State of Oklahoma OWRB WATER RESOURCES BOARD the water agency | DAM SAFETY PROGRAM

Dam Breach Modeling and OWRB Dam Regulations

GREAT SALT PLAINS RESERVOIR
Alfalfa County

Why do dams fail?

- Overtopping due to inadequate spillway design, debris blockage of spillways, and settlement of dam crest (34%)
- Foundation defect including settlement and slope instability (30%)
- Piping or internal erosion due to animal burrows, woody vegetation, and seepage around hydraulic structures (20%)

Overtopping of Tumwater Falls Dam, Washington

Hole & seepage of a dam in Oklahoma City

Dam Safety History

1972 - National Dam Inspection Act

Passed as result of a series of dam incidents, including:

Buffalo Creek Dam, West Virginia (125 deaths, $50 million)

Canyon Lake Dam, South Dakota (230 deaths, $100 million)

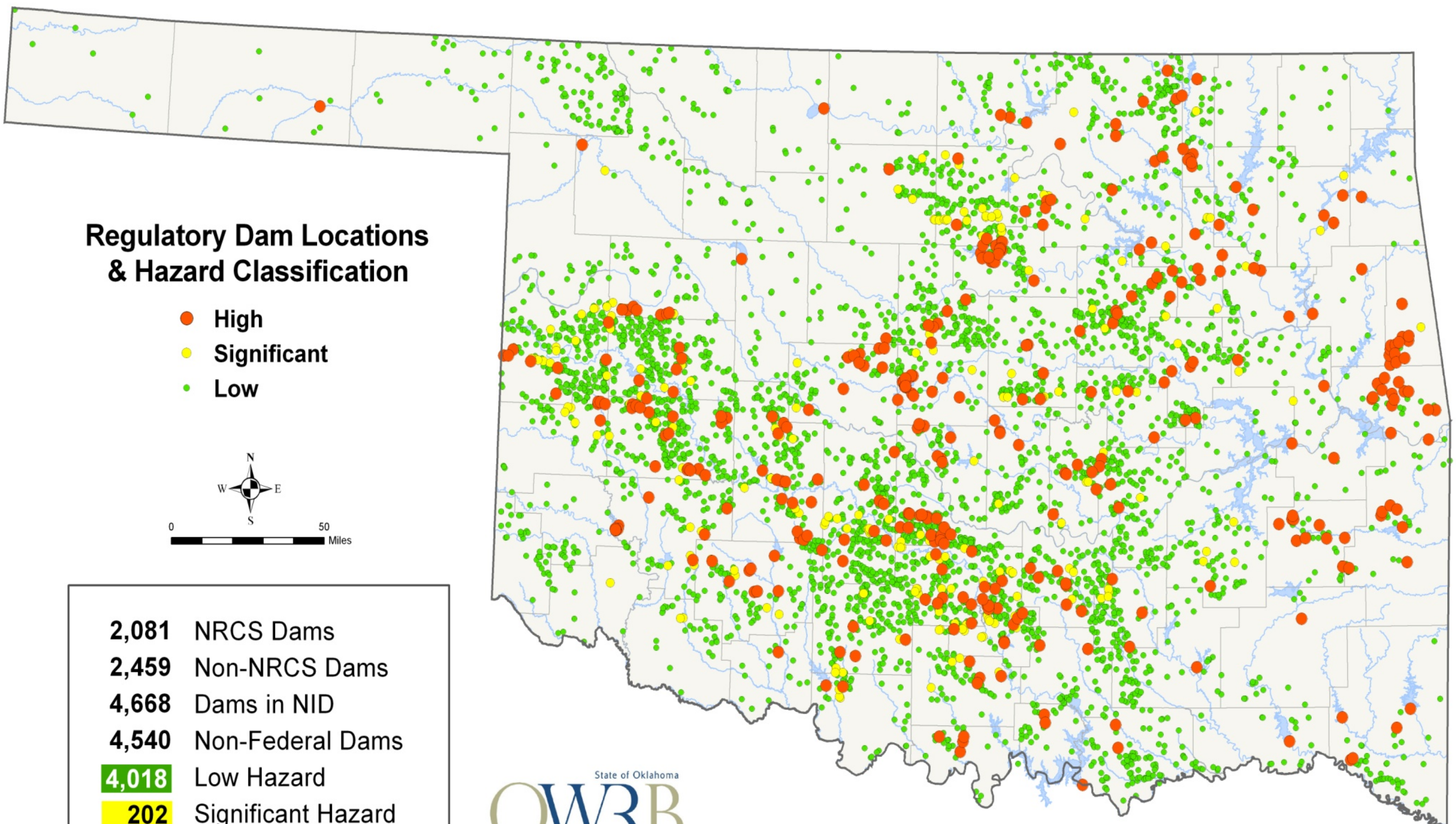
Van Norman Dam, California (near failure threatened 80,000 residents)

