When LOL Means Loss of Life

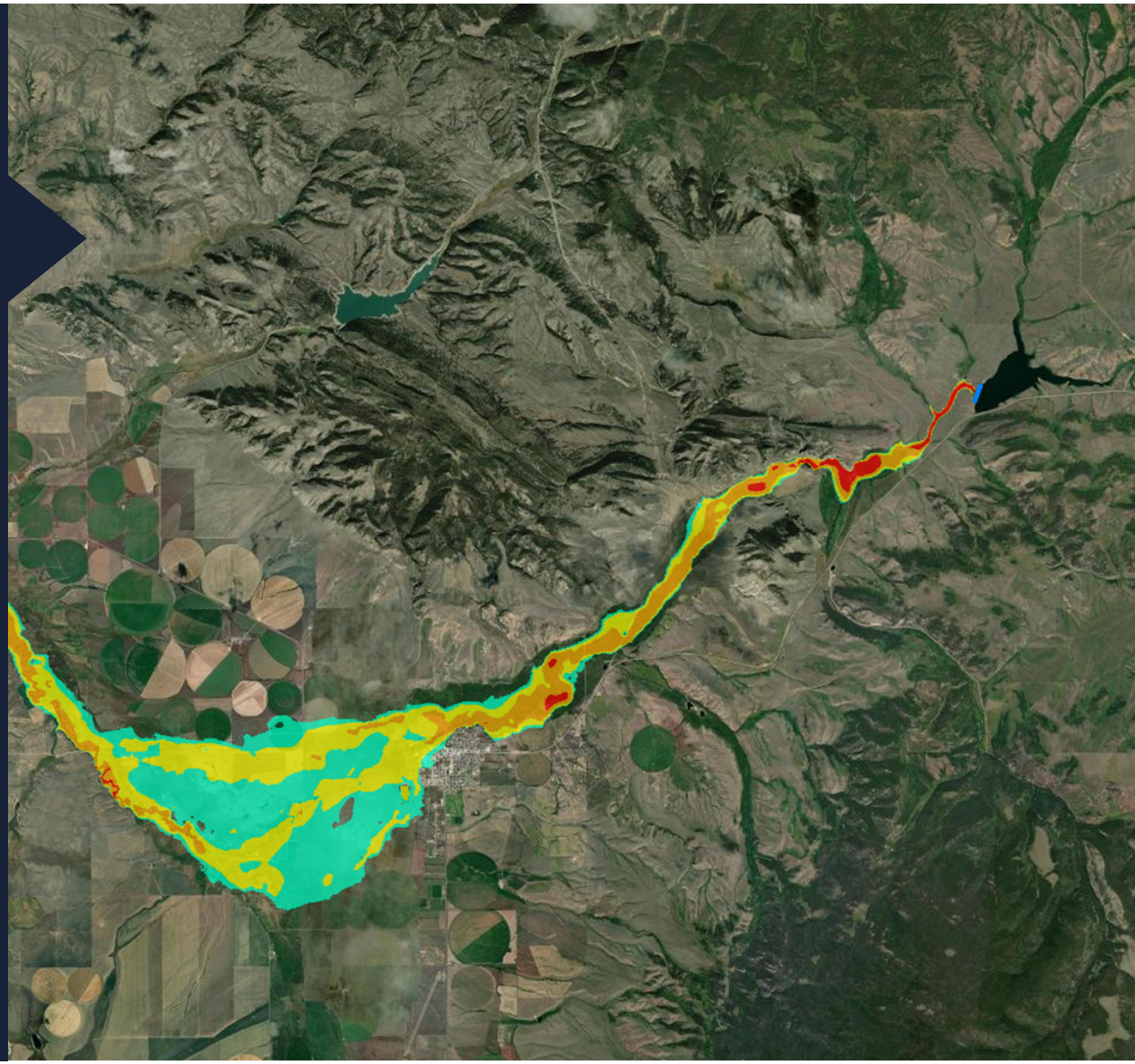
Updating Montana's Dam Failure LOL Estimation Practices (TN2 Revision)

Trace Brady, PE

Andrew Johnson, PE

DOWL

MONTANA DNRC



PRESENTATION OUTLINE

01 Introductions

02 MT Dam Safety Act & Tech Note 2 Overview

03 Key Terms

04 RCEM Overview

05 LifeSim Overview

06 Methodology Differences

07 Dam Screening Tool

08 Questions

INTRODUCTION



Trace Brady, PE | DOWL
Water Resources Engineer
Surface Water | Billings, MT



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Water Resources Engineer
Surface Water | Billings, MT

MT DAM SAFETY ACT

- MT law defines a risk-based approach for determining the **minimum** acceptable Inflow Design Flood (IDF)
- Risk = Life Loss x Probability of Dam Failure
- As Life Loss increases, the **minimum** acceptable IDF increases

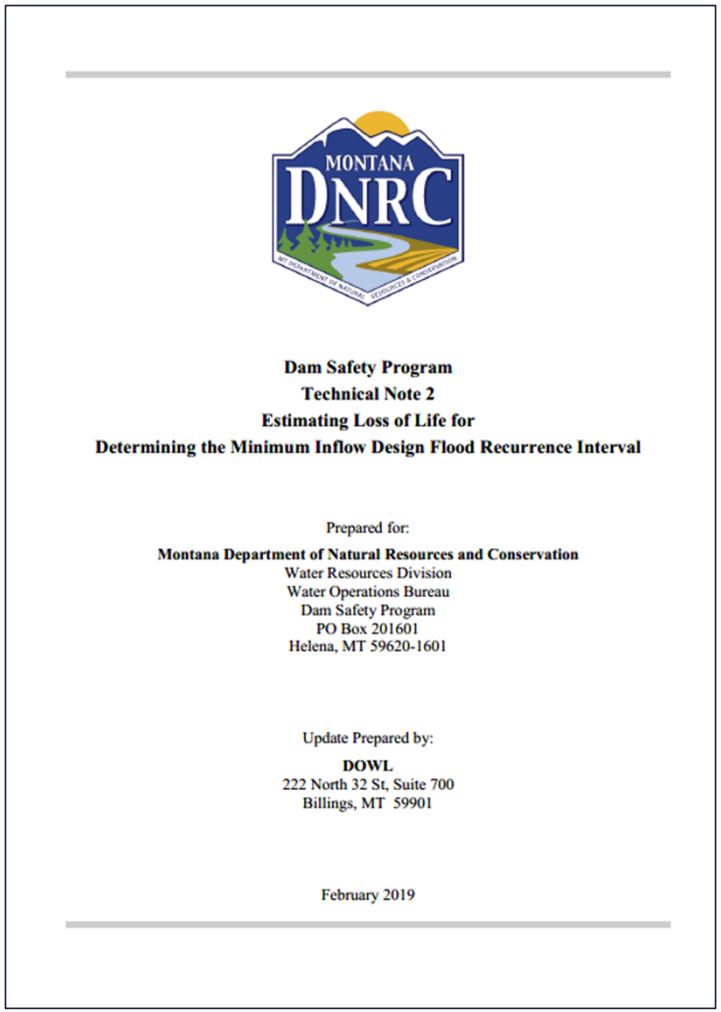
ARM 36.14.502 Summary	
Life Loss	**IDF Determination (Recurrence Interval, Years)**
0.5 < LL ≤ 5	LL x 1,000
5 < LL < 1,000	Calculate Design Precipation (Ps) $P_s = P_{5,000}(10^{rd})$
LL ≥ 1,000	Probable Maximum Flood (PMF)



Montana National Guard. (2022). *An aerial view of flooding in South Central Montana from a Montana National Guard helicopter* [Photograph]. National Guard News.

TECH NOTE 2 OVERVIEW

- Guidance document for conducting a life loss study to determine the **minimum** acceptable IDF for high-hazard dams in Montana that are regulated by the MT Dam Safety Program.
- Current Version (2019): Reclamation's Consequence Estimating Methodology (RCEM)
- Forthcoming Revision (Expected 2027): USACE's LifeSim methodology



MONTANA DNRC

Dam Safety Program
Technical Note 2
Estimating Loss of Life for
Determining the Minimum Inflow Design Flood Recurrence Interval

Prepared for:

Montana Department of Natural Resources and Conservation
Water Resources Division
Water Operations Bureau
Dam Safety Program
PO Box 201601
Helena, MT 59620-1601

Update Prepared by:

DOWL
222 North 32 St, Suite 700
Billings, MT 59901

February 2019

KEY TERMS



1

HIGH HAZARD DAM

In Montana, a dam that impounds 50 acre-feet or more in reservoir volume and whose failure would likely cause a loss of life. **Note:** MT high hazard dams are under the authority of Montana Dam Safety Program (MT DSP), as part of the MT DNRC.

