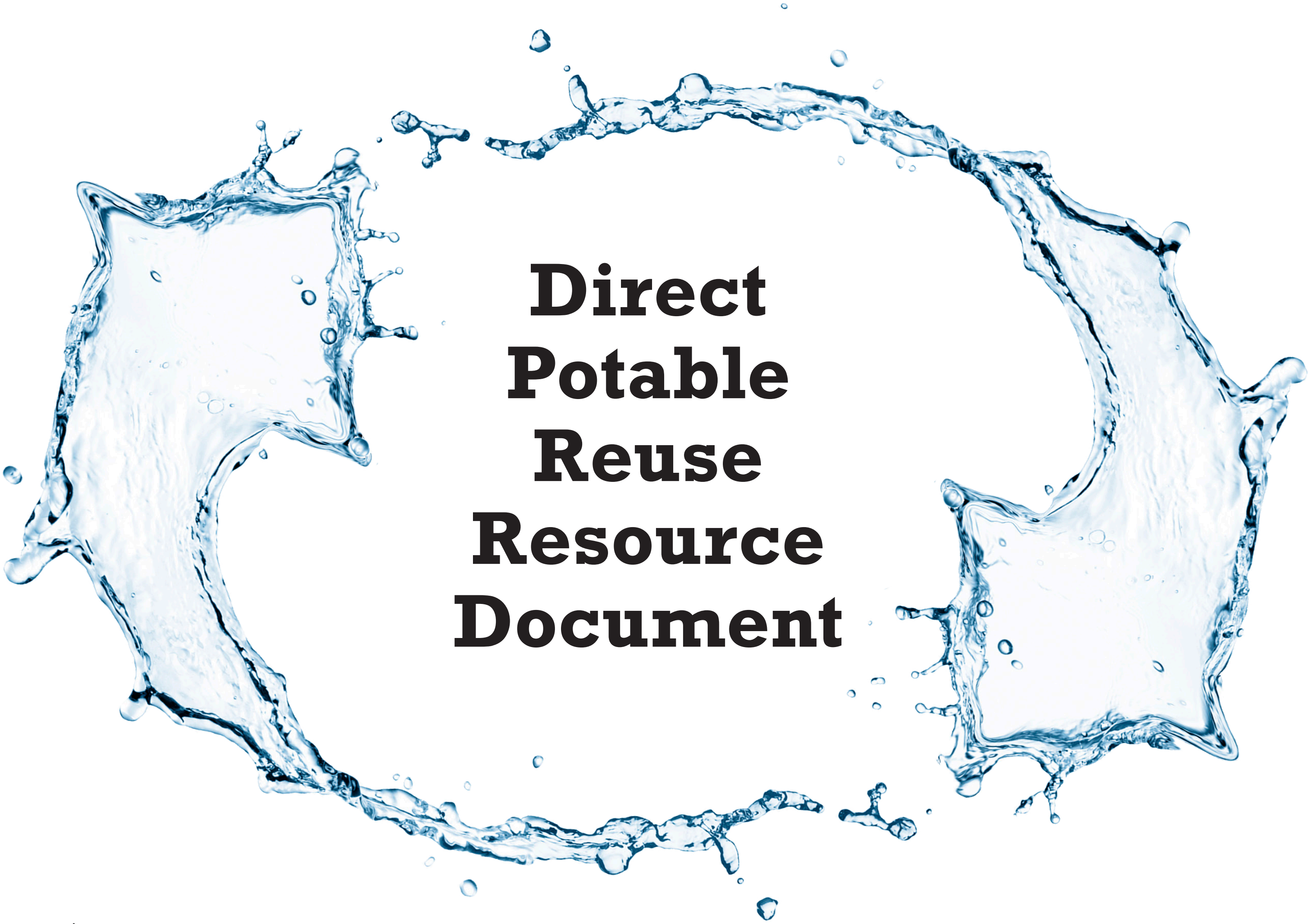
Texas Water Development Board
1700 North Congress Avenue
Austin, Texas 78711

FINAL REPORT



Direct Potable Reuse Resource Document

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Appendix

In The Appendix

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A Appendix:
Significance of Environmental Buffers

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TECHNICAL MEMORANDUM

Texas Water Development Board
Evaluating the Potential for Direct Potable Reuse in Texas
Task 7 Technical Memorandum: Significance of Environmental Buffers

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1 INTRODUCTION

Direct potable reuse (DPR) is typically defined as the introduction of reclaimed water either directly into the potable water system downstream of a water treatment plant or into the raw water supply immediately upstream of a water treatment plant. DPR eliminates or significantly minimizes the use of an environmental buffer and utilizes engineered treatment processes to treat reclaimed water prior to delivery to the potable water distribution system. Where applicable, an option to implement a DPR project will likely be weighed against alternatives for indirect potable reuse (IPR) that involve blending with other water supplies in an "environmental buffer", such as a groundwater aquifer surface water reservoir, river or constructed wetland. Due to the inherent variability of natural systems used as environmental buffers, their treatment benefits can be more difficult to quantify than engineered treatment processes. In addition to treatment, greater public acceptance and additional response time have also been cited as benefits of using an environmental buffer as part of an IPR project. As defined in Task 7 of the Scope of Work for the subject project, the purpose of this memorandum is to:

- Summarize known treatment performance of environmental buffers;
- Summarize other benefits of environmental buffers, including their value in providing positive public perception and response time to potential system upsets; and

- Identify additional research needed to better quantify the value of environmental buffers for potable reuse projects.

2 TREATMENT PERFORMANCE OF ENVIRONMENTAL BUFFERS

Much of the research related to treatment performance of environmental buffers for potable reuse applications has focused on managed aquifer recharge (MAR), which includes riverbank filtration (RBF) and soil aquifer treatment (SAT). Limited research has been carried out related to treatment performance of surface water environmental buffers such as surface wetlands, rivers and reservoirs. This section summarizes the current state of knowledge with respect to treatment performance of these systems. Because of the importance to potable reuse, the focus of the summary is on pathogens, organic carbon and constituents of emerging concern (CECs, e.g. pharmaceuticals, personal care products, etc.).

2.1 <u>Managed Aquifer Recharge</u>

Studies thus far have focused on the various removal mechanisms in MAR that are responsible for the improvement of water quality. Removal of wastewater-derived pathogens, organic carbon and CECs occur in MAR systems through processes such as filtration, solution- precipitation, ion exchange, sorption, desorption, redox reactions, microbial degradation and dilution (Kuehn and others, 2000; Hiscock and Grischek, 2002). Additional background information and research on the efficacy of MAR will be available in the published report for WateReuse Research Foundation Project 10-05, Role of Retention Time in the Environmental Buffer of Indirect Potable Reuse Projects, (expected publication date September 2014).

2.1.1 Pathogens

Pathogens may be removed from water in MAR systems by means of straining, inactivation, and attachment to the aquifer grains (McDowell-Boyer and others, 1986). Over time, pathogen levels in a MAR system decrease to a point below detection. The length of time to inactivation depends upon a number of factors including temperature, pH, humidity, organic matter present, microorganism competition, and sunlight (Schijven and others, 2003). Efficient removal of pathogens by MAR systems is well documented in the literature for both SAT and RBF.

Studies on SAT have established that inactivation of pathogens through filtration and biotransformation is very efficient. Key conclusions from SAT studies include:

- Up to 8-log virus removal was achieved in a homogeneous sandy aquifer over a distance of 25 m in approximately 25 days (NRC, 2012).

- In Israel, 5.3-log removal of total coliforms and 4.5-log removal of fecal coliforms were observed in field studies of a sandy aquifer in the Dan Region (Icekson-Tal and others, 2003)
- Multiple studies have documented the scarcity of fecal and total coliform bacteria in subsurface abstraction wells after SAT (or RBF) indicating the efficiency of SAT(Fox, 2001; Hijnen and others, 2005; Levantesi and others, 2010).

Numerous studies have also confirmed the efficiency of RBF in the removal of pathogens. Key conclusions from the literature include:

- Total coliform removal was reported in excess of 5 log in the Rhine and Meuse Rivers at transport distances of 30 and 25 m, respectively (Havelaar and others, 1995).
- Weiss and others, (2005) reported 5.5- and 6.1-log reduction of total coliforms at two separate well locations.
- Greater than 5-log removal of surrogate organisms (i.e., bacteria and viruses) were reported by Medema and Stuyfzand, (2002). Some variation (±1-log removal) was observed based on individual microorganism characteristics.
- *Cryptosporidium* surrogate removals have been reported at 2 log for transport distances of 6 m to 300 m (Gollnitz and others, 2005), while research has demonstrated RBF capable of protozoa removal of 1.9 log at 2 m (Schijven and others, 1998), and surrogate protozoa removal of 3.1 to 3.6 log at travel distances ranging from 25 to 30 m (Havelaar and others, 1995).

The 2014 California Groundwater Replenishment Regulations allow for virus removal credits of 1-log/month of underground retention time as part of a multi-barrier approach for pathogen control. As a conservative measure, the regulations only allow a credit up to six logs for any single barrier (e.g., above ground treatment or retention time).

2.1.2 Constituents of Emerging Concern

Removal of CECs in MAR systems during soil passage has been studied throughout the world by several researchers. The removal is mainly influenced by the CECs' biodegradability and concentration levels; travel time through the soil; redox conditions; and substrate availability (Sharma and Amy, 2010). Depending on their specific characteristics, some CECs are more easily degradable under aerobic conditions when compared to anoxic conditions and vice versa.

MARs look to be a robust option for treatment, as the study by Schmidt and others (2007) documented good removal after changes in discharge and water temperature. Several laboratory-scale studies have characterized the transformation and removal of CECs in SAT at travel times from 1 day up to 8 years.

Efficient NDMA removal in MAR systems has been reported by many studies (Sharp and others, 2005; Drewes and others, 2006; Nalinakumari and others, 2009). However, while many compounds are efficiently removed, some compounds do persist in MAR systems. Common characteristics of chemicals that are not easily removed include structural features to prevent enzymatic attack, which renders them resistant to biodegradation, and hydrophilic properties (Heberer, 2002).

Laws and others, (2011) reported on the removal of CECs after surface spreading (Table 1). CEC concentrations decreased in the vadose zone (first 2.4 m, 10 hour travel time), then remained reasonably constant when measured at a 70-hour travel time (7.6 m below the basin) sampling location. Concentrations decreased further when measured at extended travel times of 60 days.

Table 1: CEC Concentrations in Basin and Aquifer after Surface Spreading (Adapted from Laws and others, 2011)

Compound	Type	Basin (ng/L)	Upper Aquifer Avg. [1] (ng/L)	Lower Aquifer[2] Avg. (ng/L)
Atrazine	Herbicide	<5	5±0.2	4.0±0.1
Atenolol	Blood pressure drug	830	31±34	<1
Atrovastatin	Statin	<10	<MRL	<0.5
Benzophenone	Ingredient in cosmetics and personal care products	<1000	68±27	<50
Carbamazepine	Anti-epileptic	330	302±28	170±0
DEET	Insecticide	320	238±60	50±12
Diazepam	Anti-epileptic	<5	2±0.3	1.5±0.3
Diclofenac	Non-steroidal anti-inflamatory drug (NSAID)	24	10±2	<0.5
Fluoxetine	Anti-depressant	13	0.57±0.16	<0.5
Gemfibrozil	Chloesterol drug	880	70±63	32±2.9
Ibuprofen	NSAID	10	12±8	1.3±0
Iopromide	Contrast agent	2,700	60±41	89±18
Meprobamate	Anxiety drug	430	375±45	132±31
Musk Ketone	Ingredient personal care products	<25	<MRL	<25
Naproxen	NSAID	32	6±3	2.4±0
Phenytoin	Anti-convulsant drug	150	103±13	85±8
Primidone	Anti-convulsant drug	150	168±45	90± 2.6
Sulfamethoxazole	Antibiotic	460	390±129	207±12
TCEP	Flame retardant	400	402±15	128±39
TCPP	Flame retardant	7,200	6,483±875	797±188

Compound	Type	Basin (ng/L)	Upper Aquifer Avg. [1] (ng/L)	Lower Aquifer[2] Avg. (ng/L)
Triclosan	Anti-bacterial	6.5	6±3	<1
Trimethoprim	Antibiotic	54	58±33	3.5±2.6

[1]Travel time 10-70 hours
[2]Travel time 60 days
nanogram per liter - ng/L

Recent research indicates that pre-exposure to CECs for microbial adaptation is not needed for degradation as previous authors had indicated, but instead co-metabolism is the most likely biotransformation mechanism for CECs in MAR systems (Alidina and others, 2014).

2.2 Surface Water

Studies documenting removal performance of wastewater-derived pathogens, organic carbon and CECs in surface waters are limited. Common natural removal or transformation processes in surface waters include biotransformation and photolysis.

2.2.1 Pathogens

One of the most recent studies related to pathogen attenuation in surface waters was performed by Toze and others, (2012) who evaluated the capability of natural processes within reservoirs and waterways in South East Queensland, Australia to remove microbial pathogens and chemicals of concern. As part of this research the authors performed a literature review of the survival of enteric microorganisms in both surface water and groundwater. These studies indicated that temperature, sunlight and sediment can have significant impacts on the decay rates of enteric microorganisms in reservoirs. The authors performed experiments on pathogen decay in both the Wivenhoe Reservoir and downstream in the mid-Brisbane River. The initial assessment of pathogen decay in Wivenhoe Reservoir is summarized in Table 2.

Table 2: Initial assessment of pathogen decay in Wivenhoe Reservoir (adapted from Toze, and others, 2012, Table 4)

Microorganism	Kd (log day^{-1})	Std. Error	T90 (days)
E. coli	0.2635	0.0441	3.8
Salmonella	0.1987	0.0297	5.0
Campylobacter	0.1049	0.0157	9.5
MS2	0.2185	0.0102	4.6
Cryptosporidium	0.0783	0.0072	12.8

Kd: Microorganism decay rate- based on linear regression of log reduction of multiple samples over time.
T90: Time for a 1 log reduction; calculated as the inverse of Kd

Toze and others, (2012) also performed experiments and used measurements of water quality, physical conditions and indigenous microorganisms to evaluate the impacts of indigenous microorganisms, sunlight, water depth and flood conditions on pathogen decay rates. Key conclusions from this evaluation included:

- The presence of indigenous microbes increased the decay rate of adenovirus by a factor of approximately 3, while the microbes had only a minimal impact on the decay of the two other microorganisms tested, *E. coli* and MS2.
- In-situ experiments performed to evaluate the influence of sunlight were inconclusive due to the variability of other parameters during the measurement period. Further research performed under more controlled conditions would be beneficial.
- Decay rates of *Campylobacter* and adenovirus were more than twice as long at a depth of 15 meters, as compared to at the reservoir surface. Differences were attributed to the lower dissolved oxygen concentrations and lower temperatures at the 15 meter depth. In contrast, differences in depth had no impact on the decay rate of *E. coli* or *Salmonella*.
- Differences between pre-flood and post-flood decay rates were most predominant for Campylobacter and adenovirus. Both showed significantly faster decay rates at a 15 meter depth for post-flood conditions. This difference was attributed to mixing in the reservoir as a result of the flood and the resulting higher dissolved oxygen levels at this depth, although additional research is needed to further confirm these relationships.

A similar assessment of decay rates was performed in the mid-Brisbane River. The region of the river chosen for the evaluation had a maximum depth of about 4 meters and was in a quiet area out of the main stream flow. No water quality data were available, but the water was visually observed to be quite turbid and the rapid fouling of the equipment suggested that there were sufficient nutrients in the water to support high microbial activity. Due to the shallow water and reasonably fast water flow in the area, it was assumed that the dissolved oxygen levels were reasonably high and were approaching saturation. Baseline decay rates in the river are summarized in Table 3.

Table 3: Baseline Decay Rates in mid-Brisbane River (adapted from Toze, and others, 2012, Table 10)

Microorganism	Kd (log day^{-1})	Std. Error	T90 (days)
E. coli	0.9583	0.0274	1.0
Adenovirus	0.0175	0.0070	57
Cryptosporidium	0.0093	.11169	108

Kd: Microorganism decay rate- based on linear regression of log reduction of multiple samples over time.
T90: Time for a 1 log reduction; calculated as the inverse of Kd

Other studies investigated the fate and transport of various pathogens in surface waters. Key conclusions from these studies include:

- Factors affecting inactivation include temperature, salinity, pressure, solar radiation (both visible and ultraviolet), and predation by other organisms. The chief inactivation mechanisms are solar radiation and temperature (Brookes and others, 2004).
- Sinton and others found that microbes have differing vulnerabilities to light and determined solar inactivation rates (k_s) for several pathogens based on their experiment. The ranking from greatest to least inactivation in the study was enterococcci > fecal coliforms ≥ *E. coli* > somatic coliphages > F-RNA phages (Sinton and others, 2002).
- Microorganisms may survive in sediment for extended periods of time, thus re-suspension of sediment may contribute to fecal coliform concentration (Hipsey and others, 2005).

2.2.2 Contaminants of Emerging Concern

In addition to investigating pathogen attenuation in surfaces waters, Toze and others, (2012) also researched the fate of CECs in the Wivenhoe Dam and mid- Brisbane River. A series of experiments were completed to measure the biodegradation and photodegradation potentials of CECs in natural systems. Water quality for each of the locations is summarized in Table 4.

Table 4: Water quality parameters of water collected from Wivenhoe Dam and mid-Brisbane River for the photolysis study (adapted from Toze, and others, 2012, Table 15)

Location	pH	EC (µS/cm)	DOC (mg/L)	NO_x (mg/L)	Total N (mg/L)	Total P (mg/L)	Fe (mg/L)
Wivenhoe Dam (Expt.1)	8.55	197	9.4	-[1]	-[1]	-[1]	-[1]
Wivenhoe Dam (Expt.2)	8.85	378	6.6	<0.005	0.3	<0.1	<0.1
Brisbane River	7.37	504	7.7	<0.005	0.7	<0.1	0.14

[1] data not available
EC- Electrical Conductivity
DOC – Dissolved organic Carbon
NO_x – Nitrogen species
Total N- Total Nitrogen
Total P – Total Phosphorous

Pharmaceuticals, pesticides, endocrine disrupting chemicals, personal care products and antibiotics were selected for the study to allow for a range of physicochemical properties, contamination sources and biological modes of action. A list of the compounds analyzed in the study is summarized in Table 5 along with associated rates of photolysis. Water was sampled at no greater than a depth of 1 meter in pre-cleaned 20 liter polypropylene containers that excluded light. Note that water was collected from the Wivenhoe Dam twice and the second sampling (Experiment 2) was performed to gain additional insight into the effect of irradiance on photolysis rates.

Table 5: First order rates of photolysis (k_{photo}; d-1) under experimental conditions and corresponding half-lives ($t_{0.5}$) (in parentheses). (adapted from Toze, and others, 2012, Table 28)

Compound	Type	Wivenhoe Dam (Experiment 1)	Wivenhoe Dam (Experiment 2)	mid- Brisbane River
Atenolol	Blood pressure drug	0.17±0.03 (4.1 days)	0.13±0.06 (5.5 days)	0.37±0.1 (1.9 days)
Benzotriazole	Corrosion inhibitor	0.15±0.05 (4.8 days)	0.03±0.03 (22 days)	0.76±0.03 (0.9 days)
Methotrexate	Chemotherapy drug	0.22±0.06 (3.1 days)	0.26±0.03 (2.7 days)	0.37±0.01 (1.9 days)
Metoprolol	Blood pressure drug	0.25±0.03 (3.1 days)	nd	nd
Trimethoprim	Antibiotic	0.22±0.09 (3.1 days)	0.1±0.02 (6.8 days)	0.25±0.02 (2.7 days)
Venlafaxine	Anti-depressant	0.4±0.04 (1.9 days)	0.3±0.03 (2.3 days)	0.49±0.15 (1.4 days)
Propranolol	Blood pressure drug	2.6±0.1 (0.3 days)	2.6±0.2 (0.27 days)	1.9±0.2 (0.36 days)
Cyclophosphamide	Chemotherapy drug	0.04±0.04 (16 days)	0.01±0.03 (>30 days)	0.02±0.2 (>30 days)
Sulfamethoxazole	Antibiotic	0.84±0.1 (0.82 days)	0.79±0.2 (0.88 days)	1.02±0.2 (0.68 days)
Atrazine	Herbicide	0.12±0.05 (5.8 days)	0.27±0.06 (2.6 days)	0.35±0.02 (2 days)
Carbamazepine	Anti-epileptic	0.2±0.01 (3.3 days)	0.1±0.01 (7 days)	0.32±0.02 (2.1days)
Diethyltoluamide	Insecticide	0.11±0.01 (6.1 days)	0±0.0 (na)	0.25±0.13 (2.8 days)
Diuron	Herbicide	0.11±0.01 (3.4 days)	0.31±0.03 (2.2 days)	0.47±0.02 (1.5 days)
Sertraline	Anti-depressant	Nd	0.52±0.11 (1.3 days)	0.18±0.11 (3.8 days)

Compound	Type	Wivenhoe Dam (Experiment 1)	Wivenhoe Dam (Experiment 2)	mid- Brisbane River
2,4-dichlorophenoxy acetic acid	Herbicide	0.21±0.21 (3.3 days)	0.14±0.02 (4.9 days)	0.19±0.04 (3.6 days)
Triclopyr	Herbicide	3.1±0.6 (0.22 days)	3.55±0.7 (0.19 days)	2.34±0.3 (0.29 days)
Diclofenac	Non-steroidal anti-inflamatory drug (NSAID)	3.42±2.7 (0.2 days)	19±0.5 (0.03 days)	19±1.3 (0.04 days)

nd – not detectable
na –not tested

Key conclusions from this evaluation included:

- Photolysis was observed as an important degradation pathway for several compounds. In addition, indirect photolysis likely due to the reaction with the OH^- species enhances the rate of photolysis for a number of the compounds tested. Further research is needed to relate the relationship of depth to indirect photolysis for specific compounds.
- Rates of photolysis can be reduced based on a number of factors including a reduction in intensity of incident solar radiation through increased depth, as well as sorption to organic matter present in the surface water systems. Further research on adsorption of CECs to organic matter in surface water would be beneficial.
- Attenuation by biodegradation is of minor importance, even when BDOC and microbial inoculum are added. Where biodegradation does occur, it is likely not a predictable process between various freshwater systems.

Other studies available on the attenuation of CECs in surface water have focused on a single surface water system. Fono and others, (2006) observed a 60% to 90% decrease of ethylenediamine tetraacetate, gemfibrozil, ibuprofen, metoprolol, and naproxen as water flowed down the effluent-dominated Trinity River in Texas. Estimated attenuation rates suggested that biotransformation was more important than photolysis for most of the compounds, likely due to the extended hydraulic retention time in the large river (approximately 2 weeks). Calculated attenuation rates from laboratory- scale microcosms further confirmed the estimated results determined in the field study. The apparent importance of biodegradation in the Trinity study as compared to the Toze et al., (2012) study demonstrates that there can be significant variability in the effect of natural systems on contaminant removal, particularly in surface water systems.

(Buser and others, 1998) determined that diclofenac concentrations decreased by more than 90% in a Swiss lake. When exposed to sunlight, rapid photodegradation occurred, while diclofenac showed no degradation in the dark and negligible adsorption to sediment particles was observed under laboratory conditions. The experiment suggested that photolysis was the predominant degradation process in the lake.

2.3 Constructed Wetlands

Constructed wetlands have been used to treat wastewater and stormwater for many years. The two general types of constructed wetland systems are: surface flow and subsurface flow wetlands. Surface flow wetlands are similar to natural marsh wetlands as vegetation and hydraulic components are mimicked in design of the systems. Water flows above the ground in surface flow wetlands, through the aquatic plants. Subsurface flow wetlands are designed so that water flows below ground through a gravel and/or soil media bed. The media bed supports aquatic plants growing above the surface as well as their root system growing below.

2.3.1 Pathogens

Many studies have documented pathogen removal in constructed wetlands (Vymazal, 2005; Kadlec and Wallace, 2008). Pathogen removal in wetlands is the result of multiple mechanisms that include: solar radiation, predation, settling, pathogen die off, and filtration (Kadlec and Wallace, 2008). Removal of pathogens in constructed wetland systems correlates with hydraulic retention time (HRT); while also being affected by kinetics, superficial velocities[1], hydraulics (mostly short circuiting), wetland slopes and water depth (Kadlec and Knight, 1996; Cronk, 1996; Sauter and Leonard, 1997) A large amount of data has been collected on pathogen removal over the years; Table 6 summarizes ranges of pathogen removal in full-scale constructed wetlands. Though marked reductions of pathogens are seen in constructed wetlands, the final concentrations may not comply with discharge limits for receiving bodies of water as wildlife can also contribute pathogens to the wetlands system; additionally, removal rates can vary based upon the influent concentration (Kadlec and Wallace, 2008).

[1] Superficial velocity is the velocity of a fluid in the wetland in the absence of packing.

Table 6: Pathogen removal in constructed wetlands (adapted from Kadlec and Wallace, 2008)[2]

Wetland Type	Microorganism	log_{10} Reduction	
		Minimum	Maximum
Subsurface Flow	*Fecal Coliform*	0.44	4.44
	Total Coliform	0.23	5.87
	E. Coli	1.31	3.14
	Coliphage	0.65	4.46
	MS2	2.65	3.49
Surface Flow	*Fecal Coliform*	(-)2.79	3.16
	Total Coliform	(-)2.18	2.08
	E. Coli	(-)3.26	3.77
	Coliphage	1.29	1.72
	MS2	1.07	2.40

Vymazal, (2005) compared 60 constructed wetlands from the literature. Key conclusions included:

- Removal of Fecal and Total coliforms ranged between 95 and >99%
- Removal of fecal streptococci was between 80 and 90%.
- Hydraulic loading rate, HRT and the presence of vegetation are the primary influences on removal efficiency.

2.3.2 CECs

Several studies to date have examined constructed wetlands ability to remove CECs, with differing results. Removal of hormones (including 17β-estradiol and 17α-ethinyl estradiol) in constructed test cells ranged from 36 to 99.9 percent in two studies (Brooks and others, 2011; Gray and Sedlak, 2005). The same studies also investigated estrone removal in the test cells with mixed results; as there was no significant removal observed in one study (Brooks and others, 2011), while the other showed estrone levels increased, concluding that the increase was likely due to the fact that estrone is a metabolite of 17α-ethinyl estradiol (Gray and Sedlak, 2005).

In 2009, results from a study by Park and others categorized removal of several CECs. The study indicated good removal for atenolol, naproxen and triclosan; and medium to low removal for

[2] Values in table represent the range of reduction values for select pathogens from a number of wetland systems presented in Kadlec and Wallace, 2008. Note that some of the values increased through the wetland and are presented as a negative number.

sulfamethoxazole, dilantine, carbamazepine and diazepam. A similar study on subsurface flow wetlands categorized removal of eleven CECs over a two year period (Matamoros and Bayona, 2006). Efficient removal (>80%) of caffeine, salicylic acid, methyl dihydrojasmonate, and carboxy-ibuprofen was observed in the wetlands; ibuprofen, naproxen, and hydroxyl-ibuprofen were moderately removed (50-80%), while no significant removal of ketoprofen and diclofenac was observed. The study also found that polycyclic musks were removed at 80% in the wetland effluent, whereas concentrations in the gravel bed were high. Thus, the authors concluded that the removal of polycyclic musks is predominately due to sorption onto organic matter.

Brooks and others, (2011), summarized the removal of CECs in constructed wetlands and showed good removal for most compounds (Table 7). The authors noted that removal estimates in full scale studies were based on monitoring influent and effluent concentrations, resulting in a high level of uncertainty due to fluctuations in CEC concentrations entering the wetland. Pilot scale spiking studies have provided more precise data, likely due to increased operational control resulting in minimization of short circuiting as well as consistent influent concentrations. The authors suggested removal of CECs occurs through several mechanisms including adsorption, biotransformation, and photolysis, though there are few studies to date confirming these conclusions.

Table 7: Removal of CECs in Constructed Wetlands (adapted from Brooks and others, 2011 Table 6.1)

Compound	Type	Removal (%)	HRT (d)	Wetland type
Alkylphenols	Ingredient in detergents	75±72	2.5	Full, surface
A+CAPnEC	Ingredient in detergents; surfactant	8±48	2.5	Full, surface
Bromoacetic acid	Ingredient in pharmaceuticals	27	3.5	Full, surface
Caffeine	Stimulant drug	97	-	Pilot, subsurface
Chloroform	Ingredient in pharmaceuticals	80	3.5	Full, surface
Dichloroacetic acid	Lactic acidosis treatment drug	87	3.5	Full, surface
17β-estradiol	Female reproductive hormone	36	3.5	Pilot, surface
Estrone	Female reproductive hormone	ND	6.5	Full, surface
Ethinyl estradiol	Ingredient in oral contraceptives	44	3.5	Pilot, surface

Compound	Type	Removal (%)	HRT (d)	Wetland type
Galaxolide	Fragrance in soaps	52	-	Pilot, subsurface
Gemfibrozil	Treats high cholesterol	58±103	2.5	Full, surface
Ibuprofen	NSAID	47±37	2.5	Full, surface
Ibuprofen	NSAID	87	-	Pilot, subsurface
Naproxen	NSAID	85	-	Pilot, subsurface
Testosterone	Steroid hormone	ND	6.5	Full, surface
Triclosan	Antibacterial	68	4.3	Pilot, surface

More recent studies have focused on investigating the removal mechanisms in constructed wetlands. Key findings from the studies include:

- In a mesocosm study, several constructed wetland configurations were investigated. The authors determined removal of the CECs in the study were likely due to microbiological degradation (Hijosa-Valsero and others, 2010).
- Biotransformation combined with photolysis allowed for >90% attenuation of CECs studied (atenolol, metoprolol, propranol, trimethoprim, sulfamethoxazole, and carbamazepine) in a pilot scale system. Transformation rates were 10 to 100 times faster than previously measured rates in vegetated wetlands (Jasper and others, 2014).

While many studies have examined fate and transport of CECs in constructed wetlands, additional research is needed in order to develop a better understanding of treatment mechanisms, removal effectiveness and other constraints (Park and others, 2009).

3 OTHER BENEFITS OF ENVIRONMENTAL BUFFERS

Historically, environmental buffers have functioned not only as a method to reduce contaminants, but also as a means to add time between when reclaimed water is produced and subsequently introduced into the water supply system. Additionally, environmental buffers can help with development of a positive public perception of potable reuse projects. A decision to use an environmental buffer may also include consideration of other factors such as maintenance of lake or groundwater levels. The following section describes the other benefits of environmental buffers.

3.1 Response retention time of environmental buffers

In addition to providing additional removal of pathogens, nutrients, and CECs, environmental buffers also serve an important role by providing a response/retention time (RRT) in the event of an unexpected process upset or other impact to water quality. When an environmental buffer is included in a potable reuse scheme, if monitored properly it can provide time for utility staff to adjust operations to deal with adverse water quality events should they arise.

The 2014 California Groundwater Replenishment Regulations include provisions for developing an RRT. The RRT protects public health by requiring at least two months of subsurface retention, which serves as a buffer to prevent exposure to a slug of recharge water that potentially could impact a drinking water well The RRT is intended to allow ample time for a utility to respond to a treatment system failure and to secure an interim safe drinking water supply for potentially affected well owners. The focus is on constituents with acute health effects (bacteria, nitrate, nitrite, and perchlorate). The RRT considers time to analyze and receive the results of water quality samples (reclaimed water and groundwater), time for confirmation sampling, time to temporarily suspend the reclaimed water delivery for recharge operations, and the time to establish an interim safe water source for the nearest drinking water well(s) if adversely impacted by the replenishment project.

Currently, there is an ongoing WateReuse Research Foundation study (WRRF 12-06) to develop guidelines for engineered storage for DPR. The results of this study may help better define the need for response/retention time in a DPR system.

3.2 Public perception

The role of environmental buffers in the public acceptance of potable reuse has been the topic of several research studies. Haddad and others, (2009) explored the psychology of water reclamation and reuse; survey findings indicated that the public preferred water that has traveled through an environmental buffer (river or aquifer). Water transported 100 miles in a swift moving river was preferred to water travelling only a 1-mile stretch, while 10 years of aquifer storage was preferred to 1 year. Overall, aquifer storage was the preferred environmental buffer in the study.

In contrast, Macpherson and Snyder, 2013 found that when the public is provided the appropriate technical information, an environmental buffer may not be as important as has been assumed historically. However, public acceptance of a project can vary significantly based on local conditions; the extent to which an environmental buffer is beneficial to achieving public acceptance should be evaluated on a case-by-case basis.

In some cases, maintenance of lake levels can also be an important secondary benefit of using an environmental buffer. The public may be more accepting of a project if they perceive that the project will help maintain higher lake levels than would occur without the project. Maintenance of groundwater levels is likely to be less of a consideration to the public since the impacts are not visible and do not affect recreation. However, in certain cases, this secondary benefit may also be important.

4 RESEARCH NEEDS

Recently, the National Research Council (NRC) stated that the lack of standardized guidelines for design and operation of environmental buffers is the greatest deterrent to their expanded use (NRC, 2012). The NRC went on to say, "Additional research is needed to elucidate key attenuation processes in engineered natural systems and quantify their effects on microbial and chemical constituents of concern so that guidance for design and operation can ultimately be developed. Although each application will still require a thorough site-specific assessment, general design standards and operating procedures as well as appropriate monitoring approaches can foster a wider application of natural systems as part of reuse schemes." In addition, the Texas Water Development Board *Water Reuse Research Agenda* (TWDB, February 2011) identified research related to improving the understanding of environmental buffers as a top priority for Texas.

Further research is needed to gain insight into biotransformation, photolysis, adsorption to particulate matter, effect of hydraulic residence time, and dilution in environmental buffers. A more complete understanding of environmental systems through research is needed to establish a set of design parameters that would allow for more uniformity from system to system. Consistency across environmental buffers would allow a level of assurance that environmental buffers are contributing to the protection of human health in potable reuse projects.

