Toward Sustainable Water Systems:
Potable Reuse of Wastewater

Melon Wedick

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Why Worry About Wastewater?

Record droughts parch the southeastern United States.[1] The city of Atlanta faces the possibility of running out of water within weeks.[2] A steady decrease in mountain snow pack severely limits available freshwater in the West and Southwest.[3] Lake Mead water levels fall to 49% of capacity.[4] Meanwhile, wealthy landowners in drought-stricken areas continue to water expansive landscaping, fill their swimming pools, and flush their toilets.[5] Something is amiss in our relationship to water, one of our most precious resources.

Freshwater resources are finite, and preciously small. Although the world is largely composed of water, only about 2.5% of that is freshwater, two-thirds of which is frozen in glaciers and ice caps[6]. Not all of the remaining freshwater is renewable; a percentage of it is stored in aquifers, which we are quickly draining. The rest of the water is part of the hydrologic cycle – flowing through rivers, sitting in lakes, and being processed through evapotranspiration. If we are to maintain our freshwater resource, we must use little enough water that we do not drain the system past the point of recharge – we cannot use all there is.[7]

Demand, however, is steadily growing. The human population continues to swell apace, and every person on the planet needs water to live. In the last fifty years, water withdrawals for human uses have tripled, and this number is expected to rise as the population grows, urbanization spreads, and increased development spurs greater usage in areas of the world where demand has traditionally been low.[8] Water is essential to life, to well-being – and to agriculture and industry, both site-specific, intensive water consuming processes.

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[1] New York Times, 2007 (July 4, October 16, October 22)
[2] New York Times, 2007 (November 15)
[3] New York Times, 2007 (November 4, October 21)
[4] New York Times, 2007 (November 4, October 21)
[5] New York Times, 2007 (November 15)
[6] Postel et al, 1996.
[7] Postel et al, 1996.
[8] Larsen, 2005.

Somehow we must provide water to meet our needs without depleting our already scarce freshwater resources. Sustainable use of freshwater has not previously been treated as vital, and many communities in the United States rely upon water that is pumped out of aquifers, taken from surface lakes and rivers, or piped into desert areas from hundreds or thousands of miles away. Temporary water shortages and droughts drive home the frightening truth: if we do not use our freshwater responsibly, many places may face the reality of life with too little water. It is imperative that we as humans consider consciously our place in the hydrologic cycle.

Treating and reusing wastewater is one way we can begin to address this problem. Cloudcroft, New Mexico, is one community that has begun to do just that. In response to sustained drought conditions, the village is implementing a new water treatment system that will allow them to recycle 100% of their wastewater, 80% of which will go directly to their drinking water supply. Other communities across the country are also experimenting with water recycling and reuse, but Cloudcroft's has the distinction of connecting its outflow and intake systems most directly. Coupled with reduction of wasted water, advances in wastewater treatment and reuse could go far toward creating sustainable patterns of human water use.

