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BASELINE CONTAMINANTS OF EMERGING CONCERN IN BARTLESVILLE WATER SUPPLY, EVALUATING THE CANEY RIVER ENVIRONMENTAL BUFFER FOR INDIRECT POTABLE REUSE PROJECT

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BASELINE CONTAMINANTS OF EMERGING CONCERN IN BARTLESVILLE WATER SUPPLY, EVALUATING THE CANEY RIVER ENVIRONMENTAL BUFFER FOR INDIRECT POTABLE REUSE PROJECT

A THESIS APPROVED FOR THE
SCHOOL OF GEOSCIENCES

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SFC John A. Thigpen - "Tran, go get you that education."

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Abstract

The City of Bartlesville, Oklahoma is planning to increase their water supply through Indirect Potable Reuse (IPR), by transferring wastewater to a location about five to seven miles upstream from their water supply intake site in the Caney River. One of the many challenges is the presence of Contaminants of Emerging Concern (CEC) in the City of Bartlesville Chickasaw Wastewater Treatment Plant (CWWTP) effluent. The U.S. Environmental Protection Agency (EPA) has established Maximum Contaminant Levels (MCLs) for chemicals in drinking water supplies, but numerous CEC are unregulated because of undefined environmental toxicity or their risk to human health. Therefore, before implementing a wastewater reuse project, water suppliers must examine water quality including CEC to ensure that water delivered to the customer is reliable and safe.

In this study, we sampled six locations, including effluent, river, and lake water in Bartlesville's water supply during three sampling events (March, July, and December 2018). Samples were analyzed for a suite of 99 CEC classified as either pesticides, industrials, Pharmaceuticals and Personal Care Products (PPCPs), hormones, or others. CEC were detected for 11 of 19 pesticides, four of six industrials, 35 of 53 PPCPs, four of eight hormones, and 10 of 13 "others" in the water samples. The sampling site near Bartlesville's CWWTP effluent discharge contains the highest CEC concentrations and compounds in the PPCPs class were most abundant in the surface water, with a concentration of up to a few hundred nanograms per liter. Because we detected numerous CEC downstream from the effluent discharge site, we can compare effluent and downstream concentrations to compute bio-chemical half-life for these CEC. This

research provides baseline data to assess the environmental risk and potential human exposure to CEC, evaluate periodic tendencies, and the effectiveness of the environmental buffer to sorb and degrade CEC through aerobic microbial reactions. The evaluation of prospective IPR scenarios indicates that a few CEC (e.g., 4-nonylphenol, Amoxicillin, Iohexol, and Sucralose) may be detectable at "Upper" trace concentrations (> 100 ng L^{-1}) after traveling about five to seven miles from the planned upstream discharge point. However, transferring 50% of the effluent to the planned upstream discharge location would have no adverse impact on the water quality at the current water intake point in the Caney River.

Chapter 1. Introduction

The City of Bartlesville, Oklahoma is planning to secure long-term water supply for their residents and surrounding communities of Washington County. An implementation of Indirect Potable Reuse (IPR) project is the most desirable method of augmentation, because sediment continues to be deposited into the city's water source and the State legislature adopted the Water for 2060 Law, which has a goal to consume no more freshwater in 2060 than consumed in 2012 (Steel et al. 2012; Tetra Tech et al. 2018, 2019).

The IPR project proposes to relocate effluent discharge from the City of Bartlesville Chickasaw Wastewater Treatment Plant (CWWTP) into the Caney River upstream from the City's existing freshwater intake. The CWWTP currently discharges to the Caney River downstream from their water treatment plant (WTP) raw water intake site, and there are plans to add a second discharge location between five and seven miles upstream (Figure 1). The second discharge location will divert part of the CWWTP effluent back into the Caney River to increase potential water supply within the segment of the river (Tetra Tech et al. 2018, 2019). The Caney River will serve as an environmental buffer where it creates an intermediate discharge and holding point that promotes degradation of potential contaminants through natural processes. These include dilution, blending, and removal through filtration, photolysis, or biological degradation (EPA et al. 2017). Raw water from the Caney River intake will be pumped to Bartlesville's existing WTP for further treatment to comply with the Safe Drinking Water Act (SDWA) and Oklahoma Department of Environmental Quality (ODEQ) standards and regulation (Tetra Tech et al. 2018, 2019).

Bartlesville CWWTP contacted researchers at the University of Oklahoma (OU) to analyze baseline CEC concentration within the water supply area and effluent discharge point. Three points were selected within the Caney River. These include the potential second discharge location about five miles upstream, the current WTP raw water intake site near Johnson Park, and the evaluation post-mix site downstream from the CWWPT. Two sites located near the southern and northern side of Lake Hudson were selected for further water quality evaluation. The last sampling site is from the CWWTP effluent pipe that discharges directly downstream from the WTP raw water intake location (Table A 1).

Ninety-nine (99) unique CEC compounds were analyzed after three water-sampling events; March 20th, 2018, July 12th, 2018, and December 19th, 2018. Since CEC are so abundant and diverse, they are lumped into categories that describe their purpose, use, or characteristic (Table A 2). For this study, the compounds are categorized into pesticides, industrials, Pharmaceuticals and Personal Care Products (PPCPs), hormones, and "other" classes (Glassmeyer et al. 2017; Kolpin et al. 2002; Murray et al. 2010; Petrie et al. 2014). Compounds in the "other" category are chemicals that did not conveniently fit into one of the other groups but are commonly used and potentially occur in the environment including caffeine, sweetener, food preservative, and nicotine.

Additional data were gathered to find the instantaneous discharge measurements within the CWWTP effluent pipe and Caney River at the raw water intake point during the three water-sampling events. These values are needed to evaluate the Caney River environmental buffering effectiveness by calculating the detected CEC half-life within a mixing model of the CWWTP effluent and Caney River discharge system (Fairbairn et al.

2016; Lu et al. 2008; Vidal-Dorsch et al. 2012; Walters et al. 2010). The CEC half-life is needed to calculate the theoretical concentration of CEC within four scenarios where CWWTP effluent discharge at full flow and half flow to the proposed IPR sites, at about five and about seven miles upstream from Bartlesville's WTP raw water intake location. The theoretical CEC concentration value will determine if the secondary discharge site should be moved further upstream or implement advance treatment within the CWWTP before discharge back into the Caney River.

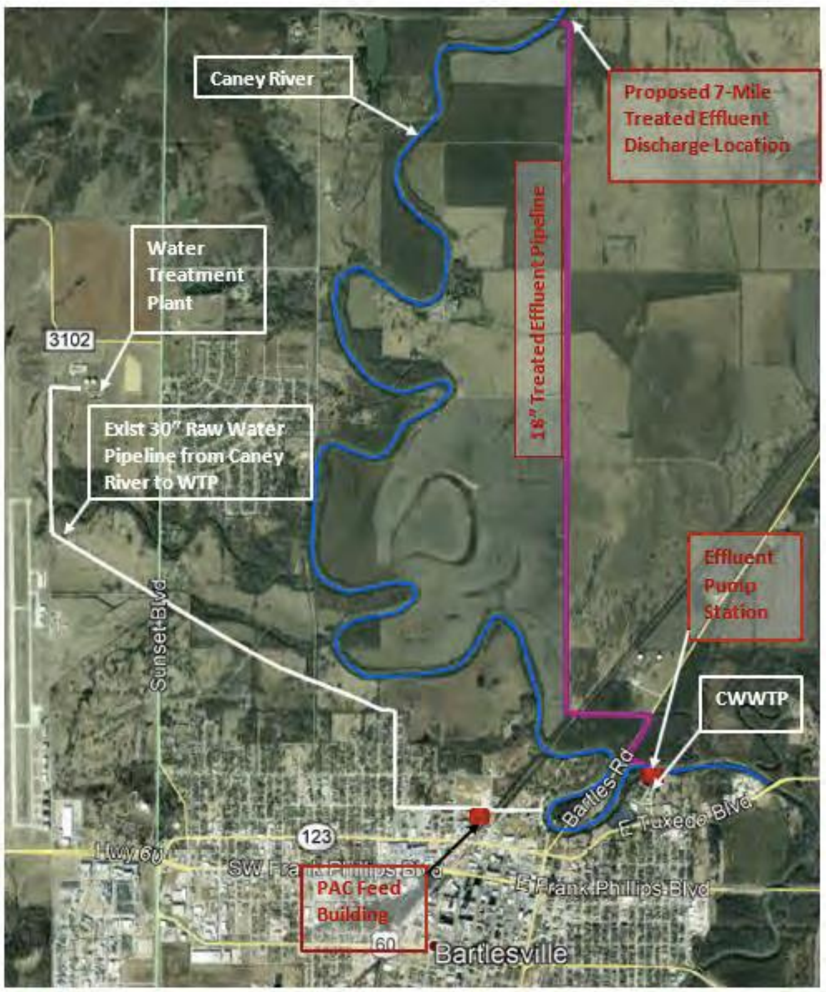

Figure 1. Proposed IPR project to reallocate part of CWWTP effluent discharge back into the Caney River (Modified from Tetra Tech 2019)

1.1 Water Reuse and Oklahoma Comprehensive Water Plan

IPR operations have long been implemented in the United States within communities that are prone to severe drought conditions. These operations involve augmenting purified water into an environmental buffer, such as groundwater aquifer or a surface water reservoir, lake, or river, before recollection for further treatment within a water treatment facility. One such example is with the Gwinnett County, Georgia IPR surface water augmentation of a capacity more than 60 million gallons per day (MGD) into the Chattahoochee River and Lake Lanier (EPA et al. 2017). Many states that have demonstrated or implemented full-scale IPR projects include Arizona, California, Colorado, Florida, Georgia, Tennessee, Texas, and Virginia. California is the leading state with the highest number of IPR projects and more than 50 years of experience (EPA et al. 2017; Tricas et al. 2018). All States follow strict Federal and self-implemented State regulations for recycled water to ensure continued protection of human health and the environment.

When the Oklahoma Legislature passed the Water for 2060 Act (House Bill 3055) in 2012, it set a statewide goal of consuming less freshwater in 2060 than in 2012 (Steel et al. 2012). The Bill creates a current cap on the water supply for the City of Bartlesville and set forth efforts toward implementation of indirect potable reuse (IPR). Under ODEQ reserved “Category 1a” for IPR in surface water, the use of reclaimed water for potable purposes by intentionally discharging to a surface water supply source, such as the Caney River (ODEQ 2014). The Caney River would be acting as an environmental buffer to create a natural system with high capacity to further purify water. The retention time of the recycled water in the raw water supply can remove CEC constituent by sorption onto sediments and biodegradation through aerobic microbial reactions (EPA et al. 2017; NRC 1998; Tetra Tech et al. 2019). The blended water is reclaimed back into Bartlesville's WTP intake site, where it will undergo further advance treatment to improve water quality before entering into Bartlesville's drinking water distribution system (ODEQ 2014; Tetra Tech et al. 2019).

1.2 Background: CEC

Contaminants of emerging concern (CEC), defined as chemicals that have the potential to adversely impact human health and the environment but are presently unregulated and not extensively monitored, may be present at trace concentrations in wastewater, surface water, groundwater, and drinking water (Kolpin et al. 2002; Glassmeyer et al. 2017). CEC are classified as synthetic or naturally occurring compounds or microorganisms that are suspected of having or have demonstrated effects on ecological and human health risks (Raghav et al. 2013). These risks have been linked with numerous endocrine, reproductive, neurologic, and carcinogenic effects within the human body (Mnif et al. 2011; Rahman et al. 2009). CEC belong to diverse chemical classes and are typically detected at trace levels (ng L^{-1}) in surface and subsurface waters. The majority of CEC found in natural water originate from wastewater treatment plants (WWTP), landfills, septic systems, agriculture, residential, commercial, and industrial sources (Acuña et al. 2015; Brooks et al. 2009; Mnif et al. 2011; Rahman et al. 2009;). The CEC are sub-categorized as pesticides, industrials, PPCPs, hormones, and "other" (Glassmeyer et al. 2017; Kolpin et al. 2002; Murray et al. 2010).

Pesticides are substances or mixtures of substances of unrelated chemicals that are used to control pests. They are often classified according to their target organism, which includes all of the following: herbicide, insecticides, nematicide, molluscicide, piscicide, avicide, rodenticide, bactericide, insect repellent, animal repellent, antimicrobial, and fungicide (NASDA 2014). They are heavily used throughout the world in industrial, commercial, and residential applications. The occurrence of pesticides in wastewater treatment plants is mainly from non-agricultural sources, such as management of sports fields, public parks and recreational areas (Köck-Schulmeyer et al. 2013; Mnif et al. 2011) or through the infiltration of agricultural runoff into the sewage systems (Birch et al. 2015). Human exposure to pesticides is through contact with the skin, by ingestion, or inhalation. Depending on the type of pesticide and the duration of the exposure there may be multiple negative health risks including dermatological, gastrointestinal, neurological, carcinogenic, respiratory, reproductive, and endocrinological effects (Alewu et al. 2012; García 2003; Köck-Schulmeyer et al. 2013; Sanborn et al. 2007; Weisenburger 1993; WHO 1990).

Industrial compounds are high production volume chemicals used as flame-retardants, polycarbonate plastic, epoxy resin, textiles, furniture, and many other materials. These industrial compounds fall into three main categories, which include Organophosphates, Alkylphenol Ethoxylates (APEs), and Bisphenol A (BPA). Organophosphates, such as the chlorinated alkyl phosphates compounds in tris-(2-chloroethyl)-phosphate (TCEP), tris-(2-chloro-, 1-methyl-ethyl)-phosphate (TCPP), and tris-(dichloro-iso-propyl)-phosphate (TDCP) have been used for several decades in many industries as flame retardants in polyurethane foam (Andresen et al. 2004; Duirk et al.

2005; EPA 2009c; Reemtsma et al. 2008). APEs, such as nonylphenol and octylphenol, are synthetic surfactants used in some detergents and cleaning products. BPA, also known as 4,4'-isopropylidenediphenol, is an organic compound used primarily to make polycarbonate plastic and epoxy resin (Deblonde et al. 2011; EPA 2009c; Yu et al. 2015). Many industrial compounds are listed as an endocrinological disruptor, with an estrogenic activity even at a concentration below 1000 ng L^{-1} (Rykowska et al. 2006). The exposure to the compounds can be particularly harmful towards young children, infants, and fetus, because of lack of feedback regulating the activity, synthesis, and elimination of hormones (Groshart et al. 2015; Rykowska et al. 2006; Saal et al. 2008).

PPCPs are a unique group of CEC, due to the effects on humans at low doses (EPA 2009c). Varieties of PPCPs are used for personal health or cosmetic reasons through over the counter medication as well as medications prescribed by a physician. Most ingested pharmaceuticals are only partially metabolized, so the portion is excreted as urine or feces into the sewage system (Ebele et al. 2017; EPA 2009c). Personal care products such as soap, shampoo, cosmetics, skincare, fragrances, and antibacterial compounds, enter wastewater from bathing, laundry, and household cleaning (Birch et al. 2015; EPA 2009c). Additional entry might come from leaching from defecting landfill, leakage from manure storage tanks, or spray irrigation of treated wastewater onto agriculture land (Grassi et al. 2012; Walters et al. 2010). PPCPs are often associated with emerging endocrinological disruptors, which can cause immune dysfunction, cancer risk, and affect the human reproductive system (Jeong et al. 2017; Vimalkumar et al. 2019).

Hormones can be categorized into three major distinct groups according to their composition: peptide/protein, steroid, and amino acid derivatives. They are unique compounds that include both naturally occurring and synthetic analogs that are structurally related to one another. Within the body, their functions can have overall effects on reproduction and sexual differentiation, development and growth, maintenance of the internal environment, and regulating the body metabolism and nutrient absorption. Hormones are intercellular chemical messengers that may disturb more than one of these functions at low doses (Nussey et al. 2001; PubChem 2019; Rahman et al. 2009; Velicu et al. 2009). The CEC compound analyzed in this study belongs within the steroid group; which includes androstenedione, EE2 (17 Alpha-ethynylestradiol), estradiol, estriol, estrone, norethisterone, progesterone, and testosterone.

The “Other” compounds are chemicals that did not conveniently fit into one of the other groups but are commonly used and potentially occur in the environment including a wide array of stimulant, sweetener, insect repellent, and paraben.

Stimulants include paraxanthine (1,7-Dimethylxanthine) and caffeine (1,3,7-Trimethylxanthine). These compounds are a psychoactive Central Nervous System (CNS) stimulant, which results in a heightened activity of medullary, vagal, vasomotor, and respiratory centers in the brain (Fairbairn et al. 2016; PubChem 2019). Sweeteners include acesulfame potassium and sucralose are used as a sugar substitute. The use of artificial sweetener has been popularized because they are stable under heat and over a broad range of pH conditions, and, consequently, have a long shelf life. The majority of the ingested sweetener is not broken down by the body and therefore present in wastewater in notable concentration (PubChem 2019; Renwick 1986; Rymon et al. 1985, 2013). DEET (N, N-Diethyl-meta-touamide) is the most common active ingredient in insect repellents. Approximately 30% of the U.S. population use some form of DEET repellents that are found in liquids, lotions, sprays, and wristbands. Since 1960, health effects have been reported in children and adults in records from poison control center data, with one of the most common effects being seizures. However, the incidence of seizure is estimated to be very low at an estimation of one per 100 million users. The U.S. EPA Office of Pesticide categorized DEET as Group D cancer classification, which is generally used for agents with inadequate human and animal evidence of carcinogenicity or which no data are available (Adgate et al. 2000; EPA 2007b, 2004). Parabens including butylparaben, ethylparaben, isobutylparaben, methylparaben, and propylparaben, are human-made chemicals often used in small amounts as preservatives in cosmetics, pharmaceuticals, foods, and beverages to prevent the growth of microbes. These endocrine-disrupting chemicals can be absorbed through the skin, blood, and the digestive system. Potential links have been suggested between parabens and breast cancer (Charles et al. 2013; Darbre et al. 2014).

Chapter 2. Study Area

The City of Bartlesville is located in northeastern Oklahoma, bisected by the Caney River that runs from North to South through of the city. The Bartlesville service area is about 282 square miles covering part of Washington, Osage, and Nowata County and part of Basin 76 of the Middle Arkansas Watershed Planning Region (OWRB 2013). The watershed region primarily relies on surface water supplies, such as The Caney River, Hulah Lake, and Lake Hudson, and there is no dependable groundwater source available for Bartlesville (Tetra Tech et al. 2019).

The Caney River, about 155 miles in length, has its headwaters in Elk County, Kansas, and flows in a south to a southeasterly direction to intersect Bartlesville halfway and enter into the Verdigris River in Rogers County, Oklahoma (Tetra Tech et al. 2019). The Caney River in basin 76 typically has flowed greater than 4,300 acre-feet per month throughout the year and greater than 65,000 acre-feet per month in the spring and early summer (OWRB 2013). The Caney River is dammed at the northeastern Osage County, Oklahoma to form Hulah Lake.

Hulah Lake is a 3,570-acre man-made reservoir with normal pool storage of 31,160 acre-feet. Bartlesville has 13,819 acre-feet (12.4 MGD) of water rights. Based on historical and projected silting and sediment deposits, Hulah Lake's dependable yield is projected to decrease to 6.4 MGD through 2035 and 4.4 MGD by 2055. Raw water from Hulah Lake is transferred into Lake Hudson for further storage. Lake Hudson has normal pool storage of 4,000 acre-feet and is a city-owned lake (OWRB 2013; Tetra Tech et al.

2019; USACE 2007). Due to its size, it is insufficient for water supply yield on its own and is considered part of the Hulah and Hudson Bartlesville supply system reservoirs.

2.1 Geography, Landscape, and Hydrology of the Region

The Oklahoma Comprehensive Water Plan (OCWP) divided the state into 82 surface water basins for water supply availability analysis and then aggregated into 13 distinct Watershed Planning Regions. The City of Bartlesville lies centered within Basin 76 of the Middle Arkansas Watershed Planning Region. Basin 76 encompasses 1,016 square miles in northeastern Oklahoma, spanning most of Washington, Osage, and Nowata Counties (OWRB 2013). The basin dominated by two large reservoirs, Hulah Lake and Copan Lake, created by the U.S Army Corps of Engineers damming the Caney River. These two lakes are located directly north of the City of Bartlesville. Lake Hudson, one-tenth in size of Hulah Lake, is a city-owned lake and is located northwest of Bartlesville and in between the two large lakes. U.S. Route 75 runs North to South of Basin 76 and divides the basin with two distinctive terrains. The western region includes lump forest, vast grassland, scattered cultivated land, and abundant river basins, while the eastern area contains mosaic patches of prairie grassland, woodland, massive cultivated land, and urban landscape (Figures 2 – 3) (OWRB 2009, 2013; Yang et al. 2018).

The surface water demand for Basin 76 in 2010 shows that 12,090 acre-feet per year (AFY) used for Municipal and Industrial, 1,190 AFY for Livestock, 840 AFY for Crop Irrigation, 360 AFY for Self Supplied Residential, and 350 AFY for Oil and Gas sector (Figure 4). Base on the planning horizon projection for 2060 estimate the total demand to be 13,330 AFY (10.26% increase) for Municipal and Industrial, 1,230 AFY

(3.36% increase) for Livestock, 2,070 AFY (146.42% increase) for Crop Irrigation, 470 AFY (30.56% increase) for Self Supplied Residential, and 1,180 AFY (237.14% increase) for Oil and Gas (OWRB 2013). These sectors are contributing factors toward the source of CEC contamination by runoff or discharge through sewage.

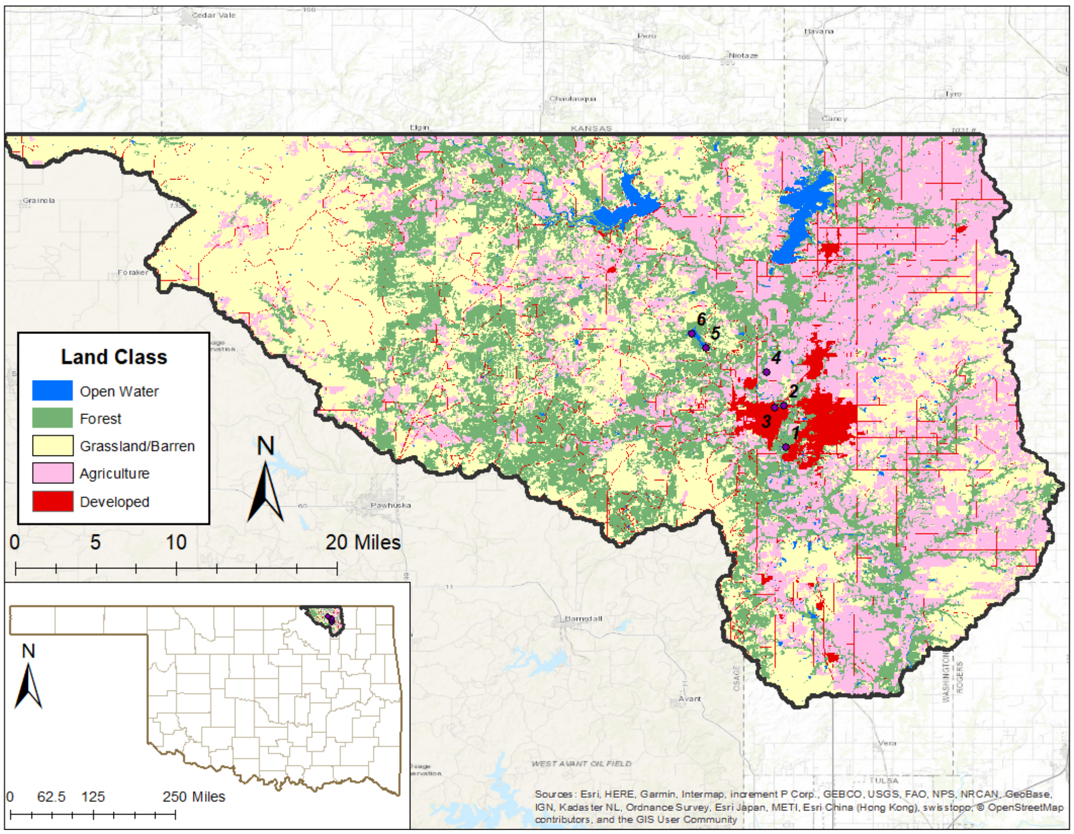

Figure 2. Land classification map of Basin 76 with the use of the National Land Cover Database (NLCD) data calculation value in Table A 7. Each count represents one pixel or 30m x 30m area within the region (Yang et al. 2018).

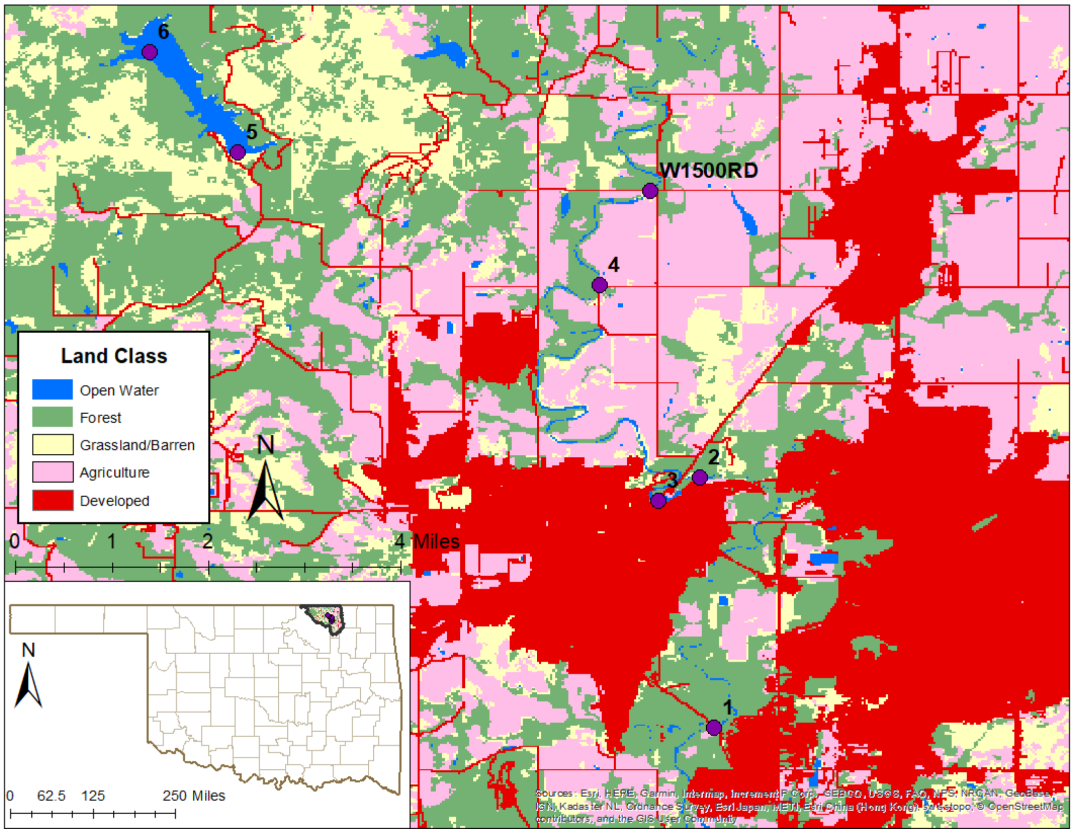

Figure 3. Land classification map of Bartlesville study area with the location points of the sample sites. Each count represents one pixel or 30m x 30m area within the region (Yang et al. 2018).