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6 ACRONYMS

ADI	Acceptable Daily Intake
AOP	Advanced Oxidation Processes
CCL3	Contaminant Candidate List 3
CDPH	California Department of Public Health
CECs	Constituents of Emerging Concern
COCs	Contaminants of Concern
CWA	Clean Water Act
DEET	N,N-Diethyl-meta-toluamide
DL	Detection limit
DOC	Dissolved Organic Carbon
DPR	Direct Potable Reuse
DWEL	Drinking Water Equivalent Level
EDCs	Endocrine Disrupting Compounds
EPA	U.S. Environmental Protection Agency
GAC	Granular Activated Carbon
GC	Gas Chromatography
HAA-5	Haloacetic acids
L	Liter
LC-MS	Liquid Chromatography with Mass Spectrometric detection
LOAEL	Lowest Observed Adverse Effect Level
MCL	Maximum Contaminant Level
MDL	Minimum Detection Level
MEC	Measured environmental concentration
mg/L	milligrams per liter
mL	milliliter
MRL	Method Reporting Limits
MTBE	Methyl-t-betylether
MTT	Monitoring Trigger Threshold
N	Nitrogen
NDMA	N-Nitrosodimethylamine
NF	Nanofiltration
ng/L	nanograms per liter

NOAEL	No Observed Adverse Effect Level
NOM	Natural Organic Matter
NRC	National Research Council
NSAID	Non-steroidal anti-inflammatory drug
PAC	Powder Activated Carbon
pCi/L	picoCuries per Liter
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonate
PNEC	Predicted No Effect Concentration
PPCPs	Pharmaceuticals and Personal Care Products
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RO	Reverse Osmosis
SDWA	Safe Drinking Water Act
SPE	Solid-Phase Extraction
SPME	Solid-Phase Microextraction
SWQMS	Surface Water Quality Monitoring System
SWRCB	State Water Resources Control Board
TCDPP	Tris (1,3-dichloro-2-propyl) phosphate
TCEP	Tris (2-chloroethyl) phosphate
TCEQ	Texas Commission on Environmental Quality
TCPP	Tris (1-chloro-2-propyl) phosphate
TDI	Tolerable Daily Intake
TDS	Total Dissolved Solids
THMs	Trihalomethanes
TOC	Total Organic Carbon
TSS	Total Suspended Solids
TX	Texas
TSWQS	Texas Surface Water Quality Standards
TWDB	Texas Water Development Board
µg/L	Microgram per liter
WHO	World Health Organization
WWTP	Wastewater Treatment Plant

B Appendix:
Relevance of Chemical Contaminants of Concern in Texas

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B1 Appendix:

Technical Memorandum

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TECHNICAL MEMORANDUM

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Date: 2015.04.27 12:10:33 -05'00'

Texas Water Development Board
Evaluating the Potential for Direct Potable Reuse in Texas
Task 2 Relevance of Contaminants of Concern

Project No.: 0866-005-01

Date: April 14, 2015

Prepared For: Project Team and Sponsors

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1 INTRODUCTION

When considering direct potable reuse (DPR) projects, contaminants of concern (COCs) and constituents of emerging concern (CECs) present in the originating wastewater (e.g., source water) and treated reclaimed water should be evaluated and examined to determine if and what additional treatment or management strategies may be required to reduce the concentration of these constituents to levels that are considered to be appropriate for DPR. COCs are defined as (1) contaminants of human health relevance for drinking water that are regulated or under consideration for regulation in Texas or at the national level; and (2) contaminants that may not pose a health risk, but that can impact treatment process effectiveness and maintenance. The U.S. Environmental Protection Agency (EPA) defines CECs as “pollutants not currently included in routine monitoring programs” that “may be candidates for future regulation depending on their (eco)toxicity, potential health effects, public perception, and frequency of occurrence in environmental media” (Lazorchak and others, 2008). CECs also include constituents that have been present in the environment for a long time, but for which analytical or health data have only recently become available (NRC, 2012). With current and future analytical methods, any chemical will be able to be detected in drinking water, reclaimed water, and/or wastewater. Detection of a CEC is not the issue, but rather its health and environmental relevance.

Some examples of CECs include pharmaceuticals and personal care products (PPCPs), endocrine disrupting compounds (EDCs), pesticides, and components of household products.

The primary goals of this technical memorandum are to:

- provide a review and summary of data that are currently available related to COCs and CECs in Texas;
- identify data gaps and provide recommendations for parameters that utilities should consider monitoring if they are interested in pursuing DPR;
- summarize regulatory standards and other available advisory benchmarks and compare to available data; and
- provide a review of analytical technology and quality assurance/quality control as it relates to monitoring and analysis of CECs and those COCs that may require more sensitive analytical methods to provide meaningful results.

2 SUMMARY OF CHEMICAL COCS AND CECS IN TEXAS

This section provides a summary of the available chemical COC and CEC data in Texas. Water quality information summarized in this section includes information from Texas Water Development Board (TWDB) reports, data provided by participating project utility sponsors and data from a literature review of published studies conducted for Texas waters.

2.1 Statewide Raw Water Quality Trends

The state of Texas spans a territory of 268,820 square miles. Geological conditions and land use across the State vary widely, affecting groundwater and surface water qualities. These water types represent the raw water quality of drinking water supplies and comprise the backbone of wastewater quality. Thus, they can also affect the chemical and aesthetic quality of reclaimed water. This section describes general trends in groundwater and surface water quality throughout the State.

2.1.1 Groundwater

Maps previously developed by the TWDB illustrating concentrations present in groundwater are a useful resource for depicting raw water quality trends (Reedy and others, 2011). Maps are available for the following parameters:

Antimony	mercury	aluminum
Arsenic	nitrate-N	chloride
Barium	nitrite-N	iron
Beryllium	selenium	manganese
Cadmium	thallium	silver
Chromium	gross alpha-radiation activity	sulfate
Copper	gross beta-radiation activity	pH
Fluoride	combined radium radiation	silica
Lead	uranium	sulfate
		total dissolved solids (TDS)

As an example, a map for TDS is shown in Figure 1[1]. Similar maps for the other parameters listed above are included in Exhibit A. Across the State, a number of contaminants with primary drinking water standards (arsenic, gross alpha-radiation, combined radium, and nitrate-as nitrogen (N)) were detected in groundwater at concentrations greater than their maximum contaminant levels (MCLs) in more than 5% of all groundwater samples analyzed. When examining constituents with secondary drinking water standards, concentrations of TDS, sulfate, manganese, iron, fluoride, and chloride were greater than the federal MCL in more than 10% of all groundwater samples analyzed.

[1] Maps were developed based on groundwater analysis from the TWDB water quality database from 1988-2010.

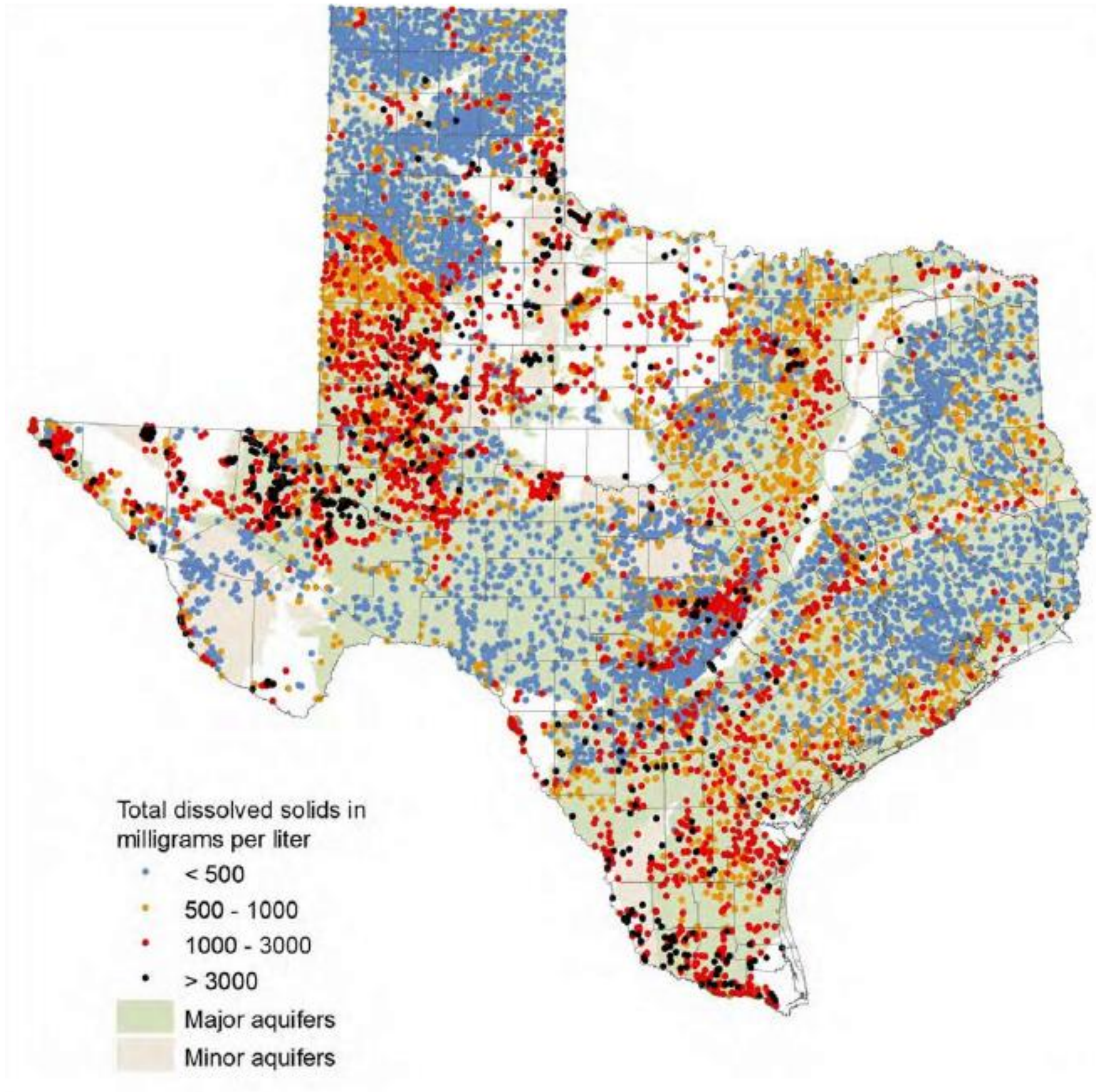

Figure 1: Treatment-limiting concentrations of TDS in Texas groundwater. Prepared by Bureau of Economic Geology (BEG for TWDB Contract #1004831125, with data from TWDB (Reedy and others, 2011). Maps for additional constituents, as well as maps of the major and minor aquifers of Texas, are shown in Exhibit A.

2.1.2 Surface Water

Similar maps were developed for surface water based upon the Texas Surface Water Quality Standards (TSWQS) and data obtained from the Texas Surface Water Quality Monitoring System database (SWQMS)[2]. The Texas Commission on Environmental Quality (TCEQ) establishes designated uses for surface waters and water quality criteria to protect those uses as part of the TSWQS. For protection of human health for drinking water uses, the criteria do not consider cost or feasibility per the Clean Water Act (CWA) in comparison to how drinking water standards are established under the Safe Drinking Water Act (SDWA). In addition, not all surface waters are designated as sources of drinking water in Texas. For TDS, chlorides and sulfates, the TSWQS criteria are typically based on historical concentrations in each stream segment; therefore, the criteria for these constituents provide a general indication of expected concentration levels. As an example, Figure 2 shows the range of TDS in surface water statewide based on the TSWQS. Maps for other constituents (alkalinity, total suspended solids (TSS), total organic carbon (TOC), hardness, and turbidity) were developed using average values of the last 10 years of historical data obtained from the SWQMS database (see Exhibit B).

[2] The Texas Surface Water Quality Monitoring System is maintained by the Texas Commission on Environmental Quality.

Secondary Drinking Water Standards		
Constituent	SMCL	SCL
TDS (mg/L)	500	1000

SMCL = secondary maximum contaminant level (EPA)
SCL = secondary contaminant level (Texas)

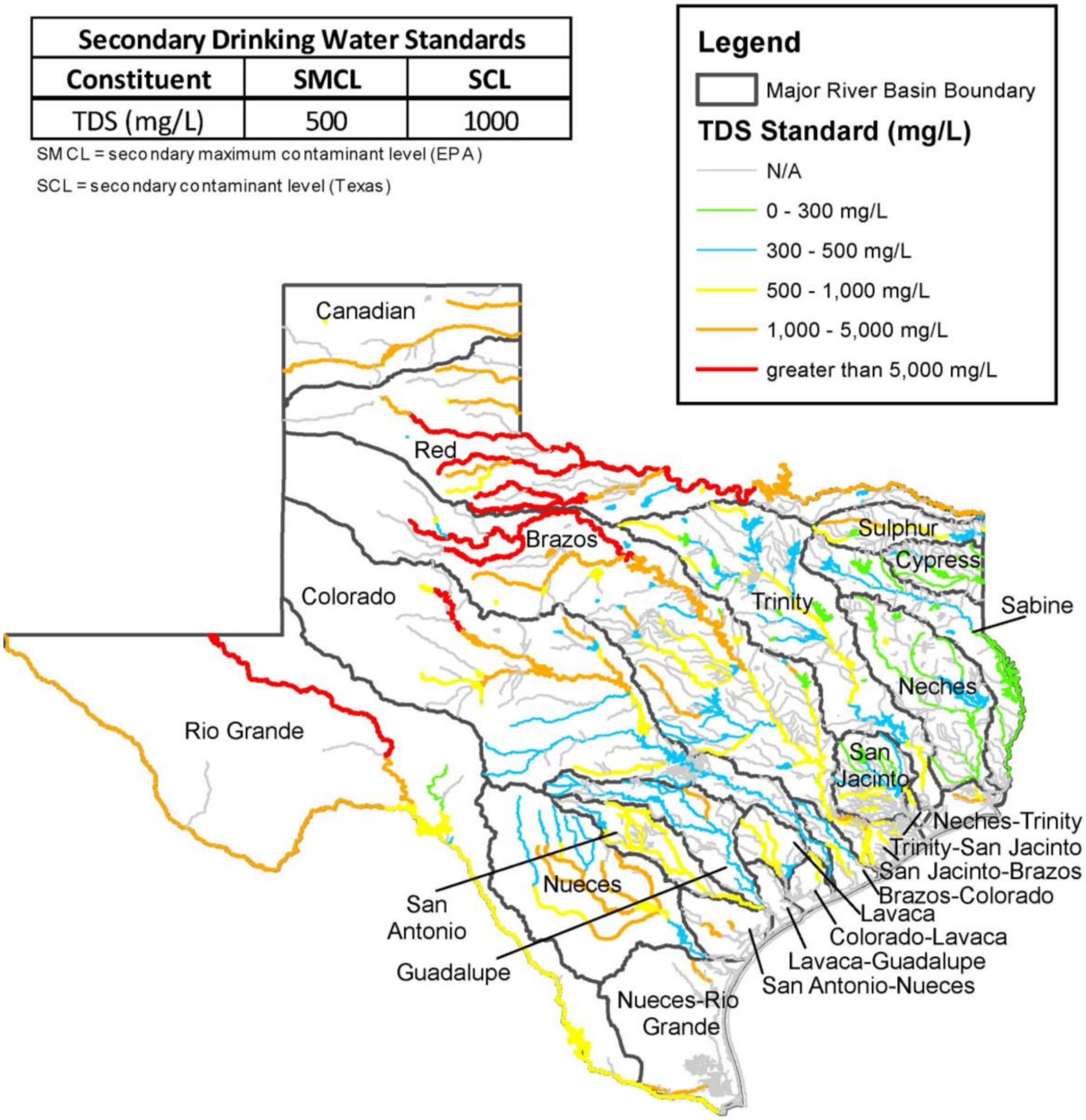

Figure 2: Texas TDS Surface Water Quality Standards and Secondary Drinking Water Standards. Maps for additional constituents are shown in Exhibit B.

Information was also obtained from the 2006 State regional water plans[3] and used to summarize water quality "concerns" identified by each of the regional water planning groups and is presented in Figure 3. Water quality concerns were not strictly defined in the regional plans, and concerns may have been interpreted differently between each of the regions. However, the constituents shown in Figure 3 do give some indication of parameters that may be of interest in planning for future water supplies in the given region.

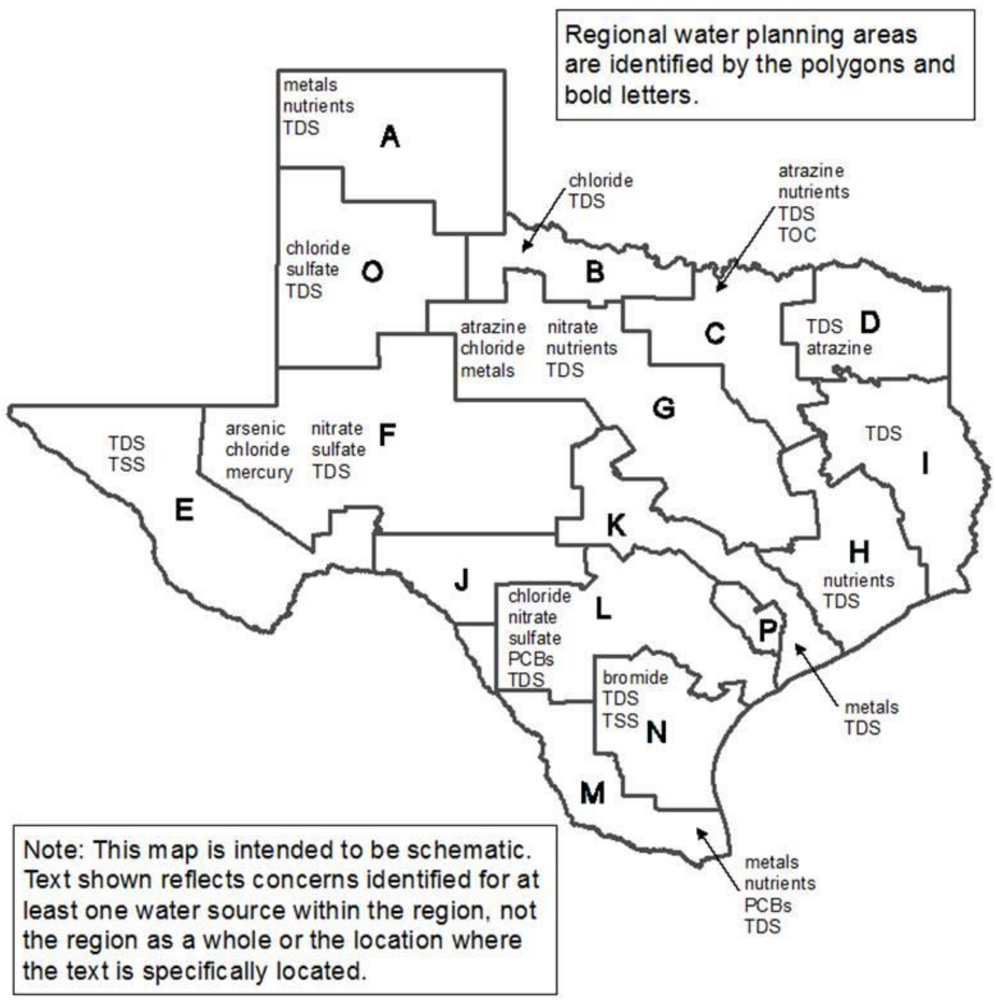

Figure 3: Summary of water quality concerns identified in the 2006 Regional Water Plans.

[3] The TWDB has implemented a regional water planning process that is updated every 5 years. Regional water planning groups in each of the 16 regions shown in Figure 3 are responsible for compiling relevant data and presenting a water supply plan. In the 2006 plans, the regional water planning groups were tasked with identifying potential water quality concerns in their regions. This information was summarized in each of the regional plans. This information was not provided in the 2011 regional plans.

2.2 Stakeholder Data

A total of 12 municipal utility stakeholders are participating in the TWDB DPR project. At the request of the technical team, each stakeholder provided three years of water quality data for both raw drinking water (ground water or surface water, depending on the utility) and treated wastewater. The data were comprised of both regulated and unregulated contaminants (if available). In general, data for the raw drinking water sources indicated that the regulated constituents (where data were provided) were at levels below the MCLs and often below detection limits. For treated wastewater, very little data were available for MCL parameters since sampling at these facilities has primarily focused on priority pollutants and other Clean Water Act requirements.

It was also of interest to evaluate the extent to which contaminants currently on the EPA's Contaminant Candidate List 3 (CCL3) are being monitored and measured[4]. This section summarizes the results of the evaluation of CCL parameters. It appeared that the data provided by the 12 stakeholders were sometimes collected using different analytical methods and detection limits. The methods and detection limits also varied by type of water sampled (e.g., raw source water versus wastewater, and in some cases by wastewater treatment plant; see Exhibit C). When contaminants were not detected at the reporting limit (RL) or the method detection limit (MDL) (information provided by the stakeholders did not always distinguish between the RL or MDL), only the values above the limit were reported as the measured value.

2.2.1 Raw Source Water

Table 1 presents data provided by stakeholders for contaminants from the CCL3 list that were sampled from raw source water supplies.[5] All contaminants listed were reported by stakeholders as not detected at the RL or the MDL, with the exception of strontium and vanadium, which were measured above the detection limit (DL)[6] by only one stakeholder for one raw water source. A complete summary of raw water data provided by stakeholders is included in Exhibit D.

[4] Under the SDWA, EPA is obligated to periodically publish lists of contaminants that are under consideration for development of MCLs. In September 2009, the EPA published the final version of the CCL3. The list contains 104 chemicals or chemical groups, including pesticides, disinfection byproducts, chemicals used in commerce, waterborne pathogens, pharmaceuticals, steroid hormones, and biological toxins.

[5] Note: For the 2009 data collection, the stakeholders did not evaluate all of the CCL3 constituents. Official sampling for the third Unregulated Contaminant Monitoring Regulation for CCL3 constituents will occur from 2013-2015.

[6] Detection limit (DL) refers to either the RL or MDL. (Information provided by the stakeholders did not always distinguish between the RL or MDL.)

Table 1: CCL3 contaminants sampled by project stakeholders in raw water.

Contaminant	Units	Min DL	Max DL	Min	Max
1,1,1,2-Tetrachloroethane	µg/L	<.5	<3	-	-
1,1-Dichloroethane	µg/L	<1	<3	-	-
1,2,3-Trichloropropane	µg/L	<1	<1	-	-
Acrolein	µg/L	<10	<20	-	-
Bromochloromethane	µg/L	<1	<1	-	-
Bromomethane	µg/L	<1	<3	-	-
Chloromethane	µg/L	<1	<3	-	-
Methyl-t-butylether (MTBE)	µg/L	<1	<2	-	-
Metolachlor	µg/L	<0.2	<1	-	-
n-Propylbenzene	µg/L	<1	<1	-	-
sec-Butylbenzene	µg/L	<1	<1	-	-
Total Molybdenum	mg/L	<0.01	<0.01	-	-
Total Strontium	mg/L	*	*	0.741	1.12
Total Vanadium	mg/L	*	*	0.022	0.051

µg/L = microgram per liter

Min DL[6]= Minimum Detection Limit and is the lowest detection limit indicated by any of the stakeholders

Max DL = Maximum Detection Limit and is the highest detection limit indicated by any of the stakeholders

*Detection limit (DL) not provided

2.2.2 Treated Wastewater

Table 2 lists contaminants from the CCL3 list that were sampled from treated effluent of project stakeholders; CCL3 data collection is not a requirement for wastewater although there is some duplication of CCL3 constituents and those on the CWA Priority Pollutant list. All contaminants listed were reported by stakeholders as not detected at the RL or the MDL, with the exception of molybdenum. Molybdenum was reported above the RL or the MDL at 2 wastewater plants (by two stakeholders). A complete summary of treated wastewater data provided by stakeholders is included in Exhibit E.

Table 2: CCL3 contaminants sampled by project stakeholders in treated wastewater.

Contaminant	Units	Min DL	Max DL	Min	Max
1,1-Dichloroethane	µg/L	<1	<14.4	-	-
Acrolein	µg/L	<5	<50	-	-
Disulfoton	µg/L	<0.5	<0.5	-	-
Diuron	µg/L	<0.05	<2	-	-
Hexachlorobenzene	µg/L	<5	<10	-	-
MethylBromide	µg/L	<5	<50	-	-

Contaminant	Units	Min DL	Max DL	Min	Max
Molybdenum	µg/L	*	<30	3.4	8.9
n-Nitrosodiethylamine	µg/L	<10	<20	-	-
n-Nitrosodimethylamine	µg/L	<10	<50	-	-
N-Nitroso-di-n-Butylamine	µg/L	<10	<20	-	-
n-Nitrosodiphenylamine	µg/L	<5	<20	-	-

Min DL= Minimum Detection Limit and is the lowest detection limit indicated by any of the stakeholders

Max DL = Maximum Detection Limit and is the highest detection limit indicated by any of the stakeholders

*Detection limit (DL) not provided

2.3 Data from Other Studies

A literature review of published studies in the state of Texas involving CECs was performed. The studies focused on different areas of the State and different CECs. A summary of the studies is provided in Table 3. A summary of contaminants sampled, together with measured concentrations (where available) is provided in Exhibit F.

Table 3: Summary of published studies investigating CECs in Texas

Reference	Contaminants	Notes
Barnes and others, 1999	21 antibiotic compounds, 40 organic wastewater compounds, 14 steroid and hormone compounds.	Study sampled the Trinity River below Dallas, TX as part of nationwide study of U.S. streams.
Fono and others, 2006	Wastewater derived compounds, pharmaceuticals.	Examined attenuation in effluent-dominated rivers. Study sampled 5 locations along the Trinity River beginning south of the Dallas/ Fort Worth Metroplex and ending near Houston, northwest of Lake Livingston.
Ging and others, 2009	277 organic compounds tested, 103 detected, including pesticides, solvents, gasoline hydrocarbons, and personal care products.	Study examined the Elm Fork of the Trinity River (near Carrollton, Texas) from 2002 to 2005.
Foster, 2007	23 known or suspected EDCs.	Investigated removal efficiency throughout the San Marcos WWTP.
Karnjanapiboonwong and Anderson, 2010	6 PPCPs.	Examined occurrence at the Lubbock Water Reclamation Plant and land application site (including soil and groundwater receiving the treated wastewater)

Reference	Contaminants	Notes
Battaglin and others, 2008	Pesticides.	Streams near the towns of Electra, DeLeon, and Tilden were examined for runoff from peanut fields.

2.3.1 Relevant Data from Outside Texas Related to DPR

The National Research Council (NRC, 2012) noted that low concentrations of a variety of organic chemicals can be present in wastewater as shown in Table 4.

Table 4: Categories of trace organic contaminants (natural and synthetic) detectable in reclaimed waters

Category	Examples
Disinfection byproducts	Bromoform, Chloroform, N-Nitrosodimethylamine (NDMA), Trihalomethanes
Household products and food additives	Alkylphenol polyethoxylates, Bisphenol A, Dibutyl phthalate, Flame retardants, Perfluorooctanoic acid, Perfluorooctane sulfonate, Sucralose
Industrial	1,4-Dioxane, Methyl tert-butyl ether, Perflurooctanoic acid, Tetrachloroethane
Naturally occurring	2-Methylisoborneol, Geosmin, Hormones (17β -estradiol), Phytoestrogens,
Personal care product ingredients	Fragrances, Pigments, Triclosan, Sunscreen ingredients
Pesticides	Atrazine, Diuron, Fipronil, Lindane,
Pharmaceuticals and metabolites	Analgesics (Acetominophen, Ibuprofen), Antibacterials (Sulfamethoxazole), Antibiotics (Azithromycin), Antiepileptics (Phenytoin, Carbamazepine), Beta-blockers (Atenolol), Oral contraceptives (Ethinyl estradiol)

Source: Table 3-3 (NRC, 2012)

A comprehensive evaluation of COC and CEC data outside of Texas is beyond the scope of this project. However, one relevant example is the data assembled to identify a list of CECs for monitoring reclaimed water for indirect potable reuse (specifically groundwater recharge) as part work conducted by an Expert Panel for the California State Water Resources Control Board (SWRCB) pursuant to its Recycled Water Policy (Anderson et al., 2010). The Panel developed a survey that considered sampling locations, analytical methods used for quantification, frequencies, and treatment processes for the water reuse practices of interest to the State Board. The survey was provided to stakeholders in California and CEC monitoring data were requested for the time period 2007 and 2009. The Panel received survey responses from water and wastewater utilities in California, the WateReuse Association of California, commercial laboratories, and research laboratories that were engaged in monitoring efforts for CECs in recycled water projects in California. The Panel screened these databases and summarized the occurrence of

CECs in these reuse applications. As a conservative approach, only the measured environmental concentrations (MECs) for CCL3 and non-CCL3 CECs representing secondary or tertiary effluent qualities were compiled to represent the final MEC for the purposes of selecting CECs for monitoring. The combined effluent qualities represent a conservative estimate of MECs for groundwater recharge projects since treatment credit was not included for additional advanced water treatment processes, dilution in groundwater, and/or incidental treatment in the soil-aquifer system after surface application.

Table 5 presents the 90th percentile MECs of CCL3 CECs (only eight were identified); Table 6 presents the 90th percentile non-CCL3 CECs (43 were identified). The next update of CEC monitoring by a SWRCB expert panel will occur in 2015.

Table 5: 90th percentile MECs of CCL3 CECs in California secondary and tertiary effluent

CCL3 CECs	Category	Occurrence in Recycled Water Secondary/Tertiary Treated (ng/L)
17**α**-estradiol	Hormone	1
17**β**-estradiol	Hormone	8.4
Erythromycin	Antibiotic	113
Estrone	Hormone	73
Ethinyl estradiol	Hormone	1
PFOA	Manufacture of Non-stick polymer	28
PFOS	Manufacture of Non-stick polymer	90
NDMA	Disinfection byproduct	68

Source: Table 5.1 (Anderson et al., 2010)
ng/L = nanogram per liter
PFOA = Perfluorooctanoic acid
PFOS = Perfluorooctane sulfonate

Table 6: 90th percentile MECs of non-CCL3 CECs in California secondary and tertiary effluent

CCL3 CECs	Category	Occurrence in Recycled Water Secondary/Tertiary Treated (ng/L)
4-Nonylphenol	Surfactant degradant	161
Atorvastatin (Lipitor)	Cholesterol medication	79
Diclofenac	NSAID	230
Epitestosterone (cis-Testosterone)	Hormone	10
Ketoprofen	NSAID	43
Metoprolol	Beta blocker medication	246
o-hydroxy atorvastatin	Cholesterol medication degradant	10
Propanolol	Beta blocker medication	25
Simvastatin hydroxyacid (Zocor)	Cholesterol medication	25
Sucralose	Artificial sweetener	26,390
Acetaminophen	Analgesic	550
Bisphenol A	Chemical used in polycarbonate plastics	286

CCL3 CECs	Category	Occurrence in Recycled Water Secondary/Tertiary Treated (ng/L)
Dilantin	Anticonvulsant	217
Tris (2-chloroethyl) phosphate (TCEP)	Flame retardant	688
4-octylphenol	Surfactant degradant	207
Atenolol	Beta blocker	1,780
Azithromycin	Antibiotic	1,200
Caffeine	Stimulant	900
Carbamazepine	Anti-epileptic	400
Ciprofloxacin	Antibiotic	100
Clofibric acid	Metabolite of various lipid regulators	820
DEET	Insecticide	1,520
Diethylstilbestrol	Hormone	10
Fluoxetine (Prozac)	Antidepressant	31
Furosemide	Diuretic	38
Gemfibrozil	Cholesterol medication	3,550
Ibuprofen	NSAID	500
Iopromide	Radiographic contrast agent	2,174
Meprobamate	Tranquilizer	430
Methylisothio-cyanate	Pesticide	114
Musk ketone	Synthetic fragrance	25
Naproxen	NSAID	851
Primidone	Anti-epileptic	264
Progesterone	Hormone	18
Salicylic acid	NSAID; used in personal care products	110
Sulfamethoxazole	Antibiotic	1,400
TCDPP	Flame retardant	296
TCPP	Flame retardant	5,920
Testosterone (trans-Testosterone)	Hormone	37
Triclocarban	Anti-bacterial	223
Triclosan	Anti-bacterial	485
Trimethoprim	Anti-bacterial	112
Warfarin	Anticoagulant	16

Source: Table 5.2 (Anderson et al., 2010)
DEET = N,N- diethyl-meta-toluamide
NSAID = Non-steroidal anti-inflammatory drug
TCDPP = Tris (1,3-dichloro-2-propyl) phosphate
TCPP = Tris (1-chloro-2-propyl) phosphate

2.4 Comparison of Contaminants of Concern in Available Data to Regulatory Standards and Guidance/Advisory Levels

The following sections discuss water quality issues unique to Texas for groundwater and surface water based upon the maps and data presented in the previous section. In locations where naturally occurring constituents are approaching concentrations close to their specific MCLs, attention should be paid to monitor these parameters more frequently.

2.4.1 Groundwater Quality Comparison

Based on state-wide occurrence data, Table 7 summarizes constituents present in groundwater supplies across the state of Texas that occasionally exceed current MCLs. This analysis suggests that major aquifers in Terry County exhibit co-occurrence of elevated concentrations of arsenic, selenium, and fluoride. Major aquifers in western central and south Texas exhibit elevated TDS concentrations (including chloride and sulfate).

While not regulated, silica occurrence in major aquifers in northwest and southeast Texas can exceed 30 mg/L, which is potentially problematic where high-pressure membranes (i.e., nanofiltration, reverse osmosis) are used for treatment, since silica can result in scale formation.

Table 7: Regulated constituents occurring in Texas groundwater supplies using major aquifers in excess of current MCLs

Constituent	SMCL & SCL [SCL only]	Region	Occurrence Level
Antimony	6 µg/L	One hot spot, western TX, Reeves County	6-12 µg/L
Arsenic	10 µg/L	Large occurrence in Western TX, Terry County; southern Texas along the Gulf coast; El Paso County	>20 µg/L
Bromide[7]	N/A	Groundwater supplies, unspecified	180 mg/L
Chloride	250 mg/L* [300 mg/L*]	Western central and southern TX	>600 mg/L
Fluoride	4 mg/L	Large occurrence in Western TX, Terry County; some excursions in San Antonio-Austin-Waco corridor	4 -8 mg/L
Nitrate	10. mg/L	Hot spots in northwest TX, in particular in Lubbock County	>20 mg/L
Selenium	50 µg/L	Large occurrence in Western TX, centered in Terry County	50-100 µg/L
Sulfate	250 mg/L * [300 mg/L *]	Western central and southern TX	>600 mg/L
TDS	500 mg/L * [1,000 mg/L *]	Western central and southern TX	>1,000 mg/L
Gross Alpha radiation	15 pCi/L	Western central part of the state; southern TX, south of San Antonio	15-30 pCi/L >30 pCi/L
Combined radium radiation	5 pCi/L	Widespread in western central TX and southeast TX	>10 pCi/L
Uranium	30 µg/L	Central Texas, Tom Green County	30-60 µg/L

* SMCL and [SCL]: SMCL= secondary maximum contaminant level (EPA standard) and SCL= secondary constituent level (TCEQ standard)

[7] Bromide is not an MCL chemical, but is important because of its impact on formation of disinfection byproducts.

2.4.2 Surface Water Quality Comparison

Table 8 summarizes constituents present in surface water that are exceeding various levels of interest.

Table 8: Constituents of interest occurring in major Texas rivers

Constituent	**SMCL & SCL [SCL only]**	**Region**	**Occurrence level**
Bromide**	none	Surface water, Coastal Bend Region	100-900 mg/L
Chloride	250 mg/L* [300 mg/L *]	Elevated levels in upper parts of Red River, Brazos River and Pecos River	>5,000 mg/L
Sulfate	250 mg/L * [300 mg/L *]	Elevated levels in upper parts of Red River, Brazos River and Pecos River	1,000-5,000 mg/L
Total dissolved solids	500 mg/L * [1,000 mg/L *]	Elevated levels in upper parts of Red River, Brazos River and Pecos River	>5,000 mg/L

*SMCL and [SCL]: SMCL= secondary maximum contaminant level (EPA standard) and SCL= secondary constituent level (TCEQ standard); **can form bromate during disinfection and ozonation

In addition to the parameters listed, hardness is elevated in many rivers in Texas with occurrence levels greater than 180 mg/L, representing very hard water.

2.4.3 Treated Wastewater Quality

Several stakeholders shared effluent water quality data from their wastewater treatment plants (WWTP) with the project team. Treated wastewater quality in Texas is well characterized regarding the 126 Priority Pollutants, which are primarily of industrial origin.[8] As expected, for those Priority Pollutants that also have MCLs, the concentrations in treated wastewater are usually below MCLs and in many cases below reporting limits and/or method detection limits. Most of the remaining Priority Pollutants are below detection limits. No data were available for other COCs or CECs.

Of the constituents that have occasionally been observed at levels above primary MCLs in drinking water supplies and based on the limited number of samples available for treated wastewater, concentrations in wastewater for antimony, arsenic and selenium remained consistently below the MCLs of 6, 10 and 50 µg/L, respectively. For stakeholders that use groundwater and surface water with elevated TDS concentrations, the treated wastewater frequently exhibited effluent concentrations for chloride and TDS in excess of the Texas SCLs.

[8] See 40 Code of Federal Regulations at 401.15.

2.5 Review of the State of Analytical Technology

Chemical monitoring in potable reuse systems can be challenging and requires additional precautions as compared to typical drinking water monitoring with regard to the water matrix, reliability of analytical methods, quality assurance plans and reporting levels. There is also interest in moving away from chemical by chemical approaches to the use of bioanalytical methods.

