Reclamation's Life Loss Estimating Methodology (RCEM)

Best Practices in Dam and Levee Safety Risk Analysis

Part C – Consequence Estimating

Last modified June 2017, presented July 2019

US Army Corps of Engineers®

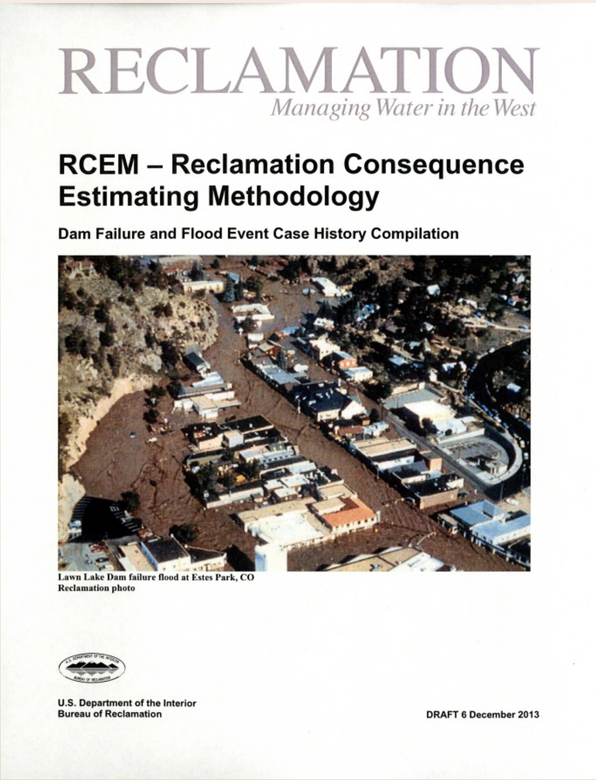
What is RCEM?

- An empirical approach to estimating dam failure life loss.
- Intended for use in dam safety risk analysis
- A revision to Reclamation’s DSO-99-06
- Considers warning time and flooding intensity to be the most critical parameters affecting fatality rate selection

Structure of Documents

- RCEM – Reclamation Consequence Estimating Methodology, Dam Failure and Flood Event Case History Compilation
- RCEM – Reclamation Consequence Estimating Methodology, Guidelines for Estimating Life Loss for Dam Safety Risk Analysis
- RCEM – Reclamation Consequence Estimating Methodology, Examples of Use

RCEM Documents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Managing Water in the West

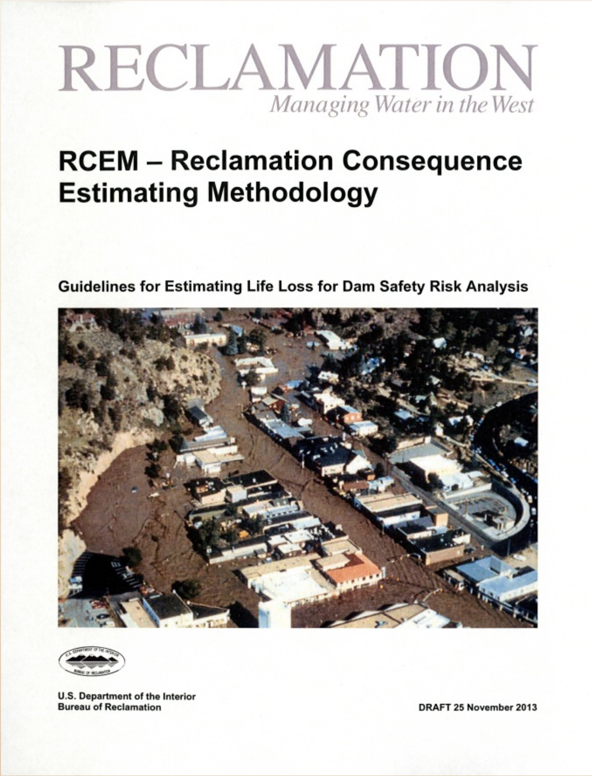
RCEM – Reclamation Consequence Estimating Methodology

Dam Failure and Flood Event Case History Compilation

Lawn Lake Dam failure flood at Estes Park, CO
Reclamation photo

U.S. Department of the Interior
Bureau of Reclamation

DRAFT 6 December 2013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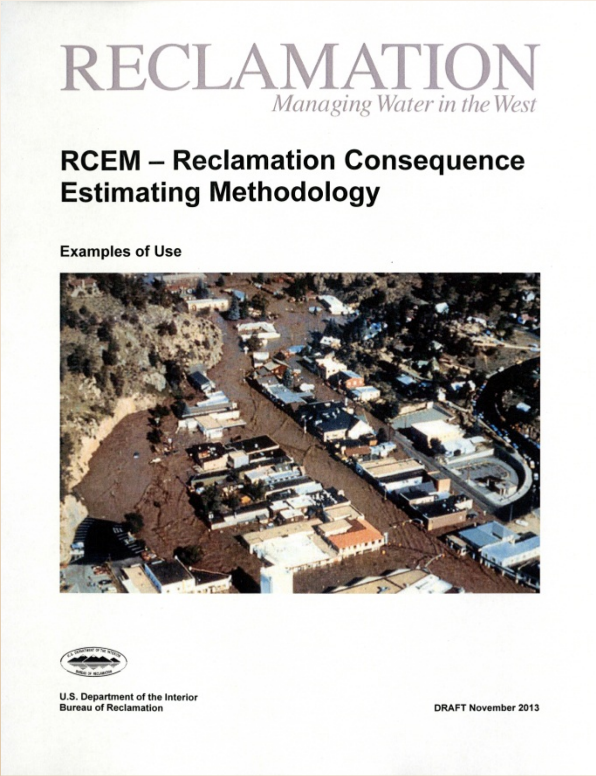
RCEM – Reclamation Consequence Estimating Methodology

Guidelines for Estimating Life Loss for Dam Safety Risk Analysis

U.S. Department of the Interior
Bureau of Reclamation

DRAFT 25 November 2013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RCEM – Reclamation Consequence Estimating Methodology

Examples of Use

U.S. Department of the Interior
Bureau of Reclamation

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Rationale for RCEM

- RCEM is based on about 60 case histories (including 40 case histories used to develop DSO-99-06); case histories were screened for data quality
- Case histories provided limited to no data on evacuation rates; but evacuation can be considered indirectly in selection of fatality rates
- RCEM encourages the use of case history data to select and support fatality rates

