12-2019

Economic and Strategic Analysis of America's Wastewater

Jorden Hansen
jhansen04@unomaha.edu

Recommended Citation

Hansen, Jorden, "Economic and Strategic Analysis of America's Wastewater" (2019). *Theses/Capstones/Creative Projects*. 74.
https://digitalcommons.unomaha.edu/university_honors_program/74

Economic and Strategic Analysis of America's Wastewater

University Honors Program Senior Thesis
HONR 4980: Thesis
University of Nebraska at Omaha
Jorden Hansen

Advisor - Dr. Christopher Decker
Submitted – 12/15/2019

This thesis has been accepted as partial fulfillment of the requirements
for completion of the University Honors Program of the
University of Nebraska at Omaha.

Christopher S. Decker
Thesis Advisor

12/16/2019
Date

Director of the Honor's Program

Date

Student

12.15.2019
Date

Table of Contents

Abstract

Whether it be tap water from a home or bottled water from a grocery store, clean water is generally accessible in the United States. Unfortunately, this convenience deters people from learning about the complex processes that make this luxury possible.

Awareness of the natural water cycle is widespread, as the simplest version is taught in grade school. It illustrates the flow of water as it changes state (liquid, to solid, to gas) in the environment. Not so commonly known is the urban water cycle which manifests residential daily use with the revolution of water. The urban water cycle is a six-step process enabling water used residentially to return to nature safely for reuse. Wastewater collection and treatment play an important role in this process. A clear understanding of these processes is established before discussing the wastewater industry.

Wastewater is an important industry facing change. New expectations and policy requirements are shifting industry norms. Due to capital and resource limitations, water pricing, management, and investment decisions are under strict scrutiny. An external analysis, through the PESTEL framework, points out the highest impact forces affecting the wastewater industry. The top six forces currently shaping the industry are privatization, price structures, urbanization, aging infrastructure, climate change, and water laws. After analyzing these trends, a glimpse into the future direction of the industry will be summarized.

Personal Interest

My interest in this topic comes from a previous internship with Kiewit Water Facilities South District. During the Summer of 2019, I worked on the Franklin WRF Modification and Expansion project. The scope of work was updating existing infrastructure and building a new solids processing building. Following project completion, the plant will have the capacity for an additional 16 million gallons per day and the ability to create class A biosolids. I frequently took advantage of being on-site by asking the engineers and craft employees to teach me about their work. This ultimately intrigued me to learn even more about the wastewater treatment process.

Water

“Water is the divine source of all living things”, said Greek philosopher Thales during the 6th century B.C.; and the truth of that statement has not changed since. Earth’s entire ecosystem depends on the availability and cleanliness of water to sustain life. In fact, water is the second most common molecule in the world behind hydrogen.

Total water volume on earth is between 1.3 and 1.4 billion km^3. The National Environmental Education Foundation (NEEF) found the top three uses of freshwater in the United States are thermoelectric power (45%), irrigation (32%), and public supply (12%) (Bradford). Powering the states, irrigating the world’s crops and farmlands, and providing for everyday life are just some of the purposes water serves. In addition, water plays an important role in manufacturing and mining processes, generates hydroelectric power, provides transportation by waterways, and makes recreational use possible. Earth’s climate would be un-livable without the massive presence of water.

Most of the water covering earth’s surface, 97.2%, is saline with another 2.15% captured in glaciers (Miller, Benjamin, & North, 2016). The remaining 1% of water is then to be distributed for public use. Public use is comprised of commercial and industrial businesses, as well as residential and community needs. Humans, plants, and animals all need an abundant water supply to remain healthy. For example, a human’s body weight is nearly 75% water! Freshwater makes our lives possible but also plays a vital role in making our lives easier, cleaner and more enjoyable.

Water can be thought of as a renewable resource, given proper treatment and release processes. Fortunately, water circulation is a closed system, meaning water doesn’t ever leave the earth. The resource is considered scarce because mother nature does not distribute water evenly, causing allocation challenges. Thus, other resource costs such as infrastructure, labor, and maintenance must be incurred to move water where and when it is demanded. This idea of water as a renewable resource is further explained by the hydrologic cycle, which illustrates how water moves throughout the planet, and the urban water cycle, which illustrates how water moves throughout urban areas.

As supply and demand for the resource change, water processes and management are under more pressure to fully capitalize. When faced with a shortage, the options of enhancing supply, managing demand, or integrating the two, are presented. For years, water shortages have been solved with supply enhancements such as enlarging dams, drilling wells, and building new plants (Griffin, 2016). With time, these supply improvement solutions have become more expensive and harder to execute. Water is physically limited, meaning continuously building new infrastructure will restrict water availability elsewhere. Due to lowered efficiencies and increasing infrastructure costs, demand management solutions are suggested to yield a greater return for the long run. Demand management includes everything from establishing policies around water rights, to enforcing higher prices or conservation requirements (Griffin, 2016). These demand focused reactions have a clear emphasis on environmental responsibility: an increasingly important topic across the globe.

Hydrologic Cycle

Water is continuously moving through the environment and transforming its state due to temperature changes. The natural water cycle, also known as the hydrologic cycle, is simplistically described as evaporation, condensation, and precipitation. The sun's heat causes bodies of water, like the ocean, to evaporate. Along with water transpired from plants (evapotranspiration), the vapors rise into the air. The second part of the process, condensation, is caused by cooling temperatures as the vapors continually rise. In the atmosphere, the particles turn back into a liquid state and condense together to form clouds. With continued condensation, the particles combine until they are heavy enough to fall to Earth's surfaces in the form of precipitation. Snowfall accumulates as ice caps and glaciers, while rain becomes surface or groundwater.

The most cost-effective and sustainable source of freshwater emerges from this natural cycle. The world receives roughly 113,000 cubic kilometers (3 quadrillion gallons) of rainfall each year (Miller, Benjamin, & North, 2016). Individuals can take advantage of the hydrologic cycle through the collection of rainwater, to reduce water demanded from a public water utility. Rainwater harvesting collects (typically with a roof) and stores (typically with a tank) rainwater for later use. It is becoming more popular for homes to implement a collection system as benefits are realized. Easy maintenance has enticed people to adopt this habit for irrigation and non-drinking uses. It also has the benefit of eliminating potential floods and soil erosion, as it decreases the volume of water penetrating the ground during a short time interval. Rainwater collection is legal at the federal level and all 50 states are supportive with few regulating collection limits and methodology (Castelo). The trend has yet to be widely accepted due to unpredictable results, high initial costs, and regular maintenance costs. Storage limits and water contamination present additional challenges to overcome.

Rainwater collection, as a product of the natural water cycle, has the potential to dramatically impact how water is supplied to residents in the United States. But until rainwater capture yields substantial sustainable benefits for the average resident in the United States, freshwater will continue to be derived from other sources. The more prominent processes for water use are captured in the urban water cycle.

The Urban Water Cycle

In engineered environments and on local scales, a different water cycle becomes apparent. Figure 1 shows the six-step process that moves water from a source to treatment, distribution, and use, to later be collected and retreated before returning to the environment. Nearly every urban city in the United States, both small and large, uses a variety of this cycle to provide water to its residents and communities.

