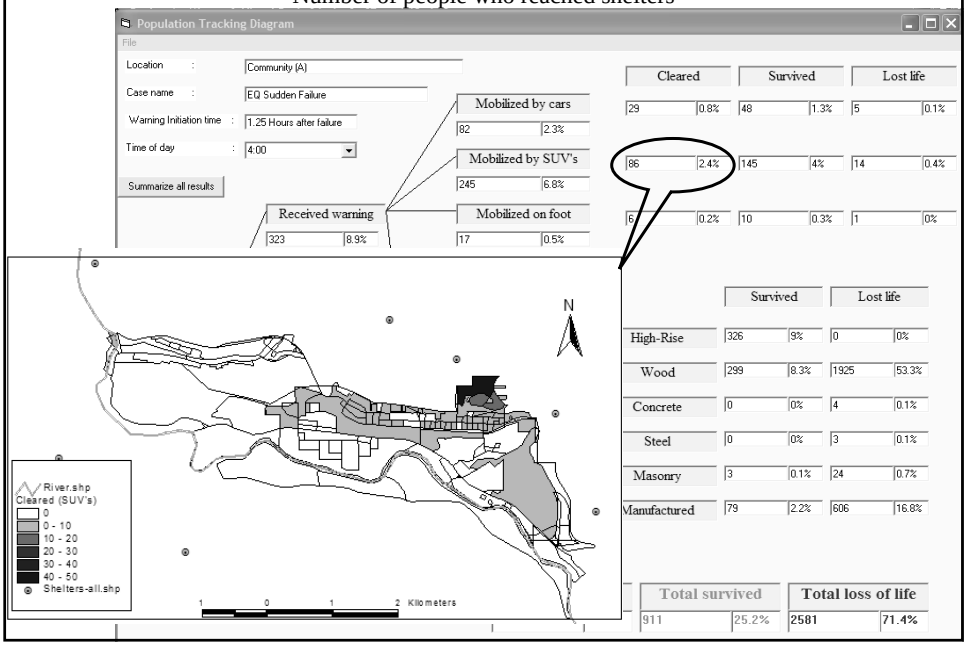
Community (A) – Remaining in Buildings

Fraction of census block population remaining in buildings at flood arrival



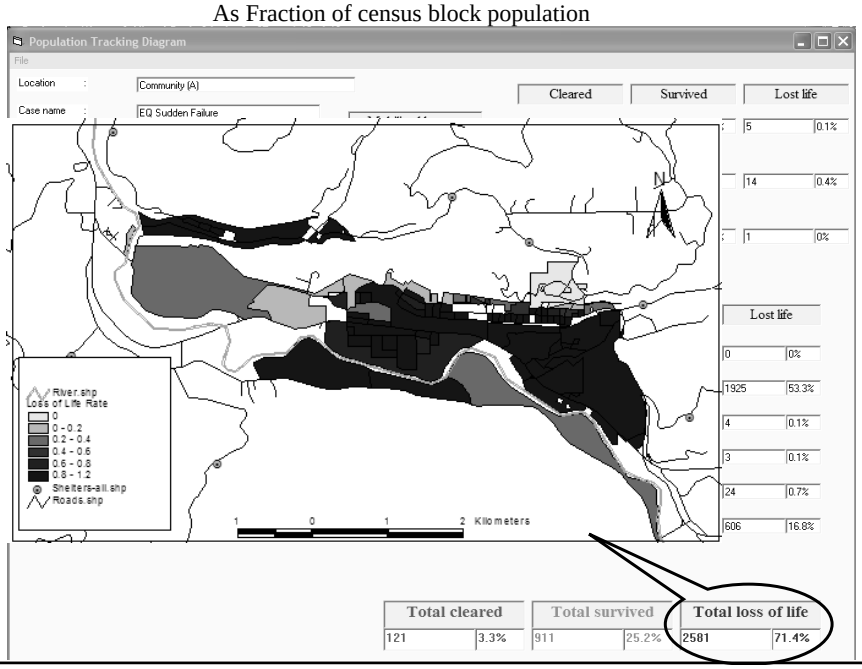
Community (A) – Clearing Flooding Area

Number of people who reached shelters



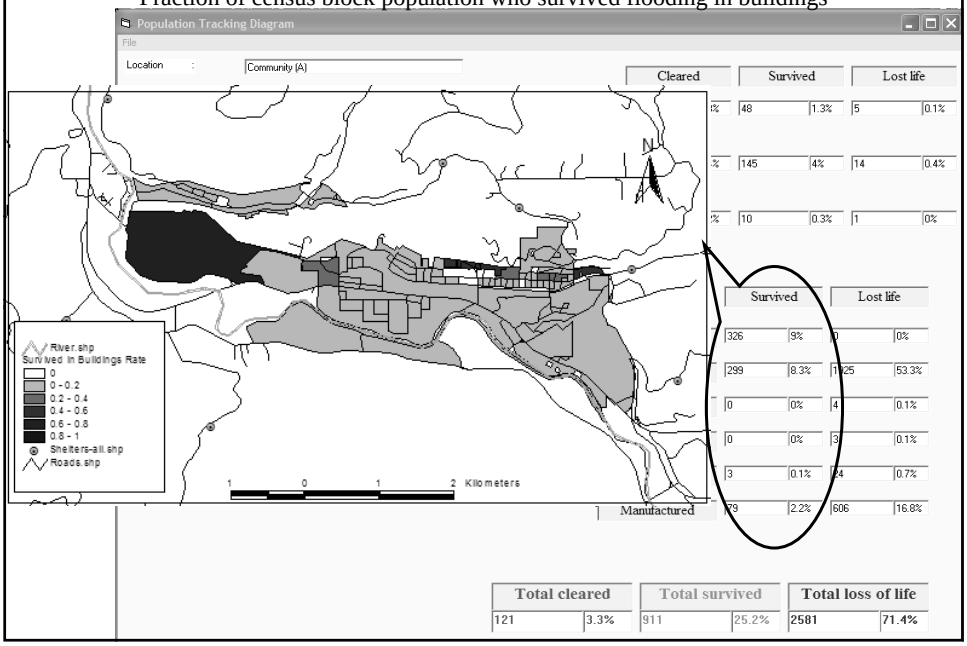
Community (A) – Fatality Rates

As Fraction of census block population



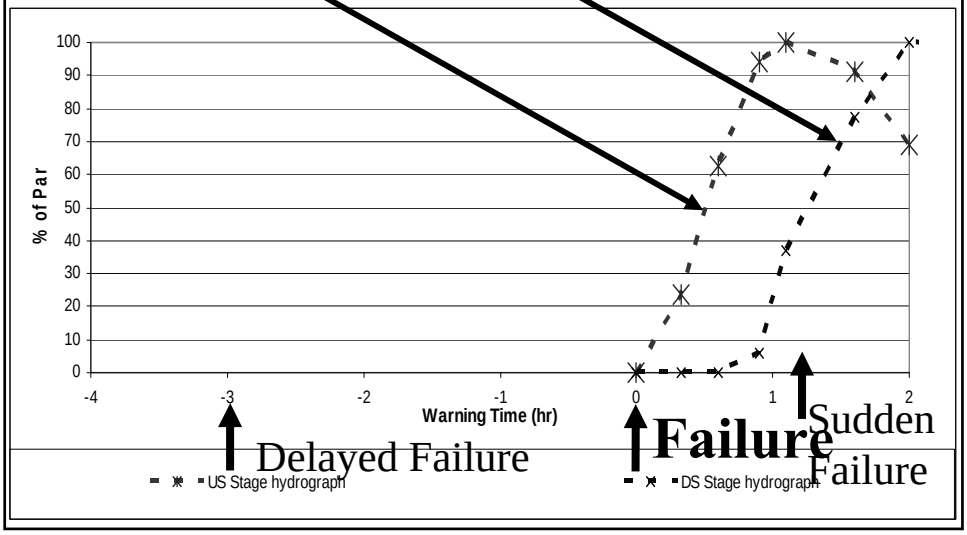
