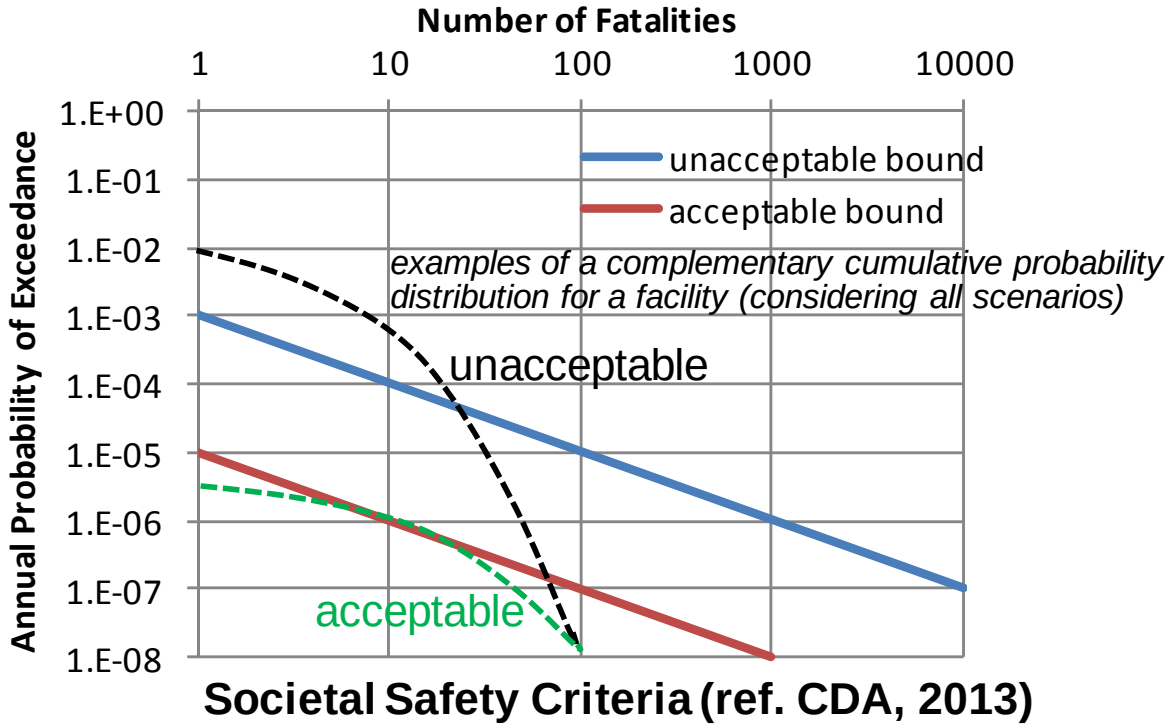

04/24 Apr 2014

Colliery Dam (Nanaimo BC)
Risk Assessment Phase 2 Workshop

by Dr. Bill Roberds

Golder Associates

Develop Colliery Dams (Nanaimo BC) Plan

- **13 Dec 2013 Meeting**
  - **Objectives -** *optimal* dam rehab option plan
  - **Criteria –** incremental *safety* risk, *financial, etc.*
  - **Design Process –** identify/evaluate dam rehab options
  - **Risk assessment** – model, uncertainties, assessments
- **21 Jan 2014 Meeting**
  - **Risk model framework** – elements/inputs/outputs/scenarios
  - **Inputs** – hypothetical / status / plans
- **04 Mar 2014 Meeting**
  - Phase 1 inputs / results
  - Phase 2 plans (rehab options, scenarios, inputs)
- **04 Apr 2014 Workshop / 24 Apr 2014 Meeting**
  - Phase 2 preliminary inputs / results
  - Subsequent revisions in response to comments

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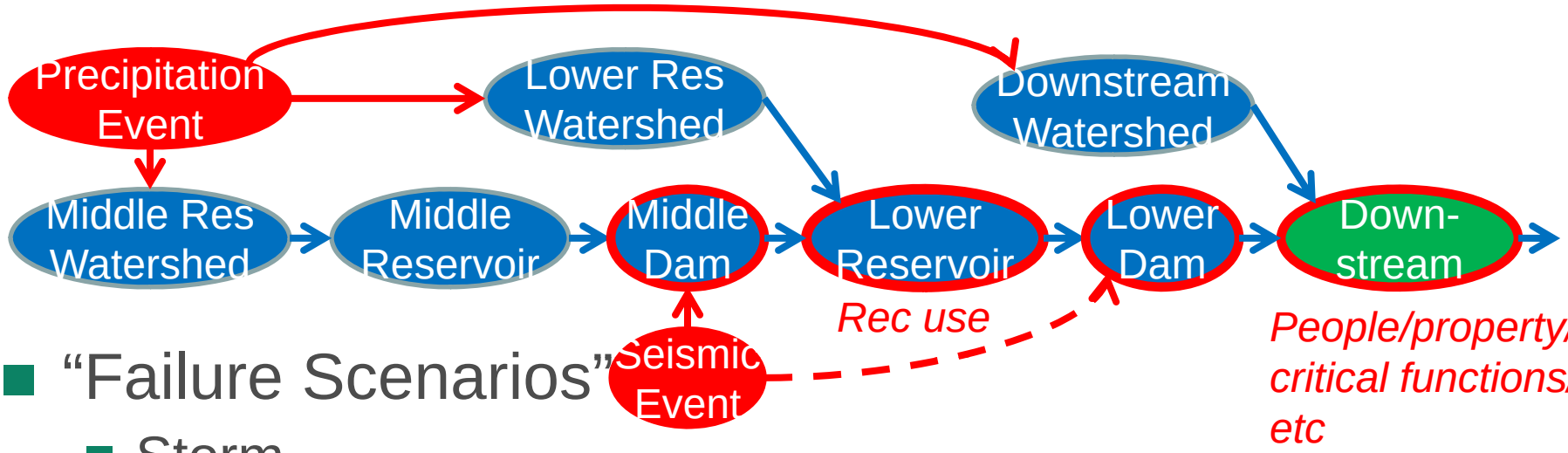
Colliery Dams (Nanaimo BC)

- Watersheds, reservoirs, dams, downstream

Middle Dam: 13m high x 50m long x 5m wide, 0.6m thick reinf concrete core, rockfill, 2.5H:1V downstream slope, 1.6H:1V upstream slope

Lower Dam: 24m high x 77m long x 10m wide, 1.2m thick reinf concrete core, rockfill, 2.2H:1V downstream slope, 1.5H:1V upstream slope

Colliery Dam System: Elements



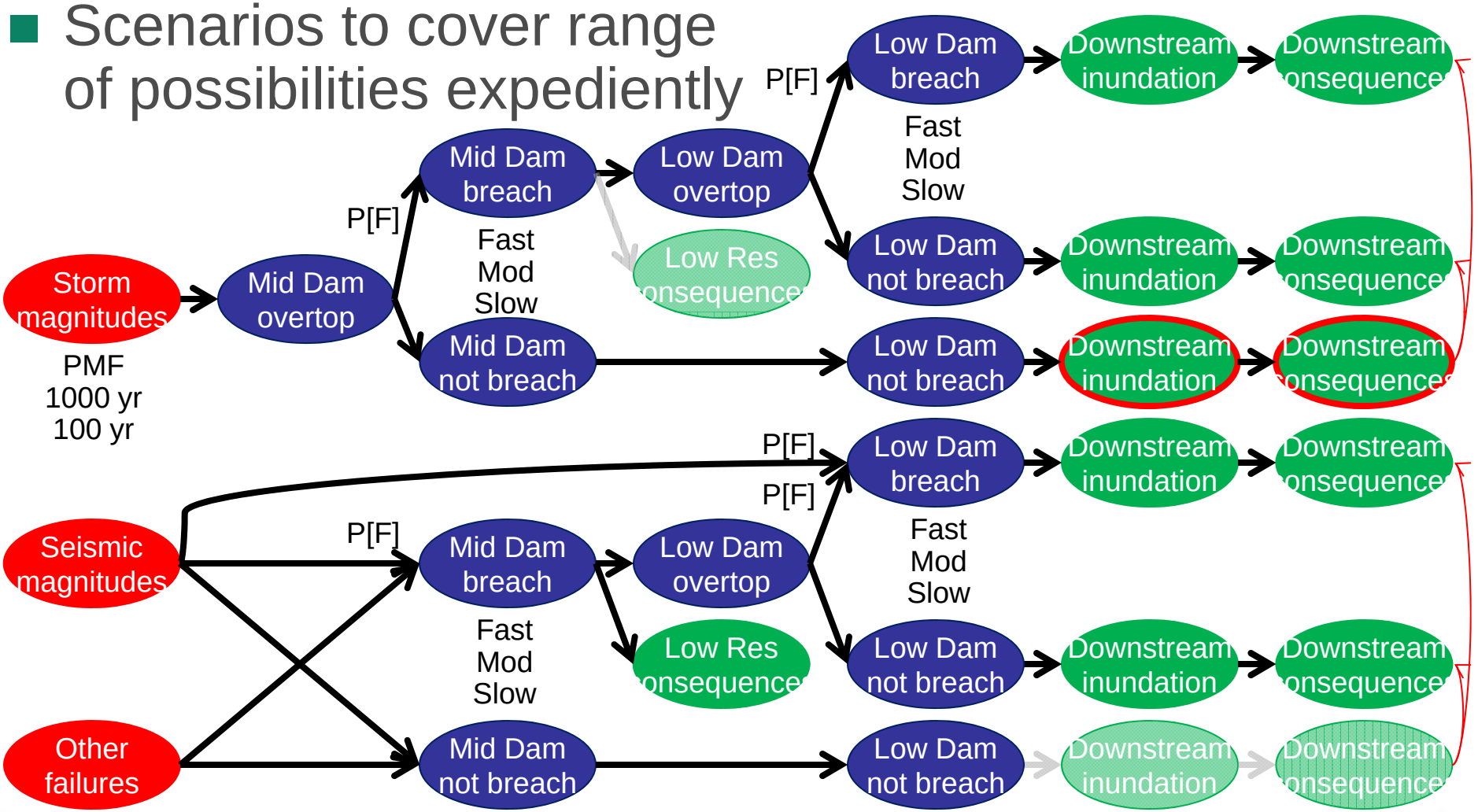
- "Failure Scenarios"
  - Storm
  - Seismic
  - Other (e.g., piping / internal erosion / degradation)
- Combine Failure Scenarios

$$p[C] = \sum_{all\,S} p[C \mid S]\, P[S] \quad and \quad P_{>}[C] = \sum_{all\,>C} p[C]$$

where C is consequence and S is comprehensive mutually exclusive set of scenarios

