

NOTES

A NOTE ON SOURCES

One of the thrilling and humbling aspects of writing about water is the vast range of people who devote their careers to studying water's impact and influence, and the libraries of literature available about water.

I have used these endnotes for three basic purposes. First, where I have done anything more than basic arithmetic to come up with a particular way of capturing water's impact in statistical or numerical terms, I have tried to provide that mathematical reasoning so others can understand how you figure out how many molecules of water there are in a single blood cell, or how you calculate that a single serving of rice requires 14.4 gallons of water. And, of course, so others can check my math.

Second, I have occasionally used the notes to expand on a point, where that explanation or additional information would have slowed down the main text, but where the information is relevant enough that curious readers might appreciate knowing more.

And I have used the notes for the traditional purpose of providing source references and credit to the work of others, which I have consulted, relied on, and quoted.

All the online references were checked and current as of October 1, 2010. Newspaper and magazine stories for which there are only standard citations, and no online links, are not available online.

For ease of use, these notes will also be available online at www.thebigthirst.com.

Most of what I've learned about water has come from conversations with a wide range of people, some quoted in the text and some not. For a more complete list of people interviewed, by chapter, see the Acknowledgments.

1. THE REVENGE OF WATER

1. The first shuttle mission, the test flight of Columbia (STS-1), was launched April 12, 1981, and succeeded without the water sound-suppression system. But the shock waves recorded during launch caused NASA to install the system before the second flight.

The peak noise at the pad comes 5 seconds after launch, according to NASA, with the shuttle at 300 feet above the pad and the full force of its five engines reflecting off the pad's surface. By the time the shuttle is rising through 1,000 feet, the noise on the pad is falling off rapidly.

Scientists with payloads on the shuttle are required to harden them to withstand 145 decibels, inside the shuttle's payload bay. NASA says the cushion of water keeps the sound down to 142 decibels inside the shuttle's payload bay. (The noise of a chain saw is about 110 decibels.)

A description of the sound suppression system at Kennedy Space Center's launchpads 39-A and 39-B is below (scroll down to "sound suppression water system"). NASA calls the on-pad water delivery valves "rain birds." <http://science.ksc.nasa.gov/shuttle/technology/sts-newsref/sts-lc39.html>.

2. The U.S. Geological Survey report *Estimated Use of Water in the United States in 2005* says that total water use for all purposes in the U.S. is 410 billion gallons a day. Of that, electric power plants use 200 billion gallons (49 percent).

Using the 2005 Census figure of 296 million Americans, electric power plants in the U.S. are using 676 gallons of water per person. As with water use, though, that doesn't mean the electricity that each of us uses requires 676 gallons of water per day—that includes electricity used for all industrial and commercial purposes.

According to data from the U.S. Energy Information Administration, in a typical year, residential customers use 37 percent of electricity generated, commercial customers use 36 percent, and industrial customers use 27 percent. (Data from 2009 are a little anomalous because of the recession.)

Electricity used in U.S. homes requires 37 percent of that 676 gallons per person per day, or 250 gallons per person per day.

The full USGS water-use report for 2005 is here (PDF). <http://pubs.usgs.gov/circ/1344/pdf/c1344.pdf>.

The EIA data on electricity use by broad sector are here. http://www.eia.doe.gov/cneaf/electricity/epm/table5_1.html.

3. *2008/2009 Sustainability Review*, Coca-Cola Company, 2009, p. 31 (PDF). http://www.thecoca-colacompany.com/citizenship/pdf/2008-2009_sustainability_review.pdf.
4. Women have less water, on average, because fat contains almost no water, and women in general have a higher percentage of body fat than men. Water weighs 8.33 pounds per gallon.
5. Peter Mayer, William DeOreo, Eva Opitz, et al., *Residential End Uses of Water*, 2000, Water Research Foundation.

The executive summary is accessible here. <http://www.waterresearchfoundation.org/research/topicsandprojects/execSum/241.aspx>.

More detail on the study is here. <http://www.unep.or.jp/ietc/Publications/ReportSeries/IETCRep9/4.paper-F/4-F-nels1.asp>.

The EPA's presentation of the study is here. <http://www.epa.gov/watersense/pubs/indoor.html>.

6. Average residential water consumption in the United Kingdom is small compared with the U.S.—40 gallons (150 liters) per person per day, according to the Office for National Statistics.
Estimated Household Water Consumption: Regional Trends 38, Office for National Statistics. <http://www.statistics.gov.uk/STATBASE/ssdataset.asp?vlnk=7812>.
 With a total population of 61.4 million people (2008), Brits use just 2.5 billion gallons of water at home.
 Average residential water consumption in Canada is closer to U.S. use—91 gallons (343 liters) per person per day.
Factsheet: Water Use & Consumption in Canada, Program on Water Governance (PDF). http://www.watergovernance.ca/factsheets/pdf/FS_Water_Use.pdf.
 With a population of 34 million (2008), that's 3 billion gallons of water per day.
 UK and Canadian households, together, use 5.5 billion gallons of water a day for all purposes.
7. Water losses by U.S. utilities are calculated by the American Society of Civil Engineers (ASCE), among others, at 7 billion gallons a day, which comes to 15.8 percent of the total “utility supply” of 44.2 billion gallons a day, as calculated by the USGS.
Drinking Water: Report Card for America's Infrastructure, ASCE, 2009. <http://www.infrastructurereportcard.org/fact-sheet/drinking-water>.
Estimated Use of Water in the United States in 2005, USGS, 2009 (PDF). <http://pubs.usgs.gov/circ/1344/pdf/c1344.pdf>.
8. *VEWA Survey: Comparison of European Water and Wastewater Prices*, Metropolitan Consulting Group, May 2006, p. 4 (PDF). [http://www.bdew.de/bdew.nsf/id/DE_id100110127_vewa-survey---comparison-of-european-water-and-wastewater-pr/\\$file/0.1_resource_2006_7_14.pdf](http://www.bdew.de/bdew.nsf/id/DE_id100110127_vewa-survey---comparison-of-european-water-and-wastewater-pr/$file/0.1_resource_2006_7_14.pdf).
9. David M. Cutler and Grant Miller, “The Role of Public Health Improvements in Health Advances: The Twentieth-Century United States,” *Demography*, vol. 42, no. 1, February 2005, pp. 1–22. <http://muse.jhu.edu/login?uri=/journals/demography/v042/42.1cutler.html>.
 The full text of the study, including charts and tables, is available online (PDF). http://www.economics.harvard.edu/faculty/cutler/files/cutler_miller_cities.pdf.
10. Cutler and Miller, PDF file at economics.harvard.edu, p. 18.
 In 1900, infectious diseases, often carried by water, were responsible for 44 percent of U.S. deaths. By 1940, they were responsible for only 18 percent of deaths. (*Ibid.*, p. 6.)
11. *Ibid.*, p. 4.
12. *Estimated Use of Water in the United States in 2005*, USGS, p. 19 (PDF). <http://pubs.usgs.gov/circ/1344/pdf/c1344.pdf>.
13. *Estimated Use of Water in the United States, 1955*, USGS, 1957. <http://pubs.er.usgs.gov/publication/cir398>.
14. No one routinely gathers data on the average monthly water bill. But the American Water Works Association (AWWA) has used usage and fee surveys to estimate that the monthly bill is \$34 per household in the U.S. (just for water, not including sewer service).
 The average monthly cable TV bill in the U.S. in 2009 was \$70; the average monthly cell phone bill in 2009 was \$93, according to a study by the research firm Centris.

Communications Services Spending Increasing, Centris, January 26, 2010 (PDF). <http://www.centris.com/Docs/PR/Nov%20Insights%20Report%20final.pdf>.

15. The average price of 1,000 gallons of tap water for residential customers in the U.S. was \$3.24, according to the 2008 survey conducted by the AWWA.
16. Al Goodman, "Spain Suffers Worst Drought," CNN, April 18, 2008. <http://www.cnn.com/2008/WORLD/europe/04/18/spain.drought/index.html>.
17. "Drought-Stricken Barcelona Ships In Water," Associated Press, May 16, 2008. <http://www.msnbc.msn.com/id/24629154/>.

Barcelona uses 220 million gallons of water a day—152,777 gallons a minute. So the *Sichem Defender's* 5 million gallons of water lasted 32 minutes.

The *Contester Defender* carried 9.5 million gallons of water, which lasted 62 minutes. That figure is from the French TV news account below:

"Barcelona's Unprecedented Drought," France 24, May 26, 2008. <http://www.france24.com/en/node/1939450/%252F2>.

Britain's *Guardian* newspaper has a good account of the arrival of the first water ship, but showed the quantity of water as different from other accounts:

Graham Keely, "Barcelona Forced to Import Emergency Water," *Guardian*, May 14, 2008. <http://www.guardian.co.uk/world/2008/may/14/spain.water>.

In terms of supplying water by supertanker, the largest supertankers carry about 3 million barrels of crude oil—at 42 gallons a barrel, that's 126 million gallons. Barcelona uses 220 million gallons of water a day. And of course, even if you could muster a continuously flowing fleet of two supertankers a day into Barcelona, you'd also have to find enough water to fill those supertankers.

Supertanker information:

Tanker Information, Pacific Energy Partners, May 2005 (PDF). <http://www.pacificenergypier400.com/pdfs/TANKERS/TankerBusEmissions.pdf>.

18. Thomas Catán, "Barcelona Relies on Water by Ship to Slake Its Thirst Amid Drought," *Times*, May 14, 2008. <http://www.timesonline.co.uk/tol/news/world/europe/article3927283.ece>.
19. The story of Orme, Tennessee, running out of water is based on these news accounts:
 - Drew Jubera, "Tennessee Town Rations Water," *Atlanta Journal-Constitution*, October 21, 2007.
 - Dick Cook, "Rain Lacking; Troubles Welling," *Chattanooga Times Free Press*, September 29, 2007.
 - "Tennessee Town Runs Out of Water in Southeast Drought," Associated Press, November 1, 2007. <http://www.foxnews.com/story/0,2933,307437,00.html>.
 - Rusty Dornin, "Town Has Water Just Three Hours a Day," CNN, November 8, 2007. <http://www.cnn.com/2007/US/11/08/dry.town/index.html>.
 - "Water Flows in Town Where Drought Dried Up Spring," Associated Press, *Knoxville News-Sentinel*, December 11, 2007.
20. Steve Helling, "The Town Without Water," *People*, December 3, 2007. <http://www.people.com/people/archive/article/0,,20170838,00.html>.
21. *Human Development Report, 2006: Beyond Scarcity: Power, Poverty and the Global Water Crisis*, UN Development Programme. <http://hdr.undp.org/en/reports/global/hdr2006/>.

1.1 billion people don't have access to drinking water: p. 2.

700 million people live on \$2 a day or less: p. 7.

(The full UN report on water and poverty is available from the page above as a PDF file, but it is 422 pages.)

22. *Human Development Report, 2006.*
1.8 billion people whose water is within 1 km: p. 35.
23. *Ibid.*
1.1 billion people use just 5 liters per day: p. 5.
24. *Ibid.*
1.8 million children die annually from water-related disease: p. 6.
25. Florida population, Table S0901, “Children Characteristics,” U.S. Census, 2006–2008. http://factfinder.census.gov/servlet/STTable?_geo_id=04000US12&-qr_name=ACS_2008_1YR_G00_S0901&-ds_name=ACS_2008_1YR_G00_.
As of 2008, Florida had approximately 1.3 million children between the ages of 6 and 11, according to the U.S. Census.
26. *Human Development Report, 2006.*
1.2 billion more people by 2025, 2.4 billion more people by 2050: p. 138.
27. *Ibid.*
Population up by factor of 4, water use up by factor of 7 since 1900: p. 137.
28. Most people find it surprising that only about 6 percent of the people who have ever lived are alive now. About 10 billion people were born between 1900 and 2010, which means in the years stretching back before 1900, 90 billion people were born and died.
For a fascinating discussion and analysis of the long history of human birth and death, see Carl Haub, “How Many People Have Ever Lived on Earth?” *Population Today*, Population Reference Bureau, 2002. <http://www.prb.org/Articles/2002/HowManyPeopleHaveEverLivedonEarth.aspx>.
29. If we just consider drinking water for humans, 3 liters per day for 30 years equals 32,850 liters per person.
 $32,850 \text{ liters per person} \times 100 \text{ billion people} = 3.3 \times 10^{15} \text{ liters.}$
Three liters per day of drinking water as the basic human requirement comes from Peter Gleick, “Basic Water Requirements for Human Activities: Meeting Basic Needs,” *Water International*, vol. 21 (1996), pp. 83–92 (PDF). http://www.pacinst.org/reports/basic_water_needs/basic_water_needs.pdf.
30. Animals alone outnumber people *at least* 1,000:1.
Scientists have identified nearly 2 million different species on Earth, of which 1.4 million are animals. (Plants, of course, contain and use water as well.)
Liz Osborn, *Number of Species Identified on Earth*, Current Results, 2010. <http://www.currentresults.com/Environment-Facts/Plants-Animals/number-species.php>.
Perhaps the most vivid example of how modest a piece of the biomass humans on Earth represent is the fact that the weight of ants, alone, roughly equals the weight of human beings.
Bert Hölldobler and Edward O. Wilson, *Journey to the Ants* (Cambridge: Belknap Press of Harvard University Press, 1998), p. 1.
31. Sid Perkins, “Trackway Site Shows Dinosaur on the Go,” *Science News*, October 26, 2002.
The fossilized, bathtub-shaped depression near La Junta, Colorado, measured

3 meters by 1.5 meters by about 0.25 meters, and so might have held 1.125 cubic meters of liquid, or 300 gallons.

32. The total water consumption for all creatures that have ever lived cannot realistically be calculated. But just to get a sense of the scale, start with the water consumption of all human beings, from note 29, above:

3.3×10^{15} liters.

If animals outnumber people in terms of mass by 1,000:1, and animals have been on Earth at least 500 million years, which is 10,000 times longer than humans:

$(1 \times 10^3) \times (1 \times 10^4) = 1 \times 10^7$ (which is 10 million times the water consumption of humans).

That gives you a figure of:

$(3.3 \times 10^{15} \text{ liters}) \times (1 \times 10^7) = 3.3 \times 10^{22}$ liters of water.

That figure is, if anything, conservative.

For comparison, at any given moment, the USGS says, there are just 1.1×10^{19} liters of liquid fresh water on Earth.

The Water Cycle, USGS. <http://ga.water.usgs.gov/edu/watercyclesummary.html>.

The chart of water distribution is at the very bottom of the page.

33. Yes, dinosaurs had kidneys.
Dinosaurs: Anatomy & Evolution, Smithsonian National Museum of Natural History. http://paleobiology.si.edu/dinosaurs/info/everything/gen_anatomy.html.
34. Water use to make steel:
Mark Ellis, Sara Dillich, and Nancy Margolis, *Industrial Water Use and Its Energy Implications*, U.S. Department of Energy (PDF). http://www1.eere.energy.gov/industry/steel/pdfs/water_use_rpt.pdf.
Water use to cool nuclear power plants:
Got Water? Nuclear Power Plant Cooling Water Needs, issue brief, Union of Concerned Scientists, December 4, 2007, p. 4. http://www.ucsusa.org/nuclear_power/nuclear_power_technology/got-water-nuclear-power.html.
35. According to the Beverage Marketing Corporation, a New York market research firm that closely tracks the bottled-water and wider beverage market, total bottled-water consumption in the U.S. in 2009 was 8.5 billion gallons. There are 8,760 hours in a year, so that's almost exactly 1 million gallons of bottled water an hour in the U.S.
"Bottled Water Confronts Persistent Challenges," Beverage Marketing Corporation, July 2010. <http://beveragemarketing.com/?section=pressreleases>.
36. The USGS reports for water use in the U.S. for 2005, for 1980, and for every five years back to 1950, can be accessed at <http://water.usgs.gov/watuse/50years.html>.
37. GDP figures for the U.S. economy, in annual dollars and adjusted for inflation, are easily accessible at MeasuringWorth.com, a Web site created by two economists to make national economic data more readily available and easier to use. <http://www.measuringworth.com/>.
38. *Agricultural Productivity in the United States*, USDA Economic Research Service. <http://www.ers.usda.gov/Data/AgProductivity/>. See the chart, in Excel format, under the heading "National Tables, 1948–2008," table 1.
39. Martin Wanielista, *Stormwater Reuse: A Summary*, 2006, University of Central Florida Stormwater Management Academy (PDF). <http://www.stormwater.ucf.edu/research/publications/Stormwater%20Reuse%20A%20Summary.doc>.

40. The Holy Quran, Surah 21, Al-Anbiya (The Prophets), 21:30.
41. The Holy Quran, Surah 25, Al-Furqan (The Criterion, The Standard), 25:54.
42. Genesis 1:1–4.
43. The way water appears in the English language is a remarkable indicator of our somewhat unconscious attitude about water. Consider, for instance, Shakespeare's use of water imagery.

Water makes an appearance in every one of William Shakespeare's 37 plays. In some, like *Macbeth*, water consistently fails to cleanse—in this case, it is unable to wash the blood from either the hands or the consciences of Macbeth and Lady Macbeth. In act 2, scene 2, Lady Macbeth exhorts, "Go get some water, / And wash this filthy witness from your hand." And a little later in the same scene, she says to Macbeth again, "A little water clears us of this deed."

Macbeth is not so sanguine. In the same scene, he replies to his wife: "Will all great Neptune's ocean wash this blood / Clean from my hand? No, this my hand will rather / The multitudinous seas in incarnadine, / Making the green one red."

Mostly, water in Shakespeare is a comic foil, or a symbol of inadequacy, deception, or impermanence.

In *Much Ado About Nothing*, the character Leonato says:

I pray thee, cease thy counsel,
Which falls into mine ears as profitless
As water in a sieve (5.1).

In *King Lear*, Shakespeare writes, "[W]hen brewers mar their malt with water." (3.2). In *Henry VI, Part 1*, "[G]lory is like a circle in the water, / Which never ceaseth to enlarge itself / Till by broad spreading it disperse to nought" (1.2).

At least two expressions involving water that survive to this day come from Shakespeare. In *Henry VI, Part 2*, Shakespeare writes, "Smooth runs the water where the brook is deep." That's the Shakespearean version of "still waters run deep." And as the rest of that moment in the play shows, despite two more water puns, Shakespeare is using water to make a point not about hydrology but about human character:

Smooth runs the water where the brook is deep;
And in his simple show he harbours treason.
The fox barks not when he would steal the lamb.
No, no, my sovereign; Gloucester is a man
Unsounded yet and full of deep deceit (3.1).

And in *Henry VIII*, a Shakespeare character observes, "Men's evil manners live in brass; their virtues / We write in water" (4.2).

The line is inscribed in a sculpture that runs along the banks of the Thames River, near the London reproduction of Shakespeare's Globe Theater. Most famously, it echoes the melancholy line John Keats asked to have inscribed on his tombstone: "Here lies one whose name was writ in water."

In terms of taking a direct slap at water, though, nothing Shakespeare wrote quite matches a line from *Othello*. At the climax of the play, as Othello is trying to justify having just smothered his wife, Desdemona, he says of her, "She's, like a liar, gone to burning hell"; "She'd turn to folly, and she was a whore." And then, the final insult: "She was false as water" (5.2).

She was false as water. Meaning, in Shakespeare's era, she was changeable, vola-

tile, unreliable. Desdemona could not be trusted. (Othello, of course, thought mistakenly that his wife had been unfaithful.)

Shakespeare wasn't typically thinking about water, of course—and Othello wasn't maligning water, he was denouncing his wife. Water was just the linguistic tool. In some ways, that makes the pattern all the more interesting, all the more revealing. Shakespeare's reflexive attitude about water was wariness.

2. THE SECRET LIFE OF WATER

1. The oldest rocks found to date were formed when Earth was just 300 million years old.

Here is an account from the *New York Times*:

Kenneth Chang, "Rocks May Be Oldest on Earth, Scientists Say," *New York Times*, September 25, 2008. <http://www.nytimes.com/2008/09/26/science/26rock.html>.

The discovery is reported in the journal *Science*:

Richard A. Kerr, "Geologists Find Vestige of Early Earth—May Be World's Oldest Rock," *Science*, September 26, 2008, vol. 321, no. 5897, p. 1755. <http://www.sciencemag.org/cgi/content/short/321/5897/1755a>.

The technical paper in *Science* appears in the same issue.

Jonathan O'Neill, et al., "Neodymium-142 Evidence for Hadean Mafic Crust," *Science*, September 26, 2008, vol. 321, no. 5897, pp. 1828–1831. <http://www.sciencemag.org/cgi/content/short/321/5897/1828>.

2. How many molecules of water are there on the surface of the Earth?

There are 1.4 billion cubic km of water on Earth, according to the USGS reference *The Water Cycle*. <http://ga.water.usgs.gov/edu/watercyclesummary.html>.