2.5.1 Water Matrix

In potable water reuse, the starting matrix is generally secondary or tertiary treated municipal wastewater. Thus, analytical methods that are to be applied for performance monitoring before and after a given process or series of processes must be capable of being applied to this more challenging matrix as well as a cleaner matrix after advanced treatment. In addition, the monitoring of organic constituents is often conducted at trace levels (i.e., ng/L), which is uniquely challenging within a wastewater matrix (that are addressed through isotope dilution methods) and contamination issues (that are addressed through laboratory and field blanks).

2.5.2 Reliability of Analytical Methods

CECs represent analytical challenges based on the lack of standardized method, their varying physico-chemical properties, the possibility for sample contamination, and their low concentrations in the environment. As a result, there is uncertainty in whether results generated by a given method accurately depict the true concentration of each CEC in a sample. Vanderford and others (2012) evaluated existing CEC methods at low ng/L detection levels in water and provided analytical guidelines for future work. This study (1) assessed preservation strategies and residual oxidant quenching agents, sample storage times, and bottle types; (2) conducted a series of single-blind inter-laboratory comparisons using unspiked and spiked whole volume aqueous samples prepared by a third party; and (3) selected and validated the most promising sampling parameters and analytical methodologies from the sample collection/preservation studies and the inter-laboratory comparisons (Vanderford, Drewes and others, 2012). The key recommendations were tied to quality assurance/quality control (QA/QC) for the following:

- Accuracy. Perform frequent laboratory fortified sample matrices to determine the analytical accuracy in each matrix. Determine control limits for each individual CEC based on the compound dependent variations seen in the inter-laboratory comparisons. Laboratory fortified sample matrices[9] (LFSMs) should be performed at both low and high levels relative to the reporting levels (RLs) of the method and the expected concentrations in the samples. Standards for the CECs being evaluated should be frequently checked for accuracy and freshly prepared on a regular basis.

[9] LFSM refers to an aliquot of an environmental sample to which a known quantity of the method analyte is added.

- Precision. Perform frequent replicates to determine the analytical precision in each matrix. Methods should be thoroughly assessed in terms of precision to ensure that reproducible results can be obtained.
- Blanks. Incorporate frequent laboratory, travel, and field blanks into sampling programs to address false positive results (e.g., detection of a compound when it is actually absent).
- RLs. Conduct formal RL determinations to ensure the reliability of each RL and thereby reduce the possibility of false negative results (e.g., an error that results in non-detect when the compounds actually is present).

2.5.2.1 Overview of Analytical Methods for CECs

Liquid chromatography with mass spectrometric detection (LC-MS) has rapidly become the dominant analytical technology for many CECs. A major difficulty with LC-MS technology is the inherent signal suppression that occurs due to matrix interferences. Since the ionization in LC-MS relies primarily upon charge transfer, co-eluting substances are able to compete for the charge and thus an apparent signal suppression can occur. In wastewater matrices, it is not unusual to observe matrix signal suppression of 80% or higher. For this reason, isotopically-labeled surrogates are often added to the water sample or sample extract, and used to correct for signal suppression since the amount added should be equivalent to the amount recovered. This allows the analyst to correct the abundance of the native signal based on the recovery of the surrogate. While this technique generally works well when exact isotopically-labeled versions of each target compound are added and are available to use (isotope dilution), the method still can suffer by raising the true detection limit by the degree of suppression. In other words, a method detection limit (MDL) developed in ultrapure water is not likely appropriate for a secondary wastewater effluent since the signal will be suppressed by the co-concentrated matrix. Thus, in order to verify method reliability in more complex matrices, it is critical to conduct spiking experiments with every batch of samples where target analytes are added to the sample, ideally during collection, at very near the method reporting level (MRL). In this way, a better understanding of true recovery can be gained.

Tandem mass spectrometry greatly reduces the chances of a false positive due to a chemical interference. With either LC-MS/MS or gas chromatography (GC) with GC-MS/MS, a peak should not be assigned as the targeted compound (analyte) unless the retention time and mass transitions are within a previously defined region. Generally, two mass transitions will be monitored for each analyte and the abundance ratio between the monitored transitions should remain relatively constant. However, despite these safeguards, it is still possible for an organic substance to yield a false positive as a chemical mimic. Recently, chemical mimics for DEET, NDMA, and perchlorate have been discovered. Thus, great care must be taken to ensure that within an extremely complex mixture, such as wastewater effluent, that numerous quality assurance/quality control checks be rigorously followed in order to ensure accuracy and precision in trace organic compound measurement.

2.5.3 Quality Control and Assurance

Quality control is the ability to determine and minimize systematic and random errors (false positives and false negatives). A systematic error (or "bias") is one in which reported values are consistently different from the true value. The ability to reproducibly determine the same value from a given sample is called the precision of the measurement, while the ability to determine the true value in an environmental sample is known as accuracy. Random errors are more difficult to track and can affect both the accuracy and precision of an analytical method. Quality assurance is the step mandated in a particular protocol and/or laboratory to produce accurate and precise analytical data, thus minimizing errors. Generally, a quality assurance project plan (QAPP) is established before actual environmental testing begins. The QAPP will specify QA/QC procedures that are to be followed and documented at each step of the particular protocol. In environmental monitoring, QAPPs address seven key considerations: problem definition, sample program design, field sampling, sample preparation, chemical analysis, data analysis, and reporting (Batley 1999).

Most aspects of QA/QC for environmental monitoring are well understood and readily attainable by well-regarded scientific research and commercial laboratories. In fact, the EPA generally provides specific protocols that should be applied to a given method. However, it is critical to determine if specific methods (i.e., EPA Methods) are designed, approved, and/or sensitive enough for the water matrix to be tested. For instance, some EPA methods are specifically designed for drinking water whereas others have been developed for wastewater. Perhaps most importantly, some methods were designed with a specific detection limit in mind that may or may not be applicable for a desired monitoring goal. Ultra-trace analysis (sub-ng/L) is inherently more difficult in terms of potential for errors.

Anderson and others (2010) provided recommended QA/QC guidelines for commercially available analytical methods (Anderson, Denslow and others, 2010):

- Detailed written protocols in place for positive and negative controls to monitor tests such as blanks, spikes, and reference materials.
- Tests to define the variability and/or repeatability of the laboratory results such as replicates.
- Measures to assess the accuracy of the test method including calibration and/or continuing calibrations, use of certified reference materials, and proficiency test samples.
- Measures to evaluate test method capability, such as limit of detection and limit of quantification or range of applicability such as linearity.
- Selection of appropriate formulae to reduce raw data to final results such as regression analysis, comparison to internal/external standard calculations, and statistical analyses.
- Selection and use of reagents and standards of appropriate quality.
- Measures to ensure the selectivity of the test for its intended purpose.

- Measures to ensure constant and consistent test conditions.

On-going quality control may involve the use of the following controls:

- Laboratory performance controls.
- Method blank or laboratory reagent blank – this negative control is used to assess the sample batch for possible contamination during the preparation and processing steps.
- Laboratory control standard or laboratory fortified blank – the laboratory control standard is used to evaluate the performance of the total analytical system, including all preparation and analysis steps. Results of the laboratory control standard are compared to established criteria. Failure to meet these criteria indicates that the analytical system is not performing correctly and may not be producing acceptable results. Control standards are typically prepared using a standard that differs from the one used to prepare the instrument calibration curve.
- Continuing calibration check – this standard is used to evaluate the reliability of the calibration curve.
- Sample-specific controls.
- Matrix spikes or laboratory fortified sample matrix – matrix-specific quality control samples indicate the effect of the sample matrix on the precision and accuracy of the results generated using the selected methods.
- Matrix duplicates – matrix duplicates are replicate aliquots of the same sample taken through the entire analytical procedure. The results from this analysis indicate the precision of the results for the specific sample using the selected method. The matrix duplicate provides a usable measure of precision only when target analytes are found in the sample chosen for duplication.
- Surrogate spikes – surrogates are chosen to reflect the chemistries of the targeted components of the method. Added prior to sample preparation/extraction, they provide a measure of recovery for every sample matrix. These are typically used in lieu of techniques like isotope dilution and when matrix characterization is not practical because the method is being used for large numbers of highly variable sample matrices.
- Limit of detection and limit of quantification – limits of detection and quantification define the lowest levels at which the instrument can differentiate between a signal and noise and the lowest level at which a value may be reported, respectively. After the initial demonstration of capability, these limits are monitored and re-evaluated, as necessary.

2.5.4 Considerations for Developing a Monitoring Program

A detailed QAPP is critical in addressing the question(s) to be addressed by a study. Ultimately, through proper planning, QA/QC, and ensuring the samples selected and collected are relevant for addressing monitoring goals, obtaining accurate and precise analytical data is possible. A sampling program that follows the predetermined QAPP can be designed to best address the desired monitoring regime. However, one of the greatest challenges in sample planning is capturing the representative characteristics of the true population (i.e., how accurately will the samples collected portray the actual environmental condition?). Moreover, will the sampling program capture spatial, temporal, and biological variability? For instance, in a large reservoir, a monitoring program with a single collection depth would not likely portray the actual environmental conditions within the reservoir. Similarly, temporal variability can also result in dramatic differences in trace organic compound occurrence. A recent publication demonstrated that time of day can greatly impact the concentration of certain CECs in WWTP effluent (Nelson, Do and others, 2011). This publication, and others, demonstrate that different days of the week, months, seasons, weather patterns, and even holidays can impact the loading of trace organic compounds from WWTPs (Huerta-Fontela, Galceran and others, 2008; Ort, Lawrence and others, 2010; Delgado-Moreno, Lin and others 2011; Gerrity, Trenholm and others, 2011). The mobility of aquatic organisms and the possibility that exposure to contaminants can change due to their mobility/migration should also be considered. Providing adequate statistical power is also an important consideration. Generally, the limiting factor in a strong statistical design will be the cost associated with increasing sample size. While it may be appealing to consider pooling of samples to reduce costs, the statistical power of the sampling program will likely be diminished, and may not have the resolution to adequately determine actual environmental conditions. Therefore, it can be advantageous to consult with a statistician with expertise in environmental monitoring before finalizing any sampling program.

Field sampling is a critical component to any successful environmental monitoring program, and is the program component where QA is required (Wagner 1995). Grab samples defined as independent discrete samples at a single point in time and space generally provide the highest degree of precision in terms of quantifying a particular chemical or group of chemicals. Compositing is an alternative method of sampling that is often utilized by WWTPs. Sample aliquots are collected at specific times or locations and combined in a common container or are added at a given flow rate to form a composite which integrates the variability in time and/or space to provide a “mean” value for the chemical (s) of interest. Composites can also be part of a pooled sample design, e.g. blood plasma from groups of fish in a certain exposure regime can be pooled to generate the sample volume required for the analyses of interest (Fick, Lindberg and others, 2010). However, sample compositing has many pitfalls and challenges to consider, including sample preservation for labile CECs. Acidification and/or biocide addition as a means for preservation is extremely difficult to accommodate and control when using automated compositing equipment. Another challenge when compositing is cleanliness between and among samples collected. A third challenge is obtaining representative field blanks and matrix spikes when using compositing devices. The decision on sampling technique should consider the environmental problem to be addressed and the sample design that best addresses the particular concern/goal.

A unique challenge in monitoring water quality is determining the fraction of chemicals bound to particles versus those that are freely dissolved. Hydrophobic organic chemicals by definition readily sorb to particles. This issue becomes especially confounding when considering stormwater and secondary WWTP effluent. Information regarding particle bound trace organic compounds is relatively sparse. Moreover, many analytical methods use subjective criteria in deciding whether to filter an aqueous sample or not, such as turbidity or sampling location within a treatment process train (Trenholm, Vanderford and others, 2006). If filtering is carried out, the type and particle retention efficiency of the filter used may not be consistent among methods considered. While solid-phase extraction (SPE)-based methods without pre-filtration theoretically load particles onto the solid-phase sorbent, the efficacy of extraction of particle bound contaminants is highly questionable. Thus, the decision to filter or not filter samples prior to trace organic compound analysis is important, especially with hydrophobic contaminants that are likely to be bound to suspended solids.

Sample preservation, storage, and transport are additional key aspects of ensuring quality monitoring data. Vanderford, Mawhinney and others (2011) detail many of the key considerations in sample containers, preservation, and holding times for some trace organic. However, specific sample handling conditions should be verified and validated for all compounds targeted for monitoring. Field blanks and matrix spikes are a critical QA/QC component that can identify false positives from contamination and false negatives from sample loss (i.e., degradation during transport). Holding times should be established for all analytical methods and sample matrices. As previously discussed, the addition of surrogate standards, preferably stable isotopically labeled analogs of targeted analytes, to environmental samples immediately after collection would allow operators to estimate end-to-end analyte recovery, and final results could be appropriately normalized. Surrogate standards could also be added to sample collection containers in advance; however, great care would be needed to prevent loss due to over filling or pre-rinsing. Blind, randomly sequenced matrix spikes, replicates, and field blanks should also be used to test for laboratory or batch-wise bias.

2.5.5 Method Reporting Limits

MRLs are critical to consider in environmental monitoring. The MRL is the lowest analyte concentration that demonstrates known quantitative quality (EPA 2004). A result below the MRL is considered to be an estimated value that does not satisfy quality control objectives. The MRL is generally a function of the instrument sensitivity, the volume of water extracted, the volume of solvent of the resulting extract, and the volume of extract injected into a particular instrument. Often, the MRL is determined by spiking laboratory purified water 7x near the estimated detection limit and using a statistical test (the student t-test) to determine the method detection limit based on the standard deviation of the response. The MRL is usually a multiplier of the MDL to achieve greater confidence in the method overall. In trace organic compound analyses, it has become common practice to extract 1 L of water and concentration to 1 mL of solvent (1000x concentration). However, it is critical to consider that not only are target trace organic compounds concentrated, but the bulk natural organic matter (NOM) is also concentrated, which may be present in mg/L concentrations. Thus, the analysis of ng/L trace organic compounds within the mixture of mg/L NOM becomes increasingly difficult and may lead to erroneous analytical results. Moreover, as discussed previously, the true MRL in an environmental matrix may not be similar to an MRL determined in purified water. For example the matrix for advanced treated reclaimed water is similar to laboratory ultrapure water. Thus, the MRL should be verified within the matrix to be evaluated.

Analytical methods with appropriate MRLs should be selected based on the desired concentration goal and not based on trying to achieve the lowest concentration possible. Most commercial analytical laboratories seek to develop the most sensitive method feasible with the instruments available. Often, MRLs below the ng/L level can be developed. However, for many trace organic compounds, such low MRLs are not needed and can increase the probability of erroneous results. Thus, it is strongly recommended that MRLs be established that are no greater than 10x lower than the applicable health or performance goals (see Section 2.6). By not forcing unnecessarily lower MRLs, it is possible to conduct analyses using far lower volumes of water and to greatly improve analytical reliability. Recent advances in on-line SPE coupled to LC-MS/MS instruments can easily achieve 10-100 ng/L MRLs with only 1-2 mL of water. Similarly, GC-MS/MS instruments equipped with solid-phase microextraction (SPME) can also achieve very low MRLs with only a few mL of water. Thus, by not arbitrarily forcing laboratories to achieve ng/L MRLs, or lower, tremendous savings in cost, time, and labor can be achieved with simultaneous improvement of data quality.

2.5.6 Bio-analytical Methods

Bioassays are tests performed using live cell cultures or mixtures of cellular components in which the potency of a chemical or water concentrate is tested based on its effect on a measurable parameter, such as inhibition or the induction of a response (including carcinogenicity and mutagenicity). For unknown chemicals that may be unknowingly released into the environment and for which there are currently no known methods for their quantification, biological monitoring or chemical screening methods could be used to quantify effects/equivalents or identify unknown chemicals and thus may offer an additional safeguard for human health or ecological health (Anderson, Denslow and others, 2010). The main advantage of bioassays is that they are able to detect the presence of chemicals based on their bioactivity rather than on their detection by analytical chemistry. An added benefit of bioassays is they can be used to measure synergistic, additive, and antagonistic interactions between compounds that may be present in a mixture. There are both *in vivo* and *in vitro* assays that have been developed, which can also be linked with analytical chemical methods to identify potential toxicants; *in vivo* bioassays are conducted using whole organisms while *in vitro* bioassays are conducted at the cellular level. Research is being conducted to further develop *in vivo* and *in vitro* bioassays that can be used to rapidly and selectively screen water for possible physiological effects (NRC, 2013; Snyder, 2014). The primary weakness of bioassays is the uncertainty surrounding the potential for quantifying adverse effects in humans with a positive response (Anderson and others., 2010 and others).

2.5.7 Summary

Most aspects of QA/QC for environmental monitoring are well understood and properly attained by the majority of well-regarded scientists and commercial laboratories. Ultra-trace analysis (sub-ng/L level) is inherently more difficult in terms of potential for false positive and false negative results. However, modern analytical techniques such as isotope dilution and automated on-line SPE offer tremendous promise for continually improving analytical data. A detailed QAPP is critical in addressing the question(s) for which a particular study is initiated. Ultimately, through proper planning, QA/QC, and ensuring the samples selected are representative of the population to be monitored, collection of accurate and precise analytical data is possible.

2.6 Suggested Monitoring Framework for Utilities Interested in Pursuing DPR

As municipalities begin exploring DPR projects, it is important that they begin considering what COCs and CECs should be monitored. This section presents a suggested monitoring framework for utilities that are interested in pursuing DPR.

2.6.1 Indicator and Surrogate Concept

The indicator and surrogate approach recommends using a combination of indicator compounds and surrogate parameters that are tailored to monitor the removal efficiency of individual unit processes. An indicator compound is an individual constituent that is a COC or a CEC that represents certain physicochemical and biodegradable characteristics of a family of trace organic constituents. The indicator compounds are important in terms of human health and/or are relevant to fate and transport of broader classes of chemicals and provide a conservative assessment of removal during treatment. A surrogate parameter is a quantifiable change of a bulk parameter that can measure the performance of individual unit processes (often in real-time, including failure) or operations in removing trace organic compounds and/or assuring disinfection. Indicator chemicals of toxicological relevance to human health are referred to as “health-based indicators”. Indicator compounds determined not to have human health relevance, but useful for monitoring treatment process effectiveness, are referred to as “performance indicators”.

It is recommended that monitoring programs for DPR projects in Texas include monitoring for: (1) human health-based indicators; (2) performance indicators; and (3) surrogates. Table 9 provides recommendations for health-based and performance indicator compounds to be monitored along with their respective MRLs. The indicators and surrogates selected are based on relevance (human health) and suitability as performance indicators. Additional background information for each compound is provided in the references listed in the last column in the table. The MRLs listed are for clean matrices, which are appropriate for the quality of water to be used for DPR in Texas.

Monitoring is divided into two phases. The first phase involves monitoring that would be initiated during piloting and/or project start-up and continue through the early years of project operation. The second phase would represent baseline operations following start-up. The third phase is the standard operating phase. Additional information is presented in Section 0.

All indicator compounds should be monitored during the initial assessment phase. Based on monitoring results and findings, the list of performance indicators required for monitoring may be refined for the baseline assessment; information collected during the baseline assessment will be used to inform the standard operating monitoring program. Quality assurance and quality control measures should be used for both collection of samples and laboratory analyses as previously discussed. Each project should develop a QAPP that includes the appropriate number of field blanks, laboratory blanks, replicate samples, and matrix spikes (see Section 2.5).

Table 9 also includes a Monitoring Trigger Threshold (MTT) for each indicator. Because many CECs do not have established drinking water standards or advisory levels, researchers have developed a method to describe an estimate of the amount of a substance in drinking water, expressed on a body-weight basis (usually in milligrams of the substance per kilograms of body weight per day), that can be ingested daily over a lifetime without appreciable risk. The procedure to derive this estimated “safe” amount involves collecting all relevant toxicity data, ascertaining the completeness of the data, determining the most sensitive toxicity outcome (taking into account sensitive population groups such as infants, children, pregnant women, and those with compromised health), and applying appropriate safety factors. Health outcomes include therapeutic dose of medications, the no observed adverse effect level (NOAEL), the lowest observed no adverse effect level (LOAEL), and carcinogenicity. Depending on the researcher conducting the study, these estimated safe amounts are called different names: Tolerable Daily Intakes (TDIs), Acceptable Daily Intakes (ADIs), or Predicted No Effect Concentrations (PNEC) (Schwab et al., 2005, Environment Protection and Heritage Council et al., 2008, Anderson et al., 2010, Bruce et al 2010a,b). In order to compare the estimated safe amounts to concentrations of chemicals in recycled water or drinking water, researchers calculate a Drinking Water Equivalent Level (DWEL). The DWEL represents the concentration of a chemical in drinking water that would be equivalent to the TDI/ADI/PNEC, assuming a 150-pound person (70 kilograms or kg) consumes 2 liters (L) of water (about 8½ cups) using the following equation.

$$DWEL(ug/L) = \frac{TDI(ug/kg-d) \times 70kg}{2L/d}$$

The MTTs in Table 9 are equivalent to the lowest MCL, advisory level, or DWEL established for each indicator.

Table 9: Suggested indicator chemicals to be included in DPR monitoring program

Constituent	Rationale	MTT (ng/L)	Reporting limit (ng/L)	Reference
THMs	Health	80,000	1,000	MCL
HAA5	Health	60,000	1,000	MCL
NDMA	Health	10	2[10]	DDW Notification Level[11]
PFOA	Health	400	10	Provisional Short-term EPA Health Advisory
PFOS	Health	200	10	Provisional Short-term EPA Health Advisory
Bromate	Health	10,000	1,000	MCL / WHO guideline
Perchlorate	Health	15,000	1,000	EPA Health Advisory
1,4-Dioxane	Health	1,000	100	CDPH Notification Level
17β-Estradiol	Health	<1	0.9	Drewes and others 2013
Atenolol	Health/ Performance	4,000	100	Bull and others 2011
TCEP	Health/ Performance	5,000	100	Minnesota Dept. of Health (2011) Guidance Value
Caffeine	Performance	[1]	50	Drewes and others 2013
Gemfibrozil	Performance	800,000	10	Schwab 2005
Iopromide	Performance	750,000	50	Environment Protection and Heritage Council and others 2008
Meprobamate	Health/ Performance	200,000	100	Bull and others, 2011
DEET	Performance	200,000	50	Minnesota Dept. of Health (2011) Guidance Value
Primidone	Performance	10,000	10	Bruce and others 2010

[10] This MRL is significantly lower than the level used for EPA Method 1625, which is approved per 40 Code of Federal Regulations Part 136 with a detection level of 50 µg/L; NDMA is part of the Priority Pollutant scan.

[11] CDPH has established Notification Levels for chemicals in drinking water without MCLs. If a chemical concentration is greater than its Notification Level in drinking water, the utility must inform its customers and consumers about the presence of the chemical, and about health concerns associated with exposure to it.

Constituent	Rationale	MTT (ng/L)	Reporting limit (ng/L)	Reference
Sucralose	Performance	150,000,000	100	CFR Title 21
Triclosan	Performance	2,100,000	50	Drewes and others 2013

CDPH = California Department of Public Health
HAA5 = Haloacetic acids
THMs = Trihalomethanes

1. The lowest MMT for caffeine is 350 ng/L based on the Threshold of Toxicological Concern, which is a predictive model (Environment Protection and Heritage Council et al., 2008). Intertox (2009) developed a toxicity-based DWEL of 8.75E+6 ng/L. Because of the wide range in the two MMT values, a value is not included in the table. Caffeine is commonly found in wastewater and thus is an appropriate indicator to use for evaluating treatment performance.

Table 10 presents a list of surrogates that should be considered for monitoring treatment of reclaimed water using various advanced water treatment processes as part of a DPR scheme. Other surrogates not listed in Table 10 may also be considered, depending on the specific situation. Where applicable, surrogates may be measured using on-line or hand-held instruments, provided that instrument calibration procedures are implemented in accordance with the manufacturer's specifications and that calibration is documented.

Table 10: Suggested surrogate parameters for advanced water treatment processes to be included in DPR monitoring program

Surrogate Parameter	Unit processes
Total organic carbon (TOC) or dissolved organic carbon (DOC)	RO, NF, GAC, PAC, ozone, AOP
UV absorbance (254 nm)	RO, NF, GAC, PAC, ozone, AOP
Fluorescence indices/ratios	RO, NF, GAC, PAC, ozone, AOP
Total dissolved solids (TDS)/electrical conductivity	RO, NF
Boron (surrogate for NDMA)	RO, NF
Aesthetics	
Temperature	RO, NF, GAC, PAC, ozone, AOP
Color (436 nm)	RO, NF, GAC, PAC, ozone, AOP
Odor	RO, NF, GAC, PAC, ozone, AOP
Hardness	RO, NF

RO = Reverse osmosis
NF = Nanofiltration
GAC = Granular activated carbon
PAC = Powdered activated carbon
AOP = Advanced oxidation processes

In addition to the surrogates suggested for advanced water treatment processes in Table 10, turbidity is a valuable surrogate for evaluating wastewater treatment ahead of the advanced water treatment processes.

2.6.2 Phased Monitoring Program

The purpose of phased monitoring is to allow monitoring requirements for health-based indicators, performance indicators and surrogates to be refined based on the monitoring results and findings of the previous phase. An initial assessment monitoring phase, followed by a baseline monitoring phase, should be conducted to determine the project-specific monitoring requirements for standard operations.

2.6.2.1 Initial Assessment Monitoring Phase

The purposes of the initial assessment phase are to: (1) identify the occurrence of health-based indicators, performance indicators, and surrogates in reclaimed water; (2) determine treatment effectiveness; (3) define the project-specific performance indicators and surrogates to monitor during the baseline phase; and (4) specify the expected removal percentages for performance indicators and surrogates. The initial assessment monitoring phase should be conducted for a period of at least one year to evaluate seasonal variability.

During the initial assessment monitoring phase, each of the health-based and performance indicators (Table 9) and appropriate surrogates (Table 10) should be monitored. Surrogates should be selected to monitor individual unit processes or combinations of unit processes that remove constituents of concern. Performance indicator and surrogate monitoring results that demonstrate measurable removal for a given unit process are candidates for use in the monitoring programs for the baseline and standard operation phases.

2.6.2.2 Baseline Monitoring Program

Based on the findings of the initial assessment monitoring phase, project-specific performance indicators and surrogates should be selected for monitoring during the baseline monitoring phase. The purpose of the baseline monitoring phase is to assess and refine which health-based and performance indicators and surrogates are appropriate to monitor the removal of COCs and CECs and treatment system performance for the standard operation of a facility. Performance indicators and surrogates that exhibited reduction by unit processes and/or provided an indication of operational performance should be selected for monitoring during the baseline monitoring phase. The baseline monitoring phase should be conducted for a period of three years following the initial assessment monitoring phase. Following the baseline operation monitoring phase, monitoring requirements should be re-evaluated and subsequent requirements for the standard operation of a project should be determined on a project-specific basis.

2.6.2.3 Standard Operating Monitoring

Based on the findings of the baseline monitoring phase, monitoring requirements for health-based and performance indicators and surrogates may be refined to establish project-specific requirements for monitoring the standard operating conditions of a DPR project.

2.6.3 Assessment of Performance

Monitoring results for performance indicators and surrogates should be used to evaluate the operational performance of a treatment process and the effectiveness of a treatment process in removing COCs and CECs. The effectiveness of a treatment process in removing COCs and CECs should be evaluated by determining the removal percentages for performance indicator chemicals and surrogates. The removal percentage is the difference in the concentration of a compound in reclaimed water prior to and after a treatment process (e.g., RO, AOP or GAC filtration), divided by the concentration prior to the treatment process and multiplied by 100.

Removal Percentage = $([X_{in} – X_{out}]/X_{in})$ (100)

X_{in} - Concentration in reclaimed water prior to a treatment process

X_{out} - Concentration in reclaimed water after a treatment process

During the initial assessment, the DPR project proponent should monitor performance to determine removal percentages for performance indicator COCs, CECs and surrogates. The removal percentages should be confirmed during the baseline monitoring phase.

Response programs should be developed for monitoring results that exceed the MTTs including collection of additional samples and/or implementation of corrective actions (for example if the ratio of the measured concentration and MTT is > 1,000). For monitoring results that are below detection or a fraction of the MTT (for example 10%), consideration should be given to discontinuing monitoring for that particular indicator compound.

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3 ACRONYMS

ADI	Acceptable Daily Intake
AOP	Advanced Oxidation Processes
CCL3	Contaminant Candidate List 3
CDPH	California Department of Public Health
CECs	Constituents of Emerging Concern
COCs	Contaminants of Concern
CWA	Clean Water Act
DEET	N,N-Diethyl-meta-toluamide
DL	Detection limit
DOC	Dissolved Organic Carbon
DPR	Direct Potable Reuse
DWEL	Drinking Water Equivalent Level
EDCs	Endocrine Disrupting Compounds
EPA	U.S. Environmental Protection Agency
GAC	Granular Activated Carbon
GC	Gas Chromatography

HAA-5	Haloacetic acids
L	Liter
LC-MS	Liquid Chromatography with Mass Spectrometric detection
LOAEL	Lowest Observed Adverse Effect Level
MCL	Maximum Contaminant Level
MDL	Minimum Detection Level
MEC	Measured environmental concentration
mg/L	milligrams per liter
mL	milliliter
MRL	Method Reporting Limits
MTBE	Methyl-t-betylether
MTT	Monitoring Trigger Threshold
N	Nitrogen
NDMA	N-Nitrosodimethylamine
NF	Nanofiltration
ng/L	nanograms per liter
NOAEL	No Observed Adverse Effect Level
NOM	Natural Organic Matter
NSAID	Non-steroidal anti-inflammatory drug
PAC	Powder Activated Carbon
pCi/L	picoCuries per Liter
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonate
PNEC	Predicted No Effect Concentration
PPCPs	Pharmaceuticals and Personal Care Products
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RO	Reverse Osmosis
SDWA	Safe Drinking Water Act
SPE	Solid-Phase Extraction
SPME	Solid-Phase Microextraction
SWQMS	Surface Water Quality Monitoring System
SWRCB	State Water Resources Control Board
TCDPP	Tris (1,3-dichloro-2-propyl) phosphate
TCEP	Tris (2-chloroethyl) phosphate
TCEQ	Texas Commission on Environmental Quality
TCPP	Tris (1-chloro-2-propyl) phosphate

TDI	Tolerable Daily Intake
TDS	Total Dissolved Solids
THMs	Trihalomethanes
TOC	Total Organic Carbon
TSS	Total Suspended Solids
TX	Texas
TSWQS	Texas Surface Water Quality Standards
TWDB	Texas Water Development Board
µg/L	Microgram per liter
WHO	World Health Organization
WWTP	Wastewater Treatment Plant

EXHIBIT A

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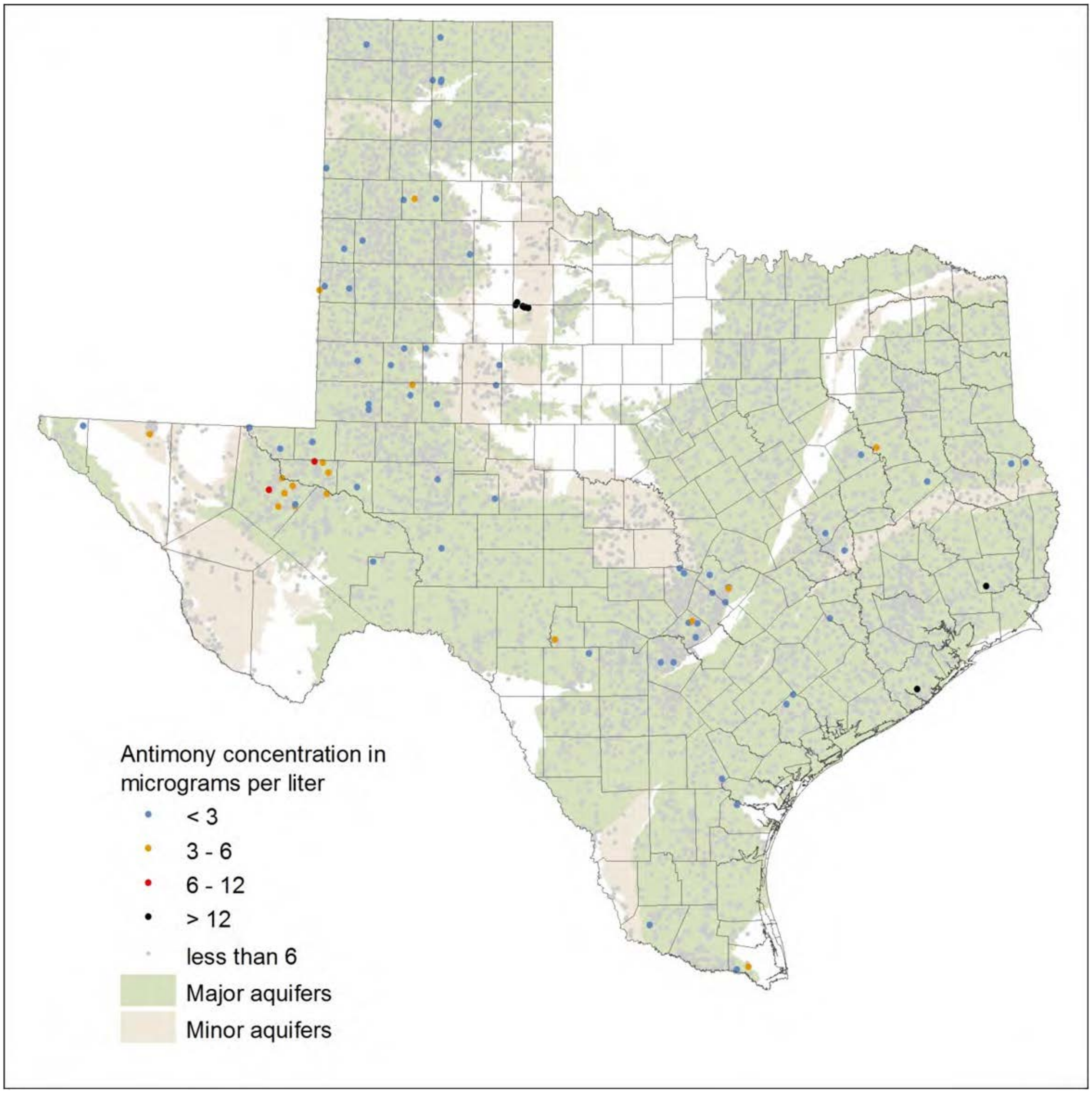

Figure 3. Antimony concentrations in Texas groundwater. Colored symbols indicate detected concentrations within indicated ranges. Smaller gray symbols and associated less than values indicate non-detects below the indicated detection limit concentration. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