1973 - OWRB Dam Safety Rules

1992 - Oklahoma Dam Safety Act

Dam Safety Mission:

Ensure the proper construction, operation, and maintenance of Oklahoma's dams



2,081	NRCS Dams
2,459	Non-NRCS Dams
4,668	Dams in NID
4,540	Non-Federal Dams
4,018	Low Hazard
202	Significant Hazard
320	High Hazard

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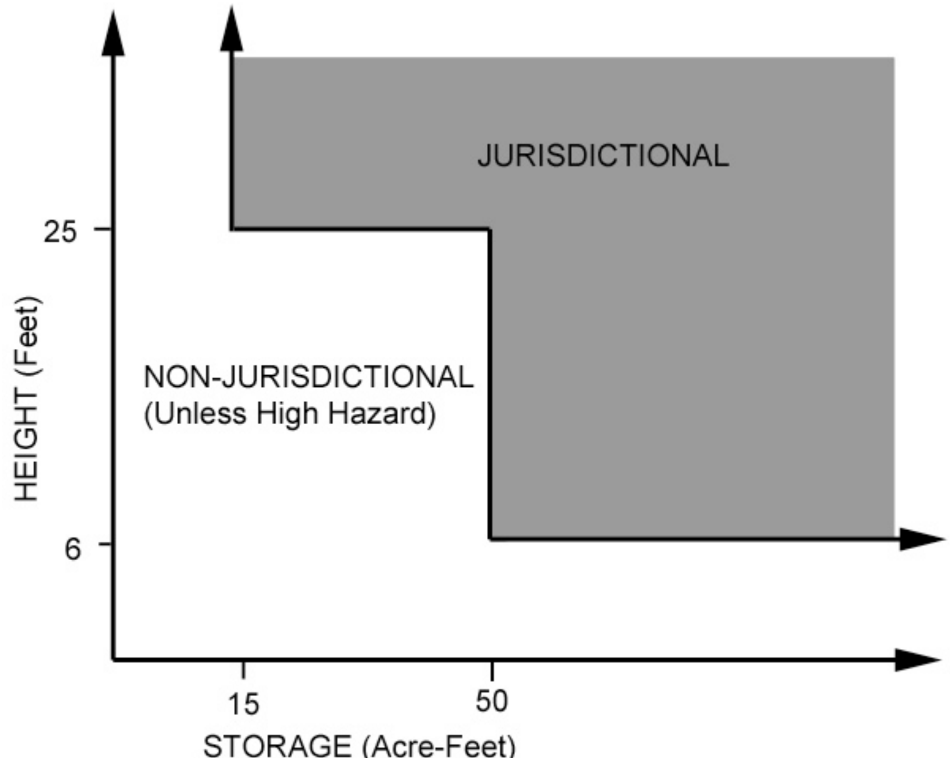
What is Jurisdictional Size?



Any sized dam determined to be high hazard-potential.

Hazard-Potential Classification	Description
Low	Failure would result in no probable loss of human life and low economic losses.
Significant	Failure would result in no probable loss of human life but can cause economic loss or disruption of lifeline facilities.
High	Failure will probably cause loss of human life.

How often should I inspect my dam?

- **HIGH** - Annually
- **SIGNIFICANT** – Every 3 years
- **LOW** – Every 5 years

Dam Safety Program Priorities/Updates

- Public awareness
- Emergency Action Planning
- Hazard-potential reclassification of dams
- Rehabilitation of structurally deficient dams

Public Awareness in 2016 -2017

- Oklahoma Real Estate Commission Workshops (2016-2017)
- Earthquakes and Infrastructure (Winter 2016)
- HEC-RAS 2D workshop (Spring 2017)
- Low hazard dam inspections (Winter 2016/Spring 2017)
- Dam safety quarterly newsletter
- Website