To get from cubic km of water to molecules of water, we're going to use basic chemistry—moles of water, and Avogadro's number, the number of molecules in a mole of a substance, 6.02×10^{23} molecules per mole.

$$(1.4 \times 10^9 \text{ cubic km of water}) \times (2.64 \times 10^{11} \text{ gallons per cubic km}) =$$

$$3.7 \times 10^{20} \text{ gallons of water on Earth.}$$

$$(3.7 \times 10^{20} \text{ gallons of water}) \times (8.33 \text{ pounds per gallon}) =$$

$$3.1 \times 10^{21} \text{ pounds of water on Earth.}$$

$$(3.1 \times 10^{21} \text{ pounds of water}) \times (4.54 \times 10^2 \text{ grams per pound}) =$$

$$1.4 \times 10^{24} \text{ grams of water on Earth.}$$

$$(1.4 \times 10^{24} \text{ grams of water}) \div (18 \text{ grams per mole of water}) =$$

$$8 \times 10^{22} \text{ moles of water on Earth.}$$

$$(8 \times 10^{22} \text{ moles of water}) \times (6.02 \times 10^{23} \text{ molecules per mole}) =$$

$$4.8 \times 10^{46} \text{ molecules of water on Earth.}$$

If our interstellar cloud were forming 1 million molecules of H_2O per second (1×10^6), that comes to 4.6×10^{40} seconds to create all the water on Earth, which is 1.5×10^{33} years—far older than the universe itself. So the water molecules are popping into existence very quickly.

3. How does one even begin to conceive of a space 420 times the size of our solar system in human terms?

One way is to use the journey of a spaceship launched by humans.

Voyager 2, which was the first spacecraft to visit Neptune and is on track to leave the solar system, flies through space at 42,000 miles an hour, fast enough to circle Earth in 35 minutes. It took *Voyager 2* twelve years to cover about half the total width of the solar system; to travel across the width of Orion’s “water factory,” *Voyager 2* would have to fly for 10,080 years, which is to say, it would have to fly for more than all of recorded human history.

Voyager: The Interstellar Mission, Neptune, NASA’s Jet Propulsion Laboratory. <http://voyager.jpl.nasa.gov/science/neptune.html>.

4. *Report of the Task Group on Reference Man*. International Commission on Radiological Protection (Oxford: Pergamon Press, October 1974), p. 364.
5. The curb weight of a 2009 Honda Odyssey minivan is 4,400 pounds. If you take 0.025 percent of that weight, you get 1.1 pounds. As it happens, a half-liter of water weighs exactly 1.1 pounds.

6. The Earth-to-apple comparison works like this.

The average depth of the oceans is 4 km, and the diameter of Earth is 12,756 km. The ratio of ocean cover to Earth’s diameter is 0.00031.

A medium apple is about 3 inches in diameter; the average thickness of an apple skin is 60 microns. Three inches is 76,200 microns, so the ratio of skin thickness to diameter of an apple is 0.00079—the apple skin is 2.5 times as thick relative to the apple as the oceans are compared to the Earth.

The thickness of apple skins is from:

I. Homutova and J. Blazek, “Differences in Fruit Skin Thickness Between Selected Apple Cultivars,” *Horticultural Science* (Prague), vol. 33, no. 3, 2006, pp. 108–113 (PDF). http://www.cazv.cz/userfiles/File/ZA%2033_108-113.pdf.

7. As it happens, the U.S. each day uses just about a cubic kilometer of water for all purposes—drinking, cooking, farming, power plants. The precise number is 1.55 km³. The volumes of water on the surface of the planet are in the millions and billions of cubic kilometers—10.5 million km³ in fresh ground water, 24 million km³ of water frozen in polar ice, 1.3 billion km³ in the oceans.

The volumes, and other data about the movement of water around Earth, are available near the bottom of the USGS Water Cycle Web site. <http://ga.water.usgs.gov/edu/watercyclesummary.html>.

Even a single cubic kilometer of water is not an intuitively understandable unit.

1 km³ = 1 trillion liters, enough to give every person on Earth 300 half-liter bottles of Evian.

Just the amount of humidity in the atmosphere at any given moment, small compared with volumes like the water in the polar ice caps or the oceans, is 12,900 km³. That’s enough water to fill a cube bigger than a mountain: 14 miles on each side, and 14 miles high.

Daily U.S. water consumption, 410 billion gallons of water for all purposes, comes from *Estimated Use of Water in the United States in 2005*, USGS (PDF). <http://pubs.usgs.gov/circ/1344/pdf/c1344.pdf>.

8. The American Museum of Natural History, New York, NY, had an exhibit about water, Water: H₂O = Life, from November 2007 to May 2008, that presented a range of water data, including the evaporation rate for an acre of trees. <http://www.amnh.org/exhibitions/water/>.

NASA reports that a one-acre corn field can evaporate 4,000 gallons of water a day.

The Water Cycle: A Multi-Phased Journey, Earth Observatory, NASA. http://earthobservatory.nasa.gov/Features/Water/water_2.php.

9. The nine days a molecule spends floating in the atmosphere before returning to Earth as precipitation—"residence time" in the atmosphere is the phrase scientists use—is part of the data presented here:

The Water Cycle—a Climate Change Perspective, Windows to the Universe, National Earth Science Teachers Association. http://www.windows.ucar.edu/tour/link=/earth/Water/water_cycle_climate_change.html.

10. Water: H₂O = Life, American Museum of Natural History. <http://www.amnh.org/exhibitions/water/>.

Having read the observation that a particular cloud doesn't usually last more than an hour, I've begun to watch clouds differently. In watching a single cloud for just a few minutes many times, I've seen what I never noticed before, that clouds are more dynamic than we realize, and that their shapes are almost never static.

11. "Rain: A Valuable Resource," *Water Science for Schools*, USGS. <http://ga.water.usgs.gov/edu/earthrain.html>.
12. Biological water volume is listed in the USGS Water Cycle Web site chart. <http://ga.water.usgs.gov/edu/watercyclesummary.html>.

The volume of the Great Lakes is here:

Great Lakes Fact Sheet, EPA. <http://www.epa.gov/greatlakes/factsheet.html>.

13. The math on the human proportion of biological water works like this.
If, for purposes of a rough estimate, we say that the average person on the planet weighs 80 pounds—including men, women, and children—and that the average person contains 57.5 percent water, then the average person contains:

$$80 \text{ pounds} \times .575 = 46 \text{ pounds of water} = 5.5 \text{ gallons.}$$

With 6.9 billion people, that's 38 billion gallons of water contained inside people.

In terms of the average weight of a person, 30 percent of the people in the world are under the age of 15.

2008 World Population Data Sheet, Population Reference Bureau, Washington, DC, 2008 (PDF). http://www.prb.org/pdf08/08WPDS_Eng.pdf.

14. Igor Shiklomanov, who was born in 1939, is director of the Russian State Hydrological Institute in St. Petersburg and a regular member of international scientific panels, including the Intergovernmental Panel on Climate Change. He did not reply to numerous e-mail inquiries requesting an interview.

A brief biography is here, from the UNESCO International Hydrological Programme. <http://www.unesco.org/water/ihp/cvshiklomanov.shtml>.

His original chart, "Water Reserves on the Earth," is in Peter H. Gleick, ed., *Water in Crisis* (USA: Oxford University Press, 1993), p. 13.

15. The world's deepest borehole was drilled in the Kola Peninsula, near Finland, as a research effort by the Soviet Union between 1970 and 1994, and reached 12,262 meters. The peninsula is still part of Russia.

- Pamela J. W. Gore, *The Interior of the Earth*, Georgia Perimeter College. <http://facstaff.gpc.edu/~pgore/geology/geol01/interior.htm>.
16. The title of the world's deepest mine passed in 2008 to South Africa's TauTona gold mine, owned by AngloGold. The mine is 3.9 km deep; the deepest tunnels require air conditioning to make mining possible, bringing the air temperature down from 131°F to 82°F. The working rock face at TauTona is 140°F.
TauTona, Anglo Gold, South Africa, Mining-Technology.com. http://www.mining-technology.com/projects/tautona_goldmine/.
 17. Don Murray, "Percy Spencer and His Itch to Know," *Reader's Digest*, August 1958, p. 114. http://www.softslide.com/volumes/v2/t3/history/readers_digest.htm.
 "Percy Spencer, Inventor, Dead; Retired Raytheon Executive, 76," *New York Times*, September 8, 1970.
 18. Murray, "Percy Spencer and His Itch to Know," p. 114.
 Percy Spencer's grandson, George (Rod) Spencer, confirms the details of his grandfather's discovery of microwaves' cooking ability in an e-mail exchange. Although many accounts report that Spencer was carrying a chocolate candy bar, Rod Spencer says it was a peanut cluster bar.
 19. Of the 130 patents Percy Spencer was awarded, the one for microwave cooking is No. 2,495,429, Method of Treating Foodstuffs. It is just 2½ pages long, and one of them is a simple, full-page diagram. It's not clear why Spencer used the word "treating" in the title—50 years later, people worry that microwave ovens can somehow "irradiate" them; in fact, they produce no radioactivity, inside or out. But Spencer corrects himself in the patent's opening sentence: "My present invention relates to the treatment of foodstuffs, and more particularly to the cooking thereof through the use of electromagnetic energy."
 Percy L. Spencer, Method of Treating Foodstuffs, U.S. Patent No. 2,495,429, October 8, 1945. http://www.google.com/patents?id=x_tuAAAAEBAJ.
 The U.S. Census provides figures on the number of appliances in U.S. homes. The latest data, released in November 2009, show 96.4 percent of all homes have a microwave, 90.6 percent have a landline telephone, 67.1 percent have a computer.
 "Homes with Cell Phones Nearly Double in First Half of Decade," U.S. Census, November 19, 2009. http://www.census.gov/newsroom/releases/archives/income_wealth/cb09-174.html.
 The data tables are here: "Extended Measures of Well-being: Living Conditions in the United States, 2005, Detailed Tables," U.S. Census. <http://www.census.gov/population/www/socdemo/extended-05.html>.
 The Popcorn Board reports that, as of 2008, Americans bought 966 million pounds of unpopped corn a year—3 pounds for every man, woman, and child in the U.S., the equivalent of 15 regular-size bags of microwave popcorn per person each year. Of that, at least 70 percent is cooked in a microwave.
Industry Facts, Popcorn Board, Chicago. <http://www.popcorn.org/Encyclopedia/Popcornica/WelcometoPopcornica/IndustryFacts/tabid/108/Default.aspx>.
 Percentage of U.S. popcorn that is microwave popcorn comes from: *Popcorn Profile*, Ag Marketing Resource Center, Iowa State University, 2010. http://www.agmrc.org/commodities_products/grains_oilseeds/corn/popcorn_profile.cfm.
 20. This elegant—and sticky—metaphor comparing water molecules to socks in a dryer comes from the American Museum of Natural History's 2007–2008 exhibit Water: H₂O = Life. <http://www.amnh.org/exhibitions/water>.

21. The calculations for how many water molecules would fit in the interior of single red blood cell are rough approximations, but work like this:

A typical red blood cell is:

8 micrometers (μm) long and 2 micrometers (μm) high.

If you simply assume that a red blood cell is a cylinder, its volume is: 3.14×16 micrometers \times 2 micrometers = 100 micrometers³ (μm^3).

$100 \mu\text{m}^3 = 1 \times 10^{-13}$ liters.

Now, how many molecules of water are in 1 liter of water?

1 liter = 1,000 grams of water.

(1,000 gm of water) \div (18.015 grams / mole of water) =
55.51 moles of water.

55.51 moles of water \times 6.022×10^{23} molecules / mole =
 3.34×10^{25} molecules of water in one liter.

So in a cell with a volume of 1×10^{-13} liters, the number of molecules

is:

$(3.34 \times 10^{25}$ molecules of water/liter) \div (1×10^{-13} liters) =
 3.34×10^{12} molecules.

So 3.34 trillion water molecules would fit inside a single red blood cell.

22. The comparisons that follow assume a suburban sidewalk that is 3 feet (0.914 meters) wide.

The microchip pathway is 90 nm (nanometers) wide; the sidewalk is 914 million nm wide—10 million times wider than the chip pathway. So each item lying on the chip—on the metaphoric sidewalk—is also 10 million times bigger than life-size.

A human hair is between 50 microns and 150 microns thick (0.00005 to 0.0001 meters)—500 to 1,000 meters in relative terms, between 1,640 and 3,280 feet high across the ordinary sidewalk.

A single red blood cell is about 8 microns wide (8×10^{-6} meters)—80 meters wide on the sidewalk.

A single particle of flu virus is about 130 nanometers long (1.3×10^{-7} meters)—1.3 meters wide on the sidewalk.

A single water molecule is about 275 picometers long (2.75×10^{-10} meters)—about 3 mm on the sidewalk.

Here are two good sites for understanding the relative size of very small objects:

Cell Size and Scale, Learn.Genetics, Genetic Science Learning Center, University of Utah. <http://learn.genetics.utah.edu/content/begin/cells/scale>.

Exploring the Nanoworld, Intro to Size and Scale, Materials Research Science and Engineering Center, University of Wisconsin Madison. <http://mrsec.wisc.edu/Edetc/nanoscale/index.html>.

23. Michael Graham Richard, *How Many Atoms Encode the Humane Genome?* April 6, 2008. <http://michaelgr.com/2008/04/06/how-many-atoms-to-encode-the-human-genome/>.

3. DOLPHINS IN THE DESERT

1. Las Vegas temperature and precipitation data—72 days a year at 100 degrees or more, 19 days of precipitation—come from the climate data available online from the National Climatic Data Center. Data through 2009—some going back 30 years, some going back more than 50 years—are in:

Comparative Climatic Data for the United States Through 2009, National Climatic Data Center, National Oceanic and Atmospheric Administration (NOAA), Asheville, NC (PDF). <http://www1.ncdc.noaa.gov/pub/data/ccd-data/CCD-2009.pdf>.

The data for days over 100 degrees come from a slightly older analysis, for Las Vegas specifically, archived here:

Climatology of the United States, No. 20, 1971–2000, Station: Las Vegas, National Climatic Data Center, NOAA, Asheville, NC (PDF). http://cdo.ncdc.noaa.gov/climate_normals/clim20/nv/264436.pdf.

2. What does it mean to say Las Vegas is the driest city in the U.S.?

The National Climate Data Center publication *Comparative Climatic Data* has data on 274 major U.S. cities and weather reporting stations, going back at least three decades. According to that compilation, the lowest-precipitation cities in the U.S. are Barrow, Alaska; Yuma, Arizona; and Las Vegas. But Yuma and Barrow are small compared with Las Vegas.

Yuma averages 3.01 inches of rain a year, with 16 days of precipitation. The city of Yuma has about 90,000 people, and the larger Yuma metro area has 190,000 people, according to U.S. Census data (2009). Yuma is 1/10th the size of Las Vegas.

Barrow, Alaska, is the only other city with less precipitation than Las Vegas, with 4.16 inches a year, on 74 days a year. Barrow, according to the census, has a population of 4,091 (2009), less than the population in many of the individual hotels on the Las Vegas Strip on a typical night.

Comparative Climatic Data for the United States Through 2009 (PDF). <http://www1.ncdc.noaa.gov/pub/data/ccd-data/CCD-2009.pdf>.

Annual number of days of precipitation is in a table that begins on p. 37.

Average annual precipitation is in a table that begins on p. 136.

A separate, slightly older analysis of precipitation data from the U.S. Census uses population data from 2000 and precipitation data from 1961 to 1990: “Cities with 100,000 or More Population in 2000 Ranked by Annual Precipitation,” table C-7, *County and City Data Book: 2000*, U.S. Census Bureau. <http://www.census.gov/statab/ccdb/cit7140r.txt>.

The U.S. Census list of 280 cities with populations of 100,000 or greater is here. <http://www.census.gov/popest/cities/SUB-EST2009.html>.

3. Details about Lake Mead’s size and capacity are here:

Hoover Dam: Frequently Asked Questions, U.S. Bureau of Reclamation, Lower Colorado Region. <http://www.usbr.gov/lc/hooverdam/faqs/lakefaqs.html>.

A list of the largest reservoirs in the U.S., by water capacity, from Stanford University’s civil and environmental engineering department:

Largest U.S. Reservoirs, National Performance of Dams Programs, Department of Civil and Environmental Engineering, Stanford University. <http://npdp.stanford.edu/damlarge.html>.

A somewhat different list—which still puts Lake Mead at the top—of the largest reservoirs by water capacity, from the U.S. Society on Dams, is here:

“Largest Manmade Reservoirs in the United States,” *Dam, Hydropower and Reservoir Statistics*, United States Society on Dams. http://www.usdams.org/uscold_s.html.

According to the U.S. Geological Survey, U.S. water utilities supply 44.2 billion gallons a day to homes and businesses, about 11 percent of the water the nation uses each day if you include electricity generation and irrigation. That 44.2 billion gallons comes to 136,000 acre-feet of water, so the 28.5 million acre-feet in a full Lake Mead would last 210 days.

USGS water-use statistics are here:

Estimated Use of Water in the United States in 2005, USGS, 2009 (PDF). <http://pubs.usgs.gov/circ/1344/pdf/c1344.pdf>.

4. Las Vegas’s formal allocation from Lake Mead is about 300,000 acre-feet of water a year. Las Vegas takes about 450,000 acre-feet, because it returns 180,000 acre-feet of treated water back to the lake, for a total “use” of 270,000 acre-feet in recent years. But even at 450,000 acre-feet, the 28.5 million acre-feet in Lake Mead would last Las Vegas 63 years.

When it’s full, Lake Mead is 157,900 acres, so if Las Vegas takes 270,000 acre-feet a year, that would lower a full lake 1.7 feet. The surface area of the lake shrinks as it falls, so Las Vegas’s 270,000 acre-feet in net withdrawals typically lower the lake between 2 and 3 feet a year.

5. Details of Las Vegas’s and Nevada’s water entitlements can be found in the most current strategic plan of the Las Vegas area’s water authority, the Southern Nevada Water Authority (SNWA): *Water Resource Plan 09*, Southern Nevada Water Authority, 2009, p. 15 (PDF). http://www.snwa.com/html/wr_resource_plan.html.

The “Law of the River,” a series of laws, court cases, and agreements among the states and the federal government, fixes how much water the various users of the Colorado River are allowed to take.

The law around use of the water is baroquely complex. The basic allocations for the three states tapping the lower Colorado, using Lake Mead, are: California, 4.4 million acre-feet a year; Arizona, 2.85 million acre-feet a year; Nevada, 0.3 million acre-feet a year.

6. The population of metro Las Vegas (Las Vegas and Clark County) in 1980 was 462,000. Thirty years later, it was 2 million. This chart, from the Las Vegas Convention and Visitors Authority, provides population figures going back to 1970:

Population Trends, Las Vegas Convention and Visitors Authority (PDF). <http://www.lvcva.com/getfile/241/Population%202009.pdf>.

The SNWA says that per-capita, per-day water use in Las Vegas in 2009 was 240 gallons, the lowest it has been in the last 14 years. What 240 gallons per person per day means is that each new resident requires 87,600 gallons of water a year.

The number of hotel rooms in metropolitan Las Vegas was 45,815 in 1980. In 2009, it was 148,941.

Historical Las Vegas Visitor Statistics (1970–2009), Las Vegas Convention and Visitors Authority (PDF). <http://www.lvcva.com/getfile/80/Historical%201970%20to%202009.pdf>.

7. Lake Mead has only been as low as it was in August 2010 twice before—for a few months in 1964–65, and for a few months in 1956. Lake Mead’s historical water levels, going all the way back to February 1935, are here, month by month:

Lake Mead at Hoover Dam, Elevation (Feet), U.S. Bureau of Reclamation, Lower Colorado Region. <http://www.usbr.gov/lc/region/g4000/hourly/mead-elv.html>.

In terms of how much water has been lost in Lake Mead, according to the Bureau of Reclamation figures for July 2010, Lake Mead is holding 10.5 million acre-feet of water, or 41 percent of capacity (level, 1,088.8 feet). Using that figure, Lake Mead's usable capacity is 25.5 million acre-feet, meaning 15 million acre-feet have disappeared since January 2000.

The Strip is conventionally defined as being 4.2 miles long (from Sahara Avenue on the north to Russell Road on the south). If, generously, you define the Strip's boundaries to extend a mile on each side of Las Vegas Boulevard, then the area of the Strip is an oblong shape of roughly 8.4 square miles, which is 5,376 acres.

Fifteen million acre-feet of water would cover 5,376 acres of land to a depth of 2,790 feet, slightly more than half a mile.