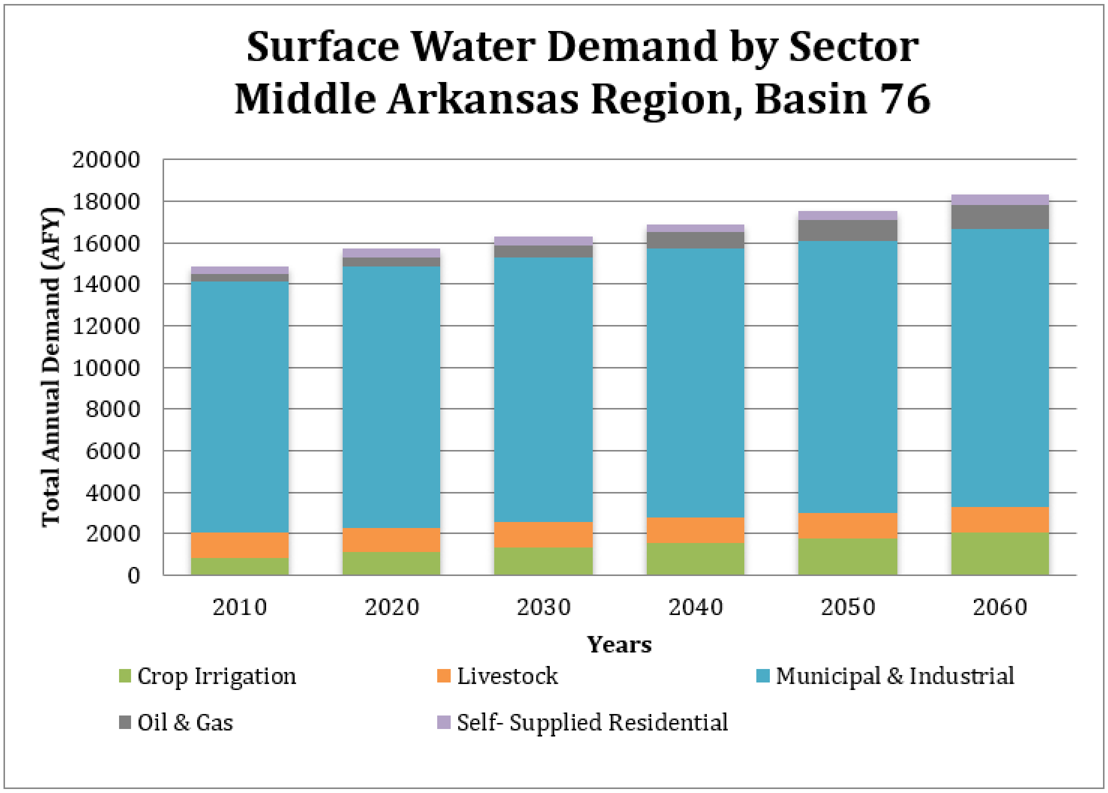

Figure 4. Surface water demand by sector of Basin 76. The projected demands chart shows a steady increase within each decade (Modified from OWRB 2013).

2.2 Bartlesville Water Supply and Future Demands

Bartlesville service area is about 282 square miles covering part of Washington, Osage, and Nowata Counties, and serves as the significant regional water supplier within the Basin 76 of the Middle Arkansas Watershed Planning Region. Bartlesville's primary source of raw water supply is Hulah Lake and has about 12.4 MGD of water rights toward the lake. For additional storage, the water in Hulah Lake is transferred into Lake Hudson as a secondary water source, which Bartlesville wholly owns with 5.4 MGD water rights (OWRB 2013; Tetra Tech et al. 2019).

In December of 2007, the Planning Assistance State (PAS) program was completed by the U.S Army Corps of Engineers (USACE) to evaluate the present and future water supply needs for Bartlesville area. These areas include the City of Bartlesville and the surrounding communities, rural water systems, and the other regions to which the city provides water. Since the City of Bartlesville supplies water to about 99% of the residents in Washington County, the 2005 water usage data from Washington County was used as a baseline to estimate the future demand scenarios for Bartlesville over a 50-year planning period (Tetra Tech et al. 2019).

The PAS Program presents three different water demand scenarios, based on population growth that create the overall drive for water consumption; Baseline Projection, Mid Projection, and High Projection. For the Baseline Projection scenario, we considered historical data and trends in the area of Bartlesville, to project the water demand to be 10.71 MGD by the year 2055. The "High Projection", which is the projection of higher growth trends in Bartlesville and estimate the water demand to be at 16.19 MGD by the year 2055. The "Mid Projection", is the average between the "Baseline Projection" and "High Projection" growth scenario, which estimate the water demand to be at 13.45 MGD in 2055 (Figure 5) (Tetra et al. 2019; USACE 2007).

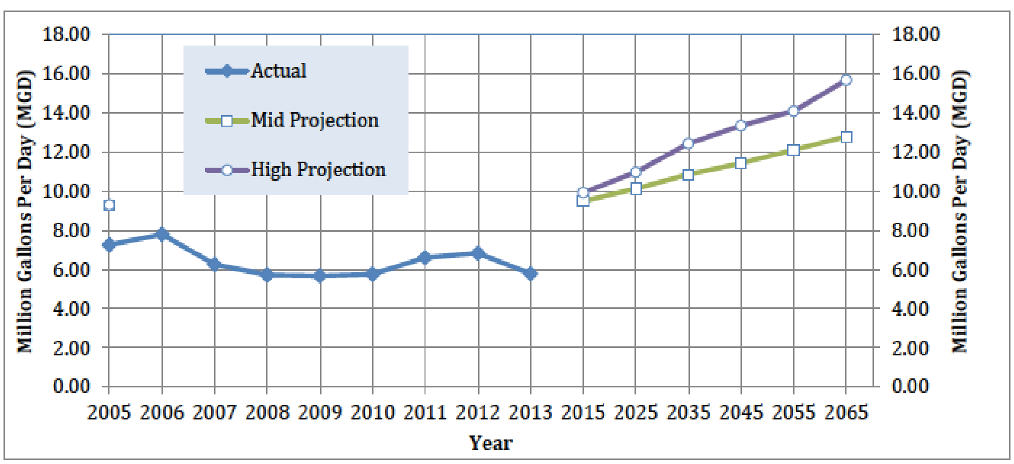

Figure 5. Water demand for actual and different projection within Bartlesville (Modified from Tetra Tech et al. 2019).

2.3 Bartlesville Wastewater Treatment

Chickasaw Wastewater Treatment Plant (CWWTP) is located at 230 North Chickasaw Ave., Northwest of Bartlesville. Bartlesville wastewater/sewer service includes a gravity collection system, lift station, flow equalization basins, and the Chickasaw Wastewater Treatment Plant (CWWTP). The wastewater is collected by a gravity system, which is made up of about 237 miles of sewer lines ranging in size from 6 inches to 42 inches in diameter. The wastewater then flows into a collection point at the lift station, which is located directly south of the CWWTP. It is designed to move the wastewater from lower to higher elevation with the use of three vertical, dry-pit centrifugal pump. The lift station holds a capacity of about 18.4 MGD and flows into the Flow Equalization Basin (FEB) for temporary storage with an additional 20 MG during high flow event. When ready to be processed, all flows are transported to the CWWTP for physical, biological, and chemical treatment before discharge continuously into the Caney River.

The CWWTP contains a headworks structure, primary clarification, activated sludge, secondary clarification, chlorination, and dechlorination treatment for wastewater treatment. The headwords structure is equipped with two aerated grit chambers with chain and bucket removal systems and an Auger Monster®. Grit is a heavy mineral matter consisting of a variety of particles including sand, gravel, cinder, and other heavy, discrete inorganic or organic biodegradable solids found in domestic sewage. Removal of grit prevents unnecessary abrasion and wear of mechanical equipment (EPA 2000). The Auger Monster® provides additional grit processing by grinding of influent solids and screening to remove solids greater than ¼-inch in diameter before sending the wastewater into the primary clarifier.

The primary clarifier provides a few hours of detention time for gravity settling to take place. The use of chain and drag scraper system helps remove sludge within the effluent. Floatable solids (scum) are removed from the surface by a skimmers process. Historically, CWWTP has a removal efficiency of 54% for total settleable solids (TSS) and 30% of dilution of biochemical oxygen demand (BOD_5). The effluent then routed to three aeration basins for a secondary treatment process.

The aeration basin provides 250 horsepower centrifugal blowers to promote and increase the rate of decomposition from microbial growth in the wastewater. CWWTP require that the basin volume provide a minimum hydraulic retention time of 6-8 hours and a BOD loading no more than 30-40 pounds BOD_5 per 1000 cubic feet. Before discharge back into the Caney River, the effluent enters through the final clarifier for removal of any remaining sludge and scum (Tetra Tech et al. 2019).

Bartlesville CWWTP (ODEQ Permit #OK0030333 and ID# S21402) has an average permitted capacity of 7.0 MGD. The objective for the relocation discharge site is to reclaim up to 4 MGD of the treated effluent and use it to augment the Caney River water supply (Tetra Tech et al. 2019). The reclaimed water will meet or exceed all the Oklahoma Department of Environmental Quality (ODEQ) rules and treatment requirements.

2.4 Study Objectives

The objectives of this study are to evaluate the CEC concentrations within the segment of the Caney River and to build a theoretical model base on the half-life of detected CEC for four scenarios within the IPR project. The four scenarios are based on CEC theoretical calculation at WTP intake site when full flow and half flow of effluent are diverted to the two upstream IPR locations, about 5.59 miles and 7.09 miles from the CWWTP. The results will help to understand the effectiveness of the environmental buffer system within the Caney River and the CEC concentrations once the IPR project is implemented. Additionally, the use of a built-in model can further replicate with other IPR project within a river environment, to assess the half-life of detected CEC and the location of propose IPR sites.

Chapter 3. Methodology

Water samples were collected from three sites within the Caney River, two sites at each end of Lake Hudson, and a treated effluent sampling location at the CWWTP discharge area. Sites within the Caney River include the potential IPR discharge location (Site 4) at the intersection of Durham Road, the current WTP raw water intake (Site 3) at Johnson Park and under Cherokee Street Bridge, and the evaluation post-mix site downstream from the CWWTP (Site 1) and under the bridge of Hillcrest Drive. Sites within Lake Hudson include the southern end of the lake (Site 5) near the Hudson Lake Dam and the northern end (Site 6) of the lake. The last sampling site is from the CWWTP effluent pipe (Site 2) that discharges directly downstream from the WTP raw water intake location (Figure 6). Three sampling events were planned in 2018 to represent different seasons and hydrologic conditions within the year. Additional sites at the second proposed IPR location (Site W1500RD) under the bridge of West 1500 Road and the Caney River, for testing our scenarios.

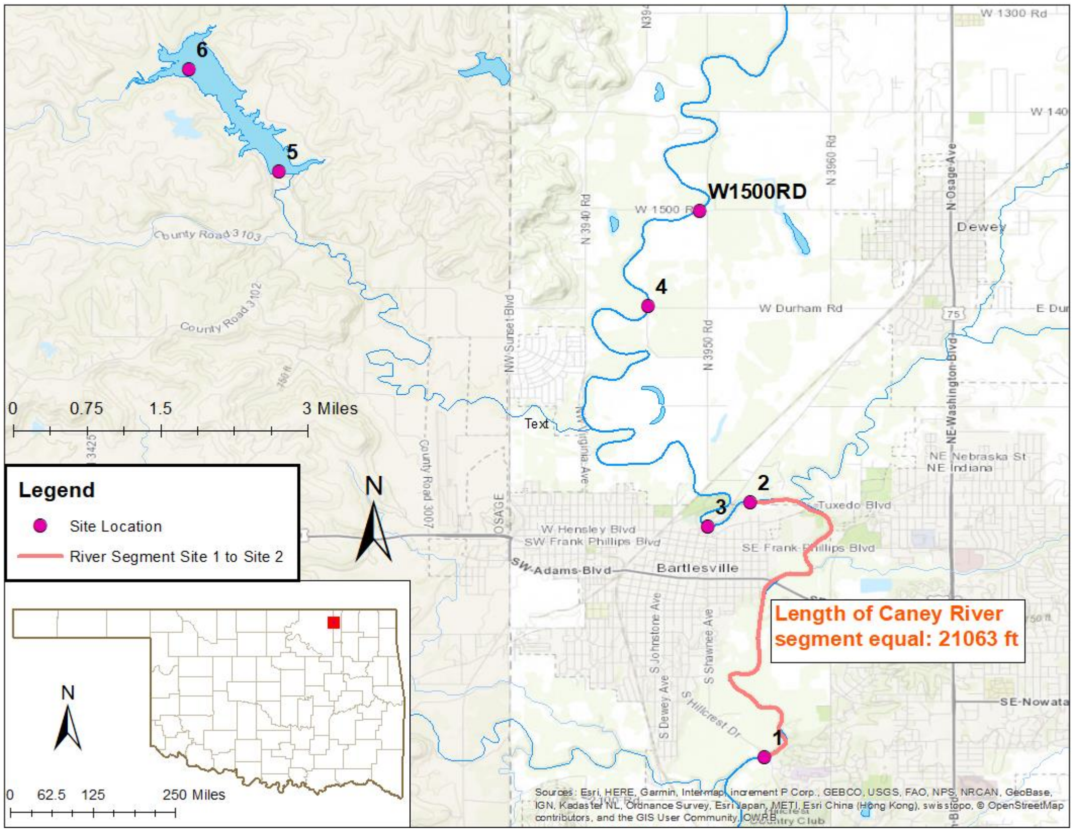

Figure 6. Sampling location for Bartlesville IPR project. Additional proposed IPR location (Site W1500RD) to test the scenarios.

3.1 Field Parameters

Parameters measured include temperature (Temp, °C), pH (pH, -Log[H^+]), conductivity (Cond, µS), oxidation-reduction potential (OPR, mV), total dissolved solids (TDS, mg L^{-1}), dissolved oxygen percent air saturation (DO%, %), and dissolved oxygen (DO, ppm). Field parameters were measured using Yellow Springs Instruments (YSI) DO200, YSI PH100, and YSI EC300 with collected sample water in a one-litter plastic beaker.

3.2 Water Sampling for CEC

Additional precautions were taken during the day of sampling since the CEC compounds were measured in trace concentration (ng L^{-1}) and are very prone to contamination. These include the use of powderless nitrile gloves during sampling and processing, avoiding touching or breathing into samples and equipment, direct contact between clothing and the sample, sampling device, and processing equipment, the connection or consumption of PPCPs compounds, such as soap and detergents, DEET and other insect repellents, fragrances, caffeine, sweeteners, prescription drugs, sunscreen, tobacco, and any over-the-counter medication.

The water sample was collected using the EPA grab method (EPA Science and Ecosystem Support Division Quality System and Technical Procedures SESDPROC-306-R4) with a one-gallon glass container sampler and two 40 ml amber vials with 25 mg Ascorbic Acid preservative at each sampling sites (EPA 1982). The one-gallon container was rinsed three times with the sample water before the collection process. The water sample then transferred into two 40 ml amber vials up to the base of the neck, with the precaution that the mouth of the vials does not come in contact with anything other than the sample water. Two blind duplicates were completed for the sampling event of March and December. An equipment blank was completed during December sampling event, by pouring deionized water into the sampling equipment and transfer into the designated sample vial. The vials are then stored in a cooler at a constant temperature of 1-4°C but above the freezing point of water until they were shipped overnight with wet ice to the analyzing laboratory, with the Chain of Custody documentation.

3.3 CEC Analyses: Eurofins Eaton Analytical Laboratory

The collected water samples were shipped overnight to Eurofins Eaton Analytical Laboratory (EEA) in Monrovia, California. CEC analysis was completed by liquid chromatography-tandem mass spectroscopy (LC/MS/MS) at EAA that followed EPA Method 537, 538, and 1694 (EPA 2007a, 2009a, 2009b). The advantage of LC/MS/MS method is to detect CEC, since the compounds are found in trace amounts (ng L^{-1}) (Köck-Schulmeyer et al. 2013; Shoemaker et al. 2015).

During the LC/MS/MS analysis, the sample solution containing the CEC compounds of interests are pumped through a porous medium made of granular solid material (stationary phase) by a solvent (mobile phase) at high pressure. The chemical interaction with the different phases causes the chemical to separate the compound one by one, based on their relative affinity to the packing material and the solvent. The wide variety of combination between the stationary phases and mobile phase allows the customization of the target compound. Once the chemicals are separated, the sample is directed to the mass spectrometer to initiate LC/MS/MS analysis for further separation and detection by their molecular masses and charges (i.e., positive and negative ions). This technique involves the exposure of ion to a magnetic or electric field that can alter the movement of ions and separated based on their mass. The information is then relayed into a computer, which graphical present the information as a mass spectrum (Figure 7). The mass spectrum of the sample can then be used to determine the concentration of known and unknown compound at trace (ng L^{-1}) amounts (Eurofins Scientific 2018).

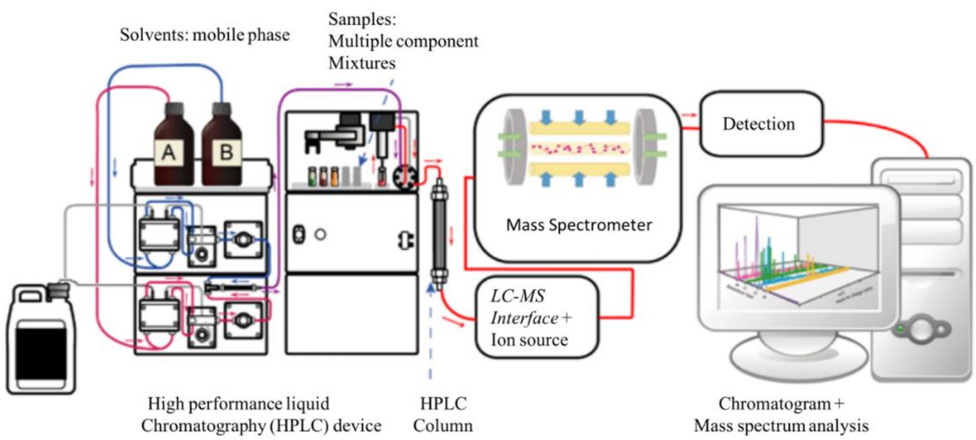

Figure 7. Liquid Chromatography-Mass Spectrometer (LC/MS/MS) diagram (Cwszot 2017).

3.4 Mixing model and Half-Life

Since the CWWTP effluent (Site 2) discharge directly after the Caney River intake point (Site 3), the area CEC concentration should be a mixture of these components. The hydrologic mixing model predicts the mixture concentration within the hydrologic flow path, by incorporating a mass balance analysis base on the concentration of CEC from treated CWWTP effluent and the Caney River (Buerge et al. 2006; Can et al. 2006; Gao et al. 2012). The mass balance equation shows that inflow, discharge with concentration from Site 2 combined with Site 3, must be equal to outflow (Harvey et al. 2015; Köck-Schulmeyer et al. 2013; Gao et al. 2012):

$$Q_A \cdot C_A + Q_B \cdot C_B = Q_T \cdot C_T \quad \text{[Eq. 2.1]}$$

Rearranging and substituting Q_T for the combined flow in Site 2 and 3 to calculate the theoretical concentration for the mixing model (C_T):

$$C_T = \frac{Q_A \cdot C_A + Q_B \cdot C_B}{Q_A + Q_B}$$ [Eq. 2.2]

Where Q (ft^3 s^{-1}) is discharged, C (ng L^{-1}) is CEC concentration reading, and the subscripts A, B, and T refers to the reading from CWWTP effluent (Site 2) discharge, the Caney River intake point (Site 3), and the theoretical mixing component, respectively. Sites that had non-detect for CEC concentration, the value of ½ the Minimum Reporting Level (MRL) was used for the model.

It was assumed that the speed of decomposition of the CEC takes place according to the first-order reaction model (Köck-Schulmeyer et al. 2013; Walters et al. 2010). The first-order rate constant equation (Eq. 2.3) and the half-life equation (Eq. 2.4) are used to find the half-life time for CEC concentration traveling from mixing model location (Site 2) towards the Caney River post-mix site, downstream from CWWTP (Site 1):

$$C_t = C_T \, e^{-kt}$$ [Eq. 2.3]

$$t_{1/2} = \frac{\ln 2}{k}$$ [Eq. 2.4]

By combining the two equations through the rate constant (k), the half-life calculation for each detected CEC calculated within the equation:

$$t_{1/2} = \frac{-t \cdot \ln 2}{\ln \frac{C_t}{C_T}}$$ [Eq. 2.5]

Where C_T (ng L^{-1}) is the CEC theoretical concentration from our mixing model or the initial concentration, C_t is the CEC concentration remains at the measured time (Site 1) or final concentration, t (hrs) is travel time from Site 2 to Site 1, and $t_{1/2}$ (hrs) is the half-life value.

Further information gathered through the USGS stream gauge at the Caney River above Coon Creek (#07174400) and Bartlesville's CWWTP (ODEQ Permit #OK0030333 and ID# S21402) for discharge reading at the time of sampling. The reading from the stream gauge only contained 30 minutes reading intervals of stage height and discharge. Channel velocity was still needed to calculate the time (t) travel from the mixing site to the downstream location (Site 1). Manual hand measurement of channel velocity with the discharge was made by USGS staff on a monthly basis and used in a log-transformed relationship (Figure 8) with data stemming back to 1985 (USGS 2019).

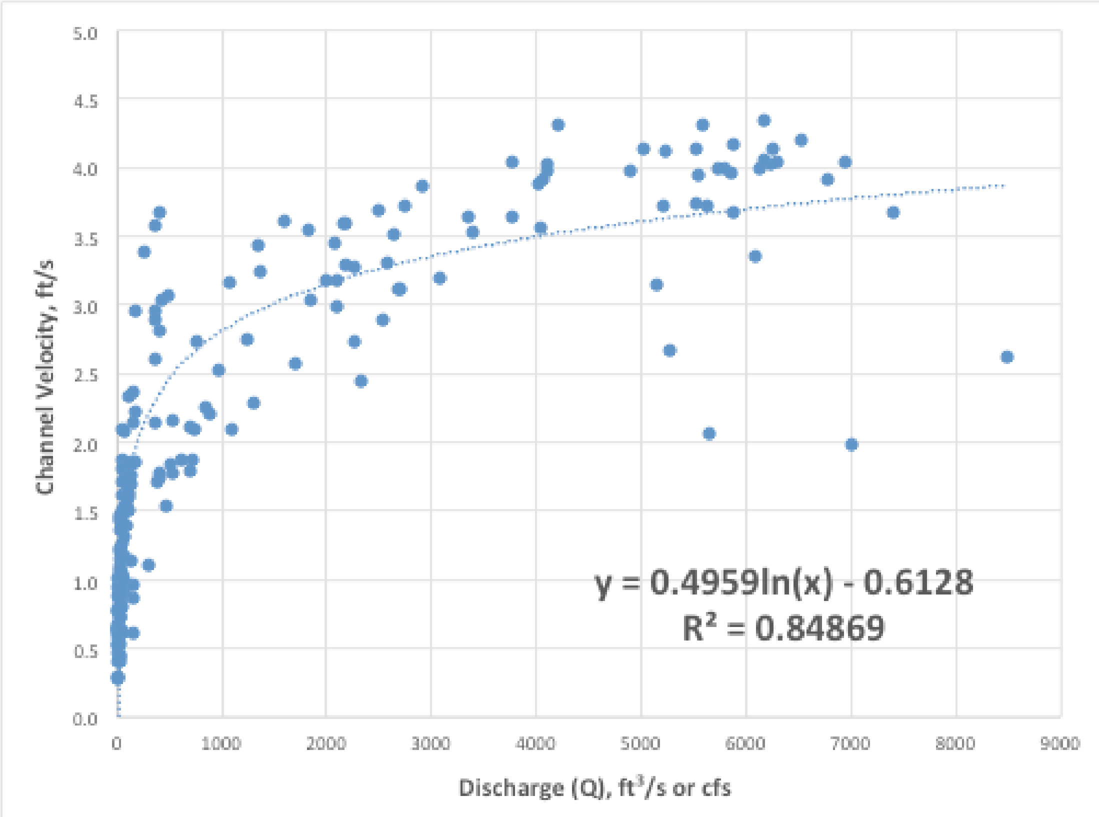

Figure 8. Log-transformed discharge and channel velocity relationship observed at USGS #07174400.

Using the measured gauge discharge at USGS Caney River above Coon Creek gauge and the relationship between log-transformed gauge discharge and channel flow field measurement, channel velocity at the USGS gage can be estimated using the following regression:

$$Channel\ Velocity = 0.4959 \cdot \ln(Gage\ discharge\ in\ cubic\ feet\ per\ seconds) - 0.6128$$

$R^2 = 0.84869$

This equation yields a strong relationship between the channel velocity and discharge, based on the R^2 value. The length of the river for the model to be at 21062 feet (3.99 miles) and was used to calculate the time (t) from the calculated channel velocity (Table A 8).

3.5 Theoretical CEC Concentration after IPR

With the calculated half-life average for the CEC detected within CWWTP effluent discharge (Table A 10 – 12), it set up four scenarios to theoretically calculate the CEC concentration values at WTP raw water intake site (Site 3) once IPR implemented. The theoretical scenarios involve using the mixing equation (Eq. 2.2) to find the theoretical mixing concentration at both proposed IPR sites and using the half-life equation (Eq. 2.5) to find the concentration that would be measured downstream (C_t, Site 3) from the IPR mixing site. These four scenarios include:

Scenario 1: Full flows redirect from CWWTP to Caney River IPR #1 (Site 4)

Scenario 2: Full flows redirect from CWWTP to Caney River IPR #2 (Site W1500RD)

Scenario 3: Half flow redirect from CWWTP to Caney River IPR #1 (Site 4)

Scenario 4: Half flows redirect from CWWTP to Caney River IPR #2 (Site W1500RD)

It was assumed that the value for CEC concentration values for Caney River IPR #1 (Site 4) would be used for site W1500RD. The length of the river from WTP raw water intake site (Site 3) to Caney River IPR #1 (Site 4) to be about 29515.2 feet (5.59 miles) and to Caney River IPR #2 (Site W1500RD) to be about 37435.2 feet (7.09 miles).

The measured distance will be used to calculate the time (t) used in the CEC half-life equation.

Chapter 4. Results and Discussion

4.1 CEC Detection

A total of 64 out of 99 unique Contaminants of Emerging Concern (CEC) compounds were detected in at least one water sample collected during one or more of the three sampling events. The results showed that 11 of 19 pesticides, four of six analyzed industrials, 35 of 53 PPCPs, four of eight hormones, and 10 of 13 others were detected using LC/MS/MS. The CEC analysis results for the three sampling events are presented in Tables A 3 – 5 and Figures B 1 – 21.

The blind duplicate and equipment blank results are presented in Table A 6. The equipment blank for December shows zero detections, which indicates that very low or no contamination issues resulted from the sampling equipment or sampling process. The blind duplicate for March matched with Site 6 results with an average absolute difference of 7 ng L^{-1}. The blind duplicate for December matched with Site 1 results with an average absolute difference of 7.28 ng L^{-1}. The low value within the two blind duplicate indicates a good quality control for the sampling and analytical methods.

The most frequently detected CEC (detection in all three events) were the 2,4-D, Atrazine, Acesulfame-K, Caffeine, Carbamazepine, Carisoprodol, DEET, Dehydronifedipine, Diclofenac, Dilantin, Diltiazem, Fluoxetine, Gemfibrozil, Iohexol, Lidocaine, Meprobamate, Primidone, Sucralose, and Theophylline. “Upper” trace concentrations (> 100 ng L^{-1}) were detected for NP (4-nonylphenol), Acesulfame-K, Amoxicillin, Iohexol, Lidocaine, Sucralose, and TCPP. The CEC specific minimum reporting level (MRL) should consider when comparing detection frequencies of CEC, which factor in at ½ of MRL.