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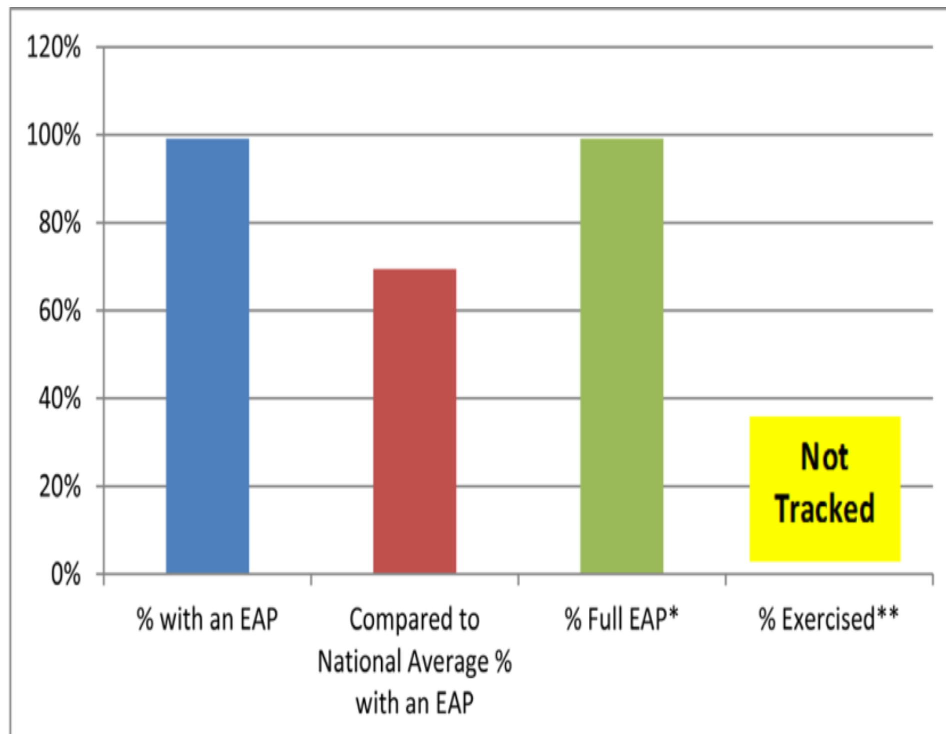
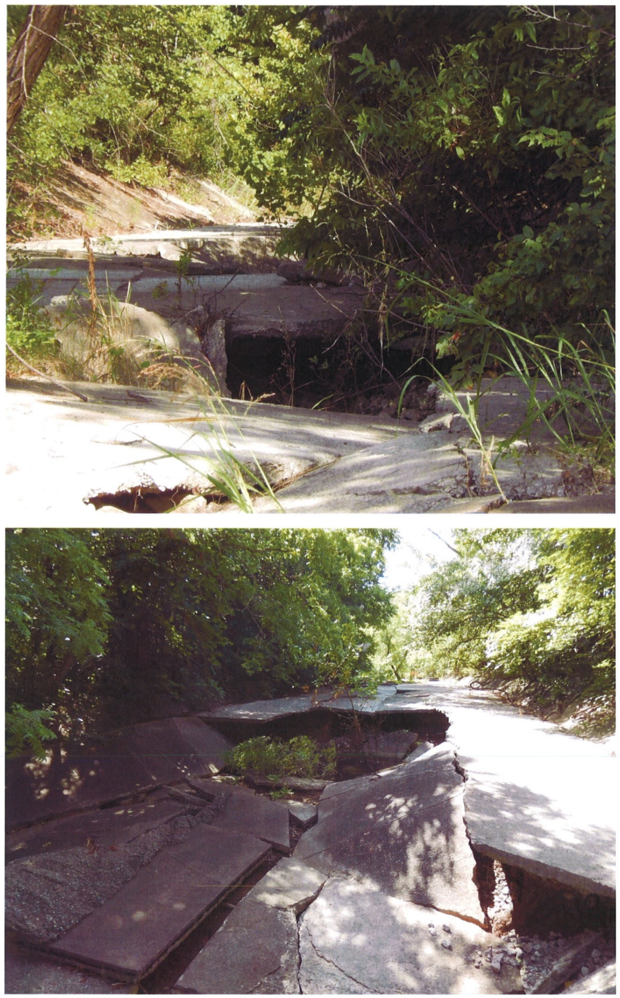
Oklahoma Dam Safety Program EAP Performance

- Based solely on the downstream risk in the event of failure
- **NOT** based on the physical condition of the structure
- Emergency Action Plans
  - 345 High Hazard Dams out of 359 (96%)
  - 92 Non-SCS High Hazard Dams out of 106 (86%)
  - Dam Breach Inundation Maps 105 out of 106 (99%)
  - Breach map 2010 and newer = 96 (90%)
  - Periodic Updates of Plans
  - Tabletop Exercises