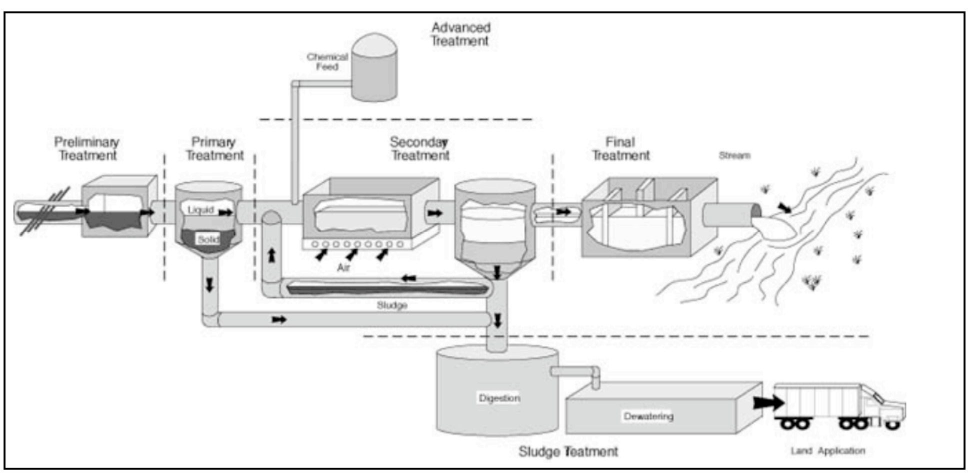
Wastewater Treatment & Reuse

Because of the closed-loop nature of the hydrologic cycle, all wastewater eventually gets reused in some form or another. Despite this fact, most wastewater treatment is not designed to produce water that is as clean as it could be. Simultaneously, many people are squeamish about the idea of reusing wastewater as drinking water. In order to make human water consumption truly sustainable, however, it is vital to consider that almost all of our wastewater is someone else's drinking water.

There are multiple ways to approach the problem of wastewater treatment. The four we will examine in this paper are: unplanned, indirect reuse; non-potable reuse; planned, indirect, potable reuse; and direct potable reuse. One other method of discharging wastewater involves treating the wastewater to a base level (i.e. below requirements for drinking water) and discharging the effluent into the ocean. This effectively removes freshwater from the cycle of use and reuse and throws it away by combining it with salt water in the ocean.

I. Unplanned, indirect potable reuse

Probably the most common of all treatment systems, unplanned, indirect reuse of water can be considered the status quo. As of 1980, "more than two dozen major water utilities, serving populations from 25,000 to 2 million people, [drew] from rivers in which the total wastewater discharge [accounted] for more than 50 percent of stream flow during low flow conditions."[9] In this system, municipal wastewater is treated in four phases (preliminary, primary, secondary, and tertiary) and then released into a nearby freshwater body, which also serves as raw water supply for communities downstream. Wastewater effluent discharged into the water body has received basic treatment, but has not been treated extensively. The treatment process that the wastewater goes through is illustrated at right.



Typical treatment train for unplanned indirect potable reuse.[10]

[9] Swayne (1980), as quoted in National Research Council [NRC], 1998 (18).
[10] Mancl, Karen.

In preliminary treatment, the water passes through some kind of screen or fence that strains large solids such as rags, paper, cans, and other debris out of the water before it enters the treatment facility. In primary treatment, suspended solids and greases are separated from the wastewater through a prolonged settling process similar to that which occurs in a septic tank. The water then goes through secondary treatment, where cultivated sewage microorganisms are added to the water to consume organic material in the wastewater. Finally, the water is disinfected, generally with chlorine or ultraviolet light, to destroy disease-causing organisms in the water. At this point, the water is considered non-hazardous and is released into a local water body.[11]

Water treated in this fashion is not suitable for consumption, although it could be used for non-potable purposes. Communities extracting raw water for their public water supplies must treat the water extensively before it meets drinking water standards. This generally works well; however, there are consequences to releasing this minimally treated water into the environment.

While standard wastewater treatment removes organic and non-organic substances traditionally found in water, it does not yet do a good job at removing "emerging contaminants," including various pharmaceuticals, industrial byproducts, and hormone supplements that are becoming increasingly prevalent in our wastewater. A study done by the U.S. Geological Survey sampled 139 steams across the United States to detect these emerging contaminants in the nation's freshwater supply. One or more of the contaminants they looked for were present in 80% of the sampled streams, and the median number of compounds found in the streams was seven, although 38 compounds were found in one instance. These contaminants range from common over-the-counter drugs like acetaminophen and ibuprofen to hormone supplements, caffeine, and solvents. The

[11] Mancl, Karen.

contaminants found in the greatest concentrations were: steroids, nonprescription drugs, detergent metabolites, and plasticizers.[12]

While the impacts of these contaminants on the environment and species' habitats are unclear at this time, some effects have been recorded or postulated. Studies are underway that look at endocrine disruption and disruption in the reproductive systems of carp (studies show male carp producing high quantities of female biomarkers).[13] While antibiotics were not found in the highest concentrations, the USGS reconnaissance report states that "even low-level concentrations in the environment could increase the rate at which pathogenic bacteria develop resistance to these compounds."[14] Meanwhile, scientists remain uncertain as to whether these compounds are effectively mitigated during drinking water treatment processes, and if not, what effects they may have on human consumers.