The results from EEA shows that Chickasaw Wastewater Treatment Plant (CWWTP) discharge location (Site 2) comprised 87% of CEC mass within the study, followed by Caney River downstream post-mix (Site 1) with 9%, and the rest (Site, 3, 4, 5, and 6) with 1 % each. The distribution of CEC mass was similar to those of the entire sampling event. December sampling had the highest total amount of CEC mass, and CWWTP discharge contributed about 92% overall. December results could come from the increased use of PPCPs during cold or flu seasons, which leads to a higher CEC mass within CWWTP. March sampling had the second-highest total amount of CEC mass, and CWWTP discharge contributed about 77% overall. July sampling had the lowest total amount of CEC mass, and CWWTP discharge contributed about 89% overall. The results indicate that the upstream sites within Caney River and Lake Hudson had a generally low CEC concentration, and the greatest contribution to CEC are within the CWWTP discharge site and downstream. Comparable CEC detections are typically found in the Wastewater Treatment Plant (WWTP) effluents from all over the world (Deblonde et al., 2011).

4.2 Field Parameters

Table 1 shows the results from our field parameters within the three sampling events. The most substantial changes within the reading of the instrument were in oxidizing-reducing potential (ORP), conductivity (Cond), and total dissolved solids (TDS). Sites from within Lake Hudson (Site 5 and 6), upstream from CWWTP (Site 3 and 4), and downstream from CWWTP (Site 1 and 2) had similar readings within the group.

Conductivity is affected by temperature and the presence of inorganic dissolved solids. Sampling event in July had the highest recorded conductivity average with the temperature at 32°C, while December had the lowest with the temperature at 6.7°C. The conductivity value corresponds to the TDS reading due to related to both specific conductivity and turbidity. The TDS reading from CWWTP effluent yielded the highest and almost doubled the amount compared with the other sites. This stem from the presence of inorganic solids that might come from Bartlesville's CWWTP (APAH, 1992; Hach Company, 1992).

ORP measures the ability of a lake or river to cleanse itself or break down waste products, such as contaminates and dead organic matters. When the ORP value is positive, the values indicate the presence of dissolved oxygen in the water and the promotion of the bacterial activity. A negative ORP value indicates the lack of dissolved oxygen in the water and could stem from excess algae growth, which causes decomposition to increase and accelerate oxygen consumption (Wetzel, 1983). Sampling event in March had the highest recorded OPR average with the reading at a positive (oxidizing) agents, while July and December were both negative (reducing) agents. The sampling site downstream from the CWWTP group (Site 1 and 2) had the highest OPR values when compared to the four other sites. One reason might come from the increase in flow within the river segment from CWWTP effluent discharged, which helps improve the natural reaeration and increase dissolved oxygen (Tetra et al. 2018, 2019).

Table 1. Sampling parameters from the three sampling events. An "*" indicates an NA result from March parameter that was missing for TDS values.

Sites	Date	Time (CT)	Temp (°C)	pH (-Log[H^+])	Cond (µS)	OPR (mV)	TDS (mg L^{-1})	DO% (%)	DO (ppm)
1	March	0908	11.5	7.25	343.1	54	NA*	6.01	6.51
2	March	1052	11.4	7.3	612	56	NA*	57.11	5.76
3	March	1116	11.1	7.71	279.1	76	NA*	73.2	7.51
4	March	1159	11	7.94	296.4	87	NA*	64.7	6.89
5	March	1333	11	7.91	175.9	86	NA*	75.5	8.08
6	March	1352	11.8	8.22	169.1	87	NA*	83.7	8.88
1	July	0900	31.1	6.79	368.2	25	214.8	53.3	3.93
2	July	0959	31.3	6.59	670	-89	403	62.2	4.74
3	July	1024	30.7	8.47	346	-121	202.4	52.1	3.9
4	July	1100	31.4	8.68	352.9	-134	204	49.7	3.62
5	July	1245	33.1	8.37	181.3	-117	101.9	74.3	5.26
6	July	1300	33.7	8.17	184.6	-104	102.4	63.1	4.44
1	December	0845	5.4	6.56	231.2	-31	236.2	87.5	11.01
2	December	0950	13.6	7.31	553	-53	461	62.7	6.37
3	December	1015	4.8	8.29	210.1	-103	219.9	74.9	9.52
4	December	1045	4.8	8.33	225.9	-107	237	85.9	10.93
5	December	1215	5.8	8.2	79.1	-100	80	81	10.06
6	December	1240	5.8	8.21	83.2	-94	84.3	84.1	10.42

4.3 Mixing Model and Half-Life

The data obtained in the study (Tables A. 3 – 5) were used to simulate the mixing model for CWWTP discharge and the Caney River, which is shown in Tables A10 – 12. The mixing model equation (Eq. 2.2) is dependent on the discharge value between the two observed sites for the CEC theoretical concentration value. The CWWTP discharge had a constant flow of 9.65 $ft^3\ s^{-1}$. The Caney River had a discharge 37.4 $ft^3\ s^{-1}$ in March, 23.7 ft^3 s^{-1} in July, and 91.3 ft^3 s^{-1} in December. During the highest recorded flow within the Caney River for December, the detected CWWTP CEC concentration was diluted on average more than 83% upon mixing into the Caney River. Hydrograph for discharge from the 2018 physical year (Figure 9) indicated that December was a greater positive anomaly from the median daily statistic from 33 years. The stretch of August to December the area experienced a long wet period, with peak discharge values in late October and mid-December. The overall average of dilution calculated between the three sampling events were more than 66%.

Two stipulations were needed for a positive calculation in half-life values (Eq. 2.5). The first being that the initial concentration (C_T) has to be higher than the final concentration (C_t). The second being that sites do not contain the same value, or it will produce an undefined (NA) value from division by zero (0). Within our model, a total of 61 unique CEC compounds were detected at CWWTP and were used for half-life calculation. Only 59 of CEC within our model pass our stipulation for a half-life value. A negative half-life was computed for two compounds, 1,7-Dimethylxanthine and Acetaminophen, which may be because there is an additional source of the CEC between the Site 2 mixing component and Site 1, analytical uncertainty (i.e., ± for concentrations) was high and made it difficult to distinguish between Site 2 mixing component and Site 1 concentrations.

The overall half-life results are shown in Table 2, along with the calculated average. Table 2 shows that 11 pesticide half-lives range from 1.93 to 134.44 hours, four industrial half-lives range from 1.74 to 9.28 hours, 34 PCPPs half-lives range from 0.99 to 187.88 hours, two hormone half-lives range from 2.17 to 4.84 hours, and eight other half-lives range from 1.63 to 245.83 hours within our calculation (Figures B 22 – 26). Amoxicillin and Sucralose have the highest calculated half-life, which suggests that they are most persistent in the environment. One explanation could be due to the concentration detect well above 10000 ng L^{-1} from the CWWTP, and that the environmental buffers within the Caney River had little effect of degrading the compounds.

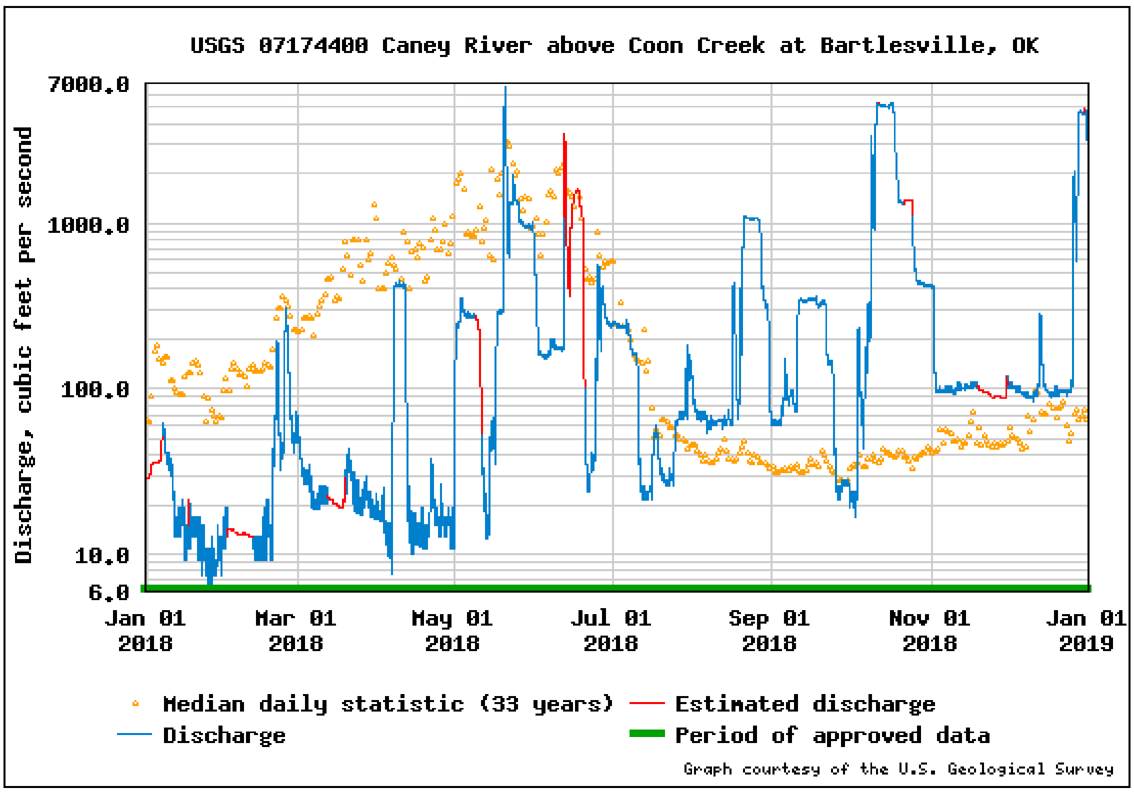

Figure 9. USGS gauge #07174400 Caney River above Coon Creek at Bartlesville, Ok hydrograph for 2018 (USGS 2019).

Table 2. CEC half-life values for the three sampling event and average. An "*" indicates an NA result from half-life calculation from non-detect within sites 1, 2, and 3 or having a negative value

Analyte	Class	March (hrs)	July (hrs)	December (hrs)	Average (hrs)

2,4-D	Pesticides	NA*	73.67	NA*	73.67
NP (4-nonylphenol)	Industrials	NA*	9.28	NA*	9.28
Acesulfame-K	Others	NA*	2.08	3.3	2.69
Albuterol	PPCPs	1.68	NA*	7.44	4.56
Amoxicillin	PPCPs	2.63	NA*	187.88	95.26
Atenolol	PPCPs	3.29	1.41	1.79	2.16
Atrazine	Pesticides	3.17	NA*	10.46	6.82
Bromacil	Pesticides	2.54	NA*	NA*	2.54
Butalbital	PPCPs	NA*	3.59	2.77	3.18
Caffeine	Others	NA*	NA*	6.43	6.43
Carbamazepine	PPCPs	5.35	2.44	3.27	3.69
Carisoprodol	PPCPs	15.22	3.23	4.69	7.71
Cimetidine	PPCPs	NA*	NA*	0.99	0.99
Cotinine	Others	NA*	6.47	3.74	5.11
DEA	Pesticides	16.49	NA*	NA*	16.49
DEET	Others	3.75	11.21	13.17	9.38
Dehydronifedipine	PPCPs	11.76	7.94	4.9	8.20
DIA	Pesticides	2.5	NA*	NA*	2.50
Diclofenac	PPCPs	8.91	1.43	4.86	5.07
Dilantin	PPCPs	2.75	4.17	6.32	4.41
Diltiazem	PPCPs	3.14	3.49	1.19	2.61
Diuron	Pesticides	NA*	NA*	1.93	1.93
Erythromycin	PPCPs	4.84	NA*	27.54	16.19
Estrone	Hormones	NA*	NA*	4.84	4.84
EE2 (17 Alpha-ethynylestradiol)	Hormones	NA*	2.17	NA*	2.17
Fluoxetine	PPCPs	1.59	2.17	2.92	2.23
Gemfibrozil	PPCPs	4.58	3.39	1.98	3.32
Ibuprofen	PPCPs	NA*	4.51	1.96	3.24
Iohexol	PPCPs	NA*	1.81	2.62	2.22
Ketoprofen	PPCPs	NA*	NA*	2.49	2.49
Ketorolac	PPCPs	NA*	NA*	1.96	1.96
Lidocaine	PPCPs	5.66	1.82	3.38	3.62
Linuron	Pesticides	NA*	5.72	NA*	5.72

Lopressor	PPCPs	NA*	2.05	2.65	2.35
Meclofenamic Acid	PPCPs	3.49	NA*	NA*	3.49
Meprobamate	PPCPs	3.81	1.73	5.22	3.59
Metformin	PPCPs	4	3.24	2.77	3.34
Methylparaben	Others	NA*	46.14	NA*	46.14
Metolachlor	Pesticides	3.06	NA*	NA*	3.06
Naproxen	PPCPs	NA*	NA*	1.82	1.82
Nifedipine	PPCPs	5.7	NA*	9.68	7.69
OUST	Pesticides	NA*	3	NA*	3.00
Pentoxifylline	PPCPs	2.4	NA*	4.69	3.55
Primidone	PPCPs	2.52	1.69	4.54	2.92
Propylparaben	Others	NA*	1.92	NA*	1.92
Quinoline	Pesticides	134.44	NA*	2.33	68.39
Simazine	Pesticides	NA*	12.78	109.85	61.31
Sulfadiazine	PPCPs	NA*	4.21	NA*	4.21
Sulfamethoxazole	PPCPs	NA*	2.05	5.91	3.98
Sucralose	Others	245.83	1.98	3.71	83.84
TCEP	Industrials	5.49	2.96	2.52	3.66
TCPP	Industrials	4.05	1.76	2.92	2.91
TDCPP	Industrials	1.74	NA*	NA*	1.74
Theophylline	PPCPs	NA*	NA*	1.14	1.14
Thiabendazole	Others	NA*	61.74	1.63	31.69
Triclocarban	PPCPs	NA*	2.64	NA*	2.64
Triclosan	PPCPs	4.84	NA*	25.14	14.99
Trimethoprim	PPCPs	3.55	NA*	3.37	3.46
Warfarin	PPCPs	14.23	NA*	NA*	14.23

4.4 IPR Scenarios

IPR scenarios required that the mixing formula (Eq. 2.2) calculate CWWTP effluent redirect to the two proposed locations (Site 4 and Site W1500RD), from Table A

13 – 14. Then it needs to be to plugged into the half-life formula (Eq. 2.5), with the average half-life value from Table 2, to find the theoretical concentration (C_t) at the Water Treatment Plant (WTP) intake location (Site 3). The results of our IPR scenario shows in Table 3 for March, Table 4 for July, and Table 5 for December calculation. The highlighted value indicating the theoretical calculation within the scenarios were higher than the actual measured value, and the darker shade represents an upper trace (> 100 ng L^{-1}) CEC concentration.

Scenario one contained the highest amount CEC that theoretically exceeded the actual measured value from Site 3, with a total of 24 on March, 13 in July, and 24 in December. Scenario four had the lowest, with 19 on March, eight in July, and 14 in December. Four CEC compound were label as upper trace amount; NP (4-nonylphenol), Amoxicillin, Iohexol, and Sucralose. These four compounds had some of the largest measured concentration within CWWTP, and the location of the propose IPR project was insufficient to have the environmental buffer remove concentration to acceptable levels. To have every CEC compound to be equal or less than the actual initial readings from Site 3, the location of the IPR project needs to be more than 515 miles of displacement within the Caney River.

Table 3. March theoretical calculation from 59 CEC compounds. All values reported in ng L^{-1}.

March 20th, 2018			**Full Flow**		**Half Flow**	
			Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**
Analyte	**Class**	**Site 3**	**Site 4**	**W1500RD**	**Site 4**	**W1500RD**

		(ng L^{-1})	(ng L^{-1})	(ng L^{-1})	(ng L^{-1})	(ng L^{-1})
2,4-D	Pesticides	30	39.855	39.164	32.584	32.019
NP (4-nonylphenol)	Industrials	410	901.772	784.895	690.037	600.603
Acesulfame-K	Others	10	32.363	20.047	19.677	12.188
Albuterol	PPCPs	2.5	3.932	2.964	2.578	1.944
Amoxicillin	PPCPs	40	304.876	300.779	186.804	184.294
Atenolol	PPCPs	2.5	7.374	4.062	4.231	2.331
Atrazine	Pesticides	52	22.821	18.889	23.001	19.038
Bromacil	Pesticides	2.5	1.456	0.878	0.979	0.590
Butalbital	PPCPs	2.5	0.552	0.368	0.552	0.368
Caffeine	Others	12	9.016	7.378	6.074	4.971
Carbamazepine	PPCPs	12.5	18.467	13.016	10.596	7.468
Carisoprodol	PPCPs	2.5	20.353	17.221	14.671	12.413
Cimetidine	PPCPs	2.5	0.020	0.005	0.020	0.005
Cotinine	Others	5	1.750	1.359	1.839	1.429
DEA	Pesticides	2.5	2.300	2.127	2.109	1.950
DEET	Others	5	20.923	18.236	12.990	11.322
Dehydronifedipine	PPCPs	2.5	1.863	1.592	1.654	1.414
DIA	Pesticides	2.5	1.444	0.863	0.968	0.578
Diclofenac	PPCPs	2.5	45.553	35.322	25.825	20.025
Dilantin	PPCPs	10	11.711	8.746	8.020	5.989
Diltiazem	PPCPs	2.5	3.351	2.043	2.043	1.246
Diuron	Pesticides	5.3	0.413	0.212	0.437	0.224
Erythromycin	PPCPs	5	7.550	6.972	5.854	5.406
Estrone	Hormones	2.5	0.927	0.710	0.927	0.710
EE2 (17 Alpha-ethynylestradiol)	Hormones	2.5	0.272	0.150	0.272	0.150
Fluoxetine	PPCPs	5	4.983	2.792	3.033	1.699
Gemfibrozil	PPCPs	2.5	1.242	0.842	0.952	0.645
Ibuprofen	PPCPs	5	1.133	0.761	1.133	0.761
Iohexol	PPCPs	50	173.999	97.173	99.532	55.586
Ketoprofen	PPCPs	12.5	0.363	0.216	0.363	0.216
Ketorolac	PPCPs	12.5	0.217	0.113	0.217	0.113
Lidocaine	PPCPs	2.5	21.895	15.339	12.501	8.758
Linuron	Pesticides	2.5	1.079	0.861	1.079	0.861

Lopressor	PPCPs	10	1.292	0.746	1.292	0.746
Meclofenamic Acid	PPCPs	2.5	22.939	15.861	13.069	9.036
Meprobamate	PPCPs	12.5	10.796	7.538	6.309	4.405
Metformin	PPCPs	2.5	11.727	7.971	6.801	4.622
Methylparaben	Others	10	9.011	8.763	9.011	8.763
Metolachlor	Pesticides	6.4	2.604	1.710	2.604	1.710
Naproxen	PPCPs	5	0.357	0.176	0.357	0.176
Nifedipine	PPCPs	10	9.774	8.265	7.818	6.611
OUST (Sulfometuron, methyl)	Pesticides	2.5	0.504	0.328	0.504	0.328
Pentoxifylline	PPCPs	12.5	0.645	0.449	0.645	0.449
Primidone	PPCPs	10	7.505	4.827	5.038	3.240
Propylparaben	Others	2.5	0.205	0.105	0.205	0.105
Quinoline	Pesticides	5.8	3.965	3.891	3.242	3.181
Simazine	Pesticides	12.5	24.144	23.642	16.284	15.945
Sulfadiazine	PPCPs	10	5.836	4.297	4.668	3.438
Sulfamethoxazole	PPCPs	2.5	1.365	0.987	1.092	0.790
Sucralose	Others	50	9061.227	8922.994	5106.170	5028.273
TCEP	Industrials	2.5	8.288	5.828	5.216	3.668
TCPP	Industrials	2.5	59.113	37.961	37.204	23.892
TDCPP	Industrials	2.5	12.629	6.030	8.448	4.033
Theophylline	PPCPs	10	0.418	0.135	0.298	0.096
Thiabendazole	Others	2.5	2.148	2.063	2.148	2.063
Triclocarban	PPCPs	5	0.809	0.496	0.809	0.496
Triclosan	PPCPs	5	7.374	6.766	5.717	5.246
Trimethoprim	PPCPs	2.5	33.459	23.055	18.930	13.044
Warfarin	PPCPs	2.5	2.270	2.073	2.055	1.877

Table 4. July theoretical calculation from 59 CEC compounds. All values reported in ng L^{-1}.

July 12th, 2018			Full Flow		Half Flow	
			Scenario 1	Scenario 2	Scenario 3	Scenario 4
Analyte	Class	Site 3 (ng L^{-1})	Site 4 (ng L^{-1})	W1500RD (ng L^{-1})	Site 4 (ng L^{-1})	W1500RD (ng L^{-1})
2,4-D	Pesticides	130	127.297	125.089	129.008	126.770
NP (4-nonylphenol)	Industrials	50	42.108	36.650	36.665	31.913
Acesulfame-K	Others	10	9.642	5.973	6.118	3.790
Albuterol	PPCPs	2.5	0.872	0.658	0.872	0.658
Amoxicillin	PPCPs	40	38.033	37.522	38.033	37.522
Atenolol	PPCPs	2.5	4.018	2.214	2.360	1.300
Atrazine	Pesticides	24	10.270	8.501	10.974	9.083
Bromacil	Pesticides	2.5	0.379	0.228	0.379	0.228
Butalbital	PPCPs	2.5	1.441	0.961	1.048	0.699
Caffeine	Others	2.5	1.184	0.969	1.184	0.969
Carbamazepine	PPCPs	2.5	14.545	10.251	8.410	5.927
Carisoprodol	PPCPs	2.5	3.943	3.336	2.792	2.362
Cimetidine	PPCPs	2.5	0.020	0.005	0.020	0.005
Cotinine	Others	5	3.240	2.517	2.670	2.074
DEA	Pesticides	9.3	6.394	5.913	6.011	5.559
DEET	Others	17	13.523	11.787	12.046	10.499
Dehydronifedipine	PPCPs	2.5	2.092	1.788	1.782	1.523
DIA	Pesticides	2.5	0.367	0.220	0.367	0.220
Diclofenac	PPCPs	2.5	13.564	10.518	7.991	6.196
Dilantin	PPCPs	10	7.609	5.683	5.733	4.282
Diltiazem	PPCPs	2.5	1.065	0.650	0.769	0.469
Diuron	Pesticides	2.5	0.208	0.107	0.208	0.107
Erythromycin	PPCPs	5	3.716	3.432	3.716	3.432
Estrone	Hormones	2.5	0.927	0.710	0.927	0.710
EE2 (17 Alpha-ethynylestradiol)	Hormones	2.5	1.452	0.801	0.930	0.513
Fluoxetine	PPCPs	5	3.078	1.724	1.971	1.104

Gemfibrozil	PPCPs	2.5	1.629	1.105	1.168	0.792
Ibuprofen	PPCPs	5	2.395	1.608	1.837	1.233
Iohexol	PPCPs	50	230.490	128.722	131.027	73.175
Ketoprofen	PPCPs	2.5	0.363	0.216	0.363	0.216
Ketorolac	PPCPs	2.5	0.217	0.113	0.217	0.113
Lidocaine	PPCPs	2.5	27.374	19.178	15.556	10.898
Linuron	Pesticides	2.5	1.925	1.536	1.551	1.238
Lopressor	PPCPs	10	7.691	4.441	4.859	2.806
Meclofenamic Acid	PPCPs	2.5	0.632	0.437	0.632	0.437
Meprobamate	PPCPs	2.5	5.604	3.913	3.414	2.384
Metformin	PPCPs	2.5	0.593	0.403	0.593	0.403
Methylparaben	Others	53	35.473	34.496	38.517	37.456
Metolachlor	Pesticides	12	1.761	1.156	1.904	1.250
Naproxen	PPCPs	5	0.357	0.176	0.357	0.176
Nifedipine	PPCPs	10	5.354	4.528	5.354	4.528
OUST (Sulfometuron, methyl)	Pesticides	5.5	1.779	1.158	1.474	0.959
Pentoxifylline	PPCPs	2.5	0.645	0.449	0.645	0.449
Primidone	PPCPs	5	8.730	5.615	5.294	3.405
Propylparaben	Others	29	2.012	1.029	2.176	1.113
Quinoline	Pesticides	2.5	2.330	2.287	2.330	2.287
Simazine	Pesticides	2.5	2.960	2.899	2.673	2.618
Sulfadiazine	PPCPs	10	7.155	5.269	5.404	3.979
Sulfamethoxazole	PPCPs	2.5	27.136	19.629	15.460	11.183
Sucralose	Others	50	9196.136	9055.845	5147.957	5069.423
TCEP	Industrials	5	37.723	26.524	21.627	15.207
TCPP	Industrials	50	78.919	50.680	48.246	30.983
TDCPP	Industrials	50	3.180	1.518	3.180	1.518
Theophylline	PPCPs	10	0.146	0.047	0.146	0.047
Thiabendazole	Others	22	15.141	14.537	14.905	14.311
Triclocarban	PPCPs	5	3.111	1.908	2.092	1.283
Triclosan	PPCPs	5	3.629	3.330	3.629	3.330
Trimethoprim	PPCPs	2.5	0.624	0.430	0.624	0.430

Warfarin	PPCPs	2.5	1.784	1.629	1.784	1.629

Table 5. December theoretical calculation from 59 CEC compounds. All values reported in ng L^{-1}.

