ogists call the "Ideomotor Effect," unconscious motion that is consistent with the person's expectations.

While many adherents swear to dowsing's effectiveness, scientific studies have yet to confirm this. In a comprehensive and clever experiment in Germany, researchers buried a plastic pipe a foot and a half below the ground. With the flick of a switch they could turn on the flow of water through the pipe. Dowsers were shown the location of the pipes and asked to determine whether water was flowing. Thirty dowsers from Germany, Denmark, Austria and France volunteered to participate. For the first ten tests, they were told the water was flowing and asked to confirm this. The control was important because it provided a baseline and ensured there were no "anomalies" in the landscape that might disrupt the dowsers' detection ability. All the dowsers agreed that water was, in fact, both present and flowing. This was followed by three days of tests when the water flow was turned on and off based on a random pattern. The dowsers' predictions matched what would be expected by pure chance. Other studies have reached similar results.

As the famed skeptic, James Randi, observed, "It is perhaps significant that the German word for the dowsing rod is *Wünschelrute*, which translates as 'wishing stick.'"

8
Finding Water for the Twenty-first Century

A dead Prime Minister.
A country in turmoil.
A battle for Canada's most precious resource—water.

On the eve of testy discussions with the U.S. Secretary of State, Prime Minister Matthew McLaughlin is killed in an accident. His son, Tom McLaughlin, returns to Canada to attend his father's funeral where he delivers a eulogy that stirs the public and propels him into politics and ultimately the Prime Minister's office. The investigation into his father's death, however, reveals that it was no accident, raising the possibility of assassination. The trail of evidence triggers a series of events that uncovers a shocking plot to sell one of Canada's most valuable resources—water.

THUS READ THE PUBLICITY MATERIALS HYPING H_2O, one of the top dramas on Canadian television in 2004. It leaves out the most exciting part, where American troops invade Canada to plunder their water supply. The two-part miniseries, produced by the Canadian Broadcasting Corporation, was nominated for a series of awards and won a Golden Nymph for Best Actor. A son succeeding his father as prime minister seems plausible enough, but would anyone really care enough about Canada's water to assassinate its head of state? Would the United States really invade its neighbor to the north for water? From the high ratings, the Canadian public seemed to think so, and with some justification. At the time, the country was embroiled in a contentious national debate over plans to sell and ship off water from the Great Lakes.

The Great Lakes come by the name honestly. They are the largest bodies of freshwater on the planet, comprising about 20 percent of the total accessible water (most freshwater is locked in glaciers and icebergs, but more on that later). Given so much water for the taking, there has been a series of proposals over the past fifty years to transport water from the Great Lakes to Texas, Las Vegas, Phoenix, and other water-scarce regions. None of these previous proposals have gone very far, though, either because of the sheer costs involved or political opposition. None have gotten very much public attention, either.

That all changed in 1998 with a permit application by a company called the Nova Group to the Ontario Ministry of the Environment. Nova requested a five-year permit to fill up to six hundred million liters of water from Lake Superior in tankers. These ships would then transport the water to Asian markets where freshwater is scarce. The business concept seemed a clever way to satisfy the increasing global demand for clean drinking water. In concept, it was little different than shipping grain from Alberta, timber from British Columbia, or oil from the tar sands of Athabasca—moving a scarce commodity from its point of origin in Canada to a foreign market.

While six hundred million liters sounds like a lot of water, keep in mind that Lake Superior, the world's largest freshwater lake, holds roughly twelve thousand cubic kilometers of water. Nova's permit allowed the company to withdraw one five-hundred-millionth of the lake's volume. That's pretty small by any measure. The ministry granted the permit with little fanfare or concern. When the deal became public, officials were in for a surprise.

The public reaction was swift and harsh on both sides of the border. Opposition arose primarily over the treatment of water as a commodity. Maude Barlow, the Canadian campaigner for a human right to water and chair of the Council of Canadians, warned that Canada would lose control of its resources: "Once the tap is turned on, we can't turn it off." While there are no cases on point, she cautioned that international trade agreements such as the North American Free Trade Agreement (NAFTA) and the General Agreements on Tariffs and Trade (GATT) would leave Canada powerless to restrict bulk water exports if water were viewed as a commodity under trade law.

Part of the opposition to bulk transfers of Great Lakes water has been proprietary on both sides of the border—it's ours and you're not going to get any. Having seen too many of their jobs, population, and prosperity move South and West, America's Rust Belt states were not feeling generous, either. As the governor of Illinois, Jim Thompson, declared, "There has been no effort by Sun Belters to give up their climate or by California to give up its redwoods. That's all right. We don't want that. But fair is fair, and Great Lakes water is not available for export." Highway billboards put up by Citizens for Michigan's Future, a nonprofit group formed to oppose diversions, put it simply. Showing caricatures of a Texas cowboy, a California surfer, and a Utah skier drinking with straws from a trough in the shape of the Great Lakes, the billboard's message read, "Back off Suckers. Water Diversion . . . The Last Straw." North of the border, some of the opposition, and certainly the driving force behind the television series *H_2O*, was latent anti-Americanism.

Concerns were also raised over the environmental impacts by continuous withdrawal from lakes that had been formed by glacier and slowly replenished. Lake Superior's level has fallen to the lowest levels since measurements were first taken in 1918. Other opponents claimed that the use of Great Lakes water was unworthy. As one critic wrote, "California suburbs also use taxpayer-subsidized water to create gardens that would be the envy of gardeners in rain-soaked England—while living in an area that receives forty centimeters of rain a year. . . . Canada has no interest in feeding this wasteful and inappropriate consumption of water." Another argued that "water shipped halfway around the world will only be affordable to the privileged and will deepen inequities between rich and poor. International trade in bulk water will allow elites to assure the quality of their own drinking water supplies, while permitting them to ignore the pollution of their local waters and the waste of their water management systems."

While overwhelming, opposition to bulk transfers was not unanimous. Supporters pointed out that freshwater was a valuable commodity and Canada should take advantage of its natural good luck just as it had with timber, oil, and other resources. And echoing the plot of the H_2O television series, the cover story in the popular magazine *Maclean's* argued Canada should "sell them our water before they take it."

