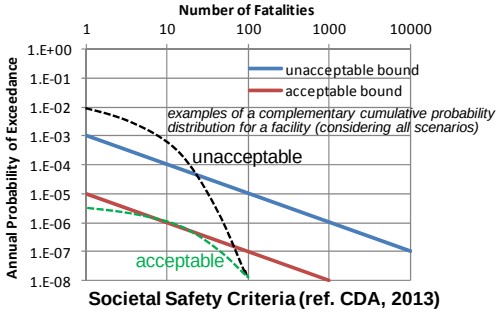
16 Feb 2016

Colliery Dam (Nanaimo BC) Risk Assessment

by Dr. Bill Roberds

1. *System Concepts ("Scenarios")*
2. *Scenario Conditional Consequences*
3. *Scenario Annual Probabilities*
4. *System Risks*



Societal Safety Criteria (ref. CDA, 2013)

Individual Safety Criteria (ref. CDA, 2013): probability of any individual dying <10^{-5}/yr

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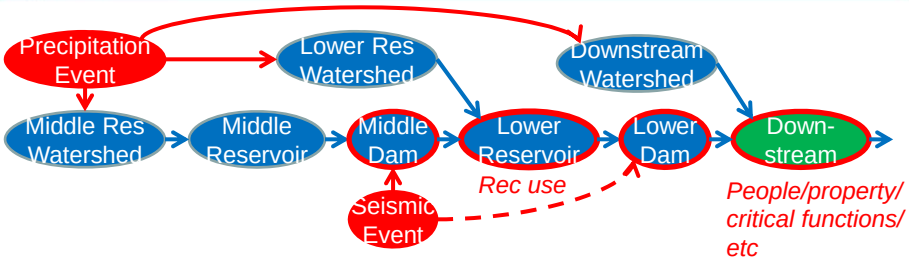
Colliery Dam System



- Set of dam failure "scenarios" (triggers & breaches)
- Consequences (fatalities & $) if each scenario occurs
- Annual probability of each scenario occurring
- Risk (uncertain annual incremental fatalities & costs, considering all scenarios)

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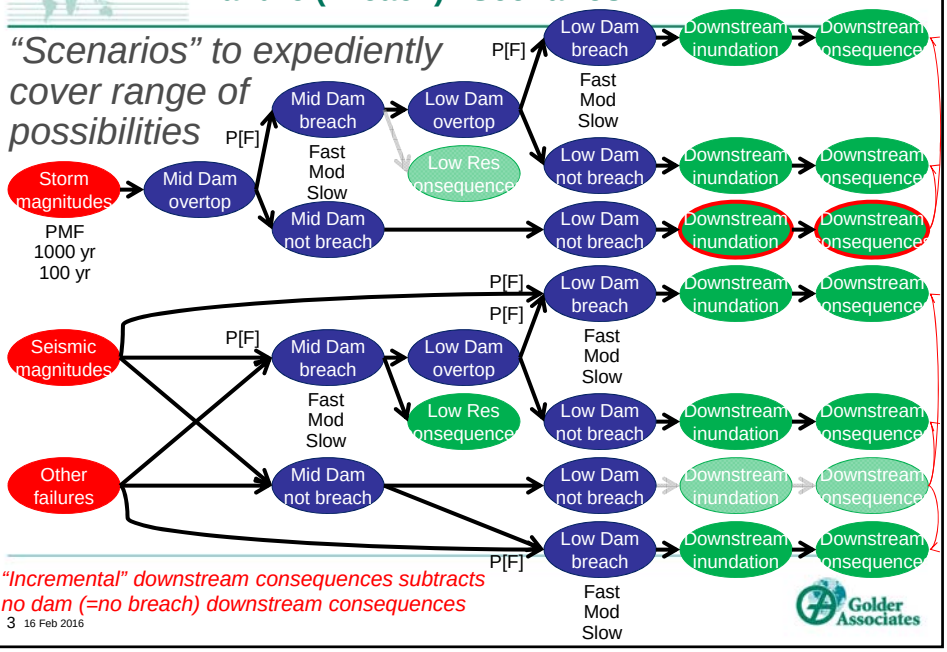
Failure (Breach) "Scenarios"

"Scenarios" to expediently cover range of possibilities



"Incremental" downstream consequences subtracts no dam (=no breach) downstream consequences

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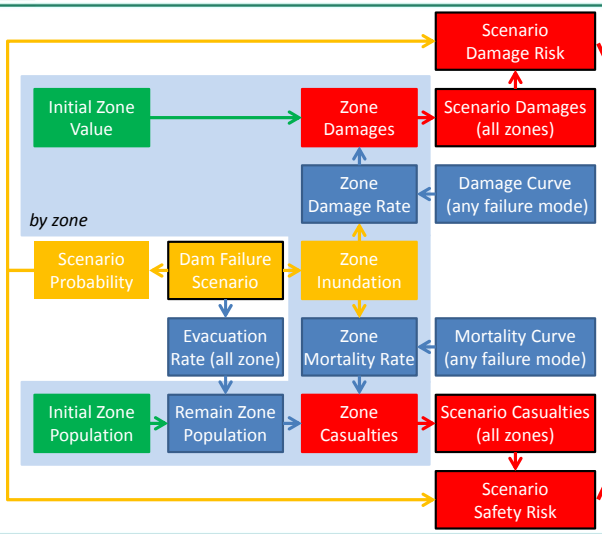
Scenario Consequence and "Risk"