Community (A) – Survival in Buildings

Fraction of census block population who survived flooding in buildings



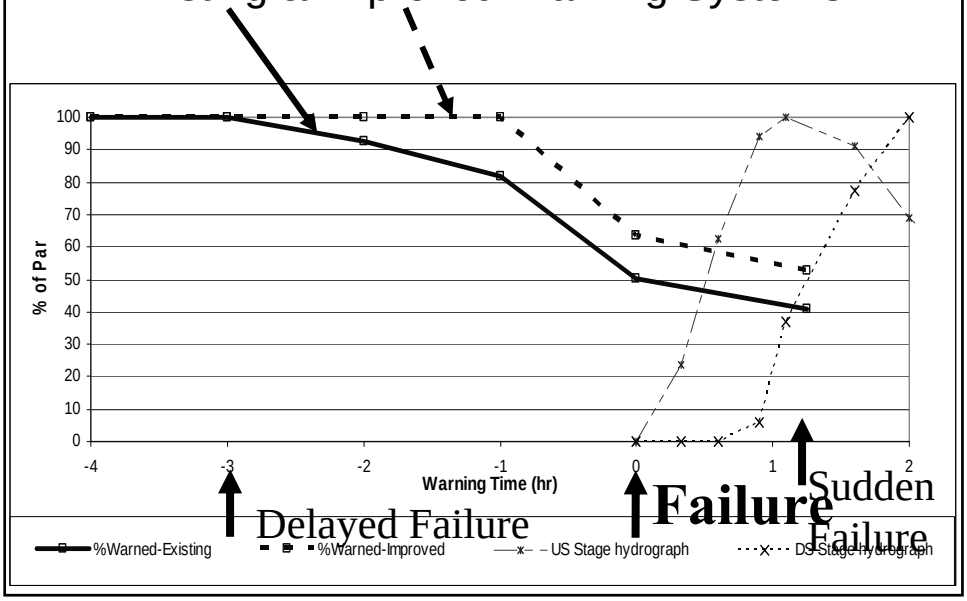
SENSITIVITY TO WARNING TIME

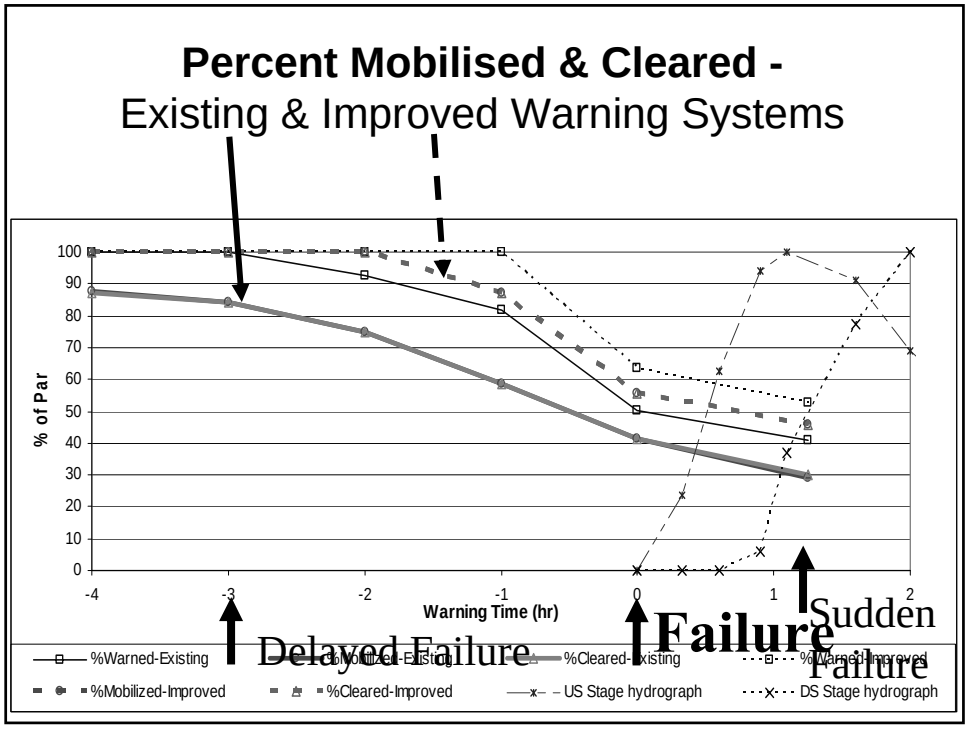
Upstream and Downstream Hydrographs

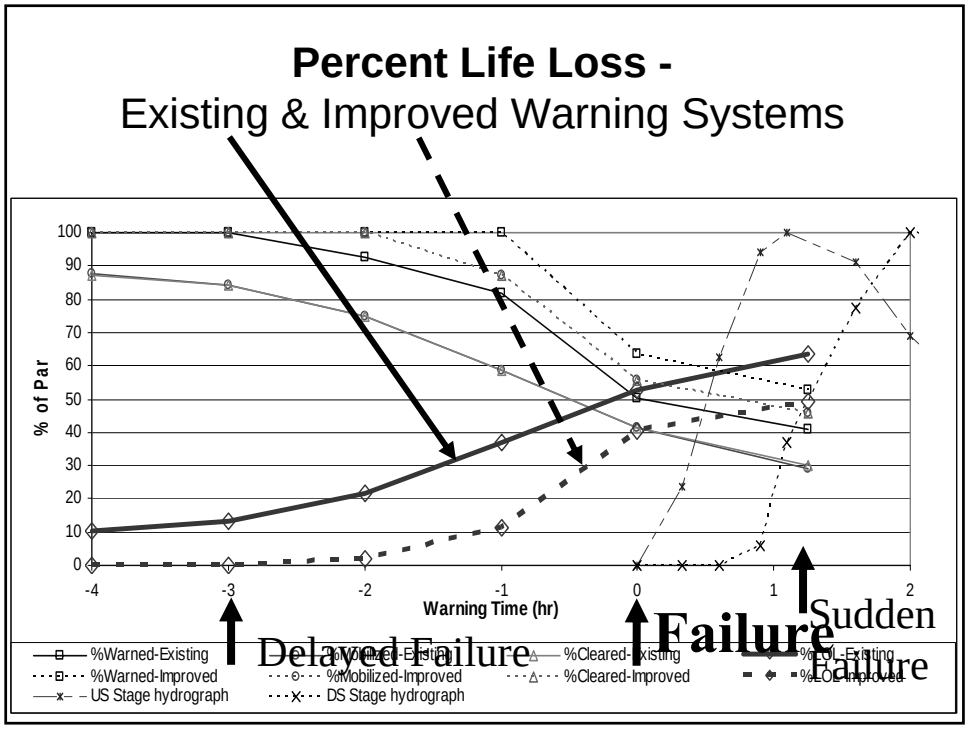


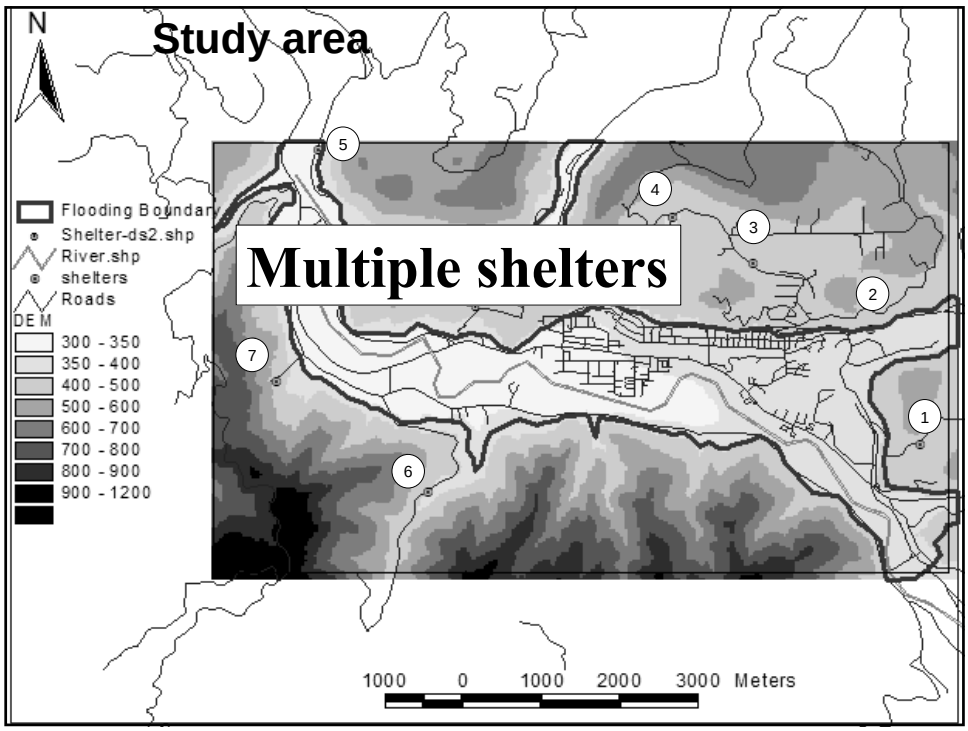
Percent Warned -

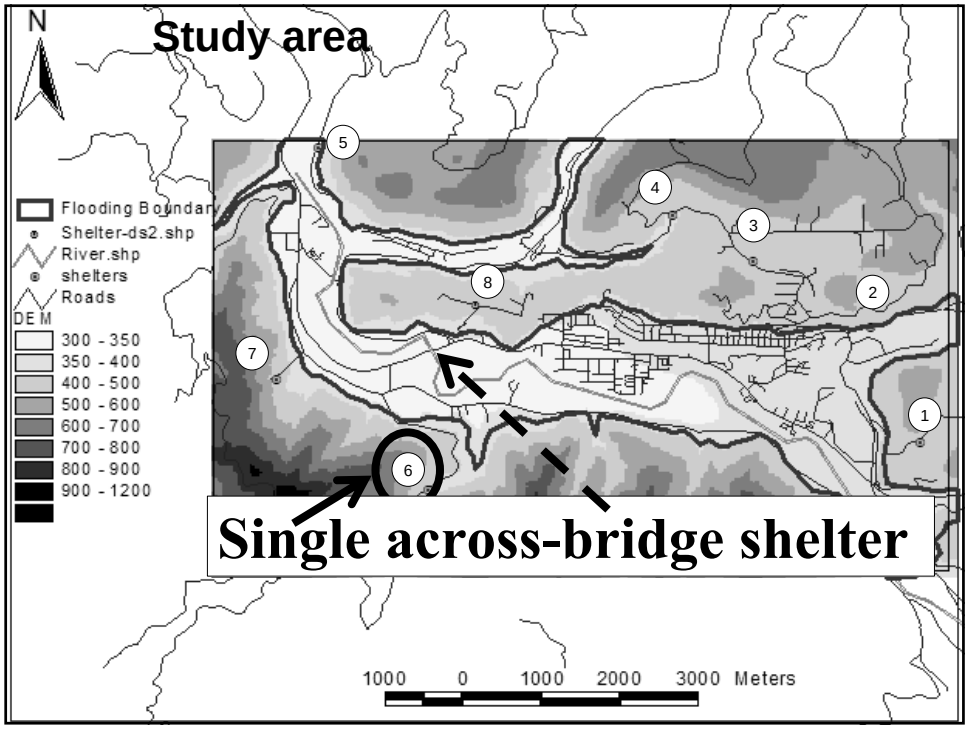
Existing & Improved Warning Systems



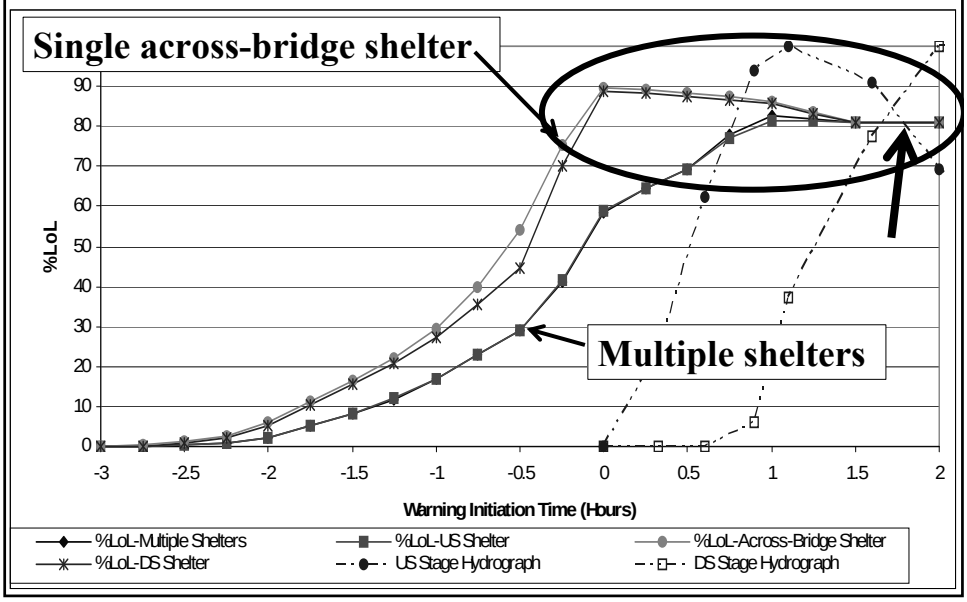