December 19th, 2018			Full Flow		Half Flow	
			Scenario 1	Scenario 2	Scenario 3	Scenario 4
Analyte	Class	Site 3 (ng L^{-1})	Site 4 (ng L^{-1})	W1500RD (ng L^{-1})	Site 4 (ng L^{-1})	W1500RD (ng L^{-1})
2,4-D	Pesticides	7.2	6.878	6.759	7.400	7.271
NP (4-nonylphenol)	Industrials	200	119.225	103.773	119.225	103.773
Acesulfame-K	Others	10	91.364	56.593	51.680	32.012
Albuterol	PPCPs	2.5	1.628	1.227	1.294	0.975
Amoxicillin	PPCPs	10	3343.080	3298.152	1868.054	1842.949
Atenolol	PPCPs	2.5	5.584	3.076	3.233	1.781
Atrazine	Pesticides	2.5	1.960	1.622	1.639	1.357
Bromacil	Pesticides	2.5	0.379	0.228	0.379	0.228
Butalbital	PPCPs	2.5	2.307	1.538	1.531	1.021
Caffeine	Others	5	4.812	3.938	3.731	3.053
Carbamazepine	PPCPs	2.5	11.744	8.277	6.848	4.826
Carisoprodol	PPCPs	2.5	3.389	2.868	2.483	2.101
Cimetidine	PPCPs	2.5	0.511	0.140	0.294	0.080
Cotinine	Others	5	5.978	4.644	4.196	3.260
DEA	Pesticides	2.5	1.868	1.728	1.868	1.728
DEET	Others	5	4.356	3.796	3.754	3.272
Dehydronifedipine	PPCPs	2.5	3.402	2.907	2.512	2.147
DIA	Pesticides	2.5	0.367	0.220	0.367	0.220
Diclofenac	PPCPs	2.5	14.364	11.138	8.437	6.542
Dilantin	PPCPs	10	6.914	5.164	5.346	3.992
Diltiazem	PPCPs	2.5	6.519	3.975	3.810	2.323
Diuron	Pesticides	2.5	1.403	0.720	0.874	0.449

Erythromycin	PPCPs	5	4.483	4.140	4.144	3.827
Estrone	Hormones	2.5	6.474	4.961	4.019	3.080
EE2 (17 Alpha-ethynylestradiol)	Hormones	2.5	0.272	0.150	0.272	0.150
Fluoxetine	PPCPs	2.5	3.087	1.729	1.849	1.036
Gemfibrozil	PPCPs	2.5	30.035	20.361	17.005	11.528
Ibuprofen	PPCPs	5	7.444	4.998	4.652	3.123
Iohexol	PPCPs	5	966.412	539.712	539.555	301.325
Ketoprofen	PPCPs	2.5	1.725	1.027	1.122	0.668
Ketorolac	PPCPs	2.5	1.425	0.740	0.891	0.462
Lidocaine	PPCPs	2.5	60.797	42.593	34.189	23.953
Linuron	Pesticides	2.5	1.079	0.861	1.079	0.861
Lopressor	PPCPs	10	21.554	12.447	12.589	7.269
Meclofenamic Acid	PPCPs	2.5	0.632	0.437	0.632	0.437
Meprobamate	PPCPs	2.5	4.198	2.931	2.630	1.836
Metformin	PPCPs	2.5	2.477	1.684	1.643	1.117
Methylparaben	Others	10	9.011	8.763	9.011	8.763
Metolachlor	Pesticides	2.5	0.521	0.342	0.521	0.342
Naproxen	PPCPs	5	2.640	1.300	1.630	0.803
Nifedipine	PPCPs	10	8.779	7.424	7.264	6.143
OUST (Sulfometuron, methyl)	Pesticides	2.5	0.504	0.328	0.504	0.328
Pentoxifylline	PPCPs	2.5	1.630	1.133	1.194	0.830
Primidone	PPCPs	2.5	10.339	6.649	5.978	3.844
Propylparaben	Others	2.5	0.205	0.105	0.205	0.105
Quinoline	Pesticides	78	2.330	2.287	2.330	2.287
Simazine	Pesticides	2.5	17.862	17.491	10.982	10.753
Sulfadiazine	PPCPs	2.5	0.799	0.589	0.799	0.589
Sulfamethoxazole	PPCPs	2.5	62.320	45.080	35.076	25.372
Sucralose	Others	50	8806.405	8672.060	4930.673	4855.454
TCEP	Industrials	5	6.289	4.422	4.101	2.884
TCPP	Industrials	50	37.722	24.225	25.278	16.233
TDCPP	Industrials	50	3.180	1.518	3.180	1.518

Theophylline	PPCPs	15	1.182	0.381	0.763	0.246
Thiabendazole	Others	2.5	19.083	18.322	11.590	11.128
Triclocarban	PPCPs	10	1.617	0.992	1.617	0.992
Triclosan	PPCPs	10	8.906	8.172	8.177	7.503
Trimethoprim	PPCPs	2.5	23.158	15.957	13.187	9.087
Warfarin	PPCPs	2.5	1.784	1.629	1.784	1.629

Chapter 5. Conclusions

In this study, the mixing equation and half-life formula were used to test the theoretical model for four scenarios when IPR is implemented. Out of the 99 CEC compounds, 61 were detected within the CWWTP discharge site. We calculated a half-life for 59 of the 61 CEC to evaluate the environmental buffer within the Caney River. Our model shows by moving the IPR location from Site 4 to Site W1500RD reduced the CEC concentration level by 28%. The transition of full flow to half flow from the CWWTP effluent reduces the CEC concentration level by 21%. Scenario four has the lowest projected CEC concentration and is recommended for the IPR project. Within Scenario four, we estimate that NP (4-nonylphenol), Amoxicillin, Iohexol, and Sucralose will be detected at upper trace concentrations. Our calculation shows that moving the IPR location further be insufficient for the environmental buffer to lower the concentration below the 100 ng L^{-1} threshold. A recommendation to the City of Bartlesville and the CWWTP would be to continue to collect samples within the Caney River and CWWTP discharge site. This strategy would help to create more accurate half-life values and evaluate the environmental buffer within the Caney River. Additionally, the four compounds identified to be an upper trace amount within scenario 4, could be lowered through advanced treatment at the CWWTP before discharge back into the Caney River.

References

Acuña, Vicenç, Daniel von Schiller, Maria Jesús García-Galán, Sara Rodríguez-Mozaz, Lluís Corominas, Mira Petrovic, Manel Poch, Damià Barceló, and Sergi Sabater. 2015. “Occurrence and In-Stream Attenuation of Wastewater-Derived Pharmaceuticals in Iberian Rivers.” Science of the Total Environment. https://doi.org/10.1016/j.scitotenv.2014.05.067.

Adgate, John L, Anne Kukowski, Chuck Strobel, Pamela J. Shubat, Shana Morrell, James J. Quckenboss, Roy W. Whitmore, and Ken Sexton. 2000. “Pesticide Storage and Use Patterns in Minnesota Households with Children.” Journal of Exposure Science & Environmental Epidemiology. https://doi.org/10.1038/sj.jea.7500078.

Alewu, B., and C. Nosiri. 2012. Pesticides in the Modern World - Effects of Pesticides Exposure. Pesticides in the Modern World - Effects of Pesticides Exposure. https://doi.org/10.5772/943.

American Water Works Association (AWWA). 2016. “Potable Reuse 101.” An Innovative and Sustainable Water Supply Solution. https://doi.org/10.1890/13-0161.1.

Andresen, J. A., A. Grundmann, and K. Bester. 2004. “Organophosphorus Flame Retardants and Plasticisers in Surface Waters.” Science of the Total Environment. https://doi.org/10.1016/j.scitotenv.2004.04.021.

American Public Health Association (APHA). 1992. Standard methods for the examination of water and wastewater. 18th ed. American Public Health Association, Washington, DC.

Birch, G. F., D. S. Drage, K. Thompson, G. Eaglesham, and J. F. Mueller. 2015. “Emerging Contaminants (Pharmaceuticals, Personal Care Products, a Food Additive and Pesticides) in Waters of Sydney Estuary, Australia.” Marine Pollution Bulletin. https://doi.org/10.1016/j.marpolbul.2015.06.038.

Brooks, Bryan W, Duane B Huggett, and Alistair B a Boxall. 2009. “Pharmaceuticals and Personal Care Products in the Environment Editorial Pharmaceutical and Personal Care Products: Research Needs for the Next Decade.” Environmental Toxicology and Chemistry / SETAC--3区. https://doi.org/10.1897/09-325.1.

Buerge, Ignaz J., Thomas Poiger, Markus D. Müller, and Hans Rudolf Buser. 2006. “Combined Sewer Overflows to Surface Waters Detected by the Anthropogenic Marker Caffeine.” Environmental Science and Technology. https://doi.org/10.1021/es052553l.

Can, O. T., M. Kobya, E. Demirbas, and M. Bayramoglu. 2006. “Treatment of the Textile Wastewater by Combined Electrocoagulation.” Chemosphere. https://doi.org/10.1016/j.chemosphere.2005.05.022.

Charles, Amelia K., and Philippa D. Darbre. 2013. “Combinations of Parabens at Concentrations Measured in Human Breast Tissue Can Increase Proliferation of MCF-7 Human Breast Cancer Cells.” Journal of Applied Toxicology. https://doi.org/10.1002/jat.2850.

Cwszot. “Liquid Chromatography Mass Spectrometer.” Wikipedia, 2017, upload.wikimedia.org/wikipedia/en/f/f9/Liquid_chromatography_tandem_Mass_spectrometry_diagram.png.

Darbre, Philippa D., and Philip W. Harvey. 2014. “Parabens Can Enable Hallmarks and Characteristics of Cancer in Human Breast Epithelial Cells: A Review of the Literature with Reference to New Exposure Data and Regulatory Status.” Journal of Applied Toxicology. https://doi.org/10.1002/jat.3027.

Deblonde, Tiphanie, Carole Cossu-Leguille, and Philippe Hartemann. 2011. “Emerging Pollutants in Wastewater: A Review of the Literature.” International Journal of Hygiene and Environmental Health. https://doi.org/10.1016/j.ijheh.2011.08.002.

Duirk, Stephen E, and Timothy W Collette. 2005. “Organophosphate Pesticide Degradation under Drinking Water Treatment Conditions: Modeling Perspectives.” Proc. - Annu. Conf., Am. Water Works Assoc.

Ebele, Anekwe Jennifer, Mohamed Abou-Elwafa Abdallah, and Stuart Harrad. 2017. “Pharmaceuticals and Personal Care Products (PPCPs) in the Freshwater Aquatic Environment.” Emerging Contaminants. https://doi.org/10.1016/j.emcon.2016.12.004.

Eurofins Scientific 2018. n.d. “Liquid Chromatography - Tandem Mass Spectrometry (LC-MS-MS).” Accessed July 3, 2019. https://www.eag.com/techniques/mass-spec/lc-ms-ms/.

Fairbairn, David J., William A. Arnold, Brian L. Barber, Elizabeth F. Kaufenberg, William C. Koskinen, Paige J. Novak, Pamela J. Rice, and Deborah L. Swackhamer. 2016. “Contaminants of Emerging Concern: Mass Balance and Comparison of Wastewater Effluent and Upstream Sources in a Mixed-Use Watershed.” Environmental Science and Technology. https://doi.org/10.1021/acs.est.5b03109.

Fairbairn, David J., M. Ekrem Karpuzcu, William A. Arnold, Brian L. Barber, Elizabeth F. Kaufenberg, William C. Koskinen, Paige J. Novak, Pamela J. Rice, and Deborah L. Swackhamer. 2016. “Sources and Transport of Contaminants of Emerging Concern: A Two-Year Study of Occurrence and Spatiotemporal

Variation in a Mixed Land Use Watershed." Science of the Total Environment. https://doi.org/10.1016/j.scitotenv.2016.02.056.

Gao, Pin, Yunjie Ding, Hui Li, and Irene Xagoraraki. 2012. "Occurrence of Pharmaceuticals in a Municipal Wastewater Treatment Plant: Mass Balance and Removal Processes." Chemosphere. https://doi.org/10.1016/j.chemosphere.2012.02.017.

García, Ana M. 2003. "Pesticide Exposure and Women's Health." In American Journal of Industrial Medicine. https://doi.org/10.1002/ajim.10256.

Glassmeyer, Susan T., Edward T. Furlong, Dana W. Kolpin, Angela L. Batt, Robert Benson, J. Scott Boone, Octavia Conerly, et al. 2017. "Nationwide Reconnaissance of Contaminants of Emerging Concern in Source and Treated Drinking Waters of the United States." Science of the Total Environment. https://doi.org/10.1016/j.scitotenv.2016.12.004.

Grassi, Mariangela, Gul Kaykioglu, Vincenzo Belgiorno, and Giusy Lofrano. 2012. "Removal of Emerging Contaminants from Water and Wastewater by Adsorption Process." In. https://doi.org/10.1007/978-94-007-3916-1_2.

Groshart, C.P., P.C. Okkerman, and A.M.C.M. Pijnenburg. 2015. "Chemical Study on Bisphenol A." Ministerie van Verkeer En Waterstaat.

Hach Company. 1992. Hach water analysis handbook. 2nd ed. Loveland, CO.

Harvey, Jud, and Michael Gooseff. 2015. "River Corridor Science: Hydrologic Exchange and Ecological Consequences from Bedforms to Basins." Water Resources Research. https://doi.org/10.1002/2015WR017617.

Jeong, Hyeri, Jongwoon Kim, and Youngjun Kim. 2017. "Identification of Linkages between EDCs in Personal Care Products and Breast Cancer through Data Integration Combined with Gene Network Analysis." International Journal of Environmental Research and Public Health. https://doi.org/10.3390/ijerph14101158.

Köck-Schulmeyer, Marianne, Marta Villagrasa, Miren López de Alda, Raquel Céspedes-Sánchez, Francesc Ventura, and Damià Barceló. 2013. "Occurrence and Behavior of Pesticides in Wastewater Treatment Plants and Their Environmental Impact." Science of the Total Environment. https://doi.org/10.1016/j.scitotenv.2013.04.010.

Kolpin, Dana W., Edward T. Furlong, Michael T. Meyer, E. Michael Thurman, Steven D. Zaugg, Larry B. Barber, and Herbert T. Buxton. 2002. "Pharmaceuticals, Hormones, and Other Organic Wastewater Contaminants in U.S. Streams, 1999-

2000: A National Reconnaissance.” Environmental Science and Technology. https://doi.org/10.1021/es011055j.

Lu, Guoping, Eric L. Sonnenthal, and Gudmundur S. Bodvarsson. 2008. “Multiple Component End-Member Mixing Model of Dilution: Hydrochemical Effects of Construction Water at Yucca Mountain, Nevada, USA.” Hydrogeology Journal. https://doi.org/10.1007/s10040-008-0322-1.

Mnif, Wissem, Aziza Ibn Hadj Hassine, Aicha Bouaziz, Aghleb Bartegi, Olivier Thomas, and Benoit Roig. 2011. “Effect of Endocrine Disruptor Pesticides: A Review.” International Journal of Environmental Research and Public Health. https://doi.org/10.3390/ijerph8062265.

Murray, Kyle E., Sheeba M. Thomas, and Adria A. Bodour. 2010. “Prioritizing Research for Trace Pollutants and Emerging Contaminants in the Freshwater Environment.” Environmental Pollution. https://doi.org/10.1016/j.envpol.2010.08.009.

National Association of State Departments of Agriculture (NASDA). 2014. “Pesticide Application Procedures.” In National Pesticide Applicator Certification Core Manual.

National Research Council (NRC). 1998. “Issues in Potable Reuse: The Viability of Augmenting Drinking Water Supplies with Reclaimed Water.” Water Science and Technology. https://doi.org/10.17226/6022.

Nussey, S., and Whitehead S. 2001. Endocrinology: An Integrated Approach. Oxford: BIOS Scientific Publishers. https://www.ncbi.nlm.nih.gov/books/NBK20/.

Oklahoma Department of Environmental Quality (ODEQ). 2014. “Regulatory Path Forward for Indirect and Direct Potable Reuse of Reclaimed Water.”

Oklahoma Water Resource Board (OWRB). 2009. “OWRB Stream System Management Basins.” http://www.owrb.ok.gov/index.php.

Oklahoma Water Resource Board (OWRB). 2013. “Oklahoma Comprehensive Water Plan Middle Arkansas Watershed Planning Region Report.” https://www.owrb.ok.gov/supply/ocwp/pdf_ocwp/WaterPlanUpdate/regionalreports/OCWP_MiddleArkansas_Region_Report.pdf.

Petrie, Bruce, Ruth Barden, and Barbara Kasprzyk-Hordern. 2014. “A Review on Emerging Contaminants in Wastewaters and the Environment: Current Knowledge, Understudied Areas and Recommendations for Future Monitoring.” Water Research. https://doi.org/10.1016/j.watres.2014.08.053.

PubChem. 2019. “PubChem Compound.” National Center for Biotechnology Information, U.S. National Library of Medicine. 2019. https://doi.org/CID=445639.

Raghav, Madhumitha, Susanna Eden, Katharine Mitchell, Becky Witte, and John Polle. 2013. "Contaminants of Emerging Concern Raise Many Questions." Water Resources Research Center, The University of Arizona, 2013.

Rahman, M. F., E. K. Yanful, and S. Y. Jasim. 2009. "Endocrine Disrupting Compounds (EDCs) and Pharmaceuticals and Personal Care Products (PPCPs) in the Aquatic Environment: Implications for the Drinking Water Industry and Global Environmental Health." Journal of Water and Health. https://doi.org/10.2166/wh.2009.021.

Reemtsma, Thorsten, Mónica García-López, Isaac Rodríguez, José Benito Quintana, and Rosario Rodil. 2008. "Organophosphorus Flame Retardants and Plasticizers in Water and Air I. Occurrence and Fate." TrAC - Trends in Analytical Chemistry. https://doi.org/10.1016/j.trac.2008.07.002.

Renwick, A. G. 1986. "The Metabolism of Intense Sweeteners." Xenobiotica. https://doi.org/10.3109/00498258609038983.

Rykowska, I, and Wasiak, Wieslaw. 2006. "Properties, Threats, and Methods of Analysis of Bisphenol A and its Derivatives Characteristics of Bisphenol A." Acta Chromatographica.

Rymon Lipinski, Gert Wolfhard von. 1985. "The New Intense Sweetener Acesulfame K." Food Chemistry. https://doi.org/10.1016/0308-8146(85)90120-7.

Rymon Lipinski, Gert Wolfhard von. 2013. "Sweeteners." Advances in Biochemical Engineering/Biotechnology. https://doi.org/10.1007/10_2013_222.

Saal, Frederick S. Vom, and John Peterson Myers. 2008. "Bisphenol A and Risk of Metabolic Disorders." JAMA - Journal of the American Medical Association, 2008. https://doi.org/10.1001/jama.300.11.1353.

Sanborn, Margaret, K. J. Kerr, L. H. Sanin, D. C. Cole, K. L. Bassil, and C. Vakil. 2007. "Non-Cancer Health Effects of Pesticides: Systematic Review and Implications for Family Doctors." Canadian Family Physician.

Shoemaker, J., Dan Tettenhorst, and A. DelaCruz. 2015. "Method 544. Determination Of Microcystins And Nodularin In Drinking Water By Solid Phase Extraction And Liquid Chromatography/Tandem Mass Spectrometry (Lc/Ms/Ms)." United States Environmental Protection Agency.

Steel, Kris, James Lockhart, and Paul Roan. 2012. Water for 2060 Act. 53rd Oklahoma Legislature. http://webserver1.lsb.state.ok.us/cf_pdf/2011-12 ENR/hB/HB3055 ENR.PDF.

Tetra Tech, and S2 Engineering PLLC. 2018. "Bartlesville WLA Studies – Caney River Monitoring and Modeling Report." Bartlesville.

Tetra Tech, and S2 Engineering PLLC. 2019. “Title XVI Feasibility Study Report – Augment Bartlesville Water Supply with Drought-Resilient Reclaimed Water.” Bartlesville.

Tricas, Marisa, Ryan Albert, Robert Bastian, Sharon Nappier, Stig Regli, Lauren Kasparek, and Roger Gorke. 2018. “2017 Potable Reuse Compendium.” https://doi.org/10.13140/RG.2.2.33592.65283.

U.S. Army Corps of Engineer (USACE). 2007. “Bartlesville Water Supply and Conveyance Study, Planning Assistance to States Program.”

U.S. Environmental Protection Agency (EPA). 1982. “EPA Handbook for Sampling and Sample Preservation of Water and Wastewater.”

U.S. Environmental Protection Agency (EPA). 2000. “Wastewater Technology Fact Sheet Screening and Grit Removal.” United States Environmental Protection Agency. https://doi.org/EPA 832-F-99-040.

U.S. Environmental Protection Agency (EPA). 2004. “Chemicals Evaluated for Carcinogenic Potential Annual Cancer Report 2018.”

U.S. Environmental Protection Agency (EPA). 2007a. “Method 1694: Pharmaceuticals and Personal Care Products in Water, Soil, Sediment, and Biosolids by HPLC / MS / MS.” EPA Method, no. December: 77.

U.S. Environmental Protection Agency (EPA). 2007b. “Toxicity and Exposure Assessment for Children’s Health (TEACH) Summaries: Diethyltoluamide (DEET) Chemical Summary.” 2007. http://www.epa.gov/teach/chem_summ/DEET_summary.pdf.

U.S. Environmental Protection Agency (EPA). 2009a. “Method 537: Determination of Selected Perfluorinated Alkyl Acids in Drinking Water by Solid Phase Extraction and Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS).” EPA Method, 1–50. https://doi.org/10.1016/j.ces.2015.03.043.

U.S. Environmental Protection Agency (EPA). 2009b. “Method 538. Determination of Selected Organic Contaminants in Drinking Water by Direct Aqueous Injection-Liquid Chromatography/Tandem Mass Spectrometry (DAI-LC/MS/MS).” EPA Method, no. November: 1–40.

U.S. Environmental Protection Agency (EPA). 2009c. “Occurrence of Contaminants of Emerging Concern in Wastewater from Nine Publicly Owned Treatment Works.” United States Environmental Protection Agency. https://doi.org/10.1016/0300-9629(93)90184-6.

U.S. Environmental Protection Agency (EPA), and CDM Smith. 2017. “Potable Reuse Compendium”. Washington, DC: EPA Office of Water.

U.S. Geological Survey (USGS), 2019, National Water Information System data available on the World Wide Web (USGS Water Data for the Nation), accessed June 10, 2019, at URLhttps://nwis.waterdata.usgs.gov/nwis/uv?cb_00060=on&cb_00065=on&format=gif_stats&site_no=07174400&period=&begin_date=2018-01-01&end_date=2019-01-01

Velicu, Magdalena, and Rominder Suri. 2009. "Presence of Steroid Hormones and Antibiotics in Surface Water of Agricultural, Suburban and Mixed-Use Areas." Environmental Monitoring and Assessment. https://doi.org/10.1007/s10661-008-0402-7.

Vidal-Dorsch, Doris E., Steven M. Bay, Keith Maruya, Shane A. Snyder, Rebecca A. Trenholm, and Brett J. Vanderford. 2012. "Contaminants of Emerging Concern in Municipal Wastewater Effluents and Marine Receiving Water." Environmental Toxicology and Chemistry. https://doi.org/10.1002/etc.2004.

Vimalkumar, Krishnamoorthi, Sangeetha Seethappan, and Arivalagan Pugazhendhi. 2019. "Fate of Triclocarban (TCC) in Aquatic and Terrestrial Systems and Human Exposure." Chemosphere. https://doi.org/10.1016/j.chemosphere.2019.04.145.

Walters, Evelyn, Kristin McClellan, and Rolf U. Halden. 2010. "Occurrence and Loss over Three Years of 72 Pharmaceuticals and Personal Care Products from Biosolids-Soil Mixtures in Outdoor Mesocosms." Water Research. https://doi.org/10.1016/j.watres.2010.07.051.

Weisenburger, Dennis D. 1993. "Human Health Effects of Agrichemical Use." Human Pathology. https://doi.org/10.1016/0046-8177(93)90234-8.

Wetzel, R. G. 1983. Limnology, 2ndedition. Saunders College Publishing. 760 pp.

World Health Organization (WHO). 1990. "Public Health Impact of Pesticides Used in Agriculture." Transactions of the Royal Society of Tropical Medicine and Hygiene. https://doi.org/10.1016/0035-9203(92)90345-D.

Yang, Limin, Suming Jin, Patrick Danielson, Collin Homer, Leila Gass, Stacie M. Bender, and Adam Case. 2018. "A New Generation of the United States National Land Cover Database: Requirements, Research Priorities, Design, and Implementation Strategies." ISPRS Journal of Photogrammetry and Remote Sensing. https://doi.org/10.1016/j.isprsjprs.2018.09.006.

Yu, Xiaohua, Jingchuan Xue, Hong Yao, Qian Wu, Arjun K. Venkatesan, Rolf U. Halden, and Kurunthachalam Kannan. 2015. "Occurrence and Estrogenic Potency of Eight Bisphenol Analogs in Sewage Sludge from the U.S. EPA Targeted National Sewage Sludge Survey." Journal of Hazardous Materials. https://doi.org/10.1016/j.jhazmat.2015.07.012.

Appendix A: Continuation Table of Collection Details.

Table A 1. Sample site number, location description, latitude, and longitude

Sites	Location Description	Latitude	Longitude
1	Caney River Post Mix (Downstream)	36.719890	-95.963028
2	CWWTP Effluent Discharge	36.757421	-95.965160
3	Caney River WTP Intake	36.753889	-95.971384
4	Caney River IPR (Upstream) #1	36.786332	-95.980253
5	Lake Hudson Southern Point	36.806225	-96.034694
6	Lake Hudson Northern Point	36.821260	-96.047877
W1500RD	Caney River IPR (Upstream) #2	36.800468	-95.972540

Table A 2. List 99 CEC compounds analyzed by EEA lab including the analyte name, class, Chemical Abstracts Service Registry Number (CAS #), and the typical use of that compound.

Analyte	Class	CAS #	Typical Use
2,4-D	Pesticides	94-75-7	Herbicide
Atrazine	Pesticides	1912-24-9	Herbicide
Bendroflumethiazide	Pesticides	73-48-3	Herbicide
Bromacil	Pesticides	314-40-9	Herbicide
Chloridazon	Pesticides	1698-60-8	Herbicide
Chlorotoluron	Pesticides	15545-48-9	Herbicide
Cyanazine	Pesticides	21725-46-2	Herbicide
DACT (Diaminochlorotriazine)	Pesticides	3397-62-4	Herbicide
DEA	Pesticides	6190-65-4	Herbicide
DIA	Pesticides	1007-28-9	Herbicide
Diuron	Pesticides	330-54-1	Herbicide
Isoproturon	Pesticides	34123-59-6	Herbicide
Linuron	Pesticides	330-55-2	Herbicide

Metazachlor	Pesticides	67129-08-2	Herbicide
Metolachlor	Pesticides	51218-45-2	Herbicide
OUST (Sulfometuron, methyl)	Pesticides	74222-97-2	Herbicide
Propazine	Pesticides	139-40-2	Herbicide
Quinoline	Pesticides	91-22-5	Herbicide
Simazine	Pesticides	122-34-9	Herbicide
BPA (Bisphenol A)	Industrials	80-05-7	Plastic
NP (4-nonylphenol)	Industrials	104-40-5	Detergents
OP (4-tert-octylphenol)	Industrials	140-66-9	Food additive
TCEP	Industrials	5961-85-3	Flame retardant
TCPP (flame retardant)	Industrials	13674-84-5	Flame retardant
TDCPP (flame retardant)	Industrials	13674-87-8	Flame retardant
Acetaminophen	PPCPs	103-90-2	Analgesic
Albuterol	PPCPs	18559-94-9	Bronchodilator
Amoxicillin	PPCPs	26787-78-0	Penicillin antibiotic
Atenolol	PPCPs	29122-68-7	Beta blocker
Azithromycin	PPCPs	83905-01-5	Antibiotic
Bezafibrate	PPCPs	41859-67-0	Cholesterol
Butalbital	PPCPs	77-26-9	Barbiturate
Carbadox	PPCPs	6804-07-5	Animal antibiotic
Carbamazepine	PPCPs	298-46-4	Anticonvulsant
Carisoprodol	PPCPs	78-44-4	Muscle relaxant
Chloramphenicol	PPCPs	56-75-7	Antibiotic
Cimetidine	PPCPs	51481-61-9	Antihistamine
Clofibric Acid	PPCPs	882-09-7	Cholesterol
Dehydronifedipine	PPCPs	67035-22-7	Blood pressure
Diazepam	PPCPs	439-14-5	Sedative
Diclofenac	PPCPs	15307-86-5	Pain reliever
Dilantin	PPCPs	57-41-0	Anticonvulsant
Diltiazem	PPCPs	42399-41-7	Blood pressure
Erythromycin	PPCPs	114-07-8	Antibiotic
Flumequine	PPCPs	42835-25-6	Antibiotic
Fluoxetine (Prozac)	PPCPs	54910-89-3	Antidepressant

Gemfibrozil	PPCPs	25812-30-0	Cholesterol
Ibuprofen	PPCPs	15687-27-1	Pain reliever
Iohexol	PPCPs	66108-95-0	Radiographic Contrast Agent
Iopromide	PPCPs	73334-07-3	Radiographic Contrast Agent
Ketoprofen	PPCPs	22071-15-4	Pain reliever
Ketorolac	PPCPs	74103-06-3	Pain reliever
Lidocaine	PPCPs	137-58-6	Anesthetic
Lincomycin	PPCPs	154-21-2	Antibiotic
Lopressor (Metoprolol)	PPCPs	51384-51-1	Beta blocker
Meclofenamic Acid	PPCPs	644-62-2	Analgesic
Meprobamate	PPCPs	57-53-4	Antianxiety
Metformin	PPCPs	657-24-9	Antidiabetic
Naproxen	PPCPs	22204-53-1	Anti-inflammatory
Nifedipine	PPCPs	21829-25-4	Antihypertensive
Oxolinic acid	PPCPs	14698-29-4	Antibiotic
Pentoxifylline	PPCPs	6493-05-6	Anti-inflammatory
Phenazone	PPCPs	60-80-0	Anti-inflammatory
Primidone	PPCPs	125-33-7	Anticonvulsant
Salicylic Acid	PPCPs	69-72-7	Anti-inflammatory
Sulfachloropyridazine	PPCPs	80-32-0	Antibiotic
Sulfadiazine	PPCPs	68-35-9	Antibiotic
Sulfadimethoxine	PPCPs	122-11-2	Antibiotic
Sulfamerazine	PPCPs	127-79-7	Antibacterial
Sulfamethazine	PPCPs	57-68-1	Antibacterial
Sulfamethizole	PPCPs	144-82-1	Antibiotic
Sulfamethoxazole	PPCPs	723-46-6	Antibiotic
Sulfathiazole	PPCPs	72-14-0	Antibiotic
Theophylline	PPCPs	58-55-9	Bronchodilator
Triclocarban	PPCPs	101-20-2	Antibacterial
Triclosan	PPCPs	3380-34-5	Antibacterial
Trimethoprim	PPCPs	738-70-5	Antibiotic
Warfarin	PPCPs	81-81-2	Blood thinner
Androstenedione	Hormones	63-05-8	Steroid hormone
EE2 (17 Alpha-ethynylestradiol)	Hormones	57-63-6	Synthetic hormone

Estradiol	Hormones	50-28-2	Estrogen hormone
Estriol	Hormones	50-27-1	Urinary estrogen
Estrone	Hormones	53-16-7	Estrogen hormone
Norethisterone	Hormones	68-22-4	Contraceptive
Progesterone	Hormones	57-83-0	Contraceptive
Testosterone	Hormones	58-22-0	Anabolic steroid
1,7-Dimethylxanthine	Others	611-59-6	Stimulant
Acesulfame-K	Others	55589-62-3	Sweetener
Butylparaben	Others	94-26-8	Paraben
Caffeine	Others	58-08-2	Stimulant
Cotinine	Others	486-56-6	Nicotine
DEET	Others	134-62-3	Insect repellent
Ethylparaben	Others	120-47-8	Paraben
Isobutylparaben	Others	4247-02-3	Paraben
Methylparaben	Others	99-76-3	Paraben
Propylparaben	Others	94-13-3	Paraben
Sucralose	Others	56038-13-2	Sweetener
Theobromine	Others	83-67-0	Food additive
Thiabendazole	Others	148-79-8	Antifungal

Table A 3. March sampling results from EEA lab; colored values indicate a detection reading and non-colored values indicate non-detect with the set MRL limit for the analysis. All values reported in ng L^{-1}.

