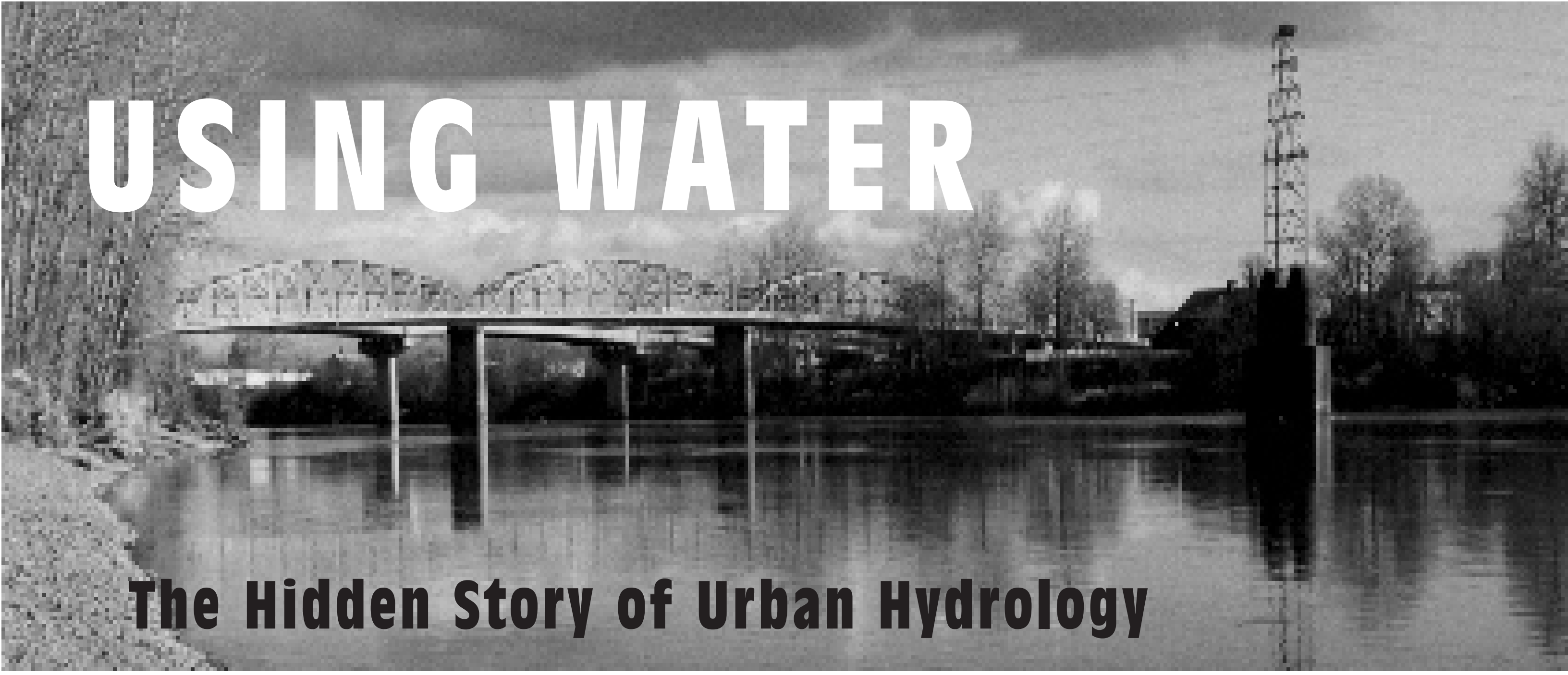


USING WATER

The Hidden Story of Urban Hydrology

The average American lives in a city or suburb and does not think about sewage. Its removal is assumed to be a civil right. Occasionally sewer drains on old city streets waft an unpleasant odor that we suspect is related to our toilets; or we pass one of the sewage treatment plants on the outskirts of town and roll up our car windows. But in general, within the city, suburbs, and frankly, anywhere with indoor plumbing, sewage is out of sight and out of mind.