Percent Mobilised & Cleared -
Existing & Improved Warning Systems
% of Par
Warning Time (hr)
Delayed Failure
Failure
Sudden Failure
%Warned-Existing
%Mobilized-Existing
%Cleared-Existing
%Warned-Improved
%Mobilized-Improved
%Cleared-Improved
US Stage hydrograph
DS Stage hydrograph


Percent Life Loss -
Existing & Improved Warning Systems
% of Par
Warning Time (hr)
Delayed Failure
Failure
Sudden Failure
%Warned-Existing
%Mobilized-Existing
%Cleared-Existing
%LOL-Existing
%Warned-Improved
%Mobilized-Improved
%Cleared-Improved
%LOL-Improved
US Stage hydrograph
DS Stage hydrograph


N
Study area
Flooding Boundary
Shelter-ds2.shp
River.shp
shelters
Roads
DEM
300 - 350
350 - 400
400 - 500
500 - 600
600 - 700
700 - 800
800 - 900
900 - 1200
Multiple shelters
1
2
3
4
5
6
7
1000 0 1000 2000 3000 Meters

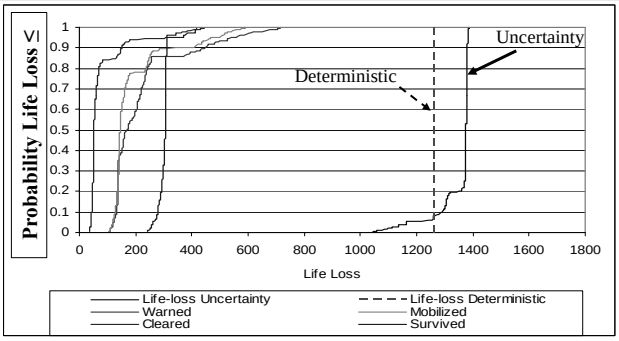

N
Study area
Flooding Boundary
Shelter-ds2.shp
River.shp