Phase 2 Scenarios

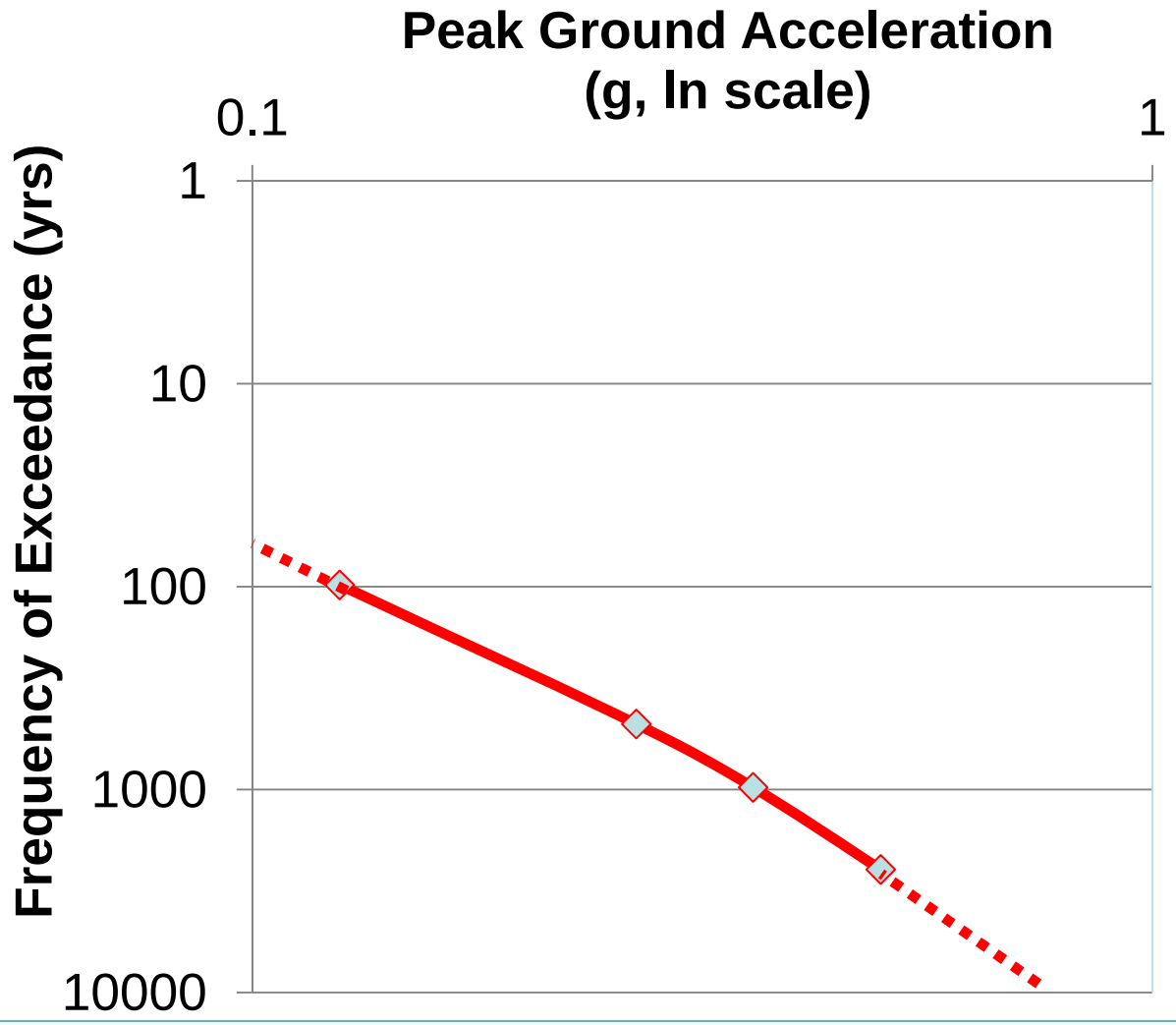
- Scenarios to cover range of possibilities expediently



Site Seismic Frequency-Magnitude (EBA 2010)

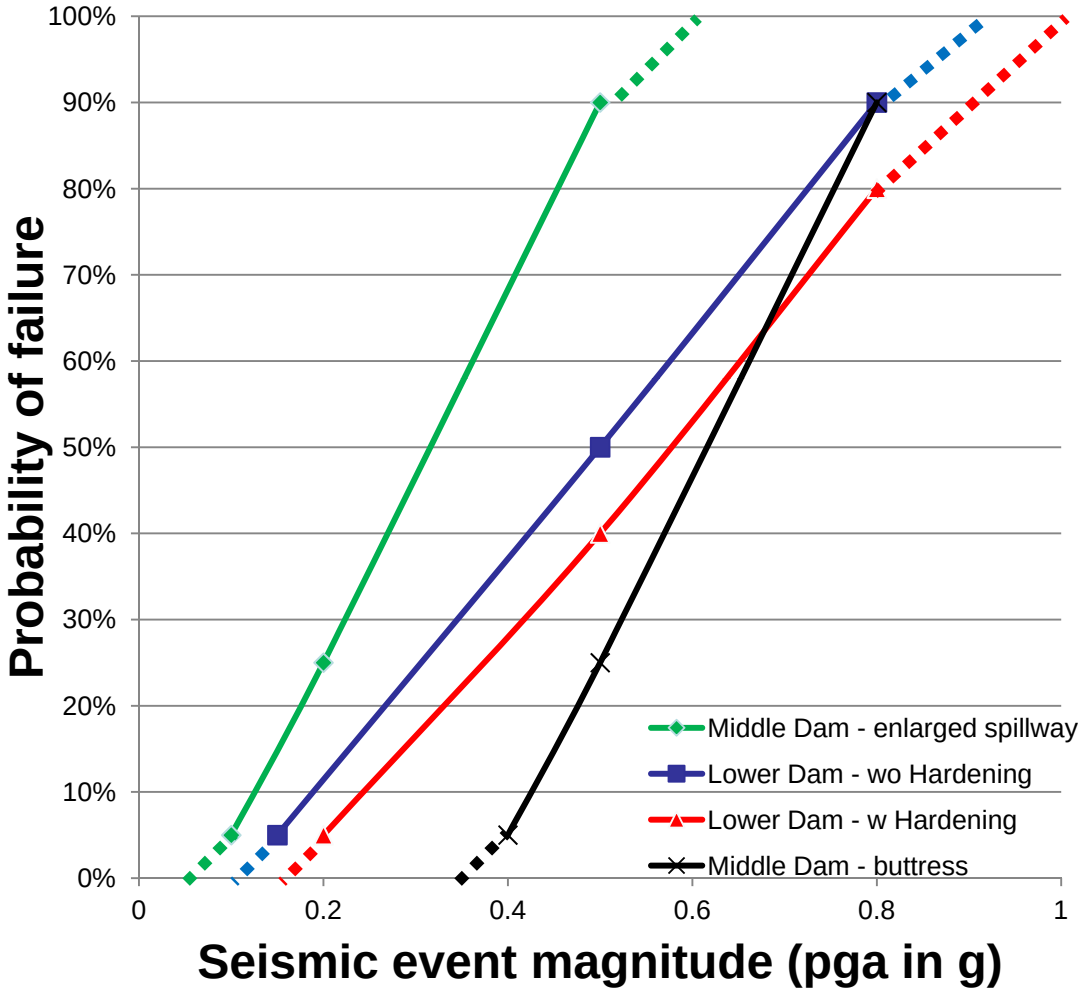
Return Period (yrs)	Peak Ground Acceleration (g)
98	0.125
475	0.267
975	0.36
2475	0.499
MCE (10k)	0.8

Note: no change resulting from recent BCHydro studies, which were not relevant to this site



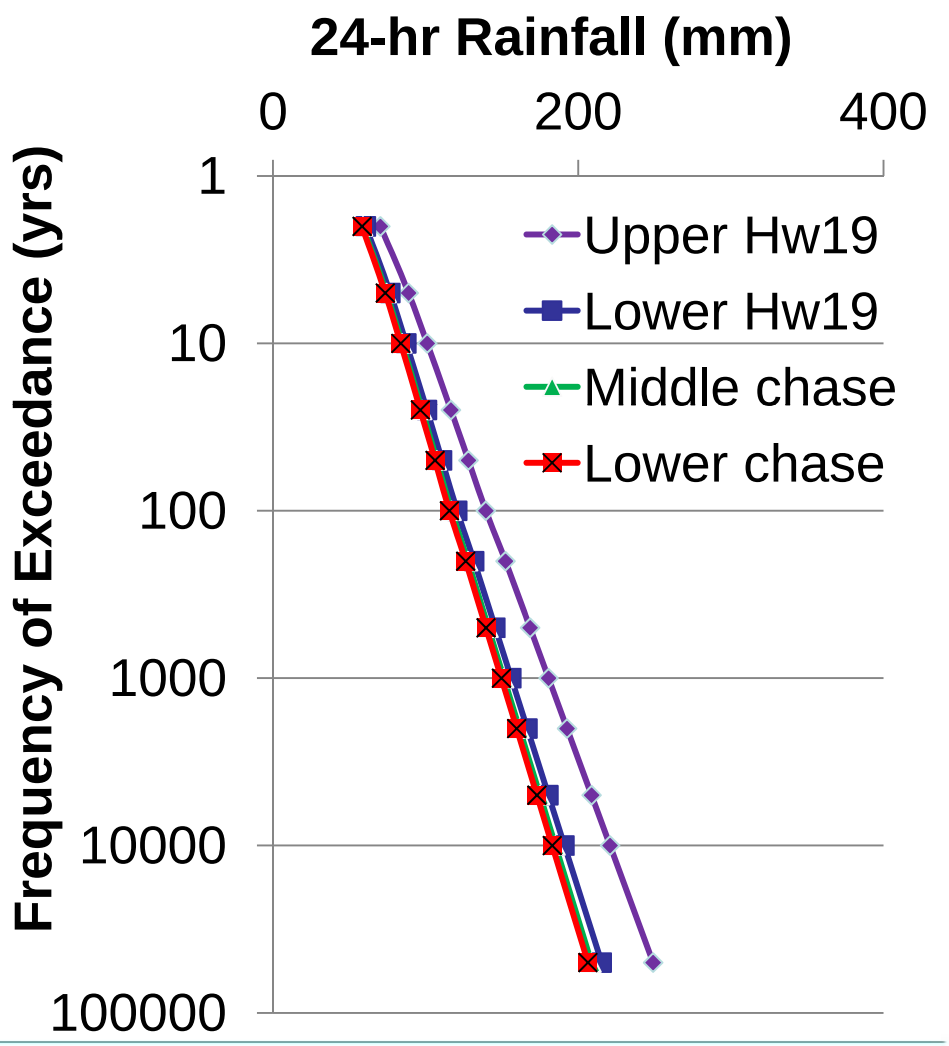
Dam Seismic Failure

- Prob of seismic failure is function of seismic magnitude and dam conditions
- Subjective - considering previous dynamic analysis results (EBA) and info on conditions of each dam/option



Site Storm Frequency-Magnitude

Return Period (yrs)*, **	24-hr Rainfall (in mm) for each sub-basin			
	Upper Hw19	Lower Hw19	Middle chase	Lower chase
2	70.3	60.8	58.9	58.3
5	88.8	76.8	74.4	73.5
10	101	87.3	84.6	83.7
25	116.5	100.8	97.7	96.5
50	128	110.7	107.3	106.1
100	139.4	120.6	116.9	115.5
200	152.3	131.7	127.7	126.2
500	168.4	145.6	141.1	139.5
1,000	180.5	156.1	151.3	149.6
2,000	192.6	166.6	161.4	159.6
5,000	208.7	180.4	174.9	172.9
10,000	220.8	190.9	185	182.9
50,000	249	215.3	208.6	206.3