But should it be? Without working sewer systems, our cities would be disgusting places to live. They would be full of disease and stink and filth. You think accidentally stepping in dog poop once a year is bad? Imagine your neighbors emptying their chamber-pots onto the street or alley from the second floor windows, thousands of tons of horse manure accumulating, your own personal sewage cesspool under the house, and dirt roads flooded with shit and water, impassable whenever it rained. Medieval Europe looked like that, and so did urban America in the 19th Century. The world's poor countries have cities that still look this way and carry the accompanying diseases and filth. Modern American cities are very clean compared to cities of the past and of the developing world, making them much more pleasant environments. We make it look easy and natural to not wallow in our own excrement and rubbish. But, Americans use an average of 100 gallons per day of water that has to come from somewhere. And, in turn, we create billions of gallons of wastewater that has to go somewhere. Our water does not come from a magical, bottomless tank of endless, clean tap water—it is diverted from the natural water cycle. And so, the quality of urban water sources is and will always be linked with the quality of the continent's freshwater resources—and visa versa.

For over 5,000 years, inhabitants of cities dumped all waste into waterways raw. There were problems with this approach, but it worked well enough that other options weren't pursued. The recent phenomenon of industrialization and population growth caused the volume of dirty water to grow while people rearranged the environment and its natural hydrology—and pollution became a big problem. Modern wastewater treatment plants were devised to lessen the burden of pollution on streams that weren't as good at cleaning water as they once were. Most people are surprised to learn that the idea of cleaning our wastewater before putting it "back" into streams, oceans, and aquifers is very new. Most cities and industries didn't start cleaning their sewage until the 1970s—which is something you probably didn't know.

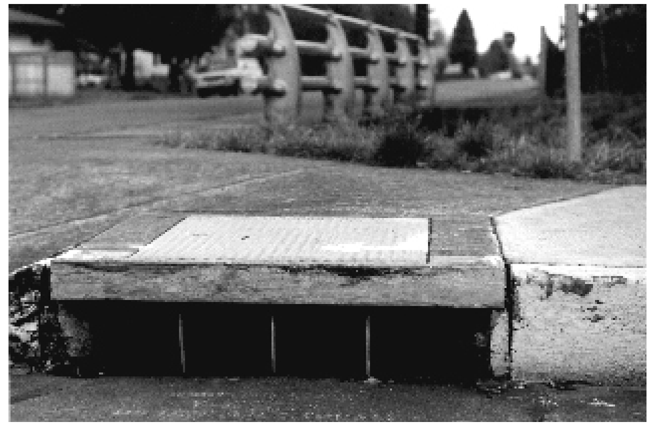
> *Our Water does not come from a bottomless tank of endless, clean tap water - it is diverted from the natural water cycle.*

Some History

Rivers have always been natural sewers and natural "treatment facilities." On a dispersed scale, this makes sense. Other living things, including aquatic species, live, die, and excrete wastes in and next to streams. It happens everywhere, and streams naturally dilute concentrated nutrients (like nitrogen) and disperse disease-causing bacteria as they ripple and flow along. The rich biota in wetlands and marshes also play a key role in cleaning water by sucking up, settling out, and decomposing nutrients. Dependence on nature for wastewater disposal only becomes a problem for people when the volume of sewage is too large for the streams to manage it naturally (and population is too dense). When streams are over-burdened, the pollution also becomes a problem for the non-human web of life.

People can get around tainted water by diverting cleaner water from far away or up-stream while efficiently moving dirty water out of the way. Ancient cities were able to develop and thrive using this basic plan. As early as 3000 BCE people in cities were building sewers, and for at least 4500 years they have been using aqueducts to divert water into cities. For a very long time, urban centers have been drawing water from rural mountain streams, springs, lakes or reservoirs, groundwater, and/or upstream rivers—and sending waste water downriver, into the ocean or lakes, and back underground through cesspool seepage. Cities that failed to fund large water projects—like those in Medieval Europe—drew water from wells and streams in the

The sewers came to combine street runoff with household and industrial/business sewage and send it out of town on river currents or outgoing tides.



same neighborhoods where sewage seeped into the ground through cesspools and flowed in from up-stream. Such places suffered from bad water and serious disease epidemics. Billions of people around the world right now live in places with these same water-supply problems.

American cities grew in the late 1700s and early 1800s without public waterworks to bring water in or take it out—and outbreaks of Cholera and Yellow Fever were a result. Shocked by thousands of deaths and the flight of frightened residents, Eastern cities began to plan and build aqueducts and reservoir systems to bring cleaner, rural water into town. Major aqueduct water projects were implemented from the 1830s to the 1850s in major US cities (all in the East). Although no one was sure what caused disease, the cities were increasingly filthy with manure and rubbish and had become extremely unpleasant. People knew that reliable, cleaner water would be used to wash everything more often and flush some of the filth away (into the rivers and harbors). The rural water supplies flowed through new kitchen sinks, making life much easier. But, eventually all the extra water flowed into sewage cesspools which then overflowed too quickly. The extra water had to have somewhere to go once it was used.