There was also a good deal of hypocrisy about the sanctity of Great Lakes water at play, though few wanted to hear about it. The Nova Group received a permit to withdraw six hundred million liters over five years. Consider, however, that Toronto withdraws 1.7 billion liters *every day* from Lake Ontario for its use. Chicago withdraws even more from Lake Michigan, more than two billion gallons of water a day, and transfers it into a shipping channel that flows into the Mississippi River. Allegedly this would fill a tanker every two hours. Nor does this include the billions of liters that are diverted from the lake for agricultural use. In the public drama playing out in the media, the Nova Group was the bad guy, threatening the future of the lakes. Local use—orders of magnitude greater and happening right now by cities and farmers bordering the Great Lakes—was scarcely mentioned. As *Maclean's* columnist Steve Maich wrote, "If it's okay to use water to irrigate crops that are then shipped across national borders; if it's okay to bottle millions of litres a year for sale in corner stores around the world; if it's okay to divert water to make steel or refine oil that is then shipped across national borders, then why not the water itself?"

The Nova Group was as surprised as anyone. This was no sophisticated multinational. The company shared an office with an accounting firm above a hairdresser. Trying to respond to the media and political onslaught, the company issued an apologetic PR statement explaining that "what started to be a simple idea to help Third World Asian countries in need of freshwater and in turn possibly help the economic climate in northern Ontario has turned into an international incident. That was not our intention." Not surprisingly, the Nova Group never shipped any water.

Just as we saw with the battle over Nestlé's bottling plans in

McCloud, commercialization of drinking water provokes strong reactions. The furor over the very idea of shipping a negligible amount of water from the Great Lakes laid bare a tender and angry range of concerns—from fear of privatization of water and environmental harm to resentment over other regions squandering their treasured local water. It catalyzed a broad public debate on both sides of the border over whether Great Lakes water should be exported to thirsty markets at all.

Responding to the public's opposition, governors of the eight Great Lakes states, from New York across to Minnesota, joined with the premiers of Ontario and Quebec to announce a ban on large-scale water transfers. Legislation passed by Congress now permits the governor of any Great Lake state to veto a water diversion for use outside of the basin. Canadian law similarly prohibits water diversions outside of the boundary water basins. Amendments to the international Great Lakes–St. Lawrence River Basin Water Resources Compact reinforced these national laws. The net result makes it virtually impossible for a business to ship large amounts of Great Lakes water outside of the watershed. The legal obstacles created to block transfers, however, include an interesting loophole. There is no restriction on the transport of water in containers of twenty liters (5.7 gallons) or less for human consumption. Either politicians or lobbyists, or likely both, were unwilling to shut down the potential bottled water market for Great Lakes water. The danger of depleting the Great Lakes one bottle at a time seems not to have been a concern.

Patricia Mulroy, the general manager for the Las Vegas Valley Water District and the Southern Nevada Water Authority, has earned an international reputation for the innovative and tough water conservation measures she has put in place for one of the fastest-growing and most arid cities in the United States. She has little patience for the Great Lakes saga. "We take gold, we take oil, we take uranium, we take natural gas from Texas to the rest of the country. We move oil from Alaska to Mexico. But they say, 'I will not give you one drop of water!' . . . They've got 14 percent of the population of the United States, and 20 percent of the freshwater in the world—and no one can use it but them? 'I might not need it. But I'm not sharing it!' When did it become *their* water anyway? It's nuts!" Or maybe not. Mulroy, who has seen more than her share of political grandstanding, describes the core problem bluntly: "Nothing makes better cheap politics than water."

AS THE PREVIOUS CHAPTERS HAVE MADE CLEAR, MANY PARTS OF THE world are getting thirsty. Access to reliable, clean drinking water is no longer a given in some places and has never been an easy option in others, where assuring water to drink remains a daily challenge. Even for those with currently adequate supplies, access to safe drinking water will only become more difficult as climate change increases the incidence of droughts, pollution despoils existing supplies, and population growth increases demand. These regions, encompassing most of the global population, will need to increase their supplies of safe drinking water. To call this a critical challenge to humanity's future is no exaggeration.

In some respects, the challenge is quite straightforward. There is no "new water" to create. Our planet's atmosphere traps our moisture, so the water we can draw from is fixed. It's the same water that the dinosaurs drank, the same as the primordial soup that served as the incubator for the emergence of life on earth. Given that, there are two basic strategies to provide more drinking water. The first is to move it from water-rich to water-scarce regions. Think tankers full of Great Lakes water plowing the seas toward the Middle East or icebergs towed from the poles. The second strategy relies on generating new supplies of water locally. Think desalination plants or so-called "toilet-to-tap" efforts—capturing, treating, and distributing sewage water.

The rest of this chapter reviews the impressive range of technologies and approaches in use and under development around the globe to increase supplies of drinking water. Some are dizzyingly high-tech, some brilliantly low-tech. As you read about these, imagine yourself as a venture capitalist. Which business opportunities would you invest in? No less a business authority than the *Wall Street Journal* has proclaimed water as the twenty-first century's equivalent of oil. There is a lot of money to be made, as well as lost, and some very clever people are in on the game.

DESPITE THE ACRIMONY AND SHUTTING DOWN OF WATER SALES FROM the Great Lakes, bulk water transfers are already happening in many parts of the world. Take Barcelona, for example. In 2008, while suffering its worst drought in sixty years, the city began shipping water from the nearby Spanish city of Tarragona and the French port of Marseille in tankers. Six ships per month delivered more than four hundred million gallons of freshwater. The cost per gallon was more than three times higher than that of regular water. The city paid, but is now building a major desalination plant. Israel has entered into an agreement with Turkey for the shipment of fifty billion liters annually from the Manavgat River. Greece and Cyprus routinely import freshwater, as well. Most of the water is shipped in tankers, just like any other liquid commodity. Aquarius Water Transportation, a company supplying far-flung Greek isles, however, tows massive bladders—gigantic rubber bags as long as a football field—behind a ship. Because freshwater is less dense than salt water, the bags float just beneath the surface.

