MODELLING WARNING HUMAN BEHAVIOR

For Use with Engineering Life Loss Estimation Models in Dam and Levee Emergencies

Dennis S. Mileti, Ph.D. Professor Emeritus
University of Colorado Boulder

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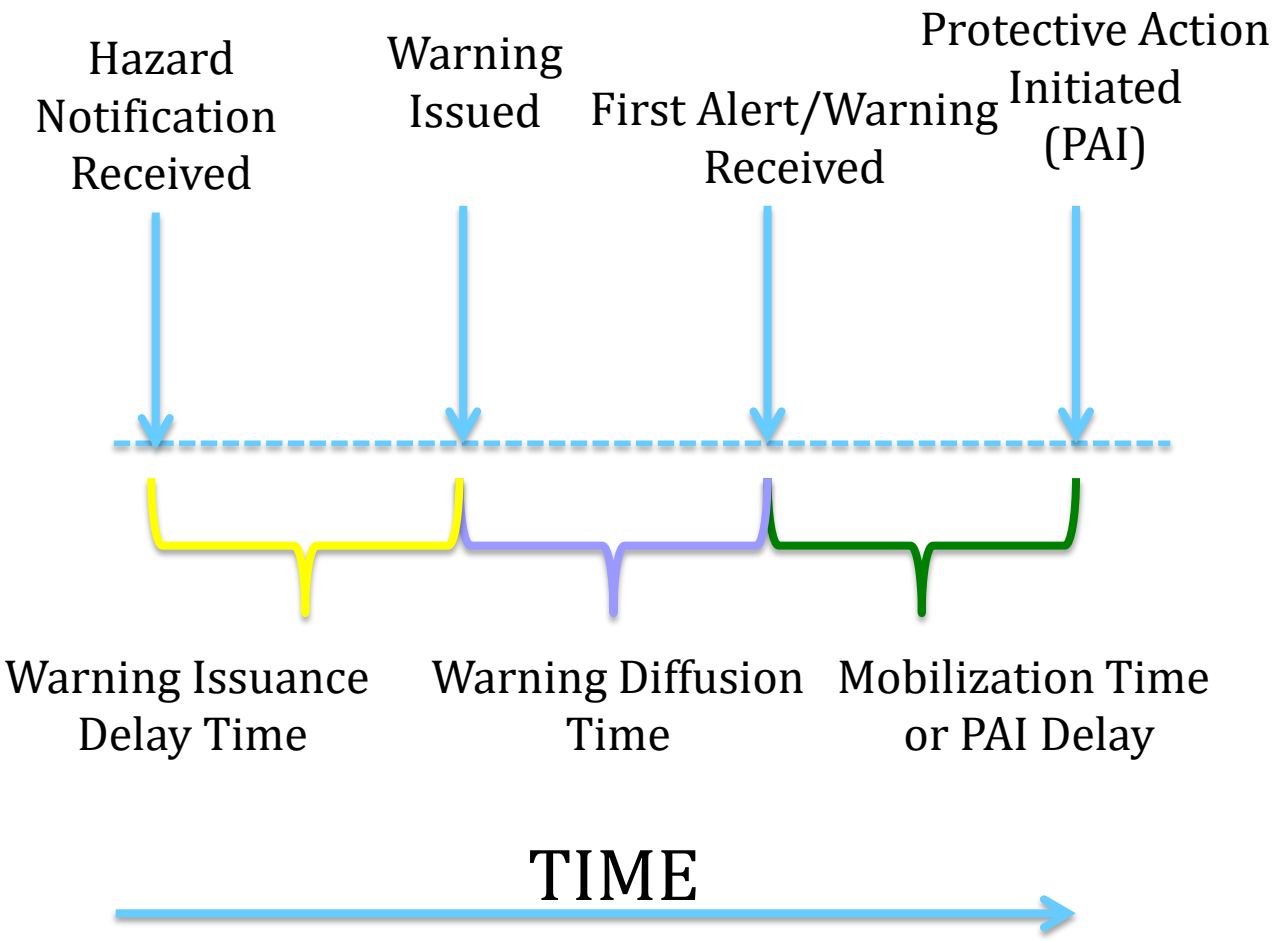
WARNING BEHAVIOR

- **Public alerts and warnings involve the behavior of people who**
  - Detect threat
    - Scientists & engineers
  - Manage/communicate threat to the public
    - Emergency managers
  - Take protective actions
    - Members of diverse publics
- **Social scientists study all of them**

TIME SEQUENCE CHART



OBJECTIVES

- **Integrate social science & engineering for USACE to**
  - Estimate of human behavior for life loss estimation
- **To develop methods & procedures**
  - To measure/classify local community behavior time estimates for warning issuance, diffusion & PAI for
    - Dam breaches & controlled releases
    - Levee breaches or overtopping
- **Prepare a local community guidebook**

APPROACH

- **Synthesis of hazards research literature**
  - Behavior & timing of actions - officials and public
  - Factors that influence warning behavior the same across hazards
- **Prepare influence factors catalogues**
  - For issuance, diffusion & PAI
  - Include factor's relative influence weights
- **Interview questions for community measurement**
  - Pre-tested, revised, pre-tested again
- **Measure synthesis for classifying communities**
  - Likely future issuance, diffusion & PAI delay
- **External review & revision as needed**

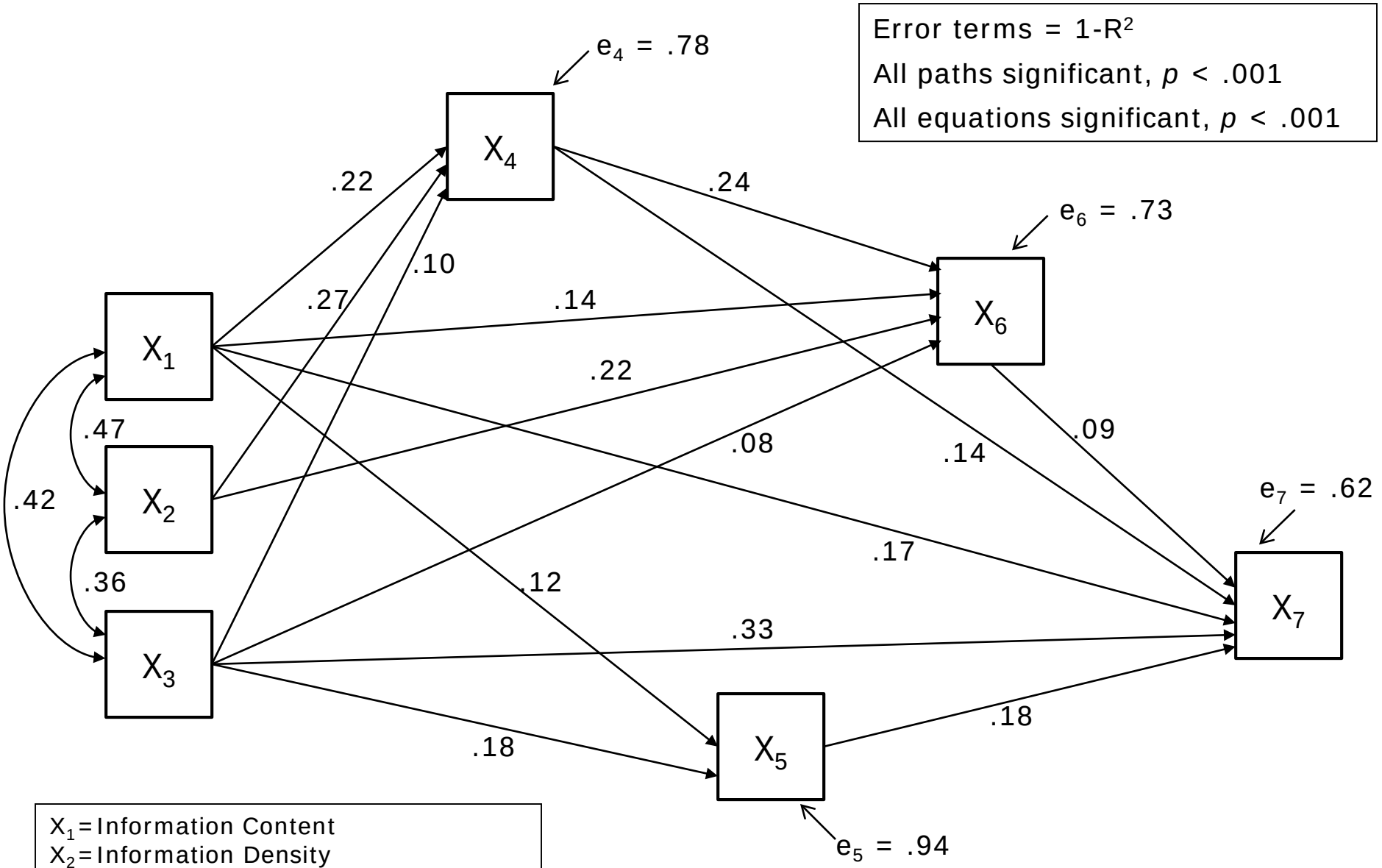
ALL HAZARDS OBSERVATION

- **Hazard types differ regarding**
  - Physical properties
  - Alert & warning lead times
  - Appropriate public protective action(s)
- **Human warning behavior predictors**
  - Are the *same* across hazard types
  - Because people stay people
  - Apply to dam & levee warning events

CURVE DEVELOPMENT FOR ISSUANCE, DIFFISUION & PAI

- **Reviewed quantitative research findings on warning timing/delay for all 3 stages**
- **Identified data from empirical studies**
  - Point observations
  - Distributions
- **Developed model equations**
- **Fitted equations to historical events**
- **Developed parameters for planning curves**