8. Figures for the number of visitors, and the percentage of visitors from the U.S.:
2009 Las Vegas Visitor Profile Study, Las Vegas Visitors and Convention Authority, GLS Research, p. 82 (PDF). <http://www.lvcva.com/getfile/107/2009%20Las%20Vegas%20Visitor%20Profile.pdf>.
9. The average historic level of Lake Mead is 1,173 feet, and Intake 1 stops being usable when the lake falls to 1,050 feet. Here is a good graphical representation of the history of Lake Mead water levels:
Lake Mead Water Levels—Historical and Current. <http://www.arachnoid.com/NaturalResources/>.
10. Pat Mulroy has told the story of trying to get rid of the smaller fountains on several occasions, including directly to me. Most of this account comes from interviewing Mulroy, and I've used contemporary newspaper accounts to check her version. But this quote, comparing the fireboat at New York New York and the canals at the Venetian, is from an oral history with Mulroy in the book:
 Corinne Platt and Meredith Ogilby, *Voices of the American West* (Golden, CO: Fulcrum Publishing, 2009), p. 268.
11. It's important to understand that the figures for gallons of water used per person per day (GPCD—gallons per capita per day) do not reflect how much water each person in Las Vegas (or any U.S. city) uses. They are simply total water consumption in the metro area, divided by total population. They include water used at hotels and hospitals, at factories and restaurants. But GPCD is a good measure of changing use overall in a community. The figures for gallons of water used per person come from the Southern Nevada Water Authority.
12. Robert Reinhold, "Battle Lines Drawn in Sand as Las Vegas Covets Water," *New York Times*, April 23, 1991. <http://www.nytimes.com/1991/04/23/us/battle-lines-drawn-in-sand-as-las-vegas-covets-water.html>.
13. The "volume discount" line comes from a profile of Mulroy written when she had been on the job just five months:
 Jamie McKee, "Conserve Now or Pay More, Water Manager Warns," *Las Vegas Business Press*, April 19, 1990.
14. Both the county commissioner's quote, and Mulroy's, are from:
 Reinhold, "Battle Lines Drawn in Sand as Las Vegas Covets Water." <http://www.nytimes.com/1991/04/23/us/battle-lines-drawn-in-sand-as-las-vegas-covets-water.html>.

15. Barbosa says that during the slowest part of the 2008–2009 recession, work at Mission’s Plant 50 was cut back from 22 hours to 16 hours a day, and water-use volumes fell by almost half. By summer 2010, business in Las Vegas’s hotels and at Mission’s laundry plants was picking back up.
16. Angel Park course superintendent Bill Rohret provided the figures on Angel Park’s water use and rounds of play. The calculations of water use per round of golf work like this. Angel Park has two large, 18-hole courses, and a smaller, 12-hole, par-3 course.
 Rohret says the two big courses average 130,000 rounds of golf a year. At 18 holes per round, that’s 2.34 million holes played.
 The par-3 course averages 30,000 rounds of golf. At 12 holes per round, that’s 0.36 million additional holes.
 Total holes played per year: 2.7 million.
 Converted to 18-hole equivalents, that comes to 150,000 rounds.
 In 2009, the course used 376 million gallons of water.
 $376 \text{ million gallons} \div 150,000 \text{ rounds} = 2,507 \text{ gallons / round.}$
 According to the American Water Works Association (www.awwa.org), the average water use in U.S. homes is 350 gallons per day, although that varies widely.
17. For purposes of its turf-removal program, popularly known as “cash for grass,” the SNWA calculates that the average homeowner uses 73 gallons of water per square foot of grass. That comes to 3.18 million gallons for every acre of lawn, or 9.8 acre-feet of water for every acre of lawn.
 The SNWA currently restricts golf courses to using 6.3 acre-feet of water per acre of turf per year—36 percent less water per acre.
18. The latest census figures (2009) show the Orlando metropolitan area with 2.1 million people, compared with Las Vegas’s 1.9 million. (Clark County’s own population figure for 2010 is 2 million in the metro area.) <http://www.census.gov/popest/metro/tables/2009/CBSA-EST2009-01.csv>.
 The number of visitors to the Orlando–Orange County region, which includes Walt Disney World, comes from the Orlando Orange County Convention and Visitors Bureau, and is reported to be 48 million, compared with the 36 million visitors Las Vegas had in 2009.
 Orlando statistics here:
Frequently Asked Questions, Orlando/Orange County Convention & Visitors Bureau. <http://www.orlandoinfo.com/media/orlando/faqs.cfm#Visitors>.
 Las Vegas statistics here:
Historical Las Vegas Visitor Statistics (1970–2009), Las Vegas Convention and Visitors Authority (PDF). <http://www.lvcva.com/getfile/80/Historical%201970%20to%202009.pdf>.
 The normal precipitation in Orlando is 48 inches; normal precipitation in Las Vegas is 4.5 inches:
Comparative Climatic Data for the United States Through 2009 (PDF). <http://www1.ncdc.noaa.gov/pub/data/ccd-data/CCD-2009.pdf>.
19. The SNWA water restrictions for golf courses are outlined here:
 “Golf Course Water Budgets,” *Drought & Restrictions: Conservation Measures*, Southern Nevada Water Authority. http://www.snwa.com/html/drought_restrictions_golf.html.
 The 6.3 acre-feet of water for each acre of turf comes to 2.1 million gallons of water, per acre, per year. That’s 5,753 gallons of water per acre per day.

The Imperial Valley and its use of Lake Mead water is discussed at greater length in chapter 9, “It’s Water. Of Course It’s Free,” starting on page 267.

The average Imperial Valley farmer uses 6.0 acre-feet of water per acre of irrigated farmland, according to the Imperial Valley Irrigation District’s reports:

2005 Annual Water Report, Imperial Irrigation District (PDF). <http://www.iid.com/Media/2005IIDWaterAnnualReport.pdf>.

20. Lawn watering is a huge consumer of water in the U.S. Even in Florida, half the water delivered to homes is used for lawn watering:

Martin Wanielista, *Stormwater Reuse: A Summary*, 2006, University of Central Florida Stormwater Management Academy (PDF). <http://www.stormwater.ucf.edu/research/publications/Stormwater%20Reuse%20A%20Summary.doc>.

According to the SNWA, 44.5 percent of all water delivered in the Las Vegas area goes to single-family homes, and 70 percent of that water ends up outside, which comes to 31 percent of water pumped used outdoors at single-family homes.

The breakdown of water use by category and customer is in the *Water Resource Plan 09*, Southern Nevada Water Authority (PDF), p. 16. http://www.snwa.com/html/wr_resource_plan.html.

21. The SNWA provided figures for total withdrawals from Lake Mead, total water returned, and consumptive use (withdrawals minus returns) for 25 years. All data are in acre-feet.

Year	Withdrawals	Returns	Consumptive Use	% Returned
1985	175,711	74,002	101,709	42
1986	194,168	81,951	112,217	42
1987	201,427	92,564	108,863	46
1988	232,407	102,987	129,420	44
1989	273,052	116,839	156,213	43
1990	294,795	116,685	178,110	40
1991	298,576	118,352	180,224	40
1992	305,669	128,118	177,551	42
1993	335,561	131,159	204,402	39
1994	361,293	135,465	225,828	37
1995	359,858	144,140	215,718	40
1996	390,508	142,006	248,502	36
1997	404,933	162,888	242,045	40
1998	401,173	156,663	244,510	39
1999	456,570	167,055	289,515	37
2000	485,870	166,014	319,856	34
2001	489,554	175,617	313,937	36
2002	500,679	175,452	325,227	35
2003	491,434	193,042	298,392	39
2004	475,761	192,755	283,006	41
2005	502,651	210,873	291,778	42
2006	522,157	229,293	292,864	44
2007	517,165	216,853	300,312	42
2008	479,974	210,320	269,654	44
2009	457,963	209,350	248,613	46

22. The SNWA explanation of how to drain your Las Vegas swimming pool into the city's sanitary sewers is at two sites.
 Step-by-step instructions are here:
 "How to Drain a Pool or Spa," *Conservation & Rebates: Pools & Spas*, Southern Nevada Water Authority. http://www.snwa.com/html/cons_pools_drain.html.
 Tips and warnings are here:
 "Pool Draining Tips," *Conservation & Rebates: Pools & Spas*, Southern Nevada Water Authority. http://www.snwa.com/html/cons_pools_draintips.html.
23. Lake Lanier's level, like that of other federal reservoirs, is measured in feet above sea level. The lake, formally named Lake Sidney Lanier, is managed by the Army Corps of Engineers. Lanier's usable water ends at 1,035 feet. Below that is the "dead pool" of water, which is inaccessible to water intakes without additional pumps. Lanier is considered full at 1,071 feet.
 Lanier reached its all-time operational low on December 26, 2007, at 1,050.79 feet, just 16 feet above the dead-pool level. It hadn't been that low since February 6, 1958, when the reservoir was first being filled.
 The history of Lanier's levels, along with other data on its operations, is here:
ACF Historic Project Data, U.S. Army Corps of Engineers: Mobile District. <http://water.sam.usace.army.mil/gage/acfhist.htm>.
24. Georgia's grab for a little slice of Tennessee River water by moving its border north got a fair amount of media attention.
 Andrea Jones and Ben Smith, "By Wide Margin, Resolutions Pass to Seek Border Change," *Atlanta Journal-Constitution*, February 21, 2008. Includes the details of the vote, the singing of "This Land Is Your Land," and the quote from Tennessee state representative Gerald McCormick. (It is no longer available free online.)
 Governor Sonny Perdue did not sign the border bill until May 14, 2008:
 Jim Galloway, "Fetch Your Buckets! Perdue Signs Up for a Border War with Tennessee," *Atlanta Journal-Constitution*, May 15, 2008. http://www.ajc.com/metro/content/shared-blogs/ajc/politicalinsider/entries/2008/05/15/fetch_your_buckets_perdue_sign.html.
 A *New York Times* account, before the final vote, is here:
 Shailla Dewan, "Georgia Claims a Sliver of the Tennessee River," *New York Times*, February 22, 2008. <http://www.nytimes.com/2008/02/22/us/22water.html>.
 The story of Chattanooga's mayor sending a truckload of water south is here:
 James Baird, "Chattanooga Mayor Pokes Fun at Southeastern Water Crisis," *Tennessee Journalist*, February 27, 2008. <http://tnjn.com/2008/feb/27/chattanooga-mayor-pokes-fun-at>.
25. The population of Atlanta in 2009 was 5.475 million, according to the census. <http://www.census.gov/popest/metro/tables/2009/CBSA-EST2009-01.csv>.
 The Atlanta real estate consulting firm Haddow & Company has an excellent table of Atlanta's population growth, since 1960, using census data:
Population Trends—Atlanta MSA, Haddow & Company (PDF). <http://www.haddowandcompany.com/marketdata/Population%20Trends%20Atlanta%20MSA%20-%202008.pdf>.
26. Details of Lake Lanier's size and operation can be found at the Army Corps of Engineers site for the lake:
 "Map Room," *Lake Sidney Lanier*, U.S. Army Corps of Engineers: Mobile District. <http://lanier.sam.usace.army.mil/MapRoom.htm>.

Lake Mead's size and capacity are described here:

Hoover Dam: Frequently Asked Questions, U.S. Bureau of Reclamation, Lower Colorado Region. <http://www.usbr.gov/lc/hooverdam/faqs/lakefaqs.html>.

Lake Lanier's historical levels are here:

ACF Historic Project Data. <http://water.sam.usace.army.mil/gage/acfhist.htm>.

27. For a profile of the Atlanta area's water system, see:
Water Supply and Water Conservation Management Plan—May 2009, Metropolitan North Georgia Water Planning District. <http://www.northgeorgiawater.com/html/88.htm>.
28. Stacy Shelton, "Metro Atlanta's Need for Water: Three Months from a Mudhole," *Atlanta Journal-Constitution*, October 11, 2007.
29. Atlanta mayor William Hartsfield's letter is excerpted in a federal court decision from July 2009 in which Atlanta's use of Lake Lanier water was ruled illegal. The full text of U.S. District Court judge Paul Magnuson's decision, in what is called the Tri-State Water Rights Litigation, is below. Mayor Hartsfield's letter is on p. 13 of the PDF.
"Memorandum and Order," *In re: Tri-State Water Rights Litigation*, U.S. District Court, Middle District of Florida, p. 13 (PDF). http://www.dep.state.fl.us/mainpage/acf/files/statements/071709_magnuson_ruling.pdf.
30. Representative Phil Gingrey's quote is here:
"Georgia Delegation Introduces Legislation to Alleviate Water Crisis," October 16, 2007. <http://isakson.senate.gov/press/2007/10/16/07water.htm>.
31. As part of its drought coverage, the *Atlanta Journal-Constitution* produced a map that shows the major water users throughout the 542-mile length of the Chattahoochee-Apalachicola river system:
Dale E. Dodson, "Heavy Demands on Our Water," *Atlanta Journal-Constitution*. <http://www.ajc.com/metro/content/metro/stories/2007/10/26/watermap.html>.
32. Bill Rankin, "Federal Judge Rules Against Ga. in Water Litigation," *Atlanta Journal-Constitution*, July 17, 2009. <http://www.ajc.com/news/federal-judge-rules-against-94051.html>.
33. Congressman Gerald Ford's question, during hearings over the construction of Lake Lanier, is excerpted (p. 16) in the federal court decision from July 2009 in which Atlanta's use of Lake Lanier water was ruled illegal.
"Memorandum and Order," *In re: Tri-State Water Rights Litigation*, U.S. District Court, Middle District of Florida, p. 16 (PDF). http://www.dep.state.fl.us/mainpage/acf/files/statements/071709_magnuson_ruling.pdf.
34. The full text of U.S. District Court judge Paul Magnuson's decision in the Tri-State Water Rights Litigation makes compelling reading for anyone interested in a compressed history of the southeastern water wars.
"Memorandum and Order," *In re: Tri-State Water Rights Litigation*, U.S. District Court, Middle District of Florida (PDF). http://www.dep.state.fl.us/mainpage/acf/files/statements/071709_magnuson_ruling.pdf.
35. *Ibid.*, p. 93.
36. *Ibid.*, pp. 94–95.
37. *Ibid.*, pp. 93–94, 95.
38. *Ibid.*, pp. 93, 96.

39. Dan Chapman and Leon Stafford, "Will Water Ruling Dry Up Growth?" *Atlanta Journal-Constitution*, July 24, 2009. <http://www.ajc.com/news/will-water-ruling-dry-99500.html>.
40. *Water Contingency Planning Task Force: Findings and Recommendations*, State of Georgia, December 21, 2009, p. 4 (PDF). http://gov.georgia.gov/vgn/images/portal/cit_1210/59/57/154449884Water%20Contingency%20Planning%20Task%20Force%20Final%20Report.pdf.
- Governor Perdue's quote is in the following. Jeremy Redmon, "Perdue: Lake Lanier Georgia's Best Option for Drinking Water," *Atlanta Journal-Constitution*, December 11, 2009. <http://www.ajc.com/news/perdue-lake-lanier-georgias-238353.html>.
41. There is ongoing coverage in the *Atlanta Journal-Constitution* of the negotiations over the allocation of water among Georgia, Alabama, and Florida. Stories in late 2009 and 2010 include:
- Jeremy Redmon, "Three Governors Say a Water-Sharing Agreement Is in the Works," December 15, 2009. <http://www.ajc.com/news/georgia-politics-elections/three-governors-say-a-241962.html>.
- Bob Keefe, "Tri-State Water Talks Bog Down," May 31, 2010. <http://www.ajc.com/news/georgia-politics-elections/tri-state-water-talks-538766.html>.
- Patrick Fox, "Lanier Ruling Anniversary Finds Perdue, Groups at Odds," July 16, 2010. <http://www.ajc.com/news/atlanta/lanier-ruling-anniversary-finds-572203.html>.
42. The text of Georgia's Water Stewardship Act of 2010 is at the link below (PDF). The exemptions from the watering limitations for home vegetable gardens, golf courses, and athletic fields are on p. 6. http://www.legis.ga.gov/legis/2009_10/pdf/hb1094.pdf.
43. Jeremy Redmon, "Corps to Tighten Spigot at Lake Lanier in Wake of Judge's Ruling," *Atlanta Journal-Constitution*, November 18, 2009. <http://www.ajc.com/news/corps-to-tighten-spigot-203870.html>.
44. Henry Brean, "Third Straw: Water Authority Digs Deep for Third Intake Pipe at Lake Mead," *Las Vegas Review-Journal*, December 13, 2009. <http://www.lvrj.com/news/water-authority-digs-deep-for-third-intake-pipe-at-lake-mead-79158322.html>.
45. Gallons per capita per day (GPCD) figures for the Las Vegas metro area for the last 21 years were supplied by the SNWA:

Year	GPCD
1989	348
1990	347
1991	344
1992	339
1993	337
1994	329
1995	327
1996	329
1997	322
1998	317
1999	315
2000	315

2001	318
2002	314
2003	294
2004	274
2005	269
2006	264
2007	255
2008	248
2009	240

46. Water Utility Climate Alliance. <http://www.wucaonline.org/html>.
 Members include: Denver Water, the Metropolitan Water District of Southern California, the New York City Department of Environmental Protection, the Portland Water Bureau, the San Diego Utilities Commission, Seattle Public Utilities, and the Southern Nevada Water Authority.

4. WATER UNDER WATER

1. The *Wall Street Journal's* "Washington Wire" noted at the time how fresh developments were elbowing equally dramatic events out of the limelight:
 Evan Perez, "Washington Wire: Palin Overshadows Hurricane Recovery, Lehman Talks," *Wall Street Journal*, September 14, 2008. <http://blogs.wsj.com/wash-wire/2008/09/14/palin-overshadows-hurricane-recovery-lehman-talks>.
 The dates of the series of events in September 2008:
 September 1: Republican vice presidential candidate Sarah Palin's daughter Bristol is revealed to be pregnant.
 September 7: Mortgage companies Freddie Mac and Fannie Mae are placed under federal control.
 September 11: Galveston residents are ordered to evacuate as Hurricane Ike approaches.
 September 14: AIG seeks its first emergency bailout of \$40 billion from the federal government; Lehman Brothers files for bankruptcy.
 September 16: The U.S. government agrees to loan AIG \$85 billion and take an 80 percent ownership stake in the insurer.
 September 20: The Bush administration proposes its first \$700 billion financial bailout.
 September 24: Senator John McCain suspends his presidential campaign to return to Washington and consult on solutions to the financial crisis.
 September 26: The FDIC seizes Washington Mutual bank, the largest bank failure in U.S. history.
 September 29: The U.S. House rejects the Bush administration's first financial bailout proposal; Citigroup purchases Wachovia's banking operations.
2. At the time, Hurricane Ike was described as the largest-ever Atlantic basin hurricane, in terms of width, but Dennis Feltgen of the National Hurricane Center says while Ike turned out to be one of the largest, both Hurricane Donna (1960) and Hurricane Betsy (1965) were bigger across.
 Hurricane Ike's wind field is described here. "Hurricane Ike 2008," *Hurricane*

History, National Hurricane Center. <http://www.nhc.noaa.gov/HAW2/english/history.shtml>.

3. The text of the “certain death” warning from the local Houston/Galveston National Weather Service office is archived at this link. http://www.srh.noaa.gov/images/hgx/projects/ike08/HGX_Products/HLS/HLSHGX_091208_1000Z.txt.

The unusually blunt nature of the “certain death” warning was noted in the media, even as Hurricane Ike approached, and was not without controversy.

The *Dallas Morning News* called it “the storm warning heard ’round the world.”

Jeffrey Weiss, “Weather Forecasters Say Hurricane Warnings Can Make the Difference Between Life, Death,” *Dallas Morning News*, September 19, 2008. <http://www.dallasnews.com/sharedcontent/dws/dn/latestnews/stories/091908dnmetcertaindeath.1677b70.html>.

National Geographic News wrote two stories about it.

Willie Drye, “Hurricane Ike’s 9-Foot Floods to Bring ‘Certain Death,’” *National Geographic News*, September 12, 2008. <http://news.nationalgeographic.com/news/2008/09/080912-hurricane-ike.html>.

Drye, “Why Hurricane Ike’s ‘Certain Death’ Warning Failed,” *National Geographic News*, September 26, 2008. <http://news.nationalgeographic.com/news/2008/09/080926-hurricane-ike-evacuation.html>.

4. The San Luis Resort’s construction on the site of Fort Crockett is described here: *The San Luis Resort History*, San Luis Resort. <http://sanluisresort.com/about-us/history/index.cfm>.
5. The water that drowned the motors in 30th Street Station turned out to have come up into the motor pits through the drains in the floor. Says Eric Wilson: “Should I have known about the drains? Yes. I have no issue accepting that blame.”
6. How much water may have filled up Galveston’s 59th Street Pump Station? The building is roughly 20 meters long and 7.7 meters wide (66 feet by 25 feet). The water rose at least 2.4 meters (8 feet) inside—and probably more like 2.75 meters. With a depth of 2.4 meters of water inside, that’s 370 cubic meters of water—97,740 gallons.
7. *Mississippi River Water Quality and the Clean Water Act: Progress, Challenges, and Opportunities* (Washington, DC: The National Academies Press, 2008), p. 102. http://www.nap.edu/catalog.php?record_id=12051.