The bulk water market is still relatively small, but many observers think it will increase significantly in the coming decades. Paul Muldoon, executive director of the Canadian Environmental Law Association, uses an intriguing analogy. While it may not make financial sense to move water around the world today, "it's a little like buying a McDonald's restaurant in 1963. Who would have ever thought you'd want to get a drive-through hamburger, but look at the way things are now." Climate models predict that much of the American South and Southwest will continue to suffer periodic droughts, even in states we normally think of as water-rich such as Alabama and Florida. The billionaire T. Boone Pickens needs no convincing. He bought more than $100 million in water rights in Texas and plans to build a two-hundred-fifty-mile pipeline to Dallas, where he will supply the expanding municipality. Dallas says the price is too high at the moment, but Pickens believes time is on his side.

An idea that has no doubt occurred to any entrepreneur clinking ice in a glass on a hot day is towing icebergs. Icebergs float free for the taking near the poles, filled with nothing but clean water. The only trick is getting them from their cold waters of origin to distant ports where they can be used. There have been serious proposals to tow icebergs since at least the 1950s.

The idea is far from crazy, except that pushing makes more sense than towing. Tugboats push massive ships every day in harbors around the world. Indeed, in the North Sea they already push icebergs away from oil platforms. Strong currents flow from both the North and South poles toward the Equator, so most of the navigational force could be supplied by the oceans themselves. Just look at the icebergs from the Arctic that are sometimes carried deep into the Atlantic Ocean, as the passengers on the doomed *Titanic* learned to their dismay.

We don't see an iceberg moving industry, though, so there are obviously some problems in the way. One concerns melting. Ocean water temperatures increase significantly between the poles and the equatorial regions, as much as 20 to 30 degrees Celsius. Moreover, the iceberg must traverse the high waves and occasional storms of the open ocean, either of which could put pressure on fissures within the iceberg, causing it to break into smaller pieces. A tug can only push one piece at a time, so everything calving off would be left to melt in the open water. Since, as we all have been told, only the tip of the iceberg rides above the water, running aground is also a significant challenge. Moving the iceberg into a shallow port where it could be broken apart and placed in tanks to melt could prove difficult.

Nonetheless, entrepreneurs continue to push the idea. As Georges Mougin, an enthusiastic iceberg proponent, explains, "An iceberg is a floating reservoir. And water from icebergs is the purest water. It was formed some 10,000 years ago."A sophisticated computer analysis Mougin developed with the aeronautics firm Dassault calculated that a tugboat pushing an iceberg at one knot per hour could, with favorable currents, move a seven-million-ton iceberg from Greenland to the Canary Islands in 141 days, losing just 38 percent of the bulk en route. This would still leave close to four million tons of frozen water for local use.

Otto Spork sought to avoid the challenges of ocean transport by investing in glaciers, instead. Chief executive of the hedge fund Sextant Capital Management, Spork was confident in his business plan. "Two years ago," he explained, "we were looking for the next big commodity and settled on water. It was underappreciated, mispriced, and growing scarce." Spork purchased water rights to three glaciers in northern Europe. Located near ports for transportation ease, he planned to use the melt from one glacier for bottled water and the other two for bulk transport by tankers and water bladders. We will never know if his plan would have worked, however, since Spork and Sextant were found guilty of fraud by the Ontario Securities Commission in 2011.

While attractive in concept, moving water large distances in tankers or frozen in icebergs remains a niche market. The more important strategy to increase sources of freshwater is creating drinking water where we already are. Entrepreneurs and engineers are combining forces to create some exciting technologies. Few of these are likely to become commercially viable, but they give a glimpse of future directions.

While a high-cost and high-tech approach, desalination holds great promise in converting plentiful ocean and brackish water into freshwater. There are a range of desalination processes currently in use. Reverse osmosis forces salt water at high pressure through a series of membranes that filter the salts out. Passing the water through a second set of finer membranes provides an even fresher water. In a sense, this is learning from nature, for the process of natural selection perfected a process for removing salts from ocean water in the evolution of species as varied as albatross and mangroves.

In distillation, salt water is heated and water vapor rises until it meets a cold surface, condensing into drops of freshwater. You may recognize this as the basis of the natural water cycle. Rather than the sun, clouds, and rain, however, distillation plants rely on industrial boiling and cooling equipment.

The benefits of desalination are indisputable. A secure source of clean water is assured from a virtually limitless supply. There are more than twelve thousand desalination plants in more than one hundred twenty countries. The Middle East accounts for almost three-quarters of global production, most notably in the oil-rich nations of Saudi Arabia, the United Arab Emirates, Qatar, and Bahrain. Israel, Malta, and the Maldives also rely heavily on desalinated water. The United States has more than two thousand desalination plants. The cities of El Paso, which relies on desalination for one-quarter of its water, and Tampa are the major adopters. Barcelona, Sydney, Algiers, and even London are constructing or have recently opened major plants.

Despite such widespread adoption, however, desalination remains a small player at the global level, accounting for less than one percent of total water consumption. Much of this is due to the lower cost of alternative surface and groundwater sources in most places. Desalination is expensive no matter how you do it. Energy and construction costs are high, making the water as much as ten times more expensive than many surface or groundwater supplies. The Saudi Arabian plant at Shoaiba produces a massive 450 million liters a day but cost more than $1 billion to construct.

Desalination also imposes high operating costs. Heating the water or forcing it through filters takes a lot of energy. Most desalination plants rely on coal- or oil-fired power plants, and the greenhouse gases emitted, unfortunately, contribute to climate change. As a result, there is increasing interest in renewable energy. The desalination plant in Perth, Australia, is partly powered by the Emu Downs Wind Farm. The plant in Sydney offsets its energy use with renewable power from an inland wind farm. Delft University in the Netherlands has a project underway that couples a small desalination plant with an on-site windmill. With the catchy title "Drinking with the Wind," the combined operation can provide enough water for five hundred families. While wind holds promise as a means to reduce desalination plants' contribution to climate change, the more common non–fossil fuel energy source is nuclear. India, Japan, Russia, and other countries rely on nuclear power both on the land and at sea to power their desalination plants. A U.S. Navy aircraft carrier uses its nuclear reactor to provide desalinated drinking water to the small city aboard—up to four hundred thousand gallons per day.