People had already been digging their own gutters and neighborhood sewers to handle runoff from storms and other excess water. Without some kind of drainage, streets and cellars routinely flooded. Dirt roads turned to mud. The increased population and high per-capita water consumption caused these DIY sewers to back up. So the cities stepped in again, this time building major sewer conduits in the 1850s, 1880s, and later. Residents quickly began to connect their cesspools (think of septic tanks, but less complicated) into the sewer to carry overflow. Cesspools didn't have to be pumped out as often, and the combined-sewer system came to be the norm. The sewers came to combine street runoff with household and industrial/business sewage and send it out of town on river currents or outgoing tides.

In the mid-1800s, the magnifying lenses of the light microscope were improved significantly, and it became possible to look at samples on a cellular level. Obviously, one of the first things scientists did with their new lenses was look at water, where they were shocked to find an alarming abundance of activity.

They had discovered microorganisms and realized that millions of tiny swimming creatures were living in their tap water. Water that looked, tasted, and smelled clear and clean contained secret living things. In 1880, Louis Pasteur published his "germ theory of disease," linking microscopic life (bacteria, viruses) to human diseases. This caused quite a stir, and within a decade several scientists had linked specific microorganisms with common epidemic diseases. This new knowledge was extremely important in the development of sanitation and drinking water treatment—although the idea of wastewater treatment lagged behind.

Other peoples in earlier cultures had been treating water for drinking far, far in the past, and some American cities were already using mechanical methods to clean grit from their water (the first municipal water-filtering system was installed in Poughkeepsie, NY in 1872). But, the weird-looking, disease-causing microscopic organisms convinced Americans to take their drinking water more seriously at the end of the century. They started to re-use very old technology to filter their water supplies. They used sand and gravel as filters (an idea at least 4000 years old) and used Alum (Aluminum sulfate $A1_2(SO_4)_3$) as a "flocculent" to clump-out microorganisms and fine particles (another old idea, from the 1st Century A.D.).

Drinking water was improved greatly by the installation of these filtering methods. But, the introduction of chlorination around 1910 made it possible to kill what microorganisms remained in the water and prevent new ones from appearing between the treatment facility and the household tap. Chlorine removed almost all threat of bacterial/viral disease from city water sources. This improved sanitation and decreased water-borne illness, although we now have reasons to be concerned about the carcinogenic properties of chlorine.

For much of the 20th Century, water was thought to be finally safe, having been rid of danger through chlorination. People *were* pretty safe from bacteria and viruses. But from the 1940s to the present, horribly carcinogenic synthetic chemicals, like industrial solvents and agrochemicals, have been produced in huge quantities and dumped into surface water and onto the ground (into aquifers). It took a few decades for the chemicals to build up and for scientists to prove they were damaging to life. Many synthetic chemicals weren't acknowledged to be carcinogens until the late 1970s-1980s after mysterious outbreaks of cancer and birth defects. Tiny amounts of heavy metals, agricultural pesticides, and industrial chemicals can harm our bodies significantly (and the bodies of all kinds of other organisms). At this time, most cities regularly test drinking water and wastewater for a long list of compounds, which are poorly understood and sometimes highly toxic, worthy of continuing public concern. Every year new chemicals are created and the EPA adds more formulas to its water quality testing list. Very little is known about potential chemical reactions between pollutant chemicals in the waterways.

How is water treated for drinking?

Today the process of drinking water treatment is surprisingly simple. I had long imagined it would be more elaborate because drinking water flowing from a tap seems so magically clean. It must comes from somewhere, but it somehow seems to have nothing to do with pond and river water. I liked to imagine that the water was distilled to purity in a highly advanced, space-age process. But, living in a city of 50,000 in western Oregon, the water coming out of my sink and shower doesn't flow through a magic wand. It goes through just a handful of steps:

I. It is diverted from the major river next to the city and mountain streams.

2. It is treated with alum to create "floc" clumps that settle out.

3. The water is sent through filters composed of sand, garnet, gravel, and activated carbon.

4. Chlorine is added.

5. It is periodically tested for dangerous heavy metals and synthetic chemicals.

6. And then, it is sent through pipes around the city to my house.

I run the tap, the shower, the garden hose, and flush the toilet and much of this drinking water becomes wastewater.