Rationale for RCEM

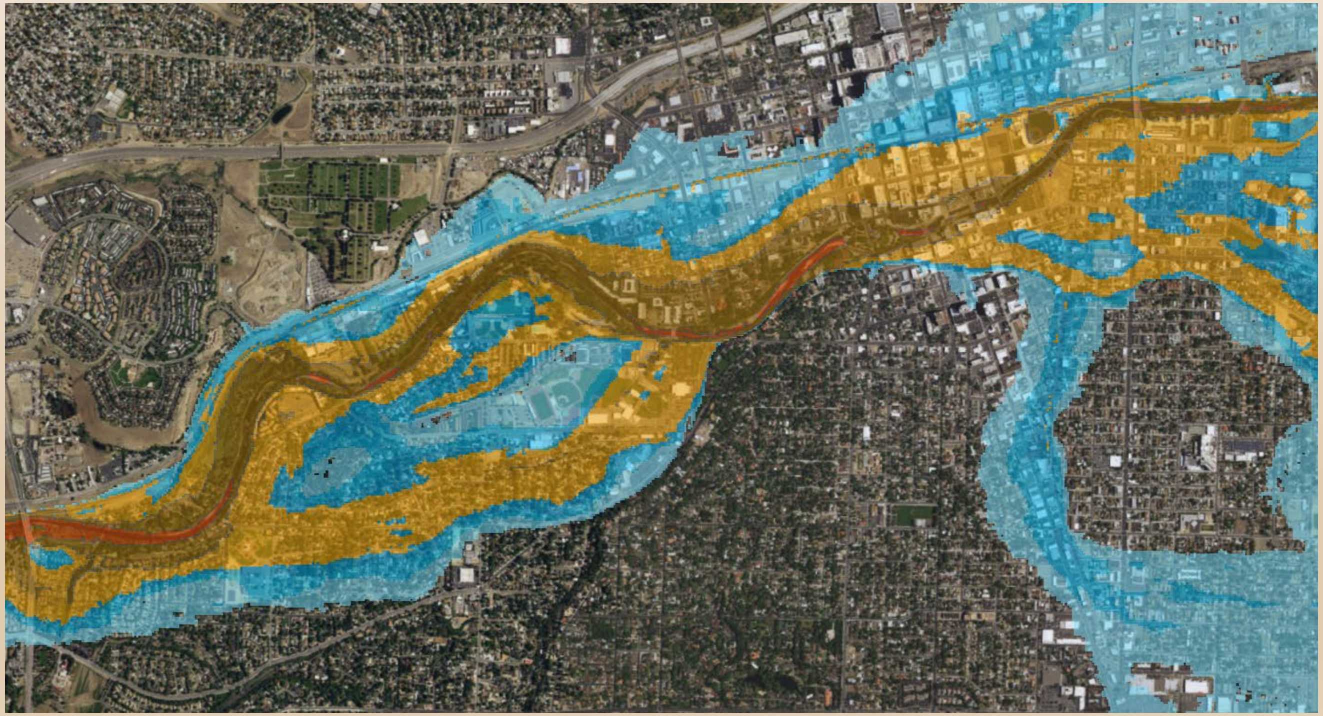
- RCEM is empirical-based, and relies on data from actual cases of dam breach and natural flood events

- RCEM makes use of flooding intensity data, in the form of DV and uses two warning time categories to aid in the estimation of fatality rates

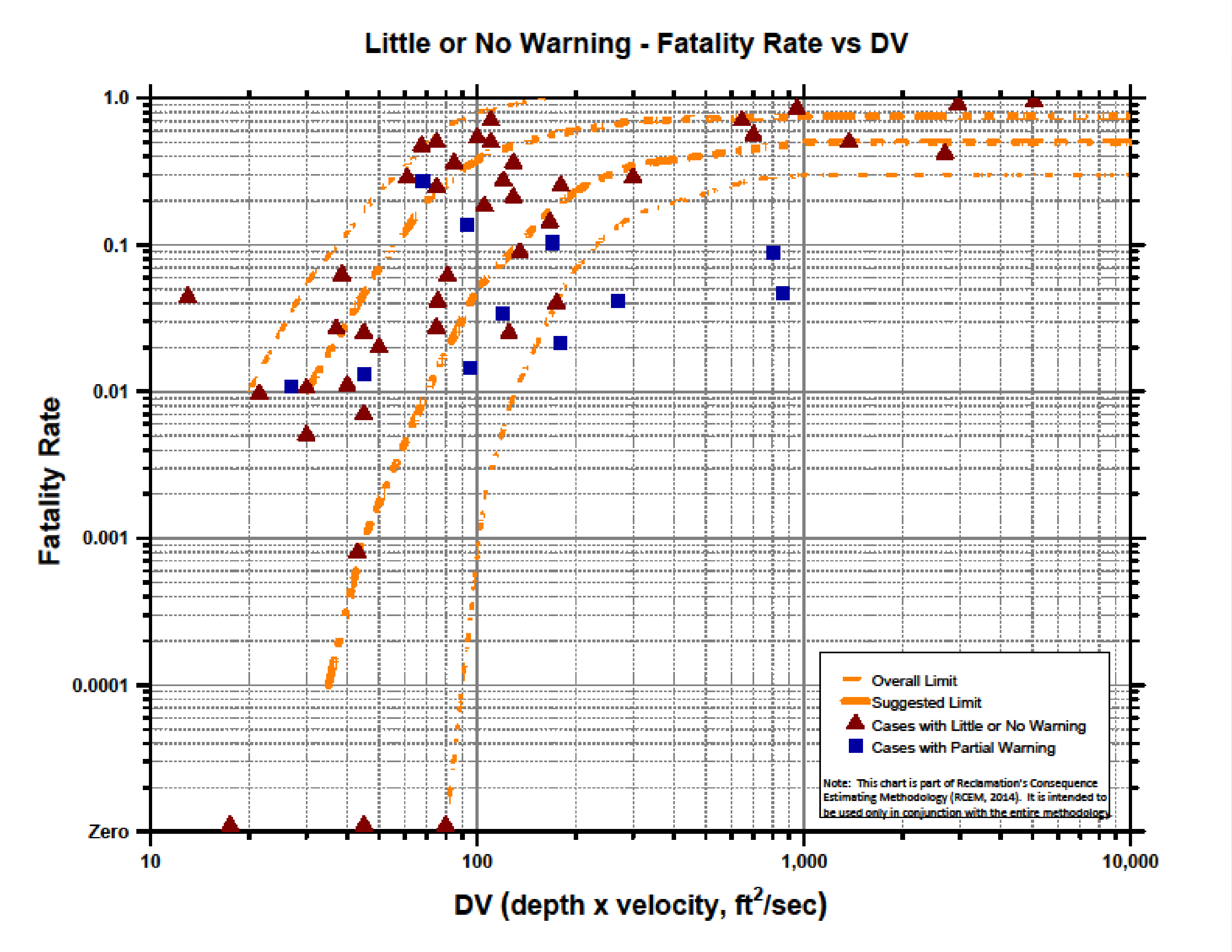
- RCEM develops a fatality rate based on these two variables and applies it to the pre-evacuation Population at Risk (PAR)

What is DV ?