Even if the energy source does not generate greenhouse gases, desalination creates a serious waste stream. Ocean water obviously contains a much higher concentration of salt than freshwater. The waste product resulting from desalination, called brine, is even more saline and is produced in large quantities. For every hundred gallons of water treated in a reverse osmosis plant, as much as fifty to eighty-five gallons will be discharged as brine. The Environmental Protection Agency treats brine as a waste regulated under the Clean Water Act. Simply discharging brine into the ocean can cause significant harm to the local marine environment. Because brine is denser than seawater, it tends to sink to the ocean bed, killing filter-feeding animals such as coral and the nonmobile eggs and juveniles of other species at the sea bottom. This is an even greater problem in semi-enclosed areas such as bays and estuaries, where water does not easily mix. As a result, some desalination plants have long pipes that discharge the brine far offshore, often using multiple branches to diffuse the discharge over a larger area.

Despite the high start-up costs, entrepreneurs are entering the desalination market. The strategy of the start-up Water Standard is to rely on desalination plants in retrofitted tankers. These ships, part of the company's H2Ocean product line, will be moored far enough offshore to avoid the environmental problems from discharging brine but close enough that transporting the freshwater to the shore via pipe or ship is practical. The company envisions producing up to seventy-five million gallons of freshwater a day. Venture capitalists clearly think there is money to be made, and have provided $250 million in funding to get the business going.

Despite its financial and environmental costs, whether powered by fossil fuels, wind, or nuclear power, desalination seems certain to become a more significant source of drinking water in the coming decades. Given the likelihood of prolonged droughts from climate change, the prospect of turning salt water into clean freshwater cannot help but be an obvious option as cities seek new sources to satisfy their growing populations. Over time, technology will continue to develop and the problems of high energy use and brine discharge may well become less significant. Desalination is not, however, a silver bullet. Because water is expensive to move across land in large quantities, particularly uphill, cities far from the coast or at high elevations will not find the technology helpful because of its high costs. Nor, of course, will poor communities unable to afford the high capital and energy costs. Peter Gleick, the noted water authority, projects that desalinated water will supply no more than 0.3 percent of the United States' water supply.

As with any market, the future for projects providing large amounts of water, whether tankers or desalination plants, depends, of course, on supply and demand. But there are other factors to consider. How expensive is it to obtain the clean water? How much does it cost to move the water from its origin to the site of consumption? And, critically, what is the city's marginal cost of supply? This last point is subtle but important. The challenge facing local government is not simply how to get water in times of drought but the most efficient way to do so. Every city has a drinking water supply system in place that provides the bulk of the water consumed. The question is how much an additional gallon of water will cost *on top* of what the system already produces. If the system generally provides enough water and extra supplies are only needed sporadically, then an expensive, temporary strategy such as tankers may be appropriate. While costly on its face, transporting water by tankers or giant bladders is considerably less expensive than installing large pipelines. If, by contrast, a steady shortfall in water supply is likely, then more capital-intensive approaches such as pipelines or even a desalination plant with much higher up-front costs that will take decades to pay off may prove a wiser long-term financial investment.

There is a trade-off between water volume and infrastructure cost. Water from a tanker may feel expensive compared to the normal cost of water but prove far less expensive for three months' supply than paying for a permanent desalination plant or miles and miles of pipes to a distant source, not to mention buying rights-of-way through private land. For an additional supply extending two or three decades, though, tankers may prove much more expensive. It all depends on how often the current system will prove inadequate and how much additional water is needed.

The other basic problem faced by water entrepreneurs is that they are not playing on a level field. They know how much it costs per gallon of freshwater to tow an iceberg or sail a tanker but, in the absence of a drought or dire situation where a city will pay almost regardless of the price, they have to match or beat the current cost of water. Unfortunately for them, urban water is not generally subject to market forces. In most cases, both the water and infrastructure are owned by the government. Even when private providers are allowed, the rates are often regulated. The net result is, more times than not, a subsidized good. There are arguments why governments may want to ensure that water is inexpensive, but make no mistake. It provides a strong disincentive for the development of additional sources by entrepreneurs who simply cannot compete on price. Because of this, much of the entrepreneurial energy has focused on emerging technologies for smaller scale supply.

The military is a good place to start. Since the time of the Roman legions and well before, every army on the move has sought to improve its logistical efficiency. Safe drinking water is critical to battle success. Generals from Vegetius to Rommel have emphasized that dangers to troops from dysentery and diarrhea can be as harmful as battlefield casualties. If safe water can be provided locally, all the better, since it avoids the costs of transport. A current initiative under development with the U.S. Department of Defense is capillary condensation. This technology captures the water vapor from burning diesel fuel. Basic chemistry suggests that one could capture one gallon of water from one gallon of diesel fuel burned.

On a smaller scale, the LifeStraw is a simple device intended for individual use to purify drinking water. About a foot long and easily hung from the neck, the plastic casing encloses filter membranes. The only energy needed is from a person who literally sucks through the straw, drawing water through the pores and filtering out bacteria and parasites. Designed to treat a thousand liters, roughly the amount a person drinks in a year, the LifeStraw costs only two to three dollars. There are reports on the web that U.S. troops use LifeStraws to drink from puddles.

Another new technology known as WaterMill produces drinking water from humidity in the air. The machine uses the dew point to create condensation, which then drips into a holding container. The manufacturer claims that the technology can turn outdoor air into approximately thirteen quarts of drinking water every day. To prevent contamination, the machine uses ultraviolet light to sterilize the water collected. Larger atmospheric water generators, such as the Air Water machine, can produce much greater volumes of water. Following the 2004 tsunami in Thailand and Sri Lanka, thirteen 3.5-ton water generators, each the size of a small trailer, were deployed. These large machines have also been used by the U.S. Marines, Indian border police, and South African military.

The PlayPump technology offers a seemingly clever approach to providing drinking water in poor rural areas. Created by a billboard executive from South Africa in the 1990s, the basic idea was to connect a spinning merry-go-round to a borehole. Playing children would provide the power to pump clean groundwater to a 2,500-liter holding tank seven meters above the playground. To create a revenue stream, the tank was enclosed within four billboards that could be leased for advertising space.

The simplicity of pumping clean water through kids having fun on the playground rather than working hard at a hand pump seemed a brilliant inspiration and generated great enthusiasm. It was awarded the World Bank's Development Marketplace Award in 2000. A few years later, First Lady Laura Bush announced funding of $16 million from the U.S. Agency for International Development and other donors, with the goal of raising $45 million more to build four thousand pumps in Africa by 2010. The rapper Jay-Z promoted the initiative in concerts and an MTV documentary.