shelters
Roads
DEM
300 - 350
350 - 400
400 - 500
500 - 600
600 - 700
700 - 800
800 - 900
900 - 1200
Single across-bridge shelter
1
2
3
4
5
6
7
8
1000 0 1000 2000 3000 Meters

Sensitivity of life-loss rates to the four emergency shelter location cases

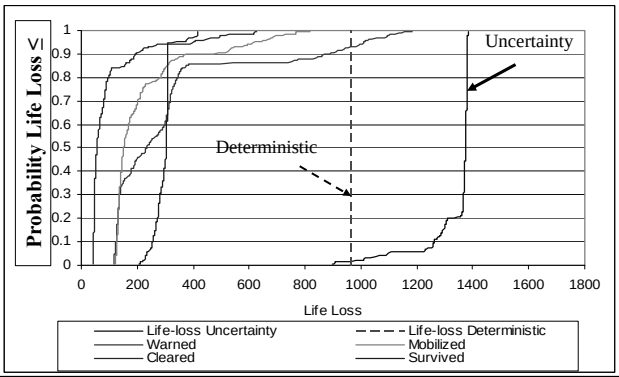


Uncertainty Mode – Sudden Failure

Inefficient warning (Sirens)

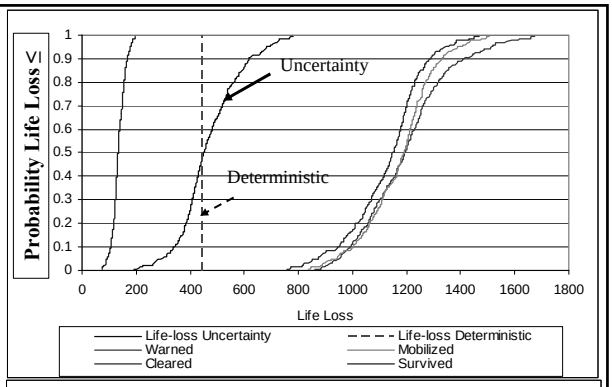


Efficient warning (Sirens and Tone-alert radios)

