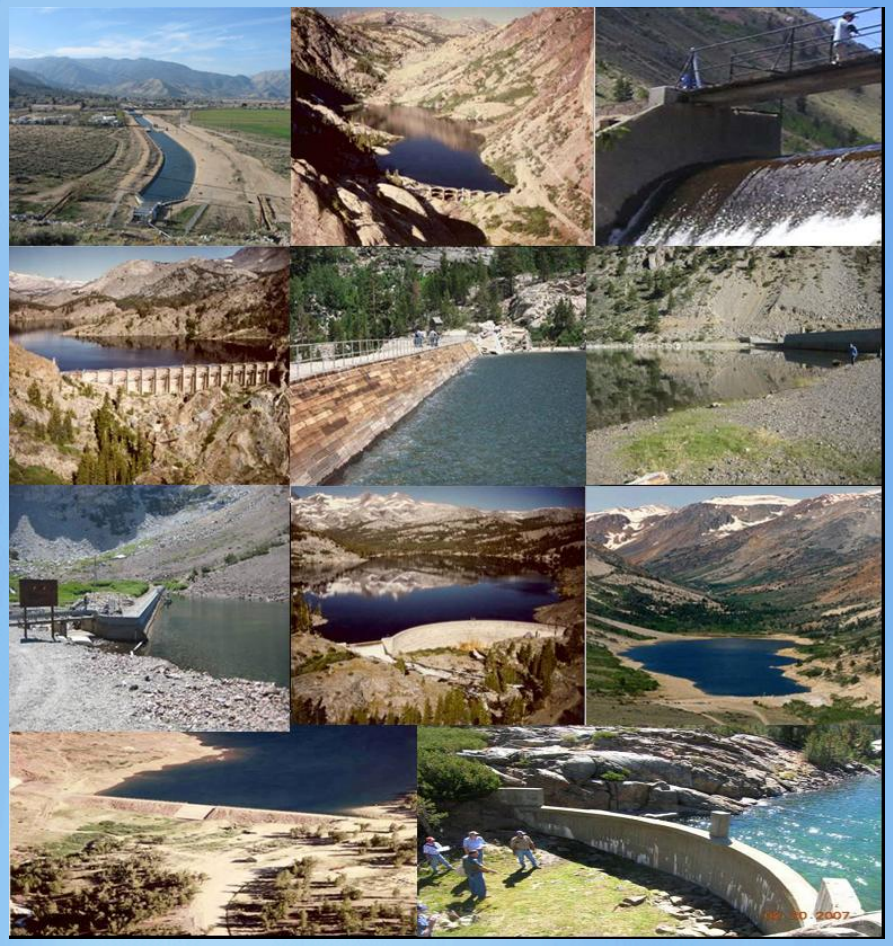
Managing Infrastructure for Dam Safety through Risk Assessment Programs (RAP) and Risk Informed Decision Making (RIDM)