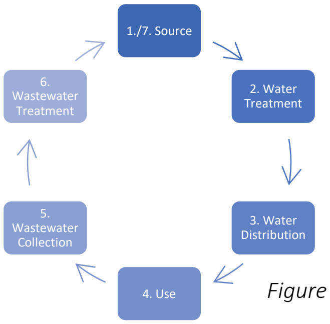


Figure 1: Urban Water Cycle

Step 1: Source

The urban water cycle begins with extraction from either a ground or surface water source. Nearly 27.4 billion gallons of water are withdrawn and delivered to residents from surface water or groundwater sources each day (Blount). The source location is chosen based on quality and availability, proximity to the user, as well as economic and legal considerations. Of all usable freshwater, 97% is groundwater (SDWF). Groundwater navigates through cracks and spaces of soil until it reaches the water table and aquifers. Groundwater extraction typically requires a less rigorous treatment process due to low pollution levels. Low treatment costs paired with availability benefits make groundwater a more convenient and prominent option of supply for single homes and small towns.

High, unsustainable extraction rates without consideration of replenishment rates pose a threat to future water supplies, especially in large cities. After it rains, it can take decades for groundwater to replenish, making groundwater sources increasingly costly due to scarcity. Currently, sourcing from lakes, rivers, and other bodies of water have a more expensive treatment process. Although, with increasing groundwater costs, these alternative surface water solutions emerge and become economically justifiable.

Step 2: Water Treatment

The second step in the urban water cycle is water treatment. After extraction from a water source, the water must undergo a disinfection process to be safe for use. The process length, complexity, and methodology vary depending on the location of where the water is sourced. A variety of pollutants affect water quality: biodegradable wastes, fertilizers, industrial wastes, sediment, and hazardous discharge. The 5-step treatment process represented in Figure 2 works to remove these pollutants.

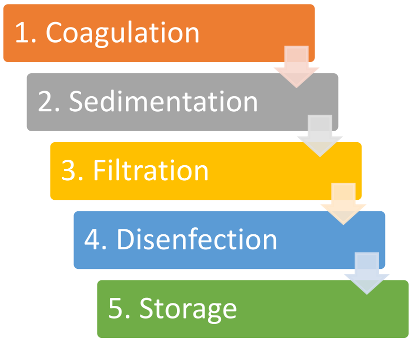


Figure 2: Water Treatment Process

Step one is coagulation, the process of changing a liquid into a solid. Positively charged chemicals are added to the water, which stick to negatively charged contaminants such as dirt. The particles combine and form clumps called floc. The second step is sedimentation, where floc is separated by settling to the bottom of the tanks to be removed. Third, water flows through a variety of filers (sand, gravel, or charcoal) to remove even smaller particles from the water such as dust, parasites, bacteria, viruses, and chemicals. To kill any remaining contaminants the water goes through the fourth step, disinfection. Chemicals, typically chlorine or chloramine, are added to the water as a final caution to thoroughly prep the water for use. For cities, the clean water is then stored either in the ground near the facility or in elevated water towers.

Step 3: Water distribution

The third step of the urban water cycle is water distribution. After the water has undergone treatment it is sent through an underground pressurized system comprised of pipes, pumps, valves, and storage reservoirs. Through this system the water is transferred either directly from the treatment facility or from a storage tank to its final destination. The U.S. has nearly one million miles of water distribution systems (EPA).

Public water systems are categorized by community and noncommunity systems. The differentiator between the two is whether the same community is being served year-round (CDC). Examples of community systems are residential areas, mobile home parks, etc., as the population served rarely alters. However, noncommunity systems such as gas stations, public schools, etc., do fluctuate consumers. “Of the approximately 155,693 total public water systems in the United States, 52,110 (33.5%) are community systems and 103,583 (66.5%) are noncommunity systems” (CDC). Also, eight percent of community water systems provide water to 82% of the U.S. population through large municipal water systems (CDC). Although noncommunity systems are more numerous, community systems serve a larger proportion of the U.S. population.

From the many distribution system types, two main systems emerge as seen in figure 3. Dead-end systems, also known as tree systems, have multiple dead-end lines off the main. This system type is easy to construct and expand while being cost-efficient. Drawbacks of this system are stagnant water and loss of supply for large areas during maintenance. In a grid iron system, water is in constant motion and has a variety of paths to reach a single destination. The design of a gridiron system is more complex and requires well-thought-out planning (Layout 2012). The combination and execution of many system types creates the availability of water for Americans across the country.

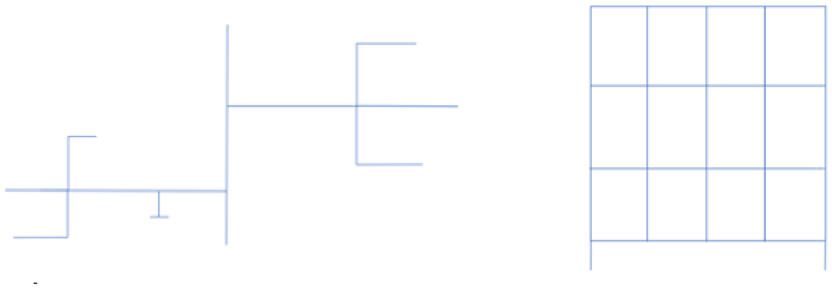


Figure 3: Tree Vs. Grid Iron Distribution System Types

Step 4: Use

The fourth step in the urban water cycle is use. Water is oftentimes used without conscious realization of the quantity being consumed. Americans use an average of 80-100 gallons of water per day indoors, which creates nearly equivalent amounts of wastewater daily. Toilets are the top contributor to residential indoor water use as they account for 26.7% (EPA). Older toilet models flush up to seven gallons, while new models are working towards flushing only one gallon. Showers (16.8%), faucets (15.7%), and appliances (21.7%) such as washing machines, represent the following top contributors of water use, respectively (EPA). Aside from residential use, commercial buildings such as restaurants and industrial buildings such as manufacturing facilities, also use enormous amounts of water. All these water uses combined contribute to the production of wastewater. Depending on what the water is used for and its geographic location, different collection methods are used.

Step 5: Wastewater collection

The fifth step of the urban water cycle, wastewater collection, is essential to begin the process of recycling water. After the contaminated water is flushed or washed down the drain, it is consolidated in a sewer system. Sewer systems are typically laid beneath roads, with manholes created at essential access points. The wastewater moves underground by a gravitational system comprised of piping and/or exhauster tracks. Many kinds of sewer systems exist such as simplified, solid free, pressurized, and vacuum sewers. Although in urban areas, two main system designs prevail: combined sewer systems and separate sewer systems.