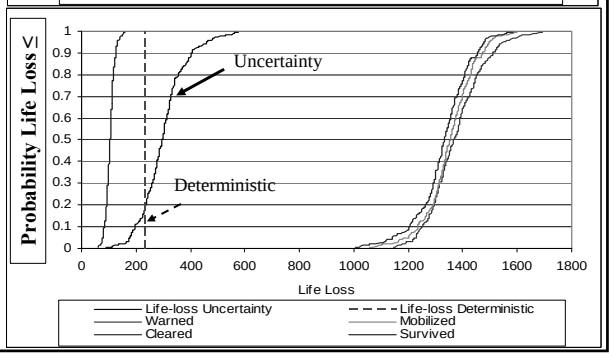


Uncertainty Mode – Delayed Failure

Inefficient warning (Sirens)

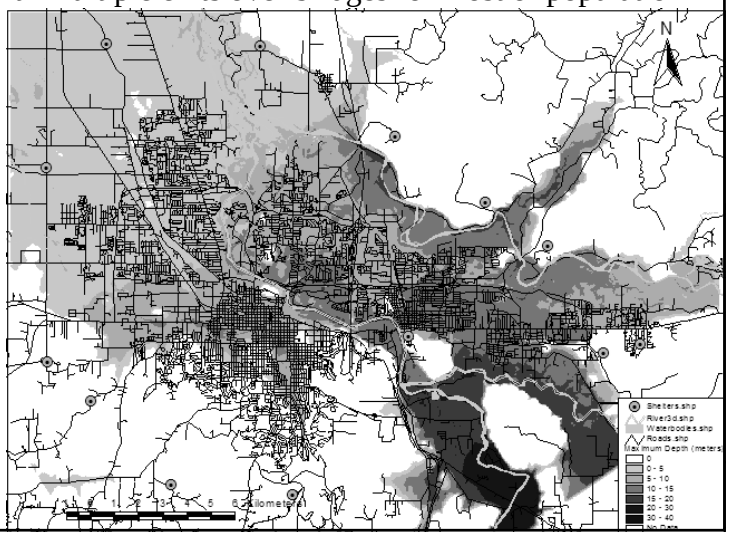


Efficient warning (Sirens and Tone-alert radios)

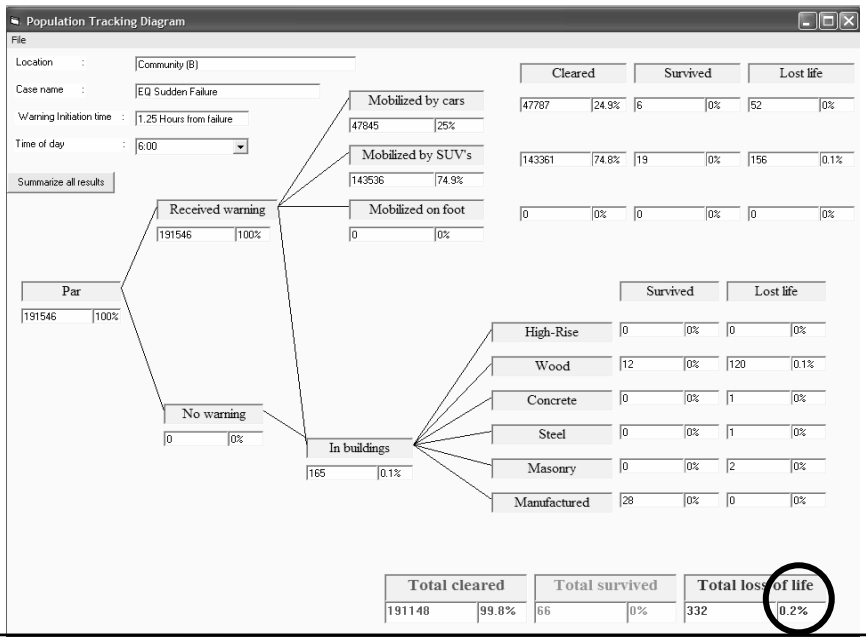


Community (B) – Maximum Inundation Depth

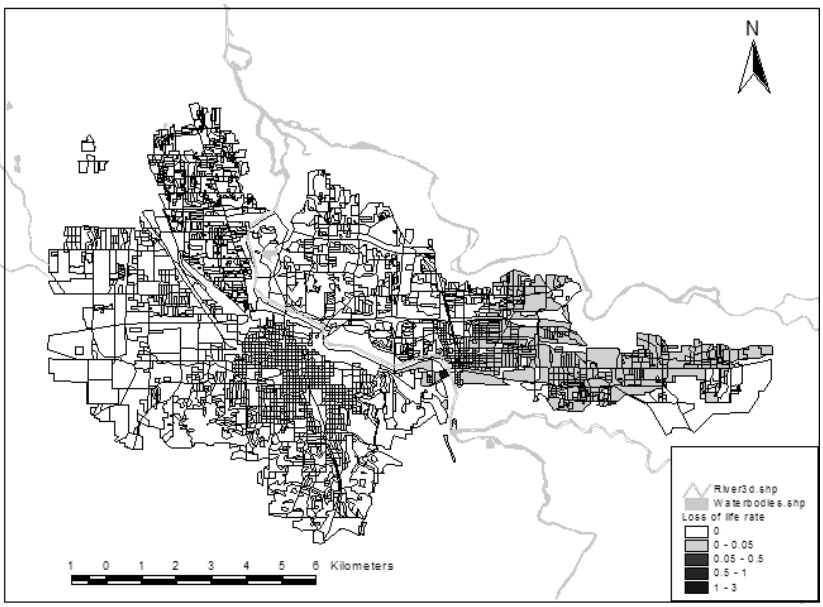
- Population about 190,000
- ~ 60 km downstream of same dam
- Wide valley with multiple exits over bridges for most of population
- Parallel rivers