March 20th, 2018							
		Sites (ng L^{-1})					
Analyte	**Class**	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**
2,4-D	Pesticides	86	110	25	30	36	32
Atrazine	Pesticides	17	43	47	52	<5	9.1
Bendroflumethiazide	Pesticides	<5	<5	<5	<5	<5	<5
Bromacil	Pesticides	<5	37	<5	<5	<5	<5
Chloridazon	Pesticides	<5	<5	<5	<5	<5	<5
Chlorotoluron	Pesticides	<5	<5	<5	<5	<5	<5

Cyanazine	Pesticides	<5	<5	<5	<25	<5	<5
DACT (Diaminochlorotriazine)	Pesticides	<50	<50	<50	<50	<50	<50
DEA	Pesticides	<5	5.3	<5	<5	<5	<5
DIA	Pesticides	<5	38	<5	<5	<5	<5
Diuron	Pesticides	71	<5	5.6	5.3	<5	<25
Isoproturon	Pesticides	<100	<100	<100	<500	<100	<100
Linuron	Pesticides	<5	<5	<5	<5	<5	<5
Metazachlor	Pesticides	<5	<25	<25	<5	<5	<5
Metolachlor	Pesticides	<5	<25	<25	6.4	<5	<5
OUST (Sulfometuron, methyl)	Pesticides	<5	<5	<5	<5	<5	<5
Propazine	Pesticides	<5	<5	<25	<25	<5	<5
Quinoline	Pesticides	6.7	11	<5	5.8	<5	6.7
Simazine	Pesticides	55	100	6.9	<25	<5	<5
BPA (Bisphenol A)	Industrials	<10	<10	<10	<10	<10	<10
NP (4-nonylphenol)	Industrials	2000	4600	710	410	650	350
OP (4-tert-octylphenol)	Industrials	<50	<50	<50	<50	<50	<50
TCEP	Industrials	25	130	<10	<50	<10	<10
TCPP (flame retardant)	Industrials	200	1300	<100	<500	<100	<100
TDCPP (flame retardant)	Industrials	<100	770	<100	<500	<100	<100
Acetaminophen	PPCPs	14	24	<5	<5	13	5.2
Albuterol	PPCPs	<5	45	<5	<5	<5	<5
Amoxicillin	PPCPs	87	1400	<80	<80	<80	<80
Atenolol	PPCPs	24	320	<5	<5	<5	<5
Azithromycin	PPCPs	<20	<20	<20	<20	<20	<20
Bezafibrate	PPCPs	<5	<5	<5	<5	<5	<5
Butalbital	PPCPs	<5	<5	<5	<5	<5	<5
Carbadox	PPCPs	<5	<5	<5	<5	<5	<5
Carbamazepine	PPCPs	40	320	<5	<25	<5	<5
Carisoprodol	PPCPs	23	130	14	<5	<5	<5
Chloramphenicol	PPCPs	<10	<10	<10	<10	<10	<10
Cimetidine	PPCPs	<5	<5	<5	<5	<5	<5
Clofibric Acid	PPCPs	<5	<5	<5	<5	<5	<5
Dehydronifedipine	PPCPs	<5	6.6	<5	<5	<5	<5
Diazepam	PPCPs	<5	<5	<5	<25	<5	<5

Diclofenac	PPCPs	80	560	<5	<5	<5	<5
Dilantin	PPCPs	<20	130	<20	<20	<20	<20
Diltiazem	PPCPs	7.1	93	<5	<5	<5	<5
Erythromycin	PPCPs	<10	30	<10	<10	<10	<10
Flumequine	PPCPs	<10	<50	<50	<10	<50	<10
Fluoxetine (Prozac)	PPCPs	<10	190	<10	<10	<10	<10
Gemfibrozil	PPCPs	<5	16	<5	<5	<5	<5
Ibuprofen	PPCPs	<10	<10	<10	<10	<10	<10
Iohexol	PPCPs	1800	7200	<100	<100	<100	<100
Iopromide	PPCPs	<5	<5	<5	<5	<5	<5
Ketoprofen	PPCPs	<5	<5	<5	<25	<5	<5
Ketorolac	PPCPs	<5	<5	<5	<25	<5	<5
Lidocaine	PPCPs	45	390	<5	<5	<5	<5
Lincomycin	PPCPs	<10	<10	<10	<50	<10	<10
Lopressor (Metoprolol)	PPCPs	<20	<20	<20	<20	<20	<20
Meclofenamic Acid	PPCPs	34	430	<5	<5	<5	<5
Meprobamate	PPCPs	20	190	<5	<25	<5	<5
Metformin	PPCPs	21	230	<5	<5	<5	<5
Naproxen	PPCPs	<10	<10	<10	<10	<10	<10
Nifedipine	PPCPs	<20	<100	<20	<20	<20	<20
Oxolinic acid	PPCPs	<10	<10	<10	<10	<10	<10
Pentoxifylline	PPCPs	<5	<5	<5	<25	<5	<5
Phenazone	PPCPs	<5	<5	<5	<5	<5	<5
Primidone	PPCPs	<20	150	<20	<20	<20	<20
Salicylic Acid	PPCPs	<100	<100	<100	<100	<100	<100
Sulfachloropyridazine	PPCPs	<5	<5	<5	<5	<5	<5
Sulfadiazine	PPCPs	<20	<100	<20	<20	<20	<20
Sulfadimethoxine	PPCPs	<5	<5	<5	<5	<5	<5
Sulfamerazine	PPCPs	<5	<5	<5	<5	<5	<5
Sulfamethazine	PPCPs	<5	<5	<5	<5	<5	<5
Sulfamethizole	PPCPs	<5	<5	<5	<5	<5	<5
Sulfamethoxazole	PPCPs	<5	<25	<5	<5	<5	<5
Sulfathiazole	PPCPs	<20	<20	<20	<20	<20	<20
Theophylline	PPCPs	44	100	<20	<20	<20	<20

Triclocarban	PPCPs	<10	<10	<10	<10	<10	<10
Triclosan	PPCPs	<10	30	<10	<10	<10	<10
Trimethoprim	PPCPs	51	640	<5	<5	<5	<5
Warfarin	PPCPs	<5	5.8	<5	<5	<5	<5
Androstenedione	Hormones	<10	<10	<50	<50	<10	<10
EE2 (17 Alpha-ethynylestradiol)	Hormones	<5	<5	<5	<5	<5	<5
Estradiol	Hormones	<5	<5	<5	<5	<5	<5
Estriol	Hormones	<10	<10	<10	<10	<10	<10
Estrone	Hormones	<5	<5	<5	<5	<5	<5
Norethisterone	Hormones	<5	<5	<5	<5	<5	<5
Progesterone	Hormones	<5	<25	<5	<5	<5	5.5
Testosterone	Hormones	<5	<25	<5	<5	9.2	<5
1,7-Dimethylxanthine	Others	19	53	<10	<10	<10	<10
Acesulfame-K	Others	220	850	22	<20	<20	<20
Butylparaben	Others	<5	<5	<5	<5	<5	<5
Caffeine	Others	470	73	<10	12	34	<10
Cotinine	Others	<10	<50	<10	<10	<10	<10
DEET	Others	14	150	<10	<10	<10	<10
Ethylparaben	Others	<20	<20	<20	<20	<20	<20
Isobutylparaben	Others	<5	<5	<5	<5	<5	<5
Methylparaben	Others	<20	<20	<20	<20	<20	<20
Propylparaben	Others	<5	<5	<5	<5	<5	<5
Sucralose	Others	9400	46000	130	<100	<100	<100
Theobromine	Others	12	<50	<10	<10	<10	<10
Thiabendazole	Others	<5	<5	<5	<5	<5	<5

Table A 4. July sampling results from EEA lab; colored values indicate a detection reading and non-colored values indicate non-detect with the set MRL limit for the analysis. All values reported in ng L^{-1}.

July 12th, 2018							
		Sites (ng L^{-1})					
Analyte	**Class**	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**

2,4-D	Pesticides	120	120	140	130	300	270
Atrazine	Pesticides	21	8.4	24	24	9.3	11
Bendroflumethiazide	Pesticides	<5	<5	<5	<5	<5	<5
Bromacil	Pesticides	<5	<5	<5	<5	<5	<5
Chloridazon	Pesticides	<5	<5	<5	<5	<5	<5
Chlorotoluron	Pesticides	<5	<5	<5	<5	<5	<5
Cyanazine	Pesticides	<5	<5	<5	<5	<5	<5
DACT (Diaminochlorotriazine)	Pesticides	<250	<250	<250	<250	<250	<250
DEA	Pesticides	12	13	7.4	9.3	7.8	9.4
DIA	Pesticides	<5	<5	<5	<5	<5	<5
Diuron	Pesticides	<5	<5	<5	<5	<5	<5
Isoproturon	Pesticides	<100	<100	<100	<100	<100	<100
Linuron	Pesticides	<5	12	<5	<5	<5	<5
Metazachlor	Pesticides	<5	<5	<5	<5	<5	<5
Metolachlor	Pesticides	13	<5	10	12	<5	<5
OUST (Sulfometuron, methyl)	Pesticides	<5	22	5.4	5.5	<5	<5
Propazine	Pesticides	<5	<5	<5	<5	<5	<5
Quinoline	Pesticides	<5	<5	<5	<5	<5	<5
Simazine	Pesticides	<5	5.9	<5	<5	<5	<5
BPA (Bisphenol A)	Industrials	<10	<10	<10	<10	<10	<10
NP (4-nonylphenol)	Industrials	<100	150	<100	<100	<100	<100
OP (4-tert-octylphenol)	Industrials	<50	<50	<50	<50	<50	<50
TCEP	Industrials	<10	660	<10	<10	<10	<10
TCPP (flame retardant)	Industrials	<100	1800	<100	<100	<100	<100
TDCPP (flame retardant)	Industrials	<100	<100	<100	<100	<100	<100
Acetaminophen	PPCPs	<5	<5	<5	<5	<5	<5
Albuterol	PPCPs	<5	<5	<5	<5	<5	<5
Amoxicillin	PPCPs	<80	<80	<80	<80	<80	<80
Atenolol	PPCPs	<5	170	<5	<5	<5	<5
Azithromycin	PPCPs	<20	<20	<20	<20	<20	<20
Bezafibrate	PPCPs	<5	<5	<5	<5	<5	<5
Butalbital	PPCPs	<5	22	<5	<5	<5	<5

Carbadox	PPCPs	<5	<5	<5	<5	<5	<5
Carbamazepine	PPCPs	13	250	<5	<5	<5	<5
Carisoprodol	PPCPs	<5	26	<5	<5	<5	<5
Chloramphenicol	PPCPs	<10	<10	<10	<10	<10	<10
Cimetidine	PPCPs	<5	<5	<5	<5	<5	<5
Clofibric Acid	PPCPs	<5	<5	<5	<5	<5	<5
Dehydronifedipine	PPCPs	<5	8.6	<5	<5	<5	<5
Diazepam	PPCPs	<5	<5	<5	<5	<5	<5
Diclofenac	PPCPs	<5	160	<5	<5	<5	<5
Dilantin	PPCPs	<20	71	<20	<20	<20	<20
Diltiazem	PPCPs	<5	23	<5	<5	<5	<5
Erythromycin	PPCPs	<10	<10	<10	<10	<10	<10
Flumequine	PPCPs	<10	<10	<10	<10	<10	<10
Fluoxetine (Prozac)	PPCPs	<10	110	<10	<10	<10	<10
Gemfibrozil	PPCPs	<5	24	<5	<5	<5	<5
Ibuprofen	PPCPs	<10	32	<10	<10	<10	<10
Iohexol	PPCPs	270	9600	<100	<100	<100	<100
Iopromide	PPCPs	<5	<5	<5	<5	<5	<5
Ketoprofen	PPCPs	<5	<5	<5	<5	<5	<5
Ketorolac	PPCPs	<5	<5	<5	<5	<5	<5
Lidocaine	PPCPs	14	490	<5	<5	<5	<5
Lincomycin	PPCPs	<10	<10	<10	<10	<10	<10
Lopressor (Metoprolol)	PPCPs	<20	250	<20	<20	<20	<20
Meclofenamic Acid	PPCPs	<5	<5	<5	<5	<5	<5
Meprobamate	PPCPs	<5	94	<5	<5	<5	<5
Metformin	PPCPs	<5	<5	<5	<5	<5	<5
Naproxen	PPCPs	<10	<10	<10	<10	<10	<10
Nifedipine	PPCPs	<20	<20	<20	<20	<20	<20
Oxolinic acid	PPCPs	<10	<10	<10	<10	<10	<10
Pentoxifylline	PPCPs	<5	<5	<5	<5	<5	<5
Phenazone	PPCPs	<5	<5	<5	<5	<5	<5
Primidone	PPCPs	<10	200	<10	<10	<10	<10

Salicylic Acid	PPCPs	<100	<100	<100	<100	<100	<100
Sulfachloropyridazine	PPCPs	<5	<5	<5	<5	<5	<5
Sulfadiazine	PPCPs	<20	70	<20	<20	<20	<20
Sulfadimethoxine	PPCPs	<5	<5	<5	<5	<5	<5
Sulfamerazine	PPCPs	<5	<5	<5	<5	<5	<5
Sulfamethazine	PPCPs	<5	<5	<5	<5	<5	<5
Sulfamethizole	PPCPs	<5	<5	<5	<5	<5	<5
Sulfamethoxazole	PPCPs	16	430	<5	<5	<5	<5
Sulfathiazole	PPCPs	<20	<20	<20	<20	<20	<20
Theophylline	PPCPs	120	<20	<20	<20	<20	<20
Triclocarban	PPCPs	<10	74	<10	<10	<10	<10
Triclosan	PPCPs	<10	<10	<10	<10	<10	<10
Trimethoprim	PPCPs	<5	<5	<5	<5	<5	<5
Warfarin	PPCPs	<5	<5	<5	<5	<5	<5
Androstenedione	Hormones	<10	<10	<10	<10	<10	<10
EE2 (17 Alpha-ethynylestradiol)	Hormones	<5	55	<5	<5	<5	<5
Estradiol	Hormones	<5	<5	<5	<5	<5	<5
Estriol	Hormones	<10	<10	<10	<10	<10	<10
Estrone	Hormones	<5	<5	<5	<5	<5	<5
Norethisterone	Hormones	<5	<5	<5	<5	<5	<5
Progesterone	Hormones	<5	<5	<5	<5	<5	<5
Testosterone	Hormones	<5	<5	<5	<5	<5	<5
1,7-Dimethylxanthine	Others	<10	<10	<10	<10	<10	<10
Acesulfame-K	Others	<20	240	<20	<20	<20	<20
Butylparaben	Others	<5	<5	<5	<5	<5	<5
Caffeine	Others	140	<50	<50	<50	<50	<50
Cotinine	Others	<10	21	<10	<10	<10	<10
DEET	Others	17	44	17	17	15	15
Ethylparaben	Others	<20	<20	<20	<20	<20	<20
Isobutylparaben	Others	<5	<5	<5	<5	<5	<5
Methylparaben	Others	37	<20	47	53	110	130
Propylparaben	Others	<5	7.2	29	29	<5	21

Sucralose	Others	1600	47000	<100	<100	<100	<100
Theobromine	Others	<10	<10	65	<10	59	<10
Thiabendazole	Others	20	20	17	22	18	22

Table A 5. December sampling results from EEA lab; colored values indicate a detection reading and non-colored values indicate non-detect with the set MRL limit for the analysis. An "*" indicates an NA result from Azithromycin reading from EEA lab. All values reported in ng L^{-1}.

December 19th, 2018

		Sites (ng L^{-1})					
Analyte	**Class**	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**
2,4-D	Pesticides	16	<5	8.6	7.2	18	17
Atrazine	Pesticides	<5	9.6	<5	<5	<5	<5
Bendroflumethiazide	Pesticides	<5	<5	<5	<5	<5	<5
Bromacil	Pesticides	<5	<5	<5	<5	<5	<5
Chloridazon	Pesticides	<5	<5	<5	<5	<5	<5
Chlorotoluron	Pesticides	<5	<5	<5	<5	<5	<5
Cyanazine	Pesticides	<5	<5	<5	<5	<5	<5
DACT (Diaminochlorotriazine)	Pesticides	<5	<5	<5	<5	<5	<5
DEA	Pesticides	<5	<5	<5	<5	<5	<5
DIA	Pesticides	<50	<50	<50	<50	<50	<50
Diuron	Pesticides	<5	72	<5	<5	<5	<5
Isoproturon	Pesticides	<100	<100	<100	<100	<100	<100
Linuron	Pesticides	<5	<5	<5	<5	<5	<5
Metazachlor	Pesticides	<5	<5	<5	<5	<5	<5
Metolachlor	Pesticides	<5	<5	<5	<5	<5	<5
OUST (Sulfometuron, methyl)	Pesticides	<5	<5	<5	<5	<5	<5
Propazine	Pesticides	<5	<5	<5	<5	<5	<5
Quinoline	Pesticides	<50	<50	<50	78	68	<50
Simazine	Pesticides	10	84	<5	<5	<5	<5
BPA (Bisphenol A)	Industrials	<10	<10	<10	<10	<10	<10
NP (4-nonylphenol)	Industrials	<400	<400	<400	<400	<400	<400

OP (4-tert-octylphenol)	Industrials	<50	<50	<50	<50	<50	<50
TCEP	Industrials	<10	94	<10	<10	<10	<10
TCPP (flame retardant)	Industrials	<100	760	<100	<100	<100	<100
TDCPP (flame retardant)	Industrials	<100	<100	<100	<100	<100	<100
Acetaminophen	PPCPs	<5	<5	<5	<5	<5	<5
Albuterol	PPCPs	<5	13	<5	<5	<5	<5
Amoxicillin	PPCPs	1600	17000	<20	<20	<20	<20
Atenolol	PPCPs	6.2	240	<5	<5	<5	<5
Azithromycin	PPCPs	NA*	NA*	NA*	NA*	NA*	NA*
Bezafibrate	PPCPs	<5	<5	<5	<5	<5	<5
Butalbital	PPCPs	<5	41	<5	<5	<5	<5
Carbadox	PPCPs	<5	<5	<5	<5	<5	<5
Carbamazepine	PPCPs	9.9	200	<5	<5	<5	<5
Carisoprodol	PPCPs	<5	21	<5	<5	<5	<5
Chloramphenicol	PPCPs	<5	<5	<5	<5	<5	<5
Cimetidine	PPCPs	<5	300	<5	<5	<5	<5
Clofibric Acid	PPCPs	<5	<5	<5	<5	<5	<5
Dehydronifedipine	PPCPs	<5	20	<5	<5	<5	<5
Diazepam	PPCPs	<5	<5	<5	<5	<5	<5
Diclofenac	PPCPs	11	170	<5	<5	<5	<5
Dilantin	PPCPs	<20	61	<20	<20	<20	<20
Diltiazem	PPCPs	<5	190	<5	<5	<5	<5
Erythromycin	PPCPs	<10	10	<10	<10	<10	<10
Flumequine	PPCPs	<10	<10	<10	<10	<10	<10
Fluoxetine (Prozac)	PPCPs	5.8	120	<5	<5	<5	<5
Gemfibrozil	PPCPs	17	610	<5	<5	<5	<5
Ibuprofen	PPCPs	<10	140	<10	<10	<10	<10
Iohexol	PPCPs	1500	41000	15	<10	<10	<10
Iopromide	PPCPs	<5	<500	<5	<5	<5	<5
Ketoprofen	PPCPs	<5	48	<5	<5	<5	<5
Ketorolac	PPCPs	<5	70	<5	<5	<5	<5
Lidocaine	PPCPs	51	1100	<5	<5	<5	<5
Lincomycin	PPCPs	<10	<10	<10	<10	<10	<10
Lopressor (Metoprolol)	PPCPs	32	770	<20	<20	<20	<20

Meclofenamic Acid	PPCPs	<5	<5	<5	<5	<5	<5
Meprobamate	PPCPs	5.4	68	<5	<5	<5	<5
Metformin	PPCPs	<5	41	<5	<5	<5	<5
Naproxen	PPCPs	<10	160	<10	<10	<10	<10
Nifedipine	PPCPs	<20	41	<20	<20	<20	<20
Oxolinic acid	PPCPs	<5	<5	<5	<5	<5	<5
Pentoxifylline	PPCPs	<5	21	<5	<5	<5	<5
Phenazone	PPCPs	<5	<5	<5	<5	<5	<5
Primidone	PPCPs	15	250	<5	<5	<5	<5
Salicylic Acid	PPCPs	<100	<100	<100	<100	<100	<100
Sulfachloropyridazine	PPCPs	<5	<5	<5	<5	<5	<5
Sulfadiazine	PPCPs	<5	<5	<5	<5	<5	<5
Sulfadimethoxine	PPCPs	<5	<5	<5	<5	<5	<5
Sulfamerazine	PPCPs	<5	<5	<5	<5	<5	<5
Sulfamethazine	PPCPs	<5	<5	<5	<5	<5	<5
Sulfamethizole	PPCPs	<5	<5	<5	<5	<5	<5
Sulfamethoxazole	PPCPs	77	1000	<50	<50	<50	<50
Sulfathiazole	PPCPs	<5	<5	<5	<5	<5	<5
Theophylline	PPCPs	<10	330	16	15	<10	<10
Triclocarban	PPCPs	<20	<20	<20	<20	<20	<20
Triclosan	PPCPs	<20	21	<20	<20	<20	<20
Trimethoprim	PPCPs	21	440	<5	<5	<5	<5
Warfarin	PPCPs	<5	<5	<5	<5	<5	<5
Androstenedione	Hormones	<10	<10	<10	<10	<10	<10
EE2 (17 Alpha-ethynylestradiol)	Hormones	<5	<5	<5	<5	<5	<5
Estradiol	Hormones	<5	<5	<5	<5	<5	<5
Estriol	Hormones	<5	<5	<5	<5	<5	<5
Estrone	Hormones	5.6	75	<5	<5	<5	5.3
Norethisterone	Hormones	<5	<5	<5	<5	<5	<5
Progesterone	Hormones	<5	<5	<5	<5	<5	<5
Testosterone	Hormones	<5	<5	<5	<5	<5	<5
1,7-Dimethylxanthine	Others	<50	<50	<50	<50	<50	<50
Acesulfame-K	Others	120	2600	<20	<20	<20	<20
Butylparaben	Others	<5	<5	<5	<5	<5	<5

Caffeine	Others	<10	30	<10	<10	<10	<10
Cotinine	Others	<10	55	<10	<10	110	110
DEET	Others	<10	16	<10	<10	<10	<10
Ethylparaben	Others	<20	<20	<20	<20	<20	<20
Isobutylparaben	Others	<5	<5	<5	<5	<5	<5
Methylparaben	Others	<20	<20	<20	<20	<20	<20
Propylparaben	Others	<5	<5	<5	<5	<5	<5
Sucralose	Others	2200	45000	<100	<100	<100	<100
Theobromine	Others	<50	<50	<50	<50	<50	<50
Thiabendazole	Others	<5	98	<5	<5	<5	<5

Table A 6. Blind Duplicate and Blanks sampling results from EEA lab; colored values indicate a detection reading and non-colored values indicate non-detect with the set MRL limit for the analysis.