8. Ronald Schuyler, an expert on wastewater treatment with the Denver engineering firm Tetra Tech (www.tetrattech.com), provided details on what kinds of bacteria help eat and digest routine waste in wastewater treatment plants, via e-mail. The most surprising thing is how little we know about how our own wastewater treatment plants operate.

“Most of the bacteria are typical soil bacteria, bacteria right out in your backyard. In fact, a typical well-digested wastewater treatment sludge ready for land disposal will have an ‘earthy’ odor,” he wrote. “I have read that we have only been able to identify about 30 percent of the bacterial species inhabiting activated sludge-type treatment processes, mainly because those are the only ones we can grow in the laboratory. Thus, we only know how to grow the other 70 percent within the wastewater treatment process, but cannot identify them yet. Most of our systems do quite well without knowing the 70 percent, or for that matter, the 30 percent. We do not have enough time or money

to identify them. All we need to know is that they will function properly when the system is controlled properly.”

9. A large tanker truck can hold 9,000 gallons of water, so 5,000 tankers would yield 45 million gallons of water a day, or about 9 gallons for each of 5 million Atlanta-area residents.
10. Major Daren Payne’s comment about there being no plan for what to do if Atlanta ran out of water is from an Associated Press story by Greg Bluestein, “No Backup if Atlanta’s Faucets Run Dry,” October 19, 2007, which was widely published, although not in the *Atlanta Journal Constitution*: http://www.breitbart.com/article.php?id=D8SCHTI00&show_article=1.
11. The *Clarion-Ledger* in Jackson, Mississippi, provided thorough coverage of the city’s water-main breaks. Just a few of the paper’s stories are cited below. The paper archives older stories, but requires payment to read them online.
 - Chris Joyner, “Water Repairs Continue,” January 13, 2010.
 - LaRaye Brown, “Businesses Coping Without Water,” January 13, 2010.
 - Gary Pettus, “Jackson Water Still Not OK to Drink,” January 16, 2010.
12. Jackson mayor Harvey Johnson’s quote “We have a disaster. It’s just not one you can see” is from Joyner, “Water Repairs Continue.”
13. The National Hurricane Center’s official report on Ike calculates that the storm surge across this bayside part of Galveston Island was between 10 feet and 15 feet.
 - Robbie Berg, *Tropical Cyclone Report: Hurricane Ike*, National Hurricane Center, pp. 6–7 (PDF). http://www.nhc.noaa.gov/pdf/TCR-AL092008_Ike_3May10.pdf.
14. Greg Bluestein, “No Backup if Atlanta’s Faucets Run Dry,” October 19, 2007. http://www.breitbart.com/article.php?id=D8SCHTI00&show_article=1.
15. This quote is from an interview that a group of Galveston city officials gave to the Austin weekly newspaper a year after Hurricane Ike hit Galveston.
 - Kate X Messer, “Q&A: Austin’s Coastal Neighbors,” *Austin Chronicle*, September 11, 2009. <http://www.austinchronicle.com/gyrobase/Issue/story?oid=oid%3A842282>.
16. Figures for states with more than 60 percent of homes without complete indoor plumbing in 1950 come from the U.S. Census Bureau. The census defines complete plumbing facilities as “hot and cold piped water, a bathtub or shower, and a flush toilet.”

State	% Without Complete Indoor Plumbing
Alabama	68
Arkansas	71
Georgia	63
Kentucky	64
Mississippi	74
North Carolina	65
North Dakota	66
South Carolina	65
South Dakota	61
Tennessee	63

“Plumbing Facilities,” *Historical Census of Housing Tables*, U.S. Census Bureau. <http://www.census.gov/hhes/www/housing/census/historic/plumbing.html>.

17. Statistics for 1960 and 1970 indoor plumbing are from the census:

“Plumbing Facilities.” <http://www.census.gov/hhes/www/housing/census/historic/plumbing.html>.

In 1960, 88 percent of U.S. households had televisions, according to the U.S. Census Bureau.

U.S. Bureau of the Census, *Statistical Abstract of the United States: 1961*, Washington, DC, 1961, p. 516 (PDF). <http://www2.census.gov/prod2/statcomp/documents/1961-09.pdf>.

In 1970, 95 percent of U.S. households had televisions, according to the U.S. Census.

U.S. Bureau of the Census, *Statistical Abstract of the United States: 1971*, Washington, DC, 1971, p. 487 (PDF). <http://www2.census.gov/prod2/statcomp/documents/1971-05.pdf>.

The census makes the texts of the *Statistical Abstracts* available online. <http://www.census.gov/prod/www/abs/statab1951-1994.htm>.
18. No one routinely gathers data on the average monthly water bill. But the American Water Works Association (AWWA) has used usage and fee surveys to estimate that the monthly bill is \$34 per household in the U.S. (just for water, not including sewer service).

The figure of \$260 per family each year for water infrastructure upkeep comes from the total infrastructure spending on water systems, compiled by the American Society of Civil Engineers (ASCE). The ASCE calculates that from 2009 to 2014, U.S. governments will spend \$29.2 billion a year maintaining water and wastewater systems; the U.S. has 112 million families.

“Estimated 5-Year Investment Needs in Billions of Dollars,” *Report Card for America’s Infrastructure*, American Society of Civil Engineers. <http://www.infrastructurereportcard.org/report-cards>.
19. Officials at the water company Aqua America provided the data on construction costs to lay replacement water pipe.

Desalination plant costs in Australia come from:

Norimitsu Onishi, “Arid Australia Sips Seawater, but at a Cost,” *New York Times*, July 10, 2010. <http://www.nytimes.com/2010/07/11/world/asia/11water.html>.

5. THE MONEY IN THE PIPES

1. There are roughly 73 million sheep in Australia—three sheep for every person. Each sheep produced an average of 10.3 pounds of greasy wool in 2009–2010.

Australia produced 21.5 percent of the greasy wool grown in the world in 2008, followed by China (19 percent), New Zealand (10 percent), and Argentina (4 percent). Greasy wool is wool weighed before it has been cleaned.

Worldwide and Australian wool production figures from:

Australian Wool Production 2009/10. Australian Wool Innovation Ltd. http://www.wool.com/Media-Centre_Australian-Wool-Production.htm.
2. Michael Grealy, “Michell Wool Dynasty Shrouded in Mystery,” *Sun-Herald* (Sydney, Australia), October 29, 1989, quoting David Coombes, then executive director of the Wool Council of Australia.

3. At home, each pound of laundry requires about two gallons of water to clean and rinse. Conventional home washing machines (top-load) hold 12–16 pounds of laundry and use 30 gallons of water.

“Washing Machines: Types of Washing Machines,” ConsumerReports.org. <http://www.consumerreports.org/cro/appliances/laundry-and-cleaning/washing-machines/washing-machine-buying-advice/washing-machine-types/washing-machine-types.htm>.

“How Much Does It Cost to Run a Washing Machine?” Michaelbluejay.com. <http://michaelbluejay.com/electricity/laundry.html>.

4. How does a half-gallon-a-minute change in showerhead flow add up to millions of gallons in water savings a year?

The showerhead in each room in Aria, down from 2.5 gallons per minute to 2 gpm, saves 0.5 gpm. If the average shower is 8 minutes, each shower uses 4 fewer gallons of water than it otherwise would. (The Water Research Foundation study of U.S. water use, *Residential End Uses of Water*, cited in chapter 1, found that people with low-flow showerheads took showers that were 8.5 minutes, on average.)

The Aria has 4,004 rooms. If, at the low end, there are 6,000 guest showers a day at the Aria (75 percent occupancy, with two people per room showering), that saves 24,000 gallons of water a day. Over the year, that’s a savings of 8.8 million gallons of water. With a few more showers—that is, with a couple months of the higher occupancy typical of Las Vegas (average hotel occupancy is 90 percent), savings could easily be 10 million or 12 million gallons of water a year.

5. The CityCenter project has earned six gold ratings for environmentally conscious design from the U.S. Green Building Council.

The development’s environmental efforts and design innovations are outlined in this press release, and detailed in a separate Web site:

“City of Gold: Vegas’ CityCenter Earns Six LEED Gold Certifications,” CityCenter Press Room, November 20, 2009. http://www2.citycenter.com/press_room/press_room_items.aspx?ID=778.

“CityCenter—Environment: The Nature of Luxury,” CityCenter. <http://www2.citycenter.com/environment/>.

6. As the calculations above show, every 0.5 gpm reduction in water used by the showerhead at the Aria hotel saves a minimum of 24,000 gallons a day—1,000 gallons an hour. Going from 2.5 gpm to 1.5 gpm saves 48,000 gallons a day, 2,000 gallons an hour.

Water consumption in Las Vegas, overall, is 400 million gallons a day, of which 59 percent is residential, or 236 mgd. As of 2008, according to the U.S. Census, there are 676,617 housing units in Clark County, which comes to 349 gallons of water per household per day. So 48,000 gallons a day would supply 138 homes.

7. Press accounts routinely describe Monsanto as the largest seller of seeds in the world:

Donald L. Barlett and James B. Steele, “Monsanto’s Harvest of Fear,” *Vanity Fair*, May 2008. <http://www.vanityfair.com/politics/features/2008/05/monsanto200805>.

Jack Kaskey, “Monsanto ‘Warrior’ Grant Fights Antitrust Accusations, Critics,” Bloomberg, March 4, 2010. <http://www.bloomberg.com/apps/news?pid=newsarchive&sid=axVdNmPtSgts&pos=7>.

Monsanto reports its seed sales each quarter. In 2009, seed sales were \$4.5 billion out of total revenue of \$11.7 billion.

Fourth-Quarter 2009 Financial Results, Monsanto, October 7, 2009, pp. 4–5. http://www.monsanto.com/pdf/investors/2009/10_07_09.pdf.

8. “Water Conservation,” *2009 Intel Corporate Responsibility Report*, Intel, pp. 41–45. <http://www.intel.com/about/corporateresponsibility/report/build/index.htm>.

Intel’s detailed water-use figures, and water use per chip produced (“normalized water use”), along with basic financial data for comparison purposes, are available at the same link.

Intel’s water productivity is even worse in per-chip terms. From 2005 to 2009, the water required to make a single chip increased 58 percent.

Still, the very existence of such detailed figures, reported voluntarily, is significant. Intel says in its 2009 CRR report that the increase in water use was due in part to the recession (“low manufacturing levels”), and in part to “the increasing complexity of our manufacturing processes” (p. 42).

9. The Muhtar Kent comment comes from his appearance on *Charlie Rose*, PBS, June 9, 2009.

Coke says it provides 1.6 billion servings of soft drinks a day—584 billion a year, or 86 for every person on the planet. A “serving,” according to Coke’s figures, is 8 ounces, so at 86 per person, Coke is serving 688 ounces of beverages to each person on the planet—57 twelve-ounce cans.

Coke says that it uses 313 billion liters of water a year, which is 83 billion gallons a year, or 227 million gallons a day. At the standard U.S. citywide consumption rate of 150 gallons per person, per day, that 227 million gallons would support a city of 1.5 million Americans.

This data is from:

2008/2009 Sustainability Review, Coca-Cola Company (PDF). http://www.thecocacola.com/citizenship/pdf/2008–2009_sustainability_review.pdf.

Basic water-use data: p. iv.

Water-use discussion: pp. 31–33.

Servings per day: p. 4.

10. Here are the calculations of Coke’s water productivity, compared with that of IBM and GE.

All figures are from 2008, the most recent year for which the water-use numbers are available.

Coke: 83 billion gallons of water per year.

\$31.9 billion in revenue.

GE: 12.3 billion gallons of water per year.

\$183 billion in revenue.

IBM: 13.4 billion gallons of water per year (just microchip manufacturing).

\$104 billion in revenue.

Each \$1 of revenue for Coke requires 2.6 gallons (333 ounces).

Combined revenue for GE and IBM is \$287 billion. Combined water use for GE and IBM is 25.7 billion gallons.

Each \$1 of revenue for GE and IBM requires 0.09 gallons (11.5 ounces).

GE water-use data from:

2008 Citizenship Report: Resetting Responsibilities, GE, p. 41 (PDF). http://files.gecompany.com/gecom/citizenship/pdfs/ge_2008_citizenship_report.pdf.

IBM water-use data from:

IBM and the Environment: 2008 Annual Report, IBM, p. 20 (PDF).
http://www.ibm.com/ibm/environment/annual/IBMEnvReport_2008.pdf.

IBM reports on p. 20 that in 2008, “microelectronics manufacturing operations achieved a 2.4 percent savings [in water use]. This translates to an annual conservation savings of 1,214 thousand cubic meters of water.” That is, 2.4 percent savings equaled 1,214,000 cubic meters of water.

By calculation, in 2008, IBM used 50.6 million cubic meters of water, or 13.4 billion gallons.

11. *2008/2009 Sustainability Review*, Coca-Cola Company, p. 31.
12. Coke’s SEC filings back to 1994 are online here. <http://ir.thecoca-colacompany.com/phoenix/zhtml?c=94566&p=irol-sec>.
 The “Raw Materials” section of Coke’s 2002 annual report begins on p. 10, *Form 10-K Annual Report for the Fiscal Year Ended Dec. 31, 2002*, Coca-Cola Company, filed March 26, 2003.
 The “Raw Materials” section of Coke’s 2009 annual report begins on p. 9, the “Risk Factors” section begins on p. 12, *Form 10-K Annual Report for the Fiscal Year Ended December 31, 2009*, Coca-Cola Company, filed February 26, 2010.
13. Intel’s SEC filings are online here. <http://www.intc.com/financials.cfm>.
14. *A Product Lifecycle Approach to Sustainability*, Levi Strauss & Co., San Francisco, March 2009, pp. 11, 15, 18 (PDF). http://levistrauss.com/sites/default/files/librarydocument/2010/4/Product_Lifecycle_Assessment.pdf.
15. The figures on ice and water savings come from Scott Steenrod, director of food and beverage operations, Celebrity Cruises.
 If each ship saves 7,500 pounds of ice a day, that’s 52,500 pounds of ice a week. At 8.3 pounds per gallon of water, that comes to 6,300 gallons of water per ship per week not required to make ice.
 Celebrity’s total fleet carries about 23,000 passengers a week; the ships together save about 55,000 gallons of water a week.
16. IBM Burlington uses 3.2 million gallons of water a day, and gathers 400 million data points about that water a day. So it gathers an average of 133 bits of data about every gallon of water.
17. IBM Burlington’s chip production in 2008 was 33 percent higher than it had been in 2000. But in 2009, chip production fell sharply, so while water use in 2009 continued to fall, the “water productivity” of the plant in 2009 wasn’t as good as in 2008.
18. IBM describes, somewhat superficially, its effort to revolutionize desalination with new filters and solar power:
 Steve Hamm, “Solar Power + Water Desalination = Rivers in the Desert,” *Building a Smarter Planet*, IBM, April 5, 2010. <http://asmarterplanet.com/blog/2010/04/solar-power-water-desalination-rivers-in-the-desert.html>.
19. Whole Foods spokeswoman Kate Lowery says that in the grocery category, yogurt was the No. 1—selling item by volume in 2007, 2008, and 2009. Water was the No. 2 item in volume in 2007, 2008, and 2009. By mid-2010, water as a product had slipped to No. 3 at Whole Foods, behind salty snacks.

20. The total U.S. wholesale bottled-water market in 2009 was \$10.6 billion, according to the industry's research leader, the Beverage Marketing Corporation. The markup on bottled water is typically 100 percent between wholesale and retail, so total sales to consumers in 2009 were roughly \$21 billion. (Sales in 2009 were down 2.7 percent from 2008 in gallons of water sold, and down 5.2 percent in revenue.)

"Bottled Water Confronts Persistent Challenges," Beverage Marketing Corporation, July 2010.

Beverage Marketing makes a wealth of data available about U.S. beverage consumption at <http://www.beveragemarketing.com/?section=pressreleases>.

Apple breaks down sales by product and by category in detail in its annual 10-K filing with the SEC.

In 2009 total iPhone sales were \$6.8 billion; total iPod sales were \$8.1 billion; total sales from iTunes were \$4 billion. Together, iPhone, iPod, and iTunes sales were \$18.9 billion.

Apple sold 21 million iPhones and 54 million iPods.

Form 10-K Annual Report for the Fiscal Year Ended September 26, 2009, Apple Inc., filed October 27, 2009, p. 41 (PDF). <http://phx.corporate-ir.net/External.File?item=UGFyZW50SUQ9MTgIOTB8Q2hpbGRJRDR0tMXxUeXB1PTM=&t=1>.

21. Total 2009 U.S. bottled-water consumption of 8.4 billion gallons comes from the Beverage Marketing Corporation. <http://www.beveragemarketing.com/?section=pressreleases>.

The American Society of Civil Engineers estimates that U.S. municipal water systems leak about 7 billion gallons a day, about 16 percent of what they pump.

Drinking Water: Report Card for America's Infrastructure, ASCE, 2009. <http://www.infrastructurereportcard.org/fact-sheet/drinking-water>.

22. Tap water is regulated in the U.S. by the Environmental Protection Agency (EPA), under the Safe Drinking Water Act. Bottled water that crosses state lines is regulated as a food product by the Food and Drug Administration (FDA). And while the FDA has adopted the EPA's drinking water standards for bottled water, the actual regulation of bottled water amounts mostly to a system of voluntary compliance and trust, because enforcement rules and factory inspections are both minimal.

For instance, the EPA requires that any significant violation of tap water standards be reported, both to the EPA and to the public, within 24 hours.

Bottled-water companies are not required to report violating water standards to either the public or the FDA—ever.

U.S. water utilities serving more than 100,000 people are required to test their water for bacterial contaminants every few hours.

Bottled-water companies, which have facilities that produce millions of bottles of water a day, are only required to test for bacterial contamination once a week, and only required to test for some contaminants once a year.

The U.S. Government Accountability Office (GAO) found in a 2009 study that, at best, bottled-water facilities are only inspected every 2 to 3 years—but that the EPA doesn't have a comprehensive list of bottling companies, so "we could not determine the percentage of bottled water facilities inspected" (p. 10). What's more, because bottled-water companies are only required to maintain records of their testing for two years (compared with 5 to 10 years for water utilities), "FDA would most likely not be aware that a contamination problem existed if a facility was not inspected within a 2-year time frame" (p. 9).

Drinking bottled water amounts to a leap of faith in the company whose water you're purchasing and consuming.

The GAO's 2009 study is:

Bottled Water: FDA Safety and Consumer Protections Are Often Less Stringent Than Comparable EPA Protections for Tap Water (GAO-09-610), Government Accountability Office, Washington, D.C.: June 2009 (PDF). <http://www.gao.gov/new.items/d09610.pdf>.

23. During the Boston water-main break and outage from May 1 to May 4, 2010, even doctors were ordered to use bottled water, to scrub in before surgery.
Tracy Jan, "Residents, Businesses Race to Adapt; Water Vanishes from Stores," *Boston Globe*, May 2, 2010. http://www.boston.com/news/local/massachusetts/articles/2010/05/02/residents_businesses_race_to_adapt_water_vanishes_from_stores.
24. The American Society of Civil Engineers (ASCE) issues an "infrastructure report card" each year, to focus attention on how the U.S. is maintaining, or failing to maintain, vital systems like roads, bridges, airports, air traffic control, schools, and water systems. The ASCE report says that actual spending on water and wastewater treatment systems (excluding dams) over the five years from 2009 to 2014 will be \$146.4 billion—including the 2009 federal stimulus funds. That comes to \$29.2 billion a year.
"Estimated 5-Year Investment Needs in Billions of Dollars," *Report Card for America's Infrastructure*, American Society of Civil Engineers. <http://www.infrastructurereportcard.org/report-cards>.
25. "S.F. Mayor Bans Bottled Water at City Offices," Associated Press, June 25, 2007. <http://www.msnbc.msn.com/id/19415446>.
Sharon Plan Chan, "City of Seattle Won't Buy Bottled Water," *Seattle Times*, March 13, 2008. http://seattletimes.nwsourc.com/html/localnews/2004280866_web_water13m.html.
Jennifer 8. Lee, "City Council Shuns Bottles in Favor of Water from Tap," *New York Times*, June 17, 2008. <http://www.nytimes.com/2008/06/17/nyregion/17water.html>.
Several universities, including Washington University in St. Louis, the University of Portland, and DePauw University in Greencastle, Indiana, have banned sales of bottled water on campus.
26. *2008 Report on Postconsumer PET Container Recycling Activity: Final Report*, National Association for PET Container Resources, p. 4 (PDF). http://www.napcor.com/pdf/2008_Report.pdf.
27. The Beverage Marketing quote about tap water comes from "Liquid Refreshment Beverage Market," Beverage Marketing Corporation, March 24, 2010. <http://www.beveragemarketing.com/?section=pressreleases>.
28. Gary Hemphill, senior vice president at Beverage Marketing, says FIJI Water was the No. 1 imported brand in 2008, but fell during the recession; San Pellegrino was the No. 1 import in 2009.
29. "President-Elect Obama Drinks FIJI Water on Election Night," FIJI Blog, FIJI Water, November 21, 2008. <http://www.fijiwater.com/blog/2008/11/president-elect-obama-drinks-fiji-water-on-election-night/>.
Susan Donaldson James, "Gym Rat in Chief? Obama's Fitness Regimen," ABC News, December 4, 2008. <http://abcnews.go.com/Health/President44/Story?id=6387559&page=1>.