As storm and surface water flow through the streets into storm drains, this water can be added to wastewater collection networks or kept separate. Combined sewers are an old system design that carries domestic sewage as well as stormwater (see figure 4). During dry weather, sewage is successfully sent to a publicly owned treatment works (POTW). During timeframes with excess rainfall or snowmelt, combined systems are designed to overflow into a public surface water. This eliminates harming infrastructure or sending too large of capacities to the wastewater treatment plant. The overflow not only contains stormwater, but also untreated human and industrial waste, toxic materials, and debris, which presents public health concerns (EPA). With increased legalities, sewer systems are no longer constructed as combined, but have switched over to separate sewer systems.

With only an estimated 700 cities still running on combined systems, separation has proven to be productive. With two separate systems (sanitary sewers and storm sewers), wastewater and stormwater remain apart. Separate systems are a healthier alternative and create treatment efficiencies as not all wastewaters require equal amounts of treatment. Stormwater, which is far less polluted than residential or commercial wastes, flows back into a nearby body of water. The highly contaminated wastewater is combined to undergo a more comprehensive treatment process at a facility. This ensures resources are spent where necessary and saved where possible. Due to the implementation of two systems, construction costs are higher, but it provides an array of benefits. This system reduces residential flooding, lessens ecological health risks, and reduces water-borne diseases spreading during overflows.

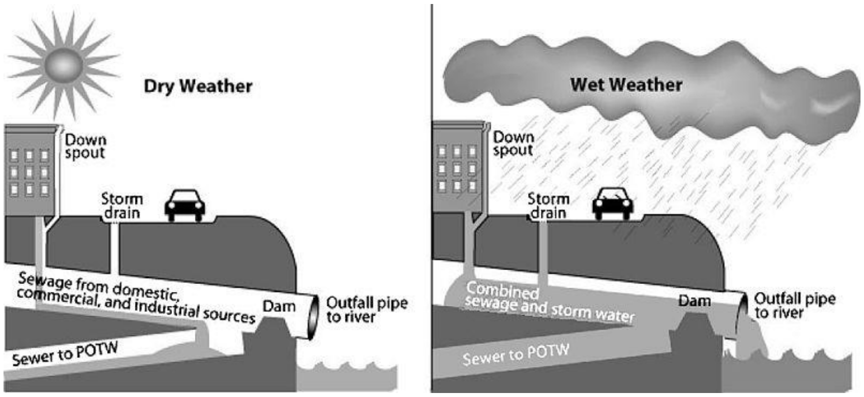


Figure 4: Combined Sewer Design
Source: all-geo.org

Step 6: Wastewater Treatment

The final step of the urban water cycle is wastewater treatment. The typical water influent is 99% water and less than one percent waste (Sowby, 2014). Prior to returning the wastewater to the environment it must undergo a treatment process to ensure it is safe. The two main types of treatment plants are biological and chemical. Biological systems are more common and are mainly used to treat household and business wastewater. Biological systems use bacteria to break down and remove simple compounds such as carbohydrates, starches, proteins, sugars, etc. The system has low operating costs and therefore is typically a more cost-effective design. Alternately, a chemical treatment plant is mainly used for industry, factory, and manufacturing wastewater. Chemical systems typically add calcium or sodium hydroxide to remove toxic metals that bacteria are unable to effectively remove. Chemical systems are a better solution for these industries as the water needs more extensive treatment prior to being returned to the environment.

At a biological wastewater treatment system, water first goes through pretreatment. The influent is screened through filters to remove large items such as feminine products, flushable wipes and other articles that could damage equipment. Waste solids from this process are transferred to a nearby landfill. The next step of the preliminary process is removing heavy and inorganic materials such as dirt and sand through grit chambers. Then, the water flows to a primary clarifier which uses settling velocity to force sludge to the bottom of the tank. The settling velocity is determined by the number and size of clarifiers at a plant and flow rates, to ensure the water leaves with less biological materials.

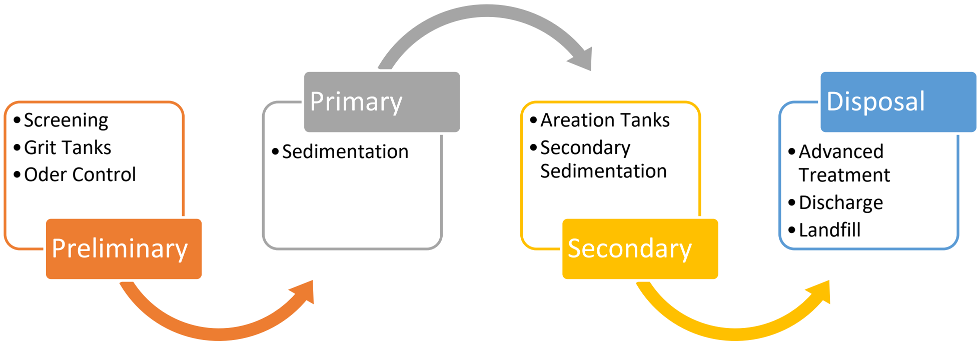


Figure 5: Biological Wastewater Treatment Process

Secondary treatment starts with primary sedimentation where organic materials are removed from the water. It then flows to aeration tanks where bacteria eat organic matter through an aerobic or anaerobic process. Aerobic treatment is typically more expensive due to the use of electricity, but typically produces higher quality water. The next step of secondary treatment has final clarifiers remove any biomass created from the previous step. Disinfection is the final step where chlorine, ozone, or ultraviolet radiation is chosen based on flowrate, location, and cost. After a total process time of 24-36 hours, the sanitary water leaves the plant and is discharged into a body of water.

Process Summary

Most urban settings use these steps to manage urban water usage. After the water is withdrawn from a natural source, it is treated and distributed for residential or commercial use. The process of recycling water begins with wastewater collection. The water is treated, likely at a wastewater treatment facility before safely returning to the natural environment.

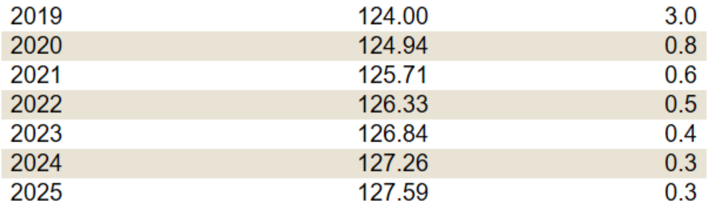
This is not the only cycle present for water recyclability, but it is the most common. 76% of America's population relies on centralized wastewater treatment system like the one described above. A variety of other wastewater treatment options are available, such as decentralized options (cesspools, septic tanks, etc.) in more remote locations. Treatment processes are extremely precise and scientific. Small overlooks and mistakes can lead to issues in affluent streams, which is why wastewater management is such an important field. Together, these systems provide a comprehensive cycle of water that contributes to America's quality of life.

Industry Background

The latter half of the urban water cycle focuses on the collection and treatment of wastewater, which are critical processes in providing reliable water services. In 2018, the wastewater treatment industry, including public and private facilities had total revenues of $47 billion, $7.1 billion of which were profits (IBIS World, 2019). Of all wastewater treatment revenues, 64.2% came from residential sources, 20.1% from government facilities, 12.3% from commercial facilities, and the additional 3.4% is from industrial businesses (IBIS World, 2019). Larger commercial and industrial facilities contribute minimally to revenue due to cost savings by installing their own systems. With nearly 20,000 cities in the United States, there are approximately 15,182 businesses in the industry (IBIS World, 2019). In the wastewater industry multiple external drivers are growing demand and market structure is experiencing change.