2

INFLOW DESIGN FLOOD (IDF)

The largest flood that a dam and its appurtenant structures are designed to safely accommodate and pass without causing failure.

3

POPULATION AT RISK (PAR)

Number of human lives at risk of injury or death in the event of a dam failure. PAR is the number of people within a dam breach flood inundation area.

KEY TERMS (CONTINUED)



4

WARNING TIME (CURRENT TN2)

The amount of time for people to evacuate a breach flood zone after they receive notification of a dam failure and before the flood failure wave arrives.

5

FLOOD SEVERITY

Hydraulic characteristics of depth, velocity, DV, flood wave arrival times, etc.

6

LOSS OF LIFE (LOL) OR LIFE LOSS (LL)

The number of human lives expected to be lost in the event of a dam failure.

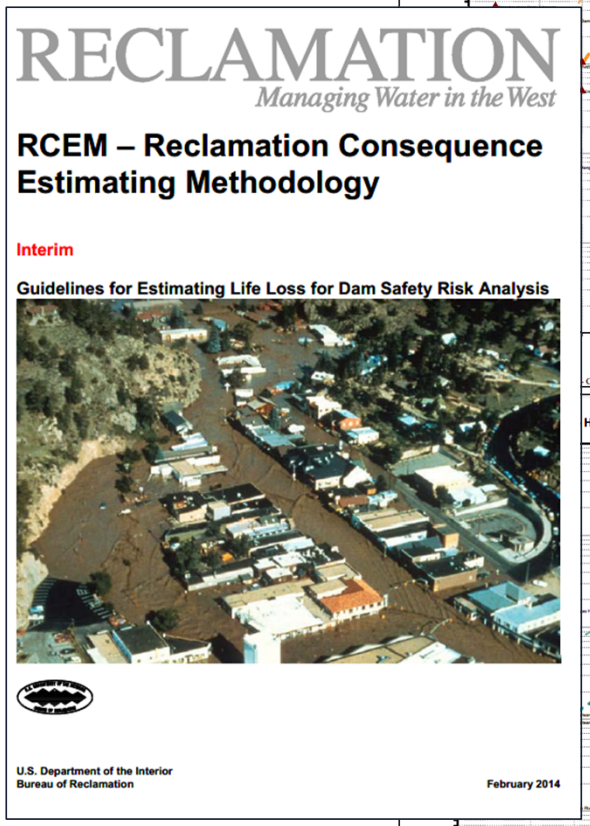
7

FATALITY RATE

The proportion of PAR who die as result of a dam failure event.

RCEM OVERVIEW

- Chart Approach (Fatality Rate x PAR)
- Fatality Rates based on case histories for flood-caused fatalities


RECLAMATION
Managing Water in the West

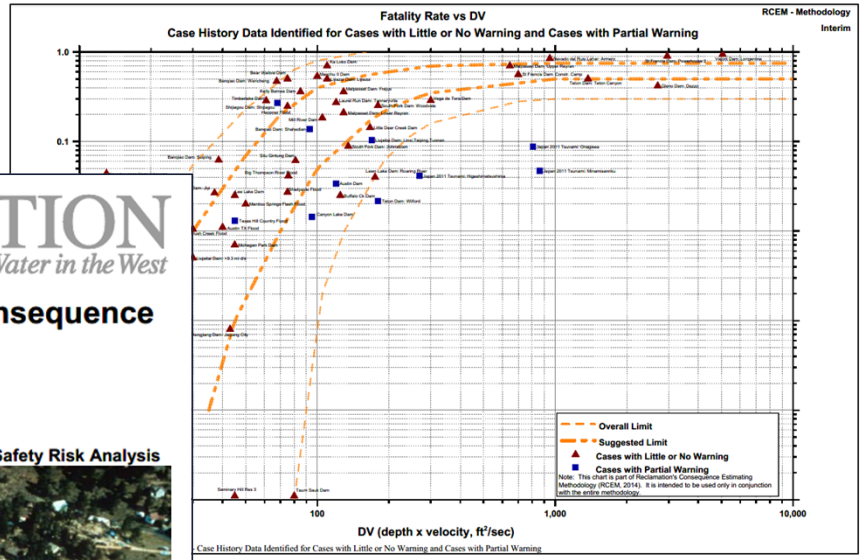
RCEM – Reclamation Consequence Estimating Methodology

Interim

Guidelines for Estimating Life Loss for Dam Safety Risk Analysis

U.S. Department of the Interior
Bureau of Reclamation

February 2014



Case History Data Identified for Cases with Little or No Warning and Cases with Partial Warning

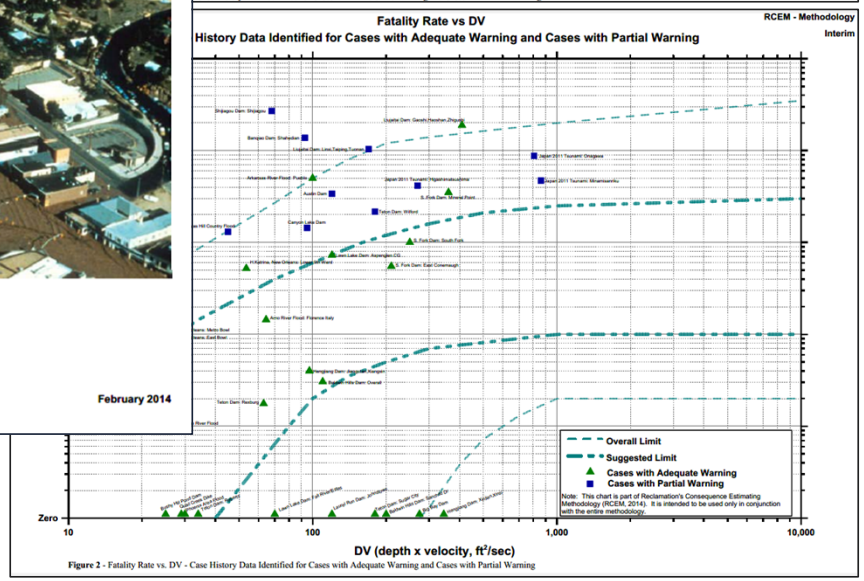
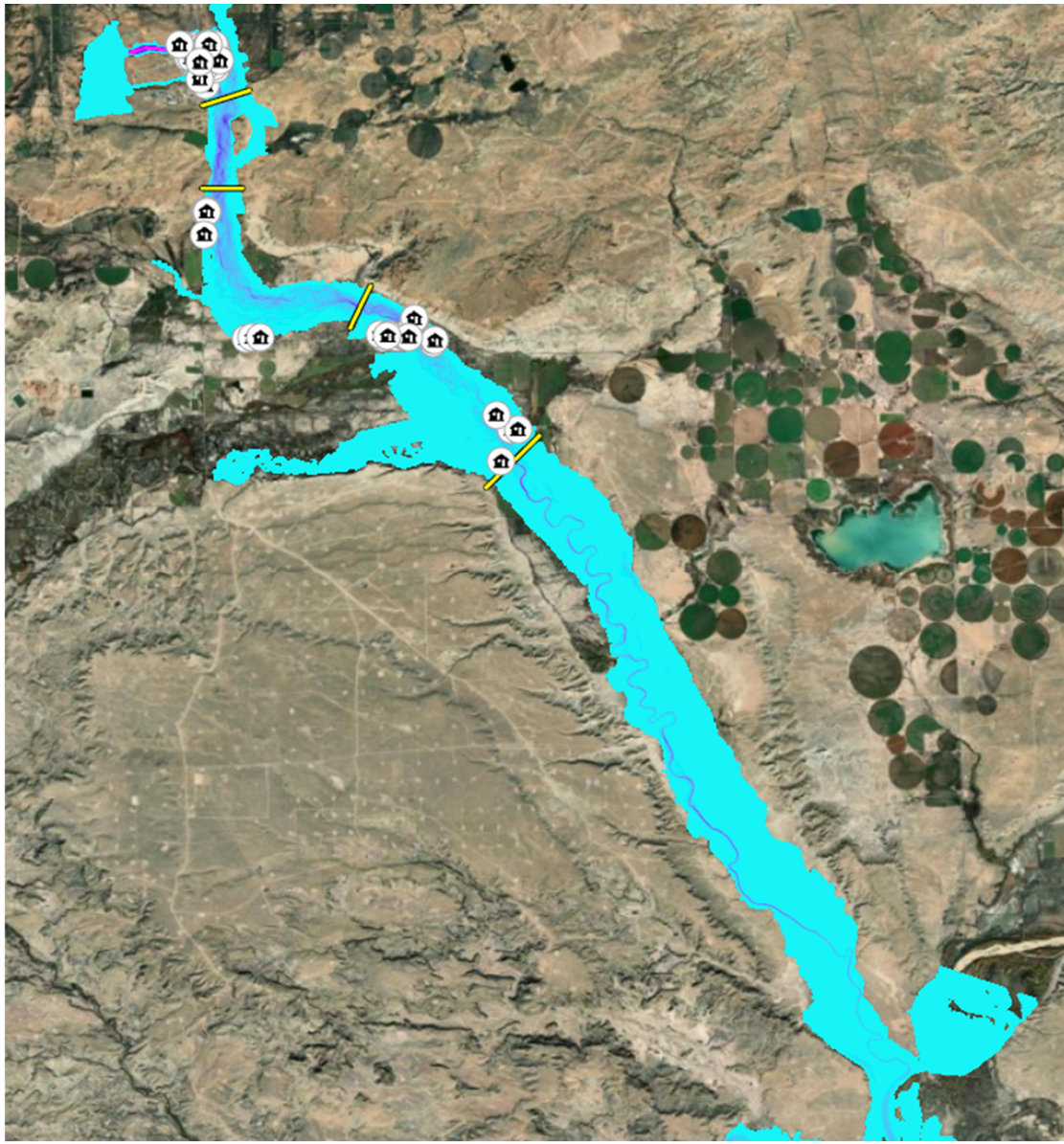