Flush toilets didn't become common until the beginning of the 20th Century. Using piped water, hotels and public buildings could afford them in the mid-late 1800s, but everyone else continued to use cesspools and outhouses because they were cheaper. Most rural farmers still lacked indoor plumbing for toilets through the 1950s. Anyway, wherever it was adopted, the flushing toilet greatly increased the volume of raw sewage generated. Meanwhile, populations of the cities grew. Storm sewers carried everything that flushed off the streets, and began to carry most household sewage too. Industrial water use and sewage creation increased and went right into the waterways. At the beginning of the century lakes and rivers in and near US cities were choked with pollutants and waste materials.

Some pioneering treatment facilities sprang up at the end of the 1800s to break down raw sewage before release into natural waterways, but most cities treated their wastewater barely if at all until the 1970s. The useful role of bacteria in decomposition was known since the 1880s, but few treatment operations used bacteria. Most operating treatment facilities before the '70s were "primary" wastewater treatment plants, only using mechanical separation methods. The landmark 1972 Clean Water Act called for major water quality improvements across the country and basically required all cities to build "secondary" treatment facilities—at quite an expense. In some places it has taken 30 years to comply. Boston released large amounts of untreated sewage into Boston Harbor until a modern secondary treatment facility was completed m 1988. The city of Los Angeles didn't get its act together until 1998 when its Hyperion Treatment Plant was finally completed. Until a few years ago LA was routinely dumping millions of gallons of raw sewage into the Santa Monica Bay because the old facility was too small. Across the country most cities still release some amount of raw sewage without any treatment during overflow events. This usually occurs when rainstorms greatly increase the volume of water flowing to the treatment facilities that handle combined-sewer inputs, and their handling capacity is exceeded. Of course, spring floods or hurricane floods often send all of a city's sewage into floodwaters.

Modern Sewage Treatment

Sewage treatment facilities are unadorned and found in desolate outskirts of town. Most were built or upgraded in the early 1970s—an era of bad architecture and creaky vinyl-covered furniture. Not to mention, they often smell like sewer gas. These days, almost every sewage treatment facility is a “secondary wastewater treatment" operation with a series of pipes, screens, tanks, troughs, service buildings, and machinery surrounded by barbed-wire fencing and fields labeled with occasional "Do not touch/drink water Keep Out" signs.

The treatment of sewage is a combination of mechanical and biological activity. 98%-99% of what flows into a treatment

facility is water, but it takes a lot of effort to get the 1-2% that isn't water back out. Cities have systems of sewer conduits that are hundreds and thousands of miles long drawing wastewater from public and private buildings and from street drains. Currently most industries that use large volumes of water are required to have their own sewage treatment plants on-site, which significantly reduces the burden on public treatment plants. What's in the sewage when it arrives at the sewage treatment facility? A lot of nasty stuff: soaps, cleaners, household hazardous wastes, dissolved heavy metals and synthetic chemical compounds, caffeine, food, feces, urine, shards of yet-undissolved toilet paper, pulp, oils and greases, cigarette butts, coffee grounds, seeds, Band-Aids, condoms, chewing gum, skin, plastic tampon applicators, condoms, rags, cans and bottles, tree parts, twigs, wood, miscellaneous pieces of metal and plastic, wrappers, small bones, bacteria, rocks, sand, silt, and other grit.

The Southerly Wastewater Treatment Plant in Columbus, OH is typical of modem secondary treatment facilities. The treatment process involves three main stages: Primary Treatment, Secondary Treatment, and Disinfection. Correspondingly, these stages are mechanical, biological, and chemical in nature. As the plant successfully separates water from what is not water, another process of treating and handling that solid, nasty 1-2% occurs.