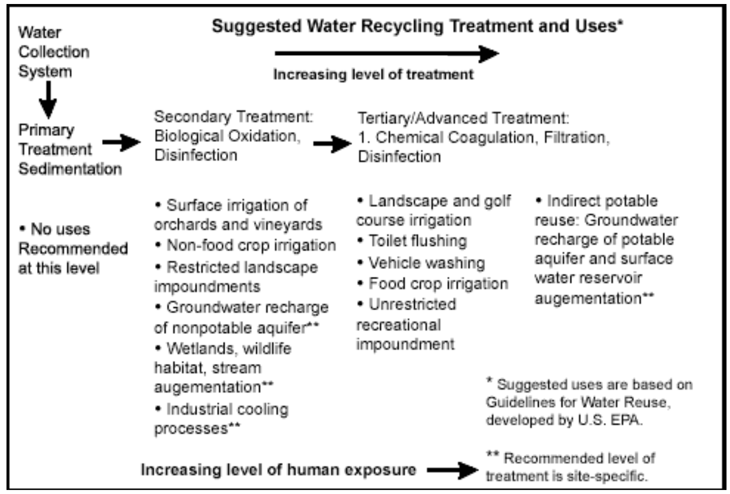
Effectively, the traditional method of dealing with wastewater says that issues of water quality are essentially somebody else's problem. Although this method has produced clean water for drinking for years, the methods involved are no longer sufficient to protect our environment from contaminants in our water. By shifting responsibility for water treatment down the line, we release toxins into the environment without any clear idea of what their effects may be.

II. Non-Potable Reuse

Non-potable reuse uses wastewater for activities that require less water purification than drinking. It is a generally accepted reuse of wastewater, and many municipalities sell their reclaimed wastewater to others for various purposes, including use in industry, crop irrigation, golf course and landscape irrigation, and household non-drinking use such as flushing toilets and washing cars. The

[12] USGS, 2002.
[13] USGS, 2007.
[14] USGS, 2002.

US EPA has developed a chart showing levels of wastewater treatment necessary for water devoted to a host of non-potable uses.[15]



Because it reserves our cleanest water for drinking and other purposes that require high levels of purification, non-potable reuse of wastewater is a step in the direction of responsible water use. It comes with a few difficulties, however. Having a separate water source for non-potable use entails having a second system of infrastructure to transport that water; this is not only expensive, but can lead to unforeseen problems.

Until recently, San Diego, California, a city that imports between 85 and 95 percent of its water,[16] has not been able to get its public to approve measures to start recycling wastewater for potable use (the city council overrode the mayor's veto of the latest proposal on November 31st of this year, and a one-year demonstration project is scheduled to begin in July 2008[17]). Instead, the city sold treated wastewater for non-potable reuse, distributing the water through its "purple pipe" infrastructure. In 2006, the North City Water Reclamation Plant treated 22.5 million gallons of wastewater per day, of which 6 million gallons per day went through tertiary treatment and were redistributed for non-potable use. The other 16.5 million gallons of wastewater per day were treated only through the secondary level, and discharged into the ocean.

San Diego's purple pipe infrastructure represents a costly investment in redundant infrastructure. While new neighborhoods are easy to fit with pipes, retrofitting existing areas can be

15 US EPA.
16 Wastewater swells water supplies, *High Country News* (2007, September 26).
17 San Diego News (2007, December 3)

costly and difficult, if not impossible. Meanwhile, an unfortunate glitch in the system, discovered in August of this year, highlights just one of the ways in which a redundant system like this can go wrong. Workers in a business park in Spring Valley, CA, learned that the foul-smelling, discolored water they had been drinking and washing with (and using in food preparation) for several weeks was in fact coming from a purple pipe containing recycled water not treated to drinking-level standards. The department of health shut down the two food-related businesses in the park, and the Otay water district was forced to pay for medical examinations of the park's employees.[18]

While non-potable reuse of wastewater prevents us from wasting drinking-quality water on enterprises that could get by with less rigorously treated water, thus saving money, energy, and water, it comes with its own set of potential problems. Installing parallel infrastructure is redundant and can potentially lead to costly mistakes, like the one made in Spring Valley. Moreover, while reusing 6 million gallons of wastewater a day is a tremendous step toward responsible use of our freshwater resource, any scenario where a city that is forced to import its freshwater throws away 16.5 million gallons a day by discharging it into the ocean is far from ideal. Non-potable reuse is a good, but at best partial, solution.