30. The GE ecomagination commercial “Clouds,” produced by BBDO New York, is available online on YouTube. <http://www.youtube.com/watch?v=SWJ7iVbKRj8>.
31. GE does not break out revenue for GE Water separately. The 2009 revenue figure of \$2.5 billion comes from:
 Scott Malone, “GE Sees Tide Coming In for Water Business,” Reuters, August 11, 2009. <http://www.reuters.com/article/idUSN2235851820090811>.
32. In order, references for GE Water’s work at the Virginia coal mine, the Algiers desalination plant, the Sydney golf course, and China’s Lake Taihu:
 “Turning Mine Water Into a Useful Resource,” GE Water Press Center, March 4, 2010. http://www.ge-energy.com/about/press/en/2010_press/030410.htm.
 “Hamma Seawater Desalination Plant,” GE Water Press Center, February 24, 2008. http://www.gewater.com/who_we_are/press_center/vpr/hamma.jsp.
 “Pennant Hills Golf Course Goes Green,” Sydney Water, May 30, 2008. <http://www.sydneywater.com.au/whoweare/MediaCentre/MediaView.cfm?ID=470>.
 Peter Ford, “Pollution Puts Chinese Lake Off Limits,” *Christian Science Monitor*, June 4, 2007. <http://www.csmonitor.com/2007/0604/p07s02-woap.html>.
 “GE Wastewater Treatment Solution to Help Restore Health of China’s Third Largest Lake,” GE Water Press Center, June 24, 2008. http://www.gewater.com/who_we_are/press_center/pr/06242008.jsp.
33. The GE Web site lists Schaefer’s discovery of cloud seeding in its timeline “The Science of Improvement,” under the title “The Rainmaker.” http://www.ge.com/innovation/timeline/eras/science_of_improvement.html.
 Schaefer’s papers are archived at SUNY Albany, and the online guide to those papers includes a biographical sketch of the scientist. <http://library.albany.edu/speccoll/findaids/ua902.010.htm>.
34. Steven Prokesch, “How GE Teaches Teams to Lead Change,” *Harvard Business Review*, January 2009, p. 7 (PDF). http://www.ge.com/pdf/innovation/leadership/hbr_crotonville.pdf.
35. GE CEO Jeffrey Immelt spoke briefly about GE’s water business at the GE investors conference on December 15, 2009. An analyst asked Immelt, “Tell us what you learned from the things which were not successes. I don’t want to pick on water. But it might be a good example.”
 Immelt replied, “Look, water was—we paid too much for growth that was hard to materialize. And we had no foundational point in the company to plug it into. So we ran it as a freestanding business, having paid 14 or 15 times EBITDA. So what do you learn? Don’t pay so much. And put things inside core businesses, right?”
 GE Water is now a part of the larger GE division, GE Energy.
 The exchange is in this presentation transcript, p. 22 (PDF). http://www.ge.com/pdf/investors/events/12152009/ge_annualoutlook_transcript_12152009.pdf.
36. Andrew C. Revkin, “Dredging of Pollutants Begins in Hudson,” *New York Times*, May 15, 2009. <http://www.nytimes.com/2009/05/16/science/earth/16dredge.html>.
 In April 2010, GE released an accounting of its costs for the initial dredging effort on the Hudson of \$561 million.
 Michael Hill, “GE Says Hudson Dredging Cost \$561M,” Associated Press, April 30, 2010. <http://abcnews.go.com/Business/wireStory?id=10523307>.
 On its own Web site, GE said that since 1990, the company had spent a total of \$830 million on the Hudson River cleanup.

“GE Reports Cost of First Phase of Dredging,” *The Hudson River Dredging Project*, GE Corporate Environmental Program. http://www.hudsondredging.com/phase_one_costs.

37. Delta’s Paul Patton sent me a sample of the Aria’s custom-designed four-hole shower-head, and we installed it in one of our bathrooms. It was a pleasure to use—the water did stay warmer, and the four holes created a cone of spray much wider, denser, and more even than from showerheads with five or ten times the number of holes. Without knowing in advance, you’d never guess that the Aria showerhead was using 25 percent or 40 percent less water than typical.

6. THE YUCK FACTOR

1. Carenda Jenkin, “Two Die of Thirst in Bush Tragedy,” *Centralian Advocate*, January 15, 2008.

The trio whose Mitsubishi Pajero ran out of water were never identified in the Australian media.

2. Paige Taylor and Victoria Laurie, “How a Simple Flat Tyre Killed Artist and Bushman,” *Australian*, January 16, 2007. <http://www.theaustralian.com.au/news/nation/how-a-simple-flat-tyre-killed-artist-and-bushman/story-e6frg6nf-111112837559>.
3. Lindsay Murdoch, “How a Desert Claimed Two Ill-Prepared Travellers,” *Age*, April 13, 2005. <http://www.theage.com.au/news/National/How-a-desert-claimed-two-ill-prepared-travellers/2005/04/12/1113251629492.html>.

The men were identified as Bradley John Richards, 40, his nephew Mac Bevan Cody, 21, and their dog, VB.

4. Bellinda Kontominas, “Triple-0 Review Urged by Coroner as Iredale Inquest Ends,” *Sydney Morning Herald*, May 8, 2009. <http://www.smh.com.au/national/triple0-review-urged-by-coroner-as-iredale-inquest-ends-20090507-aw1a.html>.
5. Katie Finn, “St. Luke’s Packed as City Prays for Rain,” *Chronicle* (Toowoomba), April 22, 2005.
6. “Toowoomba Takes Out Top Tidy Town Award,” ABC News (Australia), April 20, 2008. <http://www.abc.net.au/news/stories/2008/04/20/2221872.htm>.
7. A brief history of Toowoomba is at the official Toowoomba Regional Council Web site. The precise origins of Toowoomba as the city’s name are murky—as it happens, while the Aboriginal word for swamp is *tawampa*, two other possibilities are equally intriguing.

The Aboriginal phrase *woomba woomba* means “reeds in the swamp.” And the area was known for a melon that grew abundantly, which the natives called *toowoom* or *choowoom*.

“About Council: History: Toowoomba,” Toowoomba Regional Council. http://www.toowoombarc.qld.gov.au/index.php?option=com_content&view=article&id=111%3Atoowoomba&catid=6%3Ahistory&Itemid=18.

8. “Population Estimates by Local Government Area, 2001 to 2009,” Catalog No. 3218.0, Australian Bureau of Statistics. <http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/3218.02008-09?OpenDocument>.

9. Leisa Scott, "Beaten, Bloody Well Unbowed," *Courier-Mail* (Brisbane), September 2, 2006. <http://www.couriermail.com.au/news/beaten-bloody-well-unbowed/story-e6frer7x-111112173213>.

This is a rollicking profile of Mayor Di Thorley. The word "shit" is in the first quote from Thorley.

10. Australians have routinely used the phrase "big dry" to refer to periods of drought, although the period from 2001 to 2009 has clearly supplanted previous Big Dry periods.

In 1986, the *Courier-Mail* in Brisbane, writing about a mid-1980s drought and its impact on cattle ranchers, wrote, "Most of south-east Queensland also had been hit hard by the big dry." ("Double Blow as Prices, 'Dry' Hit QLD Cattlemen," *Courier-Mail*, April 9, 1986.)

Similarly, during a drought in the early 1990s, headlines and stories relied on the phrase: Åsa Wahlquist, "Big Dry Claims NSW Wheat Exports," *Sydney Morning Herald*, October 2, 1991.

The current dry period was being referred to as the "Big Dry" as early as 2002: Anna Merola, "The Big Dry: Lack of Rainfall Drying Up Hope," *Sunday Mail* (Adelaide), September 8, 2002.

11. Susan Searle, "The Plan to Save Our City," *Chronicle* (Toowoomba), July 2, 2005.
12. Searle, "Watering Cans Sell Out as Restrictions Tighten," *Chronicle* (Toowoomba), August 9, 2005.
13. Australia uses the metric system, and all Australian water authorities measure large water volumes in megaliters—1 megaliter is 1 million liters (264,172 gallons, or 0.8 acre-foot).

Toowoomba, a town of 120,000 people, uses about 27 megaliters of drinking water a day (about 7 million gallons—60 gallons per person). Toowoomba requires roughly 10,000 megaliters of water a year; under tight water restrictions, the city has been using 9,000 megaliters a year, about 24 megaliters a day.

Toowoomba's three reservoirs hold 127,000 megaliters of water when full—a 10-year supply. But the capacity is actually relatively small; the reservoirs would only serve 1.2 million people over that 10 years. The total volume of Toowoomba's reservoirs, when full, would only serve the needs of Las Vegas for three months.

In the U.S., the basic measure of large volumes of water is the acre-foot—the amount of water covering an acre of space (43,560 square feet), to a depth of one foot. 1 acre-foot is 325,841 gallons.

1 acre-foot is equal to 1.2 megaliters.

Toowoomba uses 27 megaliters of water a day—Las Vegas uses 1,520, New York uses 4,164 megaliters of water a day.

14. In order of appearance, here are references for information on the Occoquan Reservoir, in Fairfax County; the Orange County, California, recycling facility; and Singapore's NEWater effort:

Rob Davis, "Where Water Reuse Isn't a Dirty Word," *Voice of San Diego*, January 7, 2009. http://www.voiceofsandiego.org/environment/article_068e2ad1-1b57-5313-936c-ebd65aca818a.html.

Randal C. Archibold, "From Sewage, Added Water for Drinking," *New York Times*, November 27, 2007. <http://www.nytimes.com/2007/11/27/us/27conserve.html>.

NEWater: Plans for NEWater, PUB: Singapore's National Water Agency. <http://www.pub.gov.sg/newater/plansfornewater/Pages/default.aspx>.

15. The annual list of the richest Australians is compiled by the Australian business magazine *BRW*. As of the May 2010 list, Clive Berghofer was listed at No. 118, with an estimated net worth of A\$340 million (US\$307 million).

He was No. 110 in 2009.

BRW posts the lists online, but a subscription is required for access: “Rich,” *BRW*. <http://brw.com.au/lists/rich>.

Below is the story from the Toowoomba *Chronicle* about the 2010 list:

Jim Campbell, “Berghofer on BRW Rich List,” *Chronicle*, May 28, 2010. <http://www.thechronicle.com.au/story/2010/05/28/340m-wealth-berghofer-brw-list/>.

16. The venues in Toowoomba bearing Clive Berghofer’s name:

- Clive Berghofer Arena, Toowoomba
- Clive Berghofer Events Center, Toowoomba
- The Berghofer Pavilion, Toowoomba
- Clive Berghofer Stadium, Toowoomba
- Clive Berghofer Recreation Centre, at the University of Southern Queensland

And, at St. Vincent’s Hospital, Toowoomba, the Clive Berghofer Intensive Care Unit.

In Brisbane, the capital of Toowoomba’s state of Queensland, Berghofer donated money to the Queensland Institute of Medical Research, which now has the Clive Berghofer Cancer Research Centre.

17. “Clive Casts Doubts on Water Plans,” *Chronicle*, July 27, 2005.

I interviewed Clive Berghofer in person. The quotes in this paragraph come not from the initial story about his opposition from the *Chronicle*, above, but from a magazine story on Toowoomba’s water issues that ran during the recycling battle:

Roy Eccleston, “Bottoms Up—Aqua Blue,” *Australian*, July 29, 2006.

The story is no longer available on the *Australian’s* Web site, but its full text is here:

“Bottoms Up—Aqua Blue,” [Travestonswamp.info](http://www.travestonswamp.info/forum/viewtopic.php?t=737&sid=071a0e066b4d086ce3b9e55291f13150), July 29, 2006. <http://www.travestonswamp.info/forum/viewtopic.php?t=737&sid=071a0e066b4d086ce3b9e55291f13150>.

18. Wendy Frew, “The Yuk Factor,” *Sydney Morning Herald*, September 5, 2005. <http://www.smh.com.au/news/national/the-yuk-factor/2005/09/04/1125772411914.html>.

19. Searle, “No Sign of Scientists to Answer Questions,” *Chronicle* (Toowoomba), August 23, 2005.

20. Peter McCutcheon, “Residents Oppose Toowoomba Recycled Water Proposal,” *7:30 Report*, ABC, March 22, 2006. <http://www.abc.net.au/7.30/content/2006/s1598458.htm>.

“Chronicle: Oct. 8, 2005: Petition—MP Asks Council to Delay Water Plans,” *Water Futures*, October 8, 2005. <http://waterfutures.blogspot.com/2005/10/chronicle-oct-8-2005-petition-mp-asks.html>.

The text of the Toowoomba petition to parliament and to MP Ian Macfarlane is here:

“Recycled Sewage Water for Drinking,” Closed E-Petition, Queensland Parliament Petitions. http://www.parliament.qld.gov.au/view/EPetitions_QLD/ClosedEPetition.aspx?PetNum=528&1Index=-1.

21. The data on what's in purified recycled water in Australia come from an "expert advisory panel" of the Queensland Water Commission, appointed to provide technical guidance on purified recycled water.

The panel reported in a letter to the Queensland Water Commission, with a full technical report attached:

Paul Greenfield, Chairman, Expert Advisory Panel, Vice Chancellor, University of Queensland, letter to Elizabeth Nosworthy, Chairwoman, Queensland Water Commission, February 20, 2009 (PDF). <http://www.qwc.qld.gov.au/myfiles/uploads/purified%20recycled%20water/Interim%20water%20quality%20report/Interim%20water%20quality%20report.pdf>.

The concentration of acetaminophen is described on p. 5. (Acetaminophen is known in Australia as paracetamol.)

The amount of bisphenol A that a typical person would consume per day is from: "Monograph on the Potential Human Reproductive and Developmental Effects of Bisphenol A," NIH Publication No. 08-5994, National Toxicology Program, Center for the Evaluation of Risks to Human Reproduction, U.S. Department of Health and Human Services, September 2008, p. 5 (PDF). <http://cerhr.niehs.nih.gov/evals/bisphenol/bisphenol.pdf>.

22. In the U.S., there is no cabinet secretary exclusively for water at the national level. Of the 50 state governments, just two have a cabinet-level water official—Arizona and Idaho both have a director of water resources. Minnesota has an advisory group called the "water cabinet," composed of state officials from several departments.

During 2008, Australian Minister of Water Penny Wong was mentioned in 1,007 newspaper stories and radio broadcasts, versus 1,102 stories for then Defence Minister Joel Fitzgibbon (using a Nexis search of stories in which the name of each appeared at least three times). Fitzgibbon resigned in June 2009 as a result of questions about travel costs.

In the year after his departure, from July 2009 to July 2010, Penny Wong appears in 704 stories; the new defense minister, John Faulkner, appeared in 1,281 stories.

23. The A\$30 billion of spending in Australia just on water projects related to the Big Dry is likely conservative. As of 2010, the *New York Times* reported that Australian cities had A\$15 billion (US\$13 billion) in desalination plants either built or under construction.

The A\$30 billion comes from Australia's water utility association, the Water Services Association of Australia (WSAA), cited in this story:

Åsa Wahlquist, "Water, Special Report: Policy Hinges on Data Pool," *Weekend Australian*, March 7, 2009.

Norimitsu Onishi, "Arid Australia Sips Seawater, but at a Cost," *New York Times*, July 10, 2010. <http://www.nytimes.com/2010/07/11/world/asia/11water.html>.

24. The Australian Bureau of Statistics calculates that 85 percent of Australians live within 50 km (31 miles) of the Australian coast.

"Census of Population and Housing: Population Growth and Distribution, Australia, 2001," Catalog No. 2035.0, Australian Bureau of Statistics. <http://www.abs.gov.au/ausstats/abs@.nsf/mf/2035.0>.

Professor Leon van Shaik, of the Royal Melbourne Institute of Technology, says in the article below that half the nation's homes are within 8 miles of the coast.

"With the Blenburn House in Rural Australia, Sean Godsell Perfects an Eco-

- friendly Prototype,” *Architectural Record*, April 2008. <http://archrecord.construction.com/residential/recordHouses/2008/08Glenburn.asp>.
25. Climate, rainfall, runoff, and river flow data are from a remarkable reference document, *The Australian Water Map*. Some of the charts on the four-foot-wide map are available online:
The Australian Water Map, Earth Systems, Melbourne, Australia: 2003. <http://www.earthsystems.com.au/mapwater/index.htm>.
 26. The land area of Western Australia is 2.5 million km².
 The total land area of the Western European nations is 2.05 million km²—UK (0.24 million km²), France (0.64 million km²), Spain (0.51 million km²), Germany (0.36 million km²), and Italy (0.30 million km²).
 27. Data on changes in Perth’s rainfall and runoff are from officials of the Water Corporation, the water utility for Western Australia. The data are summarized in the Water Corporation’s most recent strategic planning document:
Integrated Water Supply Scheme: Source Development Plan, 2005–2050, Water Corporation, April 2005, p. 2 (PDF). http://www.watercorporation.com.au/_files/PublicationsRegister/22/SourcePlan_2005_Summary.pdf.
 28. Tim Flannery’s original observation about Perth comes from:
 Paul Sheehan, “The Flannery Eaters,” *Sydney Morning Herald*, June 5, 2004. www.smh.com.au/articles/2004/06/04/1086203632052.html.
 The prediction was reported in Perth’s *West Australian* newspaper, based on its interview with Flannery, June 25, 2004.
 Carmelo Amalfi, “Perth Will Die, Says Top Scientist,” *West Australian*, June 25, 2004.
 29. Adelaide residents have dramatically reduced their total water consumption, even as the city has grown. In 2002, the city used 194 gigaliters of water. In 2009, it used 137 gigaliters—a reduction of 57 gigaliters. The Perth desalination plant produces 50 gigaliters of drinking water a year; Adelaide’s planned desalination plant was originally designed to produce 50 gigaliters of water a year; its size has been doubled during planning. See the release below.
 “Water Consumption Remains Below Target,” SA Water, January 2, 2010 (PDF). <http://sawater.com.au/NR/rdonlyres/2FC06879-3EE4-4A3A-90FB-6EB876233504/0/waterconsumption.pdf>.
 “Adelaide to Double Size of Its Desalination Plant,” SA Water, May 13, 2009 (PDF). <http://sawater.com.au/NR/rdonlyres/E47D55A8-91F9-4029-A9A6-79A3EC21BE62/0/MedRelDesalMay09.pdf>.
 30. Melbourne’s swimming-pool filling restrictions are detailed here:
 “Stage 3 Water Restrictions: Frequently Asked Questions, Pools and Spas,” Target 155. <http://www.target155.vic.gov.au/stage-3-water-restrictions/frequently-asked-questions>.
 Trucking in water to fill swimming pools is described below:
 “Having Trouble Filling the Swimming Pool? There’s a Solution,” *Age*, October 8, 2007. <http://www.theage.com.au/articles/2007/10/07/1191695744867.html>.
 31. Historical figures for Melbourne’s water use:
 “Water Use,” Melbourne Water. http://www.melbournewater.com.au/content/water_conservation/water_use/water_use.asp.

Current water use figures for Melbourne:

“Water Consumption,” Target 155. <http://www.target155.vic.gov.au/water-supply-and-use/water-consumption>.

32. “Seawater Desalination Plant,” Melbourne Water. http://www.melbournewater.com.au/content/current_projects/water_supply/seawater_desalination_plant/seawater_desalination_plant.asp.

Victorian premier John Brumby’s “pray for rain” comment is from Rick Wallace, “Desal Project to Defy Slump,” *Australian*, July 31, 2009.

33. Basic information about the size and significance of the Murray-Darling Basin is from the Murray-Darling Basin Authority (MDBA):

“About the Basin,” Murray-Darling Basin Authority. http://www.mdba.gov.au/water/about_basin.

River flow data from 2007, 2008, and 2009 is from the MDBA drought updates (the “river year” runs from June 1 to May 31).

The Murray’s long-term average flow for one year: 8,840 gigaliters.

The Murray’s total flow for the three years 2007–2009: 5,040 gigaliters.

“River Murray System: Drought Update,” Murray-Darling Basin Authority, Issue No. 19, June 2009, p. 2 (PDF). <http://www.mdba.gov.au/system/files/drought-update-June-2009.pdf>.

34. In order, references for the loss of fruit trees, the shrinking of the sheep herd, and the dramatic falloff in the rice harvest are:

Debra Jopson, “Murray Towns ‘Are Living Hand to Mouth,’” *Sydney Morning Herald*, March 9, 2009. <http://www.smh.com.au/environment/water-issues/murray-towns-are-living-hand-to-mouth-20090308-8sgj.html>.