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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
    - wo breach
    - w breach (assumed geometry / duration)
- Lower Dam/Reservoir capacity/release
  - Reservoir/recreational area flood
  - Spillway release
  - Overtopping depth and duration wo breach
  - Release to downstream
    - wo breach
    - w breach (assumed geometry / duration)

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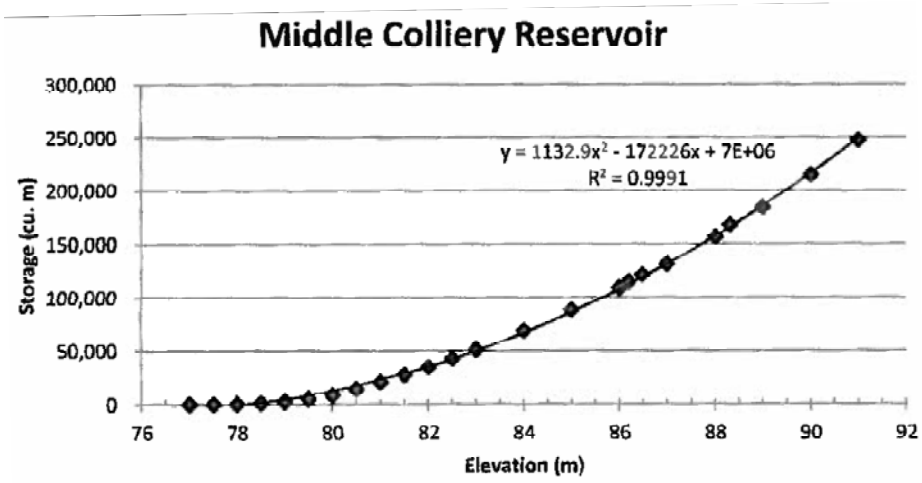
Reservoir Storage Curves

Middle Dam

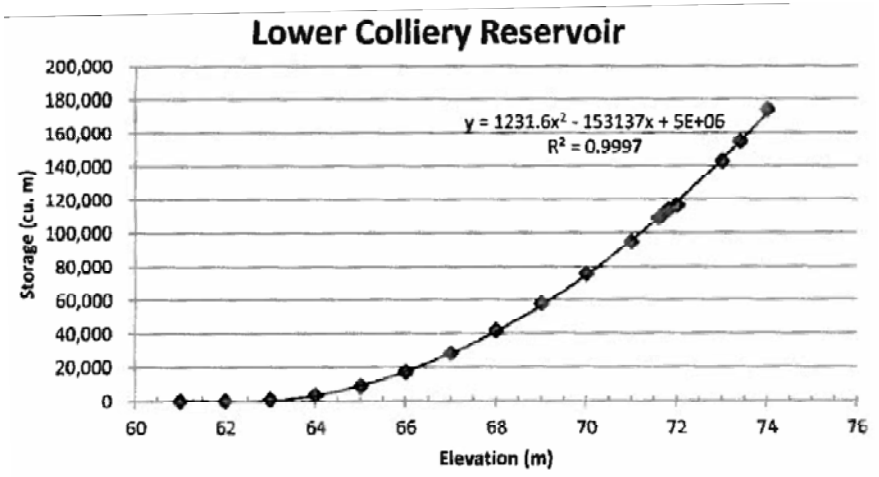
- Spillway (current/enlarged)
  - crest at 86.2 / 84.4 m
  - capacity 75 / 122 cms
- Dam crest at 88.3 m



Elevation-Storage Relationship for the Middle Colliery Reservoir

Lower Dam

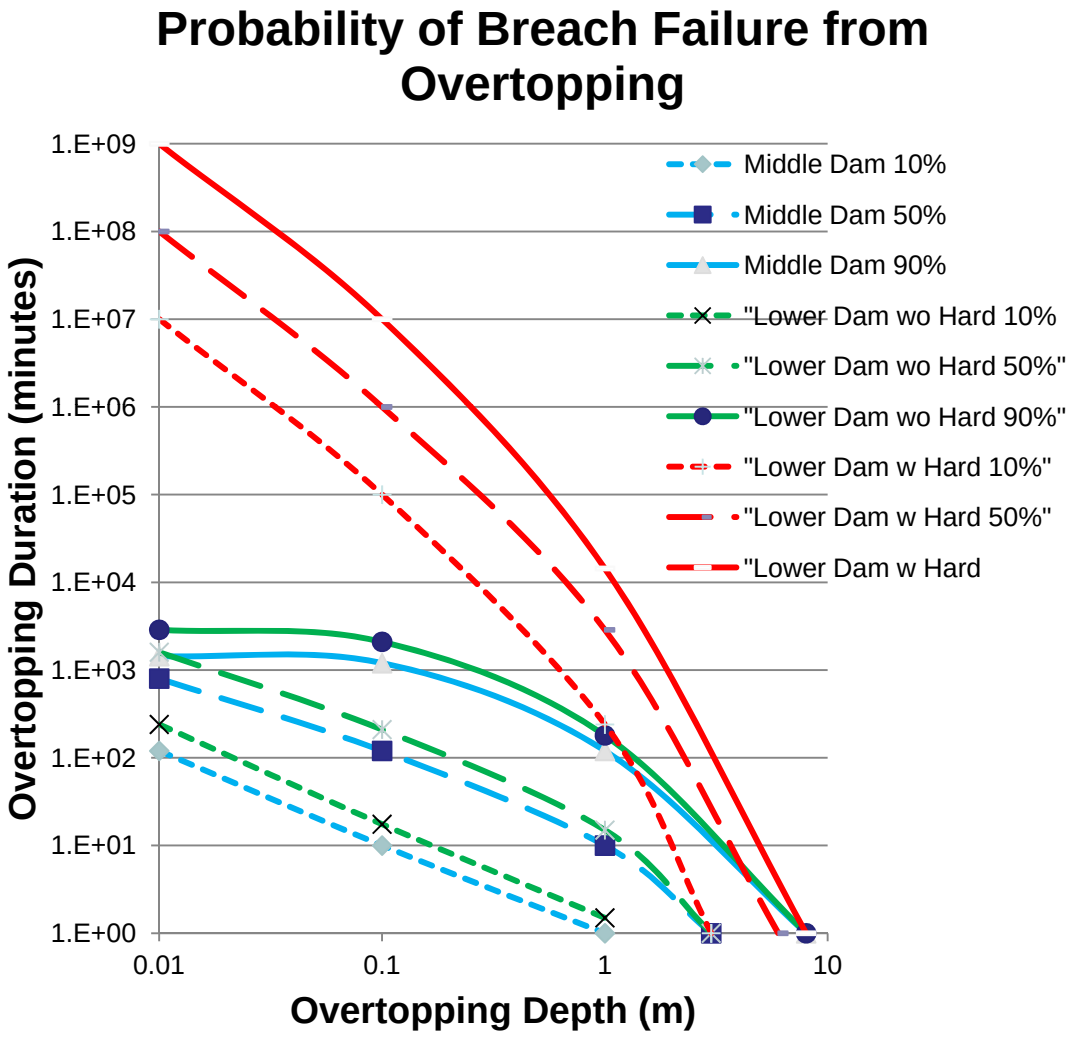
- Spillway (current/labyrinth)
  - crest at 71.6 / 71.6 m
  - capacity 25 / 125-175 cms
- Dam crest at 73.4 m



Elevation-Storage Relationship for the Lower Colliery Reservoir

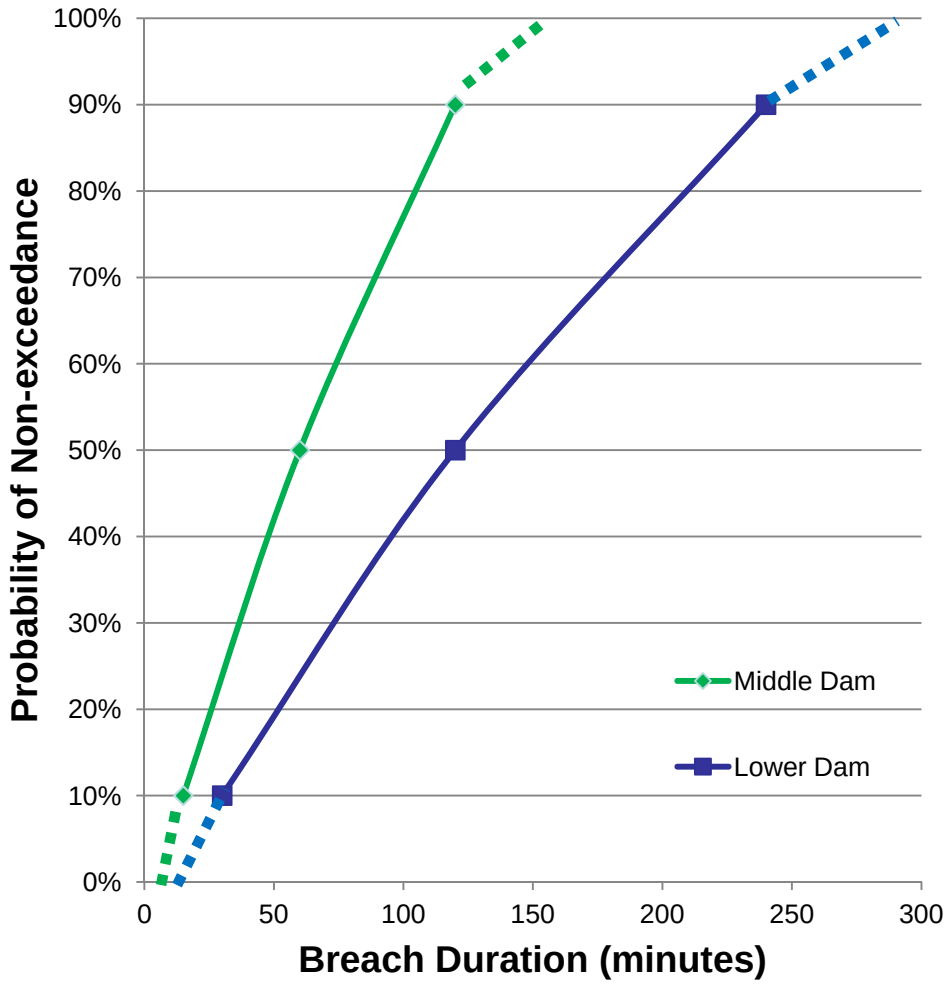
Dam Overtopping Failure

- Probability of dam breaching is function of over-topping depth / duration and dam conditions
- Subjective – considering info on conditions of each dam/option and case histories



Dam Breach Duration

- Once started, breach duration is function of dam condition (release of impoundment)
- Essentially same for seismic/other and for overtopping
- Subjective – considering info on conditions of each dam/option and case histories



Modeled Downstream Inundation / Consequence Scenarios

- Limited set (due to time/cost constraints) of modeled scenarios to cover range of possibilities
- Can interpolate/extrapolate for other scenarios (storms, breach time)

Scenario	Storm	Middle Dam Breach	Lower Dam Breach
SC3	PMF	10 min	None
SC14	PMF	10 min	10 min
SC13	PMF	60 min	120 min
SC4	PMF	150 min	None
SC8	PMF	None	None
SC5	1000yr	10 min	None
SC11	1000yr	60 min	None
SC12	1000yr	60 min	120 min
SC7	1000yr	None	None
SC1	0 (Seismic)	10 min	None