III. Planned, Indirect Potable Reuse

Planned indirect potable reuse is the next step toward water responsibility, and is currently being used in several locations around the United States. Since unplanned indirect reuse is common everywhere and has been standard practice for many years, planned indirect reuse, which generally requires that water be treated to a higher level before being returned to surface or underground freshwater sources, might seem relatively un-contentious. Public opposition, however, often stops

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[18] Merchants told water is tainted, *San Diego Union-Tribune* (2007, August 22).

these projects from moving beyond the planning phase; in San Diego and elsewhere, it has been difficult to rally support for projects labeled "toilet-to-tap."

Indirect reuse does not really represent "toilet-to-tap," however. According to the State of California:

> [. . .] indirect reuse involves the return of highly treated wastewater to a natural environment (groundwater, reservoir or stream), where it is mixed or blended with other waters for an extended period of time before being treated via sedimentation, filtration, and disinfection.[19]

Wastewater intended for potable reuse undergoes more treatment than outlined in earlier sections. It first undergoes the traditional treatment train of preliminary screening / grit removal, primary treatment / sedimentation, secondary treatment / coagulation or flocculation, and tertiary treatment / disinfection. After tertiary treatment, the water is additionally cleaned using more advanced techniques, often including a pressurized filtration step and use of several chemical treatments. Advanced treatments generally fulfill several objectives, including removal of viruses and pathogens, nutrients (nitrogen and phosphorus), trace metals, and organics, and reduction of total dissolved solids found in the water.[20] The water, which is at this point often found to be cleaner than municipalities' raw water, is then discharged to an aquifer, reservoir or other water body, where it mixes with raw waters and rests for a significant period of time before intake to a drinking water treatment plant. At the plant, the blended waters are treated, filtered, and disinfected again before being distributed in a public water system.[21]

Although approval of new projects can prove contentious (as in San Diego), indirect reuse projects have been operating continuously in this country for the past forty years. Los Angeles County began reusing a portion of its wastewater for groundwater recharge in 1962, using a method known as "surface spreading."[22] Orange County, California, has been injecting highly treated

[19] Water Environment Federation [WEF], 2006 (6).
[20] WEF, 1998 (134).
[21] NRC, 1998.
[22] WEF, 1998.

municipal wastewater into its aquifer in order to prevent saltwater intrusion and to augment drinking water supplies since 1976.[23] On November 30th of this year, the county replaced its old wastewater treatment plant with a much larger one that vastly increases the quantity of water that can be treated and injected into the aquifer.[24] In Virginia, the Upper Occoquan Sewage Authority was created in 1978 to address declining water quality in the Occoquan Reservoir that was the result of insufficiently treated wastewater emitted by several small treatment plants. The UOSA was charged with building and operating a (then) state-of-the-art treatment facility that would treat wastewater to a much higher standard before releasing it into the reservoir.[25] Other indirect potable reuse projects currently active in the U.S. include ones in Tampa and El Paso, while San Jose, San Diego, and Tucson are all experimenting with the idea.[26]

The biggest obstacle to widespread implementation of indirect reuse programs is public perception that recycled water is dangerous to drink. Studies have shown, however, that the health implications of using reused water are not significantly different from using water from raw sources, and have often shown recycled water to be cleaner than the purest available local raw water.[27] Both kinds of water undergo additional treatment before they are distributed in public water systems in order to "polish" the water to meet drinking water standards. Public education, education of the media, provision of accurate information regarding health effects and successful past implementations of reuse projects, and other public relations techniques are needed in order to make any reuse project a success.