What looks great on the drawing board, though, often faces unanticipated challenges when tested in the field. Following the

installation of several PlayPumps, the initial enthusiasm was doused with the cold water of reality. The well-known development group WaterAid chose not to adopt the PlayPump technology in its projects. Concerns ranged from high installation costs (roughly four times the costs of the alternative hand pump system) and difficulty in finding spare parts locally to a complex design that made local maintenance impractical. A more emotional charge claimed that the amount of pumping necessary to provide sufficient water for a community would require a great deal more power than could be provided by occasional playing, not to mention the fact that children might not want to play when water was most needed, such as during a hot drought. The implication was that "child labor" might be a more appropriate description than "child's play." Moreover, it is hard to imagine much of a revenue stream for billboards in poor, rural areas. As one blogger with development experience observed, "Each time I've visited a PlayPump, I've always found the same scene: a group of women and children struggling to spin it by hand so they can draw water."

REUSING WASTEWATER HOLDS TREMENDOUS POTENTIAL TO FORESTALL expensive alternative supplies of water both on Earth and in space. In May 2009, astronauts aboard the International Space Station first drank water recycled from their own urine. Seeking to celebrate the moment, the astronauts toasted to their own pee, "clinking" the water bags. The American astronaut Michael Barratt claimed "the taste is great. . . . We're going to be drinking yesterday's coffee frequently up here, and happy to do it." Not quite as catchy as Neil Armstrong's "One small step for man, one giant step for mankind," but a nice try. The processor is housed in a space toilet purchased from Russia, which passes urine into an American-made filter. Solid waste in the urine is separated out and stored to be sent back to Earth. This process can recycle 93 percent of the water it receives and reduces the fuel needed to transport the heavy liquid from Earth to space. This source of additional water also increases the number of astronauts the space station can support.

While the space station relies on a distinctly high-tech approach, recycling our sewage is not difficult to do. With enough filters, ultraviolet radiation, and other standard treatment technologies, we can take virtually any polluted water source and produce clean drinking water. Indeed, we already do. While not something most people dwell on, it's a fact that our water treatment plants deal every day with excrement from animals that live beside the rivers and reservoirs where we store our water, not to mention oil leaked on driveways, lawn fertilizer, and other gunk that washes off our streets and drains into water bodies. Where water is scarce, why not capture, treat, and reuse what we flush down our drains? Is it really much dirtier than water we already treat before piping it to our water mains and faucets? If it's good enough for astronauts, it should be good enough for us.

While it might make perfect sense to an engineer, chemist, or economist, selling the idea of "toilet-to-tap" to the general public has proven far more challenging. The basic problem is that it just feels gross. Experts in the field describe this as "the yuck factor." As Charles Fishman has memorably described, "The condoms flushed away, the stagnant water from the vase of roses that stayed too long, the washing machine water from the dog's bath towels, the sour milk poured down the kitchen drain, the deceased goldfish given a toilet-bowl funeral—you can clean all that out of the water, no problem. But no matter how crystalline the water itself, you can't filter away the images of where it comes from."

There are a few places where recycling wastewater has become an accepted, standard practice, including Windhoek, Namibia, and affluent Fairfax, Virginia, near Washington, D.C., where treated sewage makes up about 5 percent of the drinking water. Orange County, California, started reusing sewage water in the 1970s and now relies on this source for 20 percent of its water needs. To address the yuck factor, treated water is pumped into an underground aquifer where it is later extracted as groundwater. As the water percolates through the soil, it is further cleansed by microorganisms and the water's "origin" is scrubbed from the public's consciousness, as well.

The most ambitious use of toilet-to-tap is occurring in Singapore. Branded "NEWater," the reuse strategy is justified in terms of national security. A tiny country at the tip of Malaysia, Singapore has few natural resources and has traditionally relied on Malaysia for most of its drinking water. As twenty-year-old student Khaiting Tan explains, "In the past, we had to get water from another country, but what happens if the ties between the two countries are jeopardized? It's better to be self-reliant." The treated water currently meets about one-third of Singapore's daily water needs and the goal is to meet 50 percent over time. A public education initiative explains where the water comes from, why the strategy is necessary, and that the water is, in fact, cleaner than most piped water. Two remarkable statistics show just how accepted this initiative has become—more than eight hundred thousand people have visited the wastewater purification visitor's center and nineteen million bottles of NEWater have been distributed to athletic groups and at community events.

Singapore's experience proves that toilet-to-tap is clearly a viable strategy, but proof of concept has not assured acceptance in other parts of the world. Singapore, after all, is famous (notorious in some circles) for banning the sale of chewing of gum since 1992. The town of Toowoomba in Queensland, Australia, provides a cautionary tale in this regard. In the grips of a serious drought, the city council proposed treating and reusing the town's wastewater. Rival groups soon sprang up to press the contentious debate on both sides of the issue. The Toowoomba Water Futures Project (with the motto "Keep our future flowing") faced off against the memorably named Citizens Against Drinking Sewage. Charges flew back and forth ("sewage sippers" was one of the more memorable epithets). Despite the longstanding drought, the proposal to drink treated sewage water was soundly defeated in a referendum, 62 percent to 38 percent. They ended up building a much more expensive pipeline.

Despite the experience of nearby Orange County, in the face of heated opposition, San Diego's city council voted in 1999 to halt its recycled water project. The local paper, the *San Diego Union-*

Tribune, ran an editorial stating that even though your golden retriever was comfortable drinking out of the toilet bowl, it didn't mean people should as well. There is something of the profane in drinking one's own waste.

The basic challenge to recycling wastewater, of course, is perception. Water users need to feel comfortable with the water coming out of their tap, and the idea of drinking some vestige of what was recently floating in a toilet bowl is simply hard for people to accept. Opponents say it will lead to a public health disaster. Never mind that the treated water can be made cleaner than water from the local reservoir. Never mind that we are drinking the same water that dinosaurs drank seventy million years ago and that has gone through the water cycle (and various species' gastrointestinal tracts) countless times since.

Water utilities are realizing they need to take a more indirect route than toilet-to-tap. Hence Orange County's underground pumping of its treated water. San Diego learned this lesson, too. It revisited recycled water again in 2007, this time in the midst of a drought. Called the Indirect Potable Reuse project, the proposed new plant would treat sewage water and send it to reservoirs and aquifers rather than directly into water mains. It was approved. Las Vegas, El Paso, and Tucson have similarly chosen to pump treated effluent into aquifers, recharging the groundwater and later pumping up for regular use.