WHAT QUANTITATIVE SOCIAL SCIENCE DATA LOOKS LIKE


Error terms = 1-R²
All paths significant, p < .001
All equations significant, p < .001
e4 = .78
X4
.22
.24
e6 = .73
.10
.27
.14
X6
X1
.22
.47
.08
.09
.14
e7 = .62
.42
X2
.17
.12
X7
.36
.33
X3
.18
.18
X5
e5 = .94
X1=Information Content
X2=Information Density
X3=Information Observed (cues)
X4=Knowledge
X5=Perceived Effectiveness
X6=Information Seeking (milling)
X7=Preparedness Actions
Satora-Bentler χ² = 8.58, df = 4, p = .07
RMSEA = 0.020, 90% CI (.000 - .039)
CFI = 0.998

MODEL ESTIMATES

Endogenous Variable*	Beta	Estimate	SE	R^2
X_4 Knowledge	β_{41}	.22	.02	.22
	β_{42}	.27	.01	
	β_{43}	.10	.02	
X_5 Perceived Effectiveness	β_{51}	.12	.02	.06
	β_{53}	.18	.02	
X_6 Milling	β_{61}	.14	.04	.27
	β_{62}	.22	.03	
	β_{63}	.08	.04	
	β_{64}	.24	.06	
X_7 Preparedness Actions Taken	β_{71}	.17	.02	.38
	β_{73}	.33	.02	
	β_{74}	.14	.03	
	β_{75}	.18	.02	
	β_{76}	.09	.01	

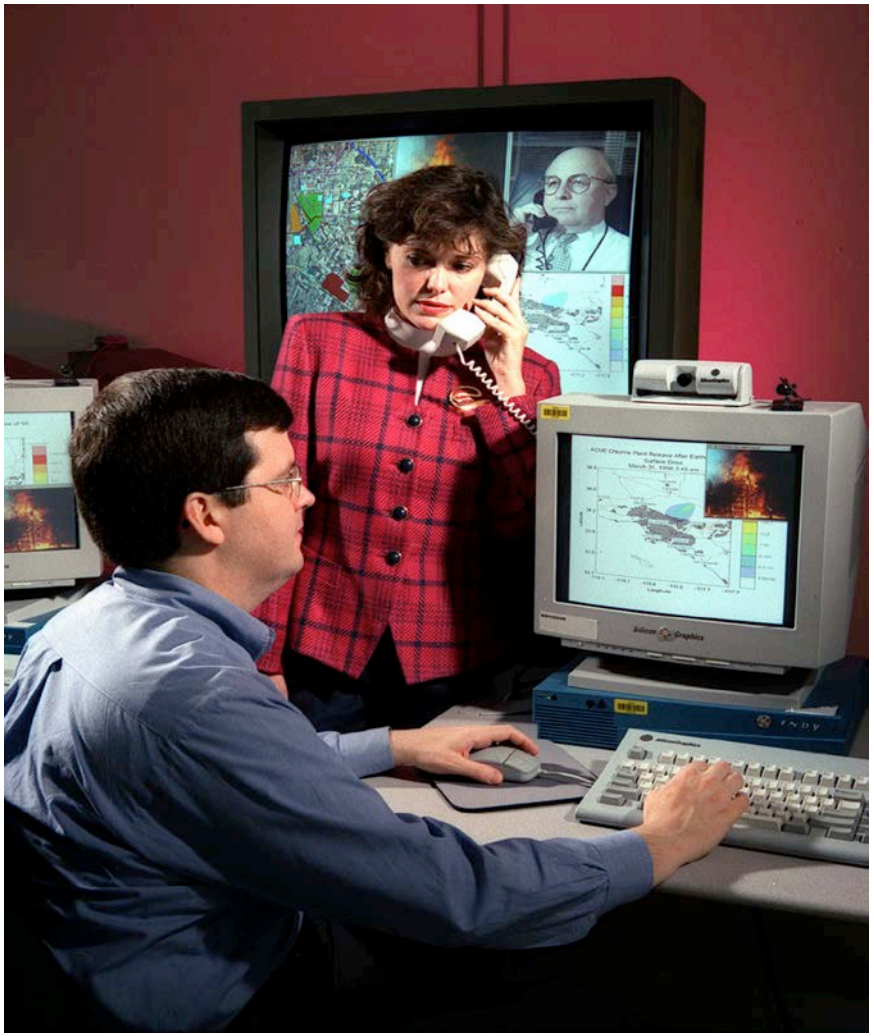
Robust Maximum Likelihood Estimation

Satorra-Bentler χ^2 = 8.58, df = 4, *p* = .07; CFI = .998; RMSEA = .020, 90% CI (.000 - .039)

All paths and equations significant at p < .001; N = 2,811

X_1 = content of information received, X_2=density of information received, and X_3=information observed

WARNING ISSUANCE DELAY



PROCESS & DEFINITIONS

- **Warning issuance is both**
  - Formal: from the official system
  - Informal: from friends & relatives
- **Formal warnings across communities**
  - Warning point is diverse
  - Decision process to issue warning varies
  - Definition of issuance “time” differs

RESEARCH BASED FACTORS THAT REDUCE WARNING ISSUANCE DELAY

PLANS & PROCEDURES

	RANK	WEIGHT
Written Warning Plan	HIGH	.20 - .25
Written Standard Operating Procedures (SOPs)	HIGH	.25 - .30
Warning Thresholds In Place	HIGH	.15 - .20
Succession Planning Detailed in SOPs	LOW	.01 - .05
Warning Responsibilities Identified	MEDIUM	.10 - .15
Clearly Defined Authority To Issue Warnings	MEDIUM	.10 - .15
Interagency Communication Rules/Procedures	HIGH	.11 - .17
Two-Way Communication Among Organizations	LOW	.01 - .05
Threat Verification Procedures Defined	LOW	.01 - .03

PERFORMANCE & INTER-PERSONAL RELATIONS

	RANK	WEIGHT
SOP Practice Is Conducted (Drills or Exercises)	MEDIUM	.13 - .16
Knowledge Of Communicating Personnel	LOW	.01 - .03
Frequency Of Interaction	LOW	.01 - .03
Ability To Improvise	LOW	.02 - .04

SYSTEM PERFORMANCE FACTORS

Failsafe Communication Mechanisms In Place	LOW	.06 - .07
Redundancies In Communications In Place	LOW	.06 - .07

SITUATIONAL FACTORS

	RANK	WEIGHT
Day Or Night	MEDIUM	.10 - .13
Power Availability (Electricity)	LOW	.01 - .03
Damage To Infrastructure	LOW	.01 - .03
Environmental Cues	LOW	.01 - .03
Time To Impact	MEDIUM	.05 - .09
Number Of People Involved	MEDIUM	.12 - .16
Experience of Community	LOW	.02 - .04

LINKS TO INTERVIEW SCHEDULE
15 ISSUANCE QUESTIONS
(Example: Responsibilities Identified)

Q 8. Is a particular person or position responsible for getting a first alert or warning out to the public? YES/NO

(IF YES) What is their name and title? _____

Do they have legal authority to do so? YES/NO

(IF NO) What is the name and title of who does? _____

Is the responsible person or position written down? YES/NO

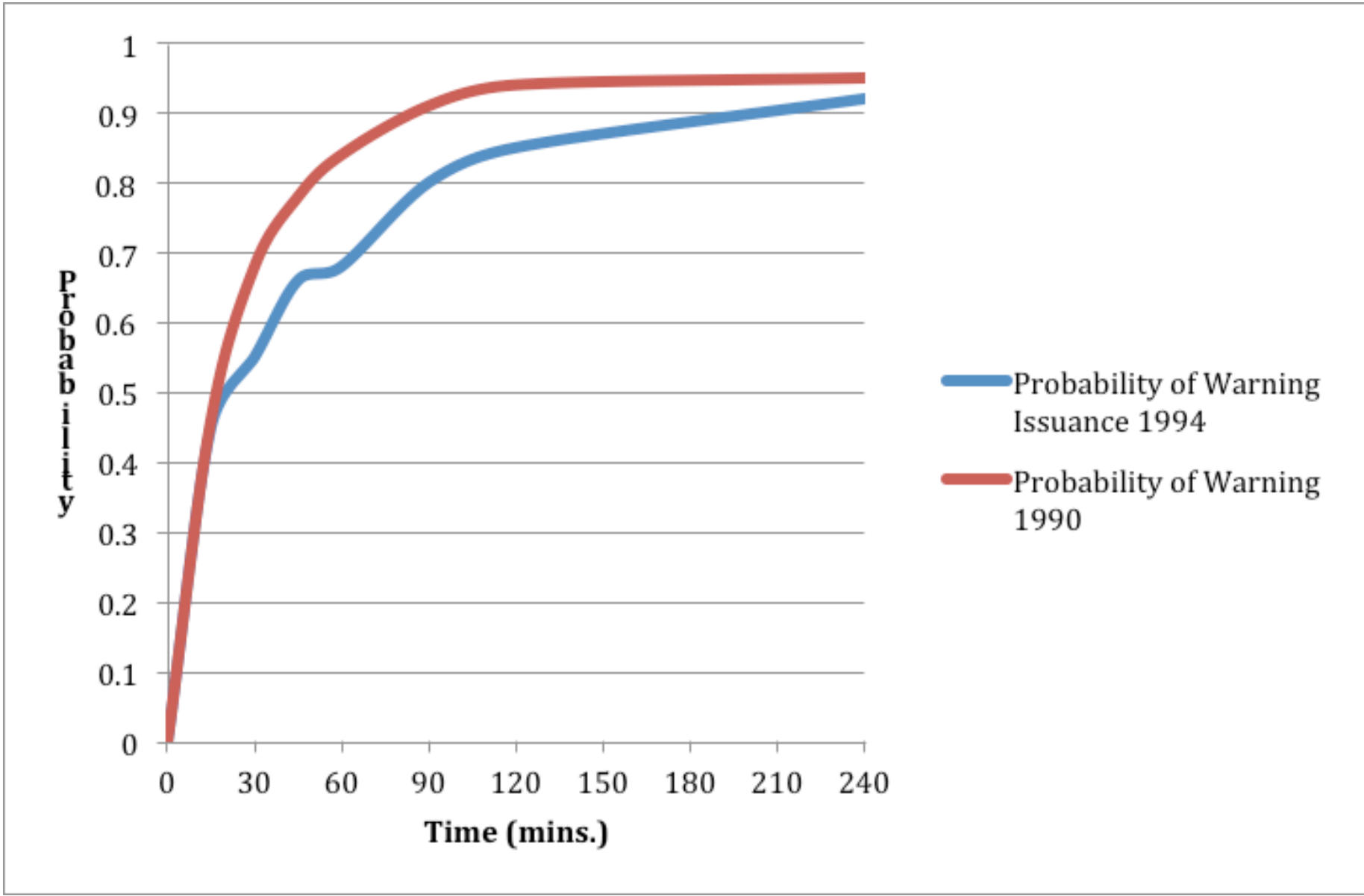
(IF YES) Where? _____

COMMUNITY CLASSIFICATION

(warning issuance delay)