Prepared by

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April & June, 2012

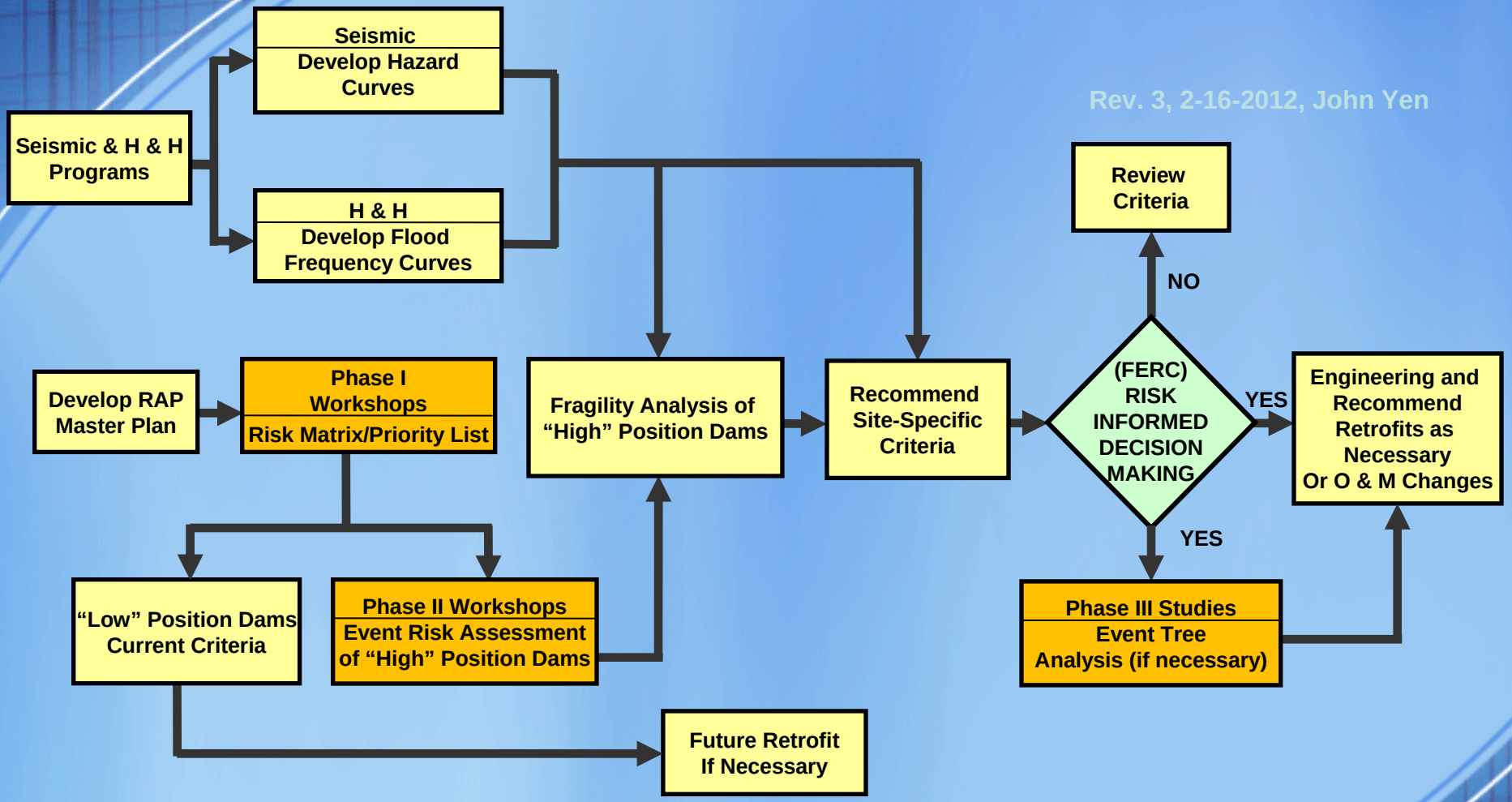
Why Risk?

- Risk by definition is something you want to avoid, so why embrace it?
- Risk encourages a broader engagement across the organization when critical decisions need to be made.
- Risk provides an informed context for participants while reducing the need to find the “exact answer.”

Risk Assessment Program
for Dam Safety

- A Risk Assessment Program (RAP) brings technical experts, operations, management, and regulators together to arrive at a common understanding of infrastructure performance and related issues.
- Initial meetings are aimed at understanding performance risks of our dams and supporting infrastructure.

Dam Safety
Risk Program Overview



Phase I Workshop

- Assess and evaluate your dams and support infrastructure on the basis of likelihood and consequence of failure.
- Assemble this information into a Risk Matrix that provides an “instant visual” for where your critical needs are.
- Develop a priority list of dams and support infrastructure for advanced engineering studies or even retrofits.

