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BOOK REVIEW

Dead Pool: Lake Powell, Global Warming and the Future of Water in the West; by JOHN LAWRENCE POWELL, Berkeley, California, University of California Press, 2009, 304 p., 26 illustrations, $27.50.—When we read history for instruction as well as pleasure, it is often to assess the follies of past leaders and failed policies. When we read environmental history, our assessment of past follies has a twist. In a typical historical narrative, the hubris behind a king's or a pope's diplomacy is typically visible to contemporary observers. An empire-in-decline announces itself by the actions of desperate governments to quell rebellions, improve finances, and battle adversaries. The paradox of environmental history is that the seeds of disaster are often planted when times are best. In fact contemporaries view the planting as a high achievement. So it is with dams and river management infrastructure. The engineering prowess required to construct the great dams of the American West, Hoover, Grand Coulee, Bonneville and Glen Canyon, was truly breathtaking. To build Hoover Dam during the early 1930's, the Colorado River had to be diverted through tunnels in the canyon walls that supported the growing dam. Atop these canyon walls, vast volumes of liquid concrete were mixed and conveyed via cable down to the growing structure, where pipes embedded within the firming blocks cooled the concrete as it cured. Hoover Dam, the largest single construction job up to that point, was finished two years ahead of schedule, and prompted Franklin Roosevelt at its dedication to proclaim it as "another great achievement of American resourcefulness, skill and determination." By the end of the 20th century, the operators of the dam were scrambling to manage the allocation of its water to thirsty communities and farmers downstream, having already consigned natural ecosystems downstream to an inconsistent trickle of once abundant riverflow.

The unintended consequences of Hoover Dam and, especially, the infrastructure projects that followed it, are the subjects of a highly readable new book by James Lawrence Powell, *Dead Pool: Lake Powell, Global Warming, and the Future of Water in the West*. The author Powell opens the book with a breathless recounting of two crises that struck the Glen Canyon Dam soon after Lake Powell filled behind it between 1963 and 1980. In 1983 an unanticipated surfeit of water in the upper Colorado River catchment nearly breached the dam; friction from water diverted into spillway tunnels tore away car-sized chunks of concrete and portions of the canyon wall. Within two more decades, a persistent drought in the same river catchment threatened Lake Powell with stagnation, its level falling near the "dead pool" level, at which its water no longer could be used to generate hydroelectric power, or even to be distributed beyond the dam. (Because silt will eventually accumulate behind a dam and displace the lowest reaches of its lake, a dam's water outlets lie well above its base, 237 feet above the original riverbed for the Glen Canyon Dam.) Within 40 years of its construction, the Glen Canyon Dam had seen riverflow conditions that had challenged its design parameters at both the high and low extremes.

How could this bad outcome elude the careful plans of civil engineers, hydrologists, and policymakers? At this point historical factors take center stage. Powell steps back into the 19th century, to an age when optimistic western expansionists hypothesized that "rain would follow the plow" and encouraged legions of new settlers to farm land that the Plains Indians (and their buffalo) rarely lingered upon for more than a season. After a generation of futility, efforts to manage the surface waters of the American West with a system of dams, both massive and modest, seized the public imagination in the early 20th century. Geology demanded that these dams be sited in challenging locations, typically the steep-walled mouths of long canyons. Hydrologists

made plans for long-term management of then-remote river segments, whose discharge had been observed for little more than a few decades. Stray evidence hinted at Nature's unpredictability: forty feet deep in the sediment at the toe of Hoover Dam, excavation crews found a piece of milled lumber, a clear indication that a Colorado-River flood had scoured that deeply at some point in the previous 100 years.

Powell catalogs the unintended consequences of Depression-era dams, for example, how Hoover Dam induced a pattern of political and legal confrontations between California, Arizona, and Mexico, and notes that the dam never lived up to the benefits touted by its initial boosters. Still, one could argue that the dam infrastructure of the early 20th century has had significant positive impacts on agriculture and urbanization, while providing emission-free power generation that pays maintenance expenses and more. Hoover Dam and Lake Mead have become fixtures in the landscape of the American West, their existence fairly stable in the face of both climate fluctuations and public opinion. In Powell's recounting, however, historical forces carried the drive for dam-building and water management to the current precarious state of Glen Canyon Dam, Lake Powell and the rest of the upper Colorado drainage basin, with each public investment becoming less and less defensible as the 20th century wore on.

