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UNTIL THE WELL RUNS DRY

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state fluid dynamics and vorticity. These approaches go back to the beginning of the 20th century but, because they are not so important in airplane and ship design, have only recently been brought to bear on animal locomotion, where they have been able to provide convincing accounts of the ways flapping wings produce lift and fish tails produce thrust. The treatment is exhaustive—but it does make exhausting reading. The penultimate chapter, "Aids to Human Locomotion," is brief and amusing. Here Alexander considers a diversity of tools, from shoes to bicycles and hang gliders. What emerges is that well-engineered shoes or bicycles are worthwhile, but human-powered flight—for practical purposes—is futile.

The book is illustrated with clear line drawings, many of which are original, and liberally sprinkled with equations that range from simple to complex. If, like me, you find Alexander's facility with mathematics and calculus daunting, you will seek, as I did, a "child's guide" to what he explains. To me, this is a weakness of the book—Alexander rarely takes the opportunity to offer simple summaries so that the reader can see where the story is leading or what it has shown. At the end of each chapter, however, he does offer his views on avenues for future research—and very interesting they are. Those who, like me, are familiar with Alexander's style will not be surprised by his approach: "Let the mass of an animal be *m*" or "Consider an animal of mass *m*" is a typical way for him to open or discuss a particular situation. This is effective, though often a little dry. A dry humor does appear—though rarely—in his work, as in his discussion of the complex muscle architecture of fishes: "My theory...has been challenged and may be wrong" (p. 287). And he can be pithily effective, as, when describing the gait changes of a pony, he writes that it "should walk at speeds less than 1.7 m/s [meters per second], trot between that speed and 4.6 m/s and gallop at higher speeds. This is what it did" (p. 128).

This is not easy reading. Do not expect to pick it up just to browse through it. It is in total contrast to Alexander's earlier book, *Locomotion of Animals* (1982), which is now sadly out of date but which can still act as a useful primer for the present book. Despite cover notes announcing that the book will be "enormously useful to advanced undergraduates," do not expect them to find it accessible. It is hard work but worthwhile and authoritative.

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UNTIL THE WELL RUNS DRY

Water Follies: Groundwater Pumping and the Fate of America's Fresh Waters. Robert Glennon. Island Press, Washington, DC, 2002. 314 pp., $25.00 (ISBN 1559632232 cloth).

The sleight of hand that has kept the western United States growing in population and affluence depends on both physical and institutional arrangements that conceal the resource limitations of the arid West. Chief among these arrangements is the West's reliance on mined groundwater, because the patterns of usage it enables are heading for a reckoning. The eastern United States also uses prodigious quantities of groundwater, sometimes with problem-

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atic results. Any water wonk in the western United States is aware of groundwater and its importance, but the average American has little reason to think about this hidden resource. By the time its importance becomes impossible to avoid, the management choices are far from appealing. *Water Follies* piles story upon story of instances where groundwater use has drained lakes, denuded desert rivers, adversely affected surface water flows, and carelessly destroyed aquatic resources.

This book is not a comprehensive guide to groundwater usage and its consequences. By that, I mean that it presents only a modicum of nationwide information about groundwater use, trends, characterization of aquifers, and state and federal policies, focusing instead on regional stories. The best reason for not doing more synthesis is that groundwater is still poorly understood, especially at the national level. Here the policy world drives the scientific world: Groundwater is viewed as a matter of state concern, not national concern. As a result, states may choose to compile this sort of information, or they may not. (In theory, surface waters also are fully controlled by states, but because of their interstate character and the federal investment through the Bureau of Reclamation and the Corps of Engineers, the federal role is much greater.) The US Geological Survey is now a leader in national groundwater studies; it has published a groundwater atlas *(http://capp.water.usgs.gov/gwa/)* and studies of specific aquifers. It has also begun a groundwater resources program that attempts to fill in significant holes in national information.