The industry has experienced a steady 1% growth rate for the past five years and is expected to grow an additional annualized rate of .6% over the next 5 years (IBIS World, 2019). This suggests a mild expected growth compared to the 23% growth by 2032, the Infrastructure Report Card expects (ASCE). One main contributor to the industry's growth is growing total number of households in the U.S. (see figure 6). The total number of households in the U.S. has been increasing since 1960 (Duffin, 2019). This requires upgrades or additions to current capacity limits. Another contributor to industry growth is increased funding for utility infrastructure (IBIS World, 2019). The value of utilities construction expenditures is expected to grow a compounded .42% between 2020 and 2025 (see figure 7) (IBISWorld, 2019). Other growth drivers are water demand and average annual precipitation.

Figure 6: Number of Households in the U.S. 2010-2019 (In Millions)
Source: Duffin, 2019



2019	124.00	3.0
2020	124.94	0.8
2021	125.71	0.6
2022	126.33	0.5
2023	126.84	0.4
2024	127.26	0.3
2025	127.59	0.3

Figure 7: Expected Value of Utilities Construction 2019-2025 (In Billions)
Source: ibisworld.com

Natural Monopoly

The market structure of the wastewater management industry is unique. It is one of the few services to be named a monopoly. Wastewater services are nonrival and excludable. Nonrival describes how the number of users does not affect consumer utility and excludable describes how consumers must pay for the services. These two characteristics describe a natural monopoly. Municipalities typically have one water owner, as the costs to society are greater where competing firms exist. A distinction of this market type is high fixed costs. Imagine the costs of constructing two competing wastewater systems in one area. Society would experience inconvenience and wasted resources, and benefits would not be realized (Warady, 2019). Another distinction of this market type is subadditive costs. This explains production by one firm is cheaper than if multiple companies joined the market. This holds true in the wastewater industry due to economies of scale and economies of scope. Market structure is one of the many trends impacting the industry that will be analyzed in the external analysis. A variety of other trends have emerged that also affect wastewater efficiencies.

External Environment Analysis

An analysis of the industry's external environment will help define how best management should respond when an action or decision is needed, by showcasing current and upcoming opportunities and threats. Creating a strategy around these findings will help improve the efficiency and effectiveness of operations in the wastewater industry. A common mnemonic used in business to organize the analysis of external forces is PESTEL. The mnemonic denotes political (P), economic (E), sociocultural (S), technological (T), ecological (E) and legal (L) forces. When considering new policies, analyzing productivity or preparing a strategy, this framework can help organize a variety of macroeconomic pressures that have the potential to impact industry performance. Due to the variety and depth of forces that impact this industry, this report is noncomprehensive. This PESTEL analysis will analyze the substantial force in each category that is currently affecting the U.S. wastewater industry.

Political

The first category of the PESTEL analysis is political (P). It refers to the processes and actions of government bodies that may affect regulations, and ultimately decision making in the industry. Planning around political pressures is a proactive approach to strategy. Because policies have the potential to transfer into legal requirements, it is beneficial to examine policies in preparation for enforced change in hopes of overcoming complications early on. Utilities are heavily regulated by government agencies due to their natural monopoly market structure; therefore, political pressures have substantial influence over operations. There are varying political philosophies about the ownership of water rights and distribution requirements of water.

In the past, government ownership of utilities was proven to be the preferred, widely accepted practice. It has become increasingly difficult for government entities to balance affordability for consumers while creating budgets to maintain these vital systems. Privatizing the water market has been a popular solution to overcome difficulties. After a city council majority vote, municipalities can outsource ownership rights to private companies in hopes of better meeting consumers' demand. This also frees up city budget to be spent on other public needs. Private systems are typically for-profit and managed by investors or shareholders (Kopaskie). As of 2016, 19 of 52 states had more private water systems than public, but 50 out of 52 states (including District of Columbia and Puerto Rico) have a larger portion of their population served by public rather than private systems (Kopaskie). This implies many small governments are giving their water rights to the private sector, while large municipalities are maintaining control of their system.

The trend of giving private companies ownership rights of water is founded on efficiency. Private ownership and consolidation are intended to create economies of scale and higher margins. If private companies are overseeing multiple facilities, they could reap additional benefits. For example, consolidated maintenance contracts could lower yearly expenses and larger insurance policies could aggregate risk. The U.S. private sector is suggested to have the capital, technology, and innovational labor available to improve the industry's efficiencies. Private sector ownership rights have been introduced in a variety of different structures.

Complete private ownership, contractual ownership, and public-private partnerships are all growing solutions for the need to cut costs while investing in improved infrastructure. Private sector ownership involves an asset sale, where a private company buys a water system from a government entity or establishes a completely new one. Another option of privatizing a utility is operation, maintenance or management contracts. In this solution, the city government still owns water rights and infrastructure, but a private company operates and/or maintains the system. The final privatization solution is a public-private partnership or mixed system. One execution of this is a government agency providing neighborhood standpipes for those consumers unwilling or unable to pay for private distribution. Those consumers unhappy with the inefficiencies of public distribution can then purchase water from the private sector for a higher cost.

As investor capital increases and service agreements become more popular, the entry barriers for private ownership are decreasing (IBIS world, 2019). This encourages more private companies to enter the market and compete for ownership. Multiple companies are not competing against one another within a city's water infrastructure, but instead competing for city water ownership rights. An increase in competition results in more competitive pricing. This will ultimately lead to smaller margins for new and existing companies. This poses a potential threat as profits are spent on maintenance and operational costs.

Some studies have shown inefficiencies in privatization. "Private utilities charge the typical household 33% more for water services, and 63% more for sewer services" (Food & Water Watch, 2009). Depending on what these margins are being used for, this could lead to positive or negative externalities. An econometric study from professors at Cornell University and University of Barcelona found that private utilities are not more efficient than public. In addition, financing is typically more expensive for private companies (Food & Water Watch, 2009). Complete privatization can be detrimental because private companies could take advantage of and exploit their position. In some cases, it led to corruption, excessive pricing, and the inability to reverse (Whitfield & McNett, 2014, p. 78). Instead of focusing on which ownership is better, the focus should be on government policies being able to either provide satisfactory water services or regulate private companies that provide those services.

Economic

The second category of the PESTEL analysis is economic (E). This category analyzes the local or global state of the economy. Topics such as interest rates, exchange rates, recession, unemployment, market prices, growth rates, etc. are included in this category. Traditional government-owned systems charge water rates differently than the new privately-owned systems do, which reflects differing abilities to improve infrastructure. The prices consumers pay affect affordability and conservation behaviors.