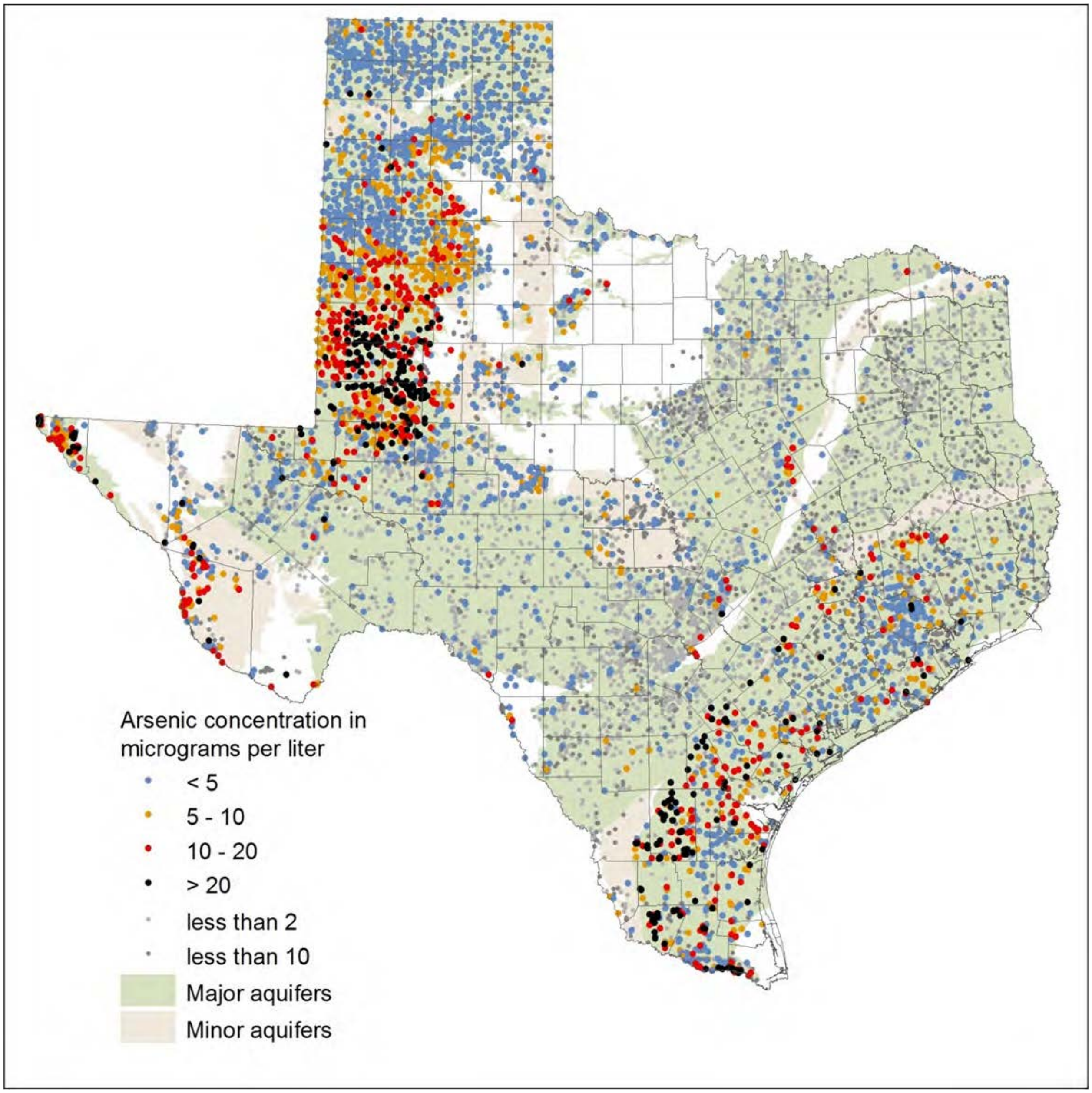

Figure 4. Arsenic concentrations in Texas groundwater. Colored symbols indicate detected concentrations within indicated ranges. Smaller gray symbols and associated less than values indicate non-detects below the indicated detection limit concentration. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

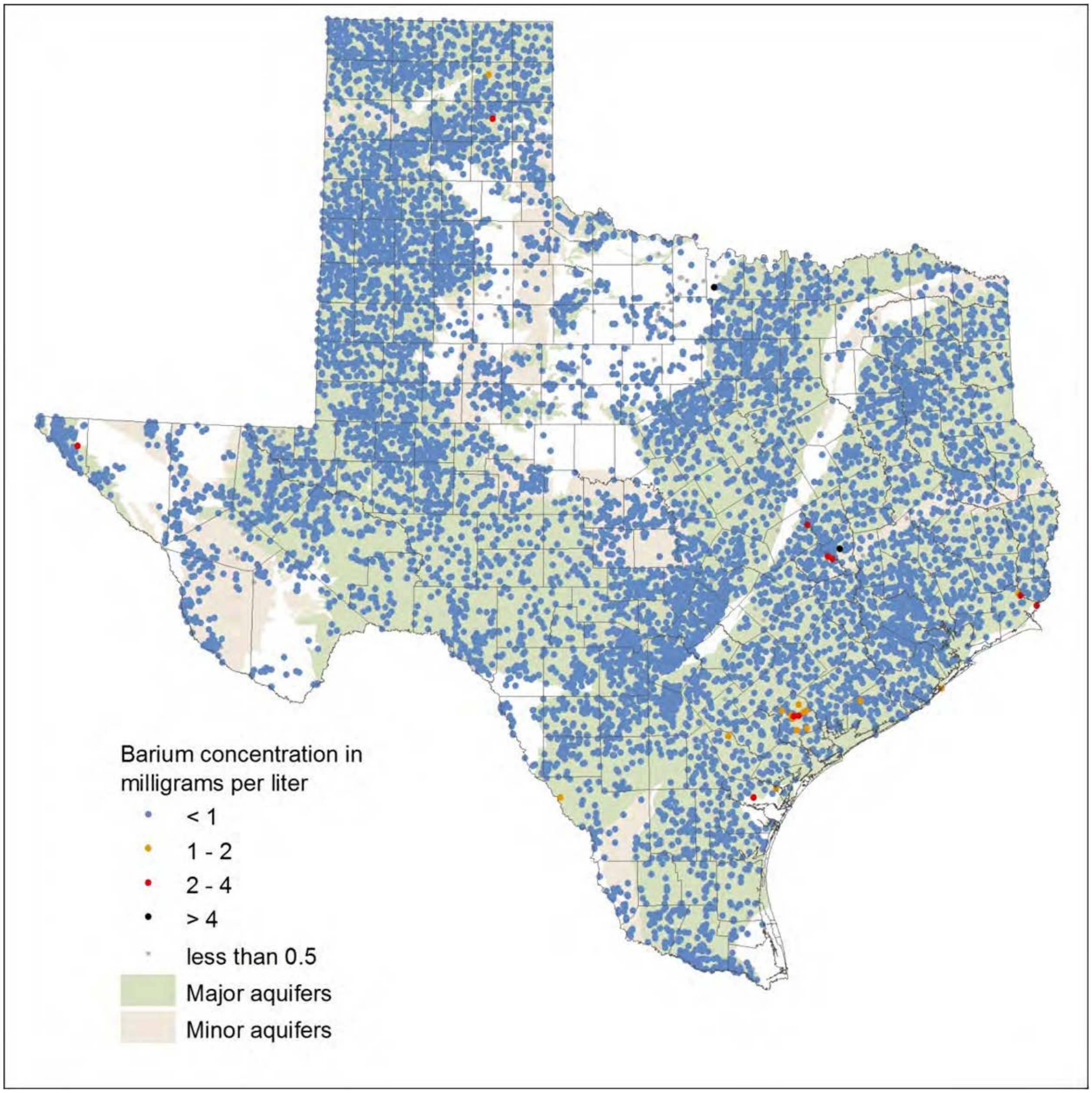

Figure 5. Barium concentrations in Texas groundwater. Colored symbols indicate detected concentrations within indicated ranges. Smaller gray symbols and associated less than values indicate non-detects below the indicated detection limit concentration. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

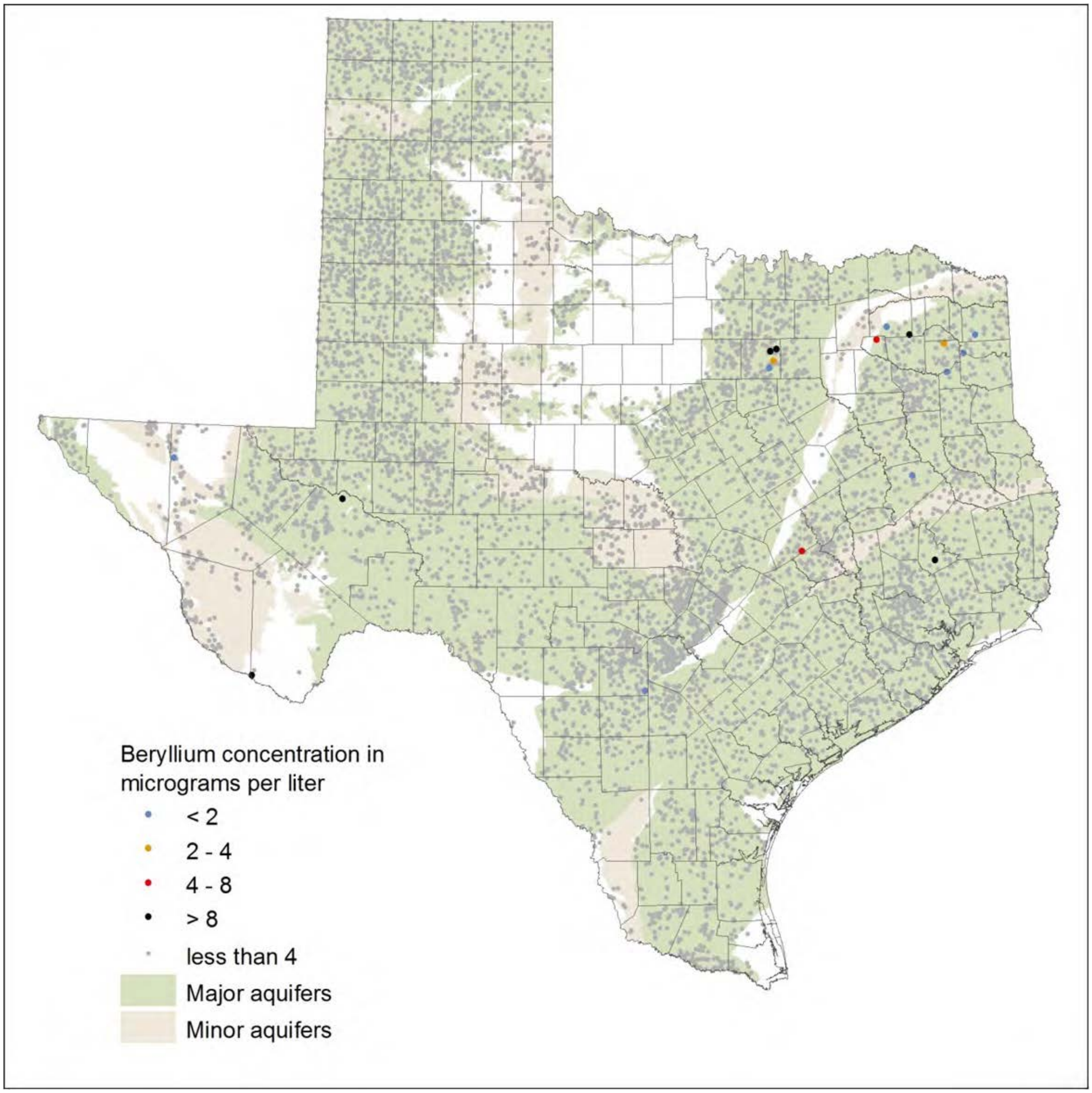

Figure 6. Beryllium concentrations in Texas groundwater. Colored symbols indicate detected concentrations within indicated ranges. Smaller gray symbols and associated less than values indicate non-detects below the indicated detection limit concentration. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

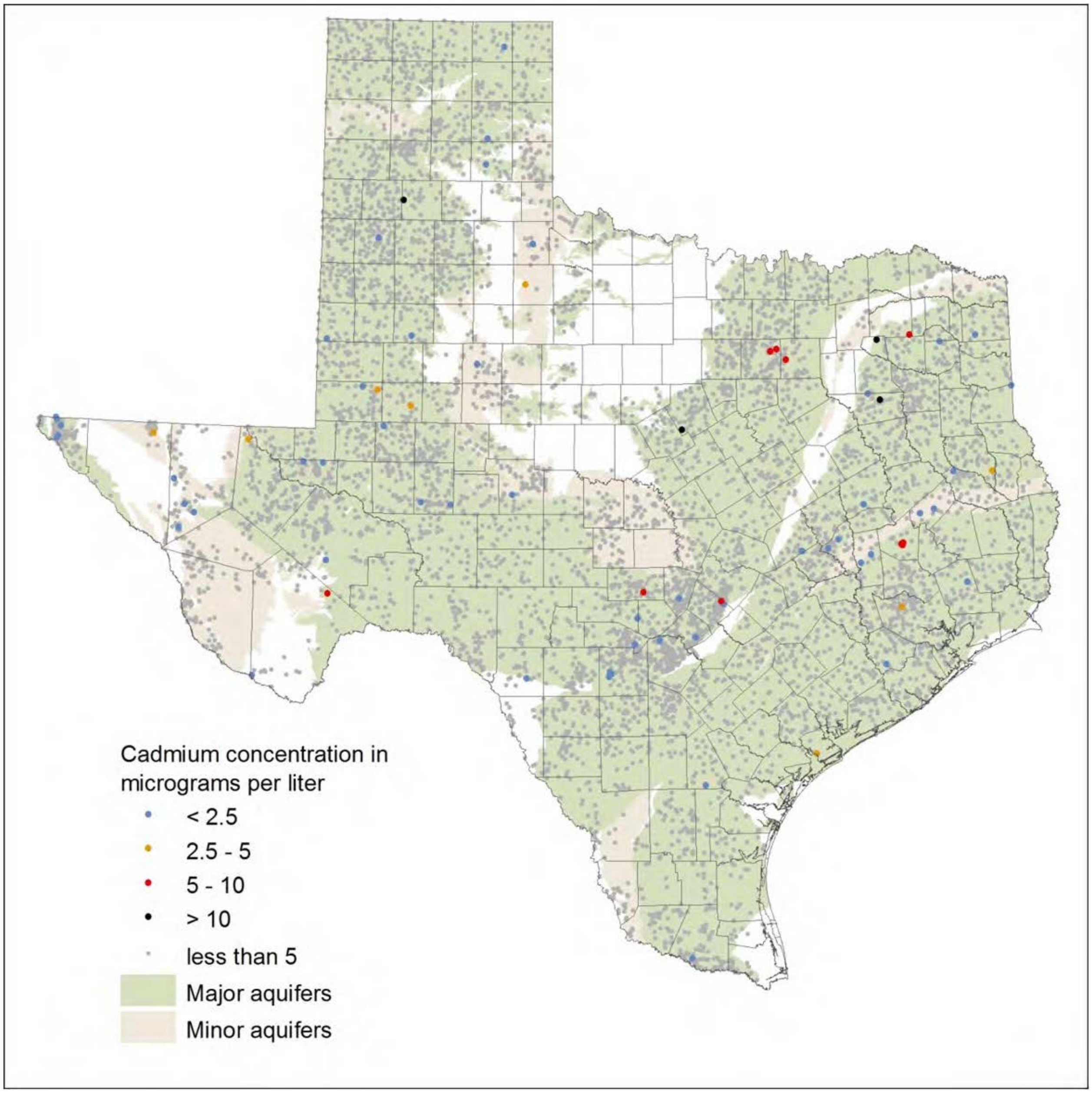

Figure 7. Cadmium concentrations in Texas groundwater. Colored symbols indicate detected concentrations within indicated ranges. Smaller gray symbols and associated less than values indicate non-detects below the indicated detection limit concentration. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

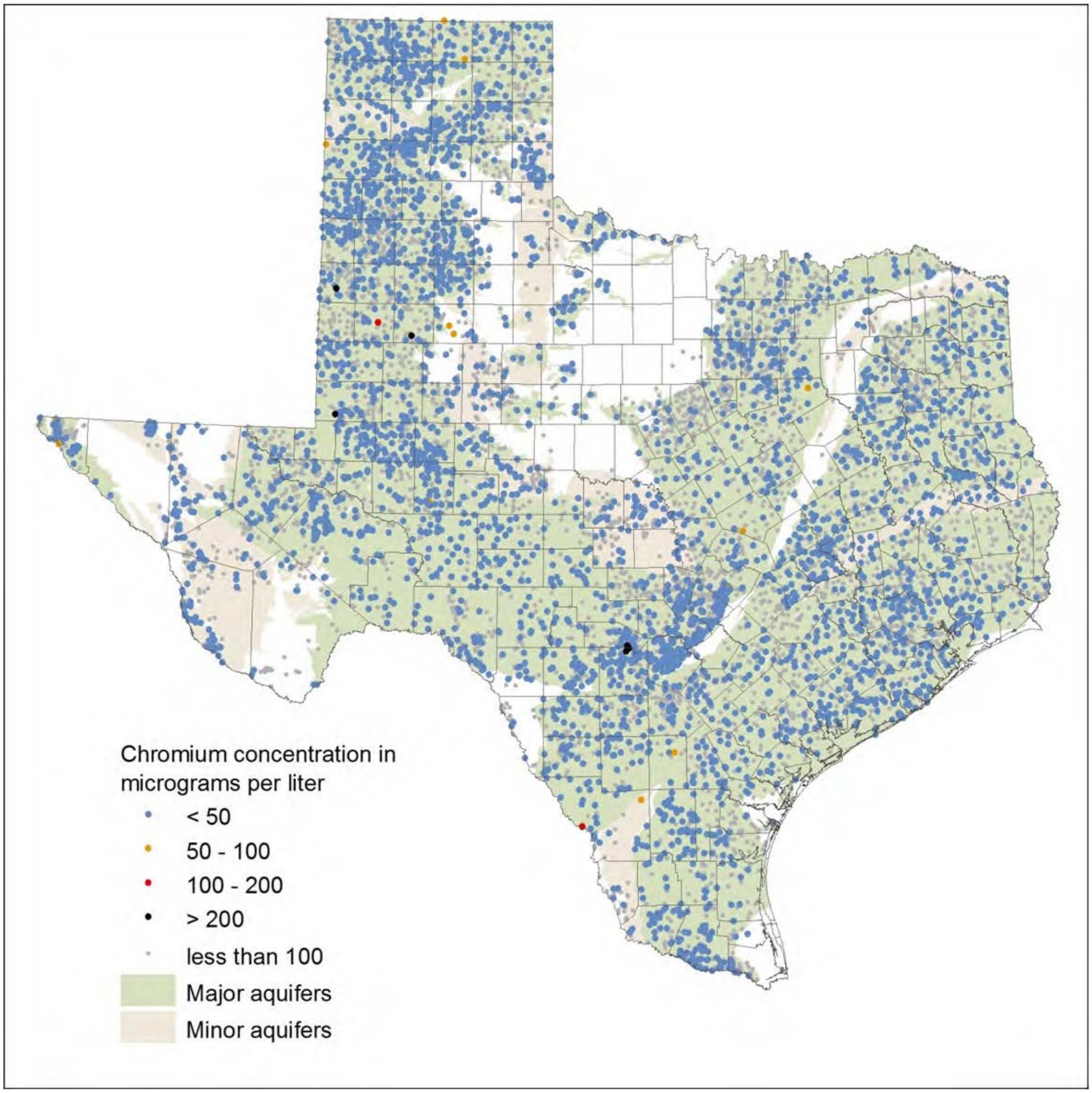

Figure 8. Chromium concentrations in Texas groundwater. Colored symbols indicate detected concentrations within indicated ranges. Smaller gray symbols and associated less than values indicate non-detects below the indicated detection limit concentration. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

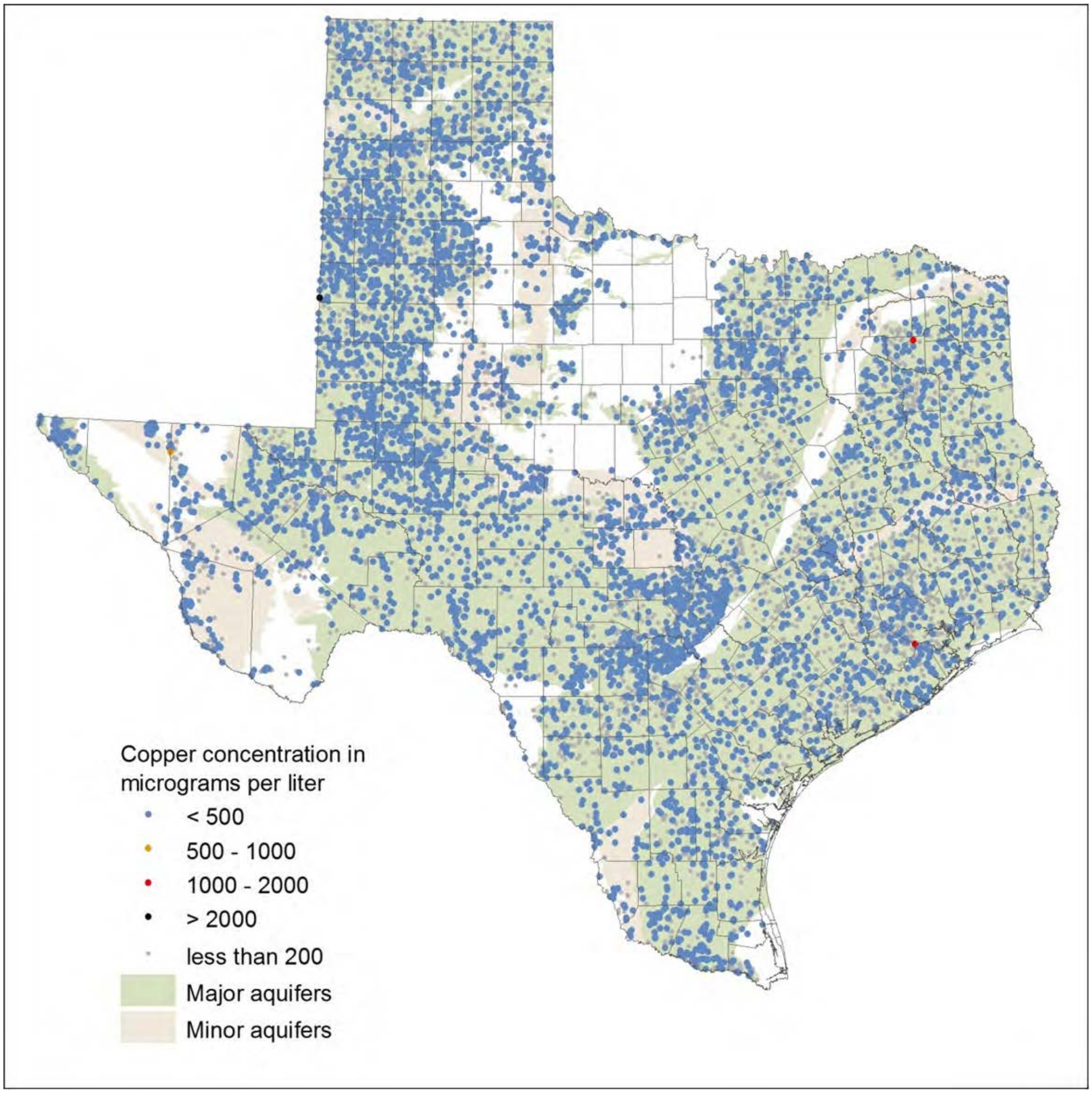

Figure 9. Copper concentrations in Texas groundwater. Colored symbols indicate detected concentrations within indicated ranges. Smaller gray symbols and associated less than values indicate non-detects below the indicated detection limit concentration. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

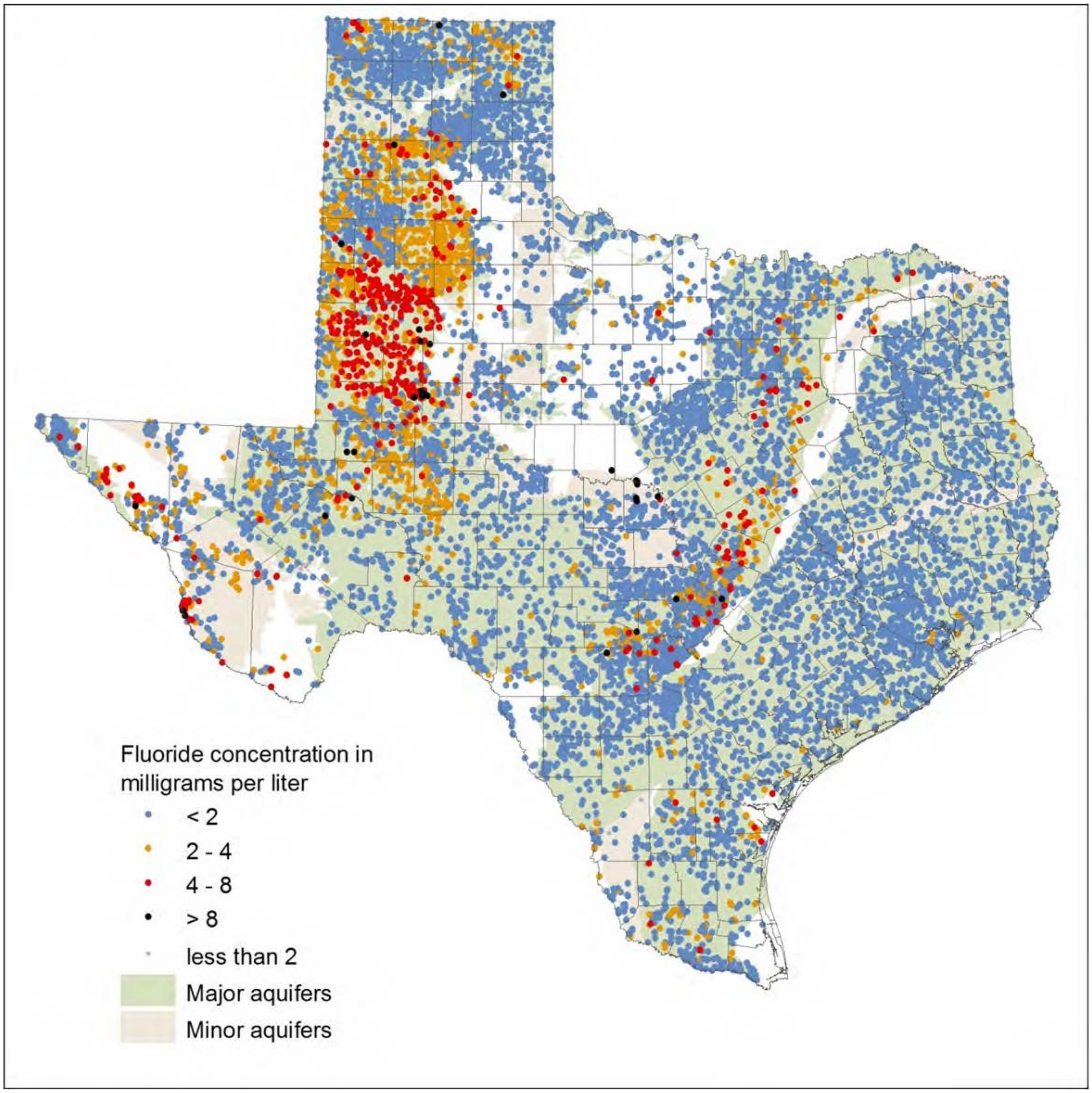

Figure 10. Fluoride concentrations in Texas groundwater. Colored symbols indicate detected concentrations within indicated ranges Smaller gray symbols and associated less than values indicate non-detects below the indicated detection limit concentration. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

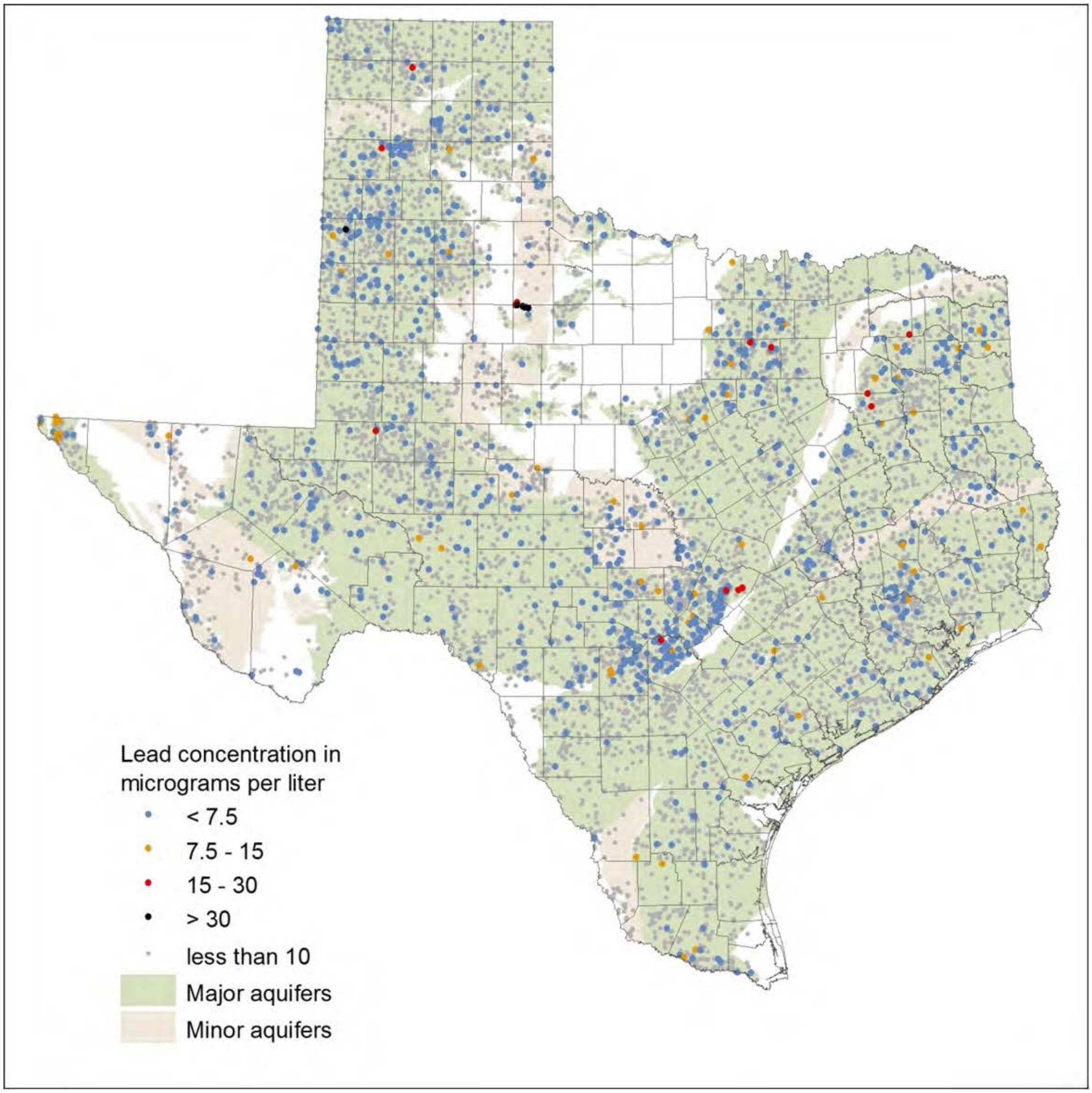

Figure 11. Lead concentrations in Texas groundwater. Colored symbols indicate detected concentrations within indicated ranges. Smaller gray symbols and associated less than values indicate non-detects below the indicated detection limit concentration. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

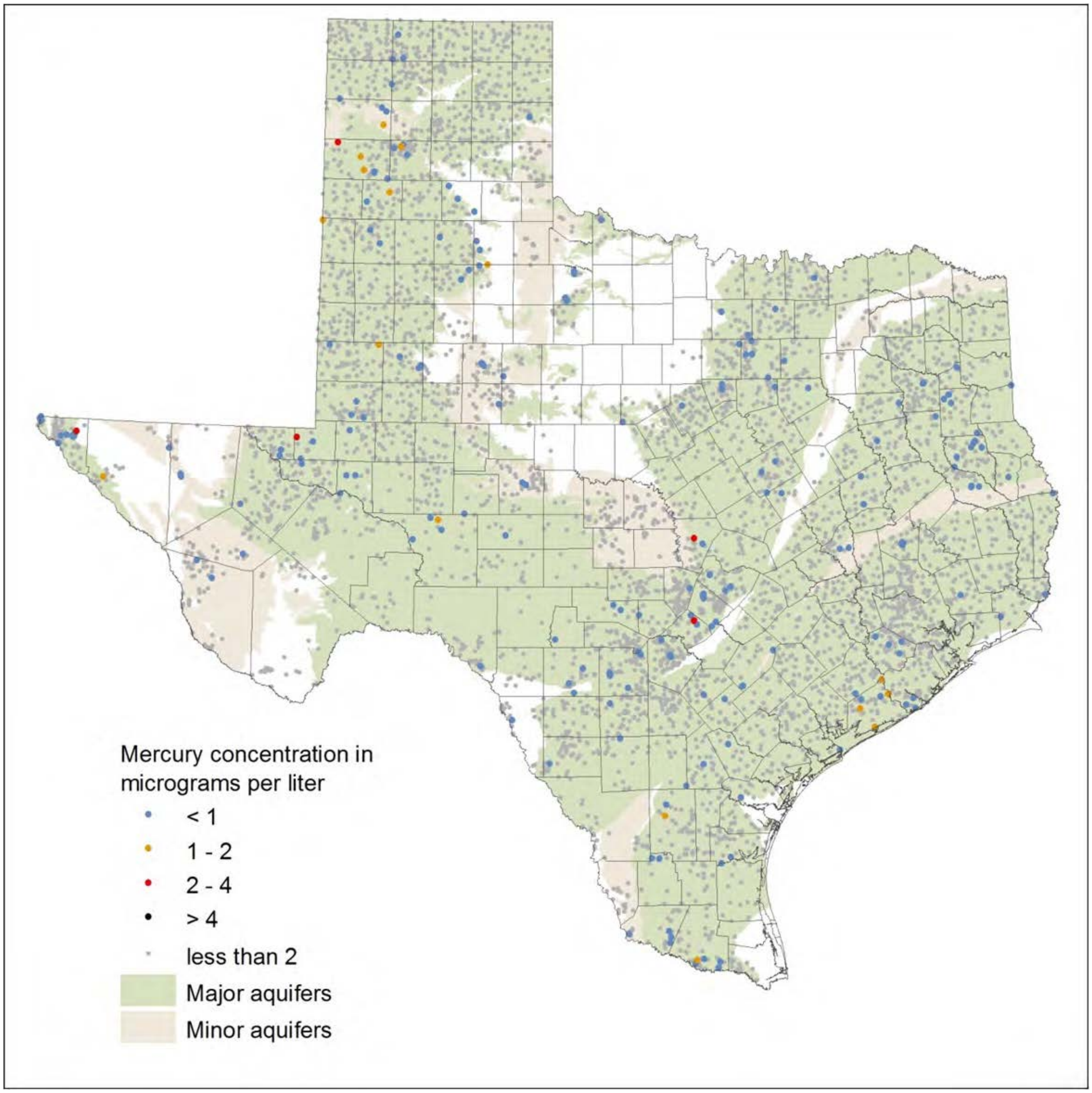

Figure 12. Mercury concentrations in Texas groundwater. Colored symbols indicate detected concentrations within indicated ranges Smaller gray symbols and associated less than values indicate non-detects below the indicated detection limit concentration. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