Phase II Workshop

- This workshop focuses on event risk assessments associated with “high risk” dams and support infrastructure.
- Outcomes may include
  - agreement to shift location within Risk Matrix based on previously unknown information or conditions
  - fragility analyses to further evaluate event risk and risk to operations

Ground Rules

1. Studies in the workshop and resulting documents are unique for SCE dams. They are confidential and should not be released to the public, or for reference by others without prior permission from SCE
2. The resulting documents may be released to the FERC for reference only upon their request and with SCE Senior Management Approval

Failure Likelihood Descriptions

- **Very High –** There is direct evidence or substantial indirect evidence to suggest it has occurred and/or is likely to occur. Or, a flood or earthquake with a return period less than 1,000 years would likely trigger the potential failure mode.
- **High –** The fundamental condition or defect is known to exist, indirect evidence suggests it is plausible, and key evidence is weighted more heavily toward likely than unlikely. Or, a flood or earthquake with a return period between 1,000 and 10,000 years would likely trigger the potential failure mode.
- **1/10,000**
- **Moderate –** The fundamental condition or defect is known to exist, indirect evidence suggests it is plausible, and key evidence is weighted more heavily toward unlikely than likely. Or, a flood or earthquake with a return period more remote than 10,000 years would likely trigger the potential failure mode.
- **Low –** The possibility cannot be ruled out, but there is no compelling evidence to suggest it has occurred or that a condition or flaw exists that could lead to its development. Or, a flood or an earthquake with a return period much more than 10,000-years would likely trigger the potential failure mode.
- **Remote –** Several events must occur concurrently or in series is required to trigger failure. Most, if not all of the events are very unlikely; potential failure is non-credible. (Note: this category may not be included on the risk matrix.)

Consequence (Simplified) Descriptions

- **Level 0 –** No significant impacts to the downstream population other than temporary minor flooding of roads or land adjacent to the river.
- **Level 1 –** Downstream discharge results in minor property and environmental damage. Damage is likely to recreation areas, roads, and bridges in low-lying areas. Direct loss of life is unlikely.
- **Level 2 –** Downstream discharge results in moderate property and environmental damage. Damage to permanently occupied structures, recreation areas, roadways, and bridges in low lying areas is possible. The potential exists for some direct loss of life.
- **Level 3 –** Downstream discharge results in extensive damage to permanently occupied structures, roadways and bridges throughout the inundation zone. Direct loss of life is likely.
- **Level 4 –** Downstream discharge results in extensive damage to permanently occupied structures, roadways and bridges throughout the inundation zone. Direct loss of life could be high.

Confidence Level

For each category rating, assign a confidence level to the rating:

- **Good:** Confidence in the rating is high; it is unlikely that additional information would change the rating
- **Poor:** Confidence in the rating is low; additional information could very well result in a change to the rating
- **Medium:** In between Good and Poor

PFMA Category

Category I – **Highlighted** – These potential failure modes have the greatest significance, considering: need for awareness, potential for occurrence, and magnitude of adverse consequences (physical possibility is evident, fundamental flaw or weakness is identified, and condition or events leading to failure are in progress or seem reasonable and credible).

Category II – **Considered but not Highlighted** – These potential failure modes are less significant than Category I. They are judged to be possible but do not need to be highlighted to the owner for various reasons. For example, the PFM does not result in a significant downstream hazard; it has a low probability of occurrence; or there is an existing monitoring or maintenance program that makes the probability of occurrence unlikely. However, conditions are such that they are physically plausible and continued awareness is important.

Category III – **More Information or Analysis Needed** – A potential failure mode in this category requires additional information and/or analysis to allow proper classification.

Category IV – **Ruled Out** – There is not a physical possibility that these potential failure modes could occur, the concern is eliminated by considered information, and/or the possibility that the failure mode could occur is so remote as to be non-credible.