Historically, water has been managed by local governments and municipalities and priced by a governing board. Due to controversy surrounding the ethics of profiting from water provision, governments typically charge a moderate rate to consumers. Water is one of the only resources whose prices are not solely dependent on scarcity, cost of service, replacement cost, volume of use, or any other common mechanism. The process of supplying water to a home is a separate process and system than the removal of wastewater from a home. Sewage rates are commonly included in water rates, such as a percentage of the total water bill, or as a fixed rate. Some cities, unconcerned with capacity and environmental issues, charge water services close to average variable cost near their break-even point. During water shortages prices are often left consistent which steers the market further away from equilibrium and makes resource use unsustainable. When under-charging occurs, infrastructure costs such as pollution control, transportation costs and management expenses, are not accounted for (Schmidheiny, 1992). To combat these challenges, many water utilities are raising their prices.

The prices Americans pay for water and wastewater services have increased faster than inflation. Bluefield found 35 of the top 50 U.S. metropolitan areas raised their water and wastewater rates from 2018 to 2019 (Layne, 2019). Three main factors contribute to high sewage prices relative to water prices: system design, population served, and system complexity. Unlike the pressurized pipes of drinking water, wastewater typically flows by gravity, therefore the pipes must be installed deep in the ground. This increases construction costs because activities such as excavation and removal of bedrock are required. The increase in costs is passed along to the consumer. In addition, the number of people who rely on wastewater treatment plant services affect price. Throughout the United States, it is common for rural households to use private systems. When a small number of households rely on a centralized facility in a specific location, the costs distributed per person are higher. The final cause of high sewage rates is the increased complexity of systems. When operational, maintenance, and replacement costs are not reflected in user fees plants operate at a financial loss. This is not uncommon in the United States which unfortunately leads to inadequate planning and funding for upgrades and improvements (Adjangba, 2015). Prices are later raised to try to recoup these costs. “Americans this year will pay an average of $104 per month in water and wastewater bills, up more than 30% in less than a decade” (Layne, 2019). Without consideration of the benefits, higher monthly water bills appear to be a bad thing. For some locations, increases in wastewater costs cause affordability issues.

Affordability

Michigan State University found water is unaffordable for 10% of U.S. households (Layne, 2019). It is a challenge to charge enough to ensure the essential resource is available to everyone. But lowering the price and operating at a loss presents additional problems. “The World Water Commission members agreed that the single most immediate and important measure that we can recommend is the systematic adoption of full-cost pricing of water services” (World Water Commission, 2000, p. 33). Because water supplies are scarce, marginal user cost should be considered. User cost is the reduction in value of an asset due to use. For example, using up scarce water resources today implies less available in the future. In this scenario prices should be higher to reflect the differences in marginal benefits and marginal costs. Having policy considerations for low-income households is the best way to combat the problem of affordability. Across the nation a variety of price structures have been implemented to find a pareto optimal outcome. Geographic locations have varying priorities based on the residents. Utility companies are tasked with identifying the price structure that best achieves the community’s priority objectives.

Conservation

The implementation of increasing costs situationally varies. Some possible tariffs include connection charges, fixed charges, volumetric charges and block charges. The most common price structure is called lifeline rates, which is a two-part system comprised of fixed and variable costs. This suggests, the national required water consumption per person to be supplied at a rate affordable to all. Consumption above this rate is at one’s discretion for a higher cost. This policy accommodates low-income households, while also encouraging conservation. Three additional structures have been successful in limiting water depletion: time of day pricing, water surcharges, and seasonal rates. In the United States, 66% of water utilities use a form of these consumption minimizing strategies to price water usage (Adjangba, 2015).

Increasing prices proves to be beneficial for equity, efficiency, and sustainability (Rogers, Silva, & Bhatia, 2001). Price increases reduce quantity demanded. Research shows demand for water is like demand for gasoline, in that although it is relatively inelastic, a change in price does in fact change consumption. For water, a 10% rise in price, leads to a 3-6% decrease in demand (Miller, Benjamin, & North, 2016). Figure 8 represents an increase in prices, reflective of a lower quantity demanded at a higher price. An increase in price will also increase supply and allow the market to reallocate resources and improve access for low-income households. These effects will ultimately lead to increased revenues to improve the system for a sustainable future.

Many considerations play into how utility prices are set. For water, operational costs, affordability for consumers, and conservation encouragement are top priorities. Pricing efficiently allows utility companies to have the capital to cover operational costs and invest in infrastructure, while adhering to consumer demands.

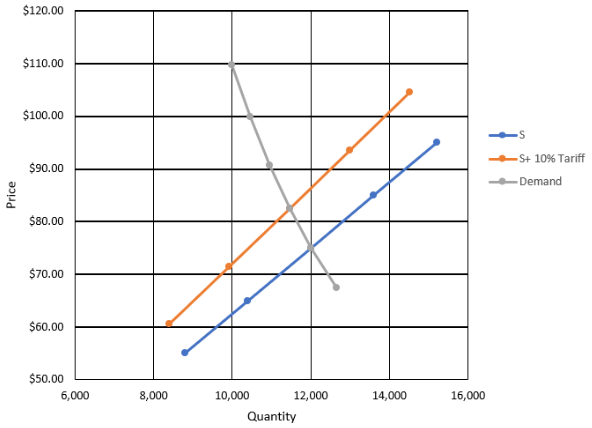


Figure 8: Impact of Tariff on Price and Quantity

Socio-Cultural

The third category of the PESTEL analysis is socio-cultural (S). Societal trends, population data, attitude and lifestyle characteristics, and cultural barriers are included in this category. Consideration of socio-cultural trends help identify potential new markets and products. Knowledge of cultures and societal changes help explain shifts in demand. The continued phenomenon of urbanization is a major force contributing to the growth of the water industry.

Many factors are known to contribute to urbanization. First, continuous improvements in agricultural technology are making farming a less labor-intensive career. To find new career opportunities, rural residents are moving towards urban areas. Second, the income difference between rural and metro areas encourage migration. Inside metropolitan statistical areas, median household income is $64,265, compared to $47,563 outside (University of Michigan, 2019). The third enticement is the wealth opportunities specifically for specialized labor. In the United States more than 300 urban areas have populations greater than 100,000 (University of Michigan, 2019). Grayline Group, an advisory and analytics firm, used the examples of Houston (energy), San Francisco (technology), and New York (finance). The combination of these three factors will continue to shift societal preferences towards living in a city.

Urbanization is expected to continue and will lead to further growth of America’s cities. Recent data of 2019 suggest 84% of US population lives in urban areas, with expectations to be 89% in 2050 (University of Michigan, 2019). In addition, cities are essential for economic prosperity, as U.S. metro economies account for 90.8% of GDP and 87.7% of jobs (University of Michigan, 2019). Urbanization has impacts on rural systems, required urban infrastructure developments, urban land subsidence.

As people move from rural to urban areas, cities face a variety of infrastructure challenges, including providing safe water utilities for a growing population. If rural communities use centralized water and wastewater systems, consumers will be affected. If prices remain constant, fewer utility payments will work to cover constant operational expenses. Over time, this will lead to inadequate maintenance and quality impairments. Alternatively, prices will continuously rise, and consumers will be required to pay more for the same service. As rural populations decrease, fewer people are paying to cover the cost of rural wastewater infrastructure.