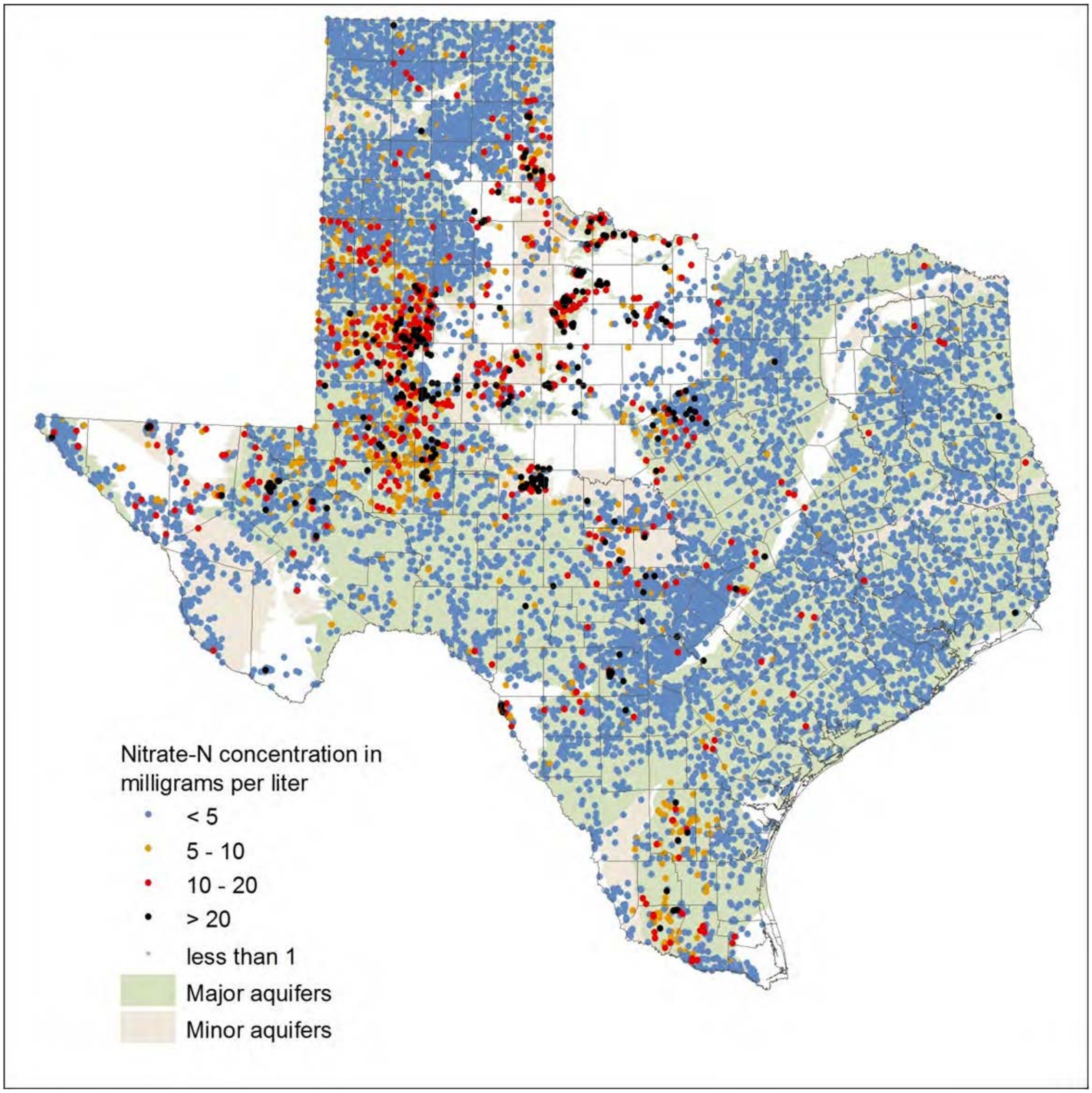

Figure 13. Nitrate-N concentrations in Texas groundwater. Colored symbols indicate detected concentrations within indicated ranges. Smaller gray symbols and associated less than values indicate non-detects below the indicated detection limit concentration. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

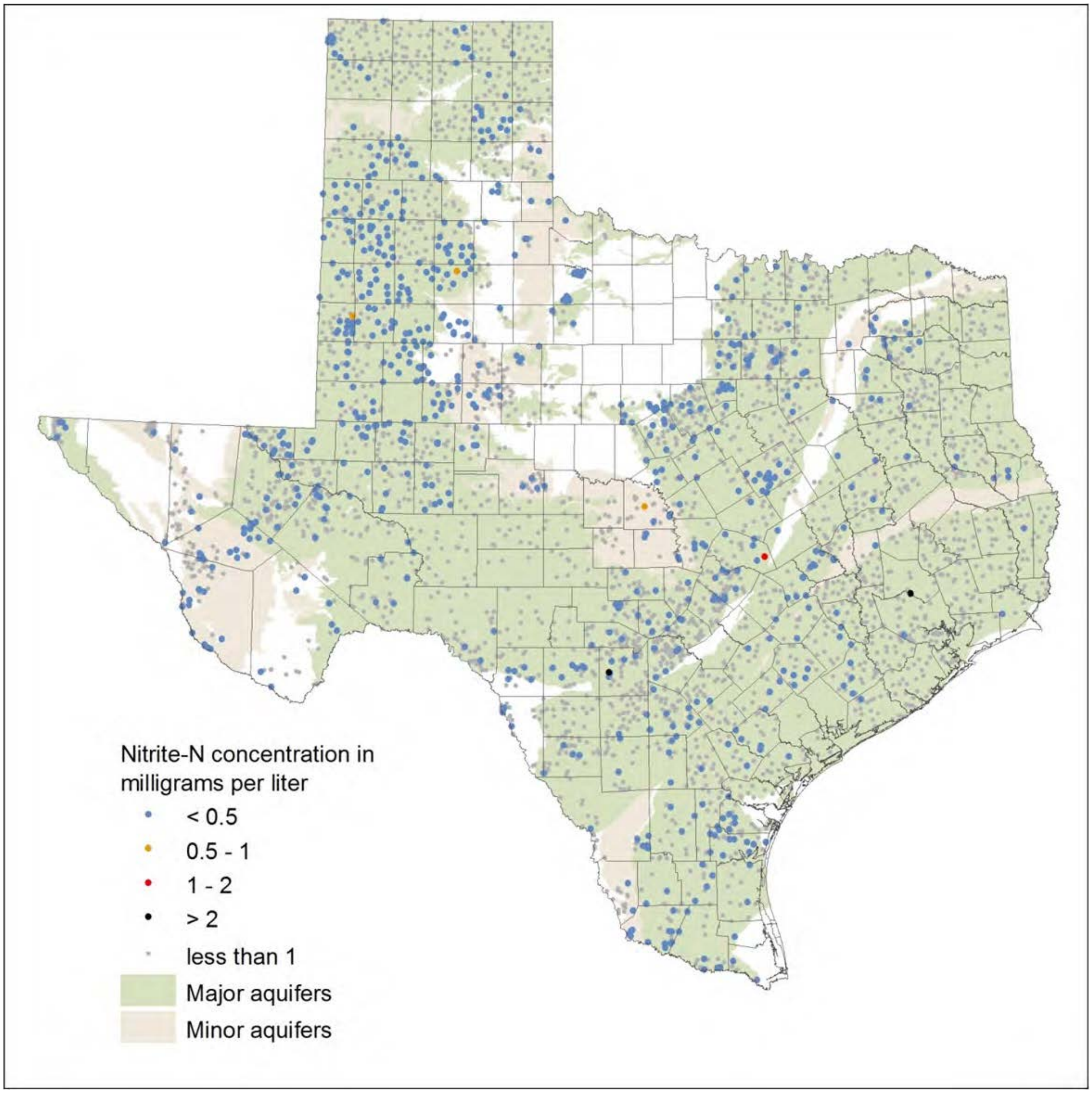

Figure 14. Nitrite-N concentrations in Texas groundwater. Colored symbols indicate detected concentrations within indicated ranges. Smaller gray symbols and associated less than values indicate non-detects below the indicated detection limit concentration. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

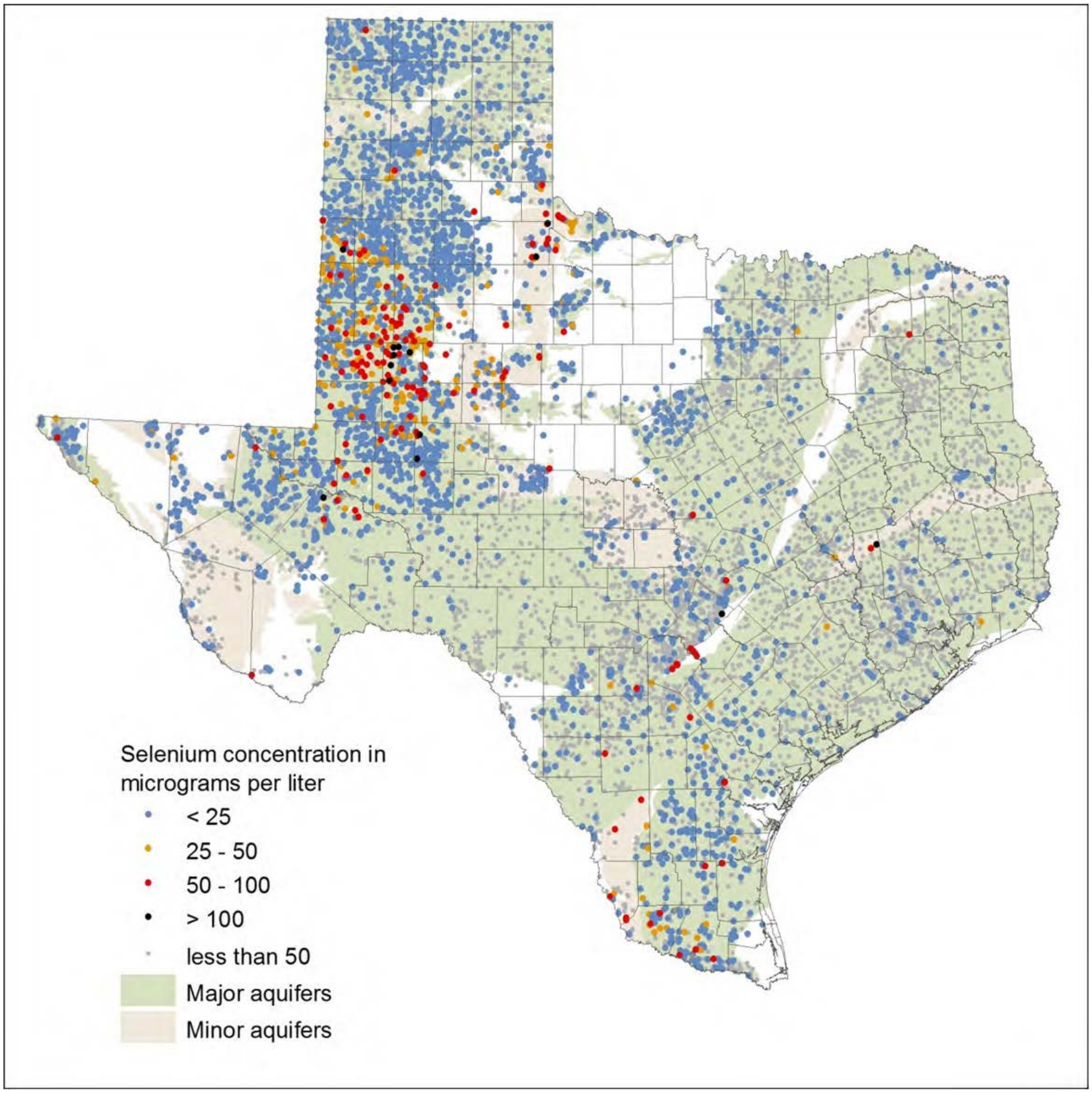

Figure 15. Selenium concentrations in Texas groundwater. Colored symbols indicate detected concentrations within indicated ranges. Smaller gray symbols and associated less than values indicate non-detects below the indicated detection limit concentration. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

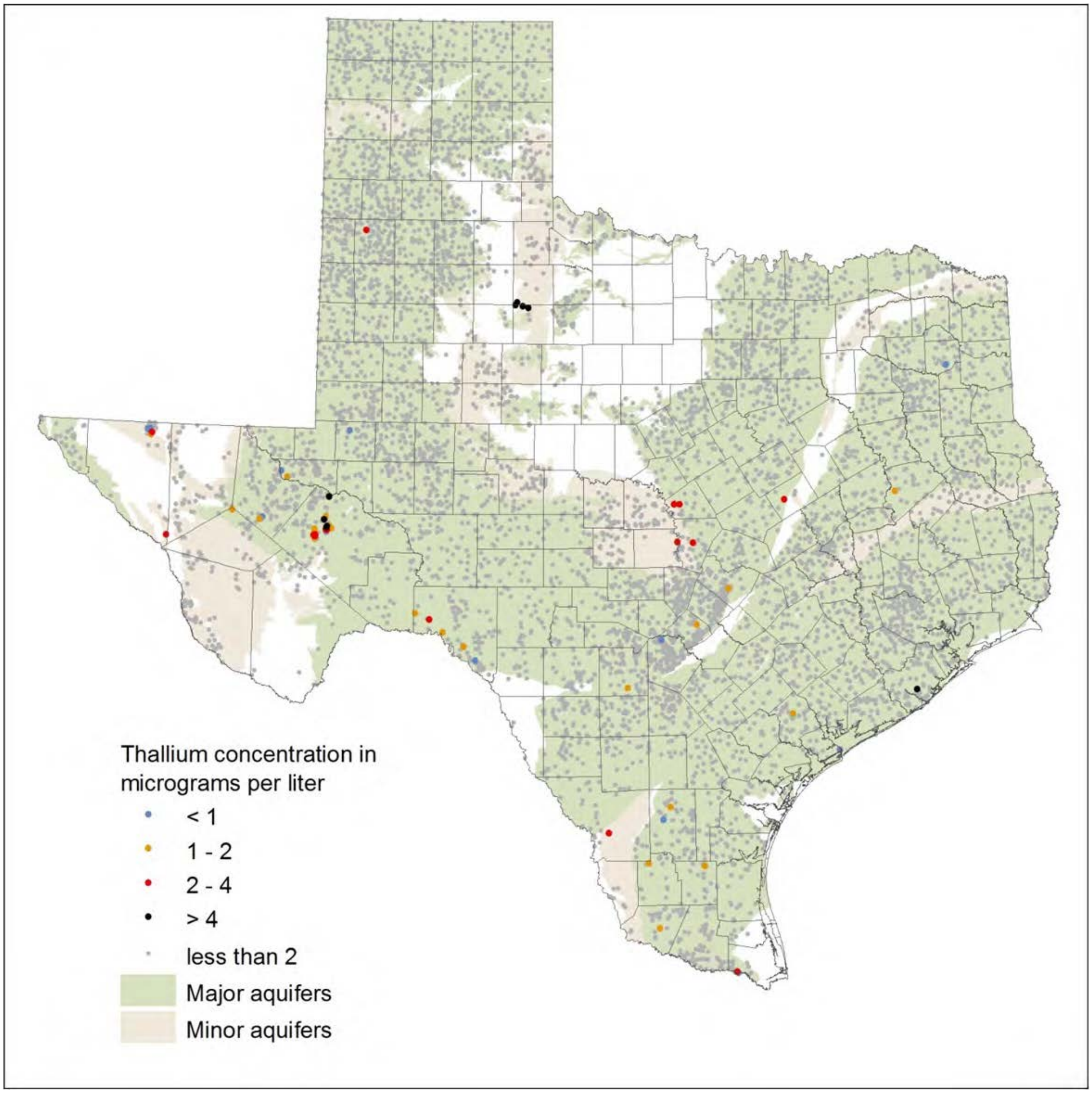

Figure 16. Thallium concentrations in Texas groundwater. Colored symbols indicate detected concentrations within indicated ranges. Smaller gray symbols and associated less than values indicate non-detects below the indicated detection limit concentration. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

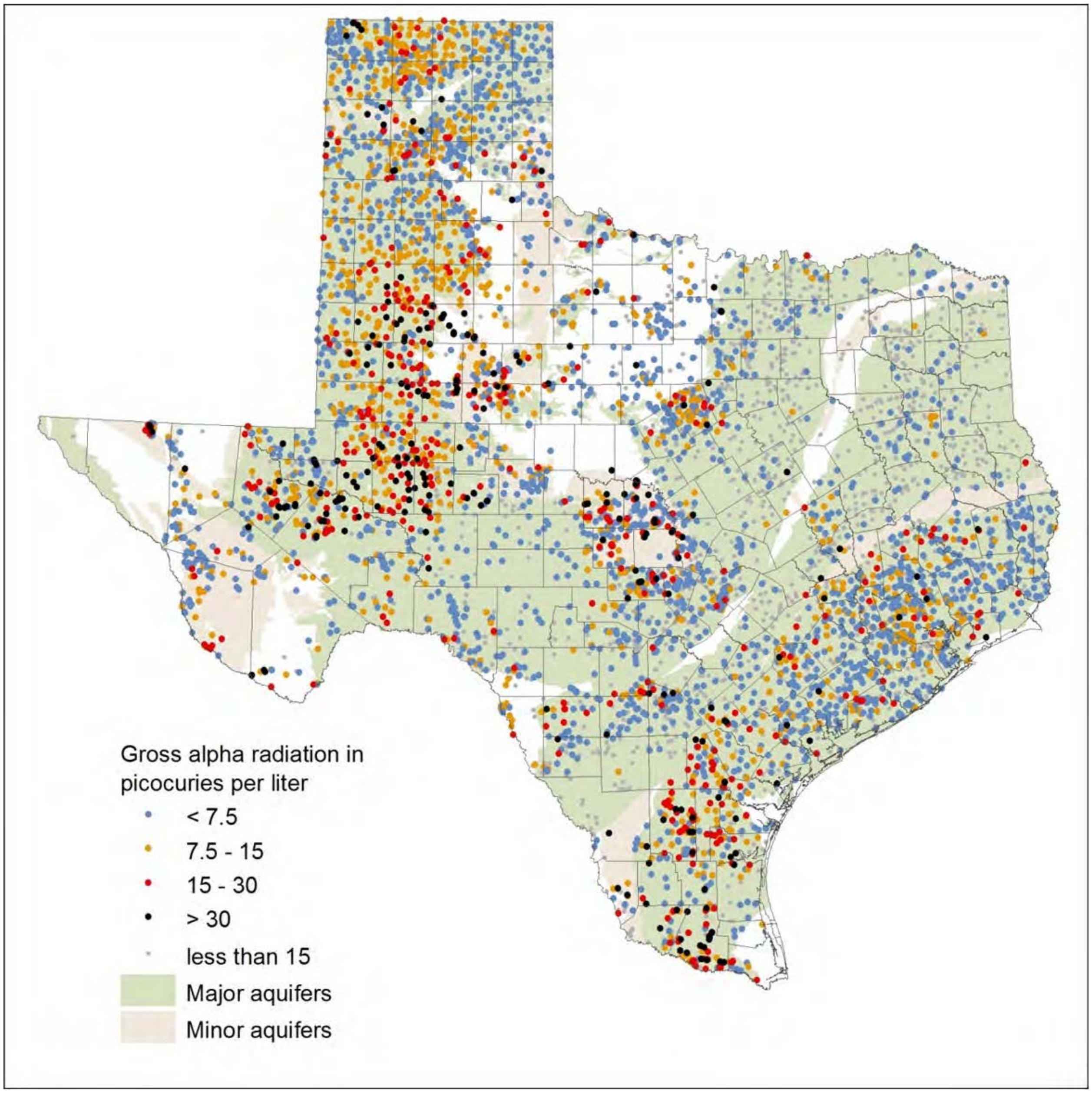

Figure 17. Gross alpha radiation activity in Texas groundwater. Colored symbols indicate detected concentrations within indicated ranges. Smaller gray symbols and associated less than values indicate non-detects below the indicated detection limit concentration. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

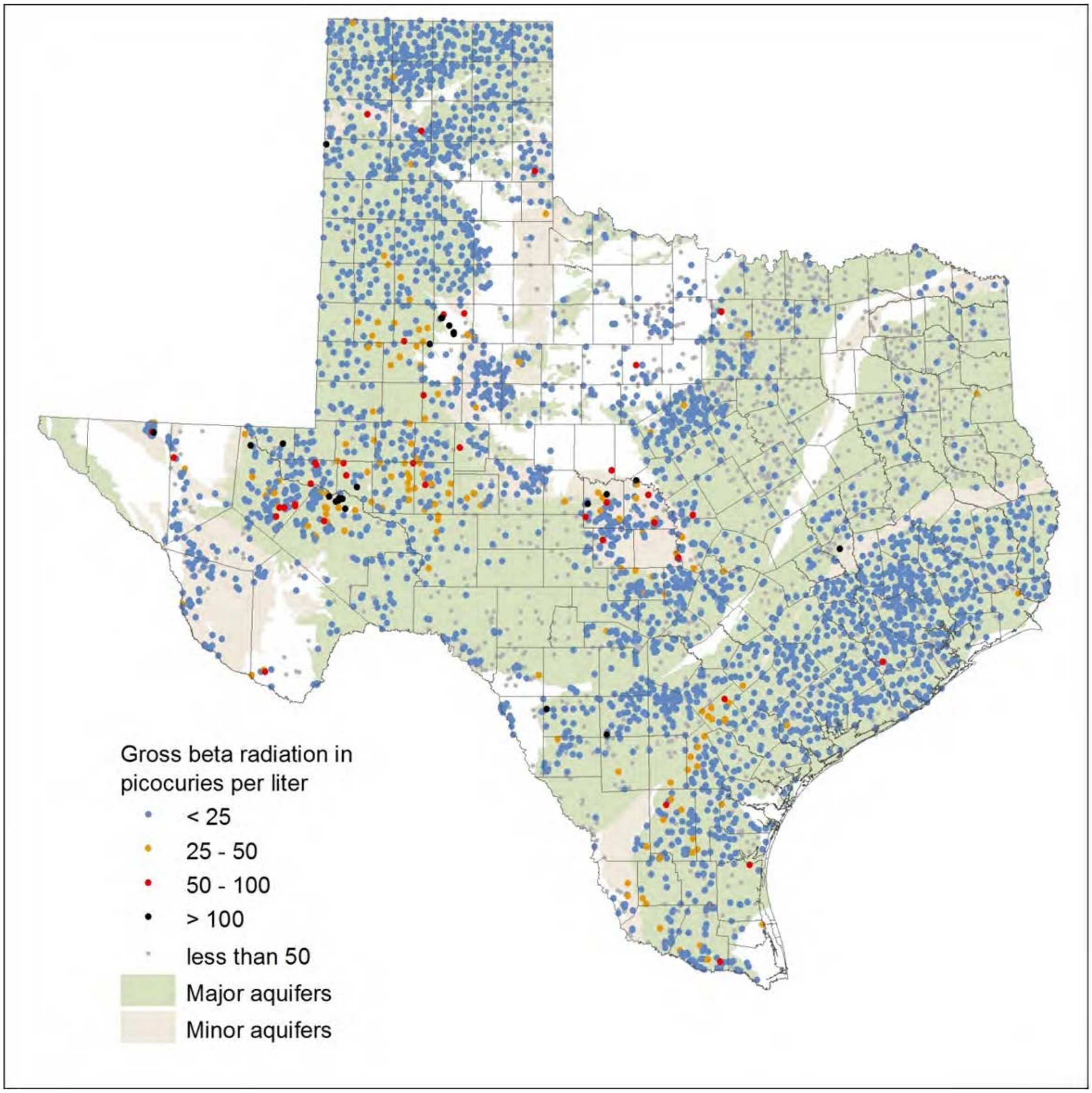

Figure 18. Gross beta radiation activity in Texas groundwater. Colored symbols indicate detected concentrations within indicated ranges. Smaller gray symbols and associated less than values indicate non-detects below the indicated detection limit concentration. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

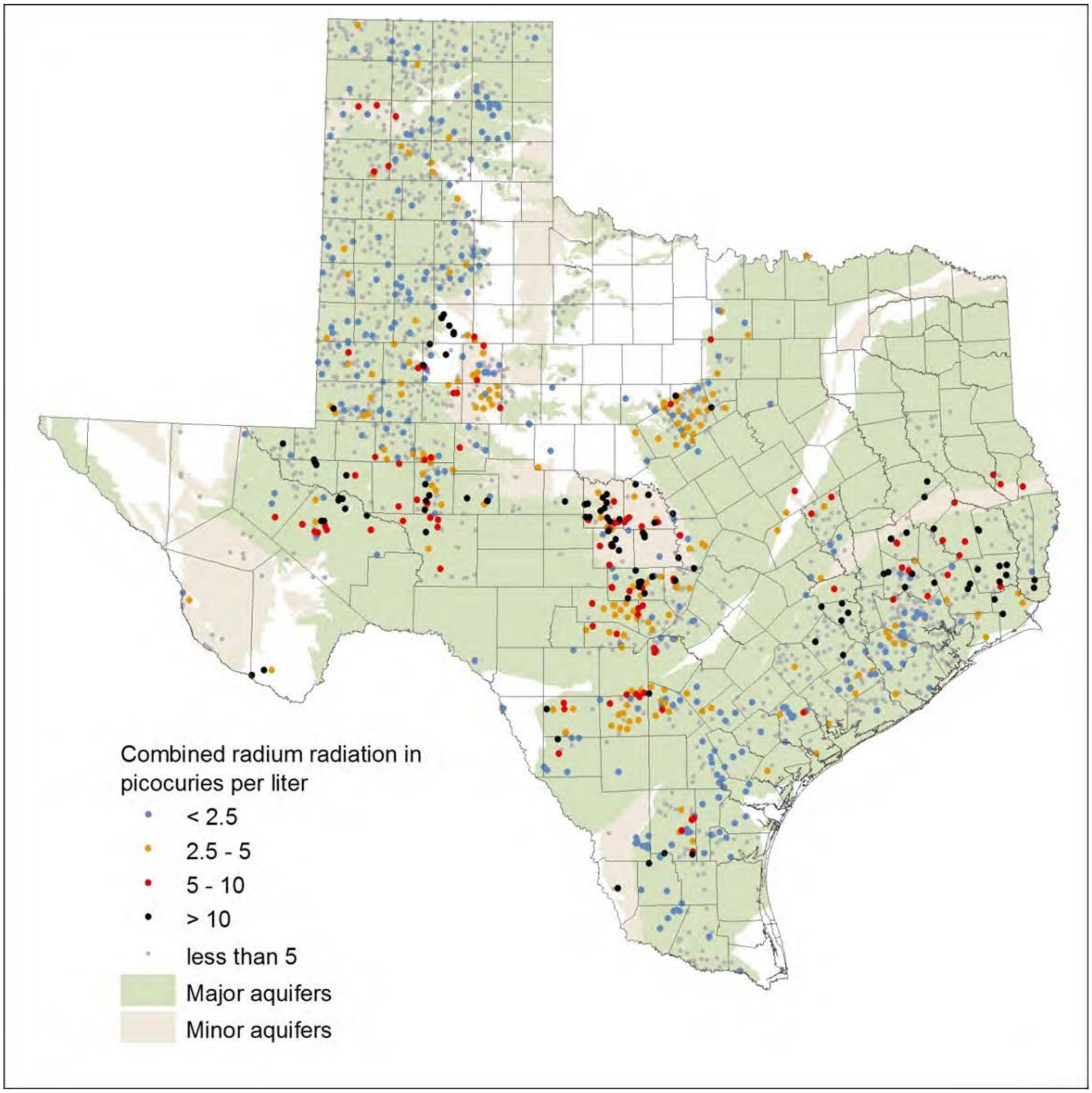

Figure 19. Combined radium radiation activity in Texas groundwater. Colored symbols indicate detected concentrations within indicated ranges. Smaller gray symbols and associated less than values indicate non-detects below the indicated detection limit concentration. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

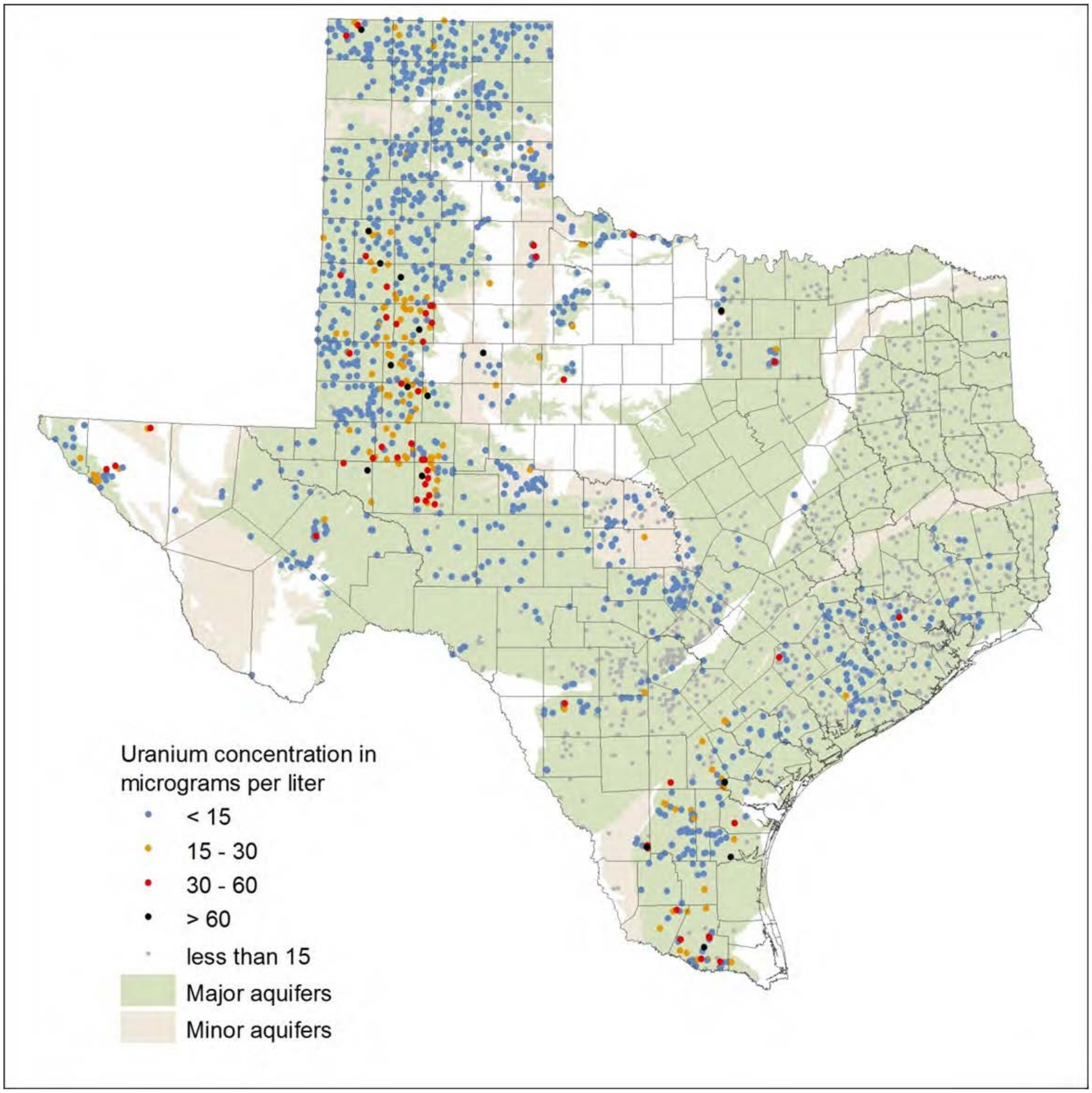

Figure 20. Uranium concentrations in Texas groundwater. Colored symbols indicate detected concentrations within indicated ranges. Smaller gray symbols and associated less than values indicate non-detects below the indicated detection limit concentration. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

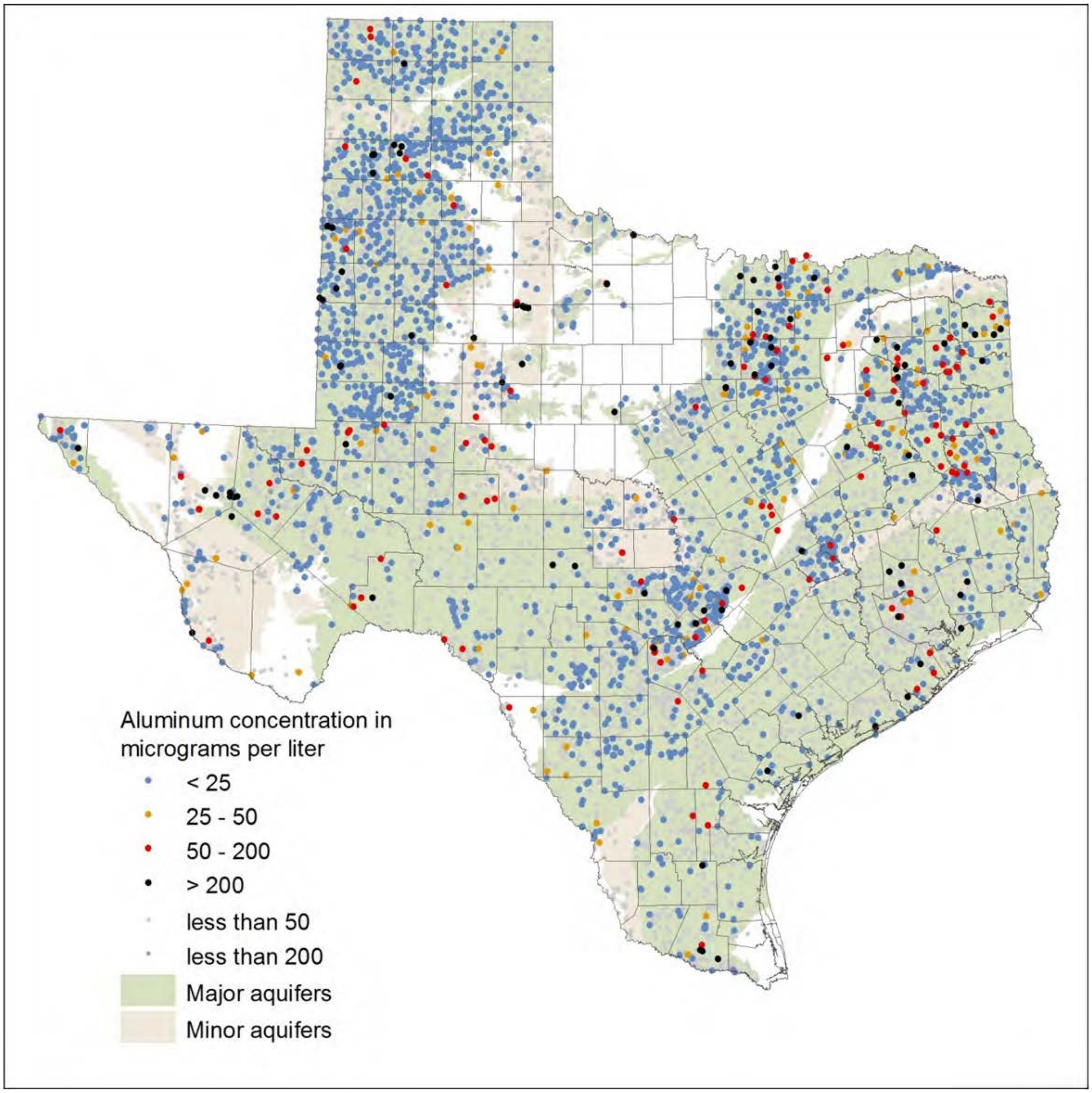

Figure 21. Aluminum concentrations in Texas groundwater. Colored symbols indicate detected concentrations within indicated ranges. Smaller gray symbols and associated less than values indicate non-detects below the indicated detection limit concentration. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