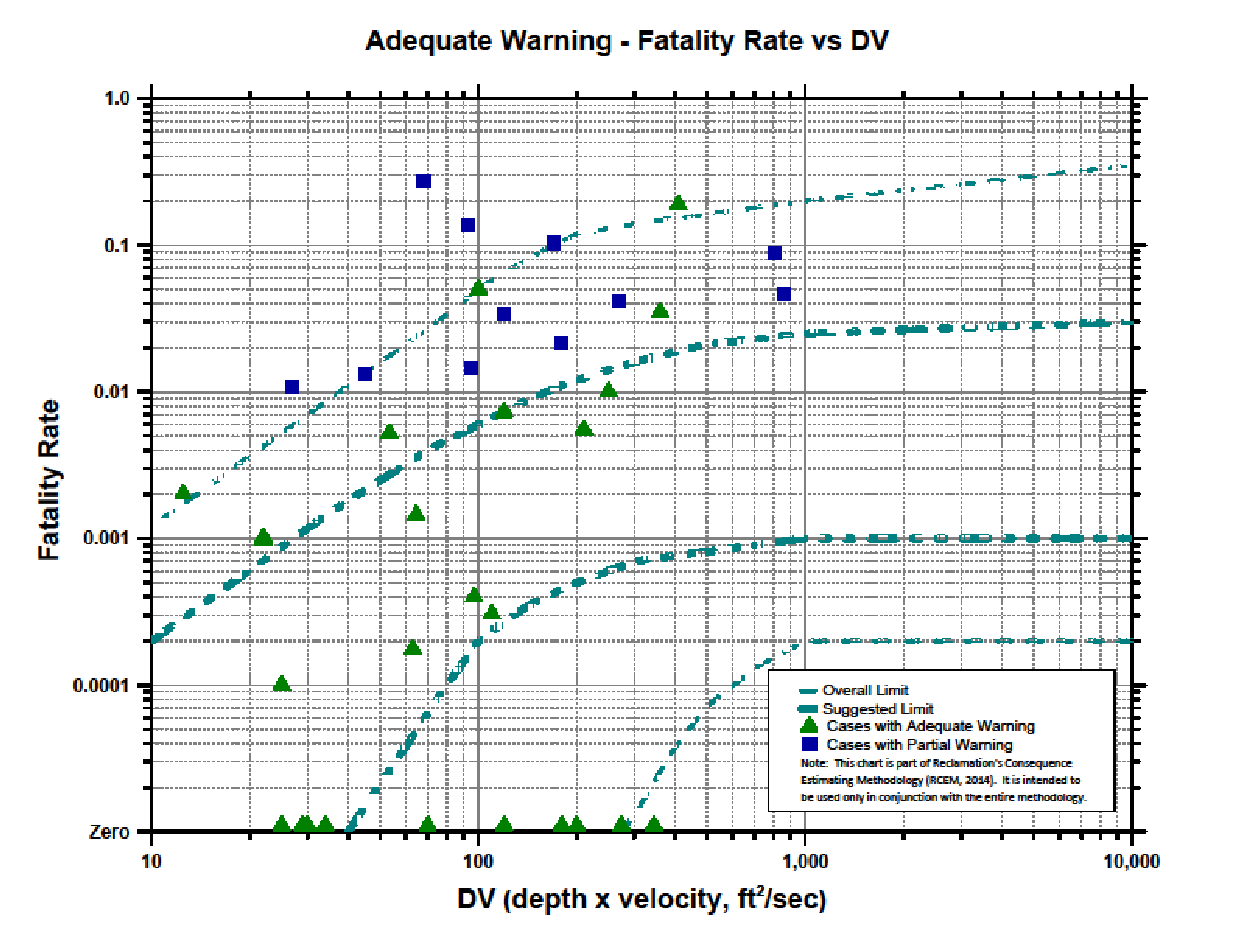
- DV is the maximum flooding depth multiplied by the maximum flood velocity, which provides a numeric measure of the intensity of flooding



Fatality Rates for Little or No Warning RCEM 2014



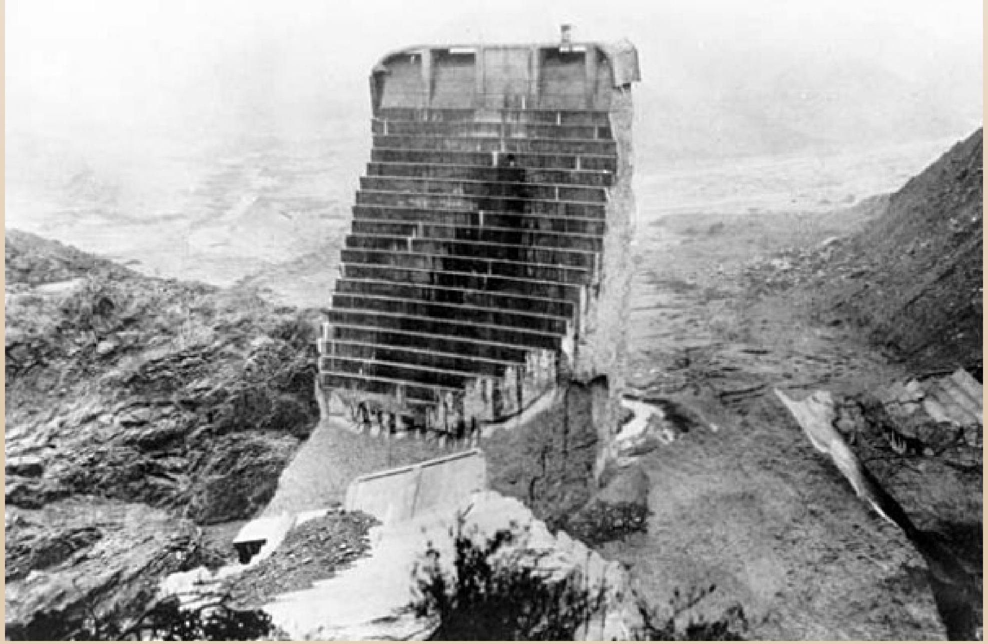
Fatality Rates for Adequate Warning RCEM 2014



RCEM Steps for Estimating Life Loss

1. Select dam failure scenarios (e.g. sunny day, flood, etc.) corresponding to dam potential failure modes

- **Static**
- **Hydrologic**
- **Seismic**



RCEM Steps for Estimating Life Loss

2. Select appropriate time categories (e.g. day/night, seasonal, weekend/weekday, etc.)

This can be fully developed such as summer day/summer night, winter day/winter night, or might be simplified down to “most optimistic” and “least optimistic”.

Estimates should reflect representative conditions for the entire year

Time Categories

- Time of day - Typically, more fatalities have occurred during night time flood events, due to people sleeping, darkness, decreased ability to spread warning and a slower evacuation response.

- Weekday/Weekend - Recreational areas such as campgrounds, or along rivers where fishing or boating are popular, will see higher PAR number on weekends

- Seasonal Variation - Recreational (transient) PAR numbers may vary widely between summer and winter months.

RCEM Steps for Estimating Life Loss

3. Review/evaluate flood inundation mapping and define appropriate reaches or areas

The inundation study is typically the basis for the life loss estimate

Inundation mapping considerations – are available scenarios appropriate for the potential failure modes being evaluated?

Factors which affect the appropriateness of the inundation study

- Breach scenario outflow volumes should be similar – is the inundation study based on PMF overtopping and you are trying to evaluate a static failure at normal full pool?

- Breach parameters – Is your inundation study based on breach parameters that are significantly different than what will be assumed for the risk analysis PFM?