Figure 2 - Fatality Rate vs. DV - Case History Data Identified for Cases with Adequate Warning and Cases with Partial Warning

— BUREAU OF —
RECLAMATION

RCEM APPLICATION SUMMARY

- Characteristic Reaches
  - PAR
  - Flood Severity
  - Warning Category
- Fatality Rate Selection
  - Characteristic DV
  - Warning Category
  - Case History?
- Life Loss = ∑ Fatality Rate x PAR



RCEM APPLICATION SUMMARY

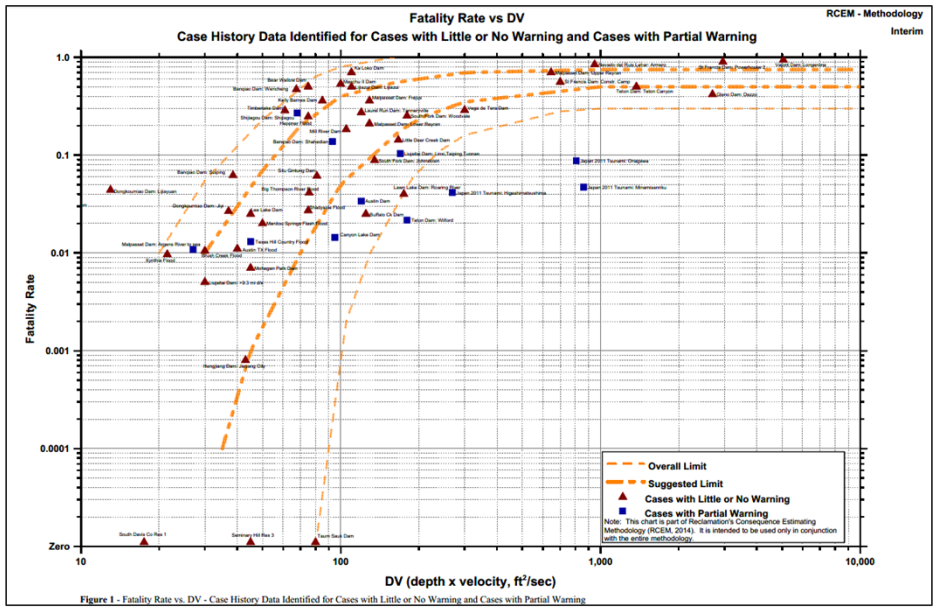


Figure 1 - Fatality Rate vs. DV - Case History Data Identified for Cases with Little or No Warning and Cases with Partial Warning

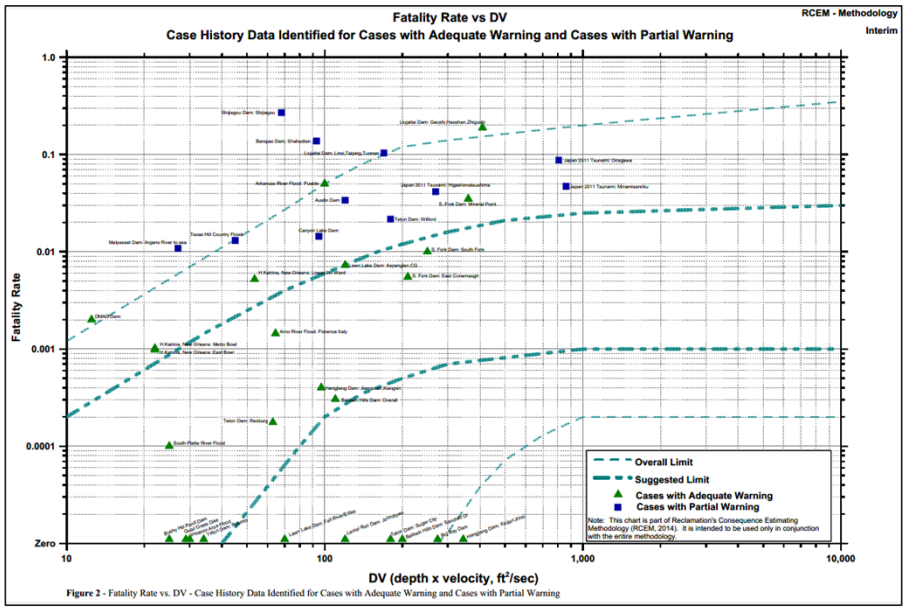
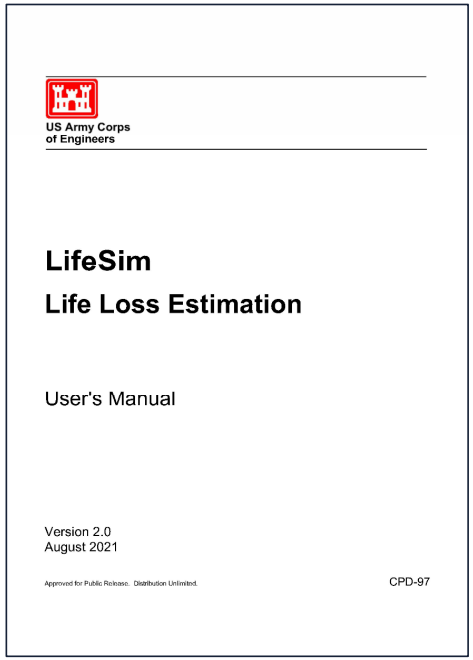


Figure 2 - Fatality Rate vs. DV - Case History Data Identified for Cases with Adequate Warning and Cases with Partial Warning

Reach	Length (valley miles)	Characteristic DV (ft^2/s)	Arrival Times at Reach Start (hr:min) (+/- Nearest 15 min.)		Population at Risk (PAR)		Warning Category	Fatality Rate	Loss of Life	
			Leading Edge	Maximum DV	Day	Night			Day	Night
1	0.0 - 1.7	40	0:00	1:00	201	234	Little to No Warning Time	0.041	8.18	9.52
2	1.7 - 2.9	0	0:30	1:15	0	0	Little to No Warning Time	0.000	0.00	0.00
3	2.9 - 6.1	0	1:00	1:30	6	5	Little to No Warning Time	0.000	0.00	0.00
4	6.1 - 9.2	20	2:00	2:30	35	39	Little to No Warning Time	0.006	0.21	0.23
5	9.2 - 19.3	0	3:00	3:45	0	0	Little to No Warning Time	0.000	0.00	0.00
								Totals =	**8.4**	**9.8**

LIFESIM OVERVIEW

- Agent-based
- Spatially-distributed
- Temporally-distributed
- Monte Carlo


US Army Corps
of Engineers

LifeSim

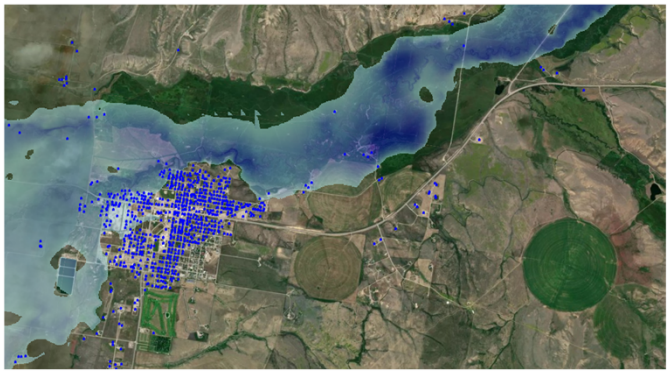
Life Loss Estimation

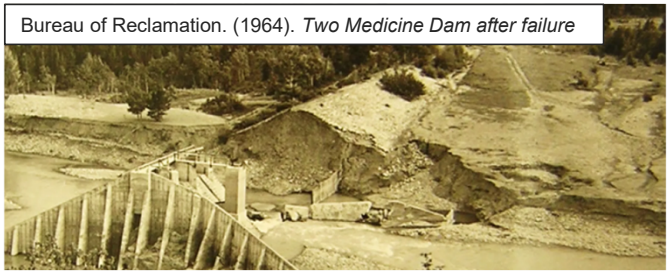
User's Manual

Version 2.0
August 2021

Approved for Public Release. Distribution Unlimited.