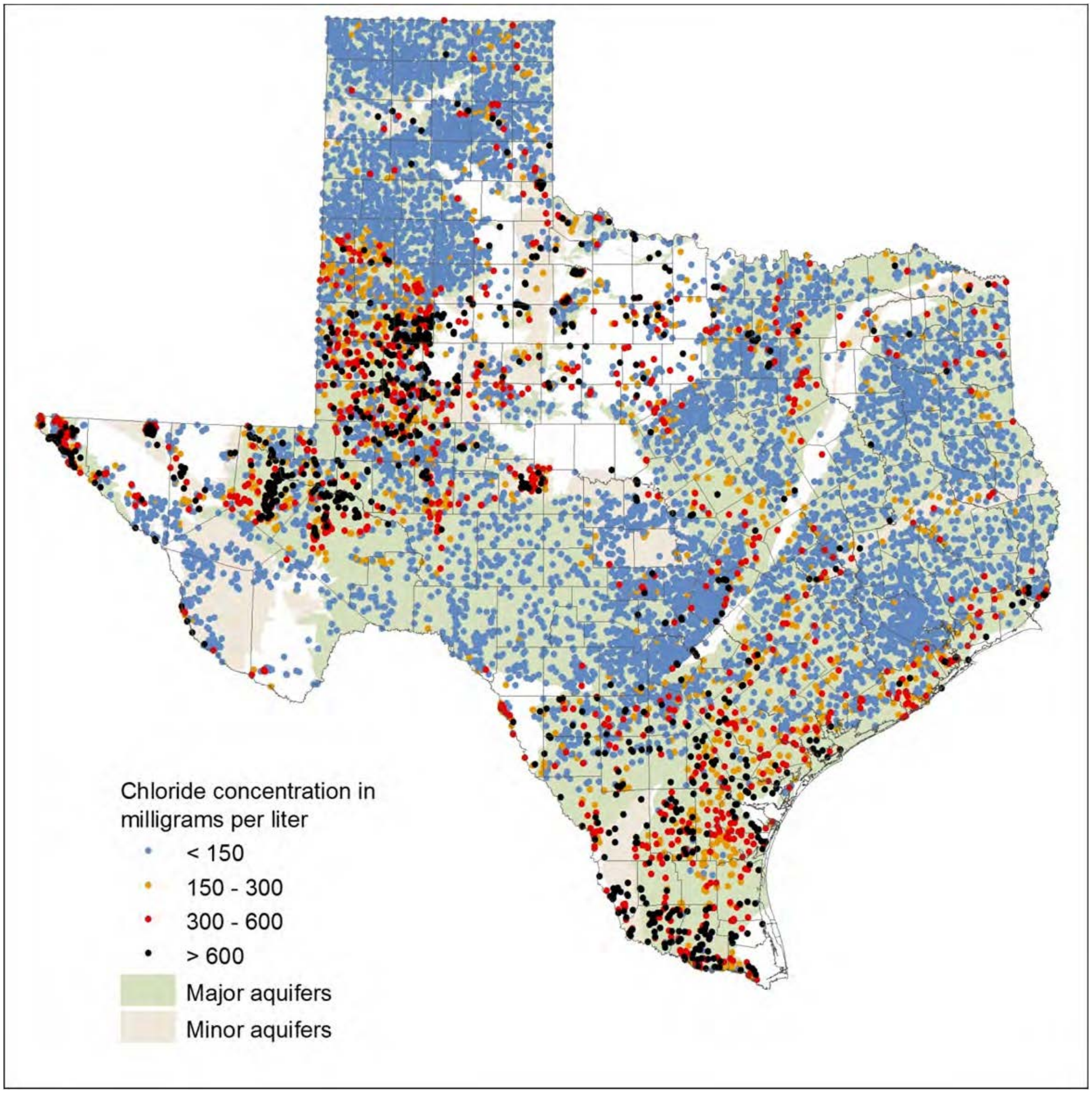

Figure 22. Chloride concentrations in Texas groundwater. Colored symbols indicate detected concentrations within indicated ranges. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

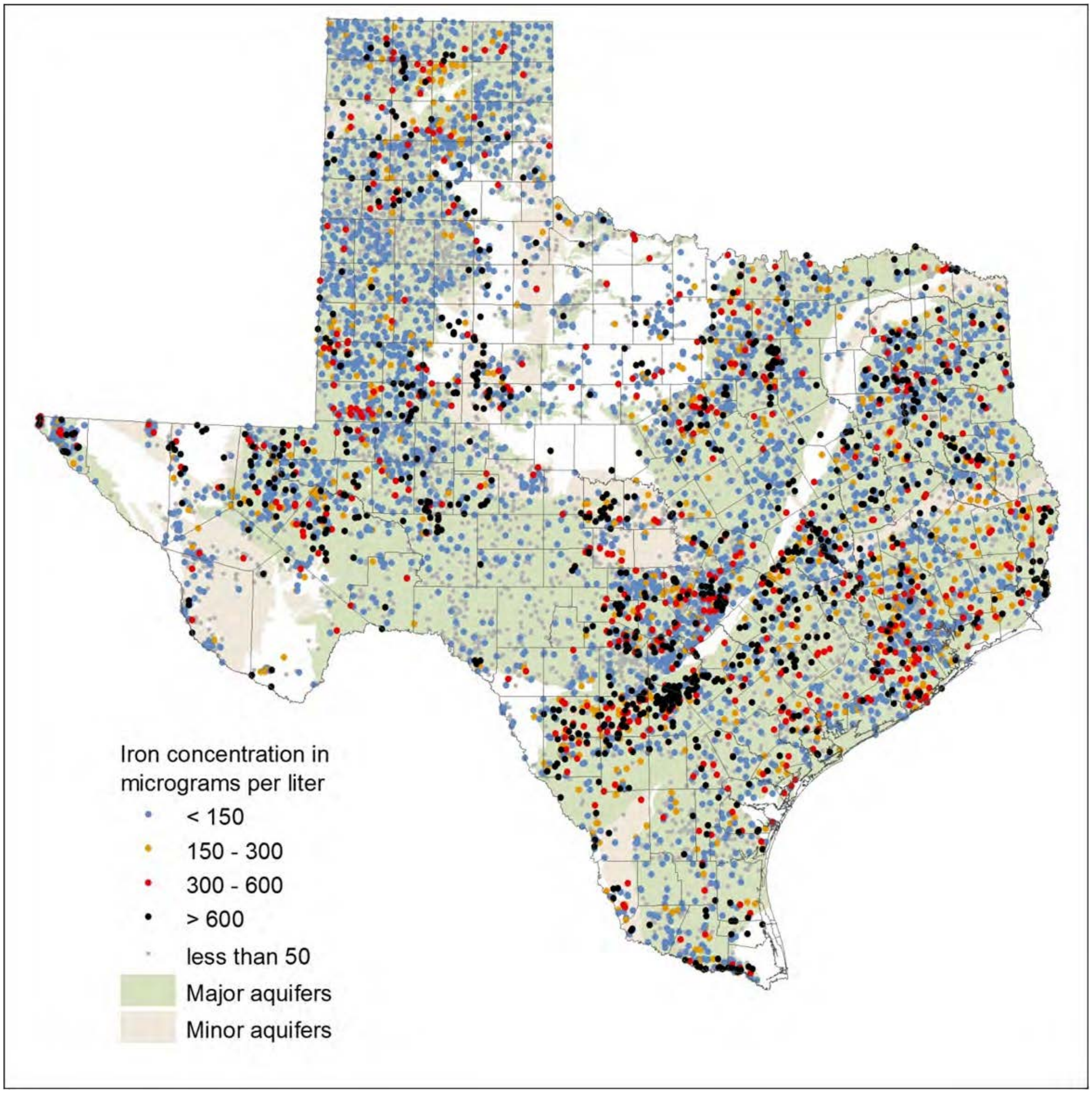

Figure 23. Iron concentrations in Texas groundwater. Colored symbols indicate detected concentrations within indicated ranges Smaller gray symbols and associated less than values indicate non-detects below the indicated detection limit concentration. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

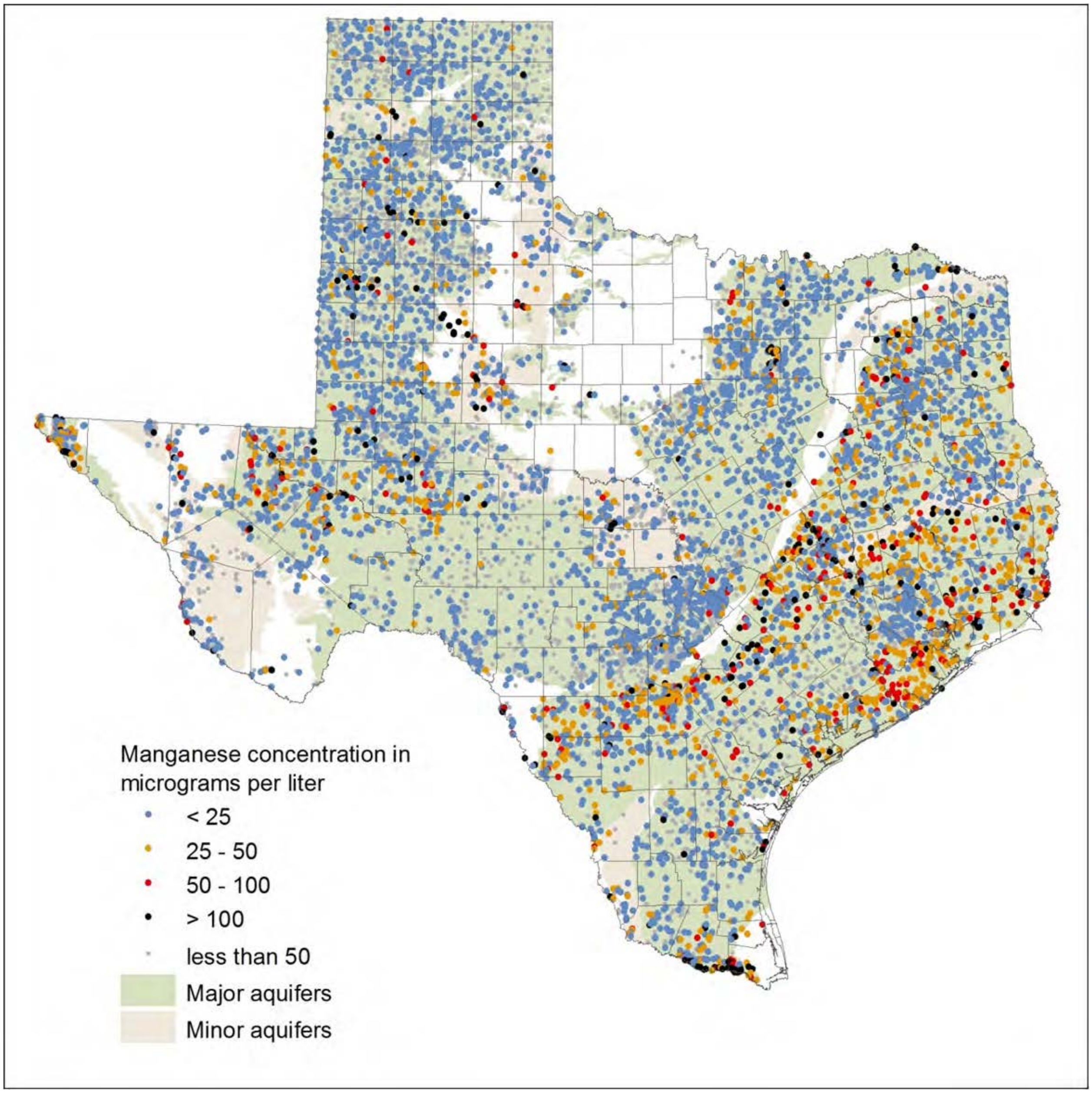

Figure 24. Manganese concentrations in Texas groundwater. Colored symbols indicate detected concentrations within indicated ranges. Smaller gray symbols and associated less than values indicate non-detects below the indicated detection limit concentration. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

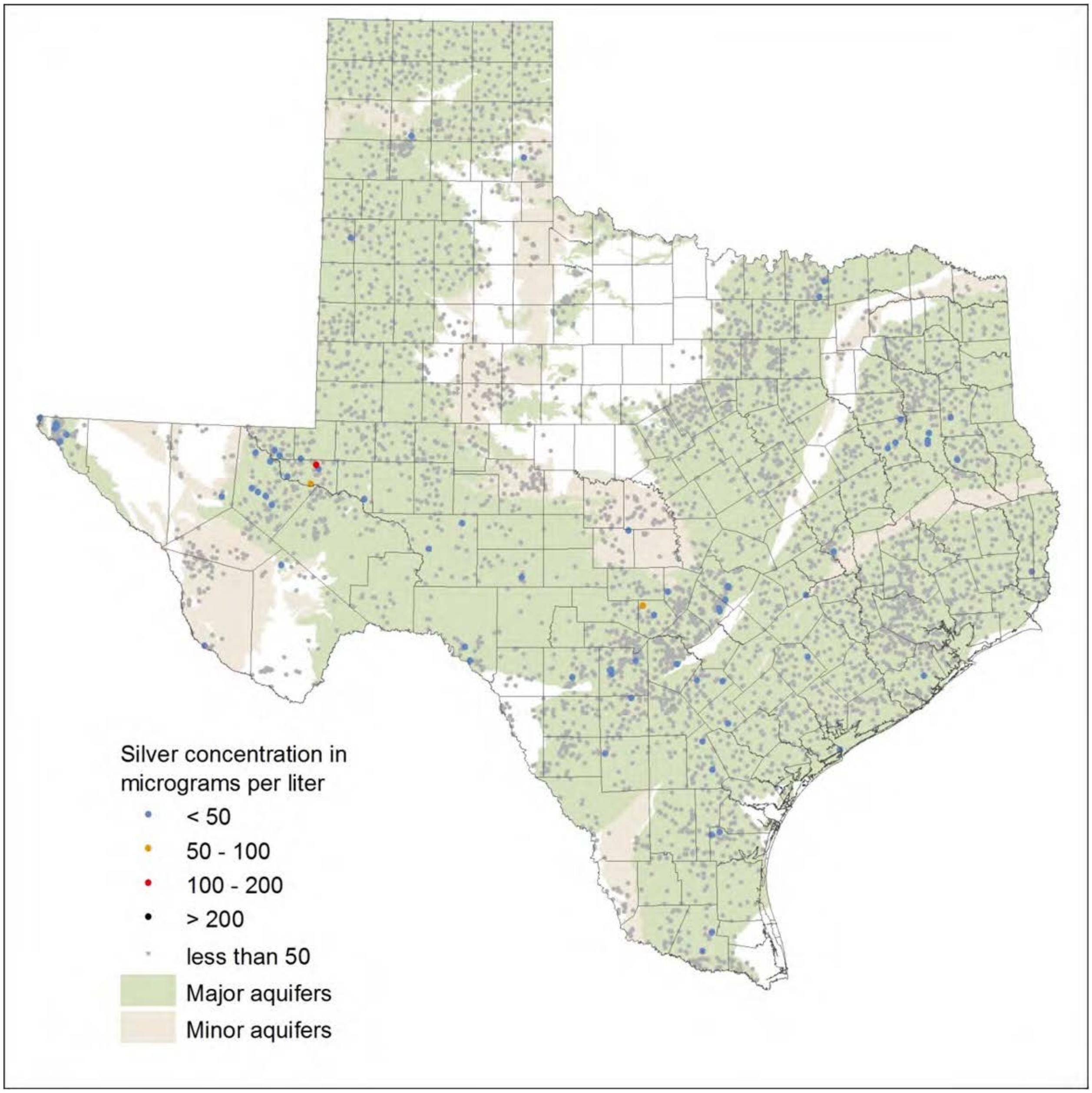

Figure 25. Silver concentrations in Texas groundwater. Colored symbols indicate detected concentrations within indicated ranges. Smaller gray symbols and associated less than values indicate non-detects below the indicated detection limit concentration. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

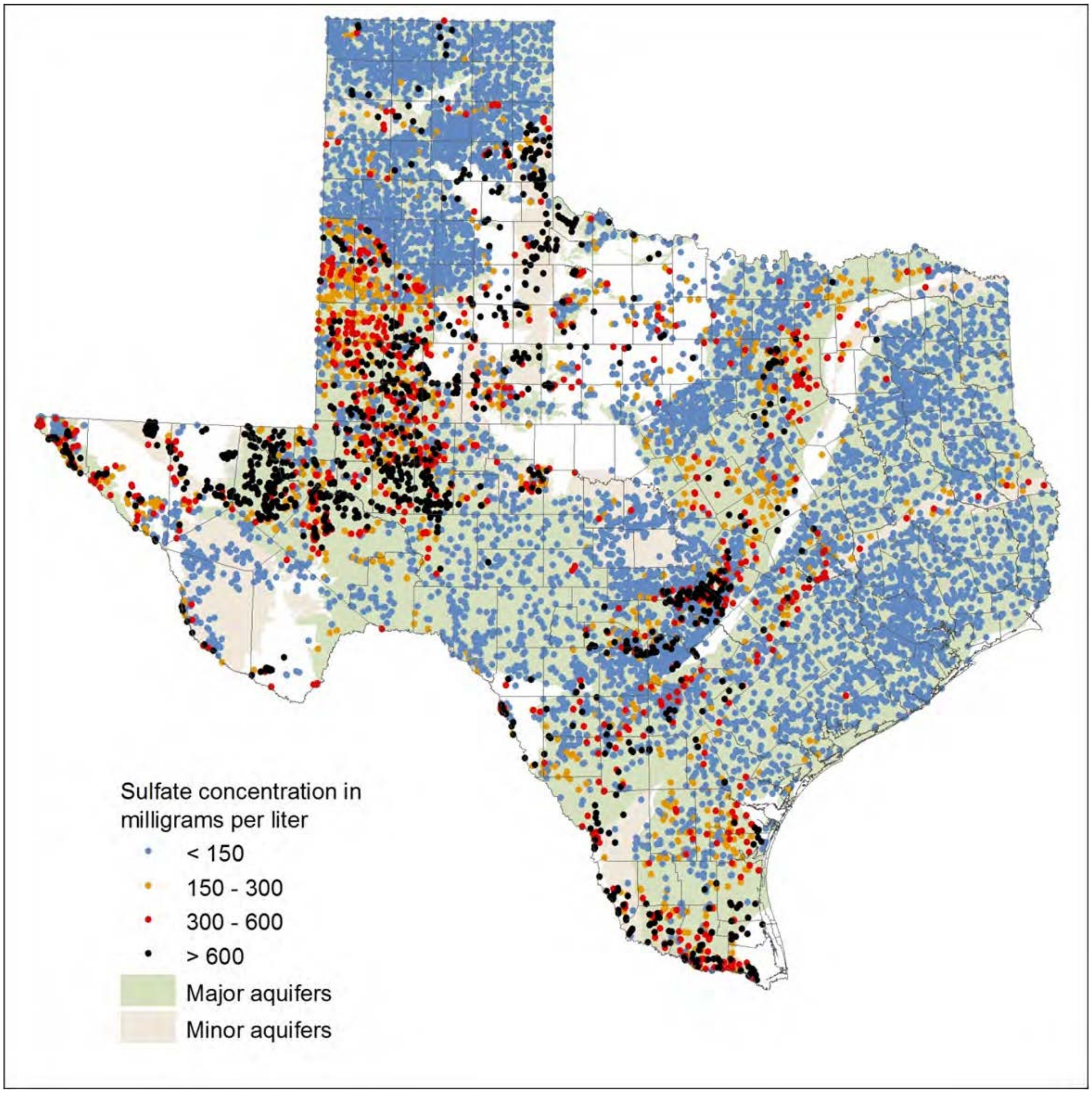

Figure 26. Sulfate concentrations in Texas groundwater. Colored symbols indicate detected concentrations within indicated ranges. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

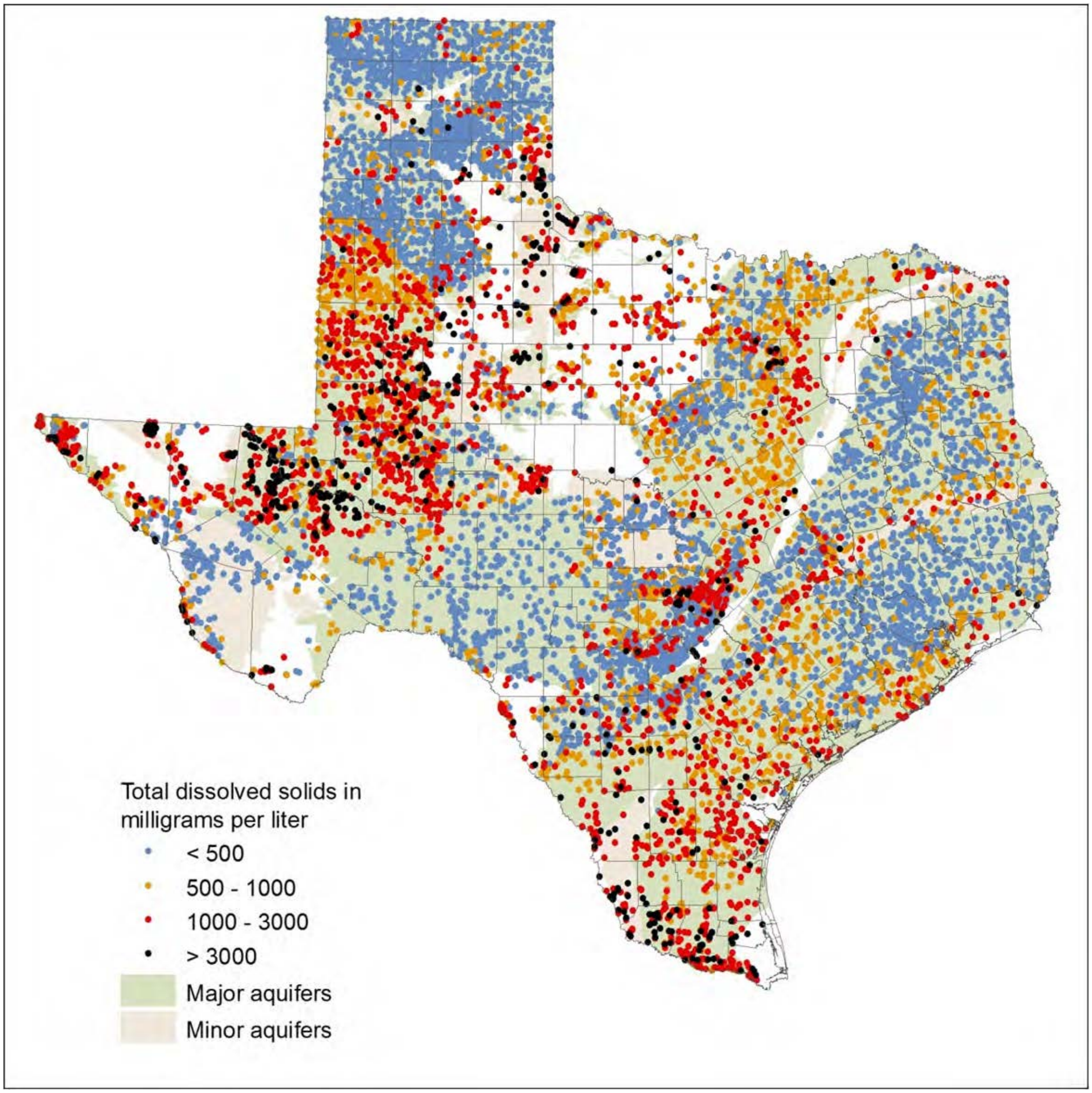

Figure 27. Total dissolved solids concentrations in Texas groundwater. Colored symbols indicate detected concentrations within indicated ranges. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

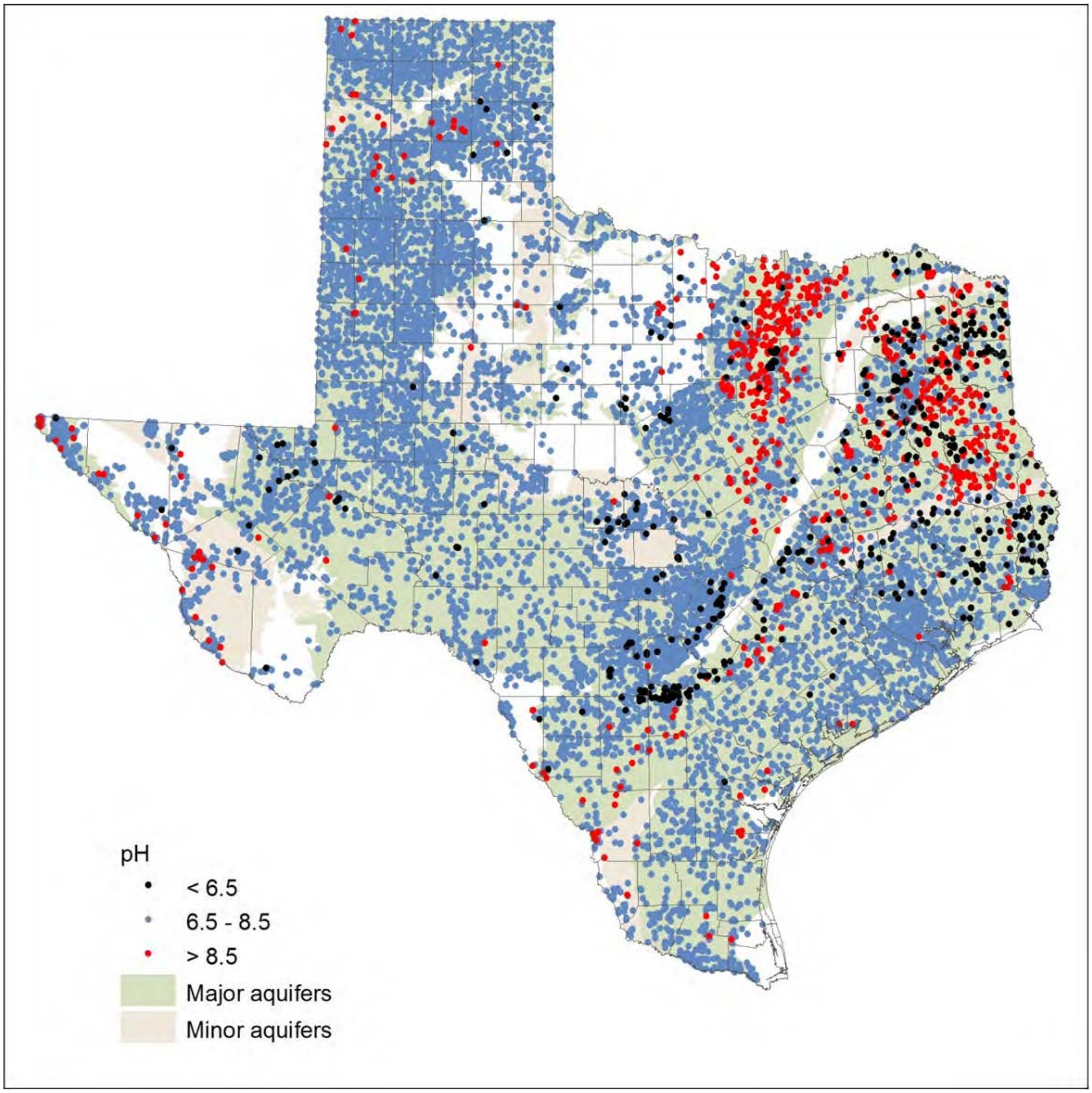

Figure 28. pH values in Texas groundwater. Colored symbols indicate detected values within indicated ranges. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

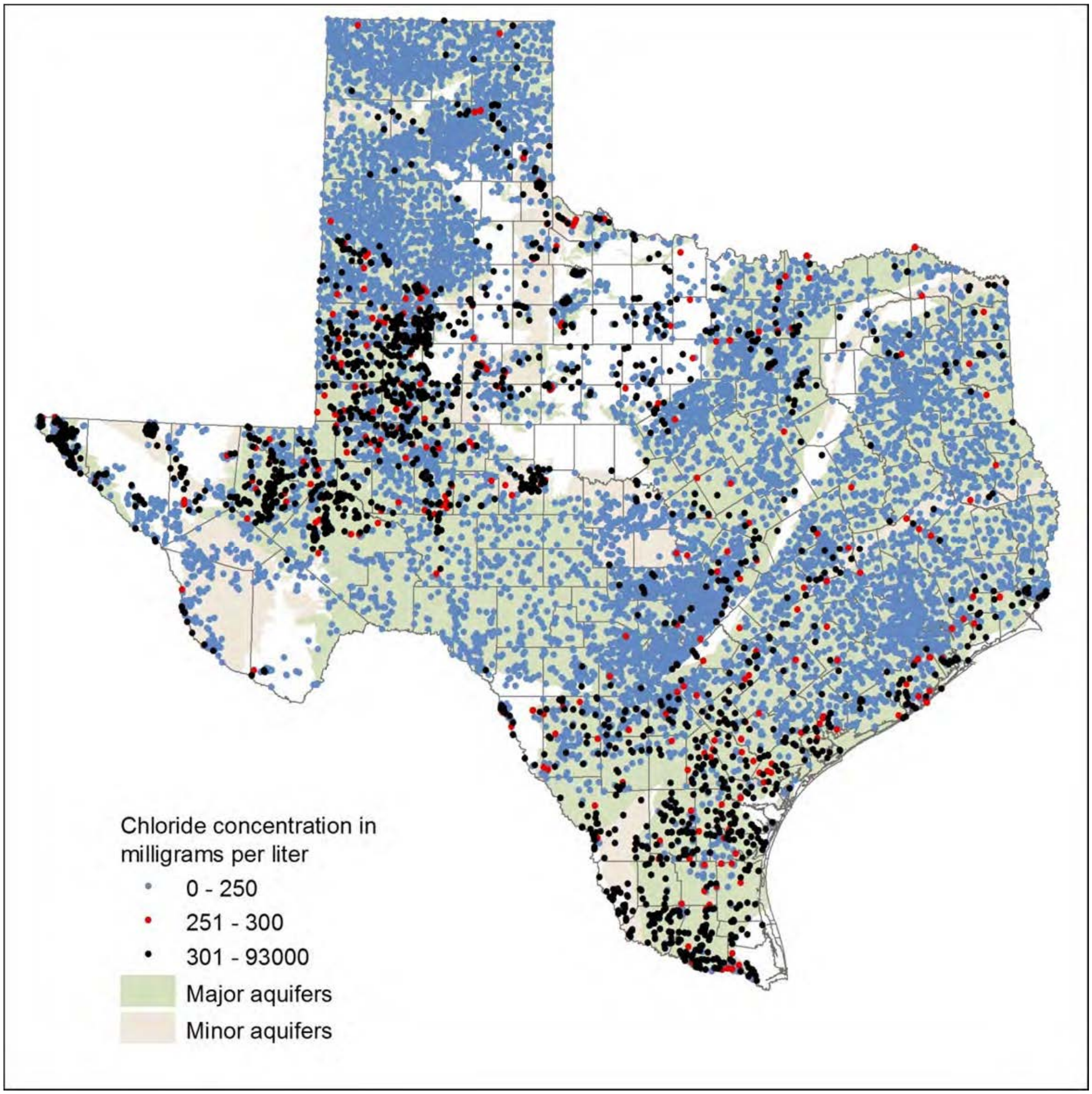

Figure 85. Treatment-limiting concentrations of chloride in Texas groundwater. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

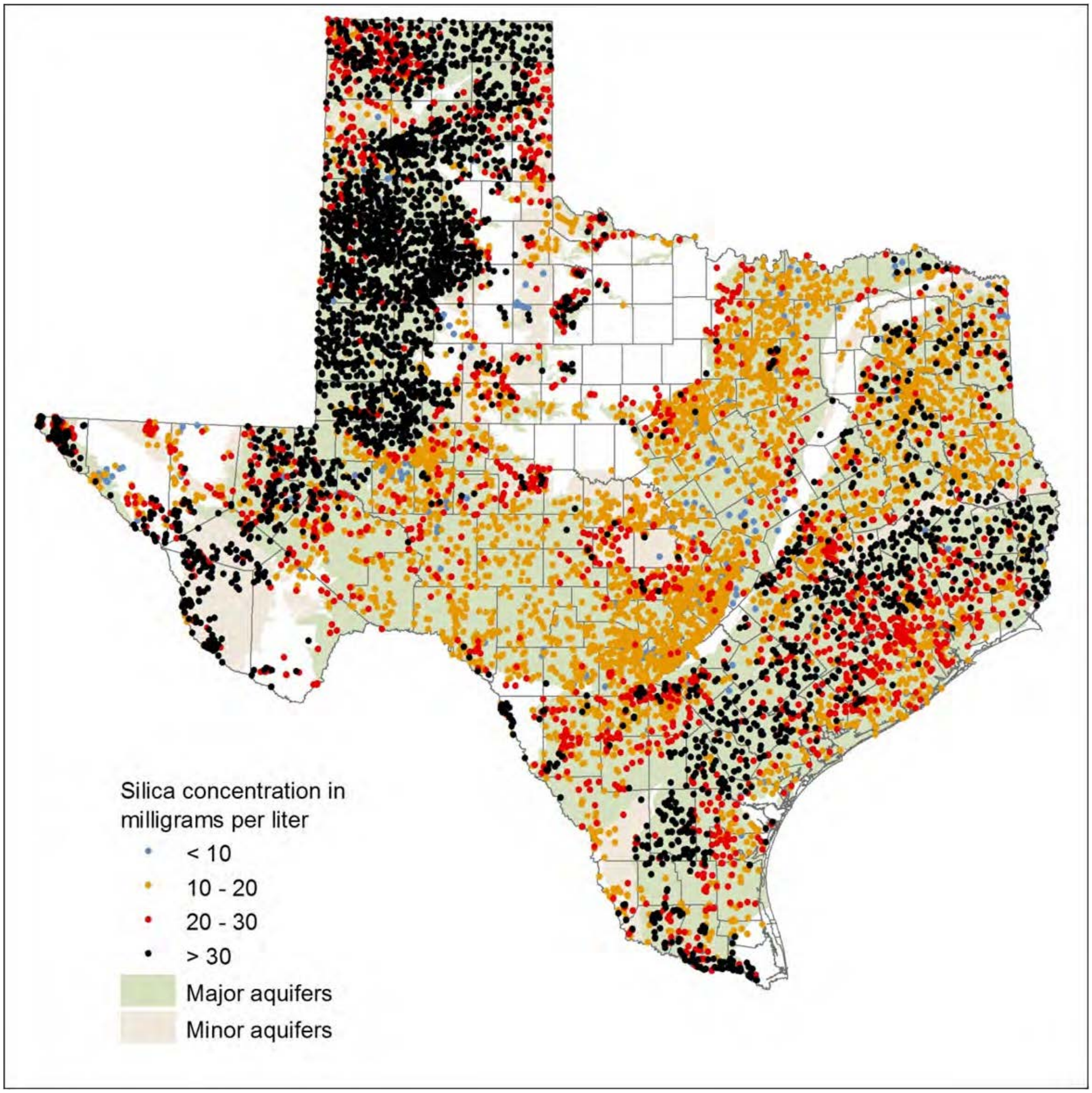

Figure 86. Treatment-limiting concentrations of silica in Texas groundwater. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

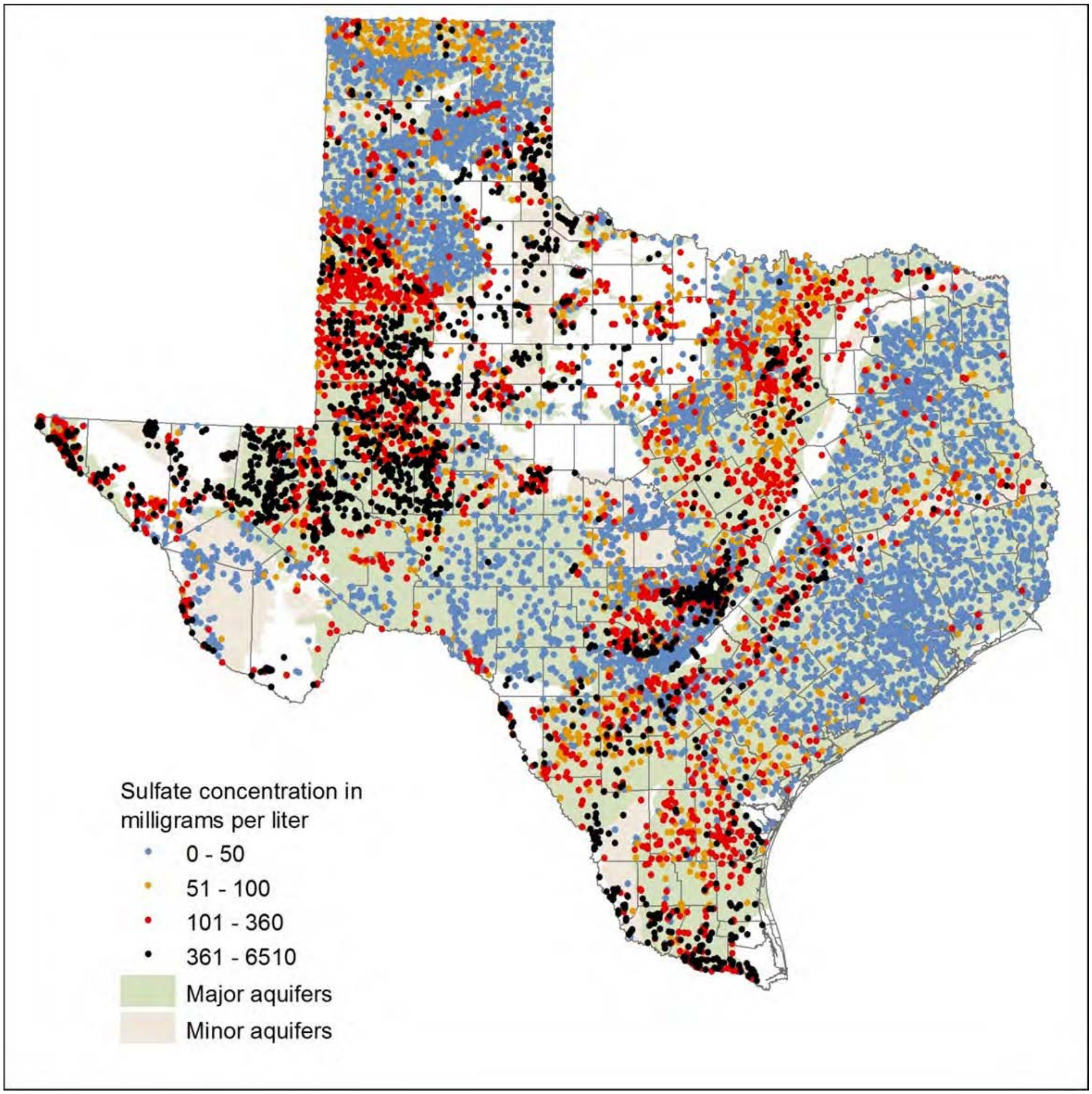

Figure 87. Treatment-limiting concentrations of sulfate in Texas groundwater. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