	QUESTION / RULE
Formalization Of Planning And Implementation Procedures	
Standard Warning Plan Is Written Down	4, 6 (if either is yes)
Standard Operating Procedures (SOP) Are Written Down	5, 7 (if either is yes)
Warning Thresholds Are In Place (Matrix)	11 (if yes)
Succession Planning Is Detailed Within SOPS	9 (if yes)
Responsibilities Are Identified	8 (if yes)
Clearly Defined Authority To Issue Warnings	8-2nd sub (if yes)
Interagency Communication Follows Rules And Procedures	14 -3rd sub (if written down)
There Is Two-Way Communication Among Organizations	15 (if yes)
Threat Verification Procedures Are Defined	13-sub (if written down)
Performance And Interpersonal Relations	
SOP Practice Is Conducted (Drills or Exercises)	21 (if yes)
Personal Knowledge Of Communicating Personnel	17 (if yes)
Frequency Of Interaction	17 (if 4 times/year+)
Ability To Improvise	18 (if yes)
System Performance Factors	
Redundancies In Communications Are In Place	16 (if yes)
Situational Factors	
Day Or Night	10 (if yes)
Power Availability (Electricity)	16-2nd sub (if yes)
Damage To Infrastructure	16-3rd sub (if yes)
Time To Impact	19 (if yes)
Number Of People Involved	20 (if 3 or less)
Experience of Community	48 (if yes)

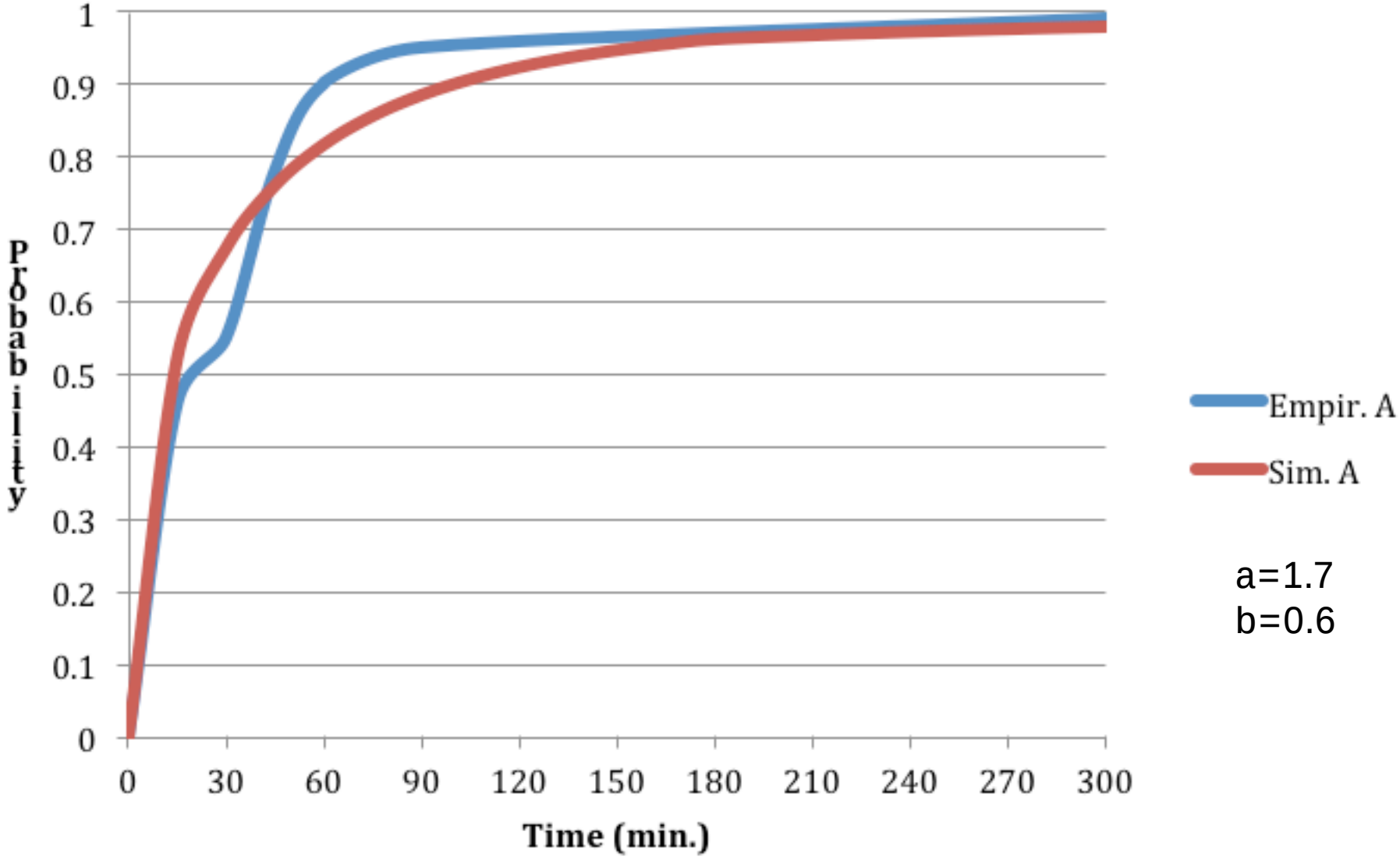
HISTORICAL ISSUANCE TIMES



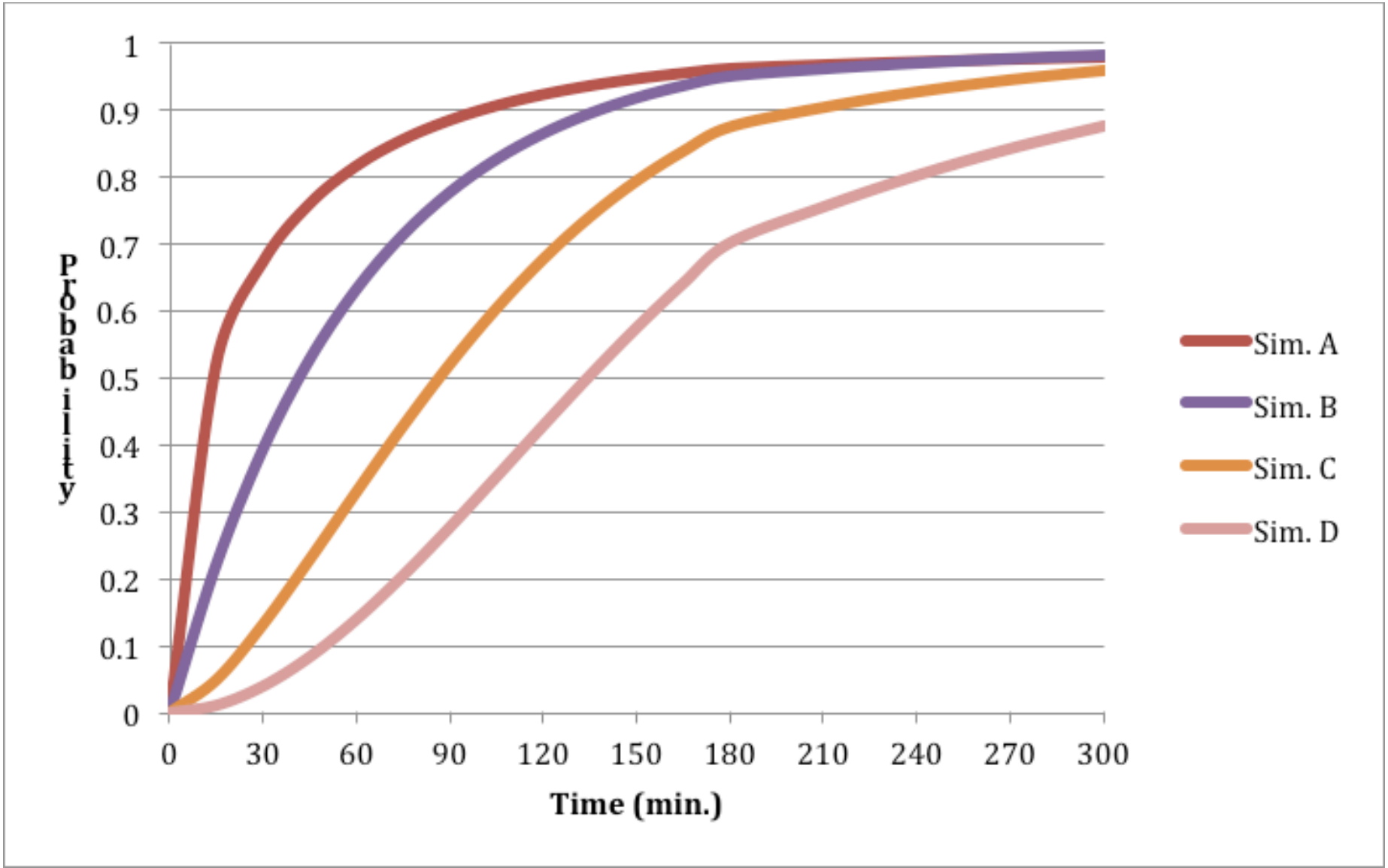
MODELING WARNING ISSUANCE

- $P_t = 1 — \exp(-at^b)$
- t = time
- a and b are constants
- fit simulated curves to empirically derived curves