CPD-97





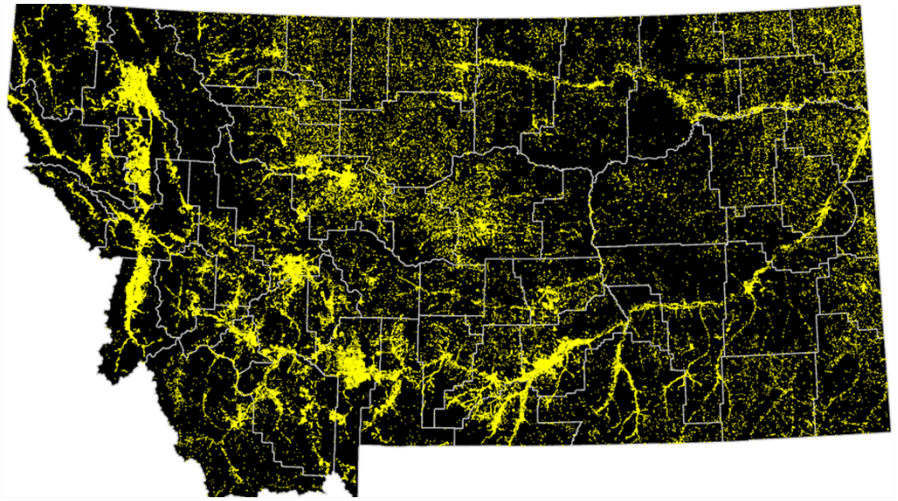
Bureau of Reclamation. (1964). *Two Medicine Dam after failure*

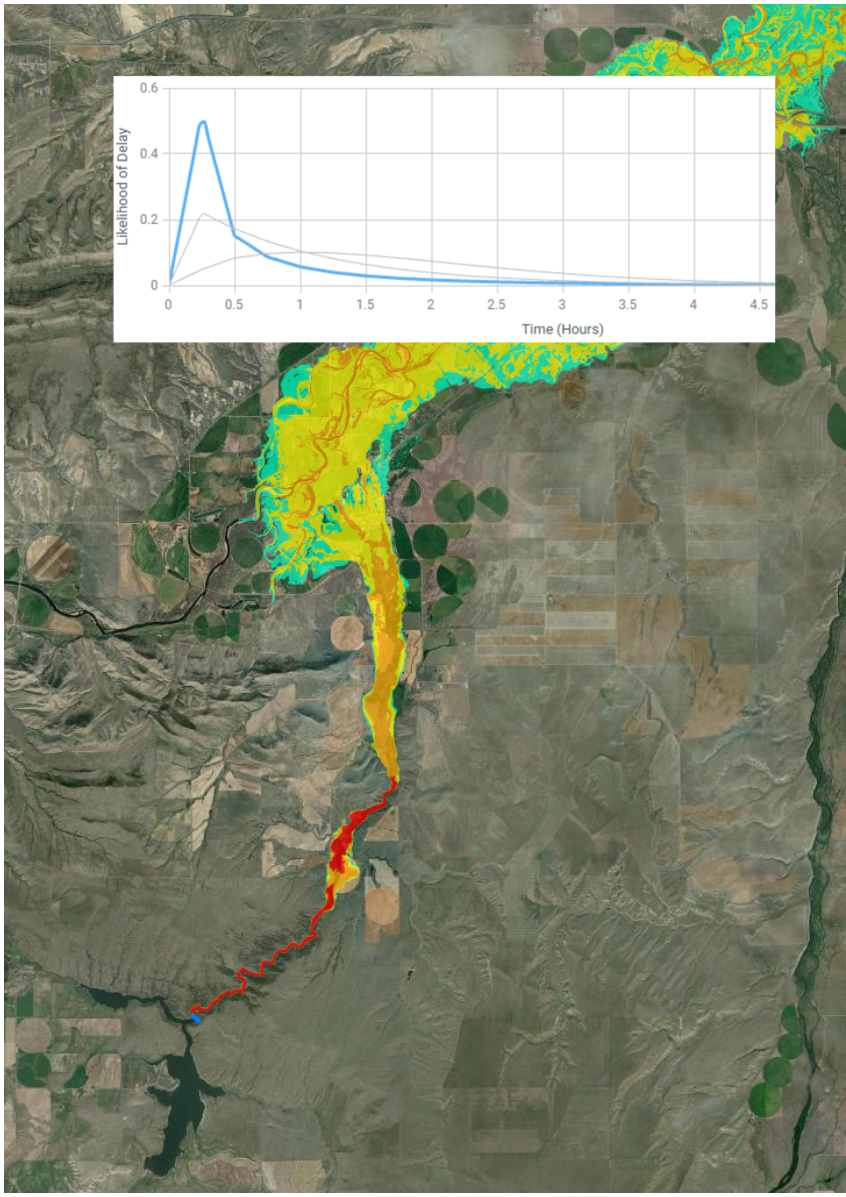
U.S.ARMY

US Army Corps
of Engineers®

LIFESIM INPUTS

- Hydraulics
- Structures/PAR
- Warning time
- Roads/Destinations





HYDRAULICS

- Top of dam failure
- Unsteady hydraulic model
- Output timestep



Billings Gazette (1937). *BBWA Canal failure*



Bureau of Reclamation. (1964). *Two Medicine Dam after failure*

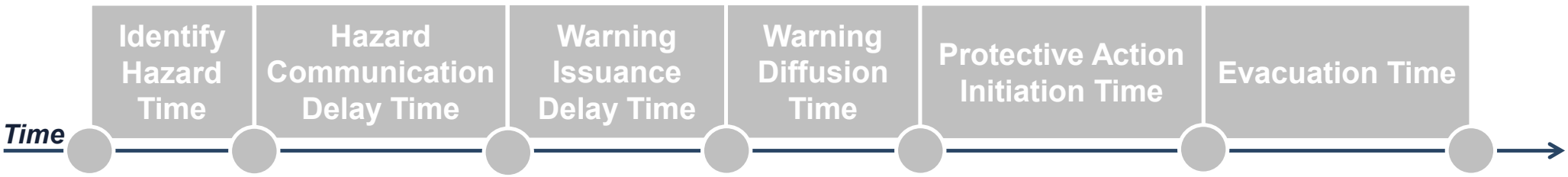
STRUCTURES/PAR

- PAR originates from structures
- Structures from the National Structures Inventory (NSI)
- Primary attributes for life loss
  - Day/night population
  - PAR mobility
  - Structure type
  - Foundation type
  - Number of stories
  - Foundation height