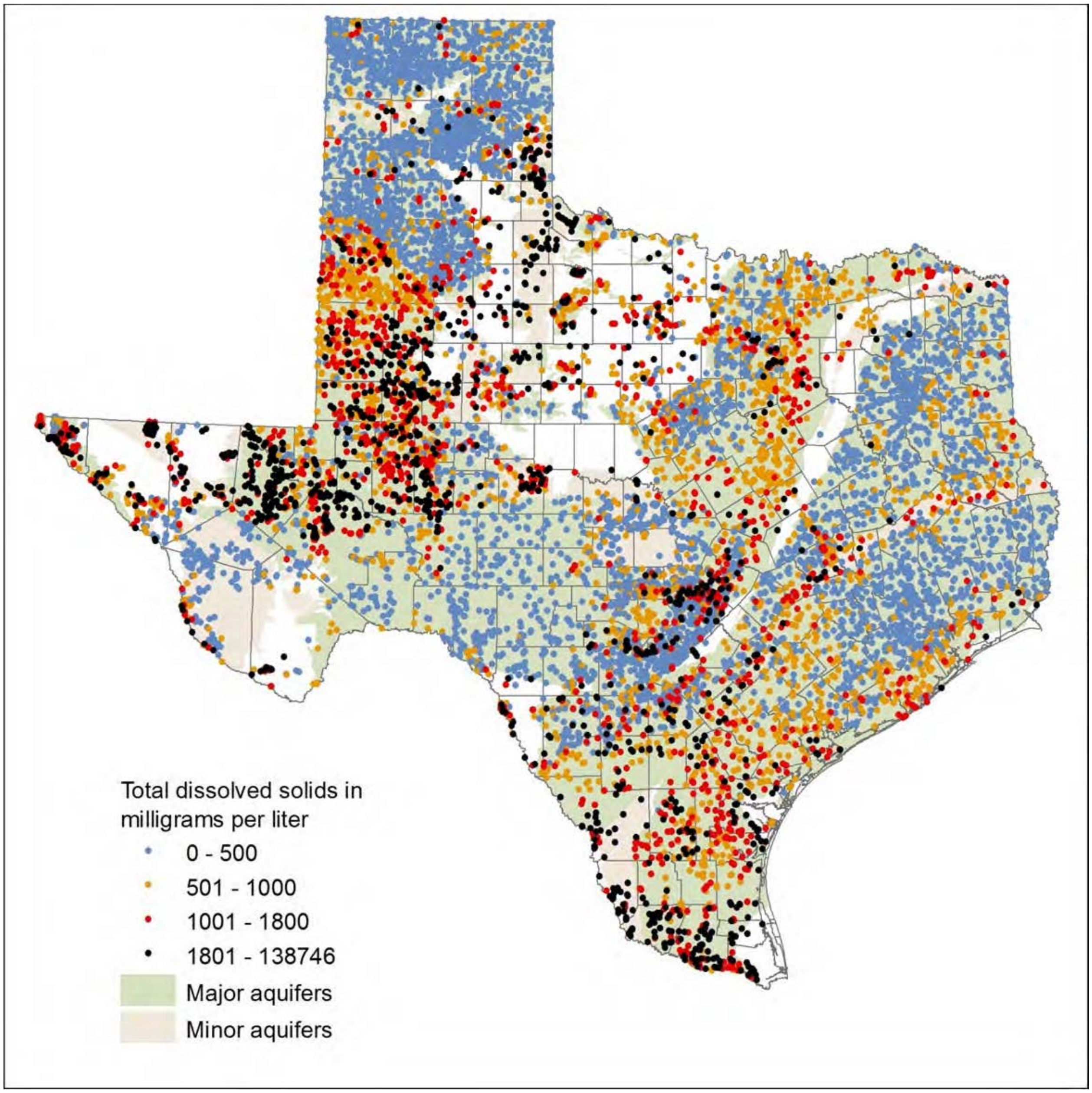

Figure 88. Treatment-limiting concentrations of TDS in Texas groundwater. Prepared by BEG for TWDB contract #1004831125, with data from TWDB, 2011.

EXHIBIT B

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Secondary Drinking Water Standards		
Constituent	**SMCL**	**SCL**
TDS (mg/L)	500	1000

SMCL = secondary maximum contaminant level (EPA)

SCL = secondary contaminant level (Texas)

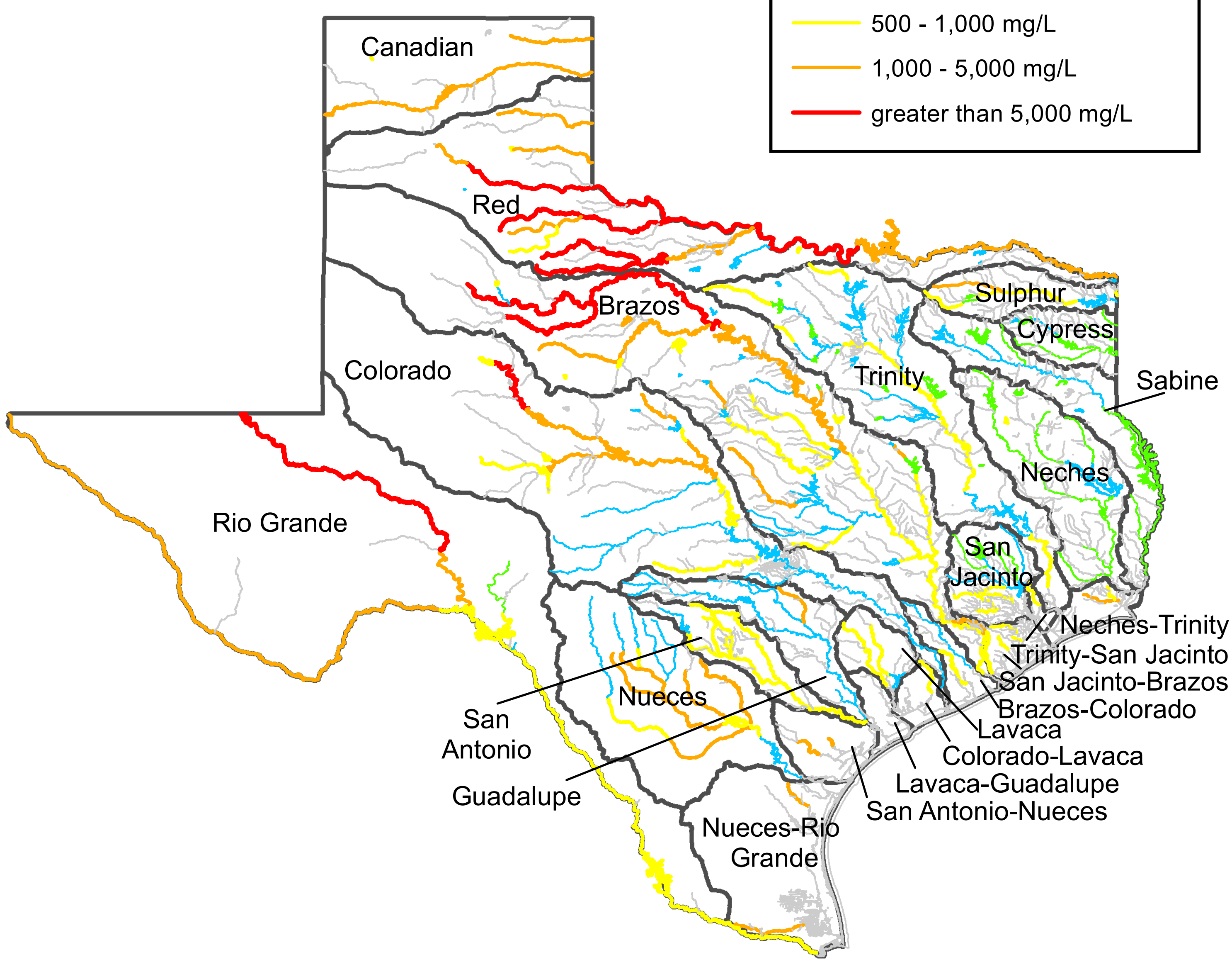

Figure 1: Texas TDS Surface Water Quality Standards

N

0 50 100 200 300 Miles

Texas Water Development Board
DPR Research Study

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Secondary Drinking Water Standards		
Constituent	SMCL	SCL
Sulfate (mg/L)	250	300

SMCL = secondary maximum contaminant level (EPA)

SCL = secondary contaminant level (Texas)

Legend

Major River Basin Boundary

Sulfate Standard (mg/L)

- N/A
- 0 - 300 mg/L
- 300 - 500 mg/L
- 500 - 1,000 mg/L
- 1,000 - 5,000 mg/L
- greater than 5,000 mg/L

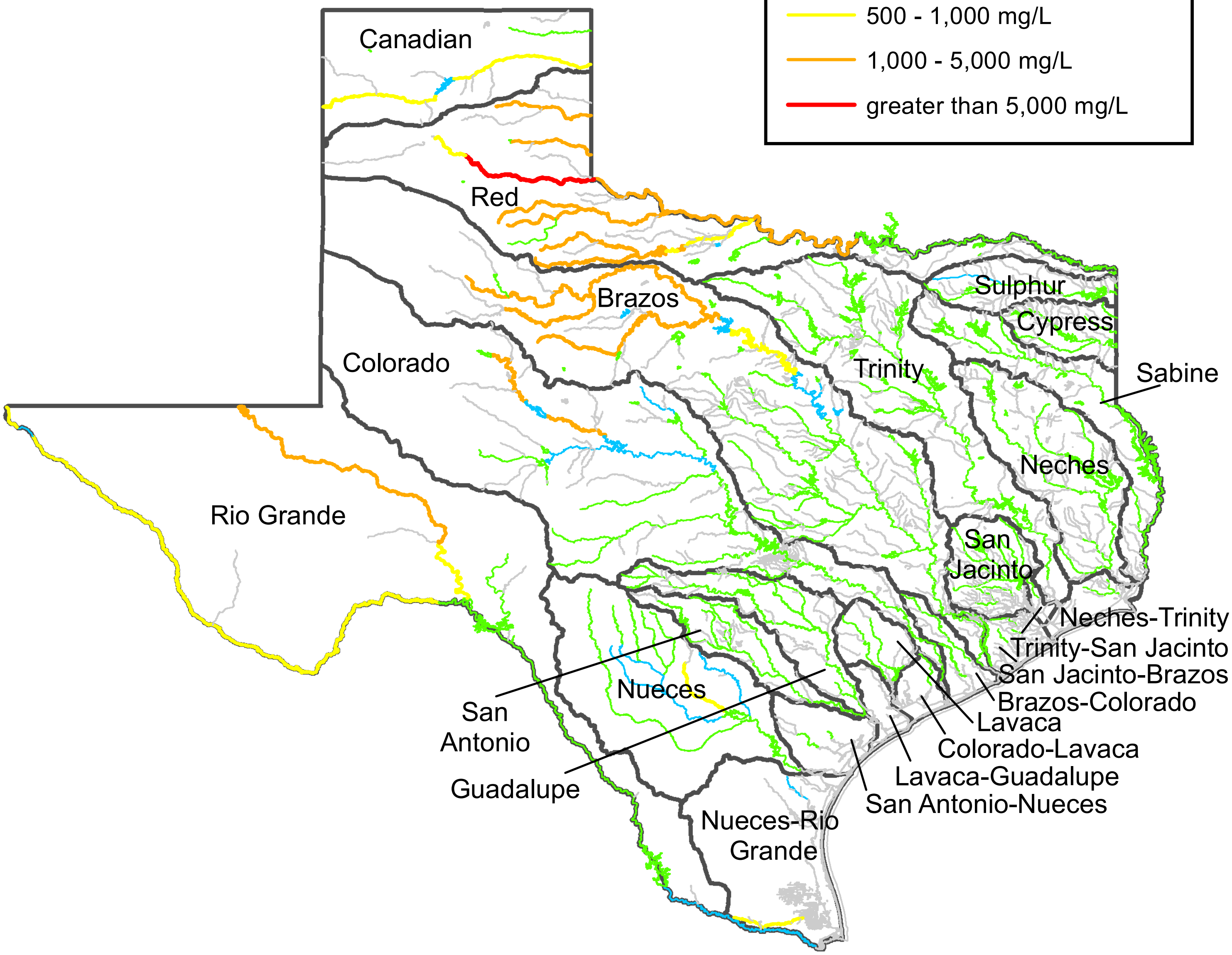

Figure 2: Texas Sulfate Surface Water Quality Standards

N

0 50 100 200 300 Miles

Texas Water Development Board
DPR Research Study

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Secondary Drinking Water Standards		
Constituent	SMCL	SCL
Chloride (mg/L)	250	300

SMCL = secondary maximum contaminant level (EPA)

SCL = secondary contaminant level (Texas)

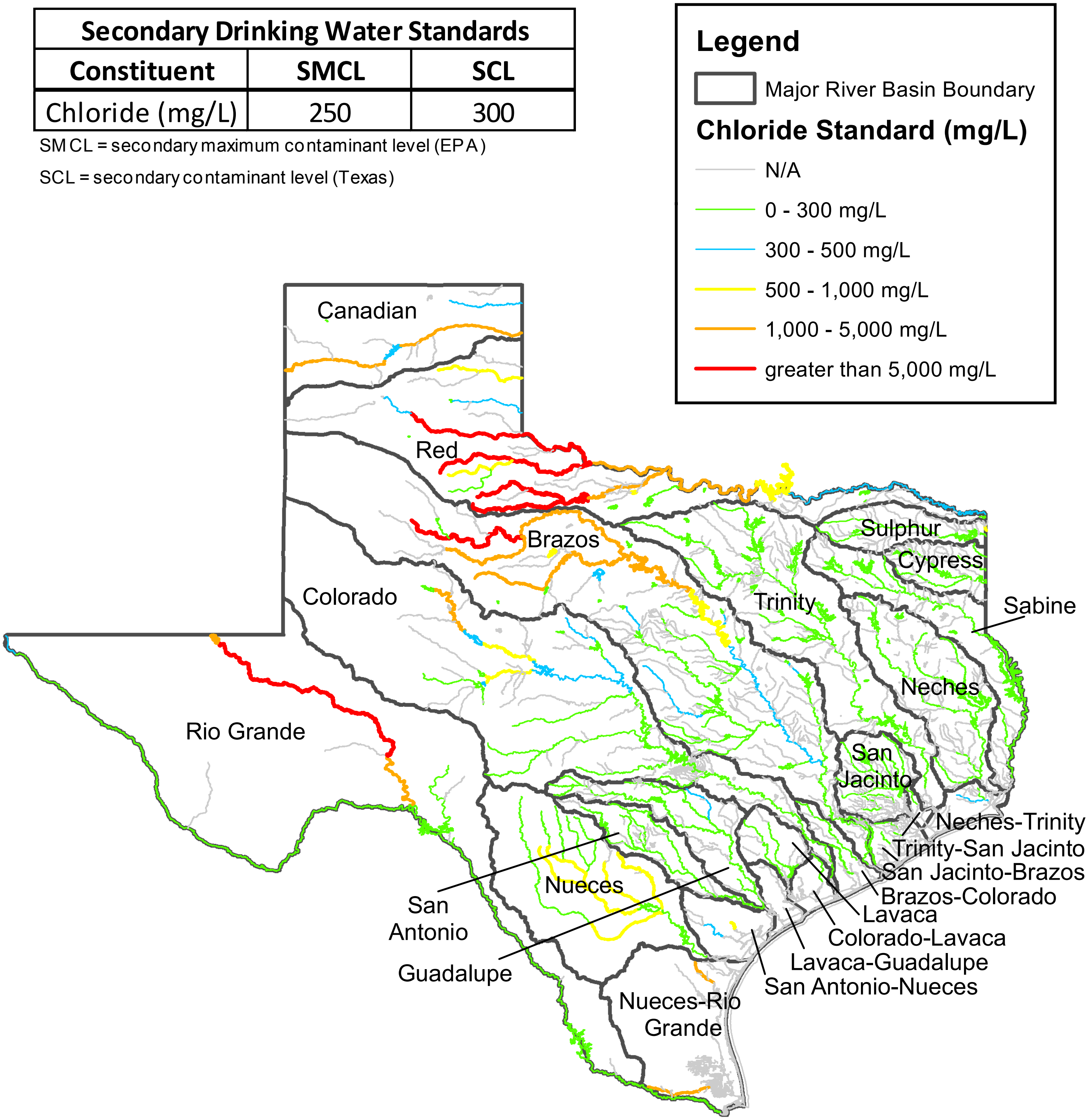

Figure 3: Texas Chloride Surface Water Quality Standards

Texas Water Development Board
DPR Research Study

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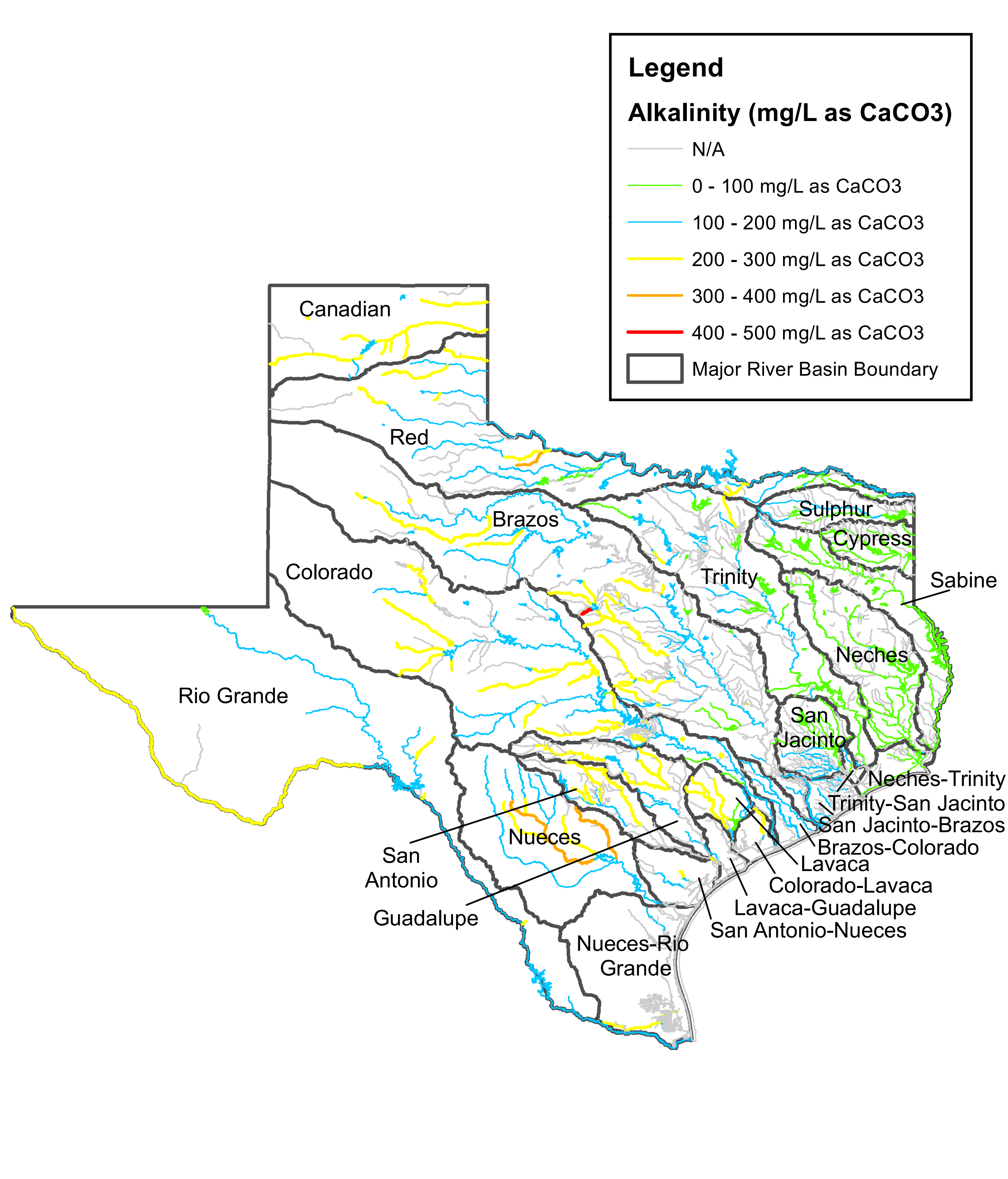

Figure 4: Average Texas Surface Water Quality Data - Alkalinity

N
0 50 100 200 300 Miles

Texas Water Development Board
DPR Research Study

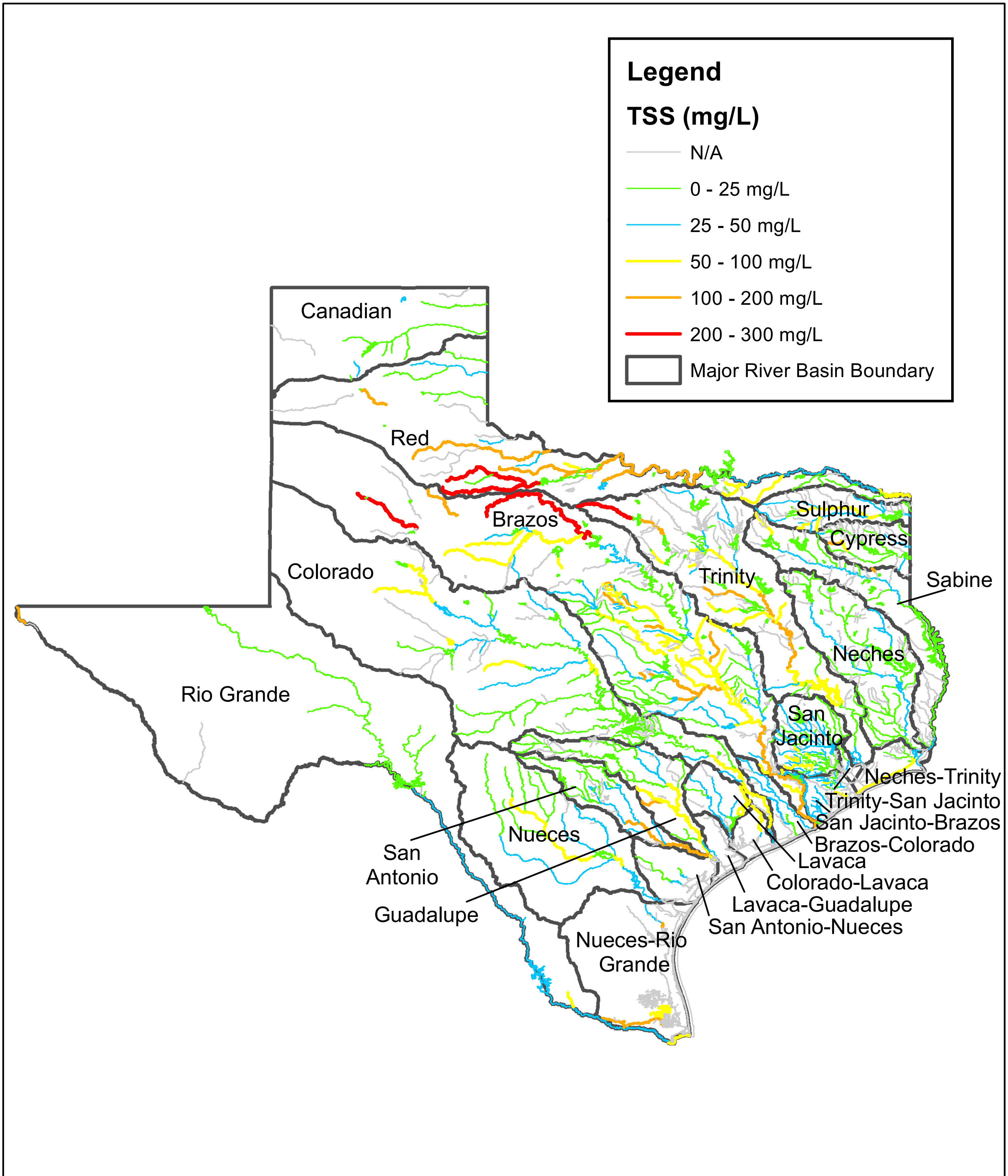

Figure 5: Average Texas Surface Water Quality Data - TSS

N
0 50 100 200 300 Miles

Texas Water Development Board
DPR Research Study

Path: F:\projects\0866\005-01\GIS\mxd\TSS.mxd

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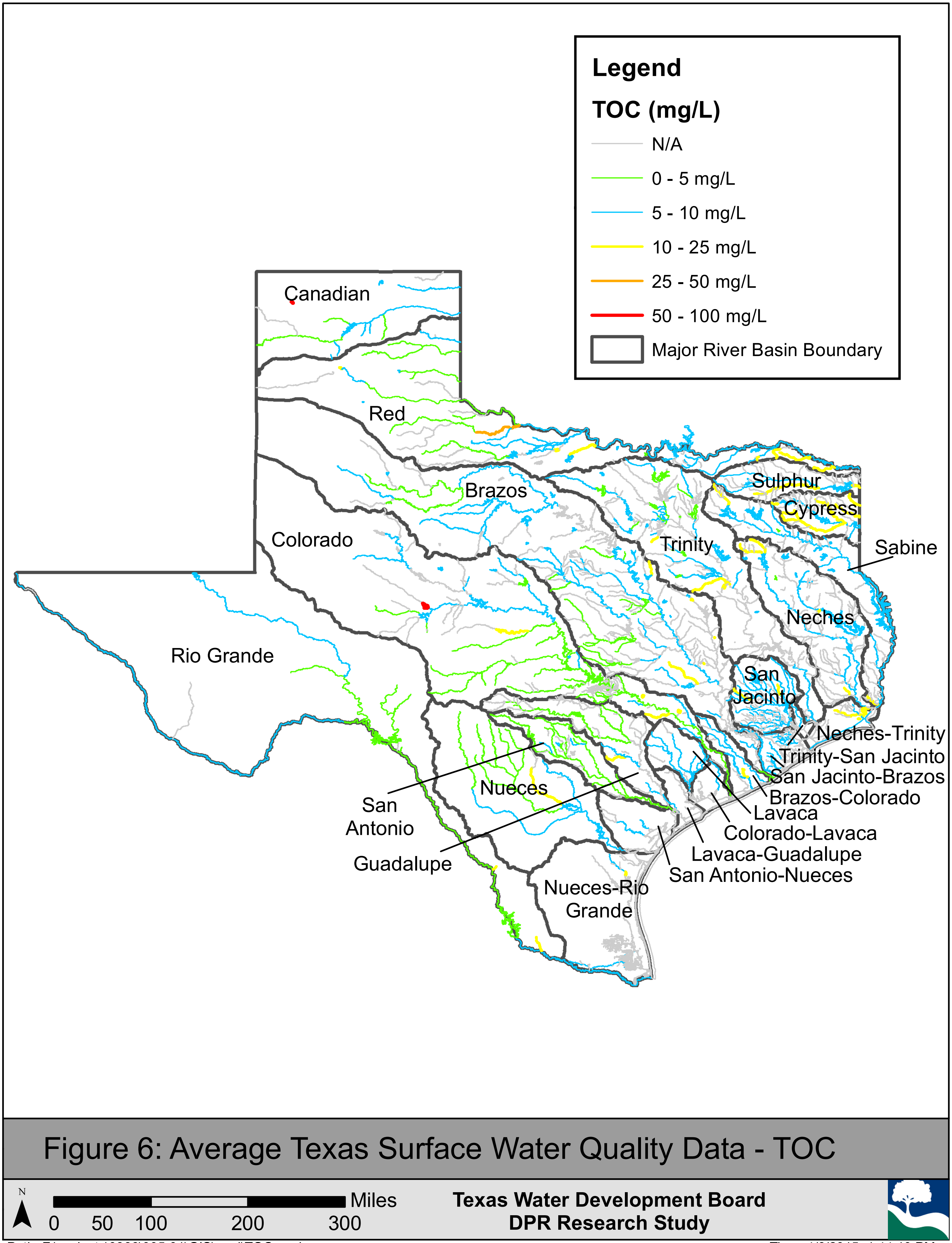

Figure 6: Average Texas Surface Water Quality Data - TOC

Texas Water Development Board
DPR Research Study

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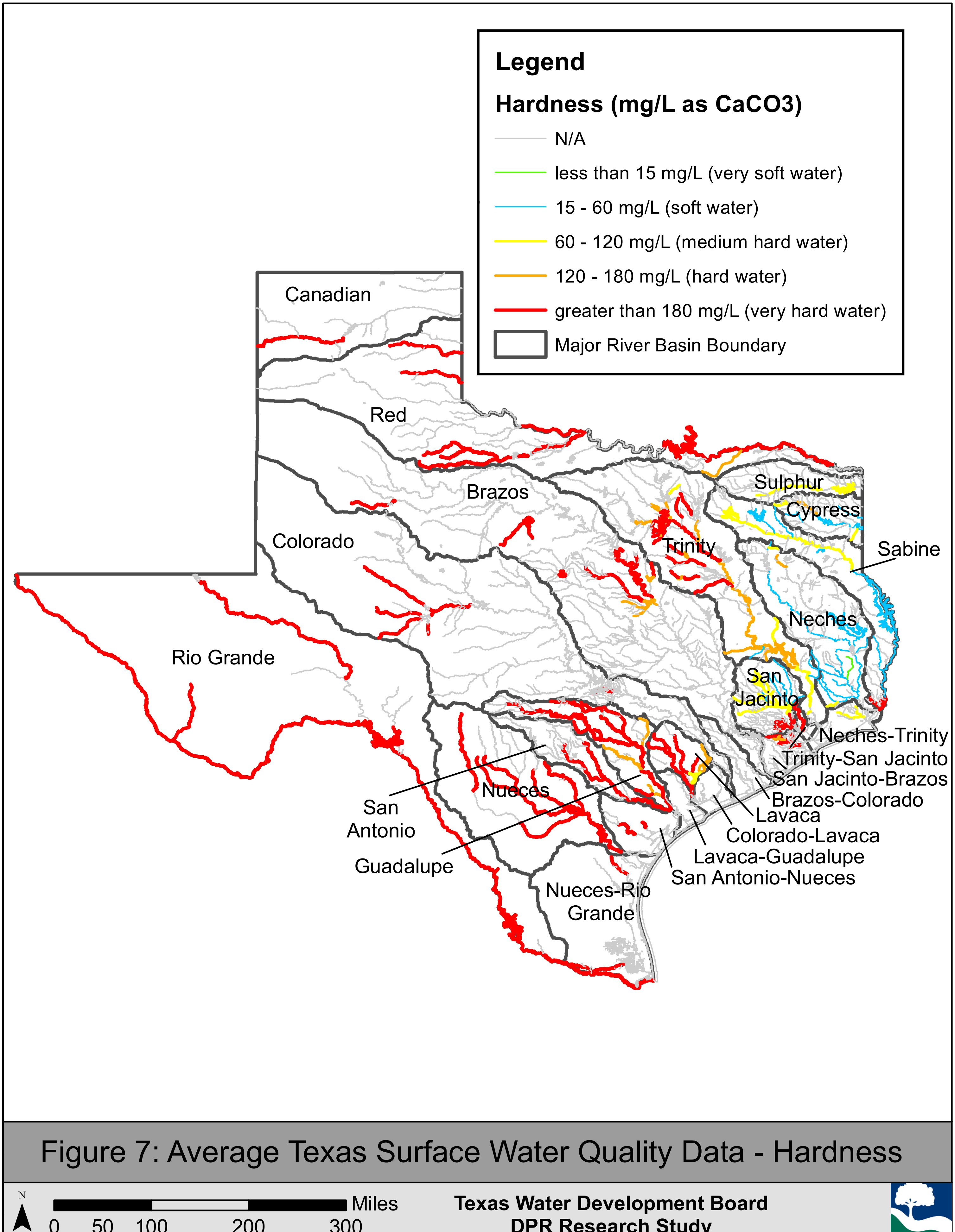

Figure 7: Average Texas Surface Water Quality Data - Hardness

Texas Water Development Board
DPR Research Study

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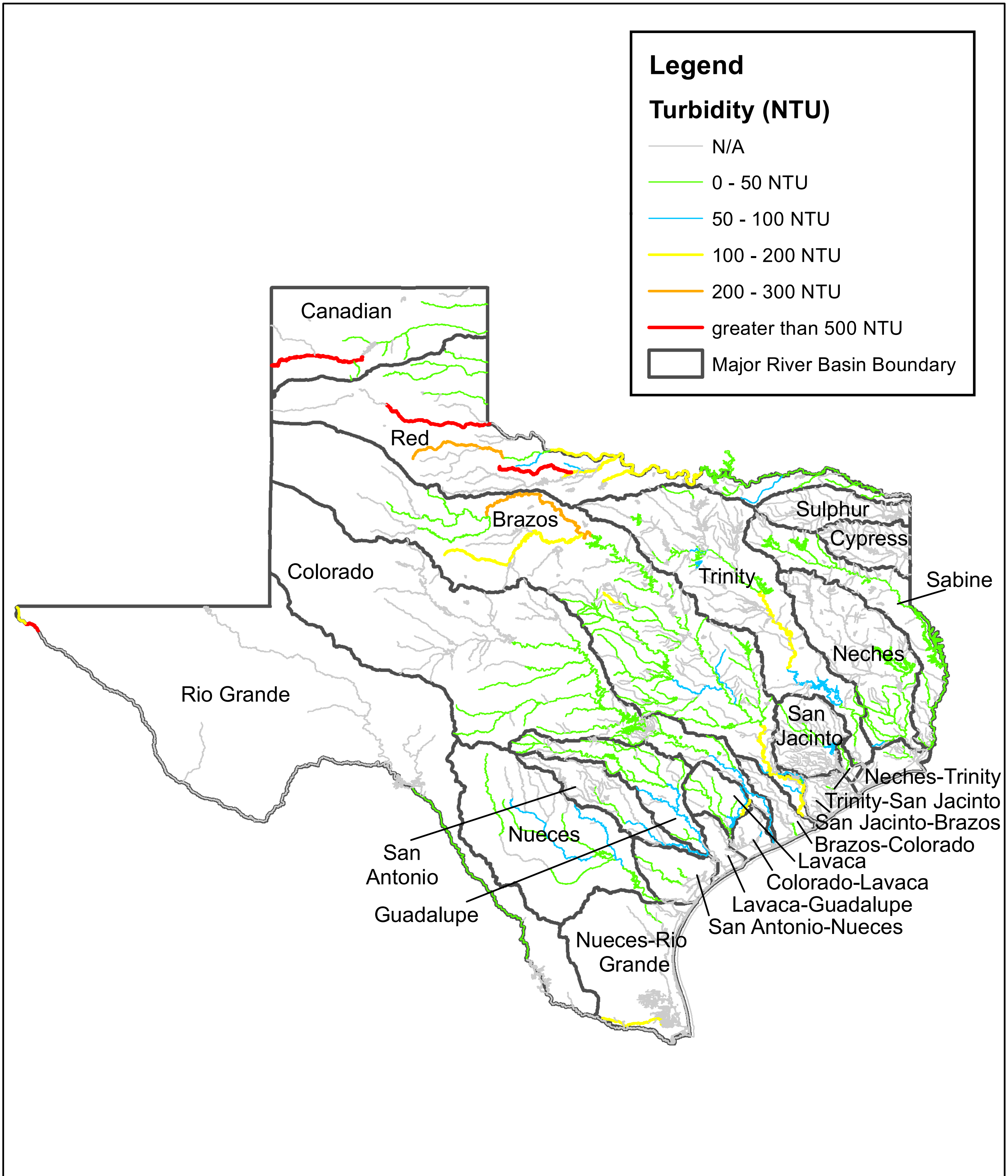

Figure 8: Average Texas Surface Water Quality Data - Turbidity

N
0 50 100 200 300 Miles

Texas Water Development Board
DPR Research Study

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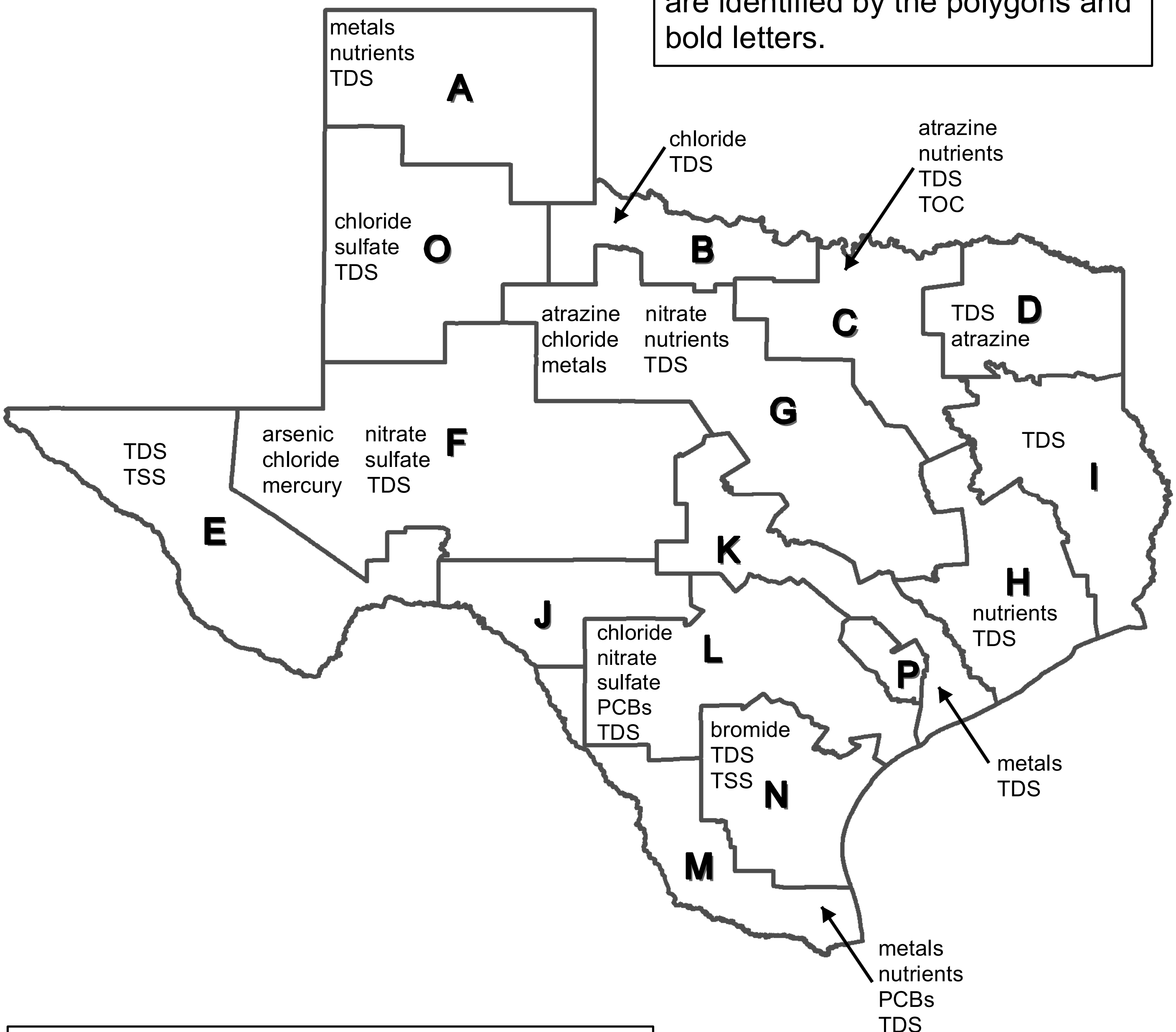
Regional water planning areas are identified by the polygons and bold letters.