Virtually anyone who thinks seriously about water shortages realizes how inefficient our current system is. Imagine if your next-door neighbor insisted on only using bottled water to flush his toilets, water his garden, or wash his cars. You'd think he was crazy. There is no rational excuse for using water clean enough to drink for washing down a driveway or watering your lawn. Yet we do just that every day. According to the American Water Works Association, the average American uses about seventy gallons of water a day. Most of our water, about 27 percent, simply goes down the drain flushing toilets. We use another 22 percent to wash clothes, and almost 20 percent for baths and showers. Once one adds in the water to wash dishes and run faucets and the water that leaks from

pipes, the remaining "Other Domestic Uses" account for only 2 percent of total water use, and drinking water is an even smaller percentage than that.

Any way you measure it, the water we use for drinking and cooking is a tiny trickle of overall water consumption. We take well over 97 percent of the water that has been treated clean enough to drink and use it for purposes where the potability of the water is irrelevant. Why do we do this? And, more to the point, why don't we stop doing this?

The simple answer is that we do it because we can. Water is very cheap. It was cheap when our basic plumbing and water distribution systems were designed and laid out. And for most people, it's still cheap. In Durham, North Carolina, I pay less than ten dollars for every thousand gallons of water delivered to my house, and the national average is a good deal cheaper than that. While I am careful about not wasting water, the motive is not saving money.

We have seen the same dynamic with another basic commodity. Until very recently, gasoline was cheap, too. Cheap gas led to highway programs, far-flung suburbs, big cars, and sprawl. The difference between gas and water is that gas has gotten more expensive, with the result of more fuel-efficient vehicles and more thoughtful trip planning. In most places, by contrast, water is still so cheap that reengineering is not worth the cost, even when water scarcity is a real problem. Cheap water leads to inefficient use. Neither cheap gas nor cheap water is inherently wrong or immoral, but each is deeply problematic in a world of scarcity.

If water systems were being built today and deliberately designed to conserve drinking water, they would look very different. It is not necessary, of course, to put in place toilet-to-tap systems. It could just as easily be "toilet-to-hydrant" or "toilet-to-rose-bush." Indeed, that is increasingly the case around the country.

The basic idea is to segregate water supplies between potable and nonpotable sources, sometimes called gray water. Dual distribution systems—with one set of pipes for potable water and the other for gray water uses such as firefighting, lawn watering, etc.—are in place all over the country, with California, Texas, Arizona, and Florida in the lead. The state of Arizona even offers a tax credit for installation of a residential gray water system. Tucson, Arizona, has constructed more than one hundred sixty miles of pipes that carry the treated gray water to nine hundred sites, including schoolyards, road medians, cemeteries, and parks. In 2005, the system handled more than 4.4 billion gallons of gray water. Tucson's golf courses consume two-thirds of the recycled water, forced by law to switch from groundwater if gray water is available.

In Honolulu, Hawaii, the wastewater treatment plant generates two grades of nonpotable water. R-1 Water is intended for landscaping and agriculture. Golf courses, now able to purchase R-1 water for only twenty-five cents per thousand gallons, switched over from the more expensive groundwater for watering their greens and fairways. Water that has been treated by reverse osmosis (RO Water) is used to feed boilers and for processes that require high-purity water. As the project manager, Ken Windram, describes, the program has been successful: "When one of the industrial customers uses the RO water, the island saves 600,000 gallons a day of drinking water. With all the industrial users combined, we save about 2.5 million gallons a day of drinking water. We charge industrial users about $5 per thousand gallons for recycled water, yet they save between $2 and $7 per thousand gallons."

Beyond treated water, other gray water opportunities may be found in rainwater harvesting (capturing rainwater from roofs) or stormwater discharge (collecting rainwater that has flowed from streets and fields). If we can overcome the challenges of creating infrastructure, these sources can save energy (thereby reducing greenhouse gases), increase supplies of nonpotable water, and increase water security.

Beyond making more efficient use of the water we consume, a major opportunity for increasing freshwater supplies lies in plugging leaks. For the average American, a remarkable 13 percent of piped water is lost through leaking. And the problem is not simply at home faucets. Many of our water systems are in a shocking state of disrepair. The *New York Times* has reported that, across the nation, a major water pipe bursts every two minutes. In our nation's capital,

a pipe bursts every day. Nor should this be surprising. Most of our nation's water systems were built decades ago. Some date back to the Civil War.

Buried beneath streets and fields, these pipes don't provoke a second thought from the average citizen until they burst and faucets run dry, yet these water mains are breaking down at an alarming rate. The EPA estimates that $335 billion will be needed simply to maintain the current water infrastructure over the next few decades, not to mention upgrading the system. While a rough estimate, we may be losing up to six billion gallons of water daily simply from leaking pipes. It costs about $200 per foot of replacement pipe, $1 million every mile, so they don't come cheap. New York City's Third Water Tunnel, currently scheduled for completion in 2020, will span more than sixty miles and meet the growing water demands of more than nine million area residents, but it comes with a six-billion-dollar price tag. Expensive, but what's the alternative?

To date, the primary option has been to bury our heads in the sand and do very little. We are starving our water system of funds, and have been doing so for years. Part of the reason is the invisibility of the water system, part is the lack of public understanding over how antiquated our infrastructure has become, and part is the belligerent refusal to pay for what the system really costs.

The obvious answer to inefficient water use and system maintenance is the same: raise water rates. When we have to pay more for something, whether gas or electricity, we either use less or do more with what we have. We drive less. We use more energy efficient appliances. We turn off the lights when leaving a room. The market signals make clear the benefits of efficiency, and we respond. And even with increased efficiency, raising water rates would still generate additional resources for needed infrastructure repairs and upgrades.

Raising water rates, though, seems almost as taboo in America as talk of raising taxes. Most people seem to assume that cheap water should be ours by right and that government, somehow, should find the means to pay for it on its own. We have taken the ready availability of water for granted in the past and intend to do so in the future.