“Sheep and Lamb Numbers Fall to Their Lowest Levels Since 1905: Agricultural Commodities, Australia, 2008–09,” Catalog No. 7121.0, Australian Bureau of Statistics, April 9, 2010. <http://www.abs.gov.au/ausstats/abs@.nsf/mediareleasesbytitle/D793AD9EE6BCF107CA257456001F1839?OpenDocument>.

“Agricultural Commodities, 2007–08,” Catalog No. 7121.0, Australian Bureau of Statistics, May 22, 2009, p. 12 (PDF). [http://www.ausstats.abs.gov.au/Ausstats/subscriber.nsf/0/0B7FE368D21623E0CA2575BD00ICE264/\\$File/7121_2007-08.pdf](http://www.ausstats.abs.gov.au/Ausstats/subscriber.nsf/0/0B7FE368D21623E0CA2575BD00ICE264/$File/7121_2007-08.pdf).

35. Lauren Novak, “Water: End of the Sprinkler,” *Advertiser* (Adelaide), April 8, 2010.

36. “Water Pollution Americans’ Top Green Concern,” Gallup Poll, March 25, 2009. <http://www.gallup.com/poll/117079/Water-Pollution-Americans-Top-Green-Concern.aspx>.

Gallup has polled about concern over drinking water going back to 1990, and the trend is, in fact, toward less worry. In 1990, 65 percent of Americans worried about drinking water “a great deal.” The number peaked in 2000 at 72 percent. The 2009 level of concern, 59 percent worried “a great deal,” is the highest since 2001.

Only 5 percent don’t worry about drinking water at all.

37. The issue of micropollutants is just starting to get both the scientific and public policy attention that it requires. Alongside the question of micropollutants, there is a whole new wave of industrial water pollutants that are just coming under scrutiny and regulation—including those from factory farms, and from natural gas drilling where huge volumes of high-pressure water, mixed with a secret brew of chemicals, are used to crack open rock deep under ground and release gas supplies.

The U.S. EPA announced plans in 2010 to dramatically overhaul and update

drinking water standards to account for the micropollutants, without providing any of the crucial specifics. But there is plenty of research and reporting for those curious about micropollutants.

In 2009, the *New York Times* produced an ambitious series called “Toxic Waters” that focused on the increasing pollution of U.S. water supplies and drinking water. The stories included several extraordinary cases of dangerous drinking water pollution, especially from coal mines and farms.

The series is available at <http://www.nytimes.com/water>.

The impact of the natural gas industry’s hydraulic fracturing technique on water supplies has been written about in great detail by the investigative reporters at *ProPublica*. <http://www.propublica.org/series/buried-secrets-gas-drillings-environmental-threat>.

For those interested in the more detailed scientific research involving micropollutants and emerging water-supply contaminants, the lab that Shane Snyder now codirects, the Arizona Laboratory for Emerging Contaminants, has links to its own current research and to the work of others at <http://www.alec.arizona.edu>.

And finally, one of the early pioneers trying to understand the impact of endocrine-disrupting chemicals on humans and animals is Dr. Frederick vom Saal at the University of Missouri–Columbia. He and his team, the Endocrine Disruptors Group, maintain a Web site with current research and an archive of studies on endocrine-disrupting substances. <http://endocrinedisruptors.missouri.edu/vomsaal/vomsaal.html>.

38. According to Toowoomba’s Alan Kleinschmidt, the new pipeline is expected to provide 10 gigaliters of water per year, or 27.4 megaliters per day.
 - 27.4 megaliters = 7.2 million gallons.
 - 7.2 million gallons × 8.33 pounds per gallon = 60 million pounds.
 - The pipeline is sending 60 million pounds of water up the hill a day—that’s 400,000 people at an average weight of 150 pounds each.

7. WHO STOPPED THE RAIN?

1. The Imperial Valley gets just 3 inches of rain a year, on average.
 - Our County . . . Our Community*, Imperial County. <http://www.co.imperial.ca.us/>.
 - The Imperial Valley is the 11th most productive agricultural producing county in the U.S., according to the USDA:
 - 2007 Census of Agriculture: County Profile: Imperial County, California*, National Agricultural Statistical Service, USDA (PDF). http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/County_Profiles/California/cp06025.pdf.
 - The number of golf courses in Phoenix, Arizona:
 - “Golf,” VisitPhoenix.com. <http://www.visitphoenix.com/media/media-kit/golf/index.aspx>.
2. In the growing season that ended in June 2010, Murray River farmers produced rice at an average of 11 metric tons per hectare, which is 4.9 tons per acre. The world average is 3.9 metric tons per hectare, 1.7 tons per acre.
 - Åsa Wahlquist, “Perfect Weather Yields a Rice Bowl Record,” *Australian*, July 12, 2010. <http://www.theaustralian.com.au/news/nation/perfect-weather-yields-a-rice-bowl-record/story-e6frg6nf-1225890495021>.

3. How do you calculate that each dinner-plate serving of rice Laurie Arthur grows requires 14.4 gallons of irrigation water?
 - One pound of dry rice cooks up to provide roughly 10 servings.
 - Arthur produces 10 metric tons of rice per hectare, which is 4.5 tons of rice per acre.
 - 1 acre = 9,000 pounds of rice.
 - Arthur uses 12 megaliters of water per hectare of rice =
 - 4.9 megaliters of water per acre = 1.3 million gallons per acre.
 - 9,000 pounds of rice = 1.3 million gallons of water.
 - 1 pound of rice = 144 gallons.
 - 1 serving = 14.4 gallons of water.
4. What's the math behind Laurie Arthur growing enough food to feed 100,000 people for a year?
 - In a good year (which was typical until 2006), his land produced 9,000 metric tons of high-calorie grain (mostly rice, with some barley and wheat), along with 2,000 sheep.
 - 9,000 metric tons of grain = 9 million kg.
 - 9 million kg = 90 kg of rice for each of 100,000 people.
 - 90 kg = 200 pounds of rice per person.
 - That's roughly 4 pounds of rice per person, per week.
 - 1 pound of cooked rice contains roughly 3,200 calories, so the rice provides 12,800 calories a week, or 1,800 calories per day per person.
 - "I'm not saying you're going to get fat on it," says Arthur, "but it's enough to survive."
 - Of course, you wouldn't want to live on just rice, but Arthur's point is that the water he uses produces enough calories to feed an entire city.
5. *Detailed Historic Timeline of the Australian Rice Industry*, SunRice (PDF). http://www.sunrice.com.au/uploads/documents/education/Detailed_History_of_the_Australian_Rice_Industry.pdf.
6. The Murray-Darling Basin is 410,000 square miles. The five states come to 408,000 square miles: Kansas, 82,000 square miles; Missouri, 69,700; Iowa, 56,300; Nebraska, 77,400, Oklahoma, 69,900; and Arkansas, 53,100.
7. "Water and the Murray-Darling Basin: A Statistical Profile, 2000–01 to 2005–06," Catalog No. 4610.0.55.007, Australian Bureau of Statistics, August 15, 2008. <http://www.abs.gov.au/ausstats/abs@.nsf/mf/4610.0.55.077>.
8. Laurie Arthur says 2006–2007 was the first zero-allocation year for Murray Irrigation Limited.
9. The Australian Bureau of Statistics says, as of 2006, 175,100 Australians identified themselves as "farmers" out of a population of 21.9 million—0.8 percent, or 1 out of 125.
 - "Agriculture in Focus: Farming Families, Australia, 2006," Catalog No. 7104.0.55.001, Australian Bureau of Statistics, August 12, 2008. [http://www.abs.gov.au/ausstats/abs@.nsf/Latestproducts/7104.0.55.001Main%20Features32006?open=document&tabname=Summary&prodno=7104.0.55.001&issue=2006&num=&view=.](http://www.abs.gov.au/ausstats/abs@.nsf/Latestproducts/7104.0.55.001Main%20Features32006?open=document&tabname=Summary&prodno=7104.0.55.001&issue=2006&num=&view=)
10. "Watering Down an Agricultural Dilemma," *Age*, February 21, 2003.

11. In order, citations for water use by Adelaide, by Melbourne, and by the Murray Basin farmers are:
 - “How Much Do We Use?” Water for Good. <http://www.waterforgood.sa.gov.au/using-and-saving-water/how-much-do-we-use/>.
 - “Water Use,” Melbourne Water. http://www.melbournewater.com.au/content/water_conservation/water_use/water_use.asp.
 - “Water and the Murray-Darling Basin—A Statistical Profile, 2000–01 to 2005–06,” Catalog No. 4610.0.55.007, Australian Bureau of Statistics, August 15, 2008. <http://www.abs.gov.au/ausstats/abs@.nsf/mf/4610.0.55.007>.
 - For the number of farmers, see “Farmers in the Murray-Darling Basin,” from the “Contents” page, Catalog No. 4610.0.55.007.
12. “River Murray System: Drought Update,” Murray-Darling Basin Authority, Issue No. 19, June 2009, pp. 1–2 (PDF). <http://www.mdba.gov.au/system/files/drought-update-June-2009.pdf>.
13. Fred Pearce, “Fertile Crescent Will Disappear This Century,” *New Scientist*, July 27, 2009. <http://www.newscientist.com/article/dn17517-fertile-crescent-will-disappear-this-century.html>.
14. Mundaring Weir overflowed on September 12, 1996.
 - The Water Corporation’s description of the dam is below, with the notation that the spill rate is 1,020 meters³ per second, which is 269,455 gallons per second, or 16 million gallons of water per minute.
 - “Mundaring Weir,” Water Corporation. http://www.watercorporation.com.au/D/dams_mundaring.cfm.
 - Pictures of the dam overflowing are here:
 - “1996 Mundaring Weir Overflow,” Mundaring Weir Hotel. <http://www.mundaringweirhotel.com.au/over.html>.
15. “Barnett’s a Canal Too Far,” On Line Opinion, February 25, 2005. <http://www.onlineopinion.com.au/view.asp?article=3079>.
 - Matt Liddy and Nadia Farha, “The Poll Vault: How the West Was Won,” ABC, February 28, 2005. <http://www.abc.net.au/elections/wa/2005/weblog>.
 - Barnett’s proposed canal was 3,700 km, which is 2,300 miles. The distance from Niagara Falls to Las Vegas is 2,264 miles.
16. The Tampa Bay, Florida, desalination plant’s woes have been extensively covered by the *St. Petersburg Times*. Here’s a small sampling of stories:
 - Craig Pittman, “Tampa Bay Water Desal Plant Isn’t Running Often Enough for Swiftmud,” *St. Petersburg Times*, August 25, 2010. <http://www.tampabay.com/news/environment/water/tampa-bay-water-desal-plant-isnt-running-often-enough-for-swiftmud/1117191>.
 - Pittman, “More Problems for Tampa Bay Water Desalination Plant,” *St. Petersburg Times*, March 17, 2009. <http://www.tampabay.com/news/environment/water/article984409.ece>.
 - Pittman, “Cost to Fix Desalination Plant Jumps by Millions,” *St. Petersburg Times*, August 7, 2004. http://www.sptimes.com/2004/08/07/Tampabay/Cost_to_fix_desalinat.shtml.
17. Here is an online water pressure calculator by depth:
 - “Pressure Calculator,” A to Z Diving. <http://www.atozdiving.co.nz/waterpressure.htm>.

Safe operating depths of U.S. submarines are not made public, but are discussed in this publication from the Federation of American Scientists:

Run Silent, Run Deep, Federation of American Scientists, December 8, 1998. <http://www.fas.org/man/dod-101/sys/ship/deep.htm>.

18. Jim Gill's pee example already assumes one conservation measure that is hardly universal: 6 liters of toilet water is just 1.6 gallons, which is a low-flow toilet. Although 3.5-gallon-per-flush toilets haven't been sold in the U.S. since 1994, many U.S. homes and businesses have fixtures that are sixteen years old, which use 3.5 gallons of water per flush. That's 13 liters of water to get rid of half-a-liter of pee—a dilution ratio of 26:1. And, in fact, very few people, even adults, pee as much as 0.5 liters a time.
19. One of the striking things about water management in Australia is how many women there are in senior positions, in contrast to the male-dominated arena of water in both the U.S. and the rest of the world. As of October 2010:

At the federal level, Penny Wong is the Australian minister for water. Three of seven members of the National Water Commission are women, and one of those, Chloe Munro, is also chairman of the consortium building Victoria's large desalination plant.

In the state of South Australia, Karlene Maywald was minister for water security for six years, until March 2010; Robyn McLeod is currently the commissioner for water security.

Sue Murphy is CEO of the Water Corporation, the water utility for Perth and Western Australia; Anne Howe is CEO of SA Water, the water utility for Adelaide and South Australia; Kerry Schott is managing director of Sydney Water; Eleanor Underwood is chairman of the board of Melbourne Water; Judith King is chairman of Power and Water, the water utility for the Northern Territory, including Darwin.

Jennifer Westacott is head of the Australia water practice for the large consulting company KPMG.

20. *Desalination in Australia*, CSIRO (Commonwealth Scientific and Industrial Research Organization), February 2009 (PDF). <http://www.csiro.au/files/files/ppcz.pdf>.
Norimitsu Onishi, "Arid Australia Sips Seawater, but at a Cost," *New York Times*, July 10, 2010. <http://www.nytimes.com/2010/07/11/world/asia/11water.html>.

8. WHERE WATER IS WORSHIPPED, BUT GETS NO RESPECT

1. The survey of water service in the 35 largest Indian cities comes from a World Bank project-planning document:
"India—Delhi Water Supply and Sewerage Project," Report No. 36065, Project Information Document, World Bank, March 15, 2006. http://www-wds.worldbank.org/external/default/WDSContentServer/WDS/IB/2006/05/03/000012009_20060503095630/Rendered/INDEX/36065.txt.
Detail on the water utilities in 20 Indian cities is in:
2007 Benchmarking and Data Book of Water Utilities in India, Asian Development Bank and the Ministry of Urban Development of the Government of India (PDF). <http://www.adb.org/documents/reports/Benchmarking-DataBook/2007-Indian-Water-Utilities-Data-Book.pdf>.
2. Divya Datt and Shilpa Nischal, eds., *Looking Back to Change Track*, TERI: The Energy and Resources Institute, New Delhi: November 2009, p. 5.
Unfortunately, the TERI report is not available online.

3. The numbers for water-related illnesses and deaths come from a sobering 2009 UNICEF/World Health Organization report devoted to diarrhea, and the toll diarrhea still takes in the developing world. *Diarrhoea: Why Children Are Still Dying and What Can Be Done* says that in India, there are 386,000 deaths of children under 5 each year (p. 7).

According to the WHO data, 88 percent of those deaths—931 per day, 39 each hour just in India—are caused by dirty water, dirty hands, and poor sanitation. The report also points out that diarrhea deaths in India and the developing world are utterly unnecessary—diarrhea is no more difficult to treat in India than in England.

Diarrhoea: Why Children Are Still Dying and What Can Be Done, UNICEF/World Health Organization, New York, 2009 (PDF). http://whqlibdoc.who.int/publications/2009/9789241598415_eng.pdf.

4. *Looking Back to Change Track*, p. 5.
5. *Ibid.*, p. 60.

The figures for incidence of diarrhea and cost are from 2008.
6. The history of urban water systems in India is a little hard to get details on. This comes from an interview with V. S. Chary, an expert on urban water systems in India and director, Centre for Energy, Environment, Urban Governance, and Infrastructure Development at the Administrative Staff College of India, Hyderabad, India. Another book with some history is:

John Briscoe and R.P.S. Malik, *India's Water Economy* (New Delhi: Oxford University Press and the World Bank, 2006).
7. The Grand hotel's lobby, with the gardens beyond it, is pictured online.

The Grand, New Delhi. <http://www.thegrandnewdelhi.com/>.
8. *The "Bird of Gold": The Rise of India's Consumer Market*, McKinsey Global Institute, May 2007 (PDF). http://www.mckinsey.com/mgi/reports/pdfs/india_consumer_market/MGI_india_consumer_full_report.pdf.

Figures for cutting the number of poor people in half: pp. 10–12.

Figures for the movement of Indians into the middle class: p. 13.

McKinsey says that in 2005, 50 million Indians qualified as middle class. By 2025, McKinsey estimates, 583 million Indians will be middle class, an increase of 533 million new middle-class Indians in 20 years, or 73,014 per day.

McKinsey's estimates assume an average growth rate of 7.3 percent for India's GDP over the 20-year period, as explained on p. 165 of the report.
9. "The World's Billionaires," *Forbes*, March 10, 2010. http://www.forbes.com/lists/2010/10/billionaires-2010_The-Worlds-Billionaires_Rank.html.

The Indians in the top 50 are:

 - #4 Mukesh Ambani (Mumbai, Reliance Industries)
 - #5 Lakshmi Mittal (London, ArcelorMittal)
 - #28 Azim Premji (Bangalore, Wipro)
 - #36 Anil Ambani (Mumbai, Reliance)
 - #40 Shashi Ruia, Ravi Ruia (Mumbai, Essar Group)
 - #44 Savitri Jindal (Delhi, Jindal Group)

The rank of nationalities among the top 50 billionaires:

 - United States: 20
 - India: 6

Hong Kong/China: 4
 Russia: 4
 Germany: 3
 United Kingdom: 1
 Saudi Arabia: 1

10. “Fuel Used for Cooking,” Census of India, 2001. http://www.censusindia.gov.in/Census_Data_2001/Census_data_finder/HH_Series/Fuel_used_for_cooking.htm.
 “Source of Drinking Water (Including Availability of Electricity and Latrine),” Census of India, 2001. http://www.censusindia.gov.in/Census_Data_2001/Census_data_finder/HH_Series/Source_of_drinking_water.htm.
 The main page for the Census of India is <http://www.censusindia.gov.in>.
11. The adult literacy rate refers to Indians 15 and over, and comes from the CIA *World Factbook*, derived from the Census of India data:
 “India: People,” *The World Factbook 2009*, Central Intelligence Agency. <https://www.cia.gov/library/publications/the-world-factbook/geos/in.html>.
 The CIA *Factbook* also reports that 70 percent of Indians are 15 or older, and that the total of those “adults” who are women is 391.5 million.
12. The announcement of the original discovery of water molecules on the Moon:
 “NASA Instruments Reveal Water Molecules on Lunar Surface,” Release No. 09–222, NASA, September 24, 2009. http://www.nasa.gov/home/hqnews/2009/sep/HQ_09-222_Moon_Water_Molecules.html.
 Seth Borenstein, “It’s Not Lunacy, Probes Find Water in Moon Dirt,” Associated Press, ABC News, September 23, 2009. <http://abcnews.go.com/Technology/wireStory?id=8655085>.
 The announcement of the discovery of large amounts of ice in Moon craters:
 “NASA Radar Finds Ice Deposits at Moon’s North Pole; Additional Evidence of Water Activity on Moon,” Release No. 10–055, NASA, March 1, 2010. http://www.nasa.gov/home/hqnews/2010/mar/HQ_10-055_moon_ice.html.
 Tariq Malik, “Tons of Ice Found on Moon’s North Pole,” *Florida Today*, March 1, 2010.
 How much ice is there in an iceberg? NASA found “at least” 660 million tons of ice in 40 craters—16.5 million tons per crater.
 NASA says large icebergs have a mass of about 1 million tons.
 “Iceberg,” *World Book at NASA*, NASA. http://www.nasa.gov/worldbook/iceberg_worldbook.html.
 The Geological Survey of Denmark and Greenland says iceberg masses can range much higher, up to 10 million tons or more.
Environmental Oil Spill Sensitivity Atlas for the West Greenland Coastal Zone, Danish Energy Agency, Ministry of Environment and Energy, 2000, pp. 8-46, 8-47 (PDF). http://www.geus.dk/departments/quaternary-marine-geol/oliespild_v_gr/PDFfiles/Chapter8/Chapter8_7.pdf.
13. This sampling of Indian headlines on the water-on-the-Moon discovery:
 “One Big Step for India, Giant Leap for Mankind,” *Times of India*, September 25, 2009. <http://timesofindia.indiatimes.com/india/One-big-step-for-India-a-giant-leap-for-mankind/articleshow/5053202.cms>.
 Full coverage from the *Times of India*:

“Special Coverage: Chandrayaan Finds Water on Moon,” *Times of India*. <http://timesofindia.indiatimes.com/chandrayaan-finds-water-on-moon/specialcoverage/5361062.cms>.

“Water on Moon Is India’s Discovery, Says ISRO Chief,” *Hindustan Times*, September 26, 2009. <http://www.hindustantimes.com/News-Feed/india/Water-on-moon-is-India-s-discovery-says-ISRO-chief/Article1-458154.aspx>.

“It’s the Finding of the Millennium: Nair,” *Times of India*, March 3, 2010. <http://timesofindia.indiatimes.com/india/Its-the-finding-of-the-millennium-Nair/article-show/5635381.cms>.