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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 Dan 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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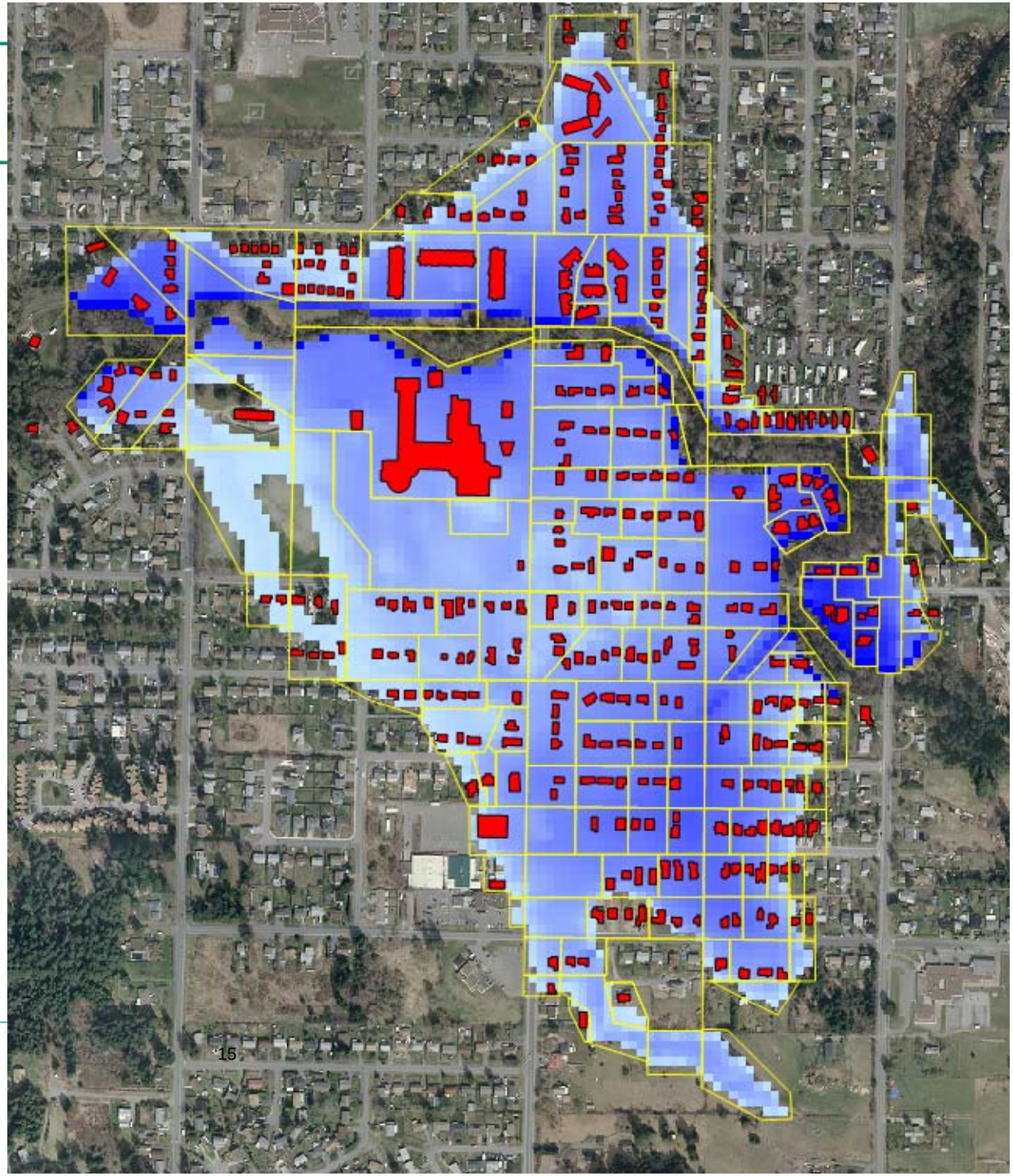
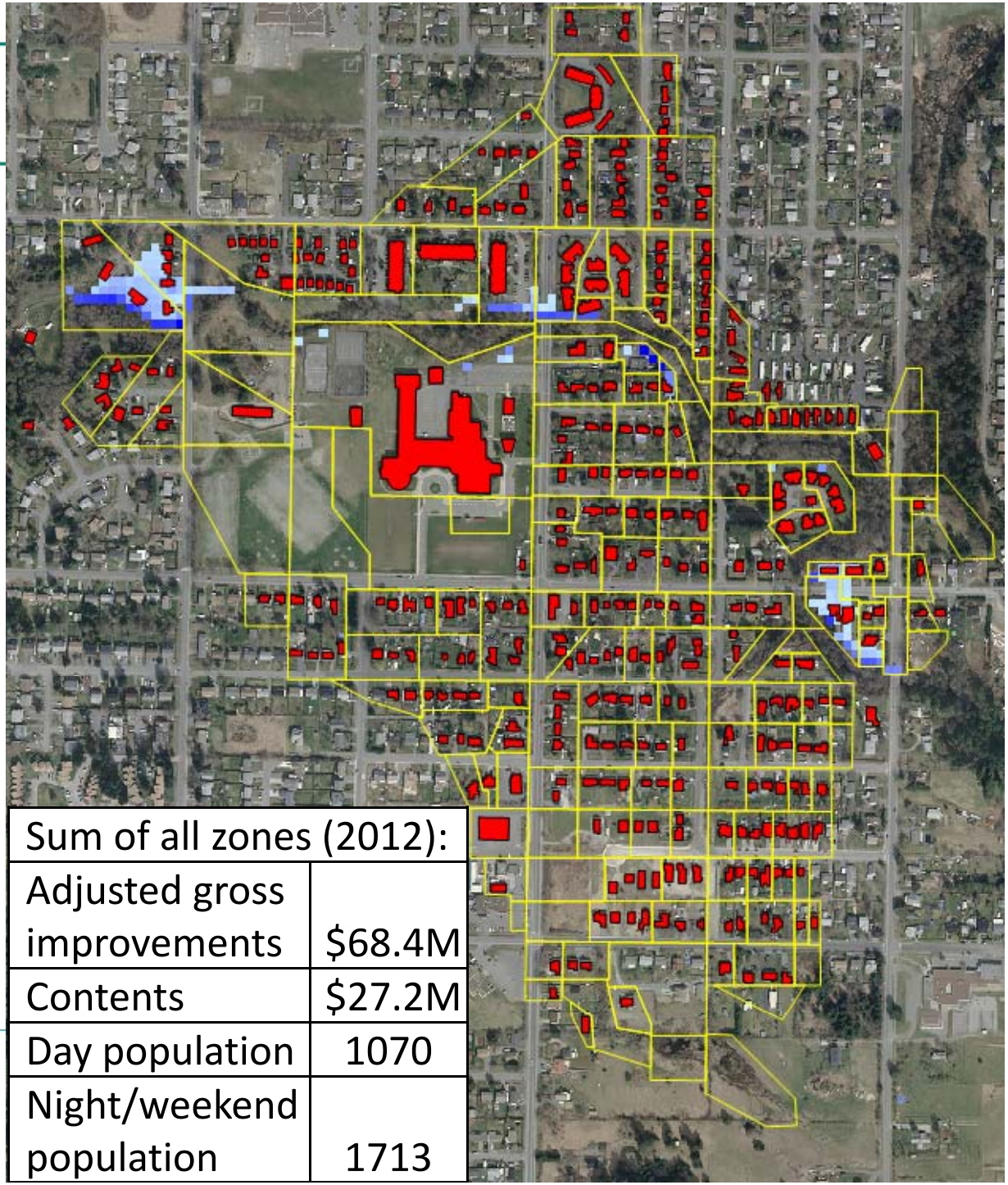
Downstream "Zones"

- >Worst Case inundation (AE 2012 – same model)
- Identified area of interest
- Subdivided area into spatial "zones" within which properties/ population can be combined



Downstream Inund Model (AE)

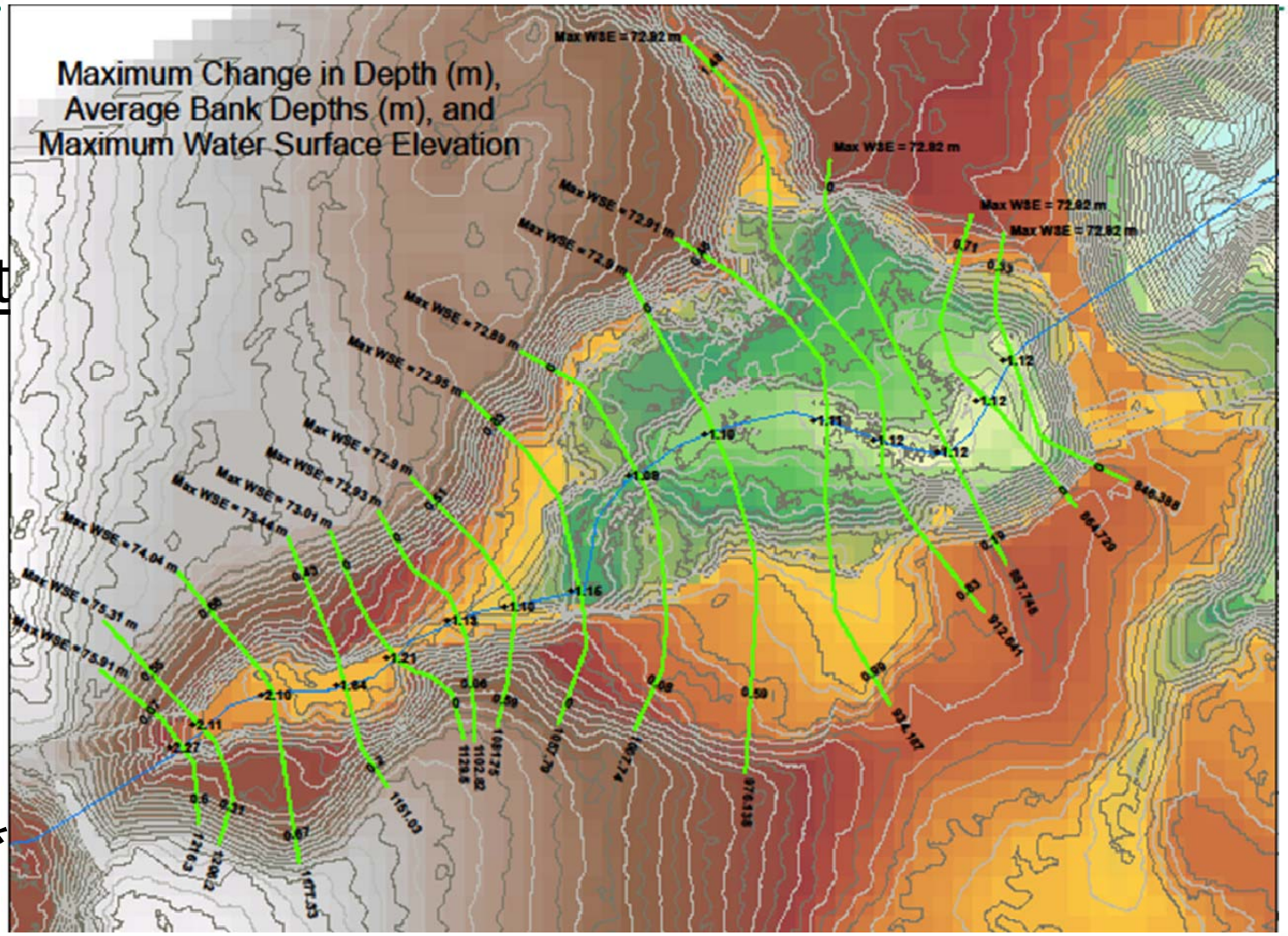
- 10m x 10m res =1 million cells
- 174 potentially affected spatial "zones", each:
  - collective structures (values) & pop-ulation (2012)
  - average inundation
- Middle Dam fast breach seismic w no Lower Dam failure is shown