Powell describes well the ways that Glen Canyon Dam has failed on its own terms as a water management system for the surrounding regions. Paradoxically, the gravitational energy stored in Lake Powell is more valuable than the water itself; the times and rates of water discharge at the dam largely follow the electric-power demands in desert cities. As a result, the water discharge through the Grand Canyon, downstream of Lake Powell, currently has a large daily cycle instead of the natural yearly cycle tied to the seasons. Sudden surges through the Grand Canyon wash away the rafts of unwary tourists. More troubling, the cold temperature of the water, drained from the frigid interior of Lake Powell rather than from a sun-warmed streambed, is one factor in the decimation of endemic fish species along this reach of the Colorado River. The endangered fish are highly-specialized capstone species in a unique, but rapidly changing, riparian ecosystem. If 21st-century drought conditions persist in the US West, Glen Canyon Dam could fail utterly as a water-management system, because the level of Lake Powell will likely fall below the dead-pool level.

For geoscientist readers of Powell's book, his discussion of how Glen Canyon Dam failed its design goals offers a way to illuminate a dusty corner of typical survey courses in physical or surficial geology. Although the stochastic variation of stream discharge can be found in most textbooks, applications of this concept focus on extreme events, such as characterizing the 100-year flood. As explained by Powell, Glen Canyon Dam offers a different perspective on riverflow fluctuations. The design of the dam and lake were based on a short duration of climate data from a wet period of the 20th century. Using a computer model for hydrologic management of the Colorado River basin, Powell argues that Glen Canyon Dam would be predicted to fail its water-management role for a typical interval of rainfall and streamflow data in other, more-arid, intervals of the 20th century. Failure is not triggered by extreme events, but rather the propensity for the yearly rainfall and discharge values to be statistically correlated year-to-year, owing to larger-scale, longer-term natural climate cycles. From such correlations, a string of dry years, none extreme, can cause the modelled level of Lake Powell to drop to dead-pool conditions, rendering the dam useless.

Institutional momentum is the simplest explanation for our predicament, but historical details are critical for drawing lessons from the past. Powell tells engaging stories of good motivations taken too far. Institutional momentum was fostered by the project-hunger of large-scale construction companies, such as Bechtel and Morrison-Knudsen, that were conjured into existence to build the first wave of Depression-era

dams. Similarly, Powell outlines how the legal division of water rights at the start of the 20th century planted a desire on the governments of upper-Colorado states (Utah, Colorado) to reap, in mid-century, the supposed economic benefits of dammed water. Finally Powell shows how the influence of a single upper-Colorado Congressman spawned a succession of marginal water-diversion projects to facilitate the cultivation of low-market-value crops, such as alfalfa. Here we see historical forces at the forefront, largely unrelated to the technical details of hydrology, climate science and environmental protection. The romance of Man's ability to control Nature is hard to resist, even when Man's control is shown to have shortcomings. In addition, our representative form of government encourages legislators to channel public money to their districts, regardless of whether a project makes sense in a larger context.

Powell predicts that trends in climate change will deepen current drought conditions in the American West, and spell doom for Lake Powell and other marginal dams as riverflow-management systems. Increasing drought in the US West is a probable bet, though not certain. The variance of model predictions is greater for climate variables, such as rainfall, whose physical processes depend more on temperature gradients than on the global-mean temperatures. Different climate models tend to agree on the global-mean temperatures under elevated levels of greenhouse gasses, but there is less agreement for temperature gradients. So-called abrupt climate change is a wild card that Nature could play sometime in the 21st century. Current general-circulation climate models of the atmosphere and ocean are typically tied to a baseline climate that resembles mid-20th century conditions. Certain abrupt climate-change scenarios could alter greatly these baseline conditions. Current trends in the precipitation-evaporation balance in the US West could shift thereby, as part of a more general, and probably unpleasant, pattern of worldwide climate disruptions. In the Pliocene, which was characterized by carbon-dioxide concentrations similar to today's values, recent research suggests a near-permanent Pacific-wide warm pool of surface waters, possibly inducing persistently wet El-Nino conditions in the US West. At various points in *Dead Pool*, Powell points out that policymakers could have made better decisions in water and land management if they had been more aware of climate statistics. Unfortunately, with human-induced climate change underway, our better knowledge of 20th-century climate statistics could offer the wrong guidance to policymakers.

Given the above uncertainties in the future course of climate change, what lessons can we learn from this book? As I write this review in Winter 2009, US policy toward climate change is shifting from a passive to an active strategy, and a global recession encourages infrastructure development as a job-creation mechanism. A reduction in consumption (that is, conservation) has limited appeal as a political strategy, so we can expect large investments in the US and other countries in alternative energy, public transport, and related infrastructure. Wind farms, carbon sequestration, bullet trains, solar-powered vehicles — it is impossible now to be certain which policies will succeed and which will fail. For successful policy strategies, new economic constituencies will materialize and form a symbiotic relationship with the central government, as well as with particular legislators at the start of their careers. As Powell documents well in a book that deserves wide attention, once a particular form of infrastructure development becomes familiar and profitable to key players in the economy, the infrastructure tends to grow beyond its utility. Sometime in the 2030s, the readers of Powell's book will likely need to apply all their powers of historical perspective to prevent the next generation's version of the Glen Canyon Dam.

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