Open Discussion Conclusions from Panel #4, Flood-Induced Dam and Levee Failure

1) The Probabilistic flood hazard analysis (specifically) and probabilistic risk assessment (PRA) (generally) for dam and levee failure needs a structured evaluation process like the SSHAC process. Because the specific analysis often relies on expert assessments which are biased by human errors, the PRA analysis should evaluate the comprehensive uncertainties of data and modeling.

2) Flood frequency analysis in Bulletin 17B is empirical, being based primarily on observed flood data. But, PFHA involves imagining processes by requiring more comprehensive evaluations (as described by SSHAC).

3) There are not adequate data on large dam failures. Reliable data on dams, dam components, and operations are generally not available to meet specific needs of risk assessments for individual dams or even components of dam systems.

    a. History shows that large dams seldom fail by flooding alone, but by a combination of factors as a system.

    b. We need more reliable data on dam/components failures and operations.

    c. Better data would enable us to reduce subjectivity significantly in risk analysis and decision making.

4) The estimation of dam and levee failures (fragility) is difficult and often subject to bias and limited by engineering tools.

5) The use of risk analyses (conducting comprehensive PFHA) is impeded by the lack of engineers who are trained and are comfortable with the methods that address probability, systems engineering for dams and levees, and risk in high hazard situations.

6) Probability and risk analysis for dams has come a long way in the past 25 years. Statistics on dam failure in 1975 (general conclusion that $P_{failure}=1x10^{-4}$) was not a welcome message to dam owners.

7) It is generally believed that the chances of dam failure are low (still around $1x10^{-4}$, not much change in 40 yrs), but failures continue to occur. Failures are rarely due to one factor, but often the "uncommon combination of not uncommon events". This needs to be addressed through risk analysis of dam systems.

8) In some cases, event trees/fault trees cannot handle complexity of events (e.g. examples from Canada and Taum Sauk dam failure events).

9) A lot of problems with data about dam failure events, structure, system and component performance:

a. In the past, engineers did not want to talk about failure

b. Failure reports tend to only be produce under regulatory requirement

c. We do not keep track of near-failure incidents which are useful to support risk analyses (In case of failures, we need to look at how we can make the data useful and operational in the future.)

d. However, some data are available:

  i. RMC (Risk Management Center of USACE) may have some information on reliability of mechanical/electrical components of dams.

  ii. CEATI Dam Safety Interest Group may be another source of similar information.

  iii. National Performance of Dams Program at Stanford has data on dam incidents.

10) Question was asked if order of magnitude uncertainty in predicting time of failure meant we have a range of 3 min to 30 min or 3 hr to 30 hr? Reply: It is order of magnitude uncertainty around predicted time of failure from a given regression equation, so it depends on the size of the dam. Point was also made that one big source of uncertainty about failure times is lack of accuracy/consistency in eyewitness reports of dam failure times.

11) Recent experience in lab dam breach tests has shown that time of failure (i.e., rate of erosion) for embankment dams is extremely sensitive to erodibility of soils, which is in turn sensitive to compaction processes and conditions during original construction. Tests are now available that can evaluate soil erodibility (in lab or in the field).

12) Historically, dams have done well. The experience worldwide looks good.

13) Tools have recently become available and continue to be developed that will enable us in the future to add probability and uncertainty to more nodes in the event trees describing sequences of events that lead to dam failure (e.g., process-based erosion and breach models).

14) Analyses should move toward Bayesian methods. Data are not perfect, but sufficiently good to have confidence in the analyses performed.

15) In other fields, society tolerates risks that are not considered acceptable in the dam's arena potentially develop improved guidance for tolerable risk limits.

16) The state of PRA in dam and levee safety is relatively new compared to other fields, such as nuclear power plants, where a 2nd or 3rd generation of PRA's is already underway.

17) Dam failure analysis has been focused heavily on geotechnical engineering practices, but should also incorporate structural, hydrologic, and hydraulic engineering aspects.

18) A major problem occurs when applying prescriptive methodologies in a “design-safe” manner. This prohibits thinking “outside the box” and hinders advancement in the field. On the other hand, it is costly, risky and challenging to analyze and tackle challenges in a manner outside the normal convention.