COMPARISON


1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Probability
0
30
60
90
120
150
180
210
240
270
300
Time (min.)
Empir. A
Sim. A
a=1.7
b=0.6

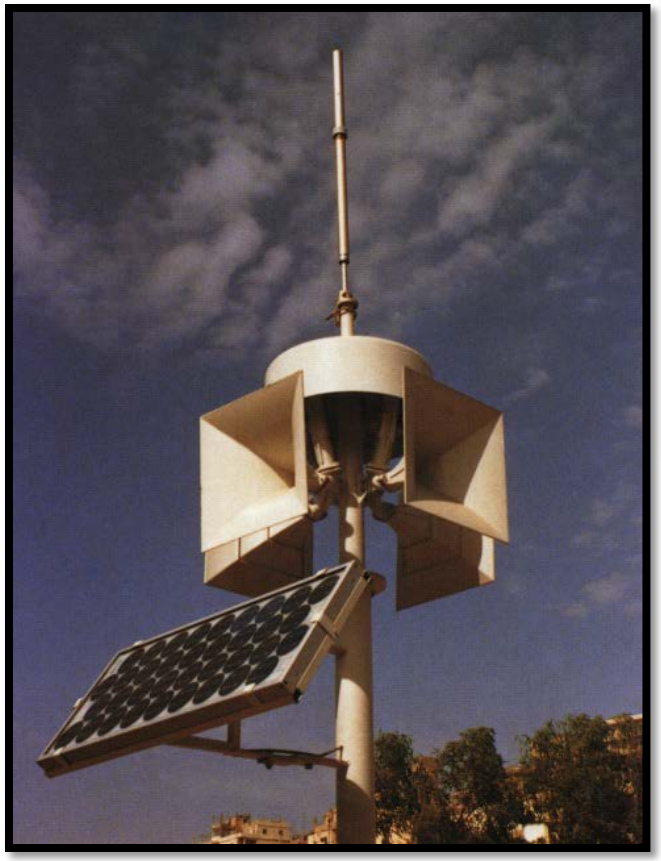
ISSUANCE PLANNING CURVES



MORE DETAILS IN

Sorensen, J., and D. Mileti (2014a). ***First Alert and/or Warning Issuance Time Estimation for Dam Breaches, Controlled Dam Releases, and Levee Breaches of Overtopping*****. Davis, CA: U.S. Army Corps of Engineers, Institute for Water Resources, Risk Management Center.**

WARNING DIFFUSION DELAY



PROCESS & DEFINITIONS

- **Direct warning (broadcast)**
- **Informal warning (contagion)**
- **Alert vs. notification**
- **First vs. multiple warnings**
- **Targeted vs. non-targeted warnings**

RESEARCH BASED FACTORS THAT INFLUENCE DIFFUSION TIME

SENDING THE 1st ALERT/WARNING

	RANK	WEIGHT
Channels: Types Of Technologies	HIGH	.17 - .20
Channels: Disruption To Infrastructure	LOW	.00 - .05
Channels: Number & Mix Of Channels	HIGH	.25 - .30
Frequency Of Distribution	HIGH	.21 - .26
Informal Notification	MOD.	.10 - .13
Environmental and Social Cues	LOW	.01 - .05

RECEIVING THE 1st ALERT/WARNING

	RANK	WEIGHT
Activity –Task	**MODERATE**	**.10 - .16**
Activity - Location And Proximity To The Hazard	**MODERATE**	**.12 - .18**
Activity - Time Of Day	**HIGH**	**.05 - .25***
Impediments - Sensory (Hearing, Visual)	**MODERATE**	**.08 - .13**
Impediments – Cognitive	**LOW**	**.01 - .02**
Impediments - Linguistic And Cultural	**LOW**	**.03 - .06**
Resources - Access To Technology	**MODERATE**	**.05 - .12**
Social Media Participation	**LOW**	**.01 - .02**
Socio-Economic Status	**MODERATE**	**.07 - .12**

*NOTE: Weights should not to be used in assigning curves since separate curves exist.

LINKS TO INTERVIEW SCHEDULE 14 DIFFUSION QUESTIONS

(Example: Message Consistency)

Q 28. Do you have ways to monitor what others might be telling the public to find rumors and incorrect information? YES/NO

(IF YES) How would that be done? _____

If rumors or incorrect information were detected, would you issue subsequent messages to correct for misinformation? YES/NO

(IF YES) How would it be done? _____

COMMUNITY CLASSIFICATION

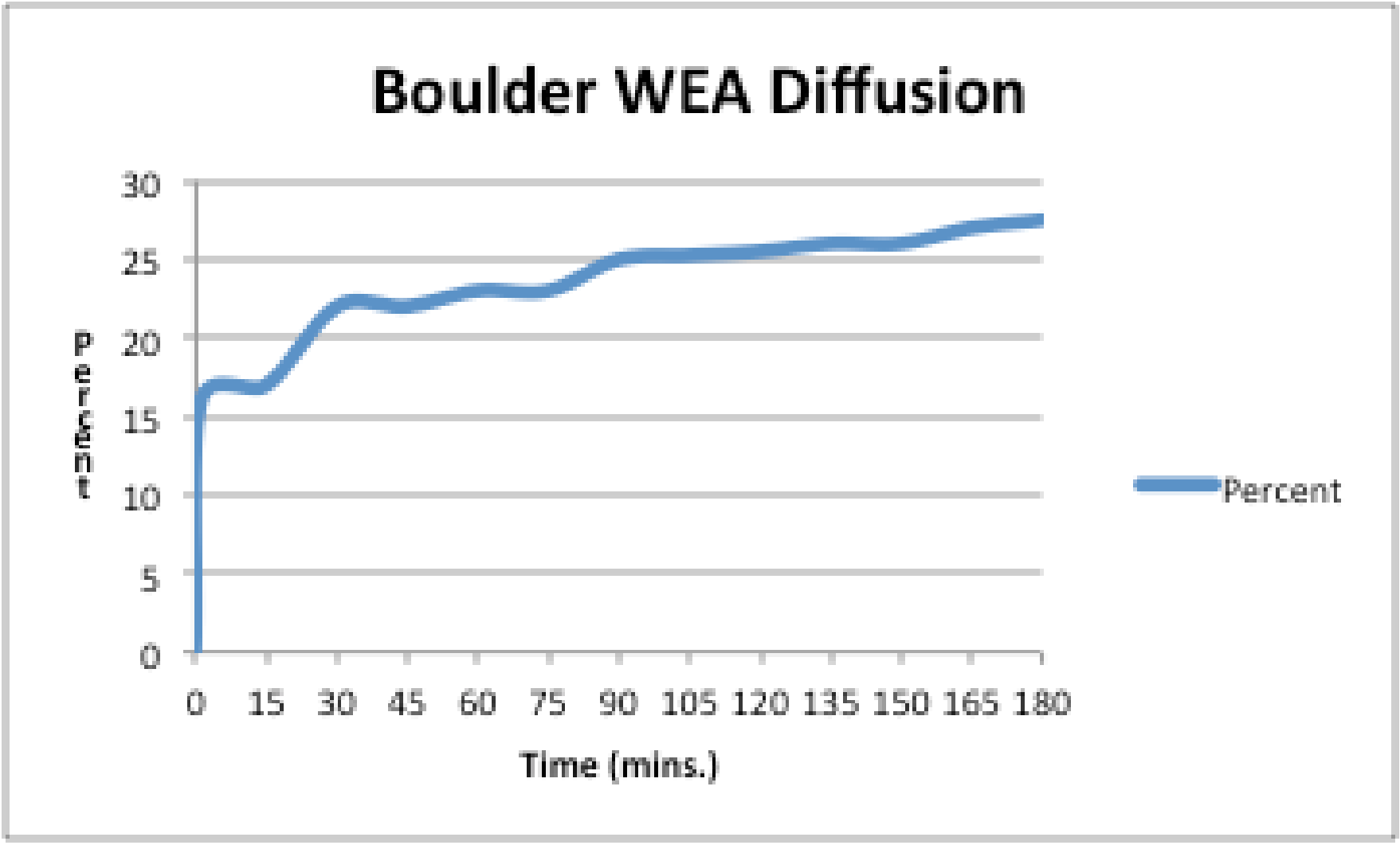
(Warning Diffusion Delay)

	QUESTION/RULE
Sending The First Alert/Warning	
Channels - Types Of Technologies	2 (if 2 or more of a certain type)
Channels - Disruption To Infrastructure	35 (if yes)
Channels - Number And Mix Of Channels	22 (if 5 or more)
Frequency Of Distribution	25 (if yes)
Informal Notification	27 (if yes)
Receiving The First Alert/Warning	
Activity –Task	29 (if yes - any special warning)
Activity – Location & Proximity To The Hazard	30 (if yes)
Activity - Time Of Day	31 (if yes)*
Impediments - Sensory (Hearing, Visual)	32, 33 (if yes to either)
Age	52 (if yes)
Impediments - Linguistic And Cultural	34 (if yes)
Resources - Access To Technology	24 (if any of special type)
Social Media Participation	24 (if 50% or more)
Socio-Economic Status	53,54,55,57 (if none are yes)