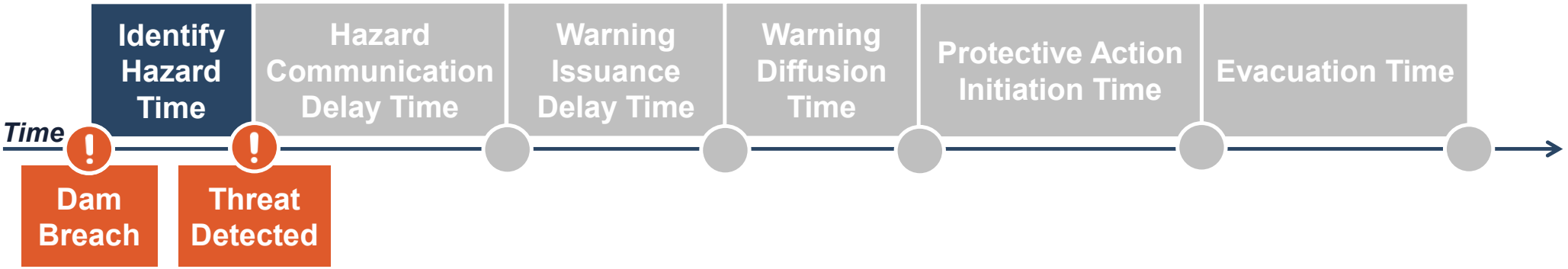


Deby Dixon (2022). *Yellowstone River near Gardiner, MT*

WARNING & EVACUATION TIMELINE



WARNING & EVACUATION TIMELINE



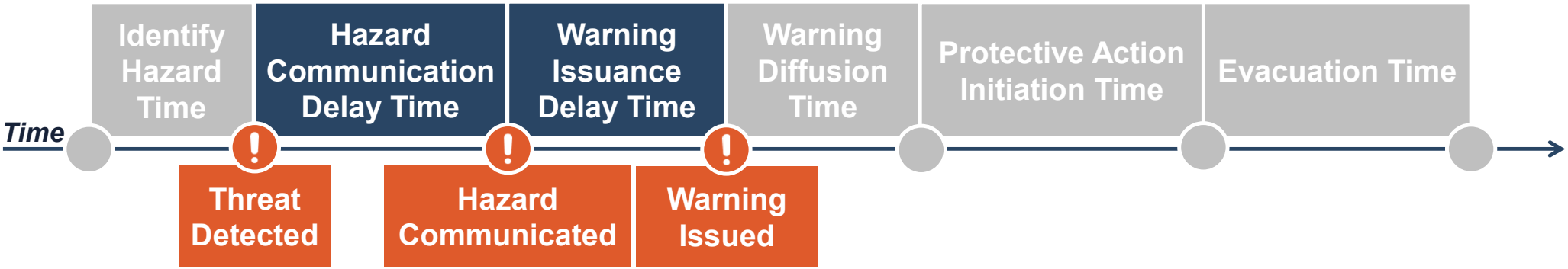






Bureau of Reclamation (1976). *Teton Dam, Idaho*

WARNING & EVACUATION TIMELINE

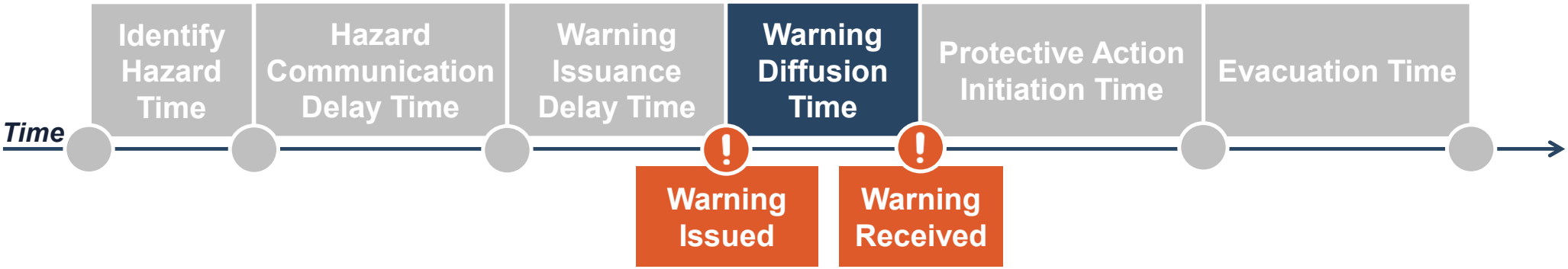


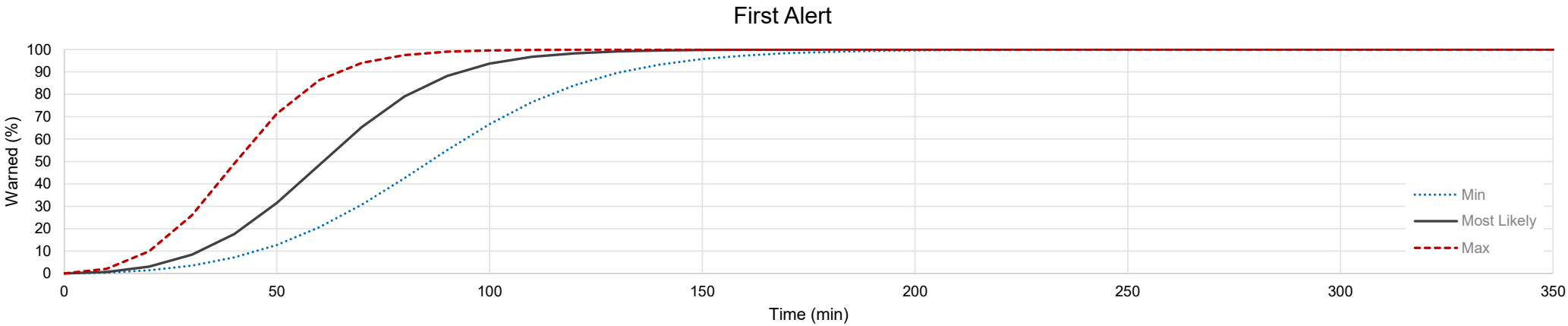




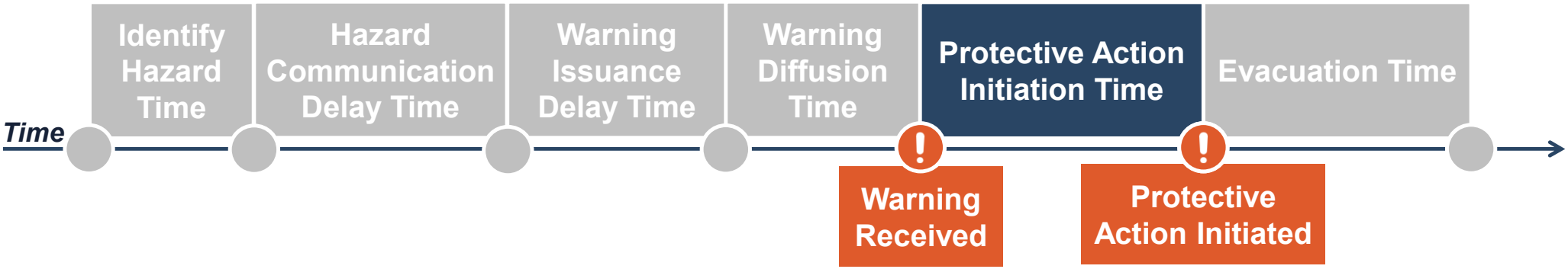


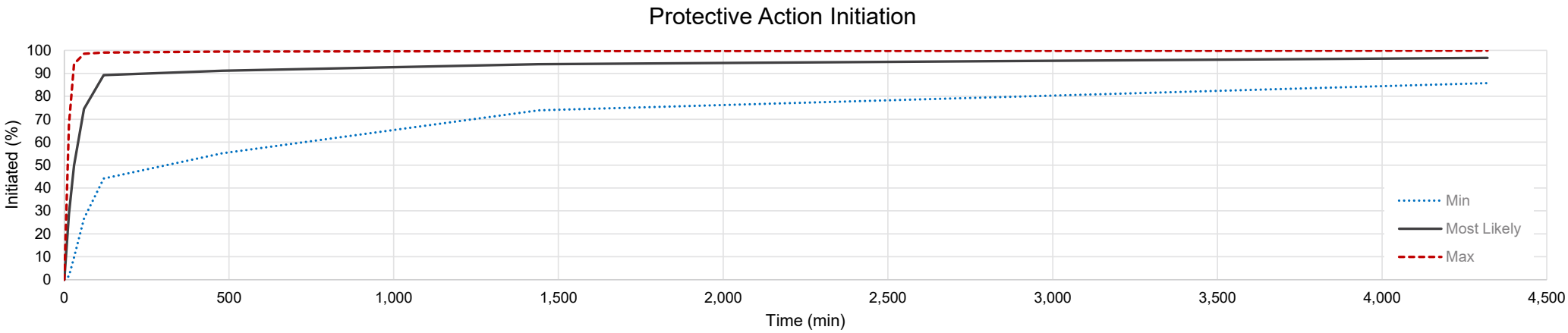
WARNING & EVACUATION TIMELINE



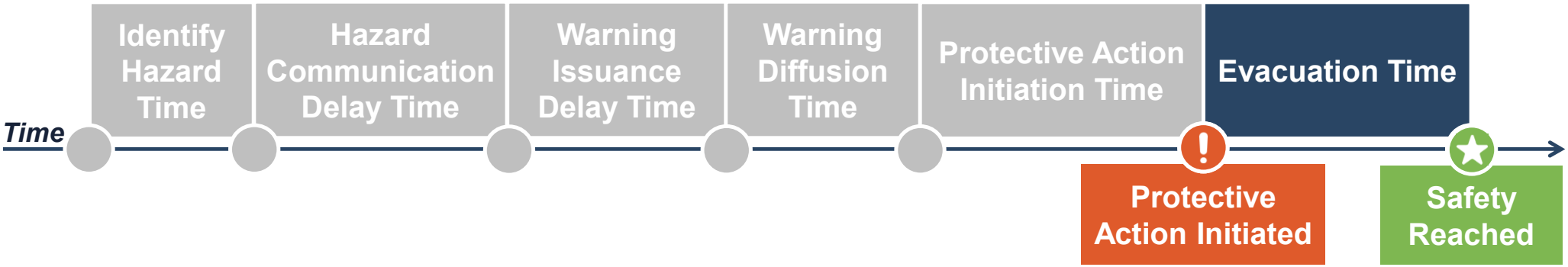


WARNING & EVACUATION TIMELINE





WARNING & EVACUATION TIMELINE



Horizontal

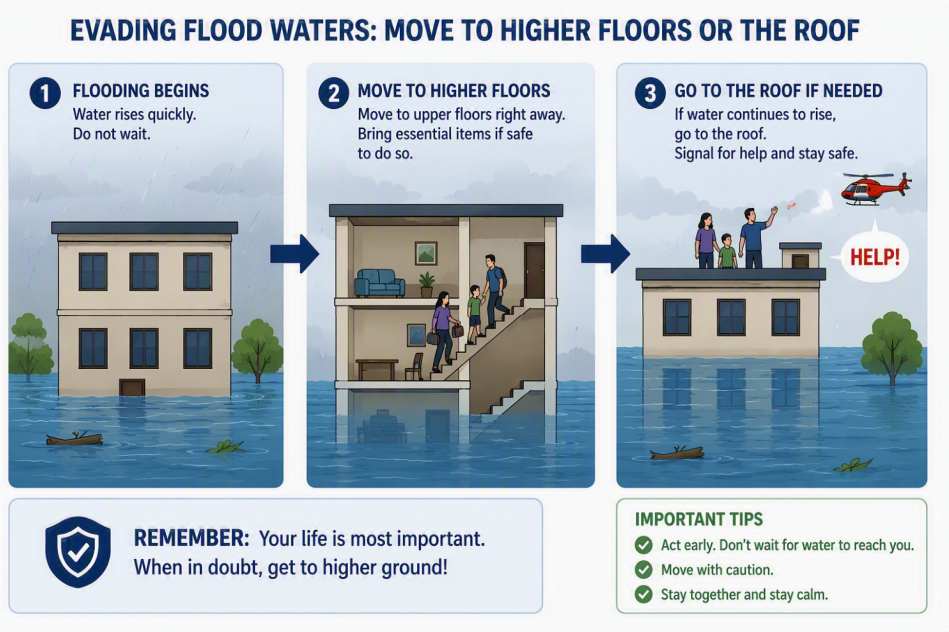


Vertical



EVACUATION

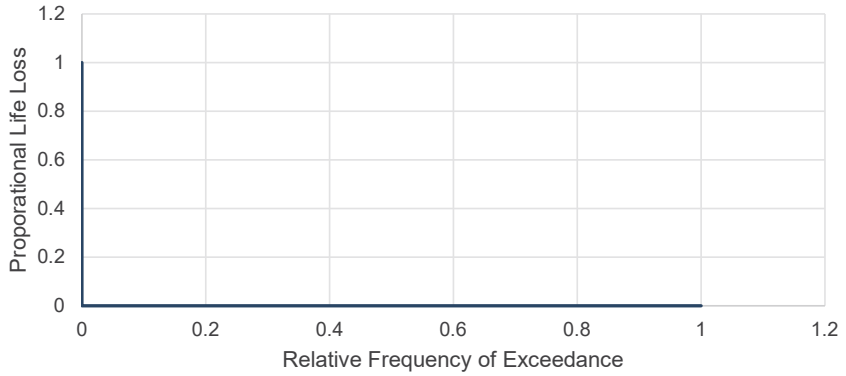
- Vertical
  - Categorize by mobility