Not only does urbanization affect processes in rural areas, but it also has externalities on urban areas. Urban sprawl is the spreading of a city into surrounding rural land removes vegetation to expand developments and create new communities. Between 2000 and 2010, urban land use increased by 15% (University of Michigan, 2019). With less vegetation, there is more runoff and erosion washing sediment into streams and sewers. With massive amounts of concrete, the water that used to soak into the water tables is now flowing into sewers or bodies of water. As buildings and roads are constructed, water systems are expanded or created to support increasing populations. If wastewater ownership/ management is unable to invest in new infrastructure, then current infrastructure is overloaded. Leaks and overflows of deficient systems lead to increased pollution into urban waterways. Out of 315 contaminants detected in a national tap water quality study, 86% were urban-related pollutants from road runoff, lawn pesticides and sewage (University of Michigan, 2019). To combat this problem, governments must make infrastructure maintenance a priority.

To combat a growing urban population, extraction rates of groundwater are likely to escalate to meet increases in demand. When cities drill deep large-capacity wells or over-extract from aquifers, water is removed from the ground at unsustainable rates. High concrete coverage hinders the grounds ability to recharge. Instead of returning to groundwater sources the water runs into sewage drains; therefore, the sediment under the concrete surfaces condenses (USGS). This leads to sinkholes, or worse, land subsidence. In the United States, more than 17,000 square miles in 45 states have been affected by subsidence (USGS). Land subsidence combined with sea-level rise presents further challenges for coastal areas. Switching to shallow groundwater banks instead of deep welling, developing long-term water distribution systems, and routinely pumping water into the ground are some suggested solutions to combat land subsidence.

Technological

The fourth category of the PESTEL analysis is technological (T). This category refers to innovations in the industry that could enhance or affect performance. Topics such as automation, research and development, and technology advancements are examples of forces included in this category. Both product and process innovations are considered in technological factors. Currently, one of the largest forces impacting the wastewater treatment industry is aging infrastructure. Innovative technologies exist but it is difficult for municipalities and local governments to implement such infrastructure.

Every four years, the American Society of Civil Engineers creates a report card that grades the United States' infrastructure by category. Graded based on physical condition, ability to meet demand, and necessary improvements, the United States overall earned a D+ in the wastewater category (ASCE). An estimated $271 billion will be needed in the United States within the next 20 years for infrastructure improvements (over 800,000 miles of public sewers and nearly 500,000 miles of private sewers) to meet forecasted demand (ASCE). Although this is a costly investment, the costs of not investing are greater.

Throughout the United States, infrastructure was created post-war era and is either near or has passed its intended lifespan. It is common for systems to support more people than they were initially intended to support. Many states have a reactionary investment model when it comes to investing in wastewater infrastructure. Once a problem is identified and designated as a priority, funds are sought out to fix it. It's challenging for wastewater plants and collection systems to proactively upgrade to innovative systems before a problem arises, due to resource limitations. Due to outdated infrastructure, freshwater sources on earth have ingested immense amounts of pollution including sewage, chemicals, and debris. Each year, between 1.8 and 3.5 million Americans get sick from drinking tainted water (Hawken, 2014, p. 31). Aged infrastructure such as cesspools, septic tanks, lagoons, and combined sewer systems are examples of inefficient infrastructure systems that are still used, but now discouraged or illegal to install. Current infrastructure, which lacks the implementation of technological innovations, presents a variety of challenges. The largest trend to overcome infrastructure inefficiencies is recycling. The technologies to reuse both sludge and water pose radical changes to the market.

Sludge Reuse

Many states are beginning to place strict regulations on the capacity of sludge taken to the landfill during the treatment of wastewater, which has encouraged industry innovation. One of the most commonly implemented innovations in the industry is biosolids. Biosolids are the outcome from treatment and processes that turn nutrient-rich organic materials from sludge into fertilizer. There are three classes of biosolids: Class A, Class A EQ, (Exceptional Quality) and Class B. This innovative process helps protect both human and environmental health. Biosolids are then used for diverse applications such as fertilizer for farms, gardens and parks, for mine reclamation, timber growth or road base. Land application of biosolids takes place in all 50 states (EPA). This is one innovative solution to a growing concern in the market.

Water Reuse

Another opportunity for innovation in the urban water cycle is to reduce the middle processes. Potable application is the process of creating drinking water from treated wastewater. Two potable solutions exist: indirect potable reuse (IPR) and direct potable reuse (DPR). IPR pumps treated water into a natural basin or reservoir where it naturally runs through the earth before being captured for drinking water. IPR uses an environmental buffer of surface or groundwater, whereas DPR does not require an environmental buffer (EPA, 2017). Regulations vary around potable water use. As of 2017, 14 States have policies to address IPR, and three states (California, North Carolina, Texas) have policies to address DPR. Bluefield expects by 2027, potable applications will account for 19% of total reuse (2017). Texas is currently one of the most developed states regarding water reuse due to recent droughts and natural disasters. The first DPR facility was a $14 million project in the United States in Big Spring, TX. At this facility they use microfiltration, reverse osmosis, and ultraviolet disinfection to treat the wastewater (Martin 2014). This recycled water (20%) is mixed with a raw water pipeline (80%) and sent to a local drinking water facility for treatment (Martin 2014). Depending on geographic characteristics and current water sources, potable reuse can present additional distribution solutions.

Technology in Current Systems

Innovations across the industry are leading to higher efficiencies and better management. Desalination, high-quality sensors, and better water quality measurement techniques are some examples of upcoming technology trends. Desalination provides a solution for coastal locations. To filter seawater to this extent requires a great amount of energy, making the process expensive. Desalination also creates the undesirable by-product of brine, which must be widely disposed of. When large amounts of brine are released into the ocean, it sinks to the seafloor and harms living ecosystems. Continued innovation in this process could provide a solution for geographic locations needing a greater water supply. High-quality sensors throughout a distribution system help monitor flow throughout a system. This can aid how municipalities charge residents. For example, if a city knew the exact level and flow of each household’s wastewater, owners can charge a usage fee rather than the common fixed fee. Finally, innovations in measurement techniques provide better data regarding water quality, such as organism, nutrient and element levels. These new and upcoming technologies are on a per facility basis and vary widely across the nation.

Ecological

The fifth category of the PESTEL analysis is Ecological (E). This category refers to scarcity of raw materials, pollution and carbon footprint goals, and other climate change initiatives. It also involves environmental aspects such as weather and climate, which largely affect industries such as tourism, farming, agriculture, and insurance. Climate change is the main ecological concern for the wastewater industry.

Due to climate change, average annual precipitation volumes are increasing, leading to increased water intake levels at wastewater facilities (see figure 9). Warmer summers cause water to evaporate at faster rates, increasing overall average annual precipitation rates. Water facilities will need to be able to accommodate larger capacities due to runoff into storm drains. In addition, rising temperatures cause plants and animals to require more water consumption. During the winter, climate change causes ice formation to occur at a slower pace, leading to less runoff water feeding into streams and rivers. Because the wastewater industry is dependent on water use, and therefore extraction of water from a source, changes in water supply are extremely impactful. Over time, climate change will continue to affect the industry.