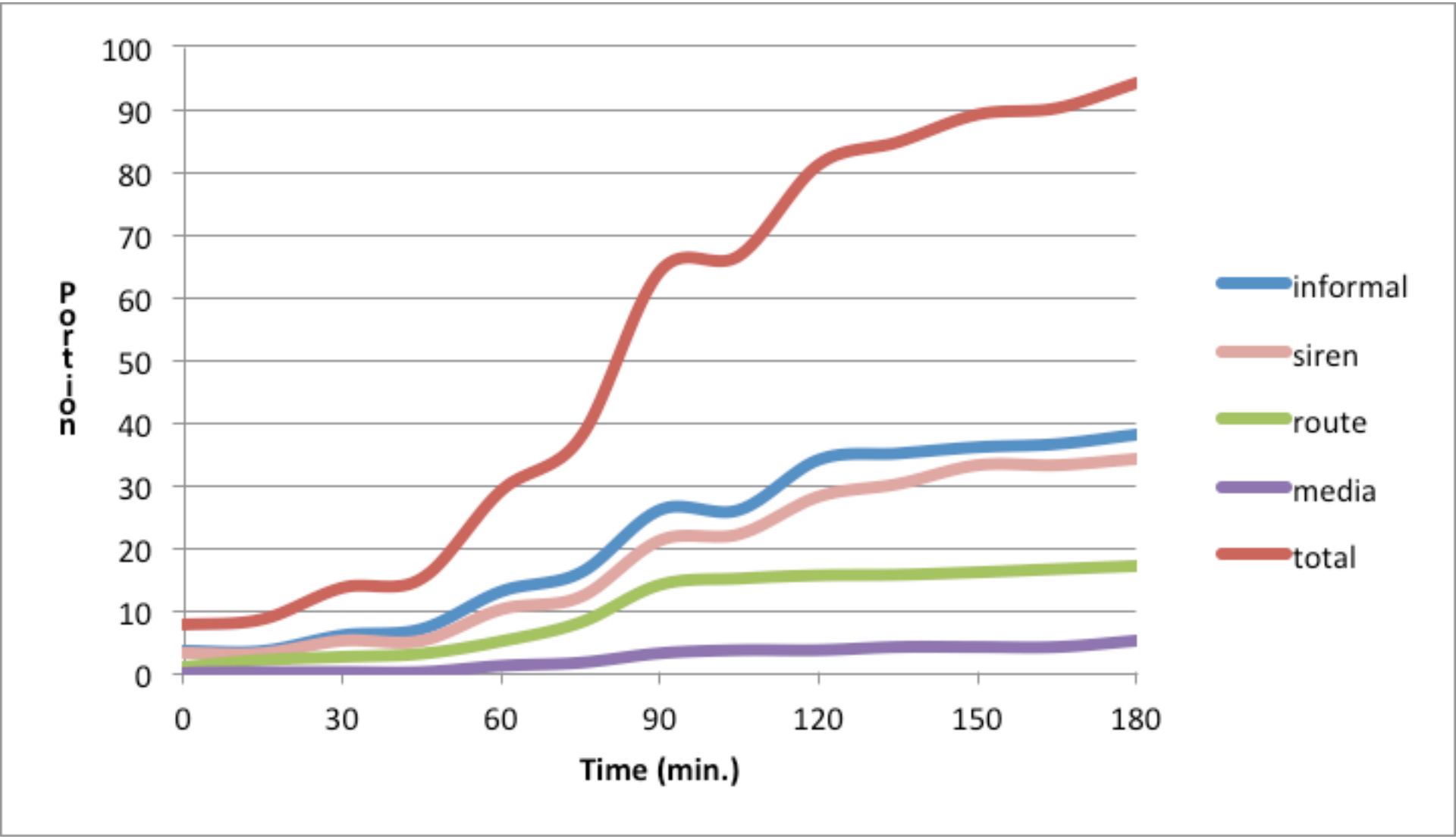
*NOTE: Weights should not to be used in assigning curves since separate curves exist.

WHAT DOES RAPID VS. SLOW DIFFUSION LOOK LIKE?

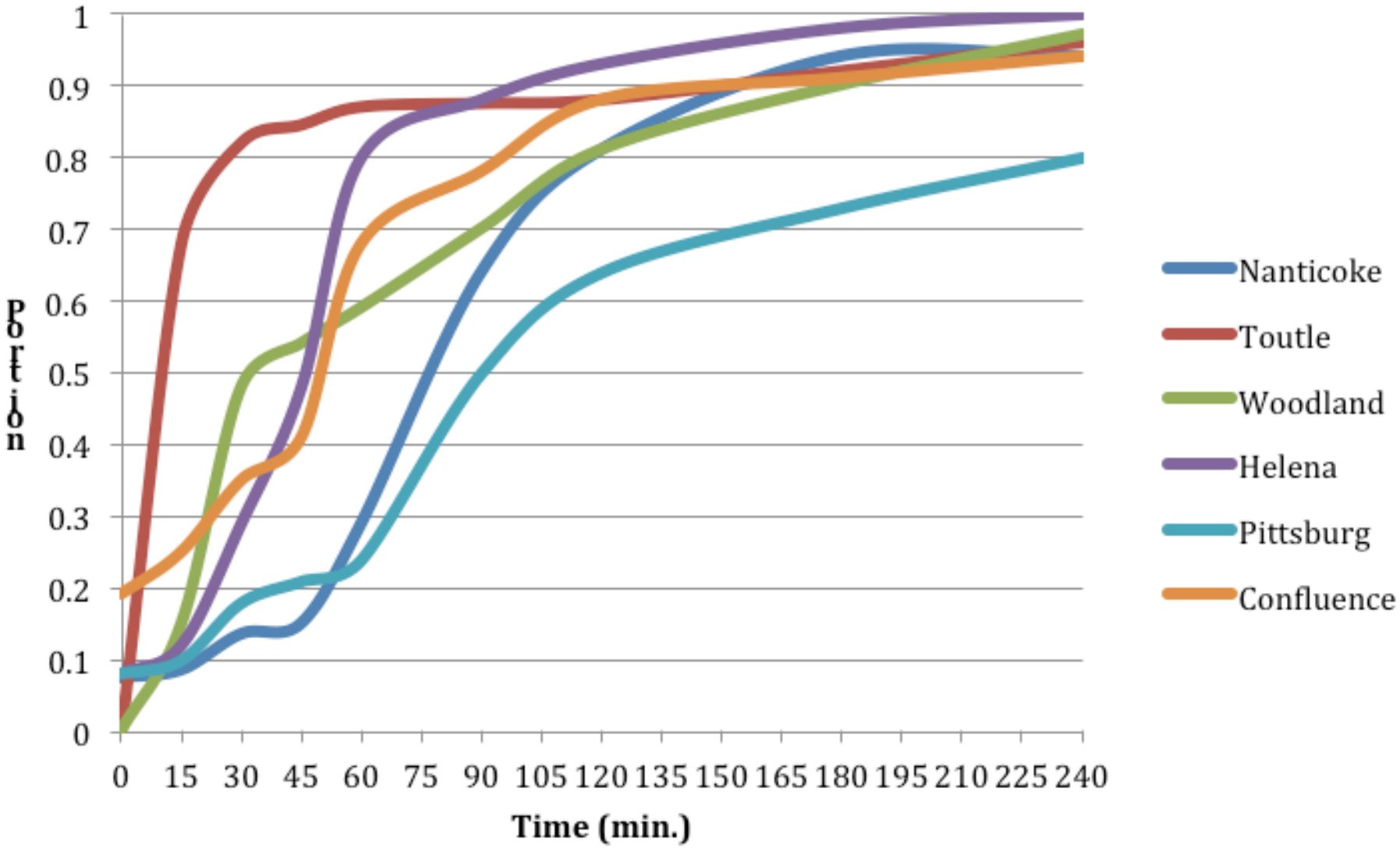
RAPID DIFFUSION
Boulder (9/2013) CO Flood