Technical Assistance to Dam Owner

Knight Lake Dam



Hominy Dam

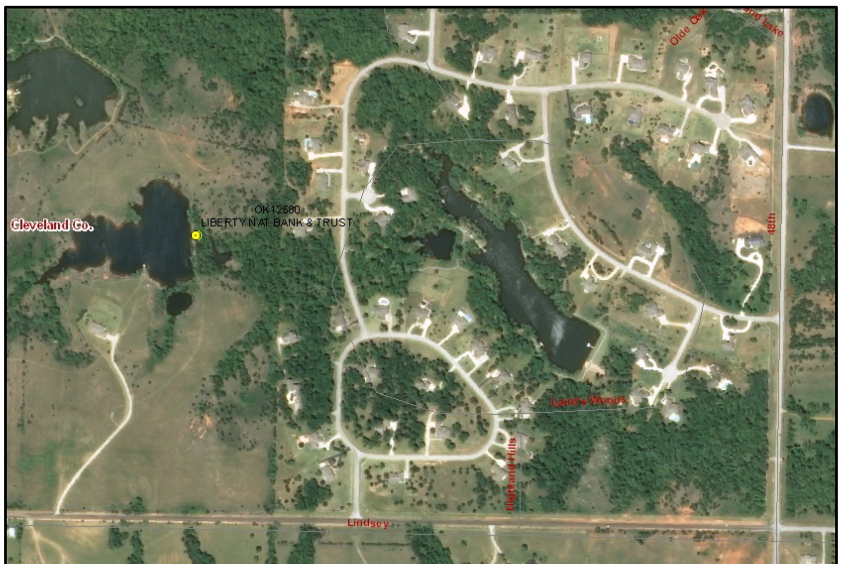
Carlton and Clayton Lake

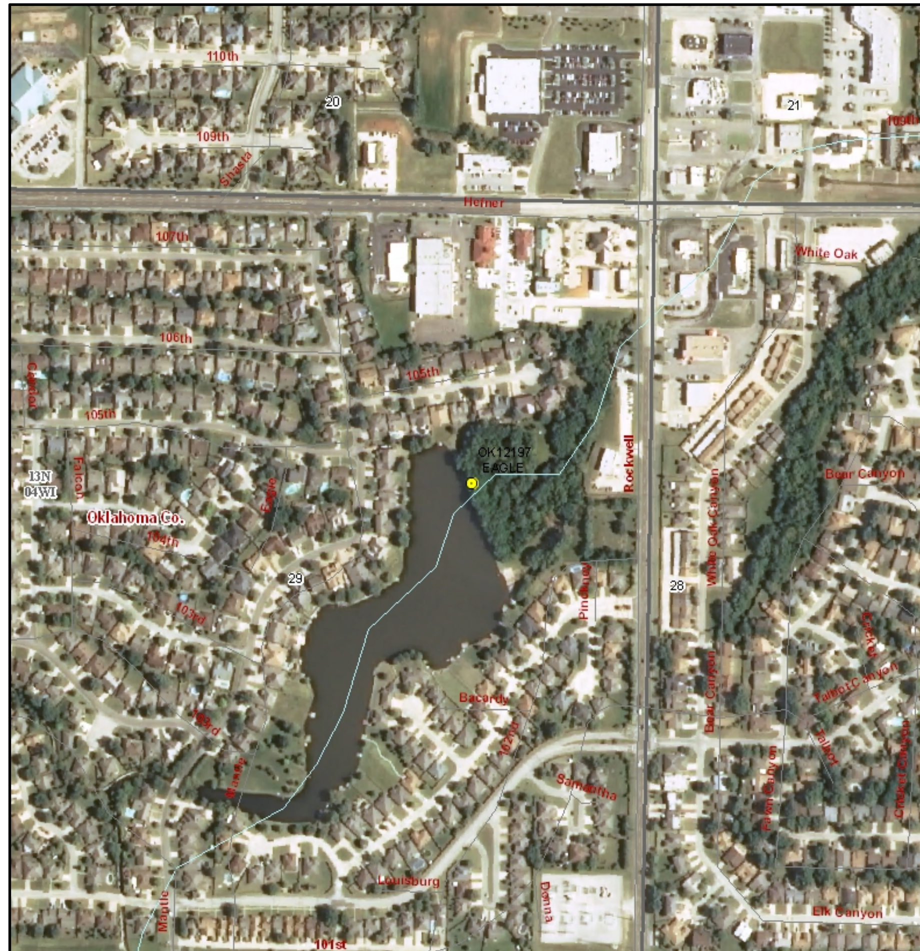
Hazard Reclassification

1. Aerial photo review (2012)
2. Breach inundation rule of thumb by FTN (2015)
3. Field visit
4. Simplified steady state analysis
5. Detailed study
6. Refer to OWRB hazard reclassification guidelines and ACER Technical Memorandum No. 11 by Bureau of Reclamation

Hazard Reclassification Initial Review

Original Reclassification Figures as of December 2011		
	Total Dams for Reclassification Review	615
	Possible Highs	368
	Possible Significant/High	152
	Possible Significant	95





Hazard Reclassification Rule of Thumb Model

- Use 10-meter resolution Digital Elevation Model (DEM)
- Estimated breach flood wave height was calculated based on the distance downstream of a dam
- The wave height at that location was added to the stream invert elevation obtained from the 10-meter DEM to produce an estimated breach flood wave elevation

Distance Downstream of Dam	Assumed Breach Flood Wave Height (H = Height of Dam)
Just Below Dam	0.500 * H
0.5 miles	0.488 * H
1.0 miles	0.475 * H
1.5 miles	0.463 * H
2.0 miles	0.450 * H
3.0 miles	0.425 * H
4.0 miles	0.400 * H
5.0 miles	0.375 * H
10.0 miles	0.250 * H