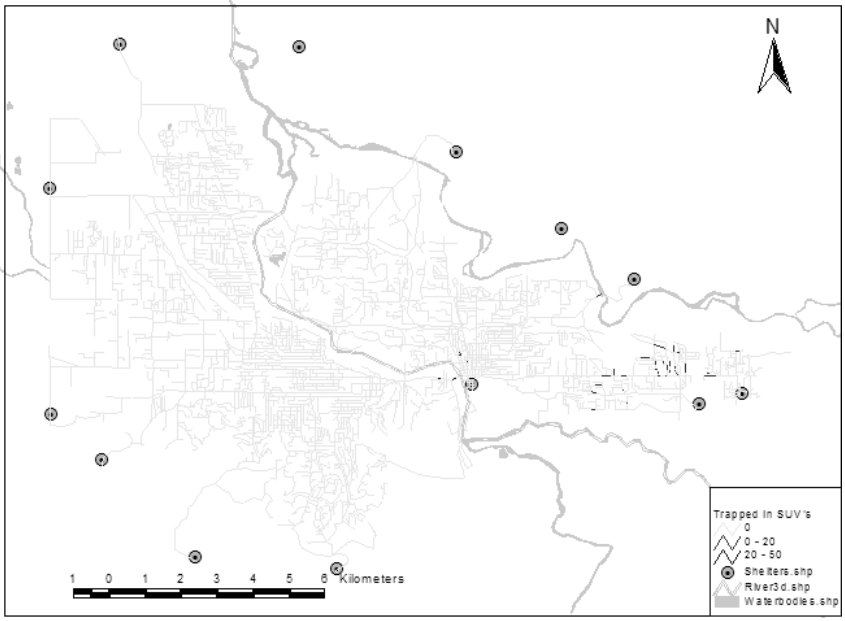
Community (B) – Population Tracking Diagram