14. *2007 Benchmarking and Data Book of Water Utilities in India*, Asian Development Bank and the Ministry of Urban Development of the Government of India, p. 3 (PDF). <http://www.adb.org/documents/reports/Benchmarking-DataBook/2007-Indian-Water-Utilities-Data-Book.pdf>.

The ADB *Data Book* sometimes overstates the utilities’ performance. A survey by the Indian magazine *Business Today* in June 2009 found that 49 percent of Bangalore residents don’t receive water even every day—although the *Data Book* says Bangalore offers water service 4.5 hours a day.

“Cover Story: Best Cities to Work, Play and Live: Cities in Numbers,” *Business Today*, June 9, 2009. http://businesstoday.intoday.in/index.php?option=com_content&task=view&id=11649§ionid=22&secid=0&Itemid=1&issueid=1166.

15. “Wipro and Thames Water: Build a Successful Long-Term Relationship,” Wipro, October 1, 2009 (PDF). <http://www.wipro.com/resource-center/library/pdf/wipro-article1.pdf>.
16. The full text of the Indian Supreme Court’s order to the central government to resolve the nation’s water problem “on a war footing” is here:

M. K. Balakrishnan & Others v. Union of India & Others, Supreme Court of India, Civil Original Jurisdiction, “Writ Petition No. 230 of 2001: Order,” April 28, 2009 (PDF). <http://kgfindia.com/judgement-28april09.pdf>.

The order got scant press coverage:

“Supreme Court Attempts to Resolve India’s Water Woes,” *Hindustan Times*, April 28, 2009.

17. The list of prominent Americans who are either Indian or of Indian origin is remarkable for its range of talent:

Film director M. Night Shyamalan, CNN journalist Fareed Zakaria, and conductor Zubin Mehta were all born in India. Indra Nooyi, the CEO of PepsiCo, C. K. Prahalad, the recently deceased Harvard management guru, and Vikram Pandit, the CEO of Citigroup—all also born in India.

Singer Norah Jones, Harvard surgeon and author Atul Gawande, and Amar Bose, founder of the company that makes Bose stereo equipment, are all children of Indian parents—as are six of the last ten U.S. National Spelling Bee champions.

18. The Indian head shake doesn’t mean only “Yes, I agree with you.” The gesture has a wide range of subtlety and interpretation. Kavita Pillay, a filmmaker based in Cambridge, MA, who went to India on a Fulbright scholarship, described it in a piece on World Hum this way:

“In its myriad iterations, the Indian head nod can mean ‘Yes,’ ‘Nice to meet you,’ and ‘I agree to the price you have just mentioned.’ It can also mean ‘Maybe,’ ‘Hell no,’

and 'You are the enemy of intelligence.' Interpreting the meaning requires time, practice, a little self-effacement, and a lot of humor."

Pillay's brief essay is highly entertaining:

Kavita Pillay, "How to Tilt Your Head Like an Indian," *World Hum*, January 30, 2006. http://www.worldhum.com/features/how-to/tilt_your_head_like_an_india_20060128/.

19. *State of Pollution in the Yamuna*, Centre for Science and Environment, May 2009 (PDF). http://www.indiaenvironmentportal.org.in/files/State%20of%20the%20Yamuna_0.pdf.
20. Andrew Buncombe, "Unholy Water: Delhi's Rotting River," *Independent*, May 1, 2008. <http://www.independent.co.uk/news/world/asia/unholy-water-delhis-rotting-river-818774.html>.
 Neha Lalchandani, "Pollution Cloud Looms Over Yamuna," *Times of India*, September 20, 2009. <http://timesofindia.indiatimes.com/news/city/delhi/Pollution-cloud-looms-over-Yamuna/articleshow/5034865.cms>.
21. Figures for the irrigation efficiency of India's farmers range from 25 percent to 40 percent. The 25 to 35 percent range comes from *Looking Back to Change Track*, TERI, p. 56.
22. Citations, in order, for continuous water service in Hanoi, Ho Chi Minh City, Phnom Penh, and Kampala:
 Hanoi: "Base Data of Hanoi Water Business Company," *Benchmarking 2004*, Southeast Asian Water Utilities Network. <http://www.seawun.org/benchmarking/basedata/basedata.asp?sRespondent=Ha%20Noi>.
 Ho Chi Minh City: *Socialist Republic of Viet Nam: Preparing the Ho Chi Minh City Water Supply Project*, Asian Development Bank Technical Assistance report, June 2008, p. 2 (PDF). <http://www.adb.org/Documents/TARs/VIE/41070-VIE-TAR.pdf>.
 Phnom Penh: "Proceedings of the Regional Consultation Workshop on Water in Asian Cities—The Role of Civil Society," *Water for All*, Asian Development Bank, October 14–16, 2002, p. 77 (PDF). http://www.adb.org/documents/books/water_for_all_series/Water_Asian_Cities/Annex.pdf.
 Kampala: *Change Management for Achieving Continuous Water Supply for All in Urban Areas*, Administrative Staff College of India. <http://www.asci.org.in/continuous-water-supply.asp>.
23. The official from the Delhi Jal Board who wrote that when people proposed 24/7 water in India, "we laugh it off as an absurdity," was Ashish Kundra, then additional CEO of the Delhi Jal Board.
 Ashish Kundra, "Water 24X7: Not Just a Pipe Dream," *Indian Express*, April 1, 2006. <http://www.indianexpress.com/news/water-24x7-not-just-a-pipe-dream/1512/0>.
24. The fact that most Indian water utilities do not recover their operating costs from water fees is detailed in *2007 Benchmarking and Data Book of Water Utilities in India*, p. 30. That the Delhi Jal Board's revenue only covers 60 percent of operating costs comes from a World Bank assessment of Delhi's water system from 2006:
 India—Delhi Water Supply and Sewerage Project," Report No. 36065, Project Information Document, World Bank.
25. "Estimated 5-Year Investment Needs in Billions of Dollars," *Report Card for America's Infrastructure*, American Society of Civil Engineers (ASCE). <http://www.infrastructurereportcard.org/report-cards>.

The ASCE also estimates, in the same chart, that of the \$255 billion in water infrastructure needs in the U.S. through 2014, only \$147 billion will be available.

26. The story of the *E. coli* deaths resulting from contaminated tap water in Hyderabad in May 2009 received extensive press coverage:
- “Hyderabad Water Contamination Raises Toll to 9,” Indo-Asian News Service, May 8, 2009. http://www.thaindian.com/newsportal/health1/hyderabad-water-contamination-raises-toll-to-nine_100190025.html.
- “Four Die, 100 Taken Ill after Drinking Contaminated Water in Hyderabad,” Indo-Asian News Service, May 5, 2009. <http://sify.com/news/four-die-100-taken-ill-after-drinking-contaminated-water-in-hyderabad-news-hyderabad-jffvy8jdddej.html>.
- “Four Die, 100 Sick after Drinking Contaminated Water in Hyderabad,” May 5, 2009, Indo-Asian News Service. http://www.thaindian.com/newsportal/health1/four-die-100-sick-after-drinking-contaminated-water-in-hyderabad-lead_100188724.html.
27. Augustin Maria, “Urban Water Crisis in Delhi. Stakeholders Responses and Potential Scenarios of Evolution,” *Idées Pour le Débat*, No. 6, 2008, Paris: Institut du Développement Durable et des Relations Internationales, p. 10 (PDF). http://www.iddri.org/Publications/Collections/Idées-pour-le-debat/Id_0806_Maria_Urban-Crisis-Water-Delhi.pdf.
- Maria’s research concluded that just 43 percent of Delhi’s population lived in settlements where they were entitled to a permanent water connection (p. 10). He also reports that, as of the most recent data he could obtain, from 2004, Delhi had 11,533 public standposts—water spigots (p. 6).
- Maria is now a water economist for the World Bank.
28. For the Census of India, the definition of “away” for purposes of getting water is on this page of charts about “amenities at home”:
- “Availability of Eminities [*sic*] and Assets,” table 16, Census of India, 2001. http://censusindia.gov.in/Census_And_You/availability_of_eminites_and_assets.aspx.
- Within the three distance categories—“within premises,” “near premises,” and “away”—the census asks whether the water comes from a tap, a hand pump, a tube well, a well, or some other source.
- The total number of households in India, and the average household size, are here:
- “Data Highlights,” Census of India, 2001 (PDF). http://censusindia.gov.in/Data_Products/Data_Highlights_Data_Highlights_link/data_highlights_hh1_2_3.pdf.
29. According to 2008 U.S. Census estimates, 177 million people live in the states east of the Mississippi River; 126 million live west of the Mississippi River.
30. There is some dispute about the minimum amount of water each person needs for basic needs. The WHO and UNICEF set 20 liters per day per person as the minimum level necessary for drinking and personal hygiene.
- The UN’s 2006 report *Beyond Scarcity: Power, Poverty and the Global Water Crisis* uses the 50 liters (13 gallons) per person per day standard as a “water poverty line,” as discussed on p. 34 of the report.
- People routinely receiving less than 50 liters per person each day live in “water poverty,” limited in their ability to bathe, cook, and keep their clothes clean. (The report is a PDF file 422 pages long.)
- Human Development Report, 2006: Beyond Scarcity: Power, Poverty and the Global*

Water Crisis, UN Development Programme. <http://hdr.undp.org/en/reports/global/hdr2006/>.

A more passionate discussion, “Diminishing Standards: How Much Water Do People Need?” comes from Les Roberts, an epidemiologist who has worked for the Centers for Disease Control and the International Rescue Committee, and who is now an associate clinical professor of population and family health at Columbia University.

Writing in 1998, Roberts pointed out that at that point the “standards” for basic water requirements were essentially random guesses, not based on any science. One limited study of refugees did find that those with more water had dramatically less diarrhea. Writing about victims of war or natural disaster, Roberts asks rhetorically why bare minimum standards for providing water are often not met. “Unfortunately, the answer will most often be because someone, somewhere, with a flush toilet and hot shower, does not think that the extra investment to provide sufficient water is really worth it.”

Les Roberts, “Diminishing Standards: How Much Water Do People Need?” *Forum: War and Water*, Geneva, 1998: International Committee of the Red Cross. <http://www.icrc.org/Web/eng/siteeng0.nsf/htmlall/57JPL6>.

31. It is a small but irresistible irony: A grown woman can reasonably carry 8 gallons of water (67 pounds). As it happens, that is almost exactly the amount of water that a grown woman’s body contains. Women are 55 percent water by weight, so the body of a 120-pound woman contains 66 pounds of water—8 gallons.
32. One of the most popular grocery store items in the U.S. these days is the 24-pack of half-liter bottles of water, shrink-wrapped into an ungainly block. The package of water weighs 26 pounds.

If you want a feel for carrying your own water, prop it on your head as you leave the grocery, and balance it there as you walk through the parking lot to your car.

The women and girls in Jargali were carrying between 41 pounds and 67 pounds of water on their heads, over the 2 km trip back home from the well.

33. There is very little agreement on the boundaries of the world’s largest metropolitan areas, and so very little consensus on their precise populations and the rankings among them.

One well-regarded source puts the 2010 population of urban Delhi at 23.2 million, ranking it fifth. According to City Population, which includes a list of adjacent areas encompassed in its population calculation, the top 10 metropolitan areas are

1. Tokyo, Japan	34.0 million
2. Guangzhou, China	24.2 million
3. Seoul, South Korea	24.2 million
4. Mexico City, Mexico	23.4 million
5. Delhi, India	23.2 million
6. Mumbai, India	22.8 million
7. New York, U.S.	22.2 million
8. São Paulo, Brazil	20.9 million
9. Manila, Philippines	19.6 million
10. Shanghai, China	18.4 million

Thomas Brinkhoff, “The Principal Agglomerations of the World,” City Population. <http://www.citypopulation.de/world/Agglomerations.html>.

34. Garima Sharma, N. K. Mehra, R. Kumar, “Biodegradation of Wastewater of Najafgarh Drain, Delhi Using Autochthonous Microbial Consortia,” *Journal of Environmental Biology*, October 2002, vol. 23 no. 4, pp. 365–71. <http://www.ncbi.nlm.nih.gov/pubmed/12674375>.
 Sharma et al. report the flow from the first enormous drain into the Yamuna as 1,668 million liters a day—441 million gallons a day, or 1 million gallons every 3.25 minutes.
35. “State of Pollution in the Yamuna,” Centre for Science and Environment, May 2009, p. 8 (PDF). http://indiaenvironmentportal.org.in/files/State%20of%20the%20Yamuno_0.pdf.
 This is a clear explanation of the U.S. EPA *E. coli* standards from the Willamette Riverkeeper:
 “*E. coli* Monitoring,” Willamette Riverkeeper. http://www.willamette-riverkeeper.org/programs/ecoli/e_colimain.htm.
36. The number of buses and auto rickshaws in Delhi comes from a 2007 study of the CNG fuel conversion, for EMBARQ, an NGO focused on environmentally sustainable urban transportation:
 Monica Bansal, “Clean It Up, Don’t Throw It Away: Greening Delhi’s Paratransit,” EMBARQ, World Resources Institute, Washington, DC, 2007 (PDF). http://www.embarq.org/sites/default/files/Monica_Bansal_Delhi_Paratransit.pdf.
 The number of taxis in New York City:
Annual Report 2009, New York City Taxi and Limousine Commission, p. 9 (PDF). http://www.nyc.gov/html/tlc/downloads/pdf/tlc_annual_report_2009.pdf.
37. Vijay Singh, “Top Celebs, VIPs Get Notices from Navi Mumbai Cess Dept.,” *Times of India*, January 25, 2010. <http://timesofindia.indiatimes.com/city/mumbai/Top-celebs-VIPs-get-notices-from-Navi-Mumbai-cess-dept/articleshow/5496470.cms>.

9. IT’S WATER. OF COURSE IT’S FREE

1. Many hotels provide their own house brand of bottled water, as if a half-liter bottle of water with the Ritz-Carlton lion-crest logo on it somehow confers a richer hotel experience, or a richer water experience.
 The most exotic version of this I’ve ever encountered was at the Hilton Hotel in Clear Lake, Texas, down the street from NASA’s Johnson Space Center. Years before water was actually discovered on the Moon, the Hilton was offering “Luna” water, with a crescent moon logo, a beautiful blue glass bottle, and the story of the Clear Lake Hilton on the back. (The hotel’s restaurant is named Luna.) “Luna” water costs \$8 for a one-liter bottle and, as of summer 2010, was still for sale at the Hilton Clear Lake.
2. Starwood Four Points hotels explains free bottled water in hotel rooms here. <http://www.starwoodhotels.com/fourpoints/index.html#/quad1/water/>.
3. The average U.S. monthly water bill—just water, not including sewer service—has been hard to calculate, but the American Water Works Association has used usage and fee surveys to estimate that it is about \$34 per household.
 The average price of 1,000 gallons of tap water for residential customers in the U.S. is \$3.24, according to the 2008 AWWA survey—10 gallons of water costs about 3 cents.

If you flush a 3-gallon-per-flush toilet 100 times, you've used 300 gallons of water—97 cents' worth in the typical U.S. home.

For comparison, if you wanted to flush the toilet once with bottled water, you'd need a full 24-pack of Deer Park half-liters (3 gallons). One flush would cost you at least \$4, as opposed to the single penny a typical flush costs.

Water in other developed countries is more expensive than in the U.S., although still inexpensive compared with either bottled water or, say, cell phone service.

In Sydney, Australia, in the midst of that nation's water crisis, municipal water cost homeowners A\$18.86 (US\$16.97) for 1,000 gallons, five times what it cost in the U.S. A single U.S. penny would still buy four half-liter bottles of water.

In Germany, the average price of water was 6.99 euros (US\$8.92) for 1,000 gallons. A single U.S. penny would buy eight half-liter bottles of water.

Thames Water has 8.5 million water customers, out of a total UK population in 2010 of 61 million people—14 percent of the population. The company posts its average water bills here:

"Our Business: Facts and Figures," Thames Water. <http://www.thameswater.co.uk/cps/rde/xchg/corp/hs.xml/4625.htm>.

4. Municipal water rates are accessible for most places online. You just need to be careful about units of water being measured. Some utilities provide rates per 1,000 gallons; some use cubic feet (1 cubic foot = 7.48 gallons); some use an industry unit, CCF, that is, cost per 100 cubic feet (748 gallons).

All rates are current as of July 1, 2010.

The Las Vegas Valley Water Authority provided the average bill, at \$23.62 per month.

The LVVWA has an online bill calculator that estimates your bill, based on water consumption. http://www.lvvd.com/apps/rate_calculator/index.cfm.

Water rates for Atlanta come from the city of Atlanta's water department Web site, which also includes an online bill calculator. <http://www.atlantawatershed.org/billcalculator>.

The water rates for "suburban Philadelphia" are for my own home in Wyncote, PA, where we are customers of the company Aqua American, and the numbers come from our bills.

5. The Imperial Valley, in Imperial County, is the 11th most productive agricultural producing county in the U.S., and the 10th most productive in California.

2007 Census of Agriculture: County Profile: Imperial County, California. National Agricultural Statistical Service, USDA (PDF). http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/County_Profiles/California/cp06025.pdf.

6. How do we know the water for a 3-pound bag of carrots from the Imperial Valley cost the farmer 1 penny?

The math works like this—references are at the end of the note.

Typical productivity of carrot farmers is 15 tons (30,000 pounds) per acre.

The Imperial Irrigation District reports that the district delivered 2.5 million acre-feet of water to its farmers in 2008, and that the district's farmers irrigate about 430,000 acres of farmland: 6 acre-feet of irrigation water for each acre of farmland.

The IID charges \$19 per acre-foot, so the water for one acre of carrots costs \$114.

Which means that the water to grow 30,000 pounds of carrots costs \$114, which is one penny for three pounds.

Carrot farm productivity:

Joe Nuñez et al., “Carrot Production in California,” *Vegetable Production Series*, UC Vegetable Research & Information Center, p. 1 (PDF). <http://ucanr.org/freepubs/docs/7226.pdf>.

Water per acre in the Imperial Valley:

2005 Annual Water Report, Imperial Irrigation District, p. 32 (PDF). <http://www.iid.com/Media/2005IIDWaterAnnualReport.pdf>.

2008 Annual Report, Imperial Irrigation District, p. 21 (PDF). http://www.iid.com/Media/iid_annual_08_web.pdf.

Water rates in 2010 for Imperial Valley farmers were \$19 an acre-foot. Those rates are set to rise to \$20 an acre-foot in 2011.

7. As noted above, the IID reports that the district delivered 2.5 million acre-feet of water to its farmers in 2008, and that the district’s farmers irrigate about 430,000 acres of farmland: 6 feet of irrigation water for each acre of farmland.

The Southern Nevada Water Authority reports that total water demand for Clark County, Nevada, is 553,000 acre-feet of water.

Water Resource Plan 09, Southern Nevada Water Authority, 2009, p. 41 (PDF). http://www.snwa.com/html/wr_resource_plan.html.

Clark County is 5.1 million acres (8,012 square miles). http://www.accessclarkcounty.com/depts/public_communications/pages/About_clark_county.aspx.

So the county uses 0.1 acre-foot of water per acre of land per year.

The farmland uses 60 times as much water per acre as the resort land does.

8. Total value of agricultural products produced in Imperial County:

2009 Annual Agricultural Crop and Livestock Report for Imperial County Agriculture, Imperial Valley Agricultural Commissioner, June 2010, p. 1 (PDF). <http://imperialcounty.net/ag/Crop%20&%20Livestock%20Reports/Crop%20&%20Livestock%20Report%202009.pdf>.

In 2009, carrots produced for routine consumption (as opposed to for processing into other foods or for feed) were worth \$54.6 million, and Imperial County farmers grew 242 million pounds, three-quarters of a pound of carrots for every person in the country, just from Imperial County (p. 4).

Total gaming revenue in Las Vegas is from the University of Nevada / Las Vegas Center for Business and Economic Research.

“Historical Economic Data for Metropolitan Las Vegas,” Center for Business and Economic Research, University of Nevada, Las Vegas, 2010. <http://cber.unlv.edu/snoutlk.html>.

9. Adam Smith, *The Wealth of Nations*, ed. Edwin Cannan (New York: Modern Library, 1965), p. 28.
10. All the price comparisons for 1912, 1963, and 2010 use the U.S. Bureau of Labor Statistics online comparative “buying power” calculator. <http://data.bls.gov/cgi-bin/cpi/calc.pl>.

The average spending on alcohol in 1960 comes from:

100 Years of U.S. Consumer Spending, 1960–61, U.S. Bureau of Labor Statistics, May 2006, p. 32 (PDF). <http://www.bls.gov/opub/uscs/1960-61.pdf>.

The complete *100 Years of U.S. Consumer Spending* is available here (PDF). <http://www.bls.gov/opub/uscs/report991.pdf>.

The cost of telephone service in 1963 is from:

“Historical Charges for Individual Residence Telephone Service,” Appendix B-5, in *Local Telephone Rates: Issues and Alternatives*, staff working paper, Congressional

Budget Office, January 1984, table B-3 (PDF). <http://www.cbo.gov/ftpdocs/109xx/doc10952/84doc01b.pdf>.