Hazard Reclassification Rule of Thumb Model

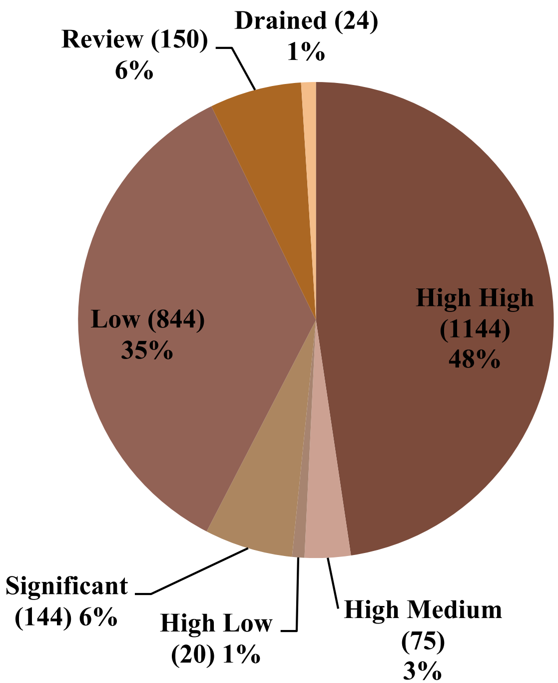
- Reviewed the inundation area for a pre-determined review distance downstream from the dam based on the reservoir surface area

- Use Microsoft BING aerial imagery 2010-2012 to visually identify man-made objects

Reservoir Surface Area	Review Distance
≤5 acres	1 mile
10 acres	1.5 miles
25 acres	2 miles
100 acres	5 miles
>100 acres	10 miles

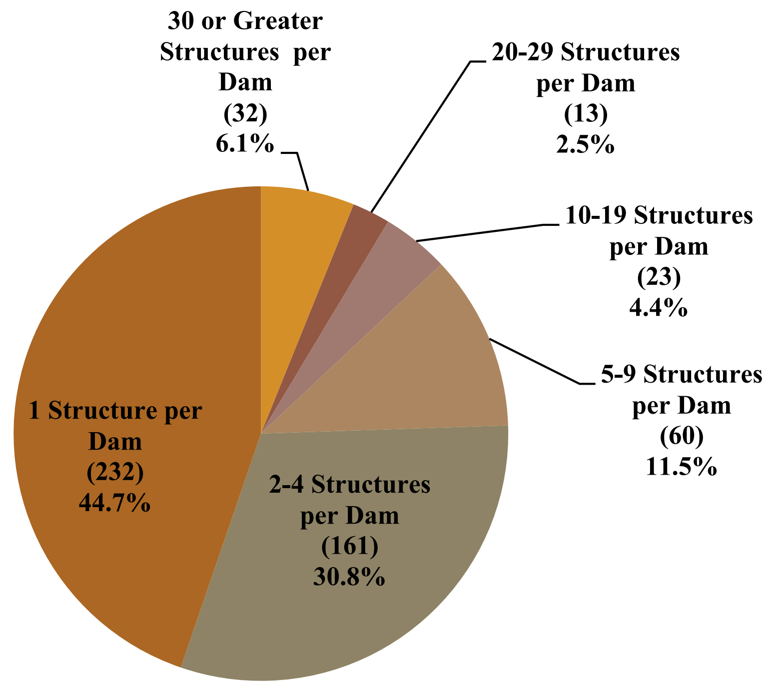
Hazard Reclassification Rule of Thumb Model

Dam Classification Summary



High (H1) Dams with Residential and Commercial Structures

(not in backwater and not in fringe)



Field Visits

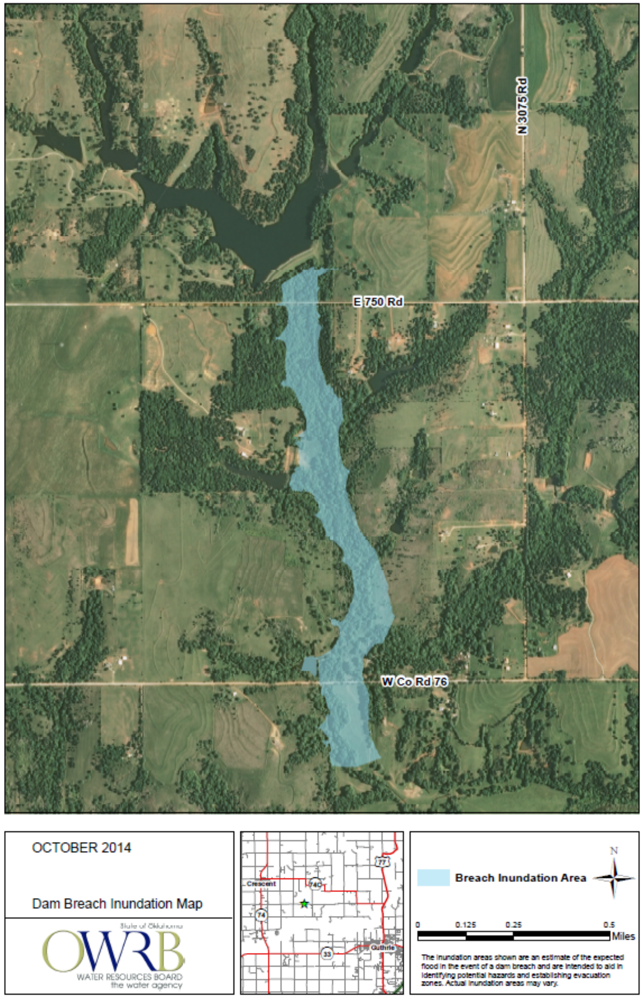
Simplified Steady State Analysis

Method:

- Steady state HEC-RAS
- Froehlich 2008 flow estimation method

$$B_{avg} = 8.239 K_o V_w^{0.32} H_b^{0.04}$$

$$T_f = 3.664 \sqrt{\frac{V_w}{g {H_b}^2}}$$



Where:

K_o = Failure Mode Factor   1.0 for piping and 1.3 for overtopping

H_b = Height of breach in feet

V_w = Reservoir volume stored in acre-feet

Simplified Steady State Analysis

Assumption:

- Piping failure
- Maximum capacity

  (Water to the top of the crest)

$$Q_p = 3.1 B_{avg} H_w^{1.5} \left(\frac{\gamma}{\gamma + T_f \sqrt{H_w}} \right)^3$$

Where:

Q_p = Dam break peak discharge in cfs
B_{avg} = Average breach width in feet
H_w = Maximum depth of water stored behind the breach in feet
T_f = Breach development time in hours
γ = Instantaneous flow reduction factor = 23.4 A_s/B_{avg} (equivalent to 'C' in Wetmore and Fread (1984))
A_s = Surface area of the reservoir in acres corresponding to H_w

Hazard Reclassification
Simplified Steady State

Detailed Study Hydrologic Analysis

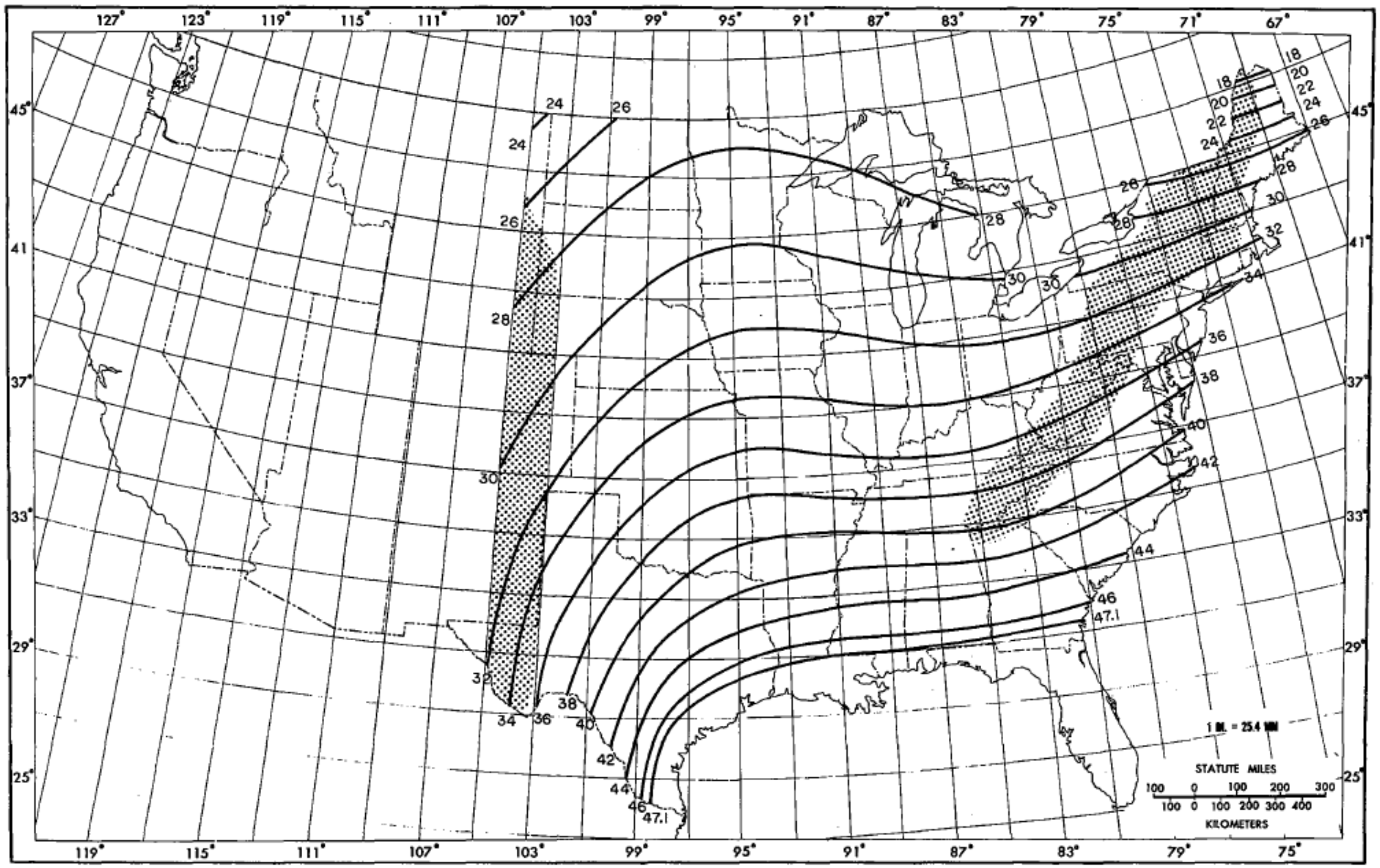
- Watershed Delineation and Flood Flow Routing
- Methods to be Used are not Specified
  - It is up to the modeler to select and justify