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

Lower Reservoir Inundation Model

- HEC-RAS
- Middle Dam fast breach seismic
- Max Δdepth <1.5m*
- Max velocity <0.5m/s*



** Except thru upstream "neck" where people rarely are*

Exposed Population – Pre-warning

- Downstream Population (pre-warning/evacuation)
  - Mostly residential, plus school and some commercial
  - Average per dwelling unit vs specific properties (AE 2012, higher than current, considering controllable future growth)
  - Different for work day (25%) vs nights/weekends (75%), but not significantly different among seasons
  - Mix of population type (age and capability) and location (in structure, in vehicle, outside) - averaged
  - Inundation random occurrence (workday vs night/weekend)

Average population in Downstream area at any particular time

Property type	Weekday (25%)	Weekend/night (75%)
Residential (avg per Dwelling Unit) / Comm	x1/3 (1/5 if >30)	3
Multifamily (avg per Dwelling Unit)	x1/4 (1/3 if <25)	3
School/daycare	533	12
Soccer field	31	3

Exposed Population – Pre-warning

- Lower Reservoir Population (pre-warning/evacuation)
  - Only recreational use – everyone is outside
  - Different for weekend day (10%), week day (25%) and night (65%), and different for summer (25%), spring/fall (50%), and winter (25%) – nobody during major storm
  - Mix of population type (age and capability) – averaged
  - Seismic only, inund. random occurrence
  - Population varies significantly - 3.9 average over a year

Average population in Lower Reservoir area at any particular time

Season | time of day/week	Weekend Day (10%)	Weekday (25%)	Night (65%)
Summer (25%)	25*	15	0
Spring/Fall (50%)	15	10	0
Winter (25%)	5	3	0

** If average summer weekend day increases to 50, average exposed population would only increase to 4.5.*

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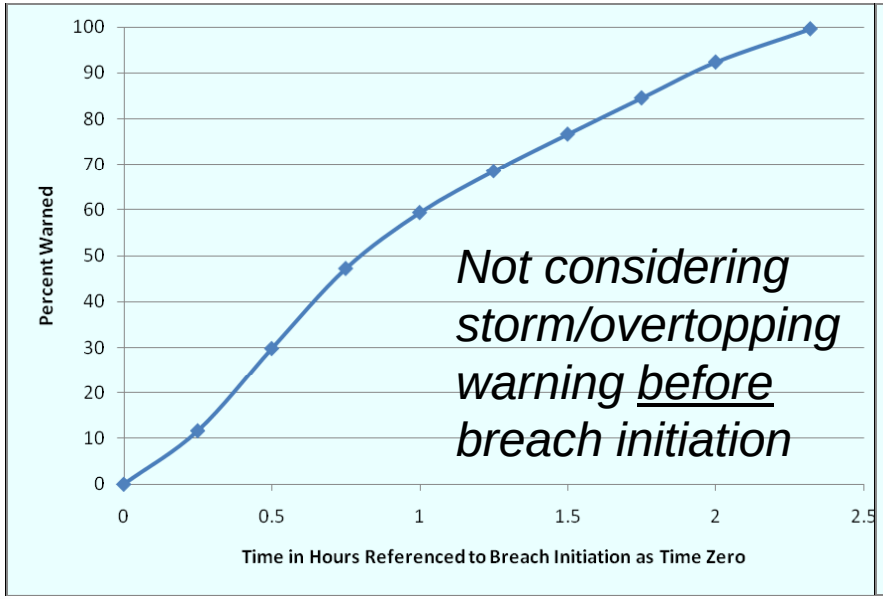
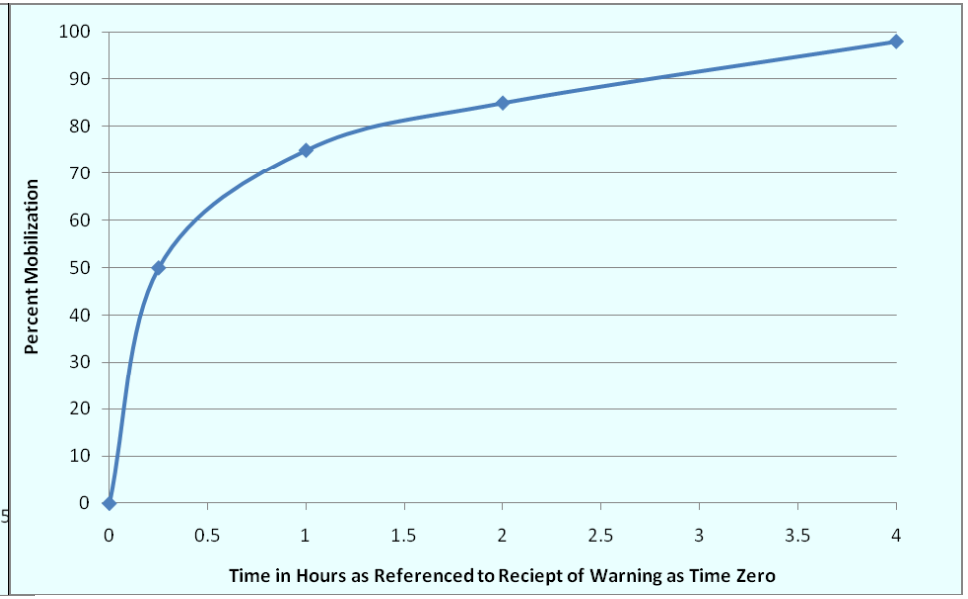
Exposed Population – Post-warning (if any)

- Evacuation time (relative to dam breach initiation):
  1. "Warning" (+/- time relative to breach initiation)*
  2. Mobilization (delay after warning to start evac)*
  3. Evacuation (transit time out of flood zone, for pedestrians and for vehicles, considering traffic): est. 0.2 to 0.5 hr





*(ref. USACE in Feinberg) * conservatively do not consider CoN procedures*

Exposed Population – Post-warning (if any)

- Downstream Pop Evac % ≈ P[warning] x P[mob] x P[avg evacuation time < avg flood arrival time] where times are relative to breach initiation

Breach type	P[Warn]	Warning (hr)	P[Mob]	Mob (hr)	Transit (hr)	P[W]* P[M]	M[ET] (hr)	S[ET] (hr)
Storm/overtopping	95%	-2 to 0.5	98%	0.1 to 2	0.2 to 0.5	93%	0.65	1.23
Seismic/other	80%	0 to 1.0	98%	0.1 to 2	0.2 to 0.5	78%	1.90	0.85

Assume evacuation time (ET) is normally distributed:
$P[ET<FAT] = \Phi\{(FAT - M[ET])/S[ET]\}$ *FAT = flood arrival time*

Breach type | flood arrival time (FAT) = development time + flood travel time	Slow/none (2.5hr)	Mod (1hr)	Fast (0.3hr)
Storm/overtopping	87%	57%	36%
Seismic/other	60%	11%	2%

- Lower Reservoir Pop Evac % assume same as seismic

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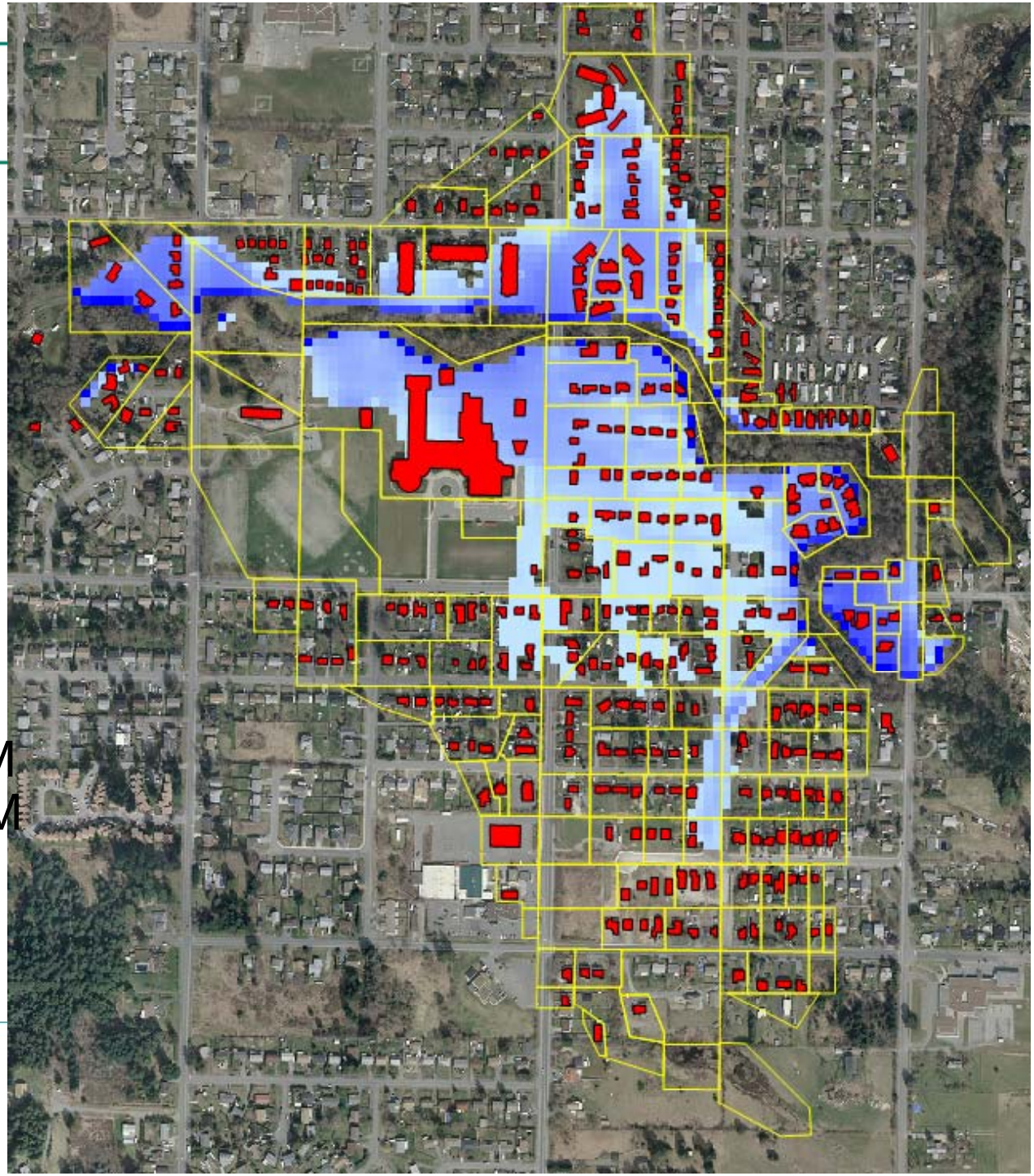
SC3 PMF Mid Dam Fast Breach Only