SLOW DIFFUSION: Nanticoke, PA



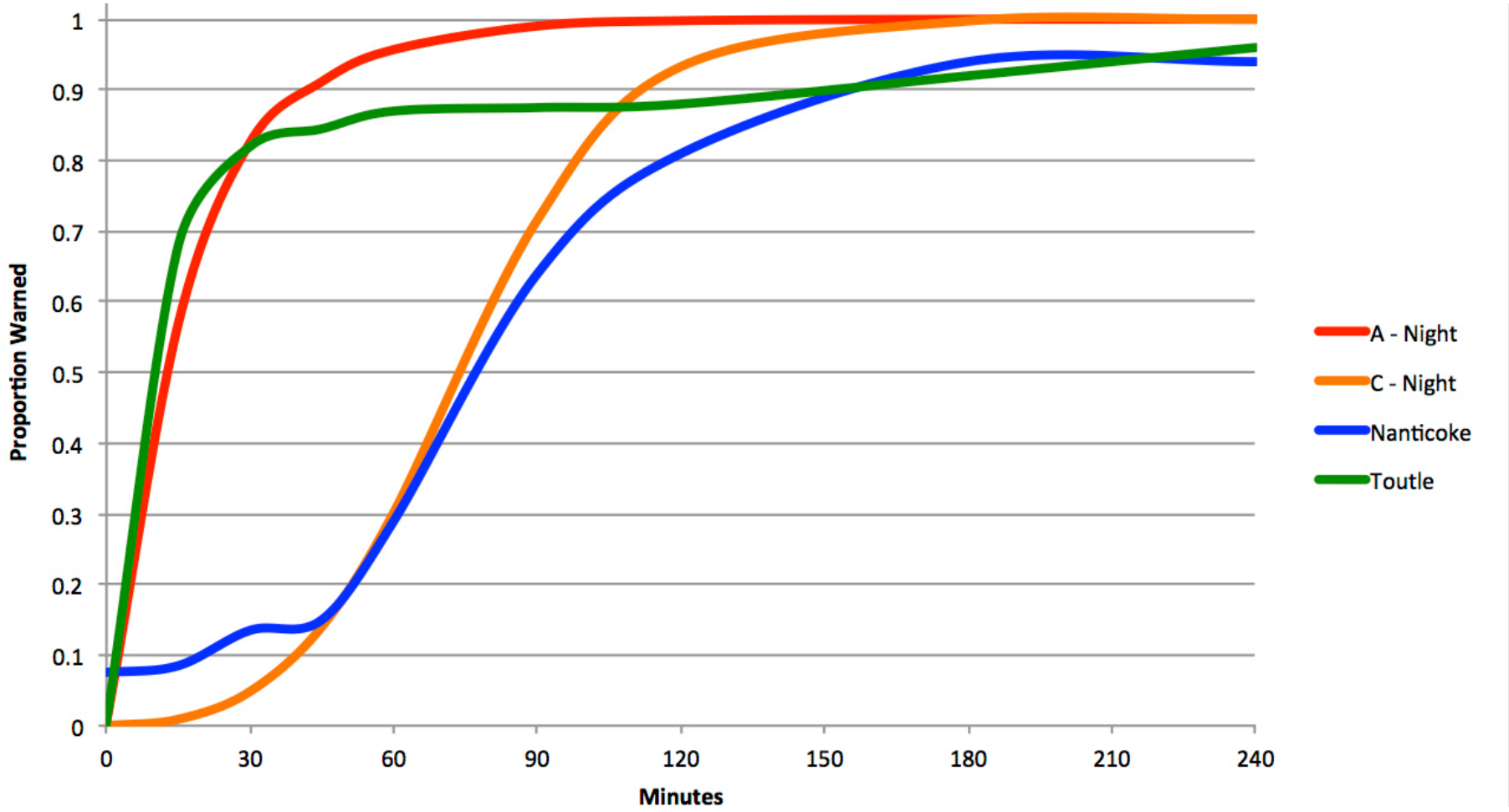
HISTORIC DIFFUSION DATA



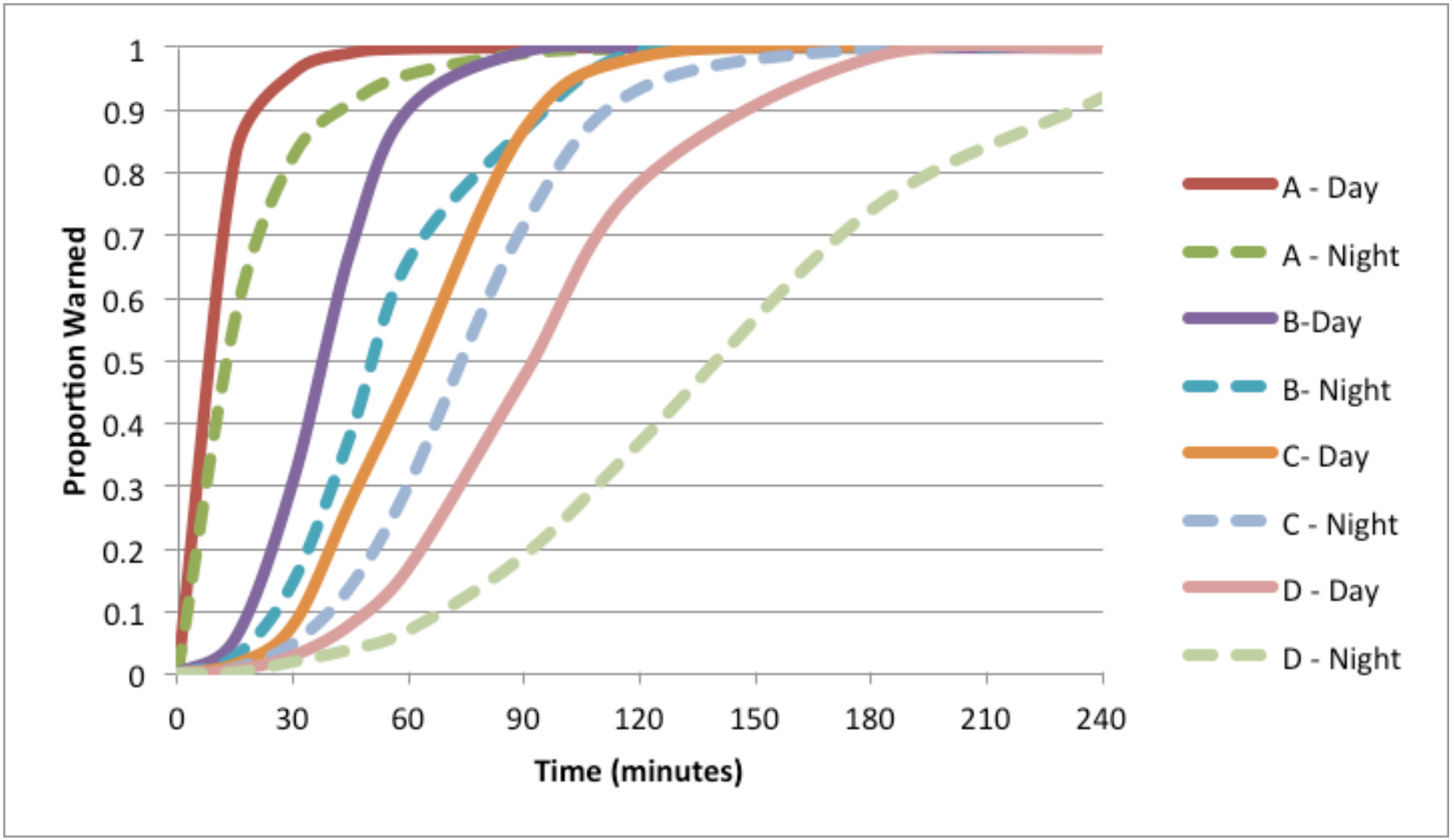
MODELING WARNING DIFFUSION

- $\Delta W/\Delta t = PUt*(Bt+Ct-Bt*Ct)$
- Where:
- W = Alerted population
- t = time
- $\Delta W \Delta t$ =the rate of population being alerted per time step
- *PUt*=The population unwarned for time step t
- *Bt*= the effectiveness of the broadcast systems in time step t
- *Ct*= the effectiveness of the indirect warning in time step t

COMPARING SIMULATED AND EMPIRICAL



DIFFUSION CURVES



MORE DETAILS IN

Sorensen, J., and D. Mileti (2014b). ***First Alert and Warning Diffusion Time Estimation for Dam Breaches, Controlled Dam Releases, and Levee Breaches of Overtopping*****. Davis, CA: U.S. Army Corps of Engineers, Institute for Water Resources, Risk Management Center.**

PAI DELAY

PROCESS & DEFINITIONS

- **Choice of actions**
- **When does initiation begin**
- **Area warned versus at risk**
- **What is compliance?**

RESEARCH BASED FACTORS THAT INFLUENCE PAI TIME

MESSAGE CHARACTERISTICS

	RANK	WEIGHT
Appropriate Content	**HIGH**	**.25 - .30**
Style	**HIGH**	**.17 - .22**
Message Length Adequacy	**MODERATE**	**.12 - .16**
Personal Channel	**HIGH**	**.13 - .18**
Delivery (Frequency)	**HIGH**	**.12 - .15**
Protective Action Type	**MODERATE**	**.05 - .10***

* NOTE: Not to be used in estimating vertical evacuation since separate curves exist

RECEIVER CHARACTERISTICS

	RANK	WEIGHT
Status Attributes	MODERATE	.01 - .10
Role Characteristics	HIGH	.10 - .17
Personal Preparedness	LOW	.01 - .02
Pre Event Knowledge	LOW	.01 - .02
Experience	MODERATE	.01 - .14
Member Isolated Group	MODERATE	.01 - .11

CONTEXT CHARACTERISTICS

	RANK	WEIGHT
Environmental Cues	HIGH	.05 - .28
Social Cues	MODERATE	.05 - .13
Location / Activity	MODERATE	.05 - .15
Day Versus Night	LOW	.01 - .05
Time To Impact	HIGH	.10 - .17
Impact Intensity	HIGH	.10 - .17

LINKS TO INTERVIEW SCHEDULE
11 PAI QUESTIONS
(Example: Guidance & Consequence Reduction)

Q 39. Would you recommend in alerts, warnings and press releases that the public take specific protective actions, for example, evacuate, move vertically, or check local media? YES/NO

Q 40. Would the alerts, warnings and emergency press releases you issue tell the public about any of the following?

The consequences of the flood and why taking the recommended protective action(s) would reduce them? YES/NO

(IF YES) What would alerts and warnings say? _____

What would press releases say? _____

COMMUNITY CLASSIFICATION

(Protective Action Initiation Delay)

	QUESTION/RULE
Message Characteristics	
Appropriate Content	38,39,40a,40b,40c (if yes to 39 & 2 others)
Style	41a,41b,44,28 (if yes to 2 or more)
Message Length Adequacy	38,39,40a,40b,40c,40d,40e,49f,40g (if yes to 5+)
Personal Channel	22 (if yes to any of a special type)
Receiver Characteristics	
Status Attributes	53,54,55,57 (if none is yes)
Role Characteristics	40e,40f (if yes to either)
Personal Preparedness/Planning	46 (if yes)
Pre Event Knowledge	46 (if yes)
Experience	48 (if yes)
Membership In A Socially Isolated Group	58 (if yes)
Context Characteristics	
Environmental Cues	40g (if yes)
Location/Activity	29 (if yes to 1 or more)
Day Versus Night	31 (if yes)
Time To Impact	43 (if yes)

EVACUATION COMPLIANCE (% warned)