For <u>each</u> scenario:



Combine <u>all</u> scen-arios:

System "risk"

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Runoff and Dam/Reservoirs Capacity/Release

- Several storm scenarios (with characteristics)
- Watershed runoff characteristics
- Middle Dam/Reservoir capacity/release
  - Spillway release
  - Overtopping depth and duration wo breach
  - Release to Lower Reservoir, either
    - wo breach
    - w breach (assumed geometry/duration) <or non-storm>
- Lower Dam/Reservoir capacity/release
  - Reservoir/recreational area flood
  - Spillway release
  - Overtopping depth and duration wo breach
  - Release to downstream, either
    - wo breach
    - w breach (assumed geometry/duration) <or non-storm>

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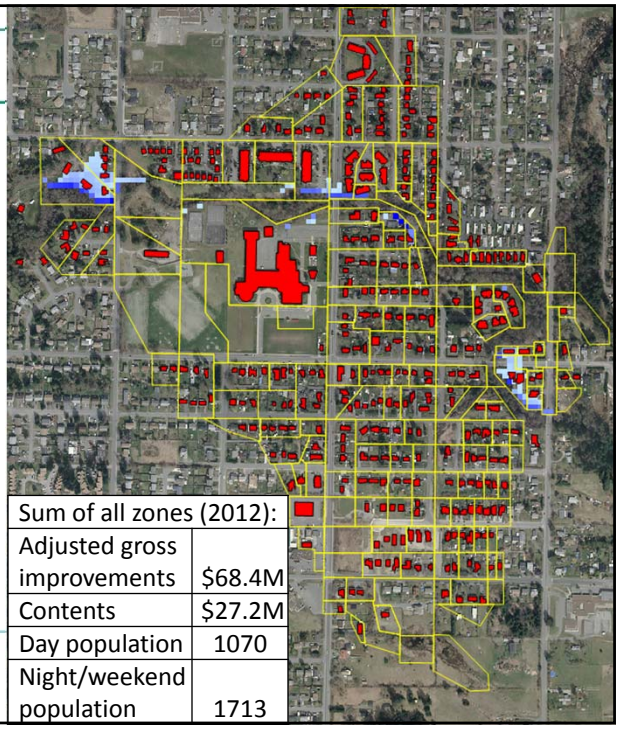
Downstream Inund Model (AE)

- 10m x 10m res =1 million cells
- 174 potentially affected spatial "zones", each:
  - collective structures (values) & population (2012)
  - average inundation (max depth & max velocity)



Sum of all zones (2012):	
Adjusted gross improvements	$68.4M
Contents	$27.2M
Day population	1070
Night/weekend population	1713

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"Conditional" Scenario Consequences

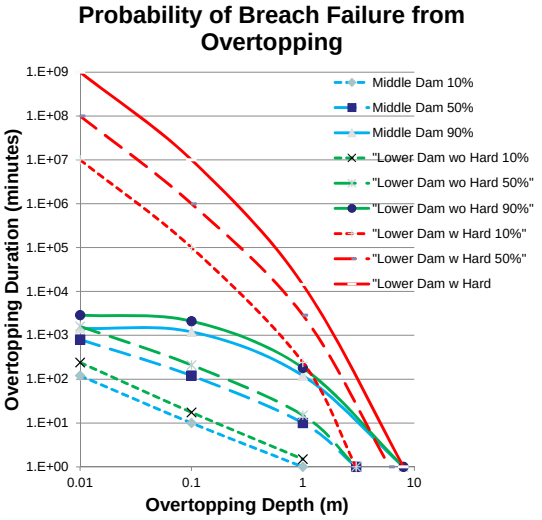
For each scenario (assuming it occurs):

- for each downstream spatial zone:
  - inundation (max depth and velocity)
  - consequences
    - ➔ damage %'s of improvements / contents
      x values = damages
    - ➔ probability of fatality per individual
      x average exposed population* = fatalities
      (*considering when & possible evacuation)
- combine over all downstream spatial zones
  - sum damages
  - sum fatalities
  - max probability of any individual dying (conservatively assume 100% time in zone pre-warning)