- Phase 1 (no Lower Dam failure) worst case scenario
- 83 zones wet
  - Max inundation
    - Depth 3.7m
    - Vel 2.0m/s
  - Property
    - Impr $44.2M
    - Cont $16.2M
  - Population
    - Day 917
    - Night 1254



Scenarios: Parameters

Scenario ID	Event Type	Return Period	Breaches	Dam Breach Duration (min)	Warn/evac Effective
SC1	Seismic/Other	All	Middle Dam Only	Fast – 10	2%
SC2**	Seismic/Other	All	Middle Dam Only	Slow – 150	60%
SC3	PMF	~ 50,000 year	Middle Dam Only	Fast – 10	36%
SC4	PMF	~ 50,000 year	Middle Dam Only	Slow – 150	87%
SC5	1000-year Flood	1000 year	Middle Dam Only	Fast – 10	36%
SC6**	1000-year Flood	1000 year	Middle Dam Only	Slow – 150	87%
SC7	1000-year Flood	1000 year	No Breach	N/A	87%
SC8	PMF	~ 50,000 year	No Breach	N/A	87%
SC9**	100-year Flood	100 year	Middle Dam Only	Fast – 10	36%
SC10**	100-year Flood	100 year	Middle Dam Only	Slow – 150	87%
SC11	1000-year Flood	1000 year	Middle Dam Only	Mod – 60	57%
SC12	1000-year Flood	1000 year	Middle&Lower Dams	Mod - 60&120	57%
SC13	PMF	~ 50,000 year	Middle&Lower Dams	Mod - 60&120	57%
SC14	PMF	~ 50,000 year	Middle&Lower Dams	Fast - 10&10	36%
SC15*	Seismic/Other	All	Middle&Lower Dams	Mod - 60&120	11%

** Scenario not modeled, but interpolated/extrapolated from other scenarios. ** not interp/extrap.*

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Scenarios: Inundation

Scen ID	# Zones Flooded	Max Depth (m)	Max Velocity (m/s)	Adj Gross Impr Value $	Contents Value $	Total Prop Value $	Day Pop.	Night Pop.
SC1	17	0.42	0.25	5,545,000	2,753,500	8,298,500	606	306
SC2**	Not interpolated/extrapolated							
SC3	83	3.71	2.00	44,231,000	16,169,500	60,400,500	917	1254
SC4	53	2.88	0.47	22,906,000	11,433,500	34,339,500	813	1032
SC5	64	3.01	1.70	37,773,000	13,008,500	50,781,500	866	1101
SC6**	Not interpolated/extrapolated							
SC7	38	1.80	1.70	14,607,000	7,284,500	21,891,500	708	652
SC8	52	2.75	1.70	22,686,000	11,323,500	34,009,500	811	1026
SC9**	Not interpolated/extrapolated							
SC10**	Not interpolated/extrapolated							
SC11	47	2.42	0.42	20,363,000	10,162,000	30,525,000	792	969
SC12	55	2.89	0.49	23,006,000	11,483,500	34,489,500	814	1035
SC13	86	3.60	4.60	44,692,000	16,368,500	61,060,500	919	1260
SC14	123	4.39	5.00	55,588,000	21,785,500	77,373,500	1001	1506
SC15*	extrapolate from SC17 (SC12 and SC13)							

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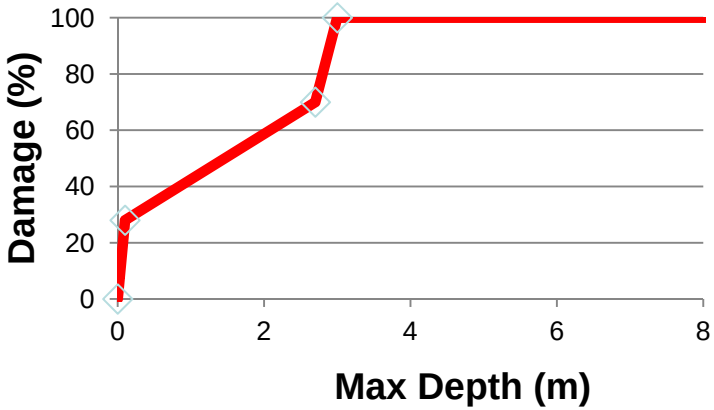
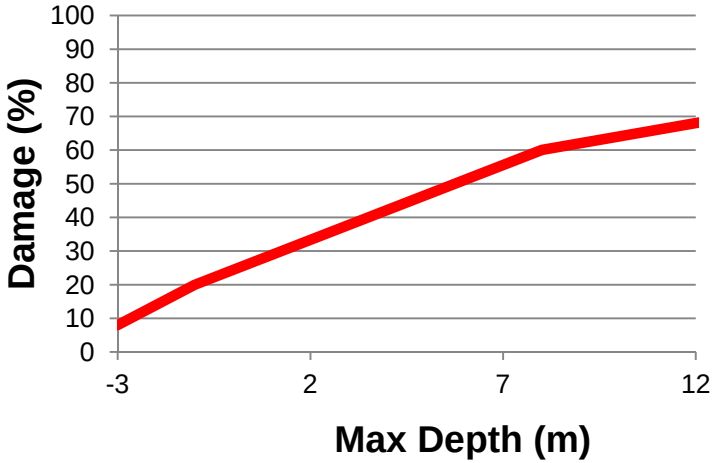
Property Damage Curves (AE 2012)

Residential Contents Damage



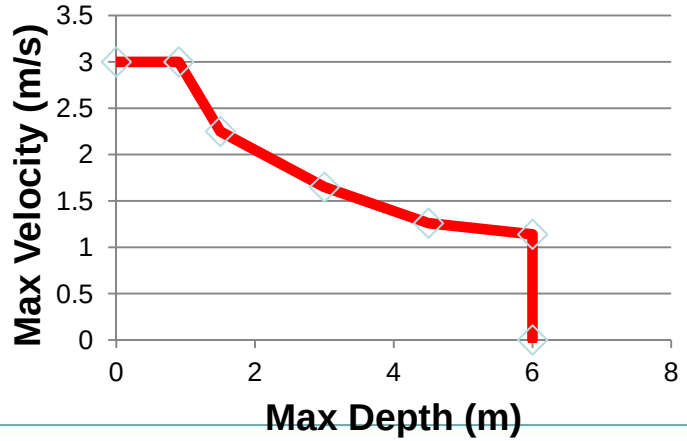
Structure Damage



Note: Assumes primarily residential 2+ story (timber) with basement

Structure type	Collapse if D*V (m2/s) >
Poorly constructed	5
Well built timber	10
Well built masonry	15
Concrete	20
Large concrete	35

Structure Collapse



Mortality Curve

Average mortality for all remaining populations (age, gender, capability, protection, etc.)

Assume remaining population is "average"

$P[F] = \Phi\{(\ln(D) - 1.46)/0.28\}$

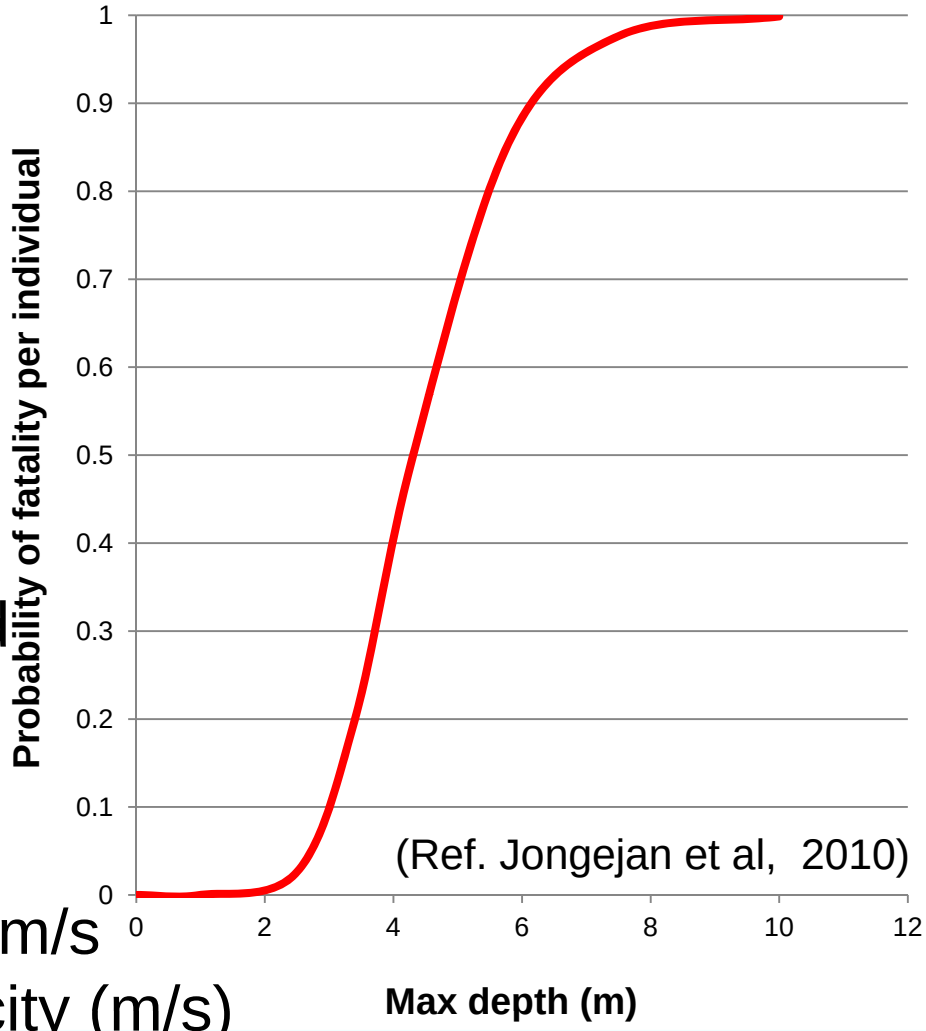
i.e., empirically derived lognormal distribution

> 0.0002 (USACE min)

= 1 if structural collapse

or if $DxV>7m^2/s$ & $V>2$ m/s

D=depth (m) & V=velocity (m/s)



"Conditional" Scenario Consequences

For each scenario (assuming it occurs):

- for each downstream spatial zone:
  - inundation (max depth and velocity)
    - ➔ 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 fatality per individual (conservatively assume 100% time in zone pre-warning)