While indirect reuse systems are a major leap forward in responsible use of freshwater, they are not sufficient by themselves. Not all wastewater is recycled; systems generally have a maximum quantity of water that can be recycled in a given day. Water that is not recycled is often disposed of,

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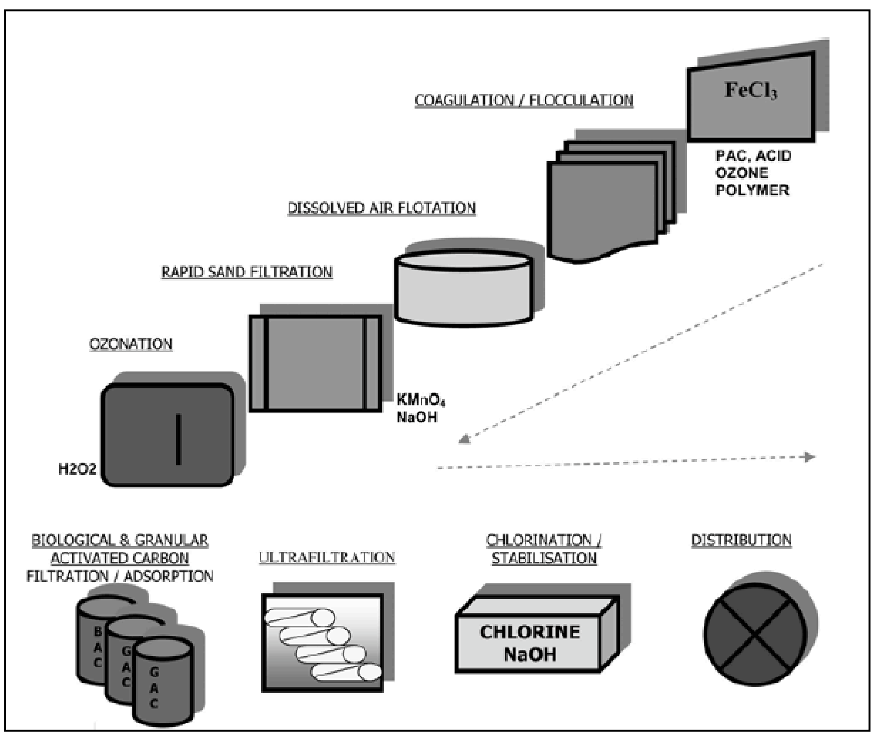
[23] NRC, 1998.
[24] From Sewage, Added Water for Drinking, *New York Times* (2007, November 27)
[25] CMHC (1); NRC, 1998.
[26] New York Times (2007, November 27); NRC, 1998; WEF, 1998.
[27] WEF, 1998; NRC, 1998.

as in San Diego. Water recycling programs taken by themselves also fail to address questions of wasted water; unless use restrictions or incentives are in place to encourage responsible use of water, valuable freshwater will still be lost. Furthermore, recycled water can be lost to leakages within the system, which should be checked for and repaired regularly.

IV. Direct Potable Reuse

The most contentious, and most comprehensive, strategy for reuse of wastewater is direct potable reuse. The differences between direct and indirect reuse are not always made clear. According to the Water Environmental Federation:

> Conceptually, direct potable water reuse is a "pipe-to-pipe" connection between the reclaimed water treatment facility and the potable water distribution system. In indirect potable water reuse, the highly treated reclaimed water is introduced to a surface or groundwater system that is ultimately used as a potable water supply. In an indirect system, the reclaimed water is blended with the natural system, and there may be a significant delay (for example, 12 months or more) between the point of reclaimed water discharge and the withdrawal into the potable water treatment facility. Also, there is a significant dilution of the reclaimed water with natural waters so that only a portion of the water being withdrawn by the potable water treatment facility originated from the reclaimed water.[28]



The only city in the world widely identified as engaging in direct potable reuse is Windhoek, Namibia. Wastewater is one of three sources for raw water treated at the drinking water plant; the other two are surface waters (collected at the Goreangab dam; this water is

[28] WEF, 1998.

often found to be of poorer quality than treated wastewater, especially during times of drought) and groundwater from boreholes. Wastewater is first treated at the Gammans water treatment plant, where it receives preliminary, primary, and secondary treatment before being piped to the New Goreangab Water Reclamation Plant. There, the wastewater effluent is mixed with surface and groundwater before entering additional phases of treatment that prepare all the water for distribution (shown in diagram, pg. 10).[29]