Blind Duplicate and Blanks for Sampling Dates					
		(ng L^{-1})			
			Blind Duplicate		Blank
Analyte	**Class**	**MRL**	**March**	**July**	**July**
2,4-D	Pesticides	<5	<5	<5	<5
Atrazine	Pesticides	<5	<5	<5	<5
Bendroflumethiazide	Pesticides	<5	<5	<5	<5
Bromacil	Pesticides	<5	<5	<5	<5
Chloridazon	Pesticides	<5	<5	<5	<5
Chlorotoluron	Pesticides	<5	<5	<5	<5
Cyanazine	Pesticides	<5	<5	<5	<5
DACT (Diaminochlorotriazine)	Pesticides	<5	<5	<5	<5
DEA	Pesticides	<5	<5	<5	<5
DIA	Pesticides	<50	<50	<50	<50
Diuron	Pesticides	<5	<5	<5	<5
Isoproturon	Pesticides	<100	<100	<100	<100
Linuron	Pesticides	<5	<5	<5	<5
Metazachlor	Pesticides	<5	<5	<5	<5
Metolachlor	Pesticides	<5	<5	<5	<5

OUST (Sulfometuron, methyl)	Pesticides	<5	<5	<5	<5
Propazine	Pesticides	<5	<5	<5	<5
Quinoline	Pesticides	<5	5.8	<5	<5
Simazine	Pesticides	<5	<5	<5	<5
BPA (Bisphenol A)	Industrials	<10	<10	<10	<10
NP (4-nonylphenol)	Industrials	<400	<400	<400	<400
OP (4-tert-octylphenol)	Industrials	<50	<50	<50	<50
TCEP	Industrials	<10	<10	<10	<10
TCPP (flame retardant)	Industrials	<100	<100	<100	<100
TDCPP (flame retardant)	Industrials	<100	<100	<100	<100
Acetaminophen	PPCPs	<5	8.4	<5	<5
Albuterol	PPCPs	<5	<5	<5	<5
Amoxicillin	PPCPs	<20	<20	<20	<20
Atenolol	PPCPs	<5	<5	<5	<5
Azithromycin	PPCPs	<20	<20	<20	<20
Bezafibrate	PPCPs	<5	<5	<5	<5
Butalbital	PPCPs	<5	<5	<5	<5
Carbadox	PPCPs	<5	<5	<5	<5
Carbamazepine	PPCPs	<5	<5	<5	<5
Carisoprodol	PPCPs	<5	<5	<5	<5
Chloramphenicol	PPCPs	<5	<5	<5	<5
Cimetidine	PPCPs	<5	<5	<5	<5
Clofibric Acid	PPCPs	<5	<5	<5	<5
Dehydronifedipine	PPCPs	<5	<5	<5	<5
Diazepam	PPCPs	<5	<5	<5	<5
Diclofenac	PPCPs	<5	<5	<5	<5
Dilantin	PPCPs	<20	<20	<20	<20
Diltiazem	PPCPs	<5	<5	<5	<5
Erythromycin	PPCPs	<10	<10	<10	<10
Flumequine	PPCPs	<10	<10	<10	<10
Fluoxetine (Prozac)	PPCPs	<5	<5	<5	<5
Gemfibrozil	PPCPs	<5	<5	<5	<5
Ibuprofen	PPCPs	<10	<10	<10	<10
Iohexol	PPCPs	<10	<10	<10	<10

Iopromide	PPCPs	<5	<5	<5	<5
Ketoprofen	PPCPs	<5	<5	<5	<5
Ketorolac	PPCPs	<5	<5	<5	<5
Lidocaine	PPCPs	<5	<5	<5	<5
Lincomycin	PPCPs	<10	<10	<10	<10
Lopressor (Metoprolol)	PPCPs	<20	<20	<20	<20
Meclofenamic Acid	PPCPs	<5	<5	<5	<5
Meprobamate	PPCPs	<5	<5	<5	<5
Metformin	PPCPs	<5	<5	<5	<5
Naproxen	PPCPs	<10	<10	<10	<10
Nifedipine	PPCPs	<20	<20	<20	<20
Oxolinic acid	PPCPs	<5	22	<5	<5
Pentoxifylline	PPCPs	<5	<5	<5	<5
Phenazone	PPCPs	<5	<5	<5	<5
Primidone	PPCPs	<5	<5	<5	<5
Salicylic Acid	PPCPs	<100	<100	<100	<100
Sulfachloropyridazine	PPCPs	<5	<5	<5	<5
Sulfadiazine	PPCPs	<5	<5	<5	<5
Sulfadimethoxine	PPCPs	<5	<5	<5	<5
Sulfamerazine	PPCPs	<5	<5	<5	<5
Sulfamethazine	PPCPs	<5	<5	<5	<5
Sulfamethizole	PPCPs	<5	<5	<5	<5
Sulfamethoxazole	PPCPs	<50	<50	<50	<50
Sulfathiazole	PPCPs	<5	<5	<5	<5
Theophylline	PPCPs	<10	<10	<10	<10
Triclocarban	PPCPs	<20	<20	<20	<20
Triclosan	PPCPs	<20	<20	<20	<20
Trimethoprim	PPCPs	<5	<5	<5	<5
Warfarin	PPCPs	<5	<5	<5	<5
Androstenedione	Hormones	<10	<10	<10	<10
EE2 (17 Alpha-ethynylestradiol)	Hormones	<5	<5	<5	<5
Estradiol	Hormones	<5	<5	<5	<5
Estriol	Hormones	<5	<5	<5	<5
Estrone	Hormones	<5	<5	<5	<5

Norethisterone	Hormones	<5	<5	<5	<5
Progesterone	Hormones	<5	13	<5	<5
Testosterone	Hormones	<5	<5	<5	<5
1,7-Dimethylxanthine	Others	<50	<50	<50	<50
Acesulfame-K	Others	<20	<20	<20	<20
Butylparaben	Others	<5	<5	<5	<5
Caffeine	Others	<5	13	<10	<10
Cotinine	Others	<10	<10	<10	<10
DEET	Others	<10	<10	<10	<10
Ethylparaben	Others	<20	<20	<20	<20
Isobutylparaben	Others	<5	<5	<5	<5
Methylparaben	Others	<20	<20	<20	<20
Propylparaben	Others	<5	<5	<5	<5
Sucralose	Others	<100	<100	<100	<100
Theobromine	Others	11	<5	<5	<5
Thiabendazole	Others	<5	<5	<5	<5

Table A 7. Figure 2 – 3 land classification scheme with the formula to the NLCD_LAND raster value; Each count represents one pixel or 30m x 30m area within the region.

	Land Classification	Count	Formula form NLCD_LAND (Value)
	Open Water	53582	(11) Open Water
	Forest	732002	(41) Deciduous Forest + (42) Evergreen Forest + (43) Mixed Forest + (90) Woody Wetlands + (95) Emergent Herbaceous Wetland
	Grassland/Barren	1170111	(31) Barren Land + (52) Shrub/Scrub + (71) Herbaceous
	Agriculture	826582	(81) Hay/Pasture + (82) Cultivated Crops
	Developed Land	140965	(21) Developed, Open Space + (22) Developed, Low Intensity + (23) Developed, Medium Intensity + (24) Developed, High Intensity

Table A 8. Information gathered through USGS stream gauge at the Caney River above Coon Creek #07174400 and Bartlesville's CWWTP with ODEQ Permit #OK0030333 and ID# S21402 parameters used for our calculation.

			Q_B		Q_A		t
Date	**Collection Time**	**Gauge Reading Time**	**Site 3 Discharge (ft^3 s^{-1})**	**Site 2 EFF Discharge (MGD)**	**Site 2 EFF Discharge (ft^3 s^{-1})**	**River velocity (ft s^{-1})**	**Time (hrs)**
March 20th, 2018	11:16 CDT	11:15 CDT	37.4	6.285	9.724	1.183	5.02
July 12th, 2018	10:24 CDT	10:15 CDT	23.7	6.235	9.647	0.957	6.21
December 19th, 2018	10:15 CST	10:15 CST	91.3	6.183	9.567	1.626	3.66

Table A 9. USGS stream gauge at the Caney River above Coon Creek #07174400 field measurements from the USGS database (USGS 2019).

Measurement Dates	Discharge (ft^3 s^{-1})	Channel Velocity (ft s^{-1})
3/19/85	6080	3.36
3/27/85	5140	3.15
10/17/85	1820	3.55
1/29/86	62.6	0.91
2/28/86	181	1.85
5/15/86	2320	2.44
7/9/86	1370	3.24
8/8/86	5650	2.06
9/24/86	752	2.73
4/27/87	351	2.9
6/12/87	3380	3.53
7/23/87	13.4	0.79
11/6/87	16.2	0.94
2/16/88	364	2.15
4/1/88	8490	2.62

6/22/88	22.1	1.08
7/12/88	30.9	1.24
8/17/88	21	1.03
12/2/88	482	3.07
12/21/88	21.9	1.02
3/2/89	79.9	1.52
3/2/89	79.9	1.52
4/14/89	419	3.04
5/25/89	2070	3.45
6/20/89	6240	4.02
6/28/89	5720	4
8/10/89	27.7	1.15
9/21/89	4100	4.03
1/23/90	1340	3.43
1/25/90	1590	3.61
4/11/90	4030	3.57
5/29/90	1990	3.18
6/28/90	42.9	2.09
9/20/90	90.3	1.51
12/7/90	40.3	1.61
2/7/91	29.3	0.99
4/4/91	30	1.48
6/12/91	2490	3.69
7/25/91	56.3	1.88
9/16/91	67.5	1.17
11/25/91	24.5	0.79
1/21/92	76.1	1.31
3/19/92	48.2	0.8
5/12/92	39.6	1.05
8/5/92	133	1.69

10/7/92	27.8	1.01
12/1/92	4100	3.98
3/3/93	2180	3.29
4/20/93	2160	3.59
5/17/93	5870	3.67
5/19/93	5880	4.17
5/21/93	6930	4.05
8/6/93	91.3	1.69
10/7/93	2260	3.27
12/8/93	968	2.53
2/23/94	2530	2.9
4/26/94	5550	3.94
6/15/94	43.5	0.62
8/10/94	146	0.97
10/14/94	36.6	0.53
12/7/94	52.9	0.93
2/16/95	28.3	0.44
4/5/95	392	1.74
6/13/95	524	2.16
8/10/95	2670	3.12
10/12/95	30.8	0.89
12/7/95	37.9	0.95
2/21/96	27.5	1.01
4/19/96	32	0.94
6/19/96	45.9	1.5
8/8/96	45.7	1.81
10/3/96	1080	3.16
1/8/97	500	1.84
3/7/97	5800	4
4/22/97	5010	4.14

7/10/97	464	1.53
8/29/97	58	1.75
10/17/97	607	1.88
1/29/98	702	2.12
3/3/98	100	1.51
4/16/98	846	2.25
6/9/98	42.2	1.02
8/3/98	33.1	0.89
10/14/98	5860	3.97
11/12/98	6170	4.06
1/26/99	91.2	1.39
3/24/99	4900	3.98
5/18/99	532	1.77
6/10/99	6780	3.91
7/7/99	5520	3.74
8/25/99	48.9	0.91
10/1/99	29.4	1.02
8/9/00	31.6	0.86
10/4/00	20.6	0.83
11/30/00	28.2	1.22
4/3/01	389	1.71
5/25/01	169	2.22
7/23/01	39.1	1.72
10/9/01	58.9	0.99
11/15/01	32.1	1.37
12/11/01	0.62	0.3
3/26/02	1.29	0.28
4/15/02	2.77	0.29
4/26/02	12.6	0.62
5/7/02	11.7	0.58

5/10/02	2640	3.51
5/29/02	3760	3.65
6/20/02	3770	4.04
7/3/02	393	1.77
8/20/02	33.2	1.45
9/6/02	28.9	1.43
10/16/02	70	2.08
12/10/02	7.86	0.54
1/30/03	11.3	1.01
3/20/03	1690	2.58
3/28/03	6250	4.14
5/1/03	1840	3.03
9/4/03	2740	3.73
10/15/03	3340	3.64
12/8/03	29.8	1.46
12/23/03	2690	3.12
2/24/04	407	2.81
3/10/04	6130	3.99
3/19/04	5230	4.12
4/16/04	355	2.96
6/18/04	712	1.88
8/16/04	29.8	1.1
10/5/04	10.5	0.94
12/13/04	1230	2.75
2/11/05	2170	3.6
3/29/05	2900	3.86
6/14/05	6170	4.35
6/29/05	4200	4.32
8/8/05	22.2	0.88
10/7/05	12.8	0.65

12/6/05	6.15	0.78
2/8/06	14.3	0.77
4/4/06	14.3	0.65
6/5/06	30	0.4
8/2/06	28.2	1.04
10/4/06	13.3	0.65
11/28/06	13.9	0.54
2/6/07	20	0.9
3/24/07	4050	3.92
5/22/07	5620	3.73
12/6/07	33.4	1.08
2/6/08	741	2.09
4/3/08	2100	3.18
6/4/08	5510	4.14
6/9/08	7400	3.68
6/10/08	7000	1.99
9/3/08	135	1.86
10/23/08	368	2.6
11/19/08	696	1.8
1/16/09	108	2.34
3/5/09	295	1.11
6/16/09	154	2.37
8/21/09	49.2	1.41
10/7/09	22.6	0.84
12/14/09	886	2.2
2/19/10	254	3.39
4/5/10	2270	2.74
9/1/10	64.4	1.53
10/20/10	50	1.46
12/9/10	19.6	0.91

4/6/11	122	1.84
6/13/11	27.4	0.87
8/16/11	15	0.89
10/17/11	13.1	0.66
11/18/11	25	0.95
3/5/12	410	3.67
6/14/12	368	3.58
7/23/12	12.4	0.63
10/1/12	10.9	0.67
12/3/12	12.6	0.64
1/3/13	7.5	0.41
1/24/13	13.7	0.61
4/30/13	2090	2.99
5/22/13	4020	3.89
6/12/13	5580	4.31
7/31/13	3080	3.19
11/19/13	155	0.87
12/18/13	142	0.61
2/19/14	16.3	0.64
4/3/14	54.3	1.26
6/9/14	48	0.61
7/31/14	31.9	0.46
10/27/14	47.9	0.63
2/18/15	19.2	0.86
4/21/15	1310	2.29
5/24/15	5270	2.67
8/17/15	123	1.14
10/7/15	20.3	0.73
1/6/16	68	1.52
2/12/16	145	2.14

3/30/16	53.6	1.19
4/7/16	2580	3.31
6/2/16	6290	4.04
8/10/16	22.9	0.73
10/24/16	176	2.96
12/6/16	42.1	1.02
2/15/17	122	1.76
4/25/17	6530	4.2
9/7/17	23.7	0.93
10/5/17	103	1.63
11/28/17	23	0.74
2/13/18	10.5	0.47
3/6/18	23.6	0.9
4/19/18	14.5	0.51
6/21/18	27.9	1.21
8/22/18	1090	2.1
10/16/18	5200	3.73
11/7/18	104	1.6
12/10/18	89.7	1.56

Table A 10. March half-life calculation with highlighted values as a positive half-life. An "*" indicates an NA result from half-life calculation from non-detect within Sites 1, 2, and 3.

March 20th, 2018		Sites (ng/L)				(hrs)
Analyte	Class	Site 1 (C)	Site 2 (C_A)	Site 3 (C_B)	Site 2 + 3 Mixing Conc. (C_T)	Half-Life ($t_{1/2}$)
1,7-Dimethylxanthine	Others	19	53	5	14.91	-14.12
2,4-D	Pesticides	86	110	30	46.51	-5.58
NP (4-nonylphenol)	Industrials	2000	4600	410	1274.63	-7.61
Acetaminophen	PPCPs	14	24	2.5	6.94	-4.88
Acesulfame-K	Others	220	850	10	183.34	-18.81
Albuterol	PPCPs	2.5	45	12.5	19.21	1.68

Amoxicillin	PPCPs	87	1400	40	320.64	2.63
Atenolol	PPCPs	24	320	2.5	68.02	3.29
Atrazine	Pesticides	17	43	52	50.14	3.17
Bromacil	Pesticides	2.5	37	2.5	9.62	2.54
Butalbital	PPCPs	2.5	2.5	2.5	2.50	NA*
Caffeine	Others	470	73	12	24.59	-1.16
Carbamazepine	PPCPs	40	320	12.5	75.95	5.35
Carisoprodol	PPCPs	23	130	2.5	28.81	15.22
Cimetidine	PPCPs	2.5	2.5	2.5	2.50	NA*
Cotinine	Others	5	25	5	9.13	NA*
DEA	Pesticides	2.5	5.3	2.5	3.08	16.49
DEET	Others	14	150	5	34.92	3.75
Dehydronifedipine	PPCPs	2.5	6.6	2.5	3.35	11.76
DIA	Pesticides	2.5	38	2.5	9.83	2.50
Diclofenac	PPCPs	80	560	2.5	117.54	8.91
Dilantin	PPCPs	10	130	10	34.76	2.75
Diltiazem	PPCPs	7.1	93	2.5	21.18	3.14
Diuron	Pesticides	71	2.5	5.3	4.72	-1.26
Erythromycin	PPCPs	5	30	5	10.16	4.84
Estrone	Hormones	2.5	2.5	2.5	2.50	NA*
EE2 (17 Alpha-ethynylestradiol)	Hormones	2.5	2.5	2.5	2.50	NA*
Fluoxetine	PPCPs	5	190	5	43.18	1.59
Gemfibrozil	PPCPs	2.5	16	2.5	5.29	4.58
Ibuprofen	PPCPs	5	5	5	5.00	NA*
Iohexol	PPCPs	1800	7200	50	1525.44	-20.71
Ketoprofen	PPCPs	2.5	2.5	12.5	10.44	NA*
Ketorolac	PPCPs	2.5	2.5	12.5	10.44	NA*
Lidocaine	PPCPs	45	390	2.5	82.46	5.66
Linuron	Pesticides	2.5	2.5	2.5	2.50	NA*
Lopressor	PPCPs	10	10	10	10.00	NA*
Meclofenamic Acid	PPCPs	34	430	2.5	90.72	3.49
Meprobamate	PPCPs	20	190	12.5	49.13	3.81
Metformin	PPCPs	21	230	2.5	49.45	4.00
Methylparaben	Others	10	10	10	10.00	NA*
Metolachlor	Pesticides	2.5	12.5	6.4	7.66	3.06
Naproxen	PPCPs	5	5	5	5.00	NA*
Nifedipine	PPCPs	10	50	10	18.25	5.70

OUST	Pesticides	2.5	2.5	2.5	2.50	NA*
Pentoxifylline	PPCPs	2.5	2.5	12.5	10.44	2.40
Primidone	PPCPs	10	150	10	38.89	2.52
Propylparaben	Others	2.5	2.5	2.5	2.50	NA*
Quinoline	Pesticides	6.7	11	5.8	6.87	134.44
Simazine	Pesticides	55	100	12.5	30.56	-5.83
Sulfadiazine	PPCPs	10	50	10	18.25	NA*
Sulfamethoxazole	PPCPs	2.5	12.5	2.5	4.56	NA*
Sucralose	Others	9400	46000	50	9532.01	245.83
TCEP	Industrials	25	130	25	46.67	5.49
TCPP	Industrials	200	1300	250	466.67	4.05
TDCPP	Industrials	50	770	250	357.30	1.74
Theophylline	PPCPs	44	100	10	28.57	-7.94
Thiabendazole	Others	2.5	2.5	2.5	2.50	NA*
Triclocarban	PPCPs	5	5	5	5.00	NA*
Triclosan	PPCPs	5	30	5	10.16	4.84
Trimethoprim	PPCPs	51	640	2.5	134.05	3.55
Warfarin	PPCPs	2.5	5.8	2.5	3.18	14.23

Table A 11. July half-life calculation with highlighted values as a positive half-life. NA value. An "*" indicates an NA result from half-life calculation from non-detect within Sites 1, 2, and 3.

July 12th, 2018		Sites (ng/L)				(hrs)
Analyte	Class	Site 1 (C)	Site 2 (C_A)	Site 3 (C_B)	Site 2 + 3 Mixing Conc. (C_T)	Half-Life ($t_{1/2}$)
1,7-Dimethylxanthine	Others	5	5	5	5.00	NA*
2,4-D	Pesticides	120	120	130	127.11	73.67
NP (4-nonylphenol)	Industrials	50	150	50	78.93	9.28
Acetaminophen	PPCPs	2.5	2.5	2.5	2.50	NA*
Acesulfame-K	Others	10	240	10	76.54	2.08
Albuterol	PPCPs	2.5	2.5	2.5	2.50	NA*
Amoxicillin	PPCPs	40	40	40	40.00	NA*
Atenolol	PPCPs	2.5	170	2.5	50.96	1.41
Atrazine	Pesticides	21	8.4	24	19.49	-56.69
Bromacil	Pesticides	2.5	2.5	2.5	2.50	NA*
Butalbital	PPCPs	2.5	22	2.5	8.14	3.59
Caffeine	Others	140	25	25	25.00	-2.46

Carbamazepine	PPCPs	13	250	2.5	74.10	2.44
Carisoprodol	PPCPs	2.5	26	2.5	9.30	3.23
Cimetidine	PPCPs	2.5	2.5	2.5	2.50	NA*
Cotinine	Others	5	21	5	9.63	6.47
DEA	Pesticides	12	13	9.3	10.37	-29.04
DEET	Others	17	44	17	24.81	11.21
Dehydronifedipine	PPCPs	2.5	8.6	2.5	4.26	7.94
DIA	Pesticides	2.5	2.5	2.5	2.50	NA*
Diclofenac	PPCPs	2.5	160	2.5	48.06	1.43
Dilantin	PPCPs	10	71	10	27.65	4.17
Diltiazem	PPCPs	2.5	23	2.5	8.43	3.49
Diuron	Pesticides	2.5	2.5	2.5	2.50	NA*
Erythromycin	PPCPs	5	5	5	5.00	NA*
Estrone	Hormones	2.5	2.5	2.5	2.50	NA*
EE2 (17 Alpha-ethynylestradiol)	Hormones	2.5	55	2.5	17.69	2.17
Fluoxetine	PPCPs	5	110	5	35.38	2.17
Gemfibrozil	PPCPs	2.5	24	2.5	8.72	3.39
Ibuprofen	PPCPs	5	32	5	12.81	4.51
Iohexol	PPCPs	270	9600	50	2812.73	1.81
Ketoprofen	PPCPs	2.5	2.5	2.5	2.50	NA*
Ketorolac	PPCPs	2.5	2.5	2.5	2.50	NA*
Lidocaine	PPCPs	14	490	2.5	143.53	1.82
Linuron	Pesticides	2.5	12	2.5	5.25	5.72
Lopressor	PPCPs	10	250	10	79.43	2.05
Meclofenamic Acid	PPCPs	2.5	2.5	2.5	2.50	NA*
Meprobamate	PPCPs	2.5	94	2.5	28.97	1.73
Metformin	PPCPs	2.5	2.5	12	9.25	3.24
Methylparaben	Others	37	10	53	40.56	46.14
Metolachlor	Pesticides	13	2.5	2.5	2.50	NA*
Naproxen	PPCPs	5	5	5	5.00	NA*
Nifedipine	PPCPs	10	10	10	10.00	NA*
OUST	Pesticides	2.5	22	5.5	10.27	3.00
Pentoxifylline	PPCPs	2.5	2.5	2.5	2.50	NA*
Primidone	PPCPs	5	200	5	61.41	1.69
Progesterone	Hormones	2.5	2.5	2.5	2.50	NA*
Propylparaben	Others	2.5	7.2	29	22.69	1.92
Quinoline	Pesticides	2.5	2.5	2.5	2.50	NA*

Simazine	Pesticides	2.5	5.9	2.5	3.48	12.78
Sulfadiazine	PPCPs	10	70	10	27.36	4.21
Sulfamethoxazole	PPCPs	16	430	2.5	126.17	2.05
Sucralose	Others	1600	47000	50	13632.21	1.98
TCEP	Industrials	5	60	5	20.91	2.96
TCPP	Industrials	50	1800	50	556.26	1.76
TDCPP	Industrials	50	50	50	50.00	NA*
Testosterone	Hormones	2.5	2.5	2.5	2.50	NA*
Theobromine	Others	5	5	5	5.00	NA*
Theophylline	PPCPs	120	10	10	10.00	-1.71
Thiabendazole	Others	20	20	22	21.42	61.74
Triclocarban	PPCPs	5	74	5	24.96	2.64
Triclosan	PPCPs	5	5	5	5.00	NA*
Trimethoprim	PPCPs	2.5	2.5	2.5	2.50	NA*
Warfarin	PPCPs	2.5	2.5	2.5	2.50	NA*

Table A 12. December half-life calculation with highlighted values as a positive half-life. An "*" indicates an NA result from half-life calculation from non-detect within Sites 1, 2, and 3.

December 19th, 2018		Sites (ng/L)				(hrs)
Analyte	Class	Site 1 (C)	Site 2 (C_A)	Site 3 (C_B)	Site 2 + 3 Mixing Conc. (C_T)	Half-Life ($t_{1/2}$)
1,7-Dimethylxanthine	Others	25	25	25	25.000	NA*
2,4-D	Pesticides	16	2.5	7.2	6.754	-2.89
NP (4-nonylphenol)	Industrials	200	200	200	200.000	NA*
Acetaminophen	PPCPs	2.5	2.5	2.5	2.500	NA*
Acesulfame-K	Others	120	2600	10	255.644	3.30
Albuterol	PPCPs	2.5	13	2.5	3.496	7.44
Amoxicillin	PPCPs	1600	17000	10	1621.389	187.88
Atenolol	PPCPs	6.2	240	2.5	25.025	1.79
Atrazine	Pesticides	2.5	9.6	2.5	3.173	10.46
Bromacil	Pesticides	2.5	2.5	2.5	2.500	NA*
Butalbital	PPCPs	2.5	41	2.5	6.151	2.77
Caffeine	Others	5	30	5	7.371	6.43
Carbamazepine	PPCPs	9.9	200	2.5	21.232	3.27
Carisoprodol	PPCPs	2.5	21	2.5	4.255	4.69
Cimetidine	PPCPs	2.5	300	2.5	30.716	0.99

Cotinine	Others	5	55	5	9.742	3.74
DEA	Pesticides	2.5	2.5	2.5	2.500	NA*
DEET	Others	5	16	5	6.043	13.17
Dehydronifedipine	PPCPs	2.5	20	2.5	4.160	4.90
DIA	Pesticides	25	25	25	25.000	NA*
Diclofenac	PPCPs	11	170	2.5	18.386	4.86
Dilantin	PPCPs	10	61	10	14.837	6.32
Diltiazem	PPCPs	2.5	190	2.5	20.283	1.19
Diuron	Pesticides	2.5	72	2.5	9.092	1.93
Erythromycin	PPCPs	5	10	5	5.474	27.54
Estrone	Hormones	5.6	75	2.5	9.376	4.84
EE2 (17 Alpha-ethynylestradiol)	Hormones	2.5	2.5	2.5	2.500	NA*
Fluoxetine	PPCPs	5.8	120	2.5	13.644	2.92
Gemfibrozil	PPCPs	17	610	2.5	60.117	1.98
Ibuprofen	PPCPs	5	140	5	17.804	1.96
Iohexol	PPCPs	1500	41000	5	3893.105	2.62
Ketoprofen	PPCPs	2.5	48	2.5	6.815	2.49
Ketorolac	PPCPs	2.5	70	2.5	8.902	1.96
Lidocaine	PPCPs	51	1100	2.5	106.591	3.38
Linuron	Pesticides	2.5	2.5	2.5	2.500	NA*
Lopressor	PPCPs	32	770	10	82.081	2.65
Meclofenamic Acid	PPCPs	2.5	2.5	2.5	2.500	NA*
Meprobamate	PPCPs	5.4	68	2.5	8.712	5.22
Metformin	PPCPs	2.5	41	2.5	6.151	2.77
Methylparaben	Others	10	10	10	10.000	NA*
Metolachlor	Pesticides	2.5	2.5	2.5	2.500	NA*
Naproxen	PPCPs	5	160	5	19.701	1.82
Nifedipine	PPCPs	10	41	10	12.940	9.68
OUST	Pesticides	2.5	2.5	2.5	2.500	NA*
Pentoxifylline	PPCPs	2.5	21	2.5	4.255	4.69
Primidone	PPCPs	15	250	2.5	25.974	4.54
Progesterone	Hormones	2.5	2.5	2.5	2.500	NA*
Propylparaben	Others	2.5	2.5	2.5	2.500	NA*
Quinoline	Pesticides	25	25	78	72.973	2.33
Simazine	Pesticides	10	84	2.5	10.230	109.85
Sulfadiazine	PPCPs	2.5	2.5	2.5	2.500	NA*
Sulfamethoxazole	PPCPs	77	1000	25	117.472	5.91

Sucralose	Others	2200	45000	50	4313.210	3.71
TCEP	Industrials	5	94	5	13.441	2.52
TCPP	Industrials	50	760	50	117.339	2.92
TDCPP	Industrials	50	50	50	50.000	NA*
Testosterone	Hormones	2.5	2.5	2.5	2.500	NA*
Theobromine	Others	25	25	25	25.000	NA*
Theophylline	PPCPs	5	330	15	44.876	1.14
Thiabendazole	Others	2.5	98	2.5	11.558	1.63
Triclocarban	PPCPs	10	10	10	10.000	NA*
Triclosan	PPCPs	10	21	10	11.043	25.14
Trimethoprim	PPCPs	21	440	2.5	43.994	3.37
Warfarin	PPCPs	2.5	2.5	2.5	2.500	NA*

Table A 13. CEC mixing model for Scenario 1 and 2. All values reported in ng L^{-1}.