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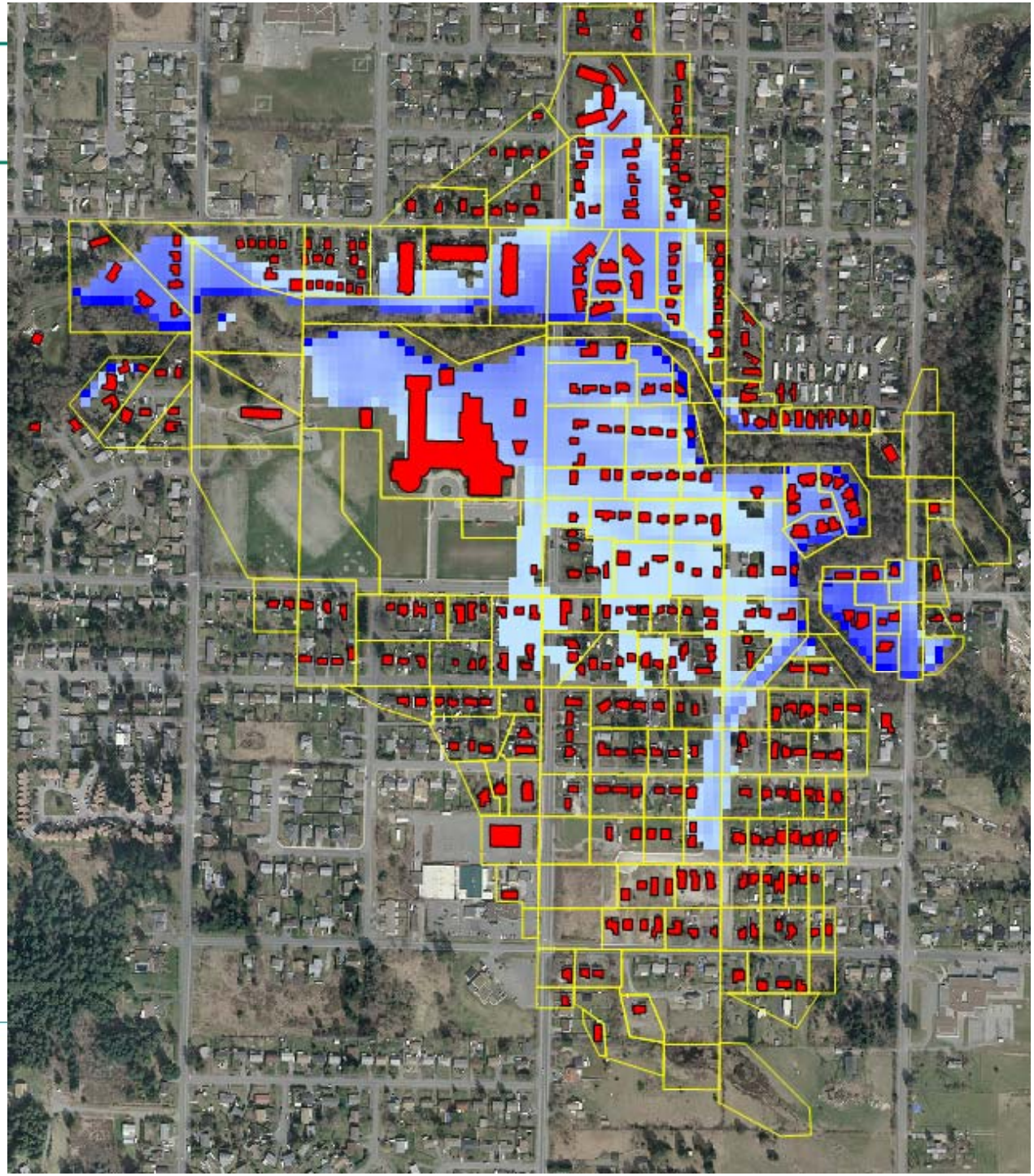
SC3 PMF Mid Dam Fast Breach Only

Downstream

- "Absolute"
  - Damages
    - Impr $7.6M
    - Cont $4.4M
    - Ttl $12.1M
  - Safety
    - #Fatal 2.0
    - Indiv 0.19
- "Incremental"
  - Damages
    - Ttl $5.3M
  - Safety
    - #Fatal 1.9
    - Indiv 0.18



Scenarios: "Conditional" Consequences

Scen ID	Scenario Consequences					Incremental Consequences		
	Building Damage	Contents Damage	Total Damage	Number Fatalities	Max Ind Ann P[F]	Total Damage	Number Fatalities	Max Ind Ann P[F]
SC1	$0.8	$0.5	$1.3	7.5E-02	2.0E-04	$1.3	7.5E-02	2.0E-04
SC3	$7.6	$4.4	$12.1	2.0E+00	1.9E-01	$5.3	1.9E+00	1.8E-01
SC4	$5.2	$3.1	$8.3	7.2E-02	9.8E-03	$1.6	1.7E-02	2.7E-03
SC5	$5.8	$3.5	$9.3	4.9E-01	6.4E-02	$5.5	4.8E-01	6.4E-02
SC7	$2.4	$1.4	$3.8	1.8E-02	1.2E-04	NA	NA	NA
SC8	$4.2	$2.5	$6.7	5.4E-02	7.2E-03	NA	NA	NA
SC11	$2.9	$1.7	$4.7	1.06E-01	8.42E-03	$0.9	8.8E-02	8.3E-03
SC12	$4.0	$2.4	$6.4	2.44E-01	3.33E-02	$2.7	2.3E-01	3.3E-02
SC13	$5.8	$3.4	$9.2	1.06E+00	1.12E-01	$2.5	1.0E+00	1.0E-01
SC14	$9.5	$5.5	$15.0	1.12E+01	6.40E-01	$8.2	1.1E+01	6.3E-01
SC1+	Add Lower Res (no sig property, 3.9 people avg pre-warn, max individ is 10% occ, P[evac]=2%, maxD→P[F]=0.0002						7.6E-04	2.0E-05

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Scenarios: Interpolated/Extrapolated

- Need other specific “expected value” scenarios

Trigger	Mod Mid Dam, No Low Dam	Mod Mid Dam, Mod Low Dam
PMF	SC19 from SC3-4 (SC5&11)	SC13
1000 yr storm	SC11	SC12
100 yr storm*	SC18 from SC17 (SC12-13,SC5&11)	SC17 from SC12-13
Seismic	SC16 from SC1 (SC5&11)	SC15 from SC17 (SC12-13)

* SC20 (no Mid or Low Dam breach) from SC7-8

- Approximate inundation by interpolation/extrapolation

Scen ID	# Zones Flooded	Max Depth (m)	Max Velocity (m/s)	Adj Gross Impr Value $	Contents Value $	Total Prop Value $	Day Pop.	Night Pop.
SC15	Incremental consequences interpolated/extrapolated							
SC16	Incremental consequences interpolated/extrapolated							
SC17	48	2.63	0.25	$20.7	$10.3	$31.1	782	919
SC18	Incremental consequences interpolated/extrapolated							
SC19	54	3.16	0.25	$22.9	$11.4	$34.3	813	1032
SC20	25	1.25	0.25	$9.0	$4.5	$13.5	635	393

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Scenarios: Interpolated/Extrapolated

- Determine conditional consequences

Scen ID	Scenario Consequences					Incremental Consequences		
	Building Damage	Contents Damage	Total Damage	Number Fatalities	Max Ind Ann P[F]	Total Damage	Number Fatalities	Max Ind Ann P[F]
SC15						(30% of SC17) + LowRes		
SC16						(10% of SC1) + LowRes		
SC17	$5.5	$3.2	$8.7	1.1E-01	1.0E-02	$4.9*	7.0E-02*	1.0E-02*
SC18						(35% of SC17)		
SC19	$6.2	$3.9	$10.1	4.4E-01	5.8E-02	$3.4	3.8E-01	5.0E-02
SC20	$2.4	$1.4	$3.8	3.9E-02	8.6E-05	NA	NA	NA
SC15+ SC16+	Add Lower Res (no sig property, 3.9 people avg pre-warn, max individ is 10% occ, P[evac]=2%, maxD➔P[F]=0.0002						7.6E-04	2.0E-05

Note: P[evac] for SC15-16 is 11% evacuation, and for SC17-20 is 57%

Combine each scenario's conditional consequences with probability of that scenario occurring ➔

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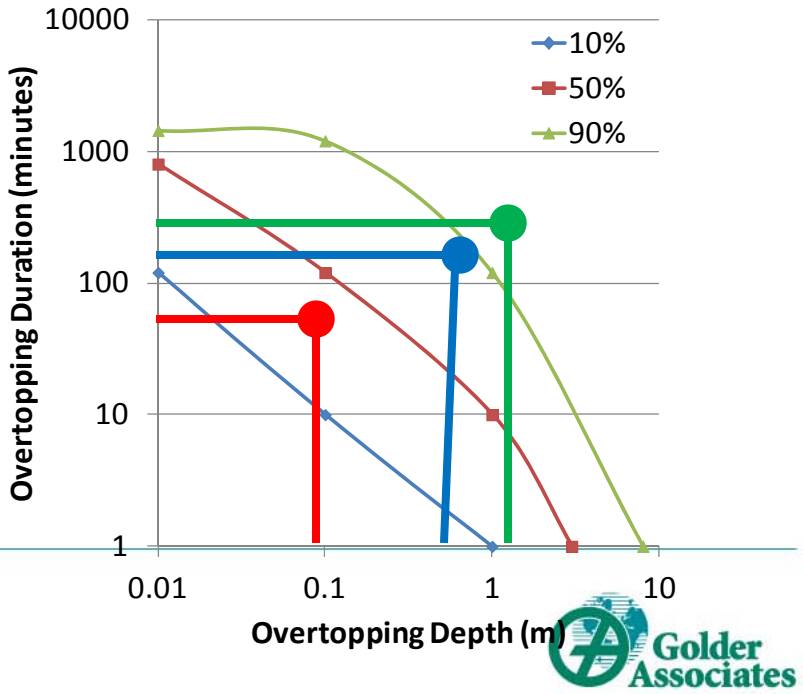
Dam Overtopping Scenario Probabilities

Storm	Spill Mid Dam		Butt Mid Dam		Lab Low Dam		Hard Low Dam	
	Max Depth (m)	Duration (hr)	Max Depth (m)	Duration (hr)	Max Depth (m)	Duration (hr)	Max Depth (m)	Duration (hr)
PMF	0.2	0.5	1.5	4.4	0/0.1*	0/0.1*	1.5/1.8*	15.5/15.4*
1000 yr	0	0	0.8	2.4	0/0*	0/0*	1.0/1.3*	7.5/7.3*
100 yr	0	0	0.1	1.0	0/0*	0/0*	0.3/0.8*	2.0/1.8
Seismic	0	0	0	0	0/0*	0/0*	0/0.7*	0/0.3*

**wo/w Middle Dam breach*

e.g., Buttress Mid Dam

Storm	Storm Ann. Prob. of Exceed	P[F]	Breach Ann. Prob. Of Exceed.
PMF	1/50,000	95%	1.9×10^{-5}
1000 yr	1/1000	85%	7.5×10^{-4}
100 yr	1/100	35%	3.5×10^{-3}
Seismic	NA	0%	0



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Dam Overtopping Scenario Probabilities

Storm	Storm Ann. Prob. of Exceed	Spill Mid Dam		Butt Mid Dam*		Lab Low Dam		Hard Low Dam	
		P[F]	Breach Ann. Prob. Of Exceed.	P[F]	Breach Ann. Prob. Of Exceed.	P[F]**	Breach Ann. Prob. Of Exceed.**	P[F]**	Breach Ann. Prob. Of Exceed.**
PMF	1/50,000	30%	$6x10^{-6}$	95%	$1.9x10^{-5}$	0/5%	$0/1x10^{-6}$	45/50%	$9/10x10^{-6}$
1000 yr	1/1000	0%	0	85%	$7.5x10^{-4}$	0/0%	0/0	20/25%	$2/2.5x10^{-4}$
100 yr	1/100	0%	0	35%	$3.5x10^{-3}$	0/0%	0/0	1/5%	$1/5x10^{-4}$
Seismic	NA	0%	0	0%	0	0/0%	0/0	0/0%	0/0