  - Move to the highest possible position within the building
- Horizontal
  - In vehicles or on foot
  - On roads
  - Traffic modeling



SHELTER & FATALITY RATE ZONES

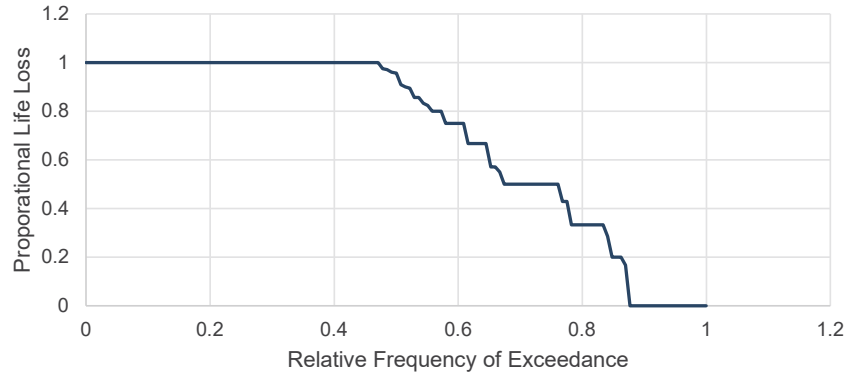
Low Hazard

- Exposed to relatively calm floodwaters, where their stability or the stability of their shelter is not at risk.
- A hazard still exists due to the potential for bad things to happen when people come in contact with water in locations not meant for such an interaction.

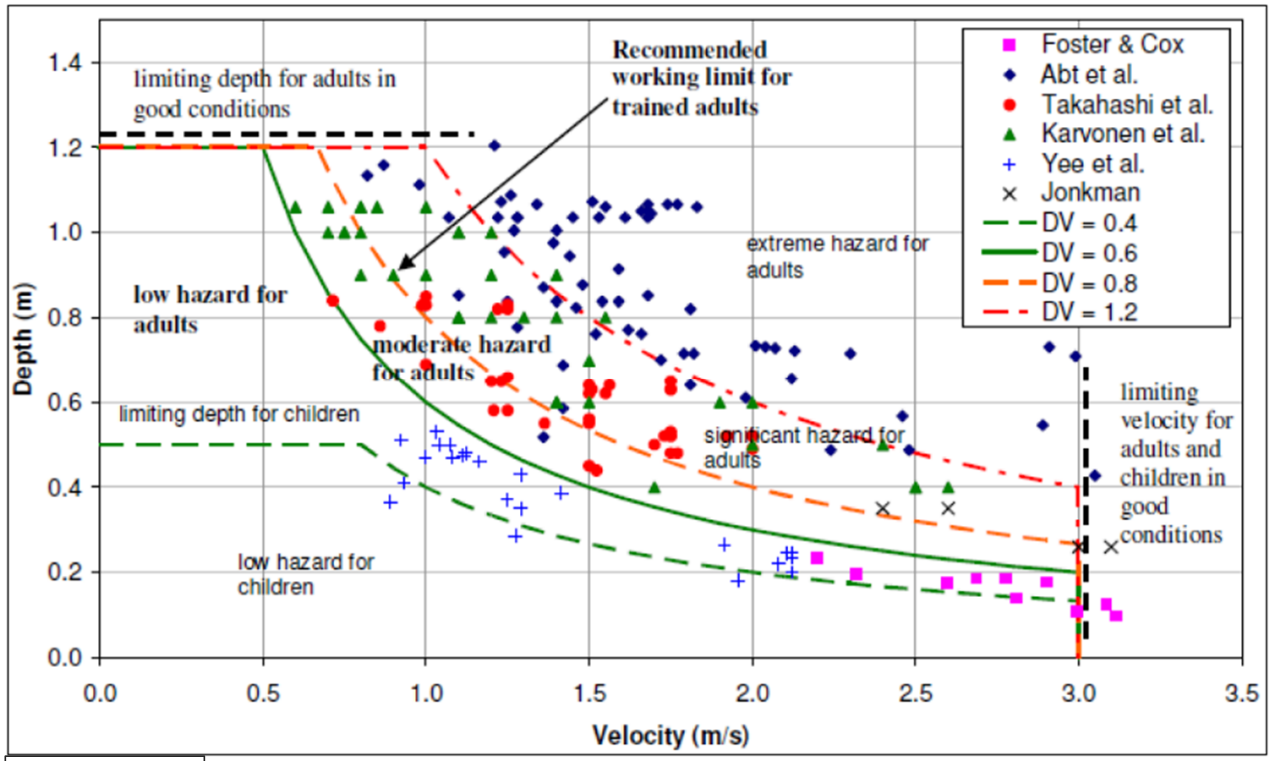


High Hazard

- Exposed to floodwaters that exceed the stability criteria or submergence criteria of the person, vehicle, or structure.
- Victims are typically swept downstream, buried in a collapsed building, or trapped underwater.

