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Three-dimensional (3D) numerical models can be a practical, efficient, and effective tool in the design and construction of dams and other hydraulic structures. A properly executed computer model can provide insights into the hydraulic behavior of a spillway or channel, derive static and dynamic loadings, estimate structural response, analyze seepage controls, and optimize control-of-water measures for construction. However, if the underlying assumptions of the model are not understood by the user, the model is not constructed properly, or results are interpreted incorrectly, the results of the model can be misleading and can lead to an inappropriate design. This paper highlights, from a holistic perspective, some of the usefulness, advantages and challenges perhaps common to three-dimensional groundwater, hydraulic, and structural numerical models. Referencing several recently completed design projects, this paper discusses the following questions:

- What is the role of 3D modeling in dam design?
- How to validate and increase confidence in model results?
- Why are field data, observational records, and laboratory experiments still needed?
- How is experience and judgement used to determine if numerical model output is accurate and reliable?

Through examples we illustrate numerous benefits of using three-dimensional models for analysis and optimization in design; specifically a hydraulic analysis of an atypical concrete spillway chute geometry, groundwater analysis for determining a dewatering measure configuration for spillway excavation, and structural analysis for anchor design for a gravity dam with variation in foundation surface.

Within this paper we also discuss the ever-important need for computer modelers to couple ‘observation’ with theory, and note a few common pitfalls that can be overcome by utilizing field observation, records, and physical model data, and learning from the large body of knowledge provided in literature. This paper is anticipated to be a practical summary of 3D modeling of dams for engineers and illustrate to dam owners potential benefits and limitations of 3D modeling to manage risk and develop cost-effective design solutions.