Probably Maximum Precipitation (PMP)

- 24-hour PMP Duration

- Storm Area
  - Drainage Areas < 10 sq. mi. apply 10 sq. mi. uniformly – at preferred orientation
  - Drainage Areas > 10 sq. mi. spatially distribute – orientation at maximum rainfall

PMP for 24 hr 10 mi²



Source: NOAA – Hydrometeorological Report No. 51

Design Flood

Size	Hazard- Potential	Design Flood (% PMF)	Minimum Freeboard (ft)
Small	Low	25%	0
	Significant	40%	0
	High	50%	1
Intermediate	Low	25%	1
	Significant	50%	1
	High	75%	3
Large	Low	50%	1
	Significant	75%	1
	High	100%	3

Detailed Study
Breach Analysis Scenarios

- **Sunny Day**
  - Piping Failure at Normal Pool Elevation, No Inflow
- **Overtopping** – Depends on Timing with Precipitation
  - Barely Overtopping
  - Maximum Water Surface Elevation Overtopping
- **Non-breach Design Flood**

Detailed Study Hydraulic Analysis

- Steady-State Hydraulic Analysis
  - Route Resultant <u>Peak Flow</u>

- Unsteady-State (Rapidly Varied) Hydraulic Analysis
  - Route Resultant <u>Flow Hydrograph</u>

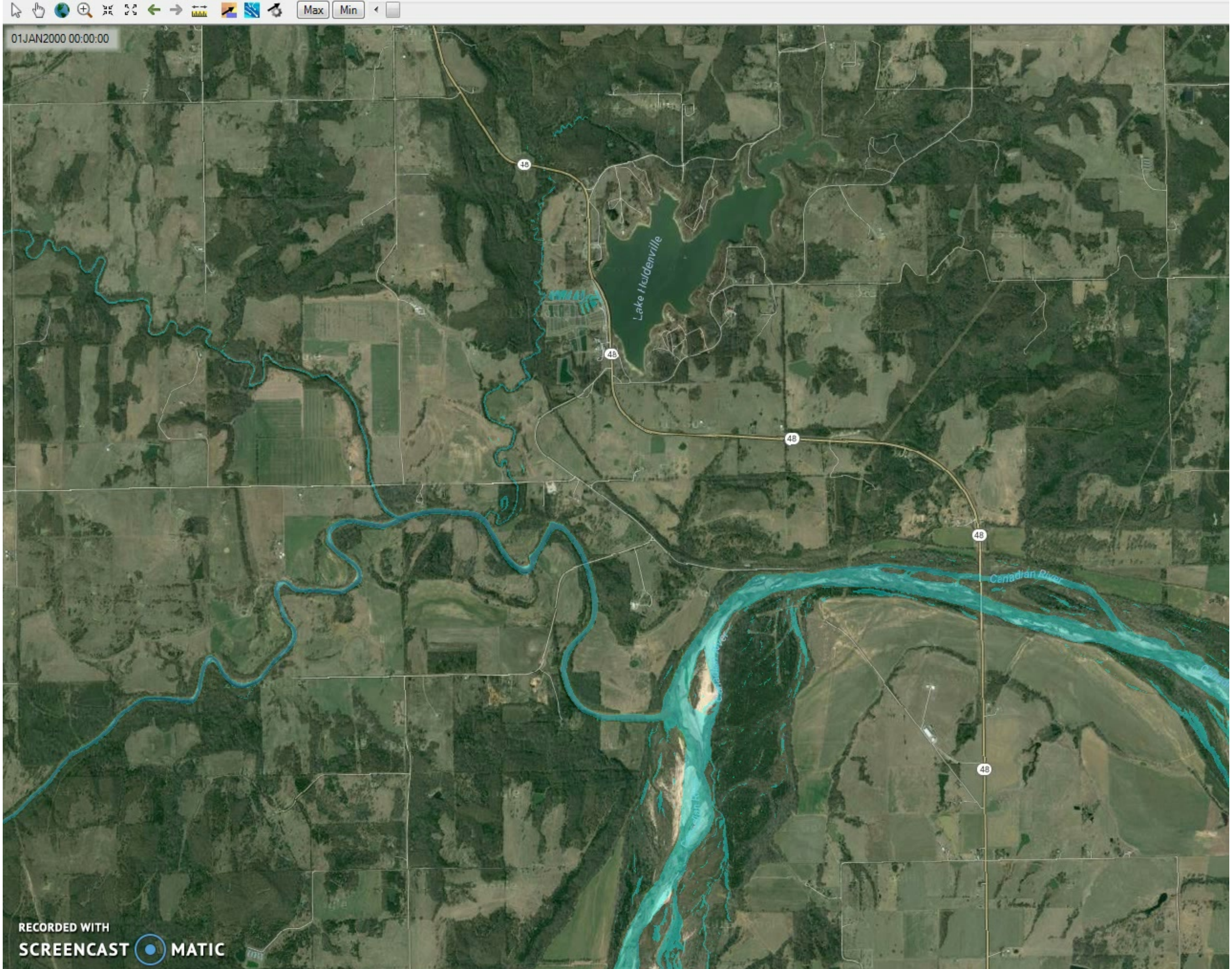
- Boundary Condition Selection is not Specified
  - It is up to the modeler to select and justify