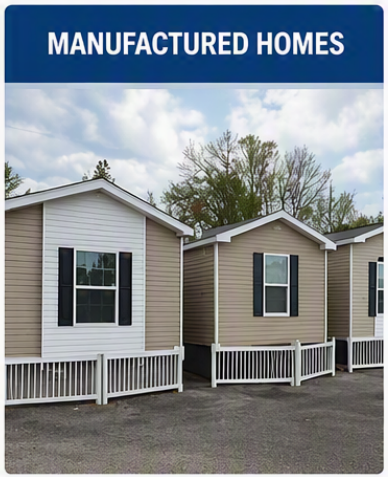


HUMAN STABILITY



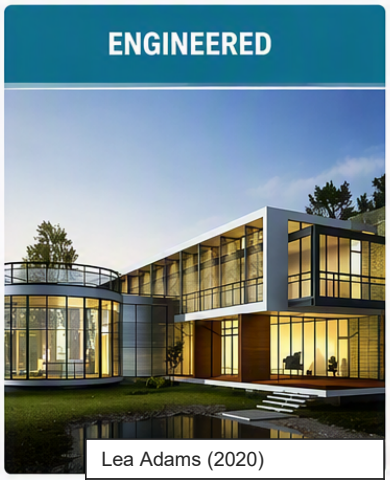
Shand et al., 2014.

STRUCTURE STABILITY

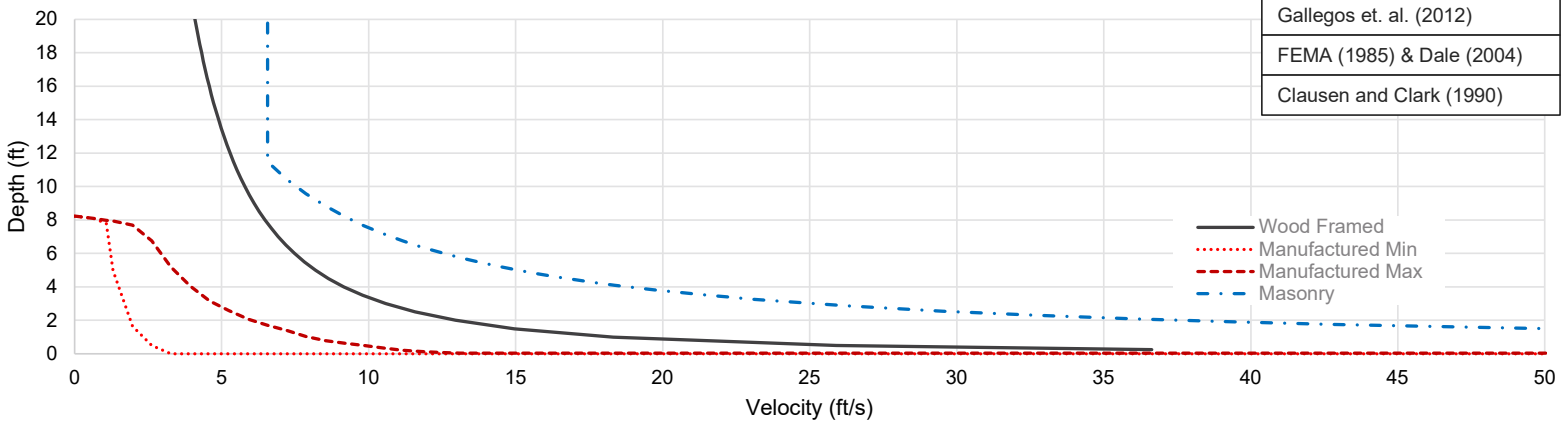






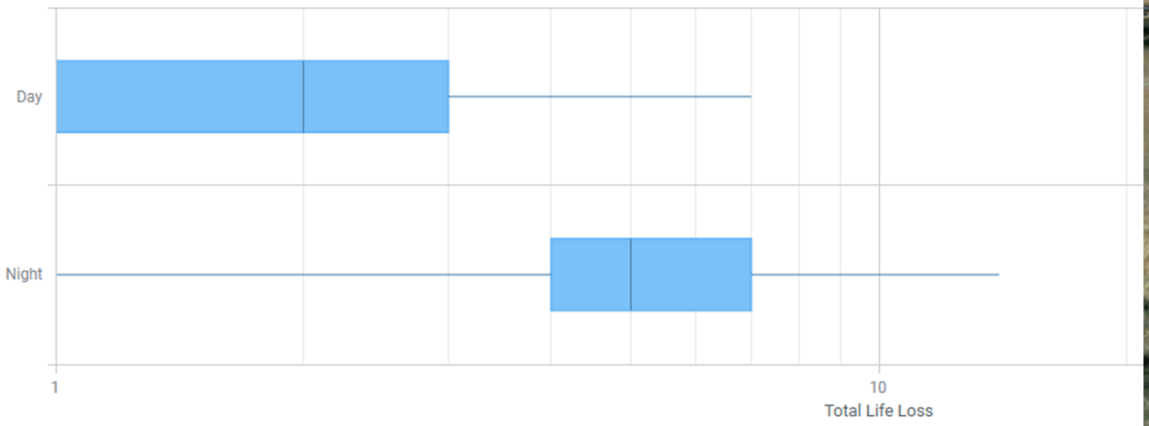


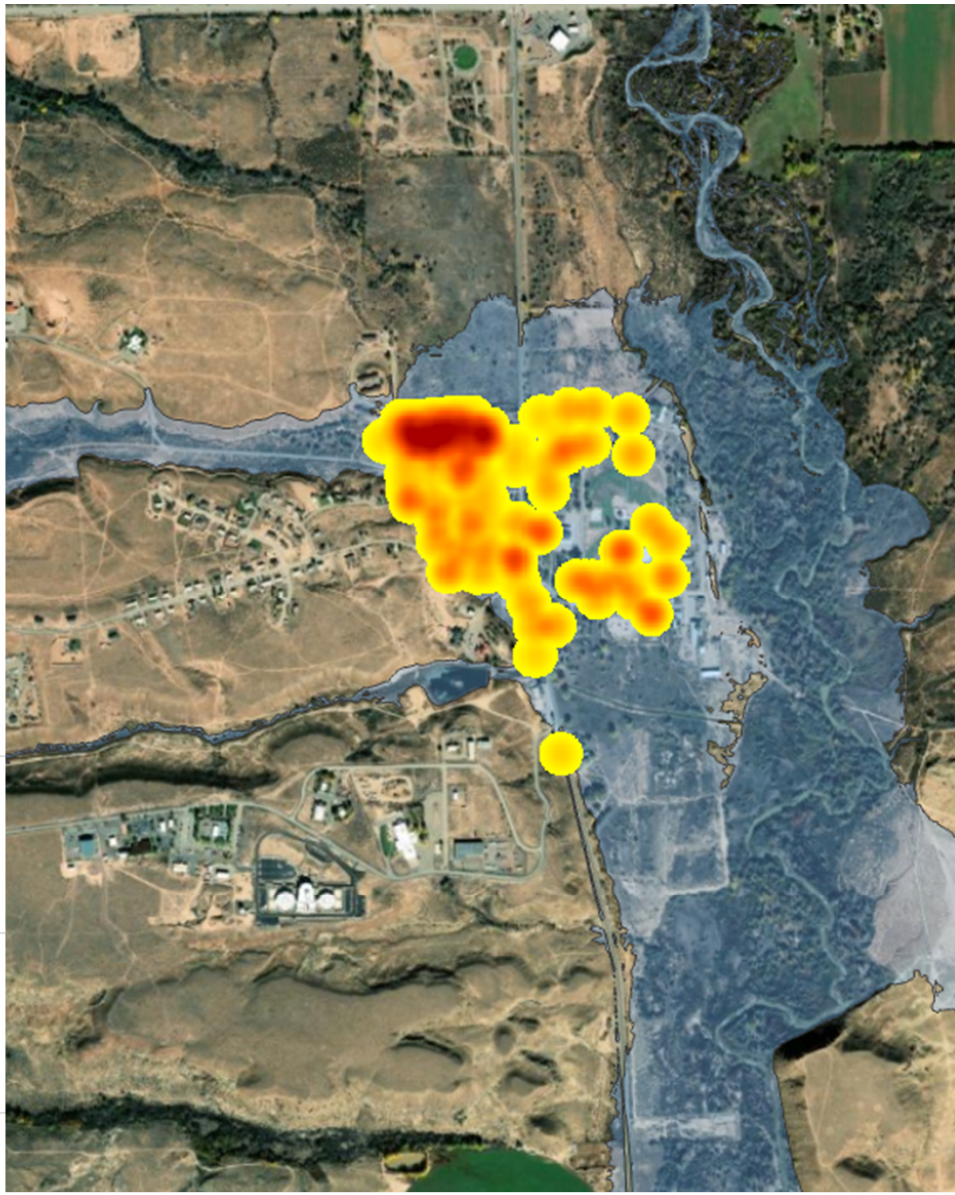
Lea Adams (2020)
Gallegos et. al. (2012)
FEMA (1985) & Dale (2004)
Clausen and Clark (1990)