Model for IPR proposed 2nd discharge location with effluent at full flow

Analyte	Class	March (ng L^{-1})			July (ng L^{-1})			December (ng L^{-1})		
		Site 3	Site 4 Theory Mix	W1500RD Theory Mix	Site 3	Site 4 Theory Mix	W1500RD Theory Mix	Site 3	Site 4 Theory Mix	W1500RD Theory Mix
2,4-D	Pesticides	30	39.916	42.540	130	127.490	135.873	7.2	6.888	7.341
NP (4-nonylphenol)	Industrials	410	912.686	1512.721	50	42.617	70.635	200	120.668	200.000
Acesulfame-K	Others	10	33.735	192.862	10	10.051	57.462	10	95.236	544.459
Albuterol	PPCPs	2.5	4.030	11.270	2.5	0.894	2.500	2.5	1.669	4.667
Amoxicillin	PPCPs	40	305.234	320.643	40	38.078	40.000	10	3347.003	3515.970
Atenolol	PPCPs	2.5	7.765	68.018	2.5	4.231	37.064	2.5	5.880	51.509
Atrazine	Pesticides	52	23.198	46.175	24	10.440	20.781	2.5	1.992	3.965
Bromacil	Pesticides	2.5	1.522	9.619	2.5	0.395	2.500	2.5	0.395	2.500
Butalbital	PPCPs	2.5	0.572	2.500	2.5	1.493	6.524	2.5	2.390	10.445
Caffeine	Others	12	9.174	19.032	2.5	1.205	2.500	5	4.897	10.159
Carbamazepine	PPCPs	12.5	19.036	68.018	2.5	14.993	53.573	2.5	12.106	43.255
Carisoprodol	PPCPs	2.5	20.650	37.937	2.5	4.000	7.349	2.5	3.439	6.318
Cimetidine	PPCPs	2.5	0.022	2.500	2.5	0.022	2.500	2.5	0.571	63.891
Cotinine	Others	5	1.789	4.484	5	3.311	8.302	5	6.110	15.318
DEA	Pesticides	2.5	2.316	3.078	9.3	6.437	8.556	2.5	1.881	2.500
DEET	Others	5	21.173	34.921	17	13.685	22.572	5	4.408	7.270
Dehydronifedipine	PPCPs	2.5	1.888	3.346	2.5	2.121	3.759	2.5	3.449	6.111
DIA	Pesticides	2.5	1.510	9.826	2.5	0.384	2.500	2.5	0.384	2.500
Diclofenac	PPCPs	2.5	46.568	117.543	2.5	13.867	35.001	2.5	14.684	37.064
Dilantin	PPCPs	10	12.011	34.763	10	7.804	22.588	10	7.091	20.524
Diltiazem	PPCPs	2.5	3.498	21.175	2.5	1.112	6.730	2.5	6.805	41.192

Diuron	Pesticides	5.3	0.438	4.960	2.5	0.221	2.500	2.5	1.486	16.842
Erythromycin	PPCPs	5	7.603	10.159	5	3.742	5.000	5	4.514	6.032
Estrone	Hormones	2.5	0.949	2.500	2.5	0.949	2.500	2.5	6.625	17.461
EE2 (17 Alpha-ethynylestradiol)	Hormones	2.5	0.287	2.500	2.5	1.529	13.334	2.5	0.287	2.500
Fluoxetine	PPCPs	5	5.240	43.176	5	3.236	26.667	2.5	3.246	26.747
Gemfibrozil	PPCPs	2.5	1.284	5.286	2.5	1.685	6.937	2.5	31.064	127.861
Ibuprofen	PPCPs	5	1.173	5.000	5	2.479	10.572	5	7.706	32.858
Iohexol	PPCPs	50	183.010	1525.438	50	242.426	2020.690	5	1016.457	8472.457
Ketoprofen	PPCPs	12.5	0.379	2.500	2.5	0.379	2.500	2.5	1.804	11.889
Ketorolac	PPCPs	12.5	0.230	2.500	2.5	0.230	2.500	2.5	1.509	16.429
Lidocaine	PPCPs	2.5	22.581	82.463	2.5	28.232	103.098	2.5	62.701	228.975
Linuron	Pesticides	2.5	1.100	2.500	2.5	1.963	4.460	2.5	1.100	2.500
Lopressor	PPCPs	10	1.355	10.000	10	8.066	59.525	10	22.605	166.830
Meclofenamic Acid	PPCPs	2.5	23.684	90.717	2.5	0.653	2.500	2.5	0.653	2.500
Meprobamate	PPCPs	12.5	11.138	41.192	2.5	5.781	21.381	2.5	4.331	16.016
Metformin	PPCPs	2.5	12.127	49.446	2.5	0.613	2.500	2.5	2.562	10.445
Methylparaben	Others	10	9.033	10.000	53	35.559	39.365	10	9.033	10.000
Metolachlor	Pesticides	6.4	2.701	12.500	12	1.827	8.452	2.5	0.540	2.500
Naproxen	PPCPs	5	0.380	5.000	5	0.380	5.000	5	2.807	36.985
Nifedipine	PPCPs	10	9.917	18.254	10	5.432	10.000	10	8.908	16.397
OUST	Pesticides	2.5	0.523	2.500	5.5	1.847	8.825	2.5	0.523	2.500
Pentoxifylline	PPCPs	12.5	0.666	2.500	2.5	0.666	2.500	2.5	1.682	6.318
Primidone	PPCPs	10	7.798	38.890	5	9.071	45.239	2.5	10.742	53.573
Propylparaben	Others	2.5	0.218	2.500	29	2.133	24.501	2.5	0.218	2.500
Quinoline	Pesticides	5.8	3.972	4.254	2.5	2.334	2.500	78	2.334	2.500
Simazine	Pesticides	12.5	24.188	26.112	2.5	2.966	3.202	2.5	17.895	19.318
Sulfadiazine	PPCPs	10	5.993	18.254	10	7.348	22.381	2.5	0.821	2.500
Sulfamethoxazole	PPCPs	2.5	1.404	4.564	2.5	27.908	90.717	2.5	64.094	208.339
Sucralose	Others	50	9073.307	9595.501	50	9208.396	9738.365	50	8818.146	9325.655
TCEP	Industrials	2.5	8.545	30.794	5	38.892	140.162	5	6.483	23.366
TCPP	Industrials	2.5	61.426	307.944	50	82.007	411.121	50	39.198	196.512
TDCPP	Industrials	2.5	13.465	198.576	50	3.390	50.000	50	3.390	50.000
Theophylline	PPCPs	10	0.461	28.572	10	0.161	10.000	15	1.304	80.795
Thiabendazole	Others	2.5	2.156	2.500	22	15.194	17.619	2.5	19.151	22.207
Triclocarban	PPCPs	5	0.844	5.000	5	3.246	19.238	10	1.687	10.000
Triclosan	PPCPs	5	7.429	10.159	5	3.656	5.000	10	8.972	12.270
Trimethoprim	PPCPs	2.5	34.556	134.051	2.5	0.644	2.500	2.5	23.917	92.780
Warfarin	PPCPs	2.5	2.288	3.181	2.5	1.798	2.500	2.5	1.798	2.500

Table A 14. CEC mixing model for Scenario 3 and 4. All values reported in ng L^{-1}.

Model for IPR proposed 2nd discharge location with effluent at half flow

Analyte	Class	March (ng L^{-1})			July (ng L^{-1})			December (ng L^{-1})		
		Site 3	Site 4 Theory Mix	W1500RD Theory Mix	Site 3	Site 4 Theory Mix	W1500RD Theory Mix	Site 3	Site 4 Theory Mix	W1500RD Theory Mix
2,4-D	Pesticides	30	31.588	31.588	130	138.450	138.450	7.2	8.127	8.127
NP (4-nonylphenol)	Industrials	410	1011.519	1011.519	50	57.751	57.751	200	200.000	200.000
Acesulfame-K	Others	10	86.179	86.179	10	27.828	27.828	10	210.754	210.754
Albuterol	PPCPs	2.5	5.794	5.794	2.5	2.500	2.500	2.5	3.314	3.314
Amoxicillin	PPCPs	40	145.415	145.415	40	40.000	40.000	10	1326.916	1326.916
Atenolol	PPCPs	2.5	27.110	27.110	2.5	15.483	15.483	2.5	20.909	20.909
Atrazine	Pesticides	52	46.690	46.690	24	22.791	22.791	2.5	3.050	3.050
Bromacil	Pesticides	2.5	5.174	5.174	2.5	2.500	2.500	2.5	2.500	2.500
Butalbital	PPCPs	2.5	2.500	2.500	2.5	4.011	4.011	2.5	5.484	5.484
Caffeine	Others	12	10.271	10.271	2.5	2.500	2.500	5	6.938	6.938
Carbamazepine	PPCPs	12.5	27.110	27.110	2.5	21.684	21.684	2.5	17.808	17.808
Carisoprodol	PPCPs	2.5	22.991	22.991	2.5	4.322	4.322	2.5	3.934	3.934
Cimetidine	PPCPs	2.5	2.500	2.500	2.5	2.500	2.500	2.5	25.560	25.560
Cotinine	Others	5	4.806	4.806	5	6.240	6.240	5	8.876	8.876
DEA	Pesticides	2.5	2.717	2.717	9.3	7.834	7.834	2.5	2.500	2.500
DEET	Others	5	16.239	16.239	17	19.093	19.093	5	5.853	5.853
Dehydronifedipine	PPCPs	2.5	2.818	2.818	2.5	2.973	2.973	2.5	3.856	3.856
DIA	Pesticides	2.5	5.252	5.252	2.5	2.500	2.500	2.5	2.500	2.500
Diclofenac	PPCPs	2.5	45.713	45.713	2.5	14.708	14.708	2.5	15.483	15.483
Dilantin	PPCPs	10	19.301	19.301	10	14.728	14.728	10	13.953	13.953
Diltiazem	PPCPs	2.5	9.515	9.515	2.5	4.089	4.089	2.5	17.033	17.033
Diuron	Pesticides	5.3	5.360	5.360	2.5	2.500	2.500	2.5	7.887	7.887
Erythromycin	PPCPs	5	6.938	6.938	5	5.000	5.000	5	5.388	5.388
Estrone	Hormones	2.5	2.500	2.500	2.5	2.500	2.500	2.5	8.120	8.120
EE2 (17 Alpha-ethynylestradiol)	Hormones	2.5	2.500	2.500	2.5	6.569	6.569	2.5	2.500	2.500
Fluoxetine	PPCPs	5	19.340	19.340	5	13.139	13.139	2.5	11.608	11.608
Gemfibrozil	PPCPs	2.5	3.546	3.546	2.5	4.166	4.166	2.5	49.588	49.588
Ibuprofen	PPCPs	5	5.000	5.000	5	7.093	7.093	5	15.464	15.464
Iohexol	PPCPs	50	604.205	604.205	50	790.232	790.232	5	3191.799	3191.799
Ketoprofen	PPCPs	12.5	2.500	2.500	2.5	2.500	2.500	2.5	6.027	6.027
Ketorolac	PPCPs	12.5	2.500	2.500	2.5	2.500	2.500	2.5	7.732	7.732
Lidocaine	PPCPs	2.5	32.536	32.536	2.5	40.287	40.287	2.5	87.569	87.569
Linuron	Pesticides	2.5	2.500	2.500	2.5	3.236	3.236	2.5	2.500	2.500
Lopressor	PPCPs	10	10.000	10.000	10	28.603	28.603	10	68.909	68.909
Meclofenamic Acid	PPCPs	2.5	35.636	35.636	2.5	2.500	2.500	2.5	2.500	2.500
Meprobamate	PPCPs	12.5	17.033	17.033	2.5	9.592	9.592	2.5	7.577	7.577

Metformin	PPCPs	2.5	20.134	20.134	2.5	2.500	2.500	2.5	5.484	5.484
Methylparaben	Others	10	10.000	10.000	53	44.132	44.132	10	10.000	10.000
Metolachlor	Pesticides	6.4	12.500	12.500	12	9.419	9.419	2.5	2.500	2.500
Naproxen	PPCPs	5	5.000	5.000	5	5.000	5.000	5	17.014	17.014
Nifedipine	PPCPs	10	13.100	13.100	10	10.000	10.000	10	12.403	12.403
OUST	Pesticides	2.5	2.500	2.500	5.5	6.687	6.687	2.5	2.500	2.500
Pentoxifylline	PPCPs	12.5	2.500	2.500	2.5	2.500	2.500	2.5	3.934	3.934
Primidone	PPCPs	10	20.852	20.852	5	20.115	20.115	2.5	21.684	21.684
Propylparaben	Others	2.5	2.500	2.500	29	27.310	27.310	2.5	2.500	2.500
Quinoline	Pesticides	5.8	3.159	3.159	2.5	2.500	2.500	78	2.500	2.500
Simazine	Pesticides	12.5	14.116	14.116	2.5	2.764	2.764	2.5	8.817	8.817
Sulfadiazine	PPCPs	10	13.100	13.100	10	14.651	14.651	2.5	2.500	2.500
Sulfamethoxazole	PPCPs	2.5	3.275	3.275	2.5	35.636	35.636	2.5	79.817	79.817
Sucralose	Others	50	3685.441	3685.441	50	3689.153	3689.153	50	3534.131	3534.131
TCEP	Industrials	2.5	14.689	14.689	5	55.770	55.770	5	11.899	11.899
TCPP	Industrials	2.5	146.889	146.889	50	185.645	185.645	50	105.033	105.033
TDCPP	Industrials	2.5	105.808	105.808	50	50.000	50.000	50	50.000	50.000
Theophylline	PPCPs	10	16.976	16.976	10	10.000	10.000	15	40.339	40.339
Thiabendazole	Others	2.5	2.500	2.500	22	17.233	17.233	2.5	9.902	9.902
Triclocarban	PPCPs	5	5.000	5.000	5	10.348	10.348	10	10.000	10.000
Triclosan	PPCPs	5	6.938	6.938	5	5.000	5.000	10	10.853	10.853
Trimethoprim	PPCPs	2.5	51.913	51.913	2.5	2.500	2.500	2.5	36.411	36.411
Warfarin	PPCPs	2.5	2.756	2.756	2.5	2.500	2.500	2.5	2.500	2.500

Appendix B: Graphs of CEC Concentration and Half-Life

Figure B 1. Pesticides class detections in ng L^{-1} for March sampling date; y-axis set in hours with scale to the log of 2.

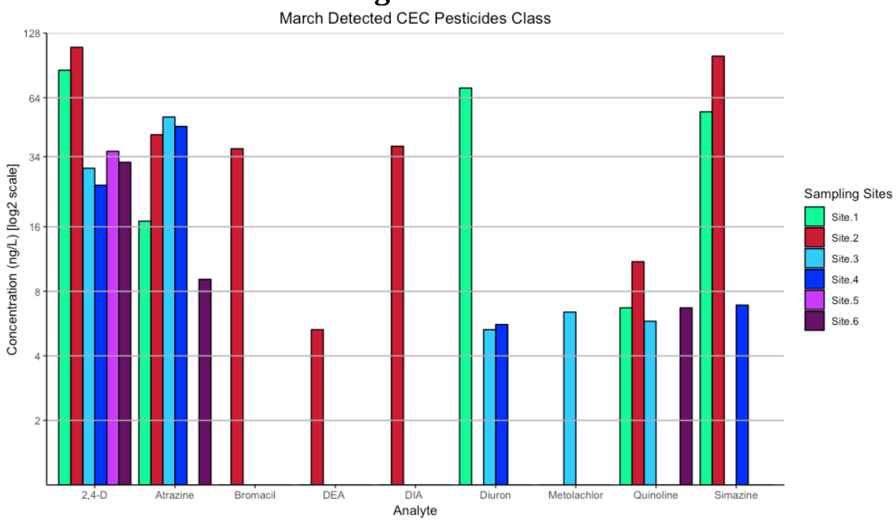

Figure B 2. Industrials class detections in ng L^{-1} for March sampling date; y-axis set in hours with scale to the log of 2.

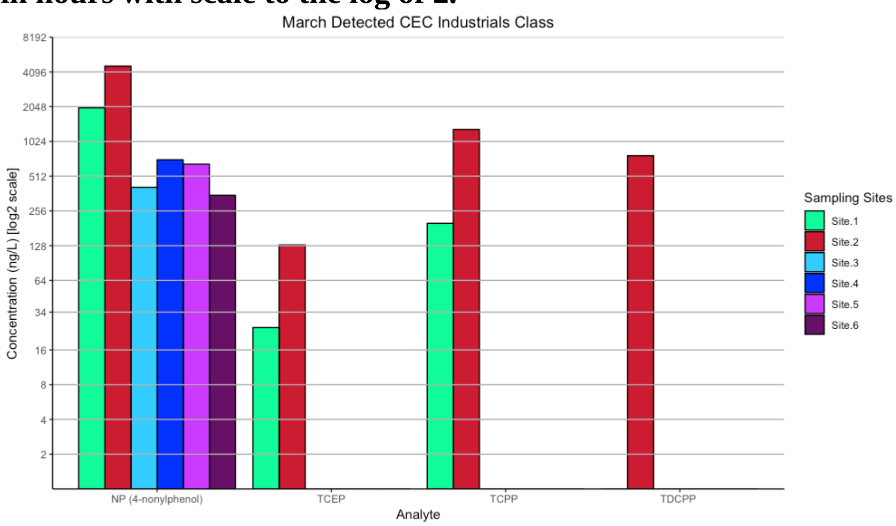

Figure B 3. PPCPs class detections in ng L-1 for March sampling date (1/3); y-axis set in hours with scale to the log of 2.

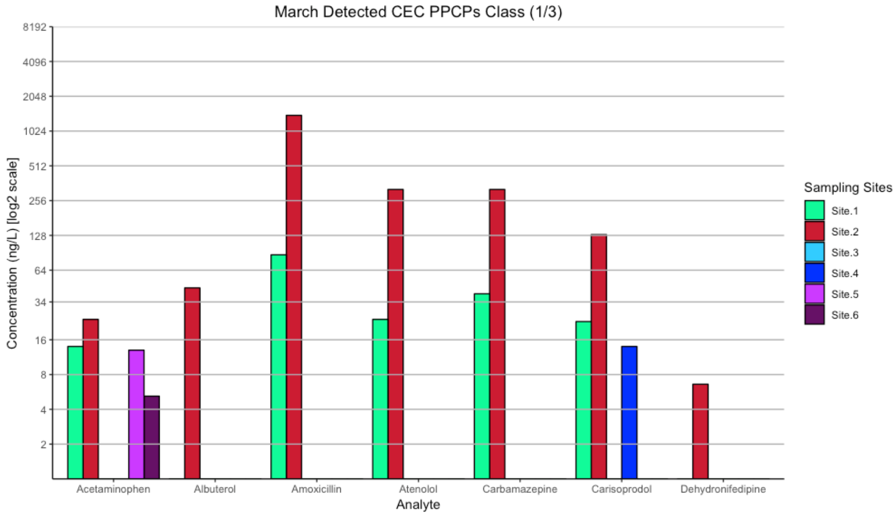

Figure B 4. PPCPs class detections in ng L-1 for March sampling date (2/3); y-axis set in hours with scale to the log of 2.

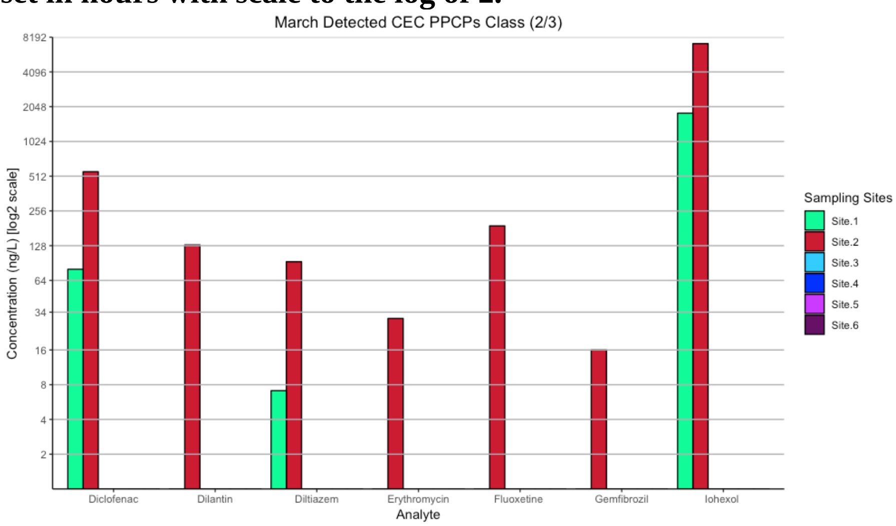

Figure B 5. PPCPs class detections in ng L^{-1} for March sampling date (3/3); y-axis set in hours with scale to the log of 2.

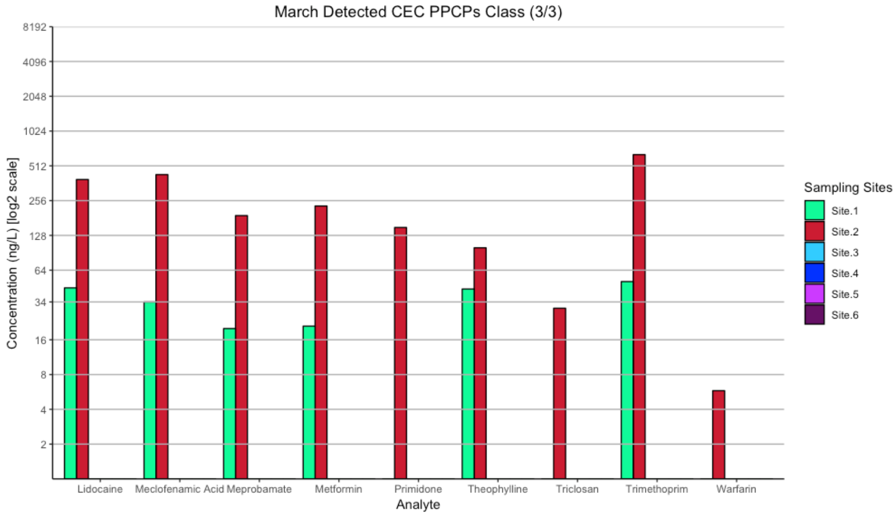

Figure B 6. Hormones class detections in ng L^{-1} for March sampling date; y-axis set in hours with scale to the log of 2.

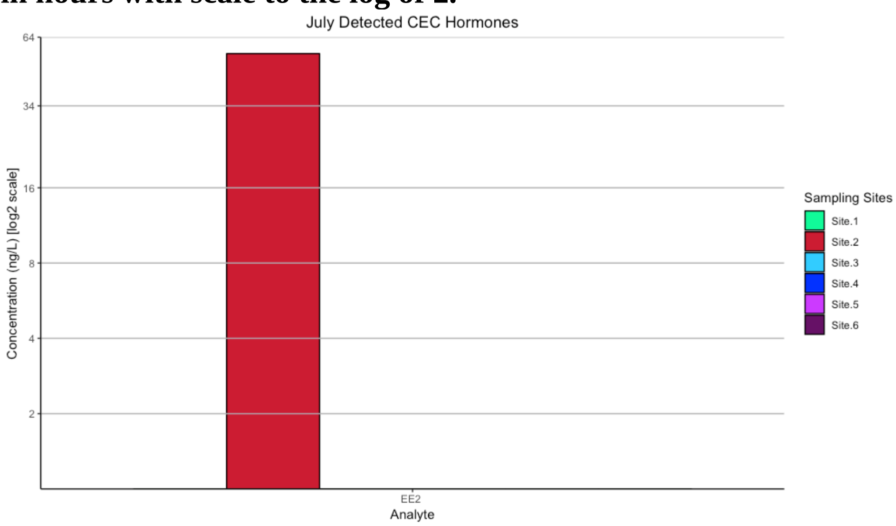

Figure B 7. Others class detections in ng L^{-1} for March sampling date; y-axis set in hours with scale to the log of 2.

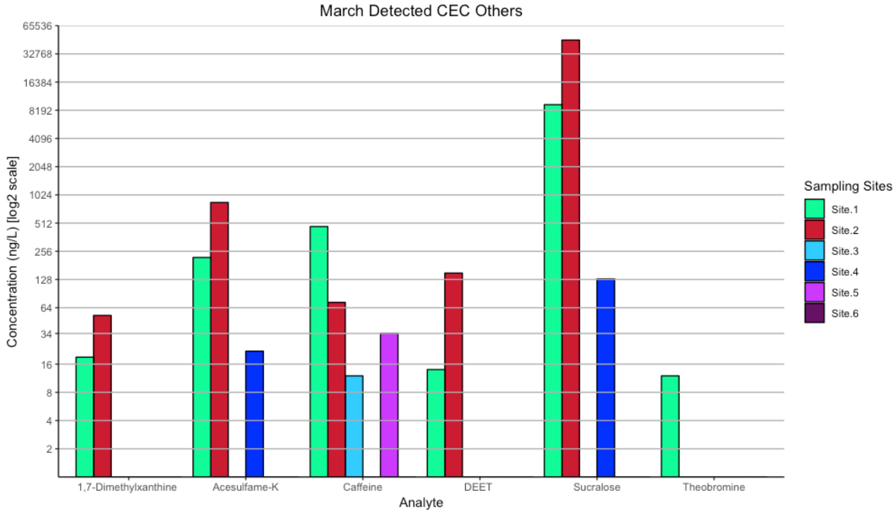

Figure B 8. Pesticides class detections in ng L^{-1} for July sampling date; y-axis set in hours with scale to the log of 2.

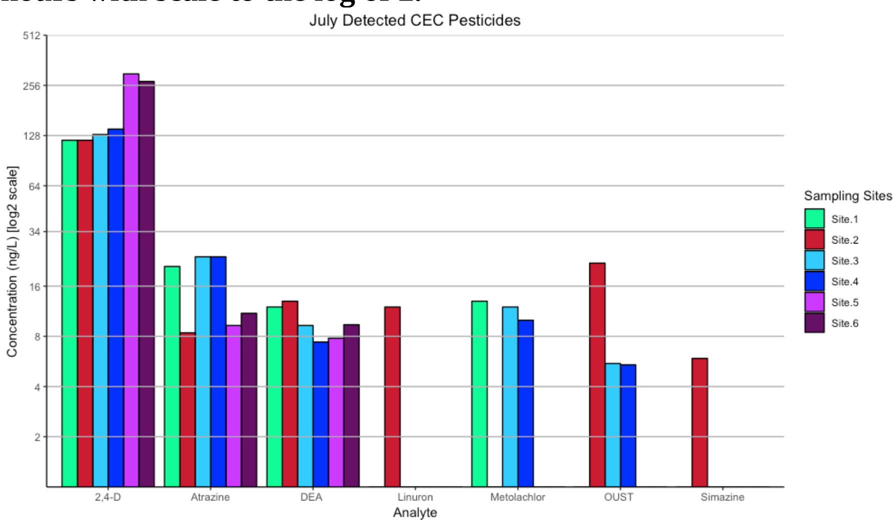

Figure B 9. Industrials class detections in ng L^{-1} for July sampling date; y-axis set in hours with scale to the log of 2.