Other Considerations

- Cascading Failure of Downstream Dams
  - Upstream dams are assumed to remain intact

- Downstream Confluences
  - Average Annual Flow

- Selection Level-Pool or Dynamic Flow Routing through Reservoir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Lake Holdenville
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ACER 11

HIGH DANGER ZONE – Occupants of most houses are in danger from floodwater.

JUDGEMENT ZONE – Danger level is based upon engineering judgement.

LOW DANGER ZONE – Occupants of most houses are not seriously in danger from flood water.

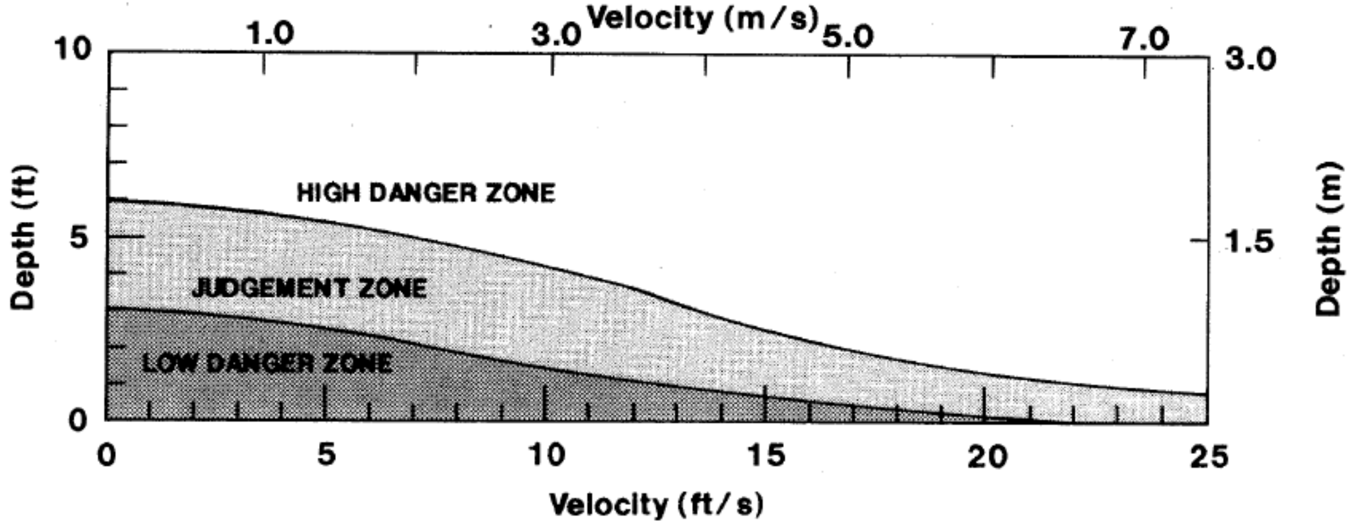

Figure 2. – Depth–velocity flood danger level relationship for houses built on foundations.

Next Step for Reclassification

- State must make a final determination of hazard-potential
- Notification to Owner
- Owner may request a hearing to present technical evidence to show that the dam should not be reclassified.

Could maintain low hazard classification if breach and non-breach flood are within one foot.

Additional Information

- OWRB's forms, guidelines, and publications are available at
  http://www.owrb.ok.gov/hazard/dam/dam_forms.php

- FEMA dam safety publication and resources
  http://www.fema.gov/plan/prevent/damfailure/publications.shtm

- Subscribe for Dam Safety Quarterly
- Email: emmamoradi@owrb.ok.gov

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Questions

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