LIFESIM RESULTS

- PAR
- Exposed Population
- Life Loss
- Fatality Rate
- Locations

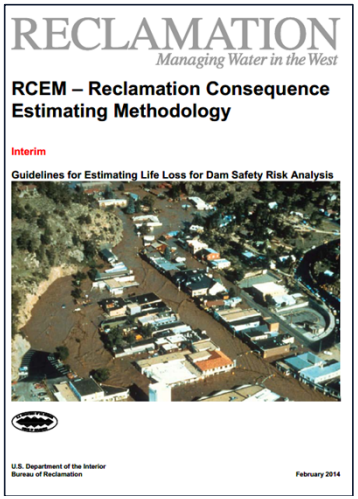




METHODOLOGY COMPARISON

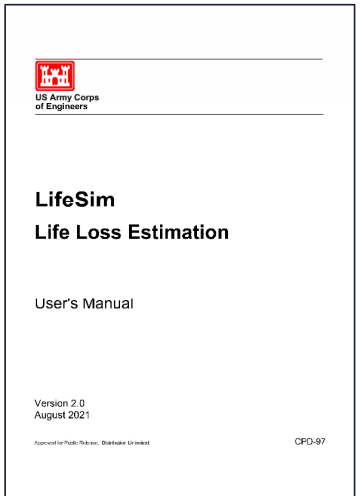
RCEM

- PAR from structures
- Fatality rate based on case histories, warning category, and characteristic DV
- Life loss from PAR x Fatality Rate

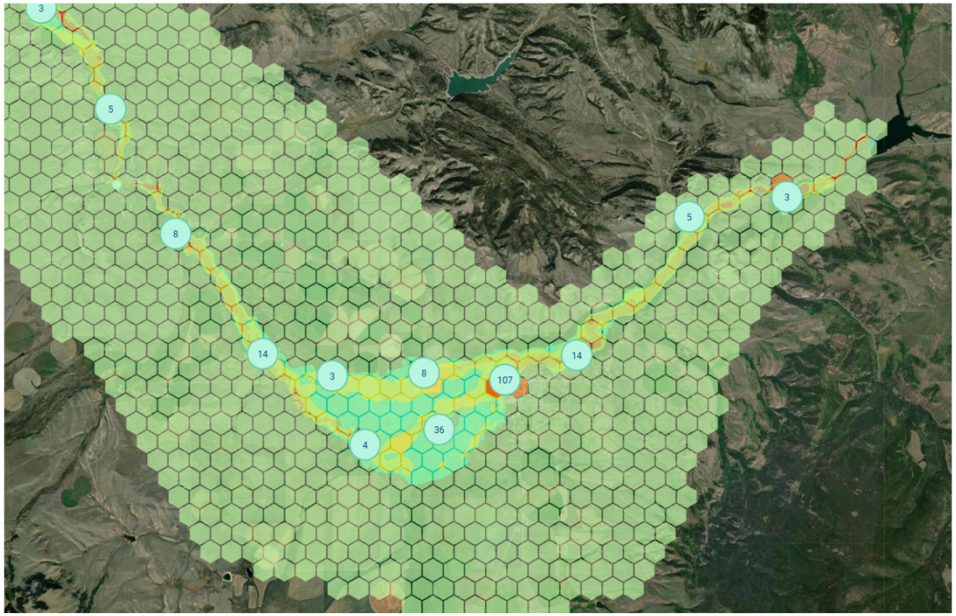


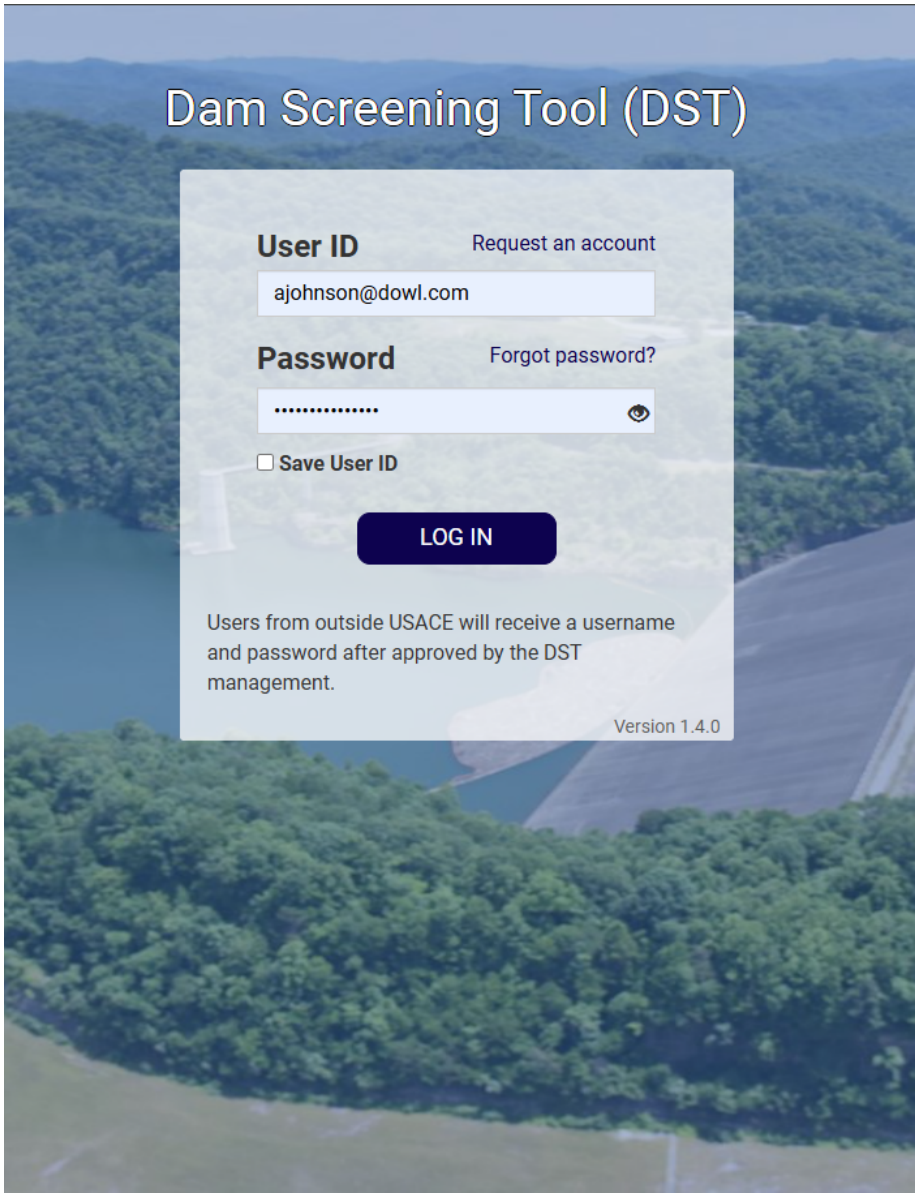
LifeSim

- PAR from structures
- PAR exposed based on warning and evacuation probability
- Life loss from flood severity (stability)



DAM SCREENING TOOL





Questions?