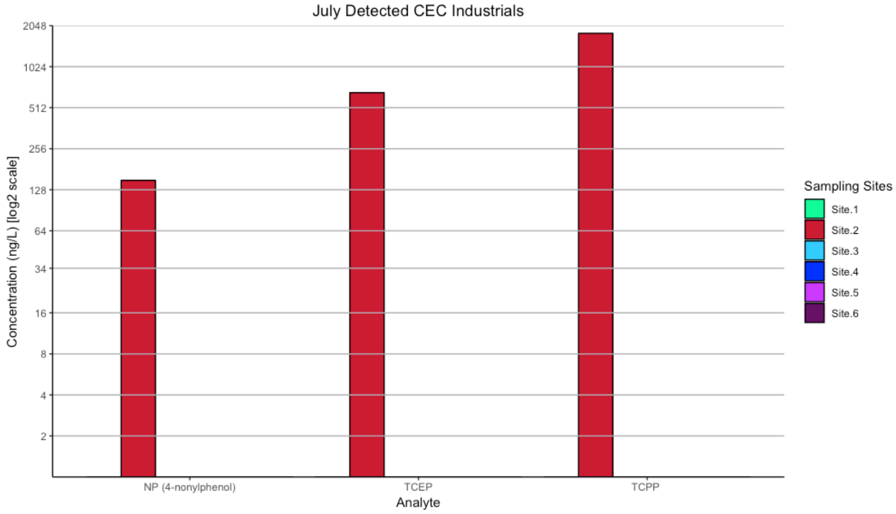

Figure B 10. PPCPs class detections in ng L^{-1} for July sampling date (1/3); y-axis set in hours with scale to the log of 2.

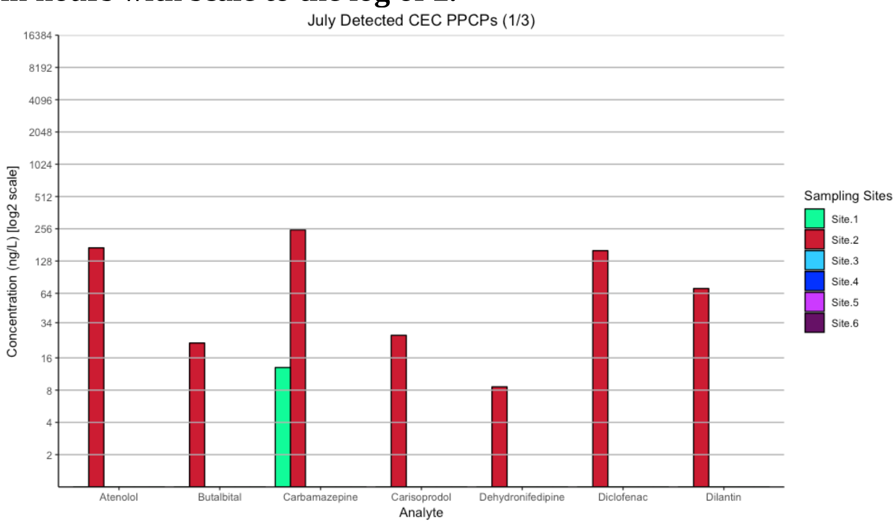

Figure B 11. PPCPs class detections in ng L^{-1} for July sampling date (2/3); y-axis set in hours with scale to the log of 2.

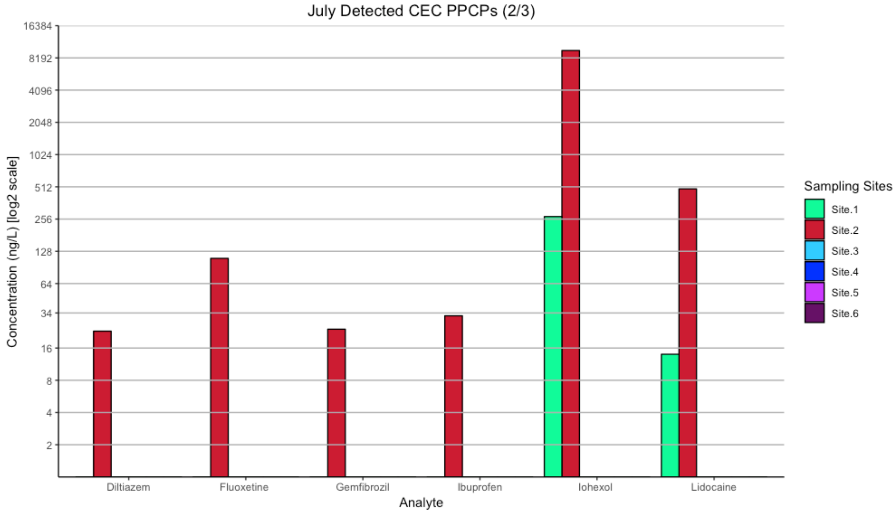

Figure B 12. PPCPs class detections in ng L^{-1} for July sampling date (3/3); y-axis set in hours with scale to the log of 2.

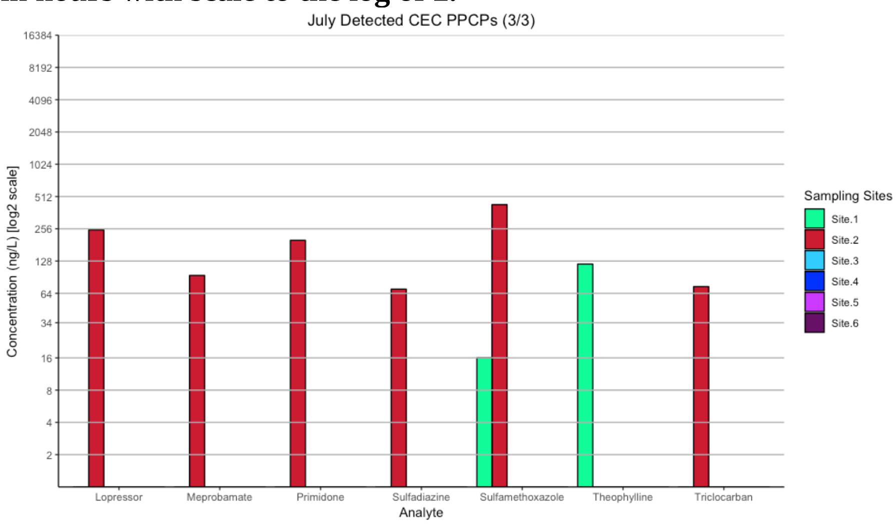

Figure B 13. Hormones class detections in ng L^{-1} for 2018 sampling date; y-axis set in hours with scale to the log of 2.

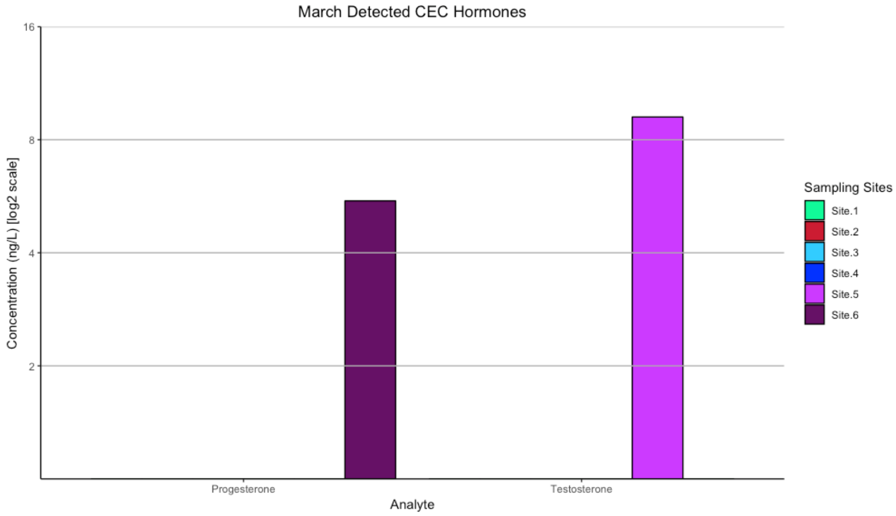

Figure B 14. Others class detections in ng L^{-1} for July sampling date; y-axis set in hours with scale to the log of 2.

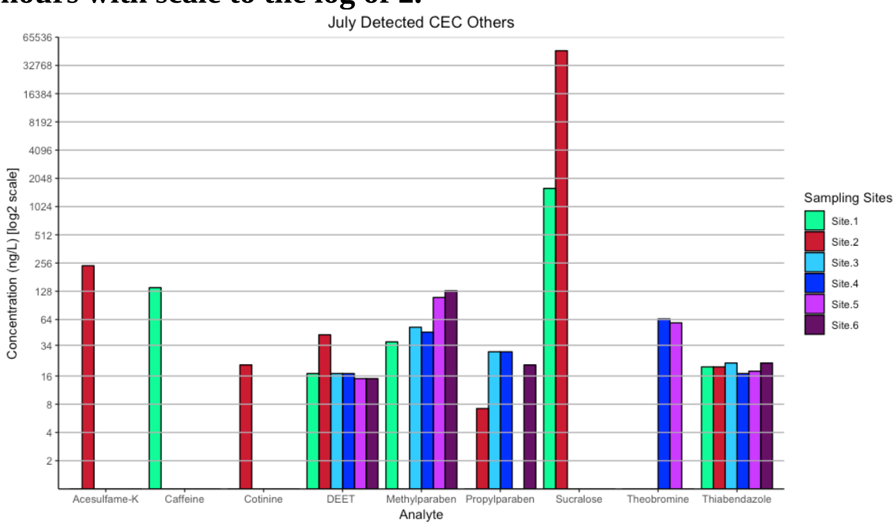

Figure B 15. Pesticides class detections in ng L^{-1} for December sampling date; y-axis set in hours with scale to the log of 2.

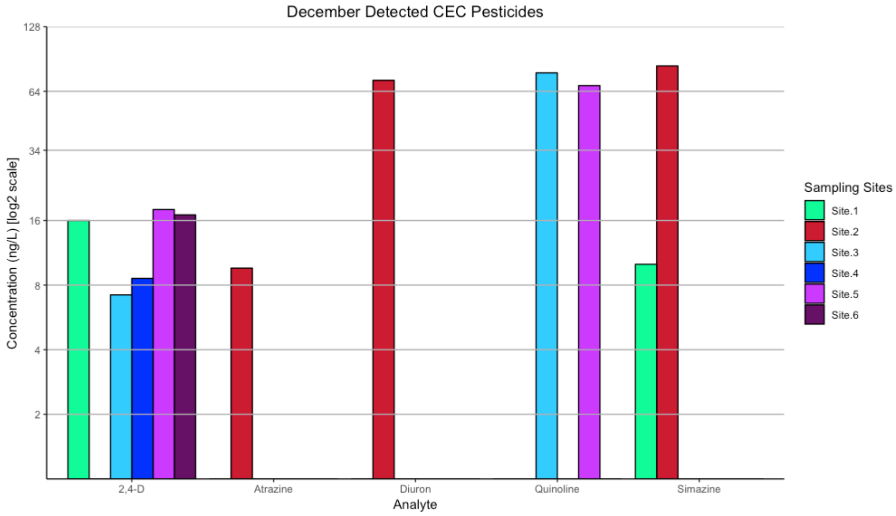

Figure B 16. Industrials class detections in ng L^{-1} for December sampling date; y-axis set in hours with scale to the log of 2.

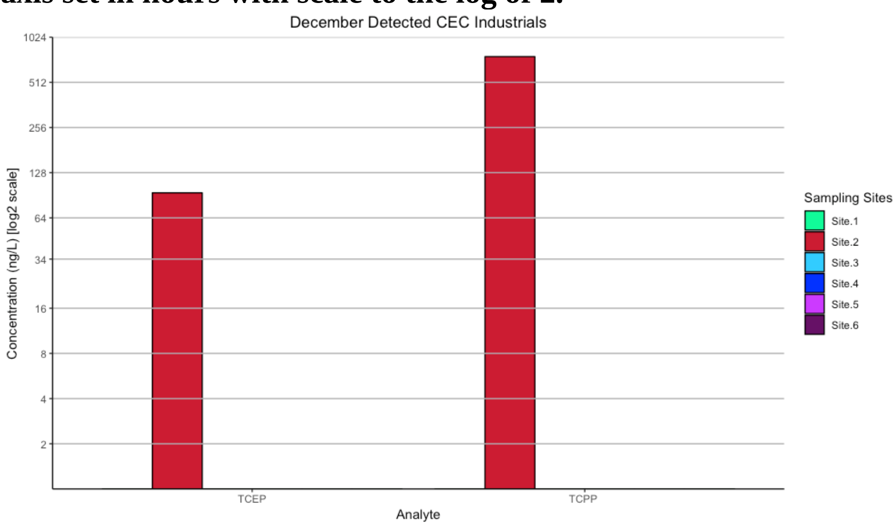

Figure B 17. PPCPs class detections in ng L^{-1} for December sampling date (1/3); y-axis set in hours with scale to the log of 2.

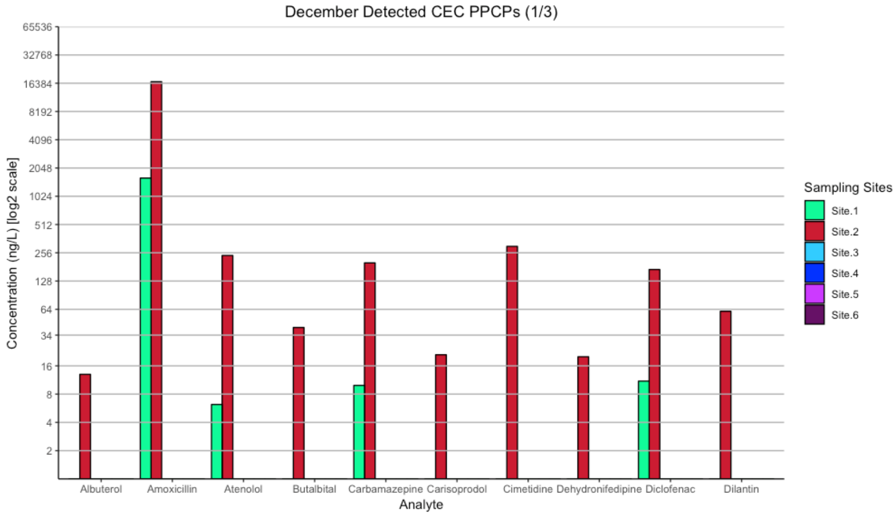

Figure B 18. PPCPs class detections in ng L^{-1} for December sampling date (2/3); y-axis set in hours with scale to the log of 2.

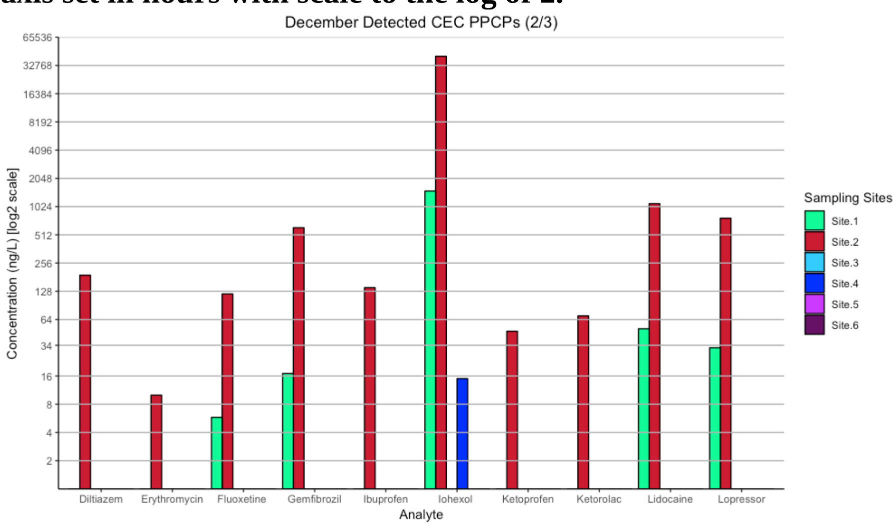

Figure B 19. PPCPs class detections in ng L^{-1} for December sampling date (3/3); y-axis set in hours with scale to the log of 2.

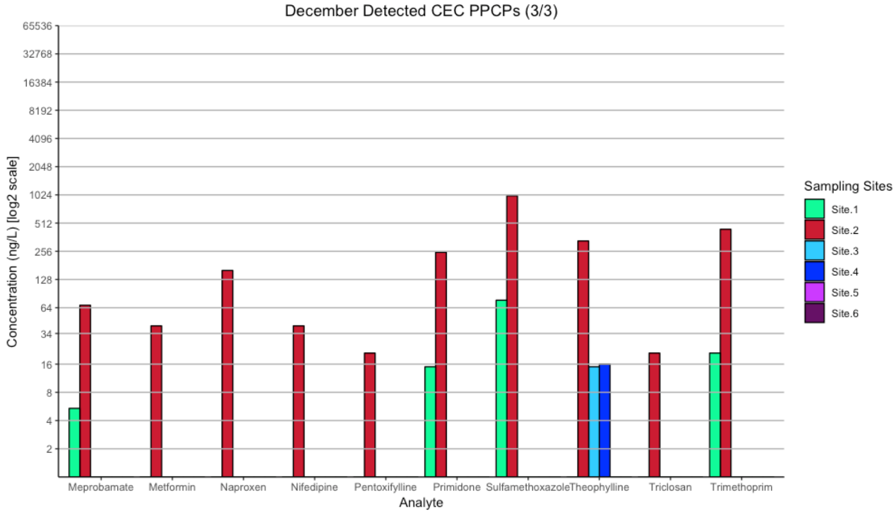

Figure B 20 Hormones class detections in ng L^{-1} for December sampling date; y-axis set in hours with scale to the log of 2.

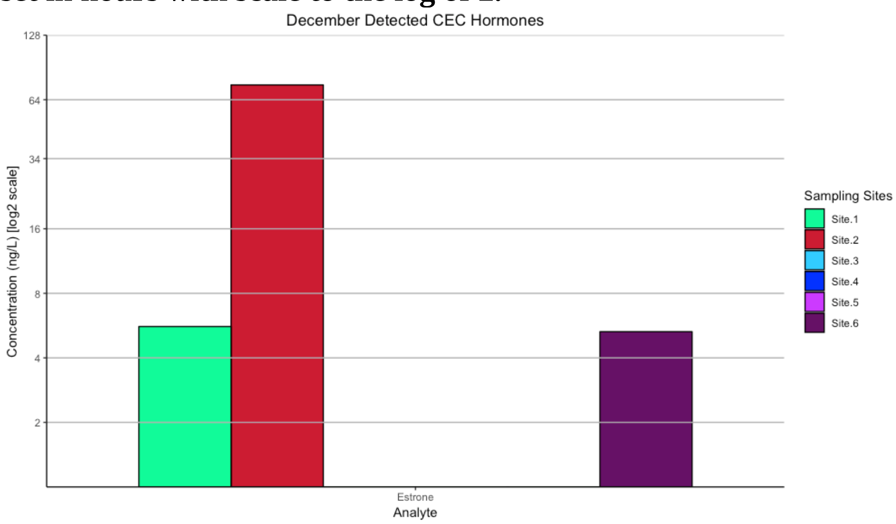

Figure B 21. Others class detections in ng L^{-1} for December sampling date; y-axis set in hours with scale to the log of 2.

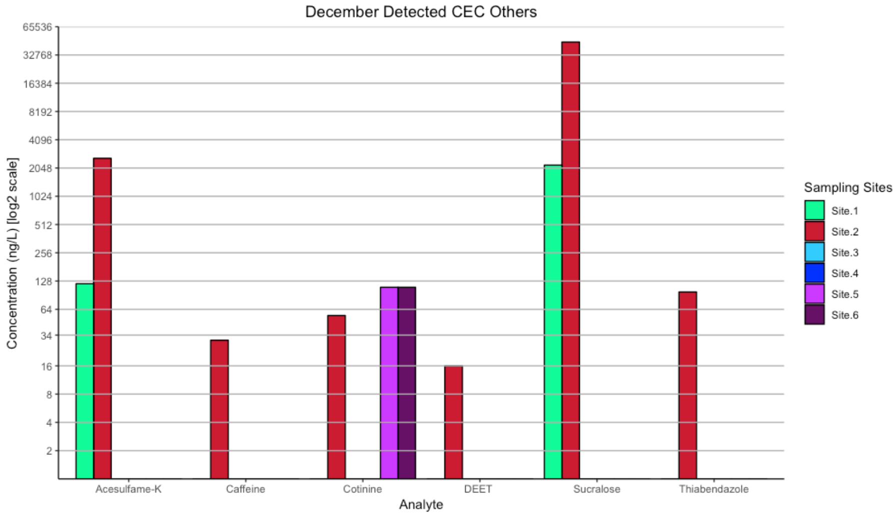

Figure B 22. Dumbbell half-life chart for detected pesticides class; x-axis set in hours with scale to the log of 2.

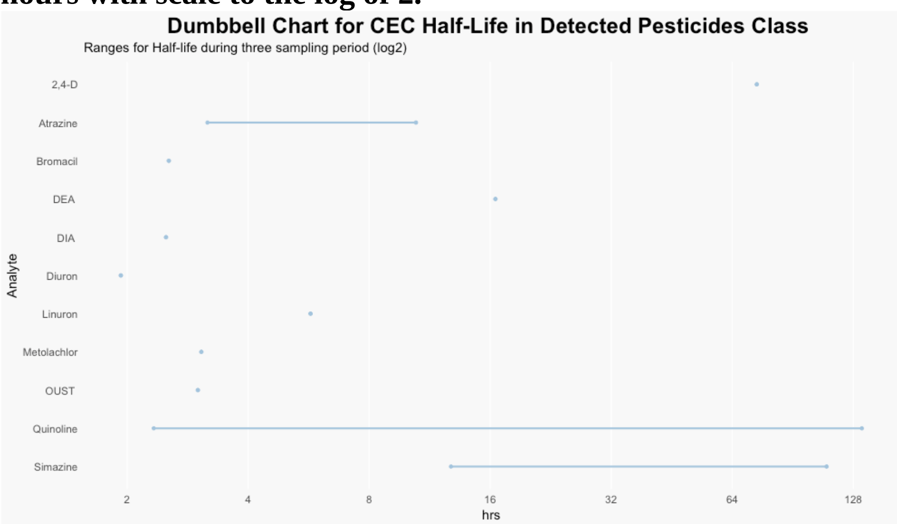

Figure B 23. Dumbbell half-life chart for detected industrials class; x-axis set in hours with scale to the log of 2.

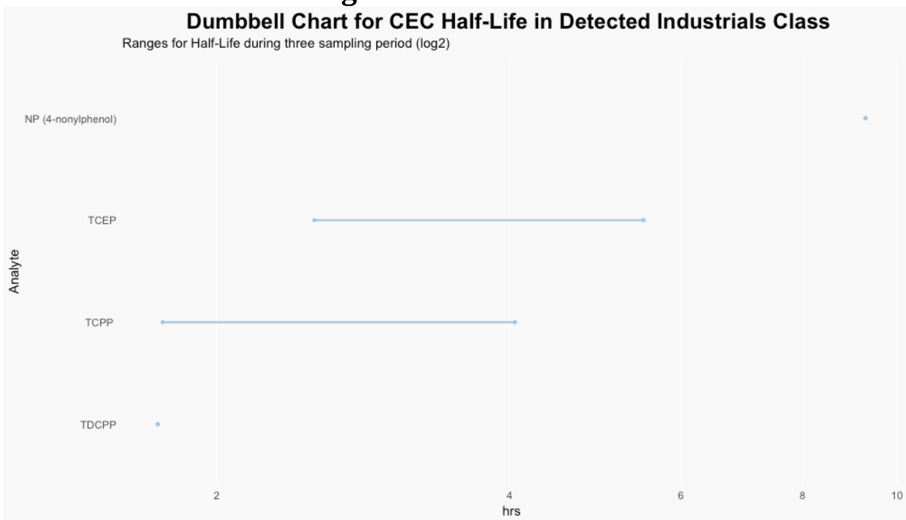

Figure B 24. Dumbbell half-life chart for detected PPCPs class; x-axis set in hours with scale to the log of 2.

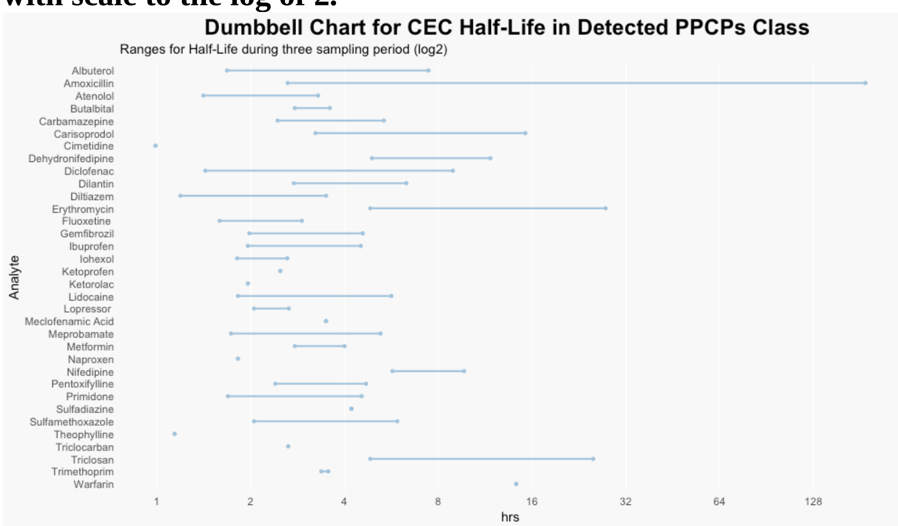

Figure B 25. Dumbbell half-life chart for detected Hormones class.

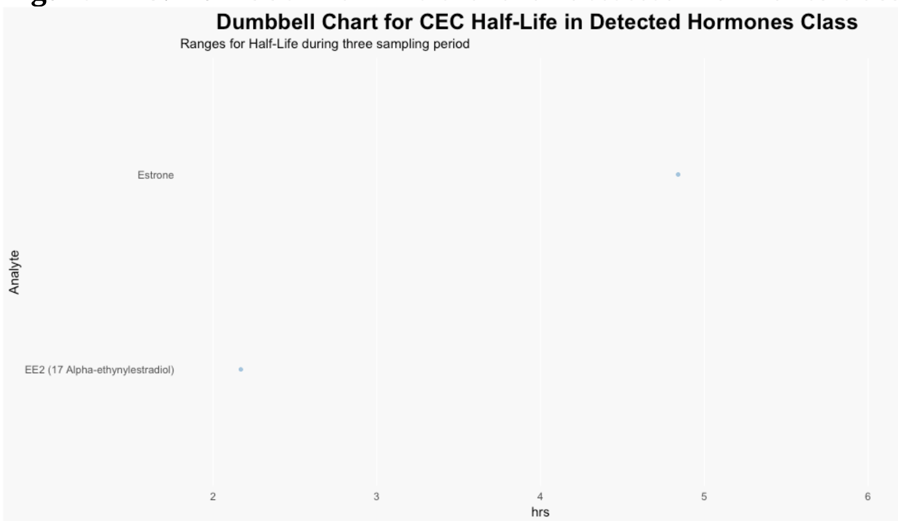

Figure B 26. Dumbbell half-life chart for detected others class; x-axis set in hours with scale to the log of 2.