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Calaveras Dam Replacement Project

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Probabilistic Dam Breach Analysis — The Future of Dam Safety is Here!

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According to the U.S. Army Corp of Engineers' National Inventory of Dams, more than 15,000 dams are rated as "high hazard" and over one third of the more than 90,000 dams in the inventory are listed as not having an emergency action plan. In seven states , more than half of the high hazard dams are operating without an emergency action plan. Government and private dam owners are confronted with the rising costs of repairing and maintaining this important infrastructure, while balancing the need for keeping public safety at the forefront within their limited budgets.

The question facing our nation is not if we should quickly invest more in dam safety, but instead how to get the most value out of each dollar invested in our dam safety programs. Emergency planning should be a foundational component for dam owners who have an obligation to protect the public and minimize their potential exposure to risks associated with dams. Emergency planning also represents a significantly lower cost item when compared to infrastructure repair, representing an area where owners can reduce risk while meaningfully communicating with and engaging the public.

An immediate area of focus within emergency planning is associated with predicting downstream flooding associated with a dam failure. Our nation's adopted methods for characterizing risks associated with dam breaching and the related downstream flooding are perhaps outdated, and most could argue, overly conservative in assessing downstream hazards related to inundation. Present methods are deterministic, reflecting a single inundated area for which an inhabited structure is either "in" or "out" of the inundated area. There is no communication of risk-no quantification of uncertainty. While such methods create a worst-case breach scenario, they are perhaps misleading, or certainly less informative than using a range of partial dam failure releases that could result in a much wider range of inundation scenarios and flood related outcomes for downstream populations and critical infrastructure.

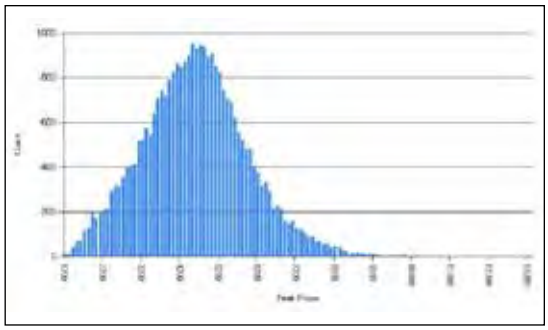

Figure 1. Distribution of dam breach peak outflow rates.

To address this uncertainty of flooding outcomes and improve decision making capabilities at the emergency planning level, Kleinschmidt has developed techniques to perform probabilistic evaluations of dam breach consequences to compliment the traditional deterministic approach. These techniques are built into the McBreach software application. This unique dam breach software allows the user to specify statistical distributions for the dam breach parameters, making way for the software to randomly sample dam breach parameter sets. Coupled with the USACE modeling software HEC-RAS, McBreach launches a Monte Carlo simulation consisting of many thousands of dam breach simulations to produce a distribution of possible dam breach peak outflow rates (Figure 1). Exceedance probabilities can then be assigned to the full range of possible dam breach peak outflow rates. The resultant output files are then mapped to visualize downstream impacts over a range of outcomes and the respective probabilities of occurrence for those outcomes, instead of a single deterministic outcome.

A key design element built into the software is the ability to randomly sample breach characteristics into several thousand (or more) breach parameter sets; each set being applied to a single dam breach simulation (or realization) in HEC-RAS. More realizations provide a more robust statistical output that demonstrates convergence of statistical moments of the computed peak discharges. But the tradeoff involved is simulation runtime. Varying the sample size provides the user with control over fidelity of output as a function of computing power available. Knowing this tradeoff is important, as statistical convergence normally occurs in the range of five to ten-thousand simulations, as shown in Figure 2. With the advent of efficiency techniques like model truncation, we have cost-effectively reduced the Monte Carlo simulation from weeks or longer, to an overnight exercise. Cloud computing can further reduce simulation times to as little as 30 minutes for up to 10,000 simulations.

So why is this new dam breach modeling practice important to

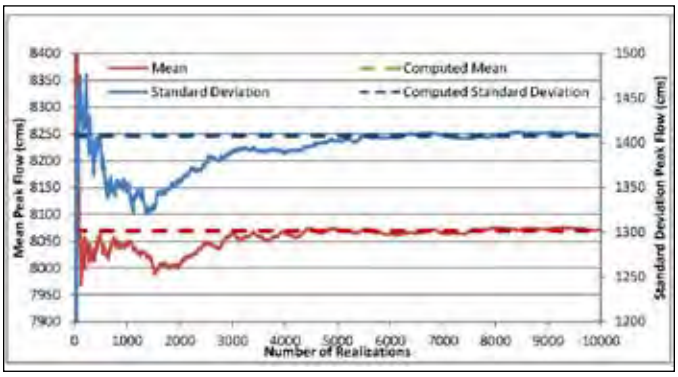

Figure 2. Number of realizations to achieve statistical convergence.

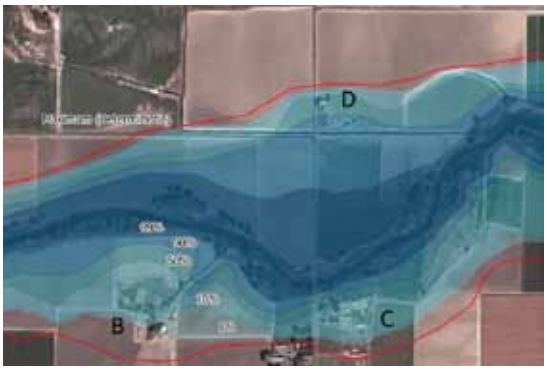

Figure 3. Exceedance Probability Inundation Map.

emergency planners? Picture a mapped overlay of shaded zones of inundation (shown in Figure 3) with stated probabilities reflecting the likelihood of flooding occurrence at a given point on the ground. As one example, high probability inundation areas (those with the highest chance of flooding) could be prioritized for evacuation and specific evacuation routes could be created that allow for organized traffic egress. With limited traffic management resources and an informed citizenry aware of staged evacuation planning, this critical thinking and risk informed decision making in advance of an event could save lives. Armed with this information, decision makers can identify the risks associated with key infrastructure. Key bridges, road intersections, can all be visualized in the context of likelihood of inundation from the breach event, coupled with the local flooding that could exacerbate the situation.

Inundation maps are a required component of emergency action plans. Having a detailed, risk-informed map arms decision makers with better information in advance of an actual emergency, transforming the state of the practice of deterministic outcomes, to those based on probabilities over a range of flooding scenarios. Getting McBreach into the hands of experienced modeling professionals will advance both the level of preparedness and decision-making capability of dam safety owners across the US, and will provide more context and understanding to the estimated consequences of a dam breach event. More information on this tool and its unique capabilities can be found at https://www.kleinschmidtgroup.com/mcbreach/.