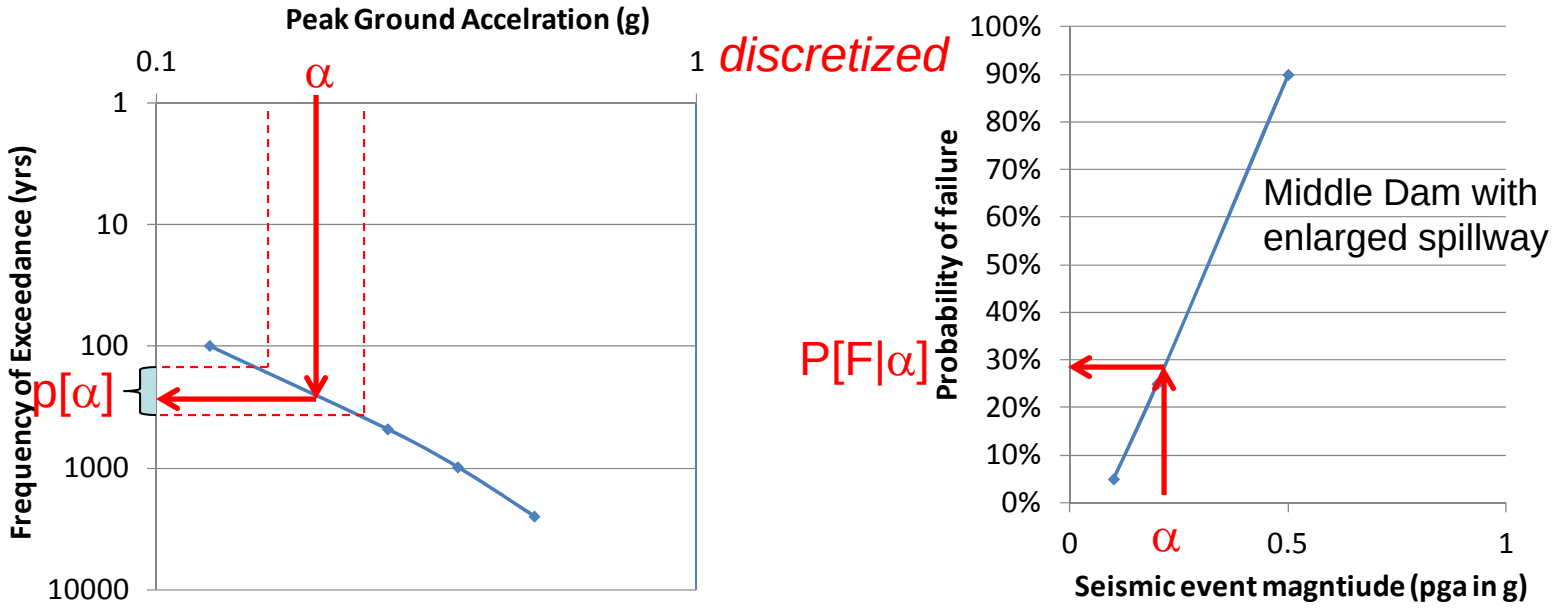
** Same as no change Mid Dam*
***wo/w Middle Dam breach*

Dam Seismic/Other Annual Scenario Probability

Failure Mode	Spill Mid Dam	Butt Mid Dam	Lab Low Dam	Hard Low Dam
Seismic	**3.5×10^{-3}**	4.2×10^{-4}	1.8×10^{-3}	1.1×10^{-3}
Other	1×10^{-3}	1×10^{-3}	1×10^{-3}	1×10^{-3}
Combined	4.5×10^{-3}	1.4×10^{-3}	2.8×10^{-3}	2.1×10^{-3}

← $P[F]=\Sigma_{all\ \alpha} P[F|\alpha]\ p[\alpha]$

← subjective



Scenarios: Results

- Annual probability of each representative scenario (from cumulative storm and seismic probability and probability of failure for storm and seismic magnitudes) – non-failure scenarios have no conseq

For example:

For No Change to Middle Dam, Hardened Lower Dam — **Conditional Incr Conseq**

Storm	Breach	P[Mid Dam]	P[Low|Mid]	P[Scenario]	Rep Scenario(s)	Damg ($M)	Fatalities	Ind Risk
PMF	Mid Dam only	1.90E-05	0.47	8.9E-06	SC19	$3.4	3.8E-01	5.0E-02
	Mid & Low Dam		0.53	1.0E-05	SC13	$2.5	1.0E+00	1.0E-01
1000 yr	Mid Dam only	7.50E-04	0.67	5.0E-04	SC11	$0.9	8.8E-02	8.3E-03
	Mid & Low Dam		0.33	2.5E-04	SC12	$2.7	2.3E-01	3.3E-02
100 yr	Mid Dam only	3.50E-03	0.86	3.0E-03	SC18*	$ 1.7	2.5E-02	3.6E-03
	Mid & Low Dam		0.14	5.0E-04	SC17	$4.9	7.0E-02	1.0E-02
Seismic	Mid Dam only	4.50E-03	0.53	2.4E-03	SC16*+Low Res	$0.1	8.2E-03	4.0E-05
	Mid & Low Dam		0.47	2.1E-03	SC15*+Low Res	$ 1.5	2.2E-02	3.1E-03
					Expected annual consequence	$0.01	2.6E-04	3.3E-05

** Conditional incremental consequences are interpolated/extrapolated*

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Scenarios: Results

Mid Dam	Low Dam	Expected Ann Incr Conseq			Exp Scenario Incr Conseq*			
		Damage	Fatalities	Max Ind	PMF	1000y	100y	Seismic
none	harden	$0.010	2.6E-04	3.3E-05	7.1E-01	1.3E-01	3.1E-02	1.5E-02
“	labyrinth	$0.009	2.1E-04	2.4E-05	4.2E-01	8.8E-02	2.4E-02	1.5E-02
buttress	harden	NA	NA	NA	NA	NA	NA	NA
“	labyrinth	$0.003	6.9E-05	6.9E-06	4.9E-01	0.0E+00	0.0E+00	1.5E-02
spillway	harden	NA	NA	NA	NA	NA	NA	NA
“	labyrinth	$0.010	2.0E-04	2.6E-05	4.2E-01	8.8E-02	2.5E-02	2.2E-02

** Combining probabilities and conditional expected values of incremental consequences for Mid Dam breach only and for both Mid and Low Dam breach scenarios.*

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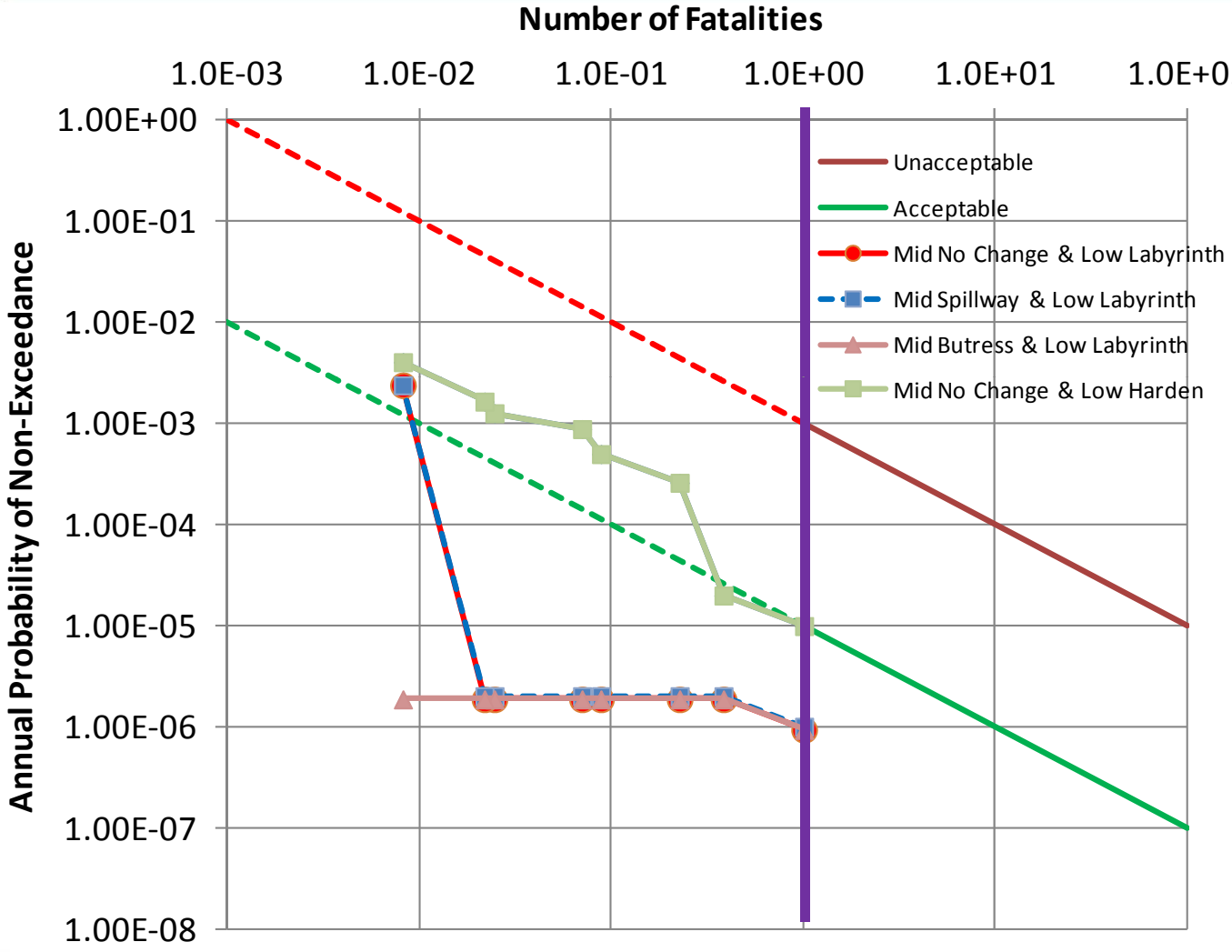
Phase 2: F-N Results



Note: This is a plot of the expected value of the conditional incremental consequence (number of fatalities) vs the annual probability of exceedance for each "trigger" scenario. There is a range around each expected value, For any scenario with an expected value of <1, the probability of 1 is less than the scenario probability.

Phase 2 Risk Assessment Summary

- Phase 2 risk assessment
  - Considers Mid & Low Dam rehab options & possible failures
  - Limited failure scenarios (interpolate/extrapolate)
  - Preliminary inputs (including subjective assessments)
- Phase 2 results
  - Negligible incremental damages for all options
  - Not unacceptable incremental F-N for all options
  - Acceptable incremental max individual risk for all options
- Additional needs
  - Approve approach / risk model
  - Finalize inputs (new info) ➔ outputs (esp for rehab options)
  - Finalize evaluation w.r.t. risk-based criteria

Thank you!

Questions?