Proportions of the water vary depending on the quality of water available from the Goreangab dam, but the system (when built in 1969) was intended to blend the water so that no more than 35% of the final product was reclaimed wastewater. At times that level has ascended to 90%.[30] Water quality is monitored closely and carefully, and adheres to standards based on a host of international templates, including standards by the U.S. EPA, the European Union, and the World Health Organization. The program runs in coordination with a water demand management campaign that has been very successful in reducing water consumption in the city, a necessity in a hot, arid place where a great deal of water is lost simply through evaporation.[31]

While Windhoek's direct potable reuse system has operated consistently and successfully for nearly forty years, it remains the only example of its kind in the world. Denver, Colorado, held a five-year demonstration project to determine the safety of direct potable reuse, and determined that it was absolutely safe – but the city got no further than implementing a non-potable reuse scheme, despite the findings.[32] As more and more indirect reuse projects are proposed, and as pristine water sources grow increasingly difficult to find, the day may come when more communities will commit to direct reuse.

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[29] du Pisani, 2006 (also image source)
[30] Lahnsteiner and Lempert, 2007.
[31] du Pisani, 2006.
[32] WEF, 1998.

Cloudcroft, New Mexico

The new wastewater reclamation project in Cloudcroft, New Mexico, represents the United States' first move in the direction of direct potable reuse. The system goes into effect this year, and when in operation will reclaim 100% of wastewater produced in the village.[33] It is important to remember that reclaiming 100% of wastewater does not free a community from dependence on outside, or naturally occurring raw water sources, since approximately 30% of water distributed will always be lost to consumption, evaporation or ground seepage. However, recycling 100% of wastewater is a vital element in responsible use of water, and the people of Cloudcroft are pioneers in this area. They also outstrip other U.S. communities in the directness of their reuse; after treatment, wastewater is blended 50 / 50 with spring and well water and left in a reservoir for only a few weeks before intake into the distribution system.[34] While this still represents indirect reuse, it is far more direct than aquifer recharge programs and similar projects. Public squeamishness often puts the kibosh on potable reuse projects; as du Pisani writes:

> Reclaimed water is widely used for aquifer recharge, during which time it loses its identity as sewage water. [. . .] At Goreangab, the history of the feed water is recognized as treated sewage, and treatment is designed to cope with just that.[35]

No one in Cloudcroft is likely to forget the history of their water, either.

Cloudcroft, New Mexico, is a small village in Otero County, home year-round to approximately 750 people. On weekends, however, the population can swell to 2,000, as tourists head

[33] Flush with a New Idea, *Waste News* (2005, November 7).
[34] Wastewater swells water supplies, *High Country News* (2007, September 26).
[35] du Pisani, 2006.

up into the Sacramento Mountains to enjoy cool weather and golf in the summertime and skiing in the winter. The village is 8,700 feet above sea level and has a land area of 1.1 square miles. Annual precipitation under non-drought conditions is 33", including 7.7' of annual snowfall.[36] On weekdays the town uses approximately 140,000 gallons of water, but on Saturdays and Sundays that number can swell to 220,000 gallons – although wells in the town produce only 150,000 gallons per day in non-drought conditions.[37] Meanwhile, every day the village produces between 80,000 and 100,000 gallons of wastewater.[38]

The village has long depended on melting snowpack to feed local springs and groundwater, the traditional sources for freshwater. A prolonged drought brought all thoughts of water security in the area to an end. By 2004, the village was forced to declare a water emergency, as spring flows had dropped precipitously, and private wells had been going dry for two years. The village had water rights to three times as much water as they were able to get out of the ground, but with no water left to be pumped, they began running out of options. Finally the village had to resort to hauling water up the mountain in tanker trucks. The village trustees and county commissioners declared a water crisis, which enabled them to access state funding to cover 75% of the cost of hauling the water, alleviating some of the burden but none of the fear of what would become of their town when the water ran out.[39] The village rationed water and tried to think of a way out of their predicament that would not entail loss of tourism as a driver of their economy; tourists would hardly come to spend time on golf courses with no grass or ski slopes with no snow. Cloudcroft needed a new, reliable source of water, and fast.[40]

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[36] Cloudcroft village website; Idcide.com

[37] Cloudcroft Declares Water Emergency, *Associated Press State & Local Wire* (2006, June 23); Wastewater swells water supplies, *High Country News* (2007, September 26); Flush with a New Idea, *Waste News* (2005, November 7).