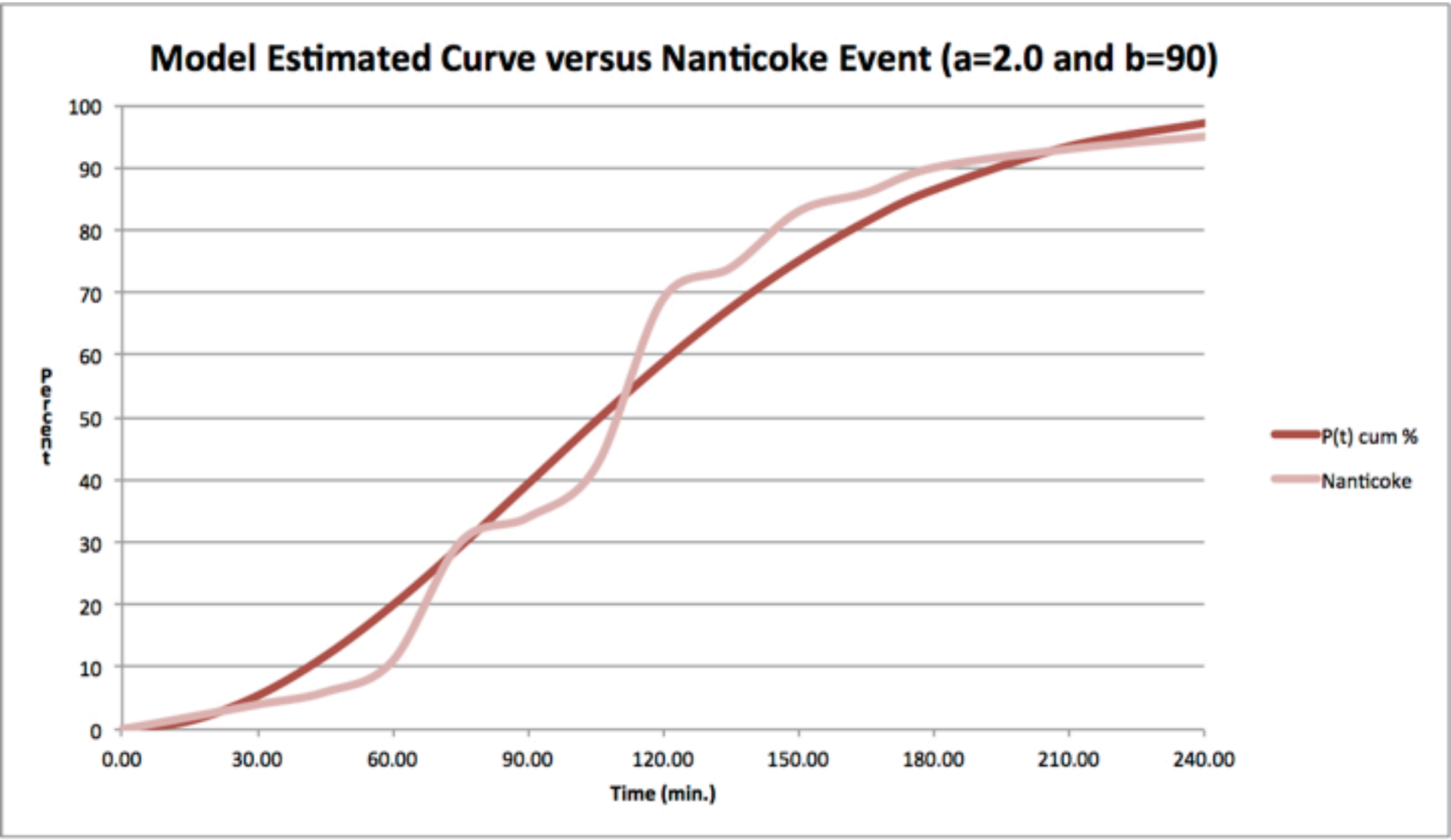
Table 6. Estimated compliance rates for dam breaches and levee flooding. (Based on Lindell and Prater, 2007 and Cutter et. al., 2011)

Zone	Event Intensity		
	Minor	Moderate	Major
Flood Area: Short Response Time	51-59	81-89	94-100
Flood Area: Long Response Time	28-34	70-76	83-89
Adjacent Zones	10-16	32-38	65-71

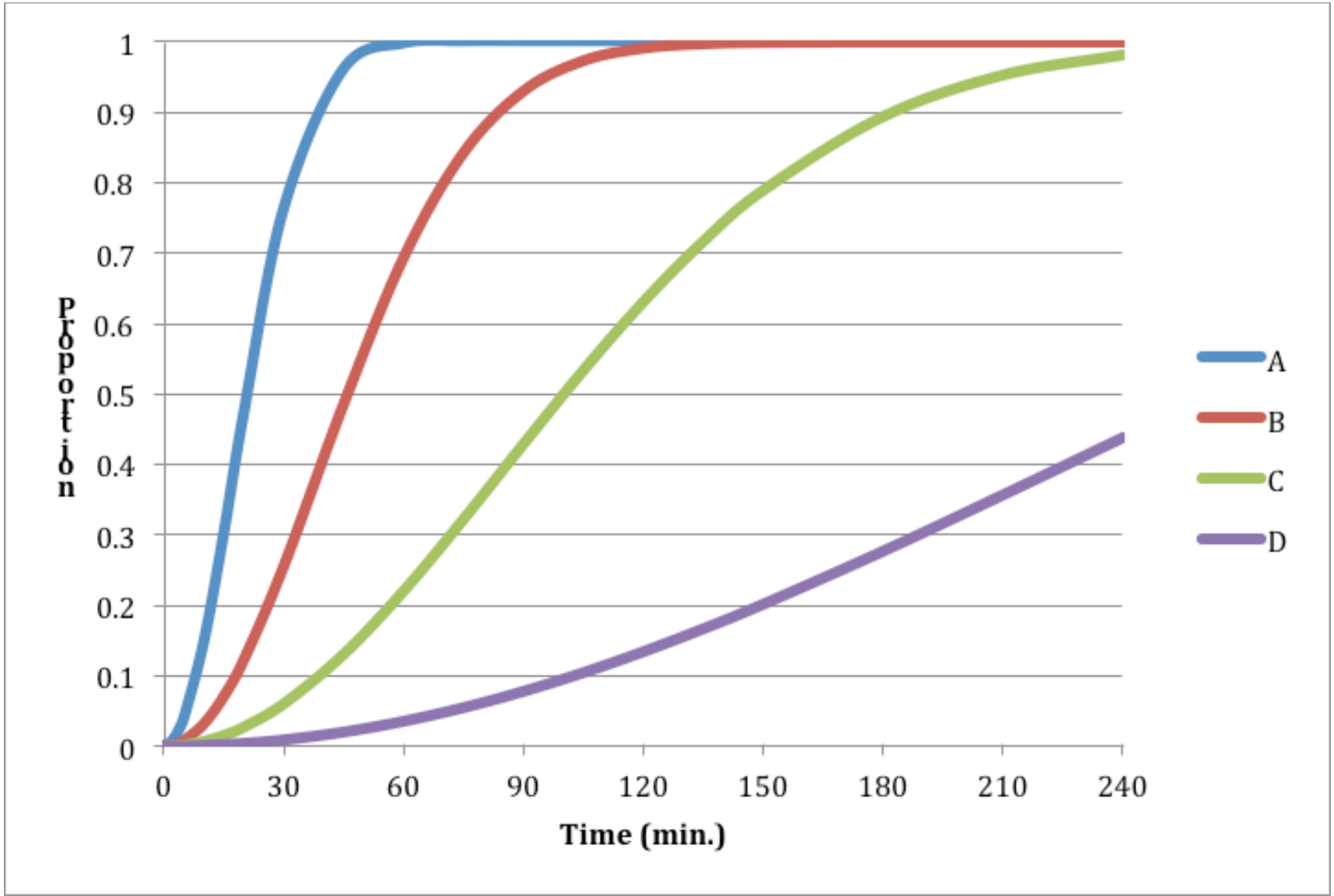
MODELING PROTECTIVE ACTION INITIATION

- $P_t = 1 - e^{[-(t\text{^}2)/ab\text{^}2)]}$
- t is time
- a and b constants
  - a: acceleration
  - b: overall timing (midpoint)

