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Solution Brief

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Rivers, Sediments and Aging Dams

By David Freyberg

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The Challenge: Removing dams without harming river ecosystems and human uses

The American West of the 20th century saw a wave of dams built to provide flood control and stability to a volatile water supply. However, natural stream and sediment flows were altered, affecting river ecosystems and hydrologic processes. The United States has approximately 84,000 large dams, with the majority reaching the end of their operational life in the coming decades. While research today focuses mainly on experimental studies designed for new dams, the complex relationships in older dammed reservoir systems have received very little attention.

As reservoir systems age and sediment continues to build up, difficult decisions will need to be made concerning their continued viability. We must better understand how these "human-altered" river systems function to determine safe and cost-effective solutions for their continued operation or decommission. In addition, we need to understand how ecosystems will be affected if the dams are altered or removed.In the San Francisco Bay Area, The Freyberg research team is studying the connection between the natural hydrology and the human impacts on the dammed river system at Searsville Reservoir (below) located in Stanford's Jasper Ridge Biological Preserve.

Searsville Dam blocks passage of threatened steelhead trout.

About the Author

David Freyberg is an associate professor of civil and environmental engineering and senior fellow, by courtesy, at the Woods Institute for the Environment. Freyberg's diverse research interests include understanding surface-subsurface interactions in coupled reservoir/sediment/river systems, valuing hydrologic ecosystem services, sediment management in small reservoirs and wetlands hydrology.

Searsville Reservoir is a unique study site. Data on stream flows and sediment deposition date back to 1892 when the dam was built. We hope to extrapolate lessons learned from the Searsville study to recommend solutions to policy-makers on how to decide the fate of aging dam and reservoir systems.

Current Dam and Reservoir Research

Our current research incorporates a two-phase process that couples field observations with developing predictive models. These models utilize the data collected in field studies to simulate the reservoir system's response to a variety of changes, both short- and long-term. Our team is currently studying two key aspects of sediment retention in aging reservoir systems. The first area of research focuses on understanding the hydrologic interactions that result in sediment deposition. The second area focuses on predicting what will happen to sediment deposits when a dam is altered or removed. Taken together, these two areas of inquiry can provide guidance on management options for aged dams and reservoirs.

Hydrologic Interactions in Aging Reservoirs

When a dam is erected, the natural sediment flow

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is profoundly altered, resulting in deposition in the backed-up reservoir. Consequently, river flows into the reservoir also are altered due to sediment accumulation. Understanding how hydrology changes in aging reservoirs is important for predicting how river flows, sediments and upstream ecosystems will change if the dam is removed. The movement of water between the reservoir and underlying sediments also has implications if the sediments are contaminated.

Research exploring these hydrologic interactions at Searsville began in 2003 with the installation of wells, known as piezometers, to measure the movement of water through sediments in the reservoir. Through regular observations of precipitation, evaporation, stream flow, reservoir surface elevation and piezometric surface (water elevation in the well), a number of unique hydrologic behaviors have been documented.

Our research team found that hydrologic conditions in the reservoir's sediment-based subsurface are intimately

Installing piezometers to monitor water levels adjacent to Searsville Reservoir.

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linked to events at the surface (i.e., precipitation, reservoir water level). We also discovered that water flow from sediments to reservoir (or vice-versa) can vary significantly with time and in direction, and that piezometric surface levels fluctuate up and down on a daily basis in response to evaporation-related events.

These findings highlight the dynamic and complex interactions of hydrologic surface and subsurface flows, and the effect they have on sediment deposition. Predicting these hydrologic interactions is extremely complex. We continue to apply new findings to develop a model that can predict the interaction of surface and subsurface stream flows in aged, silted-up reservoirs.

Sediment Behavior in Aging Reservoirs

Our focus on the behavior of sediment in aged reservoirs is based on determining how to safely remove dams and manage the sediments. Currently, very little is known about the process of sediment deposition in aged reservoirs where significant sediment accumulation has already occurred. Consequently, decision-makers are unsure about how the alteration or removal of a dam would affect existing sediment deposits and their related ecosystems. A mathematical equation known as the Brune curve has been the traditional model used for predicting sediment deposition in newly dammed river systems. However, our field research indicates that the Brune curve fails to capture the complexity of sediment trapping and deposition in aged reservoirs.

At Searsville, we observed that significant sediment deposition occurs not on the reservoir bottom but on alluvial surface upstream. This observation runs counter to the traditional predictions of how sediments behave in reservoirs. Much of this research has been conducted in conjunction with the U.S. Geological Survey in Santa Cruz to accurately determine the age of Searsville Sedtransported and deposited in the Searsville reservoir over time. In addition, the findings from these field observations have led to experimenting with software to determine its usefulness as a predictive tool for what might happen to sediment deposits if the dam is removed.

For more information on this research project go to http://www.stanford.edu/faculty/freyberg.


A knick-point blocking fish migration in an Oregon stream.

We also are studying how sediment erosion affects fish mobility in aged dam and reservoir systems, including the issue of knick-point fish migration. Knick-points are zones of relatively sharp slope change that often characterize erosion of reservoir sediment deposits.

In some cases, significant sediment erosion can block up- or downstream access for migrating fish. Although this research is ongoing, our team plans to use the findings to design a model for predicting how sediment will erode once a dam is removed.

Future Dam and Reservoir Research

Each year, researchers have access to more information than ever before, thanks to emerging technologies. As additional data are analyzed, we plan on refining our models to simulate different management options for older dam and reservoir systems. For example, we want to be able to predict the magnitude of the impact of the dam's removal, what specific ecosystems will be impacted and what species will be affected. These types of predictive models will enable decision-makers to more accurately assess infrastructure costs and the economic costs of dam maintenance, rehabilitation and renewal, as well as the less-quantifiable costs to fisheries, recreation, aesthetics and for natural flood control. Ultimately, our research can inform how to develop economically and environmentally efficient strategies for tackling the difficult decisions of how to manage aging dam and reservoir systems.