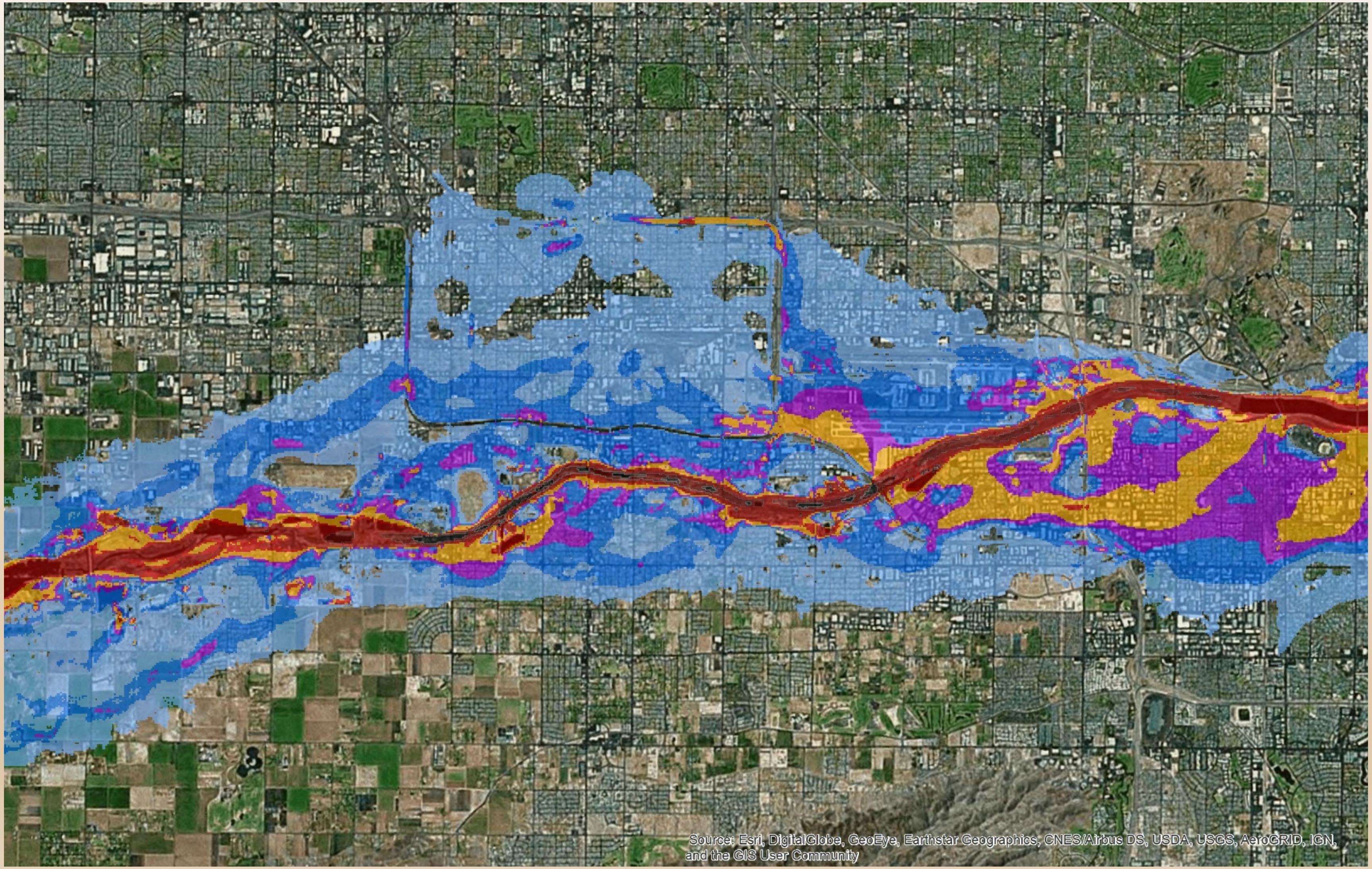
RCEM Steps for Estimating Life Loss

4. Estimate flood intensity range (i.e. DV range) for the flooded areas. Some towns/river reaches may include multiple ranges of DV. Justify the estimates.

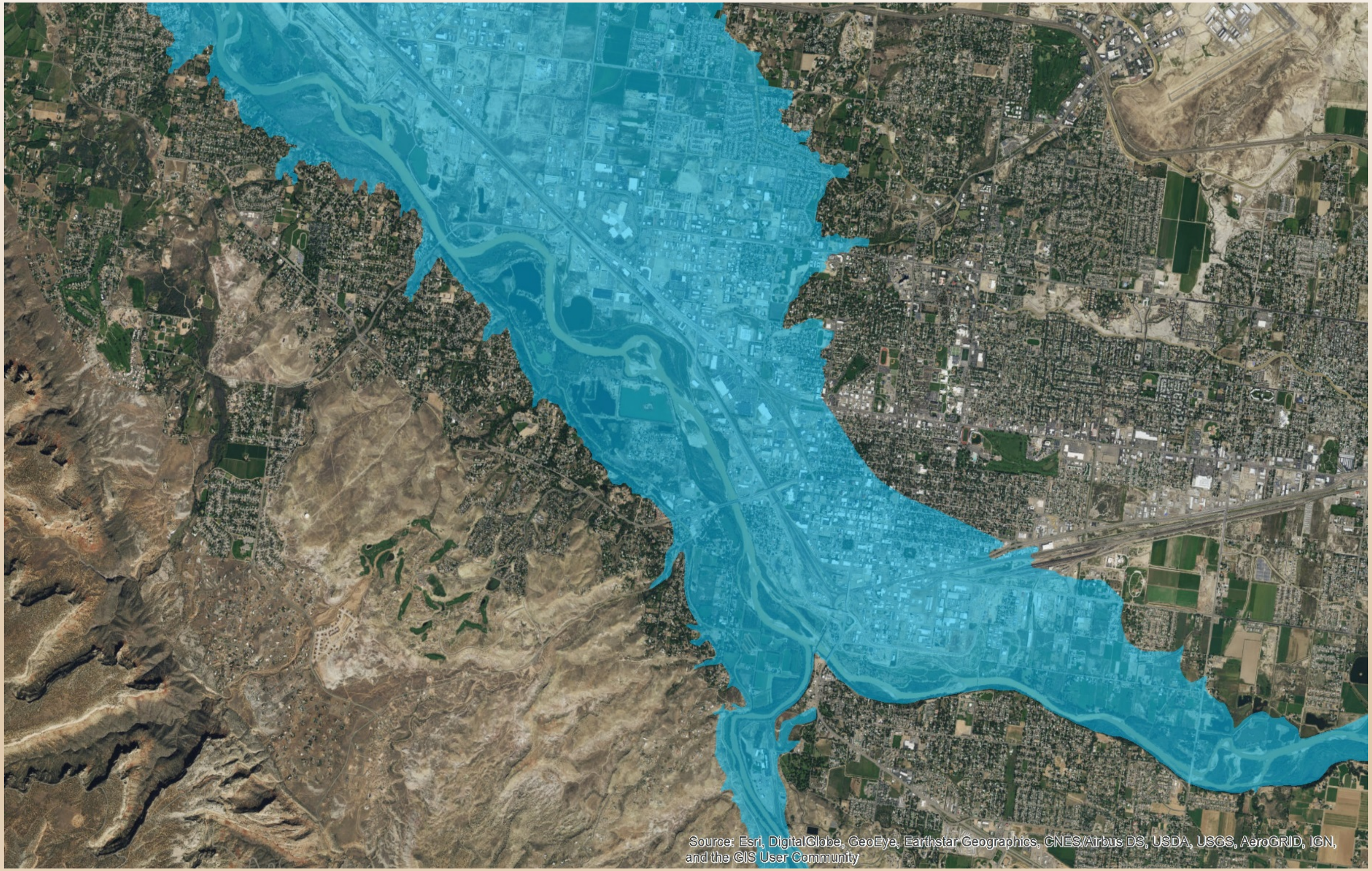
Studies with 2D modeling are best.

1D inundation studies require more interpretation.

2D DV – Well defined DV classes



1D DV – more interpretation required (and lower confidence!)