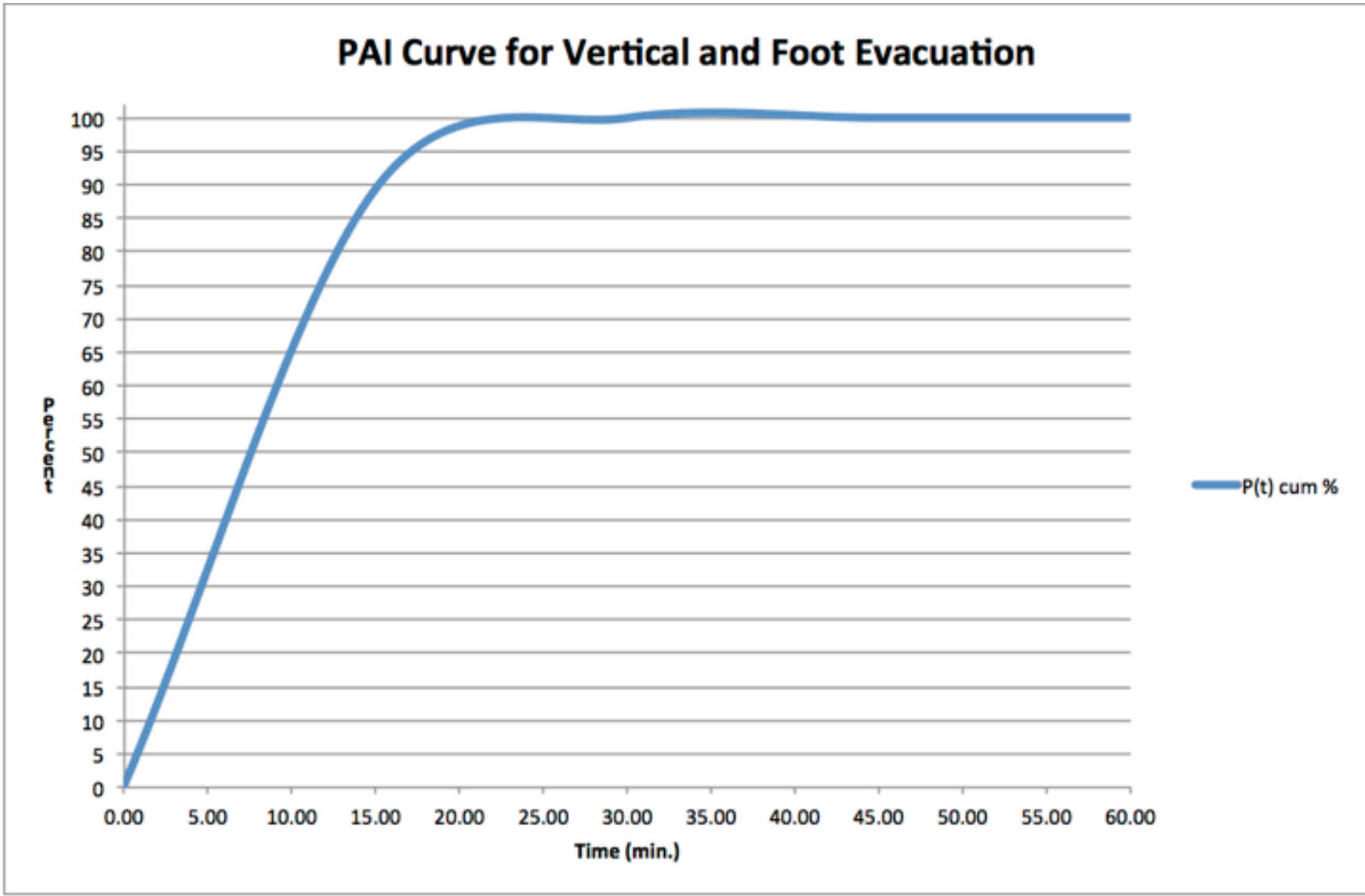
COMPARISION



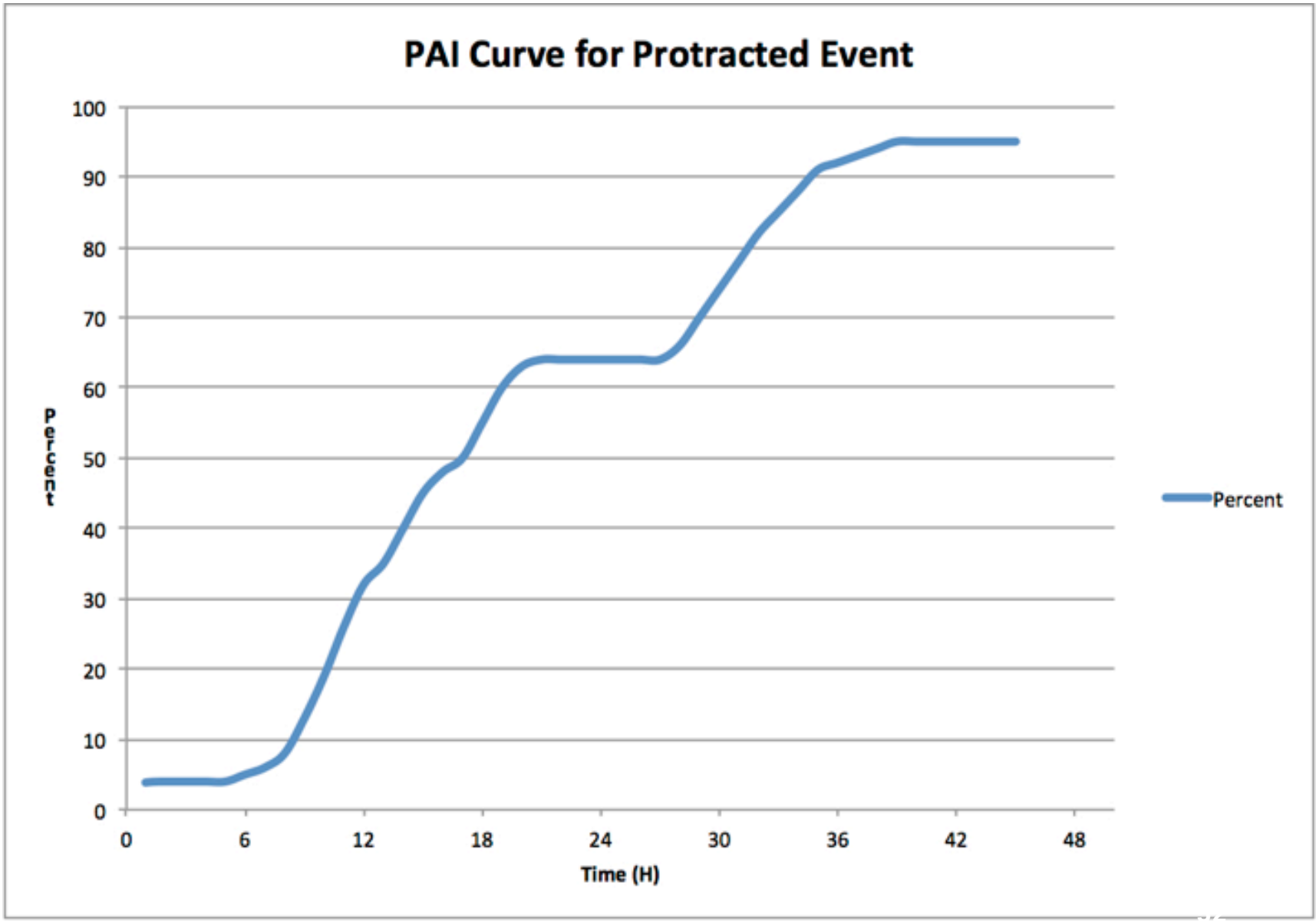
PAI PLANNING CURVES



PAI PLANNING CURVES



PAI PLANNING CURVES



MORE DETAILS IN

Sorensen, J., and D. Mileti (2014c). ***Protective Action Initiation Time Estimation for Dam Breaches, Controlled Dam Releases, and Levee Breaches of Overtopping*****. Davis, CA: U.S. Army Corps of Engineers, Institute for Water Resources, Risk Management Center.**

BRINGING IT TOGETHER FOR LIFE LOSS ESTIMATION

RESEARCH FINDINGS, CURVES INTERVIEWS, LIFE LOSS ESTIMATES

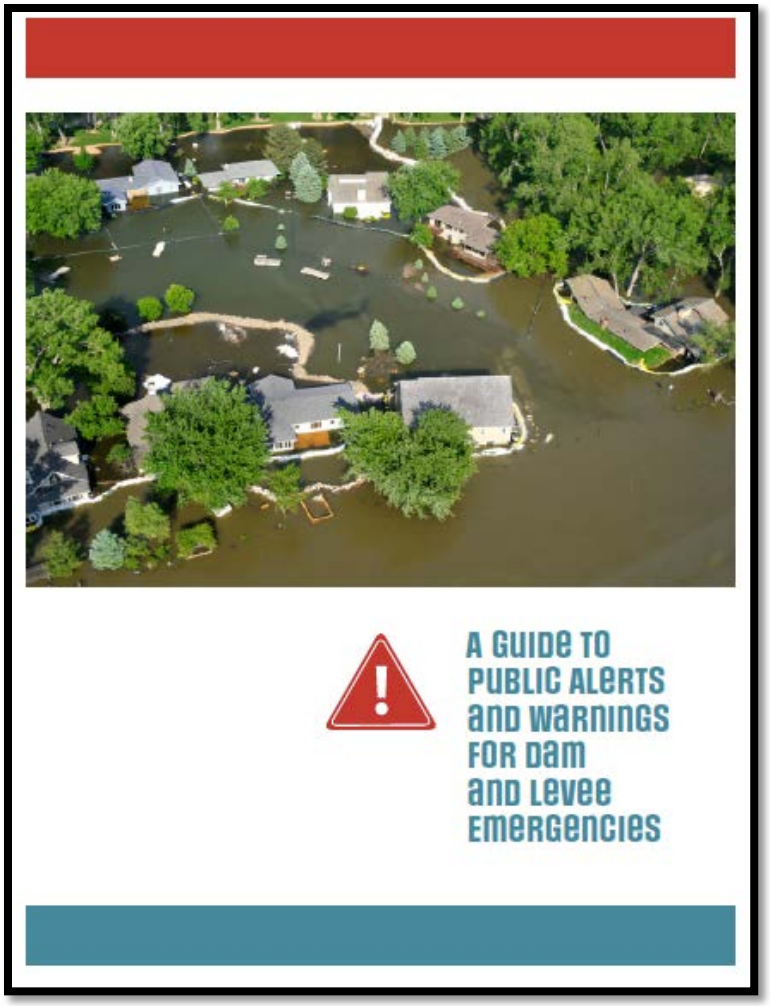
- **58 interview questions**
  - **15 Issuance questions**
  - **14 Diffusion question**
  - **11 Protective action initiation questions**
  - **18 Other questions (local threat type & more)**
- **USACE will use the rules we developed to combine question answers to assign issuance, diffusion and PAI curves to communities to estimate future life loss**

MORE DETIALS IN

- **Mileti, D., and J. Sorensen. (2015d). Interview Schedule: Community Warning Issuance, Diffusion, and Protective Action Initiation Estimation. Davis, CA: U.S. Army Corps of Engineers, Institute for Water Resources, Risk Management Center.**

- **Sorensen, J., and D. Mileti (2015e). *Influence Weights and Measures for the Factors Shaping First Alert/Warning Delay, Diffusion and Protective Action Initiation Curves for Dam Breaches, Controlled Dam Releases, and Levee Breaches or Overtopping*. Davis, CA: U.S. Army Corps of Engineers, Institute for Water Resources, Risk Management Center.**

COMMUNITY PLANNING GUIDEBOOK



GUIDEBOOK PURPOSE

- **Prepare a guidebook based on synthesized empirical social science quantitative evidence**
- **Provide emergency managers with practical ways to enhance future public alert & warning practices that could**
  - **Reduce issuance time delay**
  - **Minimize diffusion time**
  - **Accelerate protective action initiation**

GUIDEBOOK SYNTHESIS

- **How to minimize issuance delay**
  - **Written plan beforehand & what should be in it**
- **How to accelerate diffusion**
  - **Disseminate over mix of channels / technology**
- **How to reduce PA initiation**
  - **Warning messages based on repetitive social behavioral science empirical evidence**

MORE DETAILS IN

Mileti, Dennis. S., and John H. Sorensen (2015f). *A Guide to Public Alerts and Warnings for Dam and Levee Emergencies*. Davis CA: U.S. Army Corps of Engineers Risk Management Center.

Download at:

http://silverjackets.nfrmp.us/Portals/0/doc/WarningGuidebook_USACE.pdf?ver=2015-08-10-213008-520

OROVILLE DAM EVENT

- **New flood events research**

  Warning & evacuation provide first study case to update curves for life loss estimation

- **To generate**

  New data for new issuance, diffusion and PAI curves that capture the influence of new warning system types & technologies, e.g., wireless alerts & warnings, social media, etc.

THANK YOU