The \$5.65 for a single telephone line in 1963 equates to a cost of \$40 a month today.

11. The Indianapolis resident who said she gets nothing for her water rates is quoted in:

Brendan O'Shaughnessy, "Fountain of Debt May Soak Water Users," *Indianapolis Star*, April 12, 2009.

The Indianapolis resident who said she pays "hellacious water rates" is quoted in:

Brendan O'Shaughnessy, "Bond Woes Could Soak Indy Water Users," *Indianapolis Star*, February 20, 2009.
12. The El Dorado Irrigation District water rate information is from:

El Dorado Irrigation District Proposed Rate Increase—Key Issues, El Dorado Irrigation District, January 2010 (PDF). http://www.eid.org/doc_lib/02_dist_info/2010_rate_increase_fact_sheet.pdf.

John Fraser, "Viewpoints: El Dorado Water Board Trying to Make Up for Past Neglect," *Sacramento Bee*, February 4, 2010. <http://www.sacbee.com/2010/02/04/2511690/el-dorado-water-board-trying.html>.
13. Washington, DC, rate increase information:

"DC WASA Board Approves 2011 Budget, Funding Critical Infrastructure and Environmental Protection," news release, District of Columbia Water and Sewer Authority, February 4, 2010. http://www.dcwasa.com/site_archive/news/press_release_430.cfm.

Charles Duhigg, "Saving U.S. Water and Sewer Systems Would Be Costly," *New York Times*, March 14, 2010. <http://www.nytimes.com/2010/03/15/us/15water.html>.
14. Plato, "Euthydemus," trans. Benjamin Jowett, Project Gutenberg. <http://www.gutenberg.org/files/1598/1598-h/1598-h.htm>.
15. "Household TV Trends Holding Steady: Nielsen's Economic Study 2008," Nielsen-Wire, Nielsen Company, February 24, 2009. http://blog.nielsen.com/nielsenwire/media_entertainment/household-tv-trends-holding-steady-nielsen-s-economic-study-2008/.
16. For those skeptical that it is accepted wisdom that water use is inelastic in terms of price, below is a 2009 study from the California Energy Commission and the California Environmental Protection Agency.

The paper reviews the literature on the impact of price on water consumption, as well as doing its own analysis of California consumption and price data. It has fairly technical math, but here's one summary sentence, p. 4: "Studies of the impact of water price on residential water use suggest that water use is price inelastic . . . that a given percent change in water price elicits a relatively small change in water use."

And on p. 5: "Most studies suggest that water demand is inelastic."

Larry Dale et al., *Price Impact on the Demand for Water and Energy in California Residences*, California Climate Change Center, August 2009. <http://www.energy.ca.gov/2009publications/CEC-500-2009-032/CEC-500-2009-032-F.PDF>.
17. This article in *Water Efficiency*, a trade journal, says that water utilities use 3 percent of the electricity generated in the U.S.:

David Engle, "Controlling the Power," *Water Efficiency*, April 1, 2008, p. 1. <http://www.waterefficiency.net/elements-2009/water-agency-costs.aspx>.

This report from the California Energy Commission says 20 percent of the electricity used in the state goes to move and treat water:

Water Supply-Related Electricity Demand in California, Water and Energy Consulting and the Demand Response Research Center, California Energy Commission, November 2007, p. 3. (PDF). <http://www.energy.ca.gov/2007publications/CEC-500-2007-114/CEC-500-2007-114.PDF>.

The 2007 report below, from the Water Research Foundation, analyzing electricity use by U.S. water utilities, says water utilities are “the largest single user of electricity in the United States” (p. 7).

The report goes on to say that globally, water pumping and treatment consume 3 percent of total electricity generated worldwide; if agricultural uses are included, moving water consumes 7 percent of all electricity generated (p. 8).

Risks and Benefits of Energy Management for Drinking Water Utilities, Water Research Foundation, 2008. <http://www.waterresearchfoundation.org/research/TopicsandProjects/execSum/PDFReports/91200.pdf>.

The total number of power plants in the U.S. is 5,400, of which 3 percent is 162.

Frequently Asked Questions—Electricity, U.S. Energy Information Administration. http://www.eia.doe.gov/ask/electricity_faqs.asp.

18. The water rates for Santa Fe, New Mexico, are here:
 “Rate Schedule 1A,” March 1, 2009, Sangre de Cristo Water Division, City of Santa Fe. <http://www.santafenm.gov/DocumentView.aspx?DID=5269>.
19. Thames Water is in the midst of a major campaign to install water meters, with the goal of having 50 percent of London-area residences on water meters by 2015.
 “Your Water, Your Future,” news release, Thames Water, May 7, 2008. <http://www.thameswater.co.uk/cps/rde/xchg/corp/hs.xsl/6372.htm>.
 The statistic that just 22 percent of properties in Thames Water’s service area have meters comes from here:
 “Lower Charges on the Way for Thousands of Customers,” news release, Thames Water, February 5, 2008. <http://www.thameswater.co.uk/cps/rde/xchg/corp/hs.xsl/4367.htm>.
20. Mike Young has a Web site loaded with links to articles and presentations about water, economics, and his “robust water system.”
 Mike Young and Jim McColl, “Water Droplets.” <http://www.myyoung.net.au/water/index.php>.
 An accessible explanation of his framework for allocating water is:
 Young and McColl, “A Future-Proofed Basin,” University of Adelaide, 2008 (PDF). http://www.myyoung.net.au/water/publications/A_future-proofed_Basin.pdf.
21. This 2010 *New York Times* story says that the flow of the Shatt al Arab is no longer enough to keep out salt water from the Persian Gulf, and that salt water has intruded almost 100 miles upriver from the ocean, devastating everything from fruit groves and fresh-water fisheries to drinking-water supplies.
 Steven Lee Myers, “Vital River Is Withering, and Iraq Has No Answer,” *New York Times*, June 12, 2010. <http://www.nytimes.com/2010/06/13/science/earth/13shatt.htm>.
22. The *Cleveland Plain Dealer*’s coverage of the missing water fountains at the Q Arena is archived here:
 Glenn Baird, “Cleveland Cavaliers Will Reinstall Water Fountains at the Q to Comply With State Building Code,” *Cleveland Plain Dealer*, February 26, 2010. http://blog.cleveland.com/metro/2010/02/cleveland_cavaliers_will_reins.html.

The Cavaliers' statement about the water fountain removal is here:

"Quicken Loans Arena Water Update," Cleveland Cavaliers, NBA.com. http://www.nba.com/cavaliers/news/qarena_100210.html.

The Cavaliers' 2009–2010 schedule, showing 29 home games through the end of February 2010, is here:

"Cavaliers Schedule & Results," Cleveland Cavaliers, NBA.com. <http://www.nba.com/cavaliers/schedule>.

23. The basic calculation for water required to grow food is that 1 calorie of food energy requires 1 liter of water to produce. So a daily 2,000-calorie diet requires 2,000 liters (528 gallons) of water to produce. See this 2007 report on water and food from the International Water Management Institute (p. 5):

David Molden, ed., *Water for Food, Water for Life*, International Water Management Institute, 2007 (PDF). http://www.iwmi.cgiar.org/Assessment/files_new/synthesis/Summary_SynthesisBook.pdf.

10. THE FATE OF WATER

1. It is hard to imagine geysers of water and ice crystals shooting from the surface of a moon with such force that they go out hundreds of miles, straight out into space.

Scientists haven't figured out what is driving the geysers on Enceladus. The moon is just 311 miles in diameter—meaning that the circumference around its equator is 977 miles. The circumference of our own Moon is 6,786 miles; the circumference of Saturn, which Enceladus orbits, is 235,297 miles.

Enceladus, named for one of the giants in Greek mythology, is one of 62 moons of Saturn. For a brief explanation of the jets of water vapor and ice coming off Enceladus, see:

"Enceladus," *About Saturn and Its Moons*, Cassini Equinox Mission, Jet Propulsion Laboratory, NASA. <http://saturn.jpl.nasa.gov/science/moons/enceladus>.

"Jets on Saturn's Moon Enceladus Not Geysers from Underground Ocean, One Group of Researchers Say," *ScienceDaily*, June 24, 2009. <http://www.sciencedaily.com/releases/2009/06/090624152813.htm>.

An image of an ice plume from Enceladus:

"Successful Flight Through Enceladus Plume," *Image of the Day Gallery*, NASA Images. http://www.nasa.gov/multimedia/imagegallery/image_feature_1510a.html.

2. The Burj Khalifa in Dubai is 2,716 feet high.

The Sears Tower, now known officially as the Willis Tower, is 1,450 feet tall, not including its radio masts.

The Empire State Building is 1,250 feet tall, not including its lightning rod.

So together, the Willis Tower and the Empire State Building come to 2,700 feet.

For a graphic comparison of the heights of the tallest buildings in the world, here is the Burj Khalifa's site:

"World's Tallest Towers," Burj Khalifa. <http://www.burjkhalifa.ae/language/en-us/the-tower/worlds-tallest-towers.aspx>.

And this is the list of the world's tallest buildings:

"100 Tallest Completed Buildings in the World," *CTBUH Tall Buildings Database*, Council on Tall Buildings and Urban Habitat. <http://buildingdb.ctbuh.org/>.

Here is the official fact sheet on the fountain:

Fact Sheet—The Dubai Fountain at Downtown Burj Dubai, Souk Al Bahar (PDF). <http://www.soukalbahar.ae/fountain.pdf>.

In terms of cost, Mark Fuller said the fountain cost “about” \$220 million. The creators of the Burj Khalifa said in a press release that the cost was \$218 million.

The Dubai Fountain, Dubai Information Guide. <http://www.dubaifaqs.com/dubai-fountain.php>.

Just for comparison, the cost to build the Empire State Building (in 1930) was \$24.7 million. In 2010, the cost to build the fountain of the world’s tallest building was nearly ten times that amount.

Even adjusting for inflation, the Dubai Fountain is expensive. The \$24.7 million cost of constructing the Empire State Building in 1930 equals \$322 million in 2010.

3. It’s hard to appreciate the scale and wonder of a great fountain from a video, but for a taste, there are videos of many of WET Design’s fountains posted on YouTube, available with a simple search, including videos of the fountains at the Bellagio, at Burj Khalifa, Lincoln Center, and in Branson, Missouri.
4. Mark Fuller holds more than 50 patents on water-related technology, including a patent on the air-powered shooters:

Mark Fuller and Alan Robinson, Air Powered Water Display Nozzle Unit, U.S. Patent No. 5,553,779, September 10, 1996. <http://www.google.com/patents?q=%22mark+fuller%22&btnG=Search+Patents>.

Jim Doyle is typical of the range of talents WET Design has attracted. An experienced special effects designer who is WET’s director of new technology, Doyle won an Academy Award for technical achievement in 1991 for creating a particularly effective fog machine, employing liquid nitrogen, that has been widely used in Hollywood productions, including Michael Jackson’s *Thriller* video.

5. Senator Arlen Specter spoke and took questions at Muhlenberg College on April 3, 2009. A portion of the appearance was uploaded to YouTube, and is available here:
Arlen Specter on Natural Gas Drilling in PA Drinking Water, April 7, 2009. <http://www.youtube.com/watch?v=EhJ90ZqImGY>.
6. In 2009, there were only nine U.S. senators with more seniority than Arlen Specter, six Democrats: Robert Byrd, Daniel Inouye, Patrick Leahy, Max Baucus, Carl Levin, and Christopher Dodd; and four Republicans: Richard Lugar, Orrin Hatch, Thad Cochran, and Chuck Grassley.
7. As detailed in chapter 5, note 22, bottled water is much less closely regulated than tap water.

Briefly, tap water is regulated in the U.S. by the Environmental Protection Agency (EPA), under the Safe Drinking Water Act. Bottled water that crosses state lines is regulated as a food product by the Food and Drug Administration (FDA). And while the FDA has adopted the EPA’s drinking water standards for bottled water, the actual regulation of bottled water amounts mostly to a system of voluntary compliance and trust, because enforcement rules and factory inspections are both minimal.

For additional detail, see chapter 5, note 22, and:

Bottled Water: FDA Safety and Consumer Protections Are Often Less Stringent Than Comparable EPA Protections for Tap Water (GAO-09-610), Government Accountability Office, Washington, D.C.: June 2009 (PDF). <http://www.gao.gov/new.items/d09610.pdf>.

8. “Water Your Body” is from a software company called FoWare. <http://foware.com/water.html>.
9. *Human Development Report, 2006*, UN Development Programme, p. 138. <http://hdr.undp.org/en/reports/global/hdr2006/>.
10. The cost to put 1 pound of cargo into space on the space shuttle is the subject of debate, and depends on how you allocate costs, but in the detailed 2002 study, linked below, from the Futron Corporation, the cost was \$5,000 per pound to low Earth orbit, where the International Space Station flies (\$6,300 in 2010). By that standard, it cost \$41,650 per gallon to get water to the astronauts.
Space Transportation Costs: Trends in Price Per Pound to Orbit, 1990–2000, Futron Corporation, September 6, 2002, p. 3 (PDF). http://www.futron.com/upload/wysiwyg/Resources/Whitepapers/Space_Transportation_Costs_Trends_0902.pdf.
 Detail about the space station’s water recycling system is here:
 “International Space Station: Environmental Control and Life Support System (ECLSS),” NASA Facts, Marshall Space Flight Center, May 2008 (PDF). http://www.nasa.gov/centers/marshall/pdf/104840main_eclss.pdf.
 Seth Borenstein, “Drink Up: Space Station Recycling Urine to Water,” Associated Press, *USAToday*, May 21, 2009. http://www.usatoday.com/tech/science/space/2009-05-21-space-urine_N.htm.
11. Water losses in Italy and the UK:
VEWA Survey: Comparison of European Water and Wastewater Prices, Metropolitan Consulting Group, May 2006, p. 4 (PDF). [http://www.bdew.de/bdew.nsf/id/DE_id100110127_vewa-survey---comparison-of-european-water-and-wastewater-pr/\\$file/0.1_resource_2006_7_14.pdf](http://www.bdew.de/bdew.nsf/id/DE_id100110127_vewa-survey---comparison-of-european-water-and-wastewater-pr/$file/0.1_resource_2006_7_14.pdf).
 Water losses by U.S. utilities from the American Society of Civil Engineers (ASCE):
Drinking Water: Report Card for America’s Infrastructure, ASCE, 2009. <http://www.infrastructurereportcard.org/fact-sheet/drinking-water>.
 Water use by state, from:
Estimated Use of Water in the United States in 2005, USGS, 2009, p. 6 (PDF). <http://pubs.usgs.gov/circ/1344/pdf/c1344.pdf>.
12. *Human Development Report, 2006*, pp. 137–138.
13. It’s hard to get good measures for changes in overall agricultural productivity (as opposed to changes in the productivity of individual crops like corn or cotton or rice). How do you bundle improvements in production of rice with improvements in production of cotton? For purposes of this comparison in the U.S., the agricultural production figures come from the U.S. Bureau of Economic Analysis (BEA), specifically, the BEA’s National Income and Product Accounts, table 7.3.3—Real Farm Sector Output. The chart, which you set up yourself using the BEA’s Interactive Table construction page, shows the total value of U.S. farm output across the years you request, in constant dollars.
 This is the “keyword index” page for National Income account pages, for “F.” <http://www.bea.gov/national/nipaweb/IndexF.htm#F>.
 Under “farm,” table 7.3.3 is real output.
 The main BEA charting page is here. <http://www.bea.gov/national/nipaweb/Index.asp>.

With 2005 as the base year: 2005 = \$100 billion in output. Farm output for 1980 is, comparatively, \$62.2 billion.

So in constant dollars, the value of farm output rose from \$62.2 billion to \$100 billion, an increase of 61 percent.

The total water used for irrigation in the U.S. comes from the USGS's five-year water-use analysis, for 2005 and for 1980, the year irrigation withdrawals peaked.

The main USGS water-use page is here. <http://water.usgs.gov/watuse/>.

Older water-use reports, back to 1950, are accessible here (PDF only). <http://water.usgs.gov/watuse/50years.html>.

Irrigation withdrawals in 1980 were 150 billion gallons per day.

Irrigation withdrawals in 2005 were 128 billion gallons per day.

So farmers used 15 percent less irrigation water in 2005 than in 1980.

Since the dollar-value figures are constant, we can compare the productivity of the water used. One billion gallons of irrigation water a day in 1980 produced \$410 million worth of agricultural products; 1 billion gallons of water a day in 2005 produced \$780 million worth of agricultural products—the same amount of water produced 90 percent more crop, by value.

According to page 8 of the 2007 report *Water for Food, Water for Life*, from the International Water Management Institute, world food prices have fallen almost in half during that same time, so if you measured farm productivity by volume of crops produced, the water productivity of U.S. farms has risen even more dramatically than 90 percent.

14. In the U.S., consumption of carbonated soft drinks is 46 gallons per person, per year, according to 2008 figures from Beverage Marketing. That's 368 sixteen-ounce bottles of soda a year—7 a week for every man, woman, and child in the country. If you didn't drink your 7 bottles of soda last week, well, someone else drank 14.

"Smaller Categories Still Saw Growth as the U.S. Liquid Refreshment Beverage Market Shrank by 2.0% in 2008, Beverage Marketing Corporation Reports," news release, Beverage Marketing Corporation. <http://beveragemarketing.com/?section=pressreleases>.

15. Outdoor water use was put at 58.7 percent by the AWWA study from 2000:

Residential End Uses of Water, 2000, Water Research Foundation, executive summary. <http://www.waterresearchfoundation.org/research/topicsandprojects/execSum/241.aspx>.

Legal issues around use of gray water are discussed here:

R. Waskom and J. Kallenberger, *Graywater Reuse and Rainwater Harvesting*, Colorado State University, Extension, Natural Resource Publications, No. 6.702. <http://www.ext.colostate.edu/pubs/natres/06702.html>.

Guidelines for Water Reuse, U.S. EPA, September 2004. <http://www.ehproject.org/PDF/ehkm/water-reuse2004.pdf>.

16. Orange County, Florida, water rules were described to me by Bill Hurley, manager of Orange County's water reclamation division. They are detailed here:

Water Reclamation (Utilities), Orange County Government, Florida. <http://www.orangecountyfl.net/YourLocalGovernment/CountyDepartments/Utilities/WaterReclamationDivisionUtilities/tabid/656/Default.aspx>.

Orange County has a brochure for homeowners about use of treated wastewater here:

Reuse: Orange County's Reclaimed Water Program, A Customer's Guide, Orange

County Utilities (PDF). <http://www.orangecountyfl.net/Portals/0/Resources/Internet/DEPARTMENTS/Utilities/docs/ReuseBrochure.pdf>.

Orange County's water-use figures come from the county Web site, here (adjusted for daily use):

Utilities Department Statistics, Orange County Government, Florida. <http://www.orangecountyfl.net/YourLocalGovernment/CountyDepartments/Utilities/Statistics.aspx>.

17. National housing data are available from the Department of Housing and Urban Development:

“U.S. Housing Market Conditions,” U.S. Department of Housing and Urban Development. <http://www.huduser.org/portal/periodicals/ushmc.html>.

Historical home construction and sales data for the nation, through 2009, is in this compilation of statistics. Total new home sales, by year, are on p. 24:

“Exhibit 6: New Single-Family Home Sales: 1970–Present,” *Historical Data*, U.S. HUD, p. 69 (PDF). http://www.huduser.org/portal/periodicals/ushmc/spring10/hist_data.pdf.

In the same 10 years, from 2000 to 2009, 2.75 million apartment units were finished in buildings with five units or more (p. 75). Apartment buildings are easier to double-pipe than single-family homes, if only because of the density.
18. Smoking was banned by the FAA on U.S. flights of two hours or less on April 23, 1988.

“Smokefree Transportation Chronology,” Americans for Nonsmokers' Rights. <http://no-smoke.org/document.php?id=334>.
19. *2010 Corporate Social Responsibility Report*, Campbell Soup Company, 2010, p. 20. <http://www.campbellsoupcompany.com/csr/>.
20. Felix Franks, ed., *Water: A Comprehensive Treatise* (New York: Plenum, 1972).

Leland C. Allen, “Physical Chemistry of Water,” *Science*, vol. 184, April 1974, p. 152.
21. Bushkill Falls is owned by the Peters family, the descendants of Charles E. Peters, who bought the land and opened the falls to the public in 1904. The family refers to it as “the Niagara of Pennsylvania,” and the waterfalls are spectacular, although the flow is intimate compared to the majesty of Niagara.

The facility has predictably kitschy gift shops and exhibits, but the park itself, with miles of hiking trails, is immaculately maintained. It is open from late March to late November, depending on the weather and the condition of the footpaths and trails.

Admission is \$10 for adults and \$6 for children. <http://www.visitbushkillfalls.com>.