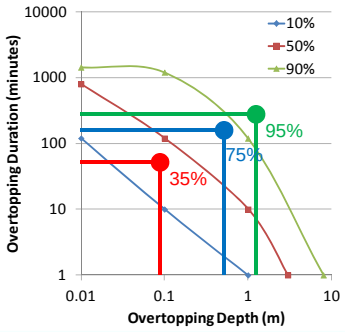
Scenario Probabilities

- Overtopping
  - Trigger (specific magnitude storm event) annual probability
  - For each dam:
    - Overtopping magnitude if trigger occurs
      - wo Middle Dam breach for Lower Dam
      - w Middle Dam breach for Lower Dam
    - Probability of dam failure if specific overtopping magnitude occurs
- Seismic *(relatively small consequence ➔ minor risk)*
  - Trigger (specific magnitude seismic event) annual probability
  - Probability of dam failure if trigger occurs
- Other *(relatively small consequence ➔ minor risk)*
  - Annual probability of dam failure (other than overtopping or seismic, e.g., piping)

Dam Overtopping Failure Probability (1 of 2)



Example determination of <u>Middle Dam</u> breach probability due to overtopping for different scenarios (PMF, 1000yr, 100yr triggers):



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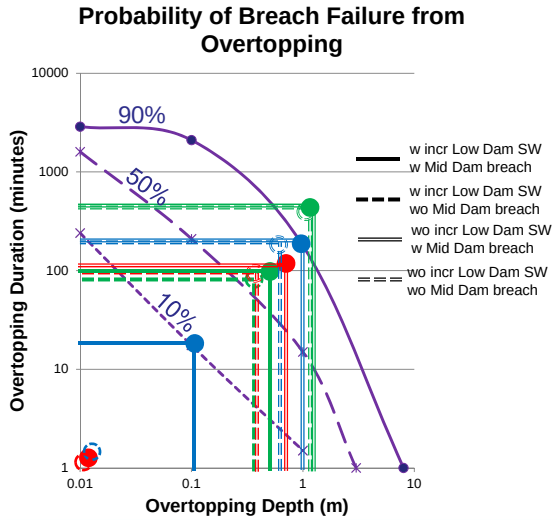
Dam Overtopping Failure Probability (2 of 2)



Example determination of <u>Lower Dam</u> breach probability for different scenarios (PMF, 1000yr, 100yr triggers) with or without increased Lower Dam spillway and with or without Middle Dam breach:

- *Increased Lower Dam spillway capacity significantly decreases overtopping and breach probability, especially for smaller storms*
- *Middle Dam has relatively small impact on overtopping and breach probability of Lower Dam*

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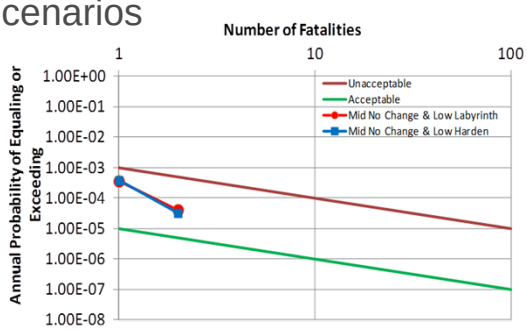
Colliery Dam System Risks

- Combine conditional consequences and probabilities over all scenarios
  - "Mean" incremental damages ($) per year (structure & contents)
  - "Mean"/uncertain incremental number of fatalities per year
  - Max incremental annual individual risk



- Risk for selected Lower Dam rehab determined to be "tolerable" (not unacceptable) and in ALARP zone ➔ reduce further if cost-effective

Recommendations for Middle Dam Rehab RA

- Continue risk approach used for Lower Dam rehab
- Update for current condition
  - If actual Lower Dam rehab spillway capacity is significantly different than previously assumed, update Lower Dam overtopping analysis ➔ probability of Lower Dam breaching ➔ risk
  - If projected downstream population & property characteristics in downstream zones are significantly different than previously assumed (from 2012), update downstream consequence analysis (not inundation anal.)
- Extend F-N curves to >2 fatalities
- For each Middle Dam rehab alternative, determine its change in risk factors ➔ scenario probabilities ➔ risks

Colliery Dam Risk Assessment

Thank you!

Questions?

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Scenario Coverage

Trigger	Mid Dam Breach only				Mid and Low Dam Breach		
	Fast	*Mod*	*Slow*	*None*	*Fast*	*Mod*	*Slow*
PMF	**SC3**	SC19*	**SC4**	**SC8**	SC14	SC13	
1000 yr storm	**SC5**	SC11	SC6**	**SC7**		SC12	
100 yr storm	SC9**	SC18*	SC10**	SC20*		SC17*	
Seismic	**SC1**	SC16*	SC2**	**NA**		SC15*	

Notes:

- *Phase 1 (Middle Dam breach only, range of breach times) SC1, 3-5, 7-8*
- *Phase 2 (mostly Middle Dam and Lower Dam breaches, and moderate breach times) SC11-14*

* *interpolated/extrapolated SC15-20*

** *not interpolated/extrapolated at this time SC2, 6, 9-10*

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