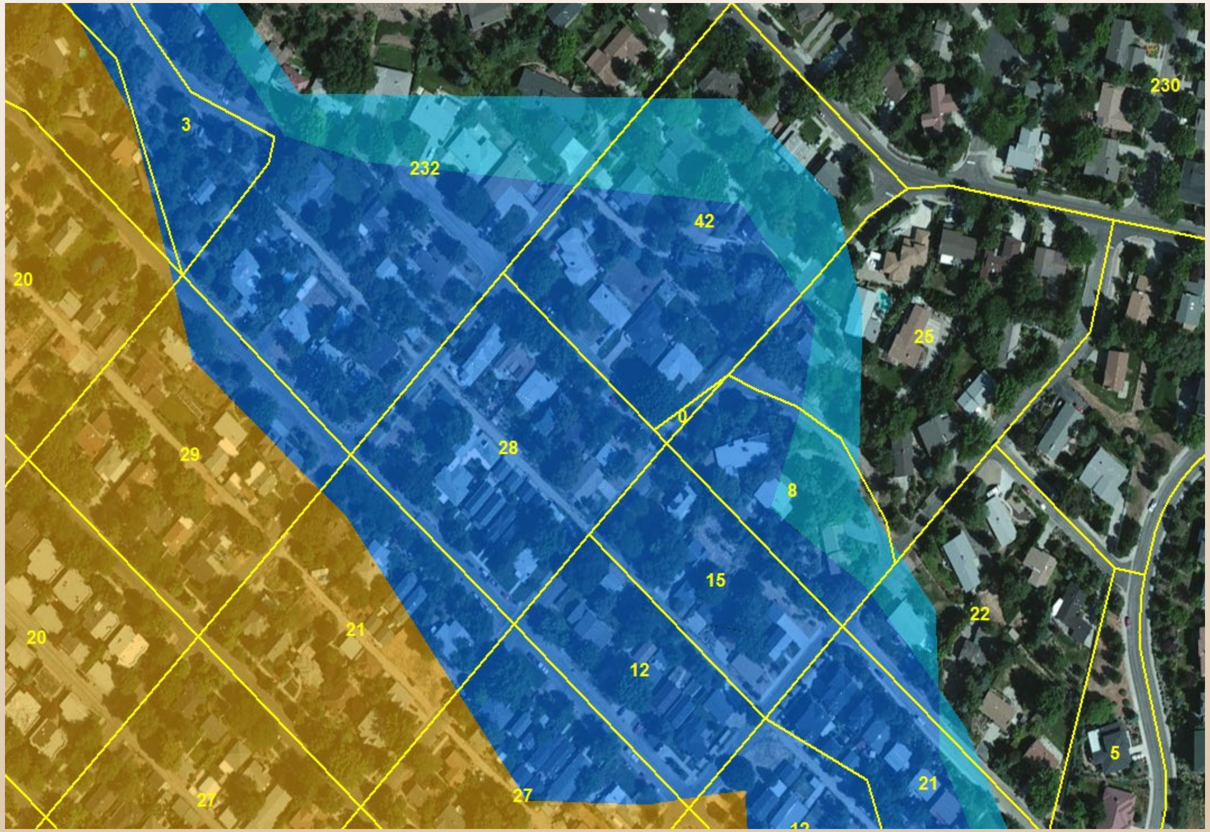
RCEM Steps for Estimating Life Loss

5. Estimate the population at risk (PAR) within each reach. Justify the estimates.

PAR is almost always residential PAR and recreational PAR.

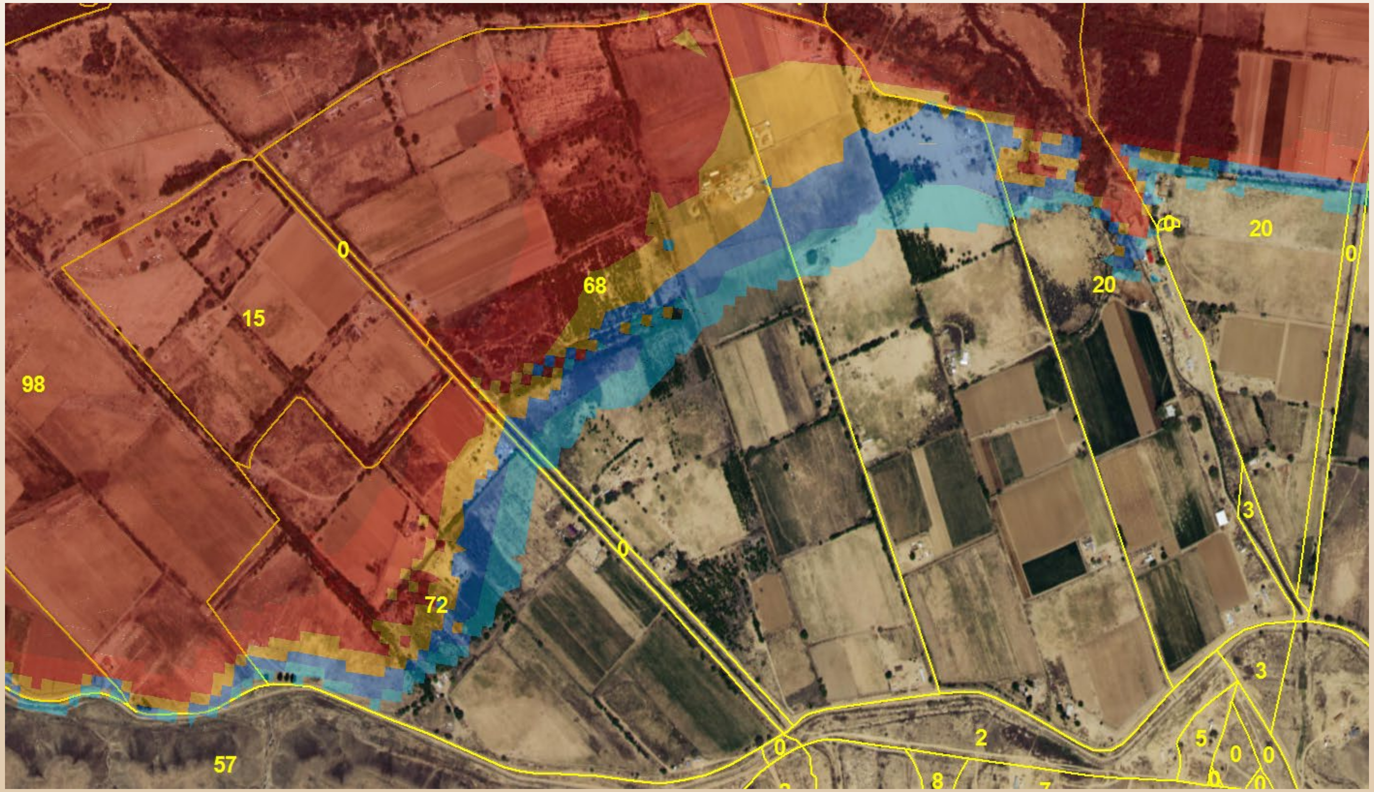
Special cases may require estimation of PAR for other conditions. Examples are: schools, industrial areas, major highways.