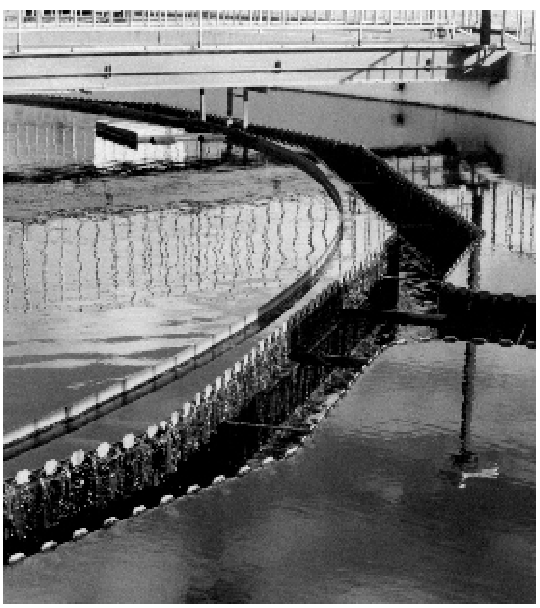
The Process

1. Wastewater comes to the facility. It

is gray with little shards of toilet paper and an occasional tree limb. The surface has a sort of foamy scum. It gets sent first through a building where "screening" occurs. Screens with not-very-small openings block larger objects from going further and rotating bars pull off rags and insoluble paper, cans, bottles, and tree parts. Everything captured here gets toted off to a sanitary landfill. All of it is hazardous waste, because it is covered with raw sewage.

2. The water flows along to channels and tanks where sand and gravel (not flushed down the toilet, unless you eat rocks- but coming off the streets through storm sewers) are removed through settling. This is an important step because the grit harms other machinery in the plant. Getting rid of it cuts down on maintenance. Anyway, as before, the stuff that is removed is taken to the sanitary landfill.

3. The raw sewage minus grit and tree limbs is pumped to an elevated height so that gravity can move the dirty water



through the rest of the plant.

4. Next, a lot of air is blown into the wastewater to (a) get rid of some of the stinky sewer gasses that have built up (like methane), and (b) to help the oils and greases to separate. Aeration increases the dissolved oxygen content, which is useful later.

5. That was just the pretreatment. The dirty water is moved to settling tanks where solid particulate matter separates from the water molecules by sinking to the bottom or floating to the top. Most such settling tanks are cylindrical, and characteristic features of a treatment plant. The heavy muck is called primary sludge (containing what is left of everyone's poop), and the floaters are called scum. Machines drag across the surface and the bottom of the tanks to remove what willingly separates. Inflated condoms, plastic tampon applicators (that aren't supposed to be flushed either), and odd, gas-filled chewing-gum spheres float around before they are removed. The water that is left over is much cleaner than what we started with, and it is called primary effluent. Many treatment operations before the 1970s and 80s released this water to waterways. But, biological treatment can make it much cleaner.

6. The primary effluent is directed into troughs filled with recycled sludge rich in trillions of bacteria hungry for dinner. This soup is aerated again, like a dirty whirlpool bath, and the active bacteria make the water warm. The bacteria eat up 95% of the remaining particulate matter and also digest and break down harmful chemicals and organic compounds. Some will even eat up TCE and gasoline.

7. Finally, the water is separated again through settling, and the bacteria-rich sludge is partly recycled and partly composted, incinerated, or used as fertilizer.

8. At this point the secondary effluent is chlorinated to get rid of extra bacteria that remain. But, right after chlorination, the water is dechlorinated by the addition of sulfur dioxide (S02: taking it down to a strict standard of "no measurable chlorine residual." (Not all treatment plants carry out dechlorination.)

9. The water is aerated one more time to fill it with dissolved oxygen. Fish and other aquatic organisms depend on it, and it occurs naturally in moving water. The end product of the sewage treatment plant is not drinkable water. Its quality and level of dissolved oxygen should be appropriate to go back into a river ecosystem, not into our houses.

10. Finally, the water gets piped to the nearby river, lake, or ocean and returns to the natural water cycle (until it gets taken up by a drinking water plant or diverted by living things).

Meanwhile, the sewage treatment plant dries all the primary sludge/scum and burns or landfills it (nasty stuff). Fertilizer is made from the cleaner waste activated sludge. Some plants capture the sewer gasses throughout the process to produce energy to run their whole operation. Others produce energy from burning sludge, or make money from selling the more refined late-stage sludge to fertilizer companies.

At the same time, you and I and everyone else continue to take our showers, flush our toilets, and wash our cars, sending dirty water in a steady stream down the pipes for another cycle of cleaning.

Us vs. the Natural Water Cycle

Most people in our country live in sanitary separation from waste disposal. It is nice to be removed from the smell of sewer gas, but the result is that most of us don't have a clue about the water we bring in and send out of our houses. Our Victorian embarrassment over bodily functions separates us further from the reality of human wastes. Sewage is not a topic of "polite" public discussion. Few of us ever poop in the woods, and the closest most Americans come to pre-plumbing sewage disposal is port-a-potties. Some women raised and living in Industrialized cities might never urinate or defecate anywhere but from a toilet seat in their lifetimes. Almost everyone uses treated and purified drinking water, 5 gallons at a time, to flush away a few ounces of urine and toilet paper. We water plants and wash our cars with drinking water. It's a waste of energy. Freshwater is a precious resource that we borrow from the rest of the ecosystem millions of gallons at a time for our convenience.