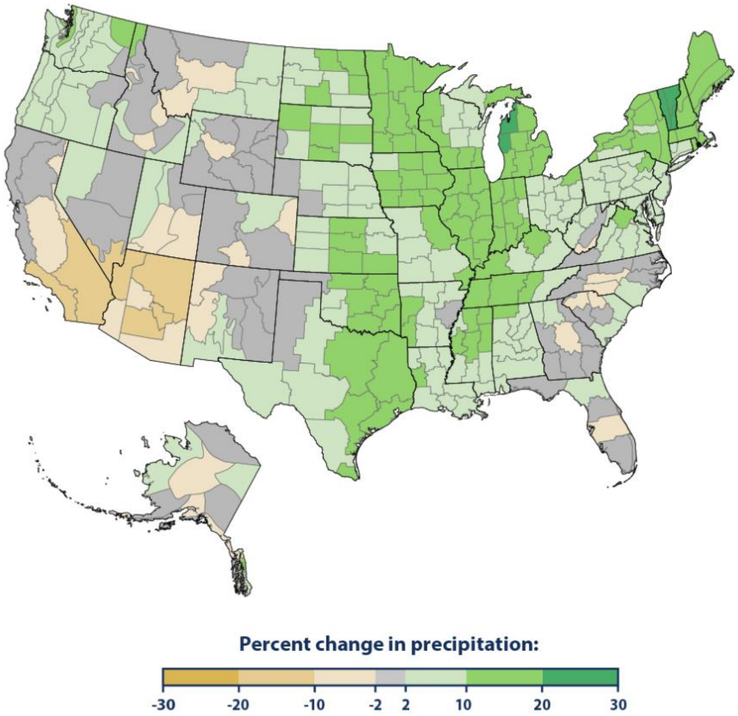


Figure 9: Change in Precipitation in the United States, 1901–2015
Source: epa.gov

Just thirty years ago, regulation allowed thousands of American cities to dispose of sewage directly into public waterways. Today, some areas are still at risk of straight pipes flowing directly into bodies of water, creating a hazard for environmental health. Dumping sewage into bodies of water has negative impacts on marine life health. “The EPA estimates almost 1.2 trillion gallons of sewage is dumped into the nation’s water every year, or 3.28 billion gallons a day” (Bloganica, 2017). As discussed above, a variety of previous infrastructure systems contaminate the environment. As previously described, combined sewer systems are designed to overflow. Precipitation events, such as rainfall or snowmelt, cause combined sewage systems to dump excess discharge, including sewage, into the environment prior to treatment. This causes health concerns, as 772 cities in the US have combined sewer systems (EPA). Combined sewer systems are a source of unnecessary pollution, so cities are working to upgrade their infrastructure when possible. Sanitary sewer systems are also susceptible to overflows. The environmental Protection Agency (EPA) estimates between 23,000 and 75,000 sanitary sewer overflows (SSO) happen every year (EPA). SSOs happen for a variety of reasons including line breaks, sewer defects, faulty design, etc. The need for infrastructure improvements has direct impacts on the environment and its inhabitants.

Legal

The sixth and final category of the PESTEL analysis is legal (L). This category refers to laws the affect operations of the industry. Certain laws impact when, how, or where business can be conducted. With the increase of environmental laws and regulations, this is specifically important for the wastewater industry. To ensure continued profitability, water owners must operate within the rules of the law. Legal pressures are typically required to be implemented, whereas political pressures are commonly enforced but not required. Water regulations by federal and state entities have become more strict to ensure water safety, quality, and supply. The industry is mostly regulated at the state level, but each state has varying policies. Few federal laws create boundaries for the wastewater industry.

The Clean Water Act (CWA) of 1972 regulates pollution of waters and establishes standards for surface waters. The National Pollutant Discharge Elimination System (NPDES) regulates sources that discharge pollutants into U.S. waters.

The Safe Drinking Water Act (SDWA) is a federal law that sets the standards for America’s drinking water. Under this regulation the Environmental Protection Agency sets standards for quality and oversees all water suppliers who implement the standards. Other popular regulations are Ground Water Rule, Coastal Laws, and Surface Water Standards. The Federal Emergency Management Agency (FEMA) updated the 100 and 500-year flood evaluation requirements to prepare for rare severity storms.

The lead and copper rule (LCR) is a regulation to limit exposure of lead and copper from the plumbing materials, as they have the potential to erode into drinking water. If lead levels reach higher than 15ppb or copper concentrations exceed 1.3ppm, the system must undergo corrective action.

A water catastrophe occurred in Flint, Michigan, beginning in 2014. The lack of treatment and testing largely affected human health. Residents complained of foul-smelling, discolored, and off-tasting water that was causing skin rashes, hair loss, and itchy skin. Follow-up studies revealed the water having extremely high lead levels, affecting the led concentration in residents' blood. These events coincided with an outbreak of Legionaries’ disease, a severe case of pneumonia, affecting nearly 100 people and killing 12. It is now estimated that one in every six homes in Flint have been abandoned. (Denchak 2018)

Because of extreme incidents like this, government agencies are responsible for direct oversight and enforcement of regulations regarding the management of water and wastewater.

Future Direction

The hydrological cycle and urban water cycle illustrate the closed system of the water cycle and how it moves throughout the U.S. With proper management and implementation, water is considered a renewable resource. Water shifts physical states and requires utilization of other resources to move it when and where it is most demanded. After looking at six forces affecting the wastewater industry the following can be concluded:

Private ownership, in its many forms, will continue to be a solution for governments unable to keep up with required infrastructure investment. The private market also prices water differently, creating new market dynamics. Although private ownership has shown inefficiencies in some markets, it has proven beneficial in others.

Sewage prices are increasing. Higher prices appear to have quality and sustainability benefits. With higher prices, more suppliers will enter the market and will improve reach and distribution of water services. Higher prices are also proven to encourage slight conservation of water within households. Finally, the externality of public affordability must be considered when determining public prices. Pricing needs to be strategic in order to cover expenses as well as upcoming maintenance costs.

Urbanization has many effects on the wastewater industry. These effects have been magnified as the population moves away from rural areas and towards urban cities. Rural water prices will continue to increase, further enticing individuals and households to move towards the city. In addition, urban areas must invest in infrastructure to minimize pollution and sedimentation.

Innovations will continue to mold industry norms. As current infrastructure sits in the U.S., an estimated $271 billion is needed to fund the next 20 years of infrastructure improvements. New innovations allowing direct recycling of sludge and water will reshape the market for water in coming years.

Climate change is increasing average annual precipitation volumes. This contributes to higher runoff volumes, requiring additional capacity at wastewater treatment plants. Also, many current systems contribute to ecological pollution, presenting environmental challenges for those areas.

Legal regulations determine when, how, and where business can take place. Multiple laws have been put in place such as the Clean Water Act, the Sage Drinking Water Act, and the Lead and Copper rule, to monitor water use, in hopes of preventing situations like Flint, Michigan.