Dealing with partially inundated census blocks



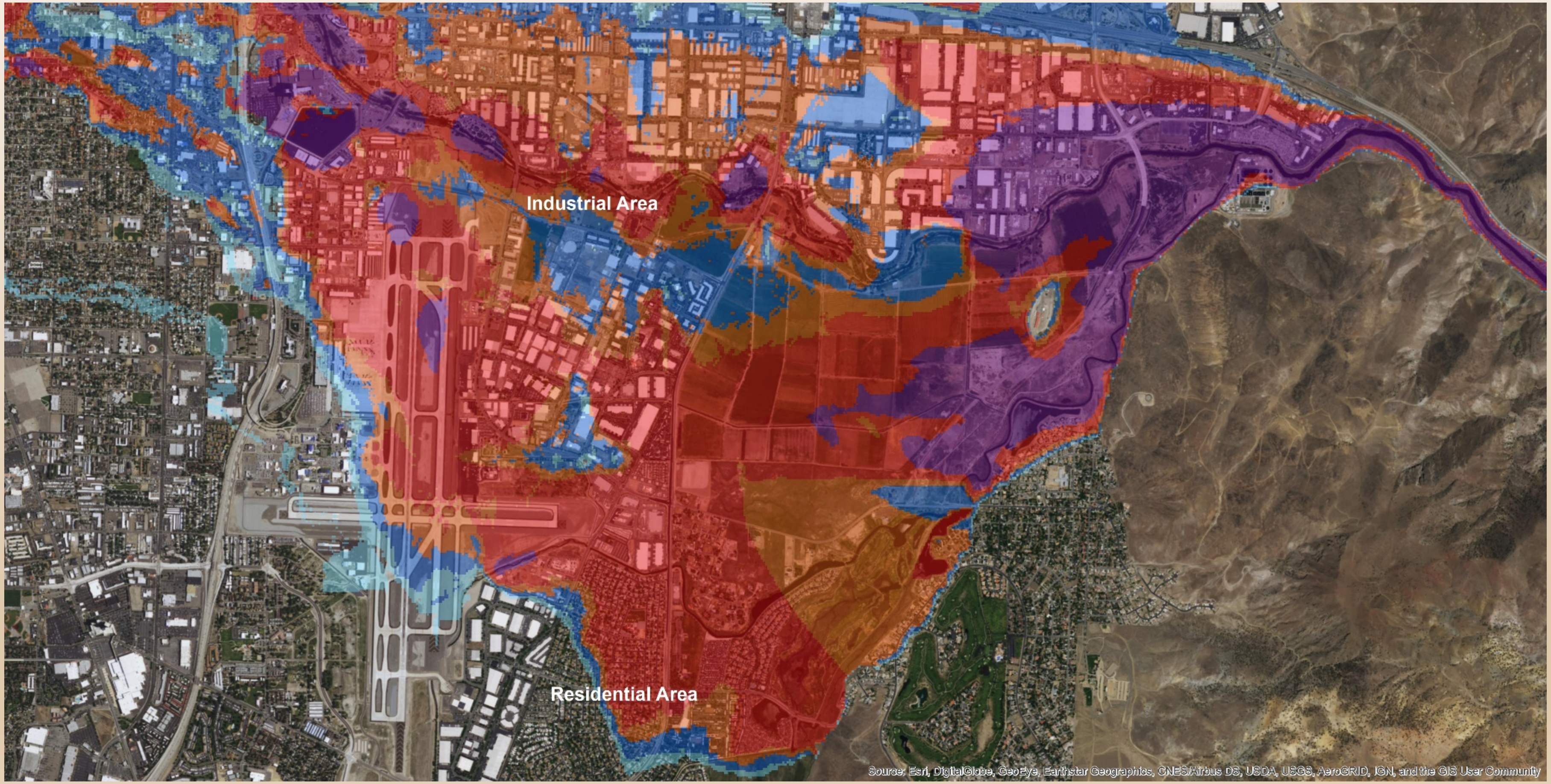
- Urban areas, small census blocks, uniform PAR distribution, use fractional percentages

Dealing with partially inundated census blocks



- Rural areas, larger census blocks, non-uniform PAR distribution, count houses and apply avg. household size multipliers

Non-typical PAR example – Large Industrial Area and Airport



RCEM Steps for Estimating Life Loss

6. Estimate when dam failure warnings would be initiated . Estimate the warning time category for flooded areas (e.g. little to no warning, adequate warning, or between the two). Justify the estimates.

- Consider the influence of flood wave travel time on warning time.

Warning and Evacuation Assumptions

Consider and make assumptions related to the following events:

- Detection of threat
- Verification (dam failure or impending failure must be verified)
- Notification – issuance of warning (both formal and informal)
- Mobilization/Evacuation – How likely is effective evacuation?

Warning and Evacuation Assumptions

- Build consensus of assumptions through team discussion.
- Consult with experts. Federal and local emergency managers
- Review case histories. Look for relevant cases which may influence assumptions.

Weighted Estimates of Warning/Evacuation

Reach No.	DV	Warning	Warning probability	Residential PAR	Recreational PAR	fatality rate low	fatality rate high	fatalities low	fatalities high
1	1500	some to none	0.8	25	3	0.35	0.7	7.8	15.7
1	1500	adequate	0.2	25	3	0.005	0.028	0.0	0.2
2	1000	some to none	0.8	60	15	0.3	0.6	18.0	36.0
2	1000	adequate	0.2	60	15	0.0025	0.022	0.0	0.3
3	200	some to none	0.6	1,085	0	0.15	0.5	97.7	325.5
3	200	adequate	0.4	1,085	0	0.002	0.01	0.9	4.3
3	75	some to none	0.6	1,725	0	0.005	0.05	5.2	51.8
3	75	adequate	0.4	1,725	0	0.0005	0.0025	0.3	1.7
3	50	some to none	0.6	1,090	0	0	0.005	0.0	3.3
3	50	adequate	0.4	1,090	0	0	0.0005	0.0	0.2
4	160	some to none	0.5	3,675	0	0.1	0.55	183.8	1010.6
4	160	adequate	0.5	3,675	0	0.001	0.008	1.8	14.7
4	50	some to none	0.5	8,550	0	0.003	0.06	12.8	256.5
4	50	adequate	0.5	8,550	0	0.0004	0.002	1.7	8.6
4	25	some to none	0.5	4,275	0	0	0.006	0.0	12.8
4	25	adequate	0.5	4,275	0	0	0.00035	0.0	0.7
5	160	some to none	0.5	3,563	0	0.075	0.4	133.6	712.6
5	160	adequate	0.5	3,563	0	0.0005	0.006	0.9	10.7
5	75	some to none	0.5	15,688	0	0.002	0.03	15.7	235.3
5	75	adequate	0.5	15,688	0	0.0003	0.001	2.4	7.8
5	25	some to none	0.5	12,500	0	0	0.003	0.0	18.8
5	25	adequate	0.5	12,500	0	0	0.0003	0.0	1.9
Totals								483	2730