[38] Flush with a New Idea, *Waste News* (2005, November 7).

[39] Couldcroft Will Haul In Water Starting Monday, *Alamogordo News* (2004, August 14)

[40] Flush with a New Idea, *Waste News* (2005, November 7).

Village leaders worked to develop both short- and long-term solutions. They eventually arrived at a three-part, long-term solution which involved: 1) closely examining existing infrastructure for leaks and fixing any that were found, ensuring that water was not being used frivolously by residents, and making sure that all incoming "wet" water was being collected and used to its maximum potential; 2) installing a new technologically advanced water treatment system that would allow the community to reuse its wastewater as drinking water; and 3) finding a new, reliable outside water source to augment their supplies.[41] State support was invaluable to the village in financing the construction of the wastewater treatment plant. In 2004 the city received $636,000 from Governor Bill Richardson's Water Innovation Fund. The other $1.4 million needed to pay for the project came from funds provided by the State Water Trust Board and annual grants from the state legislature.[42] Technical plans for the facility were drawn up with the help of engineers from the University of New Mexico and New Mexico State University.[43]

Cloudcroft's wastewater treatment system produces water suitable for both non-potable and potable reuse, allowing for total reuse. All wastewater entering the system undergoes preliminary filtration through fine screens to exclude grit, and then undergoes an aerobic biological treatment using activated sludge and a high-pressure, external, ultrafiltration membrane bioreactor that separates the liquid from any suspended solids. The membrane's pores admit no particles larger than 0.1 microns, which also removes some bacteria, pathogens, and viruses.[44] The water is disinfected using chlorine, then progresses through two settlement tanks before traveling three miles downhill (pumped solely by gravity, due to elevation differences between the two plants) to the water treatment plant, where it undergoes reverse osmosis, another membrane procedure that filters out

41 Kurland, 2007.
42 Flush with a New Idea, *Waste News* (2005, November 7); Water-saving projects get $10 million from state, *U.S. water news online* (2004, December).
43 Hanson et al.
44 WEF, 2006; Kurland, 2007; Hanson et. al.

particles larger than 0.001 microns. At this point, the permeate, or water that has passed through the reverse osmosis filter, is disinfected again, and sent to a covered pond or storage tank where it mixes in equal proportion with raw water from local springs and wells. Water and substances that did not pass through the membrane are siphoned off and stored for non-potable reuses like fighting fires, watering Cloudcroft's golf courses or producing snow for the ski resort. After three to four weeks, the blended water reenters the water treatment plant, where it undergoes ultrafiltration and is disinfected again before entering being distributed as drinking water. It is anticipated that the system will reuse roughly 80% of the town's wastewater for potable uses, and 20% for non-potable.[45]

How did a little tiny mountain village in New Mexico accomplish what San Diego could not? Its size may well have been an asset. Where the 1.3 million people living in San Diego might not all be aware of their city's water-related problems, the 750 people who call Cloudcroft home realize both that their tourist economy is uniquely dependent on water and that their wells have started going dry. A prolonged drought that resulted in the village several times declaring water emergencies and instituting use restrictions could not have gone unnoticed. And perhaps, when village administrator Michael Nivison, who shares his name with the local library, came to them and announced that the village was running dry, they knew him well enough to trust and believe him.

However it happened that Cloudcroft was able to overcome the "yuck factor" and face up to the need to embrace "toilet-to-tap," the village's threefold approach is a model of sustainable water use by addressing waste, reuse, and sustainable augmentation. Meanwhile, the city's use of its wastewater is more direct, and allows for less squeamishness, than any other reuse project in the country. As climate change, increasing urbanization, and growing populations force us to be more aware than ever of the sources and cycles of our freshwater, perhaps other cities will look to the tiny village of Cloudcroft and be inspired to emulate its policy of responsible, sustainable water use.

[45] WEF, 2006; Kurland, 2007; Hanson et al; Flush with a New Idea, *Waste News* (2005)

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