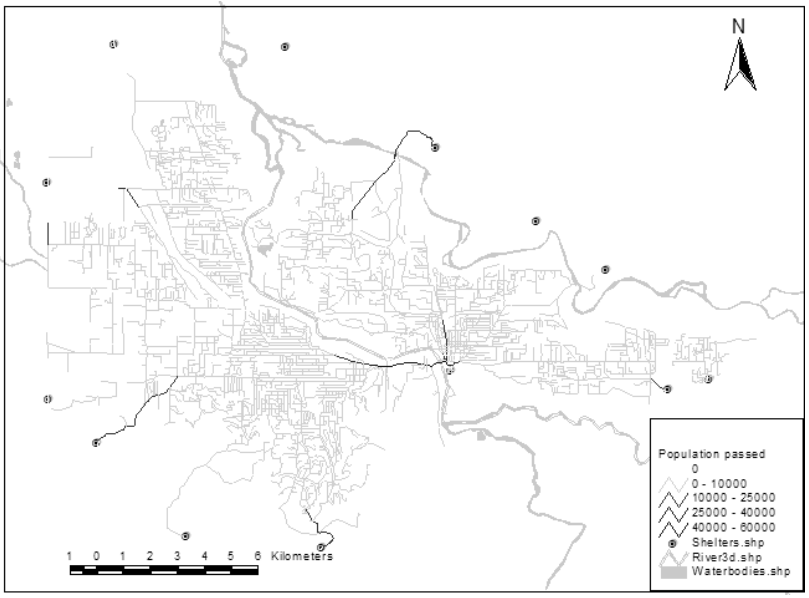
Community (B) – Loss-Life Rate



Community (B) – Trapped in SUV's

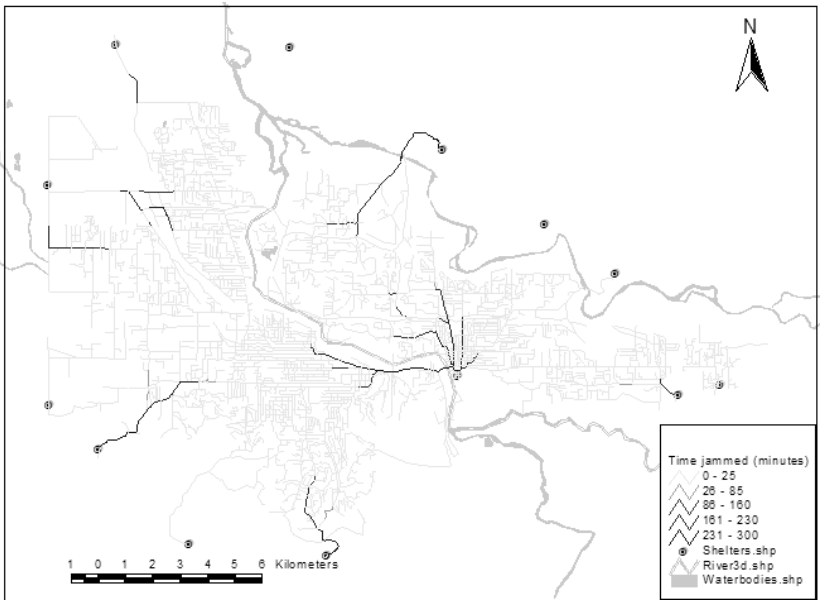


Community (B) – Road Utilisation



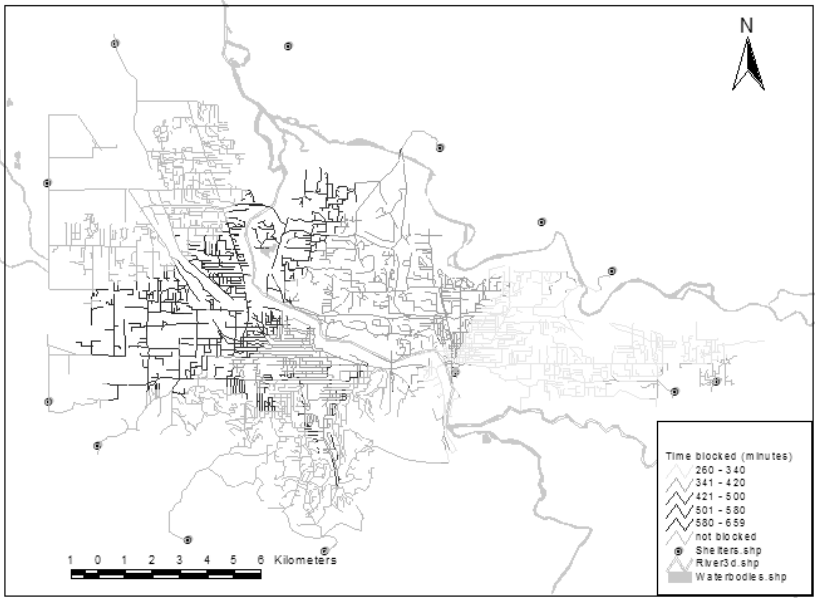
Community (B) – Traffic Jam Duration

Cumulative duration of until traffic jams by road segment in mins.



Community (B) – Time to Road Blockage

Time until road segment is blocked by flood wave arrival in mins.



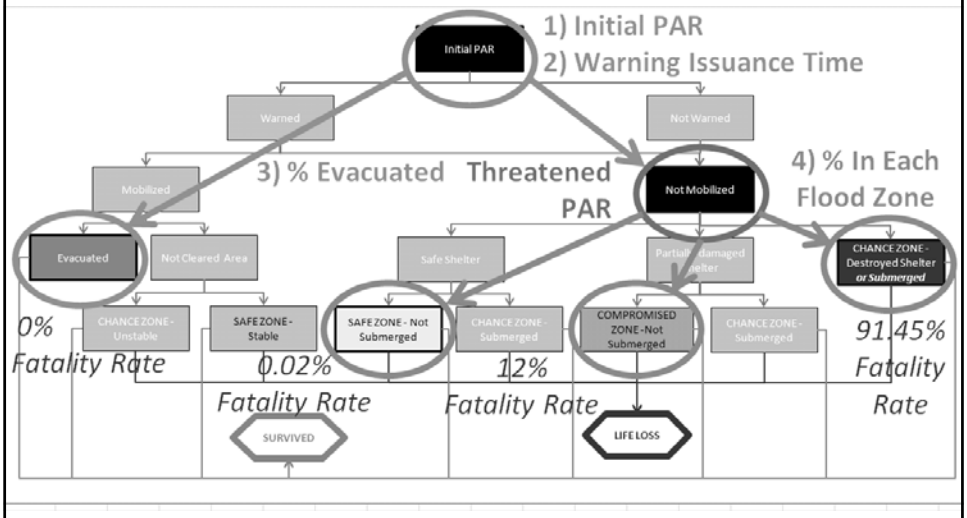
5) Conclusions

- Reasonable life-loss estimates are an essential input to Dam & Levee Safety Risk Assessment
- Use of homogeneous flood (lethality) zones in LIFESim leads to scale-independent approach to estimating fatality rates, which extracts more information from available case histories
- Life loss is intrinsically uncertain
  - Best Estimate Inputs do not in general lead to Best Estimate Outputs
    - Limitation in Deterministic approaches
  - Can incorporate probabilistic life-loss estimates in RA/PRA
- Overcomes limitations of empirical approaches
- Importance of involving the EMAs and First Responders
- For long warning times the main parameter is mobilisation non-response rate

6) LIFESim Status

- Prototype version developed in Phase 1-3
  - Proof of concept
  - Demonstrated for 2 USACE dams
  - Software not user friendly
- User-friendly version to be developed by USACE HEC
- Applied to:
  - New Orleans levee failures (IPET Study)
  - USACE Wolf Creek Dam
  - 2 FERC-regulated dams
- Simplified LIFESim:
  - DHS RAMCAP
    - For reasonable worst case malevolent act
    - Demonstrated for a hydro dam
  - Being improved by USACE HEC:
    - Screening, Periodic Assessment and Issue Evaluation types of RA

Simplified LIFESim



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