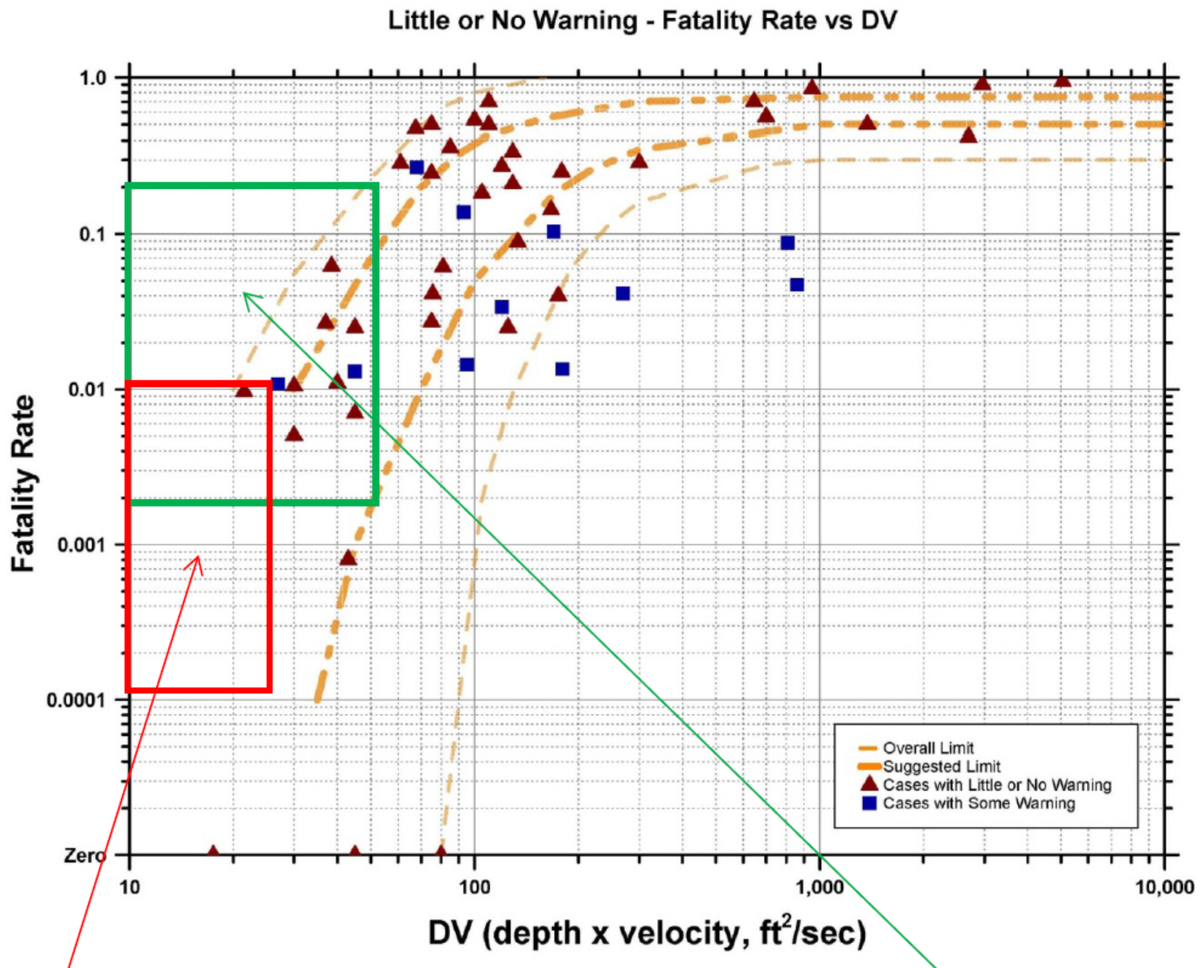
RCEM Steps for Estimating Life Loss

7. For each PAR reach, estimate an appropriate fatality rate range based on flooding intensity, warning time and other considerations. Justify the estimates.

Considerations for Selecting Fatality Rates

- Consider vulnerability of PAR
  - Sheltered in homes versus camping in tents or driving in autos
  - Knowledge of threat (locals versus tourists, warning adequacy)
  - Demographics (elderly, school children, reluctants)
- Amount of warning
  - Many hours or days in some cases versus 60 minutes
  - Adequacy of emergency management capabilities
  - Constraints to evacuation
- Adequacy of inundation model
  - Appropriate for the PFM being considered
  - 1D versus 2D
  - Reasonableness of breach parameters

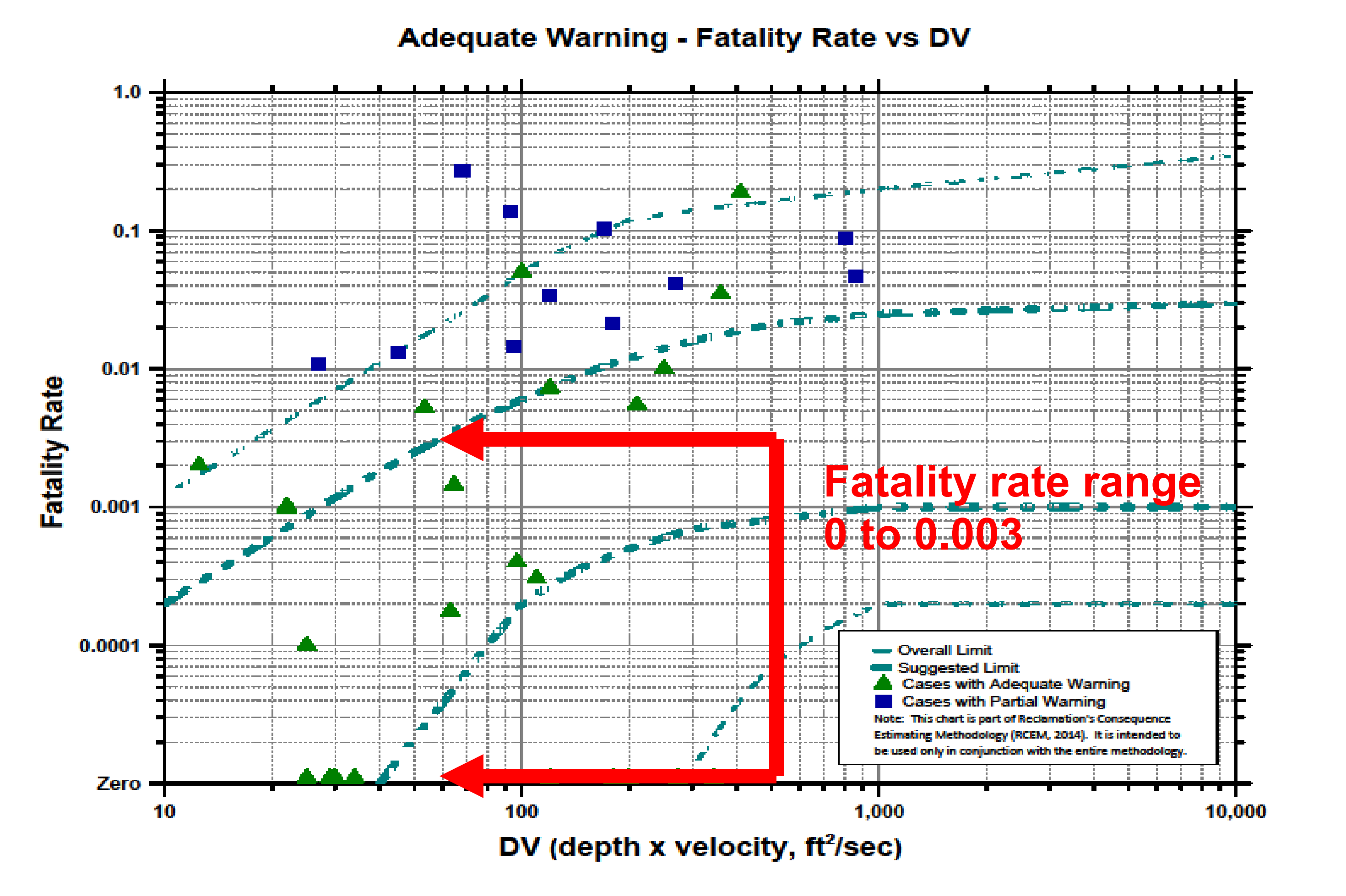
Example of fatality rate selection



No warning case for permanent residents
DV estimated to range from 5 to 25 ft^2/s
Fatality rate estimated to range from 0.0001 to 0.01
"Suggested Limits" generally assumed for fatality rate