SCE DAM SAFETY RISK ASSESSMENT PROGRAM WOKSHOP PHASE I FOR EHD

QUALITATIVE RISK ASSESSMENT MATRIX

OCTOBER 2009

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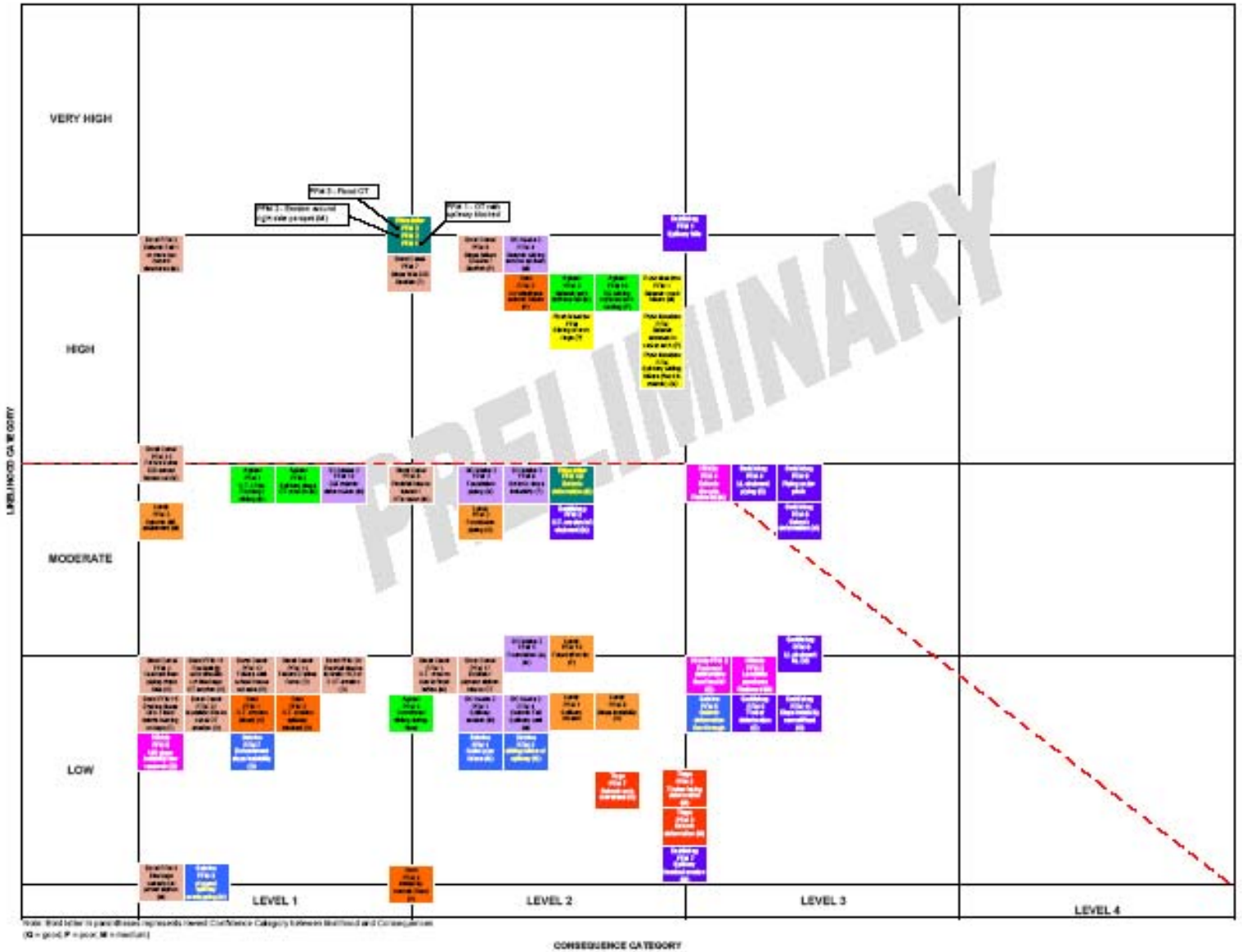