To those in the water business, our unwillingness to make the proper level of investment is foolhardy. George Hawkins, the head of the District of Columbia Water and Sewer Authority, makes a telling comparison: "People pay more for their cell phones and cable television than for water. You can go a day without a phone or TV. You can't go a day without water." When he approached the District of Columbia's City Council to ask for a modest rate raise, though, he was raked over the coals. Jim Graham, a council member, proclaimed, "This rate hike is outrageous. Subway systems need repairs, and so do roads, but you don't see fares or tolls skyrocketing. Providing inexpensive, reliable water is a fundamental obligation of government. If they can't do that, they need to reform themselves, instead of just charging more." Graham was unhelpfully silent on how a water utility can reform itself to provide the money necessary for maintenance and upgrades on a decaying system.

This is not the case across the country, of course. Some cities have embraced the importance of conservation and water pricing in an era of scarcity. Las Vegas is perhaps the best example. In order to supply the opulent fountains and water shows that grace the Strip in a city with an average rainfall of four inches per year, the water is reused and expensive. Major corporations are starting to get the idea, as well. In June 2008, the CEO of the soft drink giant Coca-Cola stated that the company would become "water neutral." Every liter of water used to produce its drinks would be offset by water conservation and recycling programs. It's not clear how this will work in practice, but such a major commitment merits attention. Water is the company's most important raw material. In 2006, Coke used 290 billion liters of water to produce its beverages. The company was badly burned by protests in Kerala, India, charging that local wells had dried up because the company's operations had depleted the groundwater supplies. Even if Coke falls short of its goal, water conservation and recycling will necessarily remain major priorities. A report by the bank JP Morgan similarly concluded that water shortages pose threats that need to be addressed

in corporate planning. As the lead author, Marc Levinson, made clear, "These are real business risks. This is not something far off in the future."

BEYOND TECHNOLOGIES THAT PRODUCE WATER, MOVE WATER, AND increase our efficiency of use, the last approach to consider for water provision is greater reliance on natural capital. New Yorkers love to brag about the quality of their tap water. In fact, they like to brag about a lot of things, but tap water is high on the list. New York City's water system provides over one billion gallons of drinking water to almost nine million New Yorkers every day. And it really is good tap water, often beating out bottled water in blind taste tests. The reason, though, is that it doesn't come from New York City. New York solved its drinking water problems in the early twentieth century through a massive engineering project, drawing water from the Catskill and Delaware watersheds located 125 miles north and west of the city and sending it through massive pipes to city reservoirs. In the late 1980s, however, New York City was forced to reassess its drinking water strategy. Congress passed an amendment to the Safe Drinking Water Act in 1986, requiring large municipalities taking their drinking water from surface water sources (i.e., reservoirs, rivers, lakes, and such) to pretreat the water prior to distribution in the water mains. When officials in New York City's Department of Environmental Protection did the calculations, they figured it was going to cost about six billion dollars to actually build a water treatment plant and hundreds of millions of dollars to operate it every year. The EPA said it would only cost three billion dollars to build, but this is still a big number. It is a lot of water for a lot of people.

New York was fretting over this cost when a clever city official named Al Appleton took a close look at the law and realized that there was a waiver provision. The law essentially said that if you could demonstrate to the EPA that there were other ways to provide safe drinking water, then you did not have to build the treatment plant. Appleton and some other folks started thinking, Since we're getting our water from the Catskills and Delaware watersheds, maybe we should think about how land management up there provides water quality in New York City and how we can influence their land management practices.

In 1905, recognizing the significance of the Catskills and Delaware watersheds to New York City's drinking water, the state assembly had granted New York City the power to regulate polluting activities in these areas. This created the unusual situation, to say the least, of a city with land use controls over communities more than a hundred miles away. In the early 1990s, acting on Appleton's strategy, the administration of Mayor David Dinkins announced new watershed rules for the Catskills and Delaware watersheds that would improve water quality, such as limits on the amount of paved surface on a property, buffers up to a thousand feet wide around reservoirs and up to five hundred feet from stream channels, and prohibitions on spreading manure within a hundred feet of a watercourse. Not surprisingly, the efforts of "rich city folk" in New York City to regulate, without prior consultation, how upstate farmers and landholders managed their properties were met with intense political opposition.

Faced with the concern of the EPA that New York City could not ensure catchment management would work, the governor of New York state stepped in and organized a stakeholder consultation process. Conducted over two years with more than a hundred fifty meetings, the group finally came up with a complex Memorandum of Agreement signed by sixty towns, ten villages, seven counties, and environmental groups that essentially exchanged payments from New York City for specific land management practices. One participant described the exhaustive process as similar to a "rolling Thanksgiving dinner with relatives you only want to see once a year."

The Memorandum of Agreement provided for $1.5 billion of spending commitments over ten years, funded by taxes on water bills (which New York City residents voted to allow) and municipal bonds. Of this, $250 million was targeted to acquisition of title and conservation easements in critical areas. $240 million was provided for "partnership programs." These ranged from new sewage treatment infrastructure, stormwater infrastructure to environmental education, and purchasing 125,000 acres around reservoirs.

The bottom line is that, for the cost at the time of a $600 million "green bond," New York City ensured that its water remained legal under the Safe Drinking Water Act. A major review by the EPA in 2002 persuaded the agency to extend the waiver treatment of surface waters for a further five years and then again in 2007. The expectation is they will waive them again in 2012.

The Catskills story is often held out as the poster child for an "ecosystem services" approach to providing clean water because it presents the core idea so neatly. New York City's managers needed to deliver clean water. They could get it one of two ways: through "built capital"—where they would build a treatment plant, engineer it, and run the water through it—or by investing in what you might call "natural capital"—where they could change the landscape practices where the water flowed to ensure the service of water purification. They found that if they invested in the natural capital rather than the built capital, they got a better deal, purely in financial terms. Obviously, there are a lot of other nature conservation benefits, in addition to the public education benefit of water users better understanding where their water comes from. Since the Catskills story was first made popular in the late 1990s, it has been held out as the prime example for why we should think differently about the provision of basic amenities.