References

ASCE. (n.d.). ASCE's 2017 American Infrastructure Report Card: GPA: D . Retrieved October 28, 2019, from https://www.infrastructurereportcard.org/.

Bloganica. (2017, May 31). What are the effects of wastewater on the environment? Retrieved December 8, 2019, from https://www.organicawater.com/effects-wastewater-environment/.

Blount, S. (n.d.). Household Water Use. Retrieved from https://www.neefusa.org/nature/water/household-water-use

Bradford, N. (n.d.). The Increasing Demand and Decreasing Supply of Water. Retrieved from https://www.neefusa.org/nature/water/increasing-demand-and-decreasing-supply-water

Castelo, J. (n.d.). Is it Illegal to Collect Rainwater: State by State Guide. Retrieved November 2, 2019, from https://worldwaterreserve.com/rainwater-harvesting/is-it-illegal-to-collect-rainwater/.

CDC. (n.d.). Drinking Water. Retrieved November 21, 2019, from https://www.cdc.gov/healthywater/drinking/public/index.html.

Denchak, M. (2018, November 8). Flint Water Crisis: Everything You Need to Know. Retrieved November 3, 2019, from https://www.nrdc.org/stories/flint-water-crisis-everything-you-need-know.

Duffin, E. (2019, November 28). Number of households in the U.S. 1960-2019. Retrieved December 7, 2019, from https://www.statista.com/statistics/183635/number-of-households-in-the-us/.

Eight Water Trends to Watch in 2018. (2017, December 1). Retrieved November 3, 2019, from https://www.waterworld.com/municipal/wastewater/article/16191746/eight-water-trends-to-watch-in-2018.

EPA. (2017). 2017 Potable Reuse Compendium. Retrieved December 14, 2019, from https://www.epa.gov/sites/production/files/2018-01/documents/potablereusecompendium_3.pdf.

Food & Water Watch. (2009, June). Questions & Answers: A Cost Comparison of Public and Private Water Utility Operation. Retrieved December 7, 2019, from https://www.foodandwaterwatch.org/sites/default/files/qa_public_private_water_fs_june_2009.pdf.

Hawken, P. (2014). Sustainable world sourcebook: critical issues, viable solutions, resources for action. Berkeley, CA: Sustainable World Coalition.

Jones, E. (2018, January 30). The Urban Water Cycle. Retrieved October 22, 2019, from https://litzsinger.org/the-urban-water-cycle/.

Kopaskie, A. (n.d.). Public vs. Private: A National Overview of Water Systems. Retrieved December 7, 2019, from https://efcnetwork.org/public-vs-private-national-overview-water-systems/.

Layne, R. (2019, August 27). Water costs are rising across the U.S. - here's why. Retrieved October 27, 2019, from https://www.cbsnews.com/news/water-bills-rising-cost-of-water-creating-big-utility-bills-for-americans/

Layout of Water Distribution System. (2012, September). Retrieved from https://www.civilengineeringterms.com/environmental-engineering-1/grid-iron-system/.

Martin, L. (2014, September 16). Texas Leads The Way With First Direct Potable Reuse Facilities In U.S. Retrieved November 3, 2019, from https://www.wateronline.com/doc/texas-leads-the-way-with-first-direct-potable-reuse-facilities-in-u-s-0001.

Miller, R. L. R., Benjamin, D. K., & North, D. C. (2016). The economics of public issues. Boston: Pearson.

Rogers, P., Silva, R., & Bhatia, R. (2001). Water is an economic good: How to use prices to promote equity, efficiency, and sustainability. Retrieved from https://entwicklungspolitik.uni-hohenheim.de/uploads/media/Water_is_an_economic_good-How_to_use_prices_to_promote_equit_02.pdf.

Schmidheiny, S. (1992). Changing course: a global business perspective on development and environment. MIT Press.

SDWF. (n.d.). Ground Water. Retrieved November 21, 2019, from https://www.safewater.org/fact-sheets-1/2017/1/23/groundwater.

Sewage Treatment Facilities in the U.S. (2019, August). Retrieved from http://ibisworld.com

Sowby, R. B. (2014, March 19). The Urban Water Cycle: Sustaining Our Modern Cities. Retrieved October 22, 2019, from https://blog.nationalgeographic.org/2014/03/19/the-urban-water-cycle-sustaining-our-modern-cities/.

University of Michigan. (2019). U.S. Cities Factsheet. Retrieved December 7, 2019, from http://css.umich.edu/factsheets/us-cities-factsheet.

USGS. (n.d.). Land Subsidence. Retrieved December 8, 2019, from https://www.usgs.gov/special-topic/water-science-school/science/land-subsidence?qt-science_center_objects=0#qt-science_center_objects.

USGS. (n.d.). Urbanization and Water Quality . Retrieved December 14, 2019, from https://www.usgs.gov/special-topic/water-science-school/science/urbanization-and-water-quality?qt-science_center_objects=0#qt-science_center_objects.

Warady, M. (2019, February 19). Death, Taxes & Natural Monopolies. Retrieved December 7, 2019, from https://waterfm.com/death-taxes-natural-monopolies/.

Whitfield, R., & McNett, J. M. (2014). A primer on sustainability: In the business environment. New York: Business Expert Press.

Appendix A:

Terms and Definitions

Class A Biosolids: designation for dewatered and heated sewage sludge that meets U.S. EPA guidelines for land application with no restrictions

Coagulation: the action or process of a liquid, especially blood, changing to a solid or semi-solid state

CSO: is the discharge of wastewater and stormwater from a combined sewer system directly into a river, stream, lake or ocean

Economic Good: a product or service which can command a price when sold

Evapotranspiration: the process by which water is transferred from the land to the atmosphere by evaporation from the soil and other surfaces and by transpiration from plants

Externalities: a side effect or consequence of an industrial or commercial activity that affects other parties without this being reflected in the cost of the goods or services involved

Floc: a loosely clumped mass of fine particles

Ground Water: is water located beneath the surface of the earth

Pareto Optimal: is an economic state where resources cannot be reallocated to make one individual better off without making at least one individual worse off

Pressurized Sewer System: system that uses pumps instead of gravity to transport wastewater

Raw water: water found in the environment that has not been treated and does not have any of its minerals, ions, particles, bacteria, or parasites removed

Runoff: the draining away of water (or substances carried in it) from the surface of an area of land, a building or structure, etc.

Settling Velocity: rate at which the sediment settles in still fluid

Simplified Sewer System: system that is constructed using smaller diameter pipes laid at a shallower depth and at a flatter gradient than conventional sewers

Sludge: muddy or slushy mass, deposit, or sediment: such as precipitated solid matter produced by water and sewage treatment processes

Solid Free Sewer System: wastewater is pre-settled, and solids removed before entering the system, simplifying design and reducing construction costs

Straight Pipes: wastewater is released from a home directly into the ground or local water supplies due to lack of access to a sewage system or septic tank

Surface Waters: is water on the surface of continents such as in a river, lake, or wetland

Vacuum Sewers System: use differential air pressure (negative pressure) to move the sewage to a central collection station