No warning case for automobile PAR
DV estimated to range from 10 to 50 ft^2/s
Fatality rate estimated to range from 0.002 to 0.2
Upper portion of curve assumed for fatality rate
(given vulnerability of automobiles in flood)

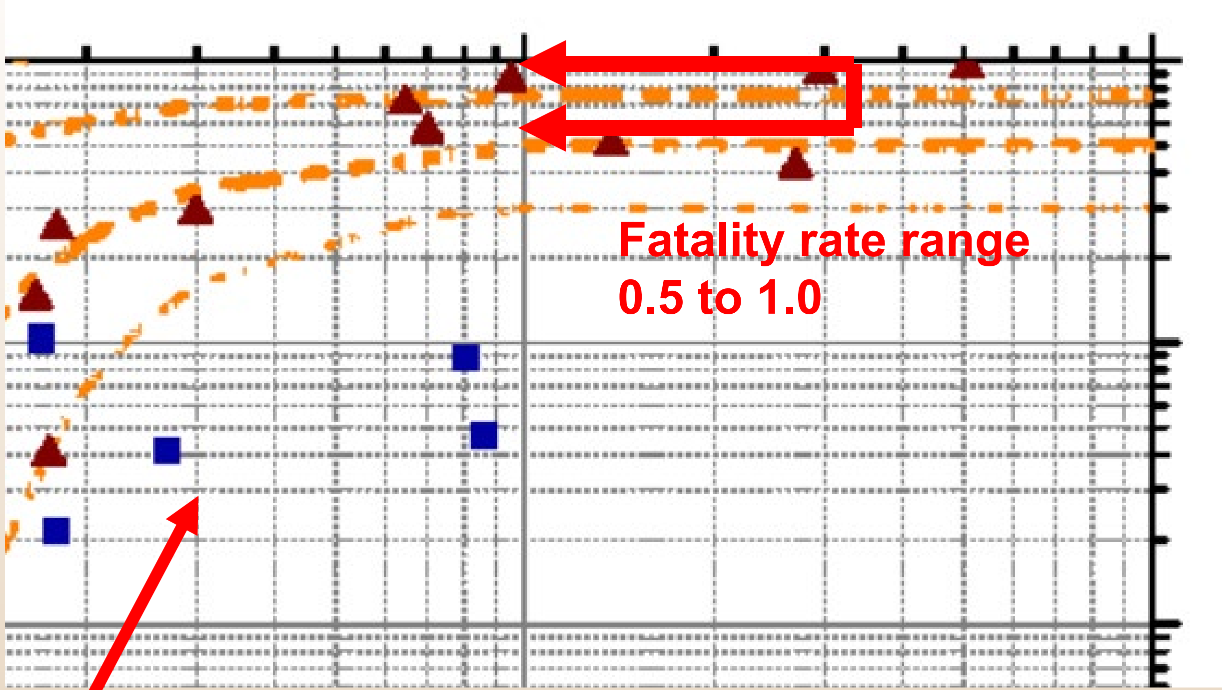
Example of fatality rate selection

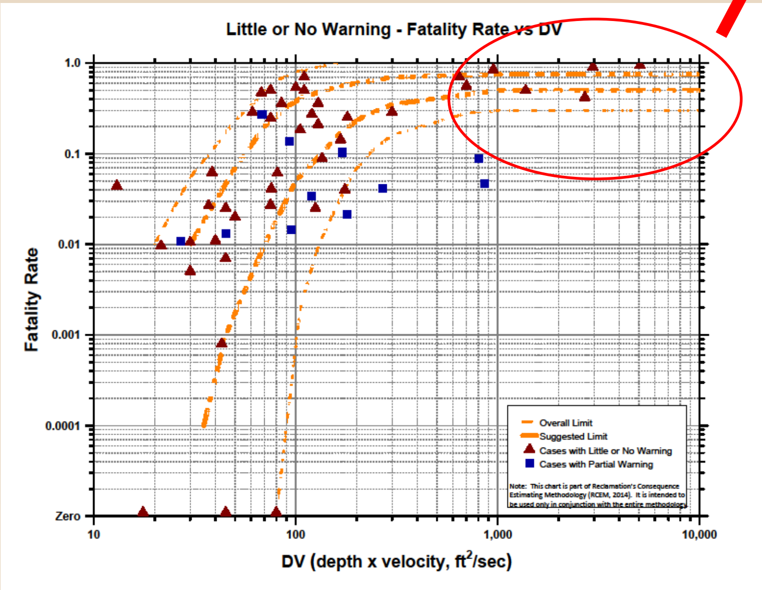


PAR is located very far downstream with more than 24 hours flood wave travel time

DV is 60 ft^2/s

Fatality Rate Selection Example - little to no warning





Fast seismic scenario, community located 1 mile downstream, nighttime conditions

DV = 1,000 ft^2/s

Use middle of suggested range to overall upper limit fatality rates

RCEM Steps for Estimating Life Loss

8. Estimate life loss range for each PAR reach. Sum the life loss estimates for each PAR to get the total estimated life loss range. Estimate life loss range for different dam failure scenarios.

Best done using a spreadsheet

RCEM Steps for Estimating Life Loss

9. Evaluate how uncertainties and variability affect overall range of life loss estimates. Perform sensitivity studies if needed.

Sensitivity study can evaluate:

Variations in breach parameters, including breach width, depth and formation time

Variations in initial reservoir levels

Variations in reservoir inflow conditions

Variations in DV

Variations in assumed warning time

Other…

RCEM Steps for Estimating Life Loss

10. Build the case for the life loss estimates by documenting all assumptions and references used. Discuss confidence in the life loss estimates.

Document in writing. Include all considerations leading to assumptions: team discussions, comparison to relevant case histories, knowledge of downstream areas, analysis of dam's response to loading conditions, community emergency plans and emergency response systems, downstream topography, etc.

Items which may affect confidence in the life loss estimates

- Flood inundation study:
  - Overall methodology and results (1D vs. 2D)
  - Failure scenario
  - Breach Parameters
  - Terrain data used for analysis
  - Are there large amounts of uncertainty regarding DV estimates?

Items which may affect confidence in the life loss estimates

- PAR estimate:

Was Tessel evaluation used as a basis?

Are there significant numbers of non-residential PAR that were not accounted for?

Could PAR have been double-counted in places?

Items which may affect confidence in the life loss estimates

- Warning and evacuation assumptions:

  Could a better understanding be developed through consulting with downstream community officials?

  Would a site visit improve understanding?

Considerations when using RCEM 2014

- Compare your dam to the case histories
- Use judgment
- Recognize that DV values may vary
- Employ sensitivity studies
- Portray life loss as a range
- Utilize a team approach

RCEM Documents

Available on Reclamation Internet:

- http://www.usbr.gov/ssle/damsafety/references.html