CONSEQUENCE CATEGORY

RAP Worksheet for Sample Dam

Worksheet for Qualitative Assessment

Tioga Lake Dam

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Potential Failure Mode Summary	PFMA Category	Likelihood Category	Rationale for Likelihood Category (Key Factors)	Likelihood Confidence	Consequence Category	Rationale for Consequence Category (Key Factors)	Consequence Confidence
1.Blocked spillway during flood results in overtopping/flow-through erosional failure	Cat II	Remote	Spillway bays are narrow. No log booms in place. Depth of overtopping could be significant if spillways blocked.Spillway depths are shallow.Vegetation is sparce above dam. No history of debris or ice problems. This type of rockfill dam is very forgiving. Two spillways at dam, providing some redundancy.	Good	2	Thunderstorm event could trigger this PFM, thus providing little warning. Tioga Resort is at risk and is only a short distance from the reservoir. Property and people at risk. Overtopping event, so lake level indicators would alert Bishop Control to this condition, providing some advanced warning.	Good
2. Timber facing deterioration leading to flow-through erosional failure	Cat II	Low	Deteriorated timber is no longer being replaced. This scenario would proceed slowly and would be detected by weirs before a rupture would occur. The redwood facing is 2 layers thick. In 1939, vandals blasted a hole in the dam that resulted in 25 cfs leakage without any impact to dam. Geomembrane installation is scheduled for 2014, which may reduce the category to Remote.	Good	2 to 3	Given the large rockfill evident on the downstream face, this event would proceed much slower than at other SCE timber faced dams. Anticipated that some time may be available to alert downstream areas. However, there is still some uncertainty regarding rate at which this PFM would progress.	Medium
3. Seismic deformation results in dam breach	Cat IV	Low	Rockfill was dumped, not compacted. Dam has not experienced even moderate intensity earthquakes. Redwood facing can accommodate some deformation. Four feet of freeboard under normal full pool. Angular rockfill is likely strong due to interlocking effects.Swaisgood analysis for 0.91g (10,000 year event) shows 0.4 foot of settlement.	Good	2 to 3	Uncertain on how fast this failure would progress. Once dam breaches, there are populated areas very close that would be impacted quickly.	Medium
4. Slope stability failure of dam under static loading	Cat IV	Remote	Dam is composed of strong angular rock fill. Rockfill is free draining. More than adequate computed factors of safety.	Good	3	This event would proceed rapidly and there would be little time to warn downstream areas.	Good

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Potential Failure Mode Summary	PFMA Category	Likelihood Category	Rationale for Likelihood Category (Key Factors)	Likelihood Confidence	Consequence Category	Rationale for Consequence Category (Key Factors)	Consequence Confidence
5. Spillway undermining erosion results in breach in main spillway	Cat IV	Remote	Spillway concrete control crest is founded directly on hard, erosion resistant granite. Spillway discharges several inches each year with no observable damage. Spillway saw about 1 foot of depth during flood of record with no damage. Spillway has gentle slopes downstream with are armored with erosion resistant cobbles and boulders.	Good	1	Loss of spillway crest would have negligible impact on peak outflows and not expected to impact main dam.	Good
6. Flood erosion of downstream fill fails arch dam	Cat IV	Remote	Arch dam foundation reportedly excavated 1.5 feet minimum into hard granite bedrock. Dam was designed to be stable even if the downstream backfill erodes away. Recent analyses show low compressive and tensile stresses for PMF load case. Significant depth of backfill on downstream side (as much as 14 feet). Large boulders are evident in drainage area, likely limiting erosion to near surface material.	Good	2 to 3	Failure of arch dam would be much quicker than main dam, but peak flows could be about the same because of smaller breach width.	Medium
7. Seismic failure of arch dam	Cat IV	Low	Backfill confines the lower half of dam, increasing stability. Analysis for 0.31g event shows dynamic tensile stresses are less thant the estimated dynamic tensile strength of concrete with pinned foundation conditions. For 10,000 year event, tensile stresses conservatively estimated to be 500 to 600 psi. Dam concrete is in good condition and includes nominal reinforcing steel in each face. Concrete tests have not been performed to validate material properties used in analysis. Adequate factor of safety for stability.	Good	2	Flows could be sufficiently high to quickly impact local downstream areas.	Good
8. Snow avalanche seiche results in overtopping wave erosion failure	Cat IV	Remote	Reservoir is drained in winter months. Reservoir is shallow and not conducive to formation of a large wave. Rockfill dam can withstand some short-term overtopping.	Good	0	No water in reservoir when avalanche would occur, so no impact to property or public.	Good

Industry Trend

1. USBR is the first major dam owner who has conducted a “Risk Assessment Program for Dams” and has developed guidelines for the program
2. The US Army Corps of Engineers (USACE) has started a program motivated by “Katrina.”
3. FERC-Washington DC has proposed a Risk Assessment Program (RIDM) with a budget plan beginning in 2010.


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The Team

John Yen setting the tone of the Workshop

The Team at Work

The Team at Work