Treatment facilities clean our dirty water only by copying the mechanics and biological activity in nature's processes, engineering them out of concrete and metal, and speeding them up.

We are shaped by our environment and by the engineering projects that shape our urban landscapes and modern life. Focused on buildings, pipes, and concrete, we drive by rivers and streams and ponds in town without thinking at all about our tap water and storm sewers. For quite a lot of people the toilet and drain are the end of the line of their wastewater. It's easy to forget or not know where all the used water goes. People dump solvents and battery acid down street and sink drains because they live their lives thinking this way. If we stop thinking about our water the moment it goes down the drain—instead of considering the entire range it will traverse, then there are no precautions to take or concerns to be felt.

Failing to understand the connection between human urban/suburban activities and the natural world is a really big problem. Every person should see him/herself first as part of the environment, and second part of a human settlement. But that point of view is rare. Lacking such perspective, water flowing in rivers and underground aquifers is seen only as a resource for people to use. We dam streams because streams are there for the purpose of giving us flood protection, hydropower, and drinking water reservoirs. We drain ancient aquifers because they have no other purpose than for us to use them up. We fill in wetlands because we can't farm or build on them. And the consequences of this one-dimentional attitude are that we have ruined our rivers and compressed valuable aquifers. Rivers become useless habitats for the creatures and plants that once thrived in them—and then we complain about fish disappearing. The entire web of life that supports a healthy stream/wetland system is important in itself, and also provides valuable water purification.

What I find most fascinating about modern wastewater treatment is that nature's own methods of cleaning water are still superior. Treatment facilities clean our dirty water only by copying the mechanics and biological activity in nature's processes, engineering them out of concrete and metal, and speeding them up. The underground conduits and directed movement of urban water deceive us into thinking this water exists separately from the hydrologic cycle and "natural" water. But, pipes leak water into the "wild" groundwater. Drinking water is sprayed into lawns and flows into "wild" urban streams. Runoff carries motor oil and antifreeze from parking lots into rivers and lakes. And, even today, raw sewage and toxic wastes flow straight into waterways during heavy rainfall events. Our secondary effluent, the treated end-product from wastewater treatment plants, is some of the best water the city gives back to "nature."

Unfortunately, now that sewage treatment is an almost universal activity, we are finding that the country's rivers are still largely polluted. Sewage treatment facilities are a practical necessity and significantly cut down the burden of pollution in our streams, estuaries, lakes, and harbors. But the streams stay dirty and dead anyway because valuable wetlands, marshes, pools, and riffles have been lost and destroyed over the past 350 years of escalating human settlement. The natural cleansing we lose by filling in wetlands and channelizing streams is compensated by settling tanks and bacterial troughs only at the output of our urban activities.

Cities and industry now contribute far less pollution to the nation's streams than non-organic agriculture. Modem agribusiness sends millions of tons of fertilizers, synthetic chemicals, soil, silt, and raw sewage (from livestock) straight to our rivers without any treatment at all. Most of our poop and spilled motor oil is ending up in the microscopic bellies of bacteria or in sanitary landfills. But we are obviously still to blame. Our greed for cheap food, hydropower, barge-friendly waterways, and unlimited water keeps the hydrology of our continent from recovering. ❖

REFERENCES

American Public Works Association (2001) www.apwa.net/About/Awards/toptencentury/hyp.htm (City of Los Angeles Hyperion Treatment Plant)

Cosgrove, J. J. (1909) *History of Sanitation*, Pittsburgh: Standards Sanitary Manufacturing Company.

Del Porto, David. (1999) *The Composting Toilet Book*. Concord: The Center for Ecological Pollution Prevention.

Goldman, J. A. (1997) *Building New York's Sewers*. West Lafayette: Purdue University Press.

Horan, Julie. (1996) *The Porcelain God: A Social History of the Toilet*. Syracuse: Birch Lane Press.

Hughes, J. Donald. (1994) *Pan's Travail: Environmental Problems of the Ancient Greeks and Romans*. Baltimore: John's Hopkins University Press.

Outwater, Alice. (1996) *Water: A Natural History*. New York: Basic Books.

Southerly Wastewater Treatment Plant, Columbus, Ohio, "Facility Description" handout. (Chapter 2 of unknown publication published/updated November, 1988)