There is a broader economic goal underpinning this approach. By making payments for ecosystem services, landowners' visions of value start to shift away from traditional commodity crops of agriculture and toward service provision. In addition to grain, corn, and timber, landowners currently may provide ecosystem services such as controlling floods, conserving nature, and cleaning water—but they do so for free. If they could be paid for some of these services, farmers would think differently and farms would look different—if a landowner is receiving multiple income streams, the land will be managed differently. Right now, farmlands are largely managed for monocultures. That is hardly surprising, since that's how farmers get paid. We have gotten very good at growing soybeans because there is a ready market for them. One can imagine a world, though, where farmers are paid for more than the produce they bring to market. A greater focus on natural capital to ensure freshwater supplies—through landowners planting riparian buffers or maintaining vegetation in critical watersheds, for example—would lead to regular payments for these valuable services. If you can change the landowners' balance sheet, you can change the landscape.

The approach of paying for ecosystem services has worked not only in New York City but also around the globe. A 2010 study reported 216 payments and $9.2 billion in transactions for watershed services protecting 289 million hectares. Most of these programs were in Latin America, where water trust funds have become an important mechanism to conserve land and protect watersheds. The Quito water fund, for example, was created by the joint efforts of the municipal drinking water provider, the electrical utility, a local brewery, and a water bottling company. These partners have committed resources toward an eighty-year trust fund. The six-million-dollar fund's investment returns, supplemented by foreign aid from nongovernmental groups and development agencies, pay for conservation projects. These have ranged from strengthening protected areas and restoring degraded lands to supporting sustainable farming practices and reforestation. The primary goal in all these has been improved water quality, though there are significant additional benefits in terms of conservation and poverty alleviation. Quito's example is being followed in other Andean cities, including Lima, Cartagena, and Bogotá.

In Tanzania, CARE International has teamed with the World Wildlife Fund and other partners to create the Equitable Payment for Water Services program. Based in the Ruvu and Sigi river basins, the program aims to protect the primary water sources for the cities of Dar es Salaam and Tanga. To serve its four million residents and businesses, the Dar es Salaam Water and Sewerage Corporation has to spend roughly two million dollars every year treating water from the Ruvu River because of its high sediment load. Much as New

York City paid landowners in the Catskills to change their land management practices, the Tanzanian program pays upper watershed farmers to improve their soil conservation activities. In practice, this means reducing farmland expansion, logging, and mining. The public water utility (and Coca-Cola, which also contributes) benefits by avoiding the cost of treating water loaded with eroded soil. The farmers benefit by being compensated for the loss of income from forgoing traditional activities. The larger community benefits from the injected resources that contribute to poverty reduction. By 2008, more than four hundred fifty farmers were receiving payments.

BENJAMIN FRANKLIN IS REPUTED TO HAVE OBSERVED, "WHEN THE well's dry, we know the worth of water." This insight is as relevant today as it was in 1774. Cities that are thirsty and have the means will pay whatever it takes to obtain safe drinking water. A long line of entrepreneurs has already taken notice, hoping to profit from this undeniable demand. Whether money is to be made through pipelines, tankers, icebergs, desalination plants, treated sewage, LifeStraws, or some other innovative technology still on a drawing board remains to be seen. The clear message is that creative technologies and payment schemes for making, moving, and purifying water will only grow in importance in the coming decades.

Are companies really going to mine water in outer space?

Any business venture funded by Google billionaires, an Academy Award–winning filmmaker, and the former chief software architect for Microsoft and run by a former NASA Mars mission manager passes the laugh test. So when this group announced in April 2012 that it was launching the company Planetary Resources to mine asteroids, it garnered a lot of media attention. The plan seems simple on its face—mine near-Earth asteroids for water and precious metals—and dauntingly complicated in practice.

Historically, the main actors in space ventures have been governments. Motivated in part by the Cold War, they were the only parties with the massive resources necessary to mobilize a space shot. This is all changing, for there are other private sector space ventures afoot. The founder of Amazon.com, Jeff Bezos, is financing Blue Origin, a company that plans to provide commercial space travel through reusable rockets. Richard Branson has launched Virgin Galactic, providing suborbital flights for space tourists.

Planetary Resources' business plan is based on four phases. The first will involve the launch of its Arkyd 100 series spacecraft. Loaded with telescopes and remote sensing technology, about six of these relatively cheap craft (a mere $10 million each) will piggyback on the planned launches of other satellites and come to rest in low orbit around the Earth. They will take a close look at asteroids, using spectroscopy and other tools to assess their likely composition. The Arkyd 200 series will be launched to a higher orbit and have its own propulsion system so it can further examine promising asteroids. The Arkyd 300 series will comprise a "robotic swarm" of robots that will approach specific asteroids from different angles and determine the final choices for mining sites. Saving the hardest for last, the fourth stage involves mining and transporting the materials to consumers, whether back to Earth or to a space station.

There are two major markets. The most obvious encompasses precious metals such as platinum, palladium, and iridium. Platinum is currently selling at $1,465 per ounce. Palladium comes in at a relative bargain of $600 per ounce. According to Planetary Resources, just one asteroid contains as much platinum, palladium, and other platinum-group precious metals than have been mined in human history. Simple math suggests the sales could be in the trillions of dollars. The problem, of course, is that if platinum and other precious metals do become more abundant because of asteroid mining, they will no longer be so precious and their price will drop. Even so, one could still expect a tidy profit. Getting the materials back to earth, though, is exceedingly difficult. And this makes mining water much more interesting.

There is plentiful water on Earth, of course, so where is the demand for outer space water? Planetary Resources has identified two moneymaking opportunities. The first is providing water for astronauts in space stations or manned missions. Lifting anything two hundred miles or more above the surface of the Earth requires a lot of propulsion, and that's expensive. It currently costs roughly $10,000 per pound of payload delivered into orbit. This means it costs $125,000 to provide drinking water for three astronauts on the space station. Using a local water source instead of transporting water into outer space is both cheaper and more efficient.

Another market for water lies in energy. Splitting molecules of water releases hydrogen and oxygen—two of the key sources for rocket propulsion. As with water, this could provide a much cheaper local fuel source than flying a mission's fuel from the Earth. One can imagine space vehicles filling up at "orbiting gas stations" before traveling beyond the earth's orbit to the universe and beyond.

There are plenty of criticisms one can make of Planetary Resources' venture, but thinking small is not one of them. As journalist Will Oremus has succinctly described, "This space-mining venture is either going to be a spectacular success or a spectacular failure. Either way, the emphasis will be on spectacular."

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