Still, critical pieces of information that are needed for meaningful policy at a national level need to be culled out so that public policymakers can understand the limitations of public reliance on groundwater. It would also be useful for policymakers to understand the hydrologic connections between surface water and groundwater at a larger scale: for example, to what extent river ecosystems across the nation are affected by groundwater pumping and what conflicts among users will be caused by declining river levels. These relationships are difficult to describe at a large scale, but if policy is to be formulated at a national level, a more comprehensive picture is required than what federal agencies have provided.

The approach taken in this book is to provide well-drawn stories of the abundant dysfunctions our water managers have condoned. The author, a professor of law at the University of Arizona, has the versatility to comprehend both the physical and the legal causes of these follies, and he paints a convincing picture of society's unwillingness to unwind the forces that have landed it in such positions. Why should Perrier be able to claim water rights that will affect a fragile river? Why does the political establishment of a once-pastoral Arizona valley insist on permitting more development when it threatens a unique desert ecosystem? Must we eat "wild" blueberries irrigated with water that salmon need? Should water that underlies the dry Hopi Reservation be used to slurry coal hundreds of miles away? The author might be chided for overusing references to Rube Goldberg in describing the machinations by

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which communities avoid the consequences of their actions, but the context makes it hard to avoid such overuse. My personal favorite is the attempted repair of a lake in Florida that had been drawn down by associated groundwater pumping. The fix? Pump additional groundwater to refill it, thereby making the lake even more prone to drawdown.

Each case study includes an instructive discussion of the options that are available to address the problem associated with groundwater use. These solutions are based in the problem area: Can water be imported from another basin? Can agricultural uses be limited or water transferred from agriculture? Can alternative water supplies be found? Glennon also examines systemic solutions. These measures closely track the solutions offered to reform water management—for example, appropriate pricing, dedicating water to streams, conserving, and collecting data. They are solidly based and have been used by different regions across the nation to manage water conflicts.

That said, the problems unique to mined groundwater were not given the concerted attention that I would have liked to have seen. Understanding of the problems caused by mining groundwater is rare, even where it shouldn't be. My reaction when I moved from Maryland to New Mexico and learned about the widespread groundwater mining was one of incredulity. It seemed beyond reason that entire regions of the state were deliberately drawing down aquifers that were the basis of their economies and communities. Since that time I have bought a home in Albuquerque, where the aquifer is often said to have a life expectancy of only a few decades. The extraordinary has become commonplace. It truly is mind-boggling that societies treat their water and their futures in this fashion.

Professor Glennon does not engage head-on with the issues involved in groundwater mining, although his recommendations encompass mined basins. He recommends the Arizona approach, for example, in which certain aquifers are protected from further overdraft through a requirement that replacement water supplies be found. But is this truly a sustainable policy, if the replacement waters are drawn from other aquifers or from surface waters? New Mexico's major cities are moving toward replacing the water drawn from mined aquifers with water drawn from the Rio Grande, probably at a fatal cost to the Rio Grande silvery minnow. Is this a desirable move toward protection of groundwater, or is it an unacceptable pressure to put on surface waters?

Years ago, the National Water Commission called for an end to groundwater mining. While few westerners could conceive of this occurring, those who judge actions by intergenerational equity or sustainability might ask how our use of fossil groundwater can be justified. Economists (and lawyers who practice water law, where prior appropriation makes usage a mandate) are less troubled by groundwater mining, and a hearty conversation could occur between the perspectives of economics and sustainability. This book contains much of the background material for such a conversation.

Groundwater use and its consequences will be the topic of more and more seminars, political briefings, and ultimately public policies. *Water Follies* puts a face on the abstractions of groundwater mining, drawn-down springs, dewatered rivers and lakes, and all the other important relationships that are obscured to all but a few sectors of our society. The author makes no attempt to conceal his well-founded outrage at the abuses that have been committed with a pump, and this book may well launch a generation newly motivated to protect groundwater.

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