Note: This map is intended to be schematic. Text shown reflects concerns identified for at least one water source within the region, not the region as a whole or the location where the text is specifically located.

Figure 9: Surface Water - Drinking Water Quality Considerations (as described in 2006 Regional Water Plans)

N

0 50 100 200 300 Miles

Texas Water Development Board
DPR Research Study

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EXHIBIT C

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TWDB Direct Potable Reuse Research Study
Available Sampling Methods

SamplingMethod	Sponsor	Parameter
EPA 524.2	3	1,1,1,2-Tetrachloroethane
EPA 524.2 Volatiles	10	1,1,1,2-Tetrachloroethane
EPA 524.2	3	1,1,1-Trichloroethane
EPA 624	4	1,1,1-Trichloroethane
EPA-524	7	1,1,1-Trichloroethane
EPA 524.2 Volatiles	10	1,1,1-Trichloroethane
EPA 524.2	3	1,1,2,2-Tetrachloroethane
EPA 624	4	1,1,2,2-Tetrachloroethane
EPA-524	7	1,1,2,2-Tetrachloroethane
EPA 524.2 Volatiles	10	1,1,2,2-Tetrachloroethane
EPA 524.2	3	1,1,2-Trichloroethane
EPA 624	4	1,1,2-Trichloroethane
EPA-524	7	1,1,2-Trichloroethane
EPA 524.2 Volatiles	10	1,1,2-Trichloroethane
EPA 524.2	3	1,1-Dichloroethane
EPA 624	4	1,1-Dichloroethane
EPA-524	7	1,1-Dichloroethane
EPA 524.2 Volatiles	10	1,1-Dichloroethane
EPA 624	4	1,1-Dichloroethene
EPA-524	7	1,1-Dichloroethene
EPA 524.2 Volatiles	10	1,1-Dichloroethene
EPA 524.2	3	1,1-Dichloroethylene
EPA 524.2	3	1,1-Dichloropropene
EPA 524.2 Volatiles	10	1,1-Dichloropropene
EPA 524.2	3	1,2,3-Trichlorobenzene
EPA 524.2 Volatiles	10	1,2,3-Trichlorobenzene
EPA 524.2	3	1,2,3-Trichloropropane
EPA 524.2 Volatiles	10	1,2,3-Trichloropropane
EPA 524.2	3	1,2,4-Trichlorobenzene
EPA-524	7	1,2,4-Trichlorobenzene
EPA 524.2 Volatiles	10	1,2,4-Trichlorobenzene
EPA 524.2	3	1,2,4-Trimethylbenzene
EPA 524.2 Volatiles	10	1,2,4-Trimethylbenzene
EPA 524.2 Volatiles	10	1,2-Dibromo-3-chloropropane
EPA-524	7	1,2-Dibromoethane
EPA 524.2 Volatiles	10	1,2-Dibromoethane
EPA 624	4	1,2-Dichlorobenzene
EPA 524.2 Volatiles	10	1,2-Dichlorobenzene
EPA 524.2	3	1,2-Dichloroethane
EPA 624	4	1,2-Dichloroethane
EPA-524	7	1,2-Dichloroethane
EPA 524.2 Volatiles	10	1,2-Dichloroethane

TWDB Direct Potable Reuse Research Study
Available Sampling Methods

SamplingMethod	Sponsor	Parameter
EPA 624	4	1,2-Dichloroethane-d4
EPA 524.2	3	1,2-Dichloropropane
EPA 624	4	1,2-Dichloropropane
EPA-524	7	1,2-Dichloropropane
EPA 524.2 Volatiles	10	1,2-Dichloropropane
EPA 524.2	3	1,3,5-Trimethylbenzene
EPA 524.2 Volatiles	10	1,3,5-Trimethylbenzene
EPA 524.2	3	1,3-Dichlorobenzene
EPA 624	4	1,3-Dichlorobenzene
EPA 524.2 Volatiles	10	1,3-Dichlorobenzene
EPA 524.2	3	1,3-Dichloropropane
EPA 524.2 Volatiles	10	1,3-Dichloropropane
EPA 624	4	1,4-Dichlorobenzene
EPA 524.2 Volatiles	10	1,4-Dichlorobenzene
EPA 525.2	3	2,2',3,3',4,4',6-Heptachlorobiphenyl
EPA 525.2	3	2,2',3,3',4,5',6,6'-Octachlorobiphenyl
EPA 525.2	3	2,2',3',4,6-Pentachlorobiphenyl
EPA 525.2	3	2,2',4,4',5,6'-Hexachlorobiphenyl
EPA 525.2	3	2,2',4,4'-Tetrachlorobiphenyl
EPA 524.2	3	2,2-Dichloropropane
EPA 524.2 Volatiles	10	2,2-Dichloropropane
EPA 525.2	3	2,3-Dichlorobiphenyl
EPA-525.2	3	2,4,5-TP(SILVEX)
EPA 525.2	3	2,4,5-Trichlorobiphenyl
EPA-525.2	3	2,4-D
EPA 524.2	1	2-Butanone(MEK)
EPA 524.2	3	2-Butanone(MEK)
EPA 525.2	3	2-Chlorobiphenyl
EPA 624	4	2-ChloroethylvinylEther
EPA-524	7	2-ChloroethylvinylEther
EPA 524.2	3	2-Chlorotoluene
EPA 524.2 Volatiles	10	2-Chlorotoluene
EPA 524.2	3	2-Hexanone
SM 6040B	10	2-Isopropyl-3-Methoxypyrazin
SM 6040B	10	2-Methylisoborneol
SM 6040D Geosmin & MIB	10	2-Methylisoborneol
SM6040D	10	2-Methylisoborneol
EPA 608	10	4,4'-DDD
EPA 608	10	4,4'-DDE
EPA 608	10	4,4'-DDT
EPA 524.2	3	4-Chlorotoluene
EPA 524.2 Volatiles	10	4-Chlorotoluene
EPA 524.2	3	4-Isopropyltoluene

TWDB Direct Potable Reuse Research Study
Available Sampling Methods

SamplingMethod	Sponsor	Parameter
EPA 524.2 Volatiles	10	4-Isopropyltoluene
EPA 524.2	3	4-Methyl-2-pentanone(MIBK)
EPA 524.2 Volatiles	10	4-Methyl-2-pentanone(MIBK)
EPA 525.2	3	Acenaphthene
EPA 525.2	3	Acenaphthylene
EPA525.2	10	Acenaphthylene
EPA 524.2	3	Acetone
EPA 524.2 Volatiles	10	Acetone
EPA 624	4	Acrolein
EPA 524.2	3	Acrylonitrile
EPA 624	4	Acrylonitrile
EPA 524.2	3	a-Dichlorobenzene
EPA 525.2	3	Alachlor
EPA-525.2	3	Alachlor
EPA525.2	10	Alachlor
EPA 525.2	3	Aldrin
EPA525.2	10	Aldrin
EPA 608	10	Aldrin
SM 20 10200 C,D,E,F	5	AlgaeCount
EPA 608	10	alpha-BHC
EPA 525.2	3	alpha-Chlordane
EPA525.2	10	alpha-Chlordane
SM 3500 Al B	1	Aluminium
EPA200.8	3	Aluminium
SM 4500 NH3D	1	Ammonia
SM 4500-NH3 H	4	Ammonia
SM20 4500-NH3 G	5	Ammonia
EPA 525.2	3	Anthracene
EPA525.2	10	Anthracene
EPA 200.7	1	Antimony
EPA 200.8	3	Antimony
EPA 608 OC Pest/PCB (Modified)	10	Aroclor-1016
EPA 608	10	Aroclor-1016
EPA 608 OC Pest/PCB (Modified)	10	Aroclor-1221
EPA 608	10	Aroclor-1221
EPA 608 OC Pest/PCB (Modified)	10	Aroclor-1232
EPA 608	10	Aroclor-1232
EPA 608 OC Pest/PCB (Modified)	10	Aroclor-1242
EPA 608	10	Aroclor-1242
EPA 608 OC Pest/PCB (Modified)	10	Aroclor-1248
EPA 608	10	Aroclor-1248
EPA 608 OC Pest/PCB (Modified)	10	Aroclor-1254
EPA 608	10	Aroclor-1254

TWDB Direct Potable Reuse Research Study
Available Sampling Methods

SamplingMethod	Sponsor	Parameter
EPA 608 OC Pest/PCB (Modified)	10	Aroclor-1260
EPA 608	10	Aroclor-1260
EPA 200.7	1	Arsenic
EPA 200.8	3	Arsenic
EPA 525.2	3	Atrazine
EPA-525.2	3	Atrazine
EPA 525.2 Semi-Volatiles	10	Atrazine
EPA525.2	10	Atrazine
EPA 200.7	1	Barium
EPA 200.8	3	Barium
EPA 524.2	3	Benzene
EPA 624	4	Benzene
EPA-524	7	Benzene
EPA 524.2 Volatiles	10	Benzene
EPA 525.2	3	Benzo(a)anthracene
EPA525.2	10	Benzo(a)anthracene
EPA 525.2	3	Benzo[a]pyrene
EPA-525.2	3	Benzo[a]pyrene
EPA525.2	10	Benzo[a]pyrene
EPA 525.2	3	Benzo[b]fluoranthene
EPA525.2	10	Benzo[b]fluoranthene
EPA 525.2	3	Benzo[g,h,i]perylene
EPA525.2	10	Benzo[g,h,i]perylene
EPA 525.2	3	Benzo[k]fluoranthene
EPA 525.2	10	Benzo[k]fluoranthene
EPA 200.7	1	Beryllium
EPA 200.8	3	Beryllium
EPA 608	10	beta-BHC
SM 2320B	3	Bicarbonate
SM20 5210 B	5	BOD
EPA 525.2	3	Bromacil
EPA525.2	10	Bromacil
EPA 300.1	10	Bromate
EPA 300.1	1	Bromide
EPA 300.0	4	Bromide
EPA Method 300.1A BNOPF	7	Bromide
EPA 300.1	10	Bromide
EPA 524.2	3	Bromobenzene
EPA 524.2 Volatiles	10	Bromobenzene
EPA 524.2	3	Bromochloromethane
EPA 524.2 Volatiles	10	Bromochloromethane
EPA 524.2	3	Bromodichloromethane
EPA 624	4	Bromodichloromethane

TWDB Direct Potable Reuse Research Study
Available Sampling Methods

SamplingMethod	Sponsor	Parameter
EPA 524.2	5	Bromodichloromethane
EPA-524	7	Bromodichloromethane
EPA 524.2 Volatiles	10	Bromodichloromethane
EPA524.2	10	Bromodichloromethane
EPA 524.2	3	Bromoform
EPA 624	4	Bromoform
EPA 524.2	5	Bromoform
EPA-524	7	Bromoform
EPA 524.2 Volatiles	10	Bromoform
EPA524.2	10	Bromoform
EPA 524.2	3	Bromomethane
EPA 624	4	Bromomethane
EPA-524	7	Bromomethane
EPA 524.2 Volatiles	10	Bromomethane
EPA 525.2	3	Butachlor
EPA525.2	10	Butachlor
EPA 525.2	3	Butylbenzylphthalate
EPA525.2	10	Butylbenzylphthalate
EPA 200.7	1	Cadmium
EPA200.8	3	Cadmium
SM 3111B	1	Calcium
200.7	3	Calcium
EPA200.7	3	Calcium
EPA 200.8	4	Calcium
Ca Total 200.8 ICP-MS	9	Calcium
EPA-525.2	3	Carbofuran
SM 2320B	3	Carbonate
EPA 524.2	3	Carbondisulfide
EPA 524.2 Volatiles	10	Carbondisulfide
EPA 524.2	3	Carbontetrachloride
EPA 624	4	Carbontetrachloride
EPA-524	7	Carbontetrachloride
EPA 524.2 Volatiles	10	Carbontetrachloride
508.1 Rev. 2.0	3	Chlordane
EPA-525.2	3	Chlordane
EPA 608	10	Chlordane
EPA 300.1	1	Chloride
EPA 300.0	3	Chloride
SM4500-Cl B	3	Chloride
EPA 300.0	4	Chloride
SM 4500-Cl D	4	Chloride
SM20 4500-Cl B	5	Chloride
EPA Method 300.1A Cl_SO4	7	Chloride

TWDB Direct Potable Reuse Research Study
Available Sampling Methods

SamplingMethod	Sponsor	Parameter
Chloride EPA 300.0	9	Chloride
Chloride EPA 325.2	9	Chloride
Chloride SM 4500-Cl-E	9	Chloride
SM 4500-ClO2E	1	ChlorineDioxide
SM 4500 Cl-G	1	ChlorineResidual
SM 4500 Cl G	7	ChlorineResidual
SM 4500 Cl G	7	ChlorineResidual
Hach 10250 Chlorine Residual	10	ChlorineResidual
SM 4500-ClO2E	1	Chlorite
EPA 624	4	Chlorobenzene
EPA-524	7	Chlorobenzene
EPA 524.2 Volatiles	10	Chlorobenzene
EPA 524.2 Volatiles	10	Chlorodibromomethane
EPA 524.2	3	Chloroethane
EPA 624	4	Chloroethane
EPA-524	7	Chloroethane
EPA 524.2 Volatiles	10	Chloroethane
EPA 524.2	3	Chloroform
EPA 624	4	Chloroform
EPA 524.2	5	Chloroform
EPA-524	7	Chloroform
EPA 524.2 Volatiles	10	Chloroform
EPA524.2	10	Chloroform
EPA 524.2	3	Chloromethane
EPA 624	4	Chloromethane
EPA-524	7	Chloromethane
EPA 524.2 Volatiles	10	Chloromethane
SM20 10200 H	5	Chlorophyll-a
EPA 200.7	1	Chromium
EPA 200.8	3	Chromium
EPA 525.2	3	Chrysene
EPA525.2	10	Chrysene
EPA-524	7	cis-1,2-Dichloroethene
EPA 524.2 Volatiles	10	cis-1,2-Dichloroethene
EPA 524.2	3	cis-1,2-Dichloroethylene
EPA 524.2 Volatiles	10	cis-1,3Dichloropropene
EPA 524.2	3	cis-1,3-Dichloropropene
EPA 624	4	cis-1,3-Dichloropropene
EPA-524	7	cis-1,3-Dichloropropene
EPA525.2	10	cis-Nonachlor
SM 2120 C	3	Color
EPA Method 110.1	7	Color
SM 2510B	1	Conductivity

TWDB Direct Potable Reuse Research Study
Available Sampling Methods

SamplingMethod	Sponsor	Parameter
SM2510 B	3	Conductivity
SM 2510 B-97-EC	7	Conductivity
Conductivity EPA 120.1	9	Conductivity
EPA 200.7	1	Copper
EPA 200.8	3	Copper
305.1	3	Corrosivity
Giardia/Cryptosporidium 1623 (Sub-Contract ASRV)	9	Cryptosporidium
10-204-00-1-X	1	Cyanide
SM 4500-CN E	3	Cyanide
SM 4500-H B	3	Cyanide
Hach 8027 SM	10	Cyanide
EPA-525.2	3	Dalapon
EPA 608	10	delta-BHC
EPA 525.2	3	Di(2-ethylhexyl)adipate
EPA-525.2	3	Di(2-ethylhexyl)adipate
EPA525.2	10	Di(2-ethylhexyl)adipate
EPA 525.2	3	Di(2-ethylhexyl)phthalate
EPA-525.2	3	Di(2-ethylhexyl)phthalate
EPA525.2	10	Di(2-ethylhexyl)phthalate
EPA 525.2	3	Dibenz[a,h]anthracene
EPA525.2	10	Dibenz[a,h]anthracene
EPA 524.2	3	Dibromochloromethane
EPA 624	4	Dibromochloromethane
EPA-524	7	Dibromochloromethane
EPA524.2	10	Dibromochloromethane
504.1 Rev. 1.1	3	Dibromochloropropane
EPA 524.2	3	Dibromochloropropane
EPA-525.2	3	Dibromochloropropane
EPA 524.2	3	Dibromomethane
EPA 524.2 Volatiles	10	Dibromomethane
EPA 524.2	3	Dichlorodifluoromethane
EPA 624	4	Dichlorodifluoromethane
EPA 524.2 Volatiles	10	Dichlorodifluoromethane
EPA 524.2	3	Dichloromethane
EPA-524	7	Dichloromethane
EPA 525.2	3	Dieldrin
EPA525.2	10	Dieldrin
EPA 608	10	Dieldrin
EPA 525.2	3	Diethylphthalate
EPA525.2	10	Diethylphthalate
SM 2510 B	3	DilutedConductance
EPA 525.2	3	Dimethylphthalate
EPA525.2	10	Dimethylphthalate

TWDB Direct Potable Reuse Research Study
Available Sampling Methods

SamplingMethod	Sponsor	Parameter
EPA 525.2	3	Di-n-butylphthalate
EPA525.2	10	Di-n-butylphthalate
EPA-525.2	3	Dinoseb
EPA-525.2	3	Diquat
EPA 200.8	4	DissolvedAluminium
EPA 200.7	5	DissolvedAluminium
EPA 200.8	4	DissolvedArsenic
EPA 200.7	5	DissolvedArsenic
EPA 200.8	4	DissolvedBarium
EPA 200.7	5	DissolvedBarium
EPA 200.8	4	DissolvedBoron
EPA 200.8	4	DissolvedCadmium
EPA 200.7	5	DissolvedCadmium
EPA 200.8	4	DissolvedChromium
EPA 200.7	5	DissolvedChromium
EPA 200.8	4	DissolvedCopper
EPA 200.7	5	DissolvedCopper
EPA 200.8	4	DissolvedIron
EPA 200.8	4	DissolvedLead
EPA 200.7	5	DissolvedLead
EPA 200.8	4	DissolvedManganese
EPA 200.7	5	DissolvedNickel
SM 5310C	1	DissolvedOrganicCarbon
SM 5310 C	4	DissolvedOrganicCarbon
SM 5310B	10	DissolvedOrganicCarbon
SM 5310B SM	10	DissolvedOrganicCarbon
SM 5310B TOC/DOC	10	DissolvedOrganicCarbon
SM 5310B TOC/DOC Screen	10	DissolvedOrganicCarbon
EPA 200.8	4	DissolvedSelenium
EPA 200.7	5	DissolvedSelenium
EPA 200.7	5	DissolvedSilver
EPA 200.8	4	DissolvedZinc
EPA 200.7	5	DissolvedZinc
SM 9223 B	4	E.Coli
SM9223 B	5	E.Coli
SM 9223B Coliforms	10	E.Coli
SM9223 B	10	E.Coli
EPA 608	10	EndosulfanI
EPA 608	10	EndosulfanII
EPA 608	10	EndosulfanSulfate
EPA-525.2	3	Endothall
508.1 Rev. 2.0	3	Endrin
EPA-525.2	3	Endrin

TWDB Direct Potable Reuse Research Study
Available Sampling Methods

SamplingMethod	Sponsor	Parameter
EPA525.2	10	Endrin
EPA 608	10	Endrin
EPA 608	10	EndrinAldehyde
EPA 608	10	EndrinKeton
EPA 524.2	3	EthylBenzene
EPA 624	4	EthylBenzene
EPA-524	7	EthylBenzene
EPA 524.2 Volatiles	10	EthylBenzene
504.1 Rev. 1.1	3	Ethylenedibromide
EPA 524.2	3	Ethylenedibromide
EPA-525.2	3	Ethylenedibromide
EPA 524.2	3	Ethylmethacrylate
SM 9222D Fecal Coliform	10	FecalColiform
SM9222 D	10	FecalColiform
EPA 525.2	3	Fluorene
EPA525.2	10	Fluorene
EPA 200.7	1	Fluoride
EPA 300.1	1	Fluoride
EPA 300.0	3	Fluoride
SM4500-F C	3	Fluoride
EPA 300.0	4	Fluoride
SM 4500-F C	4	Fluoride
SM 4500-F C	4	Fluoride
EPA Method 300.1A BNOPF	7	Fluoride
EPA 300.0 PartA Anions	10	Fluoride
EPA300.0	10	Fluoride
EPA525.2	10	gamma-BHC
EPA 608	10	gamma-BHC
EPA 525.2	3	gamma-Chlordane
EPA525.2	10	gamma-Chlordane
SM20 6040 B	5	Geosmin
SM 6040B	10	Geosmin
SM 6040D Geosmin & MIB	10	Geosmin
SM6040D	10	Geosmin
Giardia/Cryptosporidium 1623 (Sub-Contract ASRV)	9	Giardia
EPA-525.2	3	Glyphosate
EPA 900.0	1	GrossAlpha
EPA 900.0	3	GrossAlpha
EPA 900.0	1	GrossBeta
EPA 900.0	3	GrossBeta
SM 2340B	1	Hardness
SM 2340 C	3	Hardness
SM 2340B	3	Hardness

TWDB Direct Potable Reuse Research Study
Available Sampling Methods

SamplingMethod	Sponsor	Parameter
SM 2340 B	4	Hardness
SM20 2340 C	5	Hardness
EPA 130.1 T-HARD	7	Hardness
EPA 525.2	3	Heptachlor
EPA-525.2	3	Heptachlor
EPA525.2	10	Heptachlor
EPA 608	10	Heptachlor
508.1 Rev. 2.0	3	HeptachlorEpoxide
EPA-525.2	3	HeptachlorEpoxide
EPA525.2	10	HeptachlorEpoxide
EPA 608	10	HeptachlorEpoxide
EPA 525.2	3	Hexachlorobenzene
EPA-525.2	3	Hexachlorobenzene
EPA525.2	10	Hexachlorobenzene
EPA 524.2	3	Hexachlorobutadiene
EPA 524.2 Volatiles	10	Hexachlorobutadiene
EPA 525.2	3	Hexachlorocyclopentadiene
EPA-525.2	3	Hexachlorocyclopentadiene
EPA525.2	10	Hexachlorocyclopentadiene
SM 9215B	10	HPC
SM 9215D		HPC
SM4500-S D	3	HydrogenSulfide
EPA525.2	10	Indeno(1,2,3-cd)pyrene
EPA 525.2	3	Indeno[1,2,3-cd]pyrene
EPA 524.2	3	Iodomethane
SM 3111B	1	Iron
EPA 200.7	3	Iron
Fe Total 200.8 ICP-MS	9	Iron
EPA 524.2	3	Isopropylbenzene
EPA 524.2 Volatiles	10	Isopropylbenzene(Cumene)
EPA 200.7	1	Lead
EPA200.8	3	Lead
EPA 525.2	3	Lindane
EPA-525.2	3	Lindane
EPA 624	4	m/p-Xylene
EPA 524.2 Volatiles	10	m/p-Xylene
SM 3111B	1	Magnesium
200.7	3	Magnesium
EPA 200.7	3	Magnesium
EPA 200.8	4	Magnesium
EPA 200.7	1	Manganese
EPA200.8	3	Manganese
Mn Total 200.8 ICP-MS	9	Manganese

TWDB Direct Potable Reuse Research Study
Available Sampling Methods

SamplingMethod	Sponsor	Parameter
EPA 200.7	1	Mercury
EPA 245.1	3	Mercury
EPA 245.1	4	Mercury
EPA 525.2	3	Methoxychlor
EPA-525.2	3	Methoxychlor
EPA525.2	10	Methoxychlor
EPA 608	10	Methoxychlor
EPA 624	4	Methylenechloride
EPA-524	7	Methylenechloride
EPA 524.2 Volatiles	10	Methylenechloride
SM20 6040 B	5	Methylisoborneol
EPA 524.2	3	Methylmethacrylate
EPA 524.2	3	Methyl-t-butylether(MTBE)
EPA 524.2 Volatiles	10	Methyl-t-butylether(MTBE)
EPA524.2	10	Methyl-t-butylether(MTBE)
EPA 525.2	3	Metolachlor
EPA525.2	10	Metolachlor
EPA 525.2	3	Metribuzin
EPA525.2	10	Metribuzin
EPA 524.2	3	Monochlorobenzene
EPA 524.2	3	Naphthalene
EPA 525.2	3	Naphthalene
EPA 524.2 Volatiles	10	Naphthalene
EPA 524.2	3	n-Butylbenzene
EPA 524.2 Volatiles	10	n-Butylbenzene
EPA 200.7	1	Nickel
EPA 200.8	3	Nickel
EPA 200.8	4	Nickel
EPA 300.1	1	Nitrate
EPA 353.2	3	Nitrate
SM 4500-N03 E	3	Nitrate
EPA 300.0	4	Nitrate
SM4500-NO3H;NO2B	4	Nitrate
SM20 4500-N03 E	5	Nitrate
EPA Method 300.1A BNOPF	7	Nitrate
Nitrate Lachat/Spec (Calc.)	9	Nitrate
Nitrate Lachat/Spec (Calculated)	9	Nitrate
EPA 300.0 PartA Anions	10	Nitrate
EPA300.0	10	Nitrate
SM 4500 NO3-H Nitrate	10	Nitrate
SM4500-NO3-H	10	Nitrate
Nitrate+Nitrite Nitrogen EPA 353.2	9	Nitrate+Nitrite
SM 4500 NO3-H Nitrate	10	Nitrate+Nitrite

TWDB Direct Potable Reuse Research Study
Available Sampling Methods

SamplingMethod	Sponsor	Parameter
EPA 300.1	1	Nitrite
EPA 353.2	3	Nitrite
HACH 8507	3	Nitrite
EPA 300.0	4	Nitrite
SM4500-NO3H;NO2B	4	Nitrite
EPA Method 300.1A BNOPF	7	Nitrite
Nitrite Nitrogen EPA 353.2	9	Nitrite
Nitrite Nitrogen EPA 354.1	9	Nitrite
EPA 300.0 PartA Anions	10	Nitrite
EPA 353.2	10	Nitrite
EPA300.0	10	Nitrite
EPA 524.2	3	n-Propylbenzene
EPA 524.2 Volatiles	10	n-Propylbenzene
EPA 524.2	3	o-Dichlorobenzene
EPA-524	7	o-Dichlorobenzene
SM 4500-P F	4	Orthophosphate
SM20 4500-P E	5	Orthophosphate
EPA Method 300.1A BNOPF	7	Orthophosphate
EPA 300.0 PartA Anions	10	Orthophosphate
EPA 365.1 Ortho-Phosphate	10	Orthophosphate
EPA300.0	10	Orthophosphate
EPA-525.2	3	Oxamyl
EPA 624	4	o-Xylene
EPA 524.2 Volatiles	10	o-Xylene
EPA 524.2	3	para-Dichlorobenzene
EPA 624	4	p-Bromofluorobenzene
EPA-524	7	p-DICHLOROBENZENE
EPA 525.2	3	Pentachlorophenol
EPA-525.2	3	Pentachlorophenol
EPA525.2	10	Pentachlorophenol
SM 4500 H+B	1	ph
SM 4500-H B	3	pH
SM4500-H B	3	pH
SM 4500 H+B-pH	7	pH
SM 4500 H+B-pH	7	pH
pH (Field)	9	ph
pH EPA 150.1 - potable	9	ph
SM 4500H+B Field pH	10	pH
EPA 525.2	3	Phenanthrene
EPA525.2	10	Phenanthrene
SM 2320B	1	PhenolphthaleinAlkalinity
SM 2320B	3	PhenolphthaleinAlkalinity
SM2320 B	3	PhenolphthaleinAlkalinity

TWDB Direct Potable Reuse Research Study
Available Sampling Methods

SamplingMethod	Sponsor	Parameter
SM2320 B-97-Alk-P	7	PhenolphthaleinAlkalinity
SM20 10200 H	5	Pheophytin a
EPA 300.1	1	Phosphate
EPA-525.2	3	Picloram
EPA-525.2	3	PolychlorinatedBiphenyls
SM 3111B	1	Potassium
200.7	3	Potassium
EPA 200.8	4	Potassium
EPA 525.2	3	Prometon
EPA 525.2	3	Propachlor
EPA525.2	10	Propachlor
EPA 525.2	3	Pyrene
EPA525.2	10	Pyrene
EPA 903.0	3	Radium-226
EPA Ra-05	3	Radium-228
SM 7500-Ra D	3	Radium-228
EPA/600/2-87/082 appendix D	3	Radon-222
EPA 524.2	3	sec-Butylbenzene
EPA 524.2 Volatiles	10	sec-Butylbenzene
EPA 200.7	1	Selenium
EPA 200.8	3	Selenium
SM 4500-Si02 D	3	Silica
SM 4500 Si F-SiO2	7	Silica
SM4500SiO2C		Silica
EPA 200.7	1	Silver
EPA 200.8	3	Silver
EPA 525.2	3	Simazine
EPA-525.2	3	Simazine
EPA525.2	10	Simazine
SM 3111B	1	Sodium
200.7	3	Sodium
EPA 200.7	3	Sodium
EPA 200.8	4	Sodium
Na Total 200.8 ICP-MS	9	Sodium
EPA 524.2	3	Styrene
EPA-525.2	3	Styrene
EPA 524.2 Volatiles	10	Styrene
EPA 300.1	1	Sulfate
ASTM 0516-90	3	Sulfate
EPA 300.0	3	Sulfate
15th Ed. SM 426C	4	Sulfate
EPA 300.0	4	Sulfate
EPA Method 300.1A Cl_SO4	7	Sulfate

TWDB Direct Potable Reuse Research Study
Available Sampling Methods

SamplingMethod	Sponsor	Parameter
EPA 300.0 PartA Anions	10	Sulfate
EPA300.0	10	Sulfate
Sulfate EPA 300.0		Sulfate
Sulfate EPA 375.2		Sulfate
Sulfate EPA 375.4		Sulfate
EPA 524.2	3	t-Butylbenzene
SM 2550	1	Temperature
SM 4500 H+B-Temp	7	Temperature
SM 4500 H+B-Temp	7	Temperature
SM 2550B Temperature	10	Temperature
EPA 524.2 Volatiles	10	tert-Butylbenzene
EPA-524	7	Tetrachloroethene
EPA 524.2 Volatiles	10	Tetrachloroethene
EPA 524.2	3	Tetrachloroethylene
EPA 624	4	Tetrachloroethylene
EPA 524.2	3	Tetrahydrofuran
EPA 524.2 Volatiles	10	Tetrahydrofuran
EPA 200.8	3	Thallium
EPA 200.7	1	Titanium
EPA 524.2	3	Toluene
EPA 624	4	Toluene
EPA-524	7	Toluene
EPA 524.2 Volatiles	10	Toluene
EPA 624	4	Toluene-d8
SM 2320B	1	TotalAlkalinity
SM 2320B	3	TotalAlkalinity
SM2320 B	3	TotalAlkalinity
SM 2320 B	4	TotalAlkalinity
SM20 2320 B	5	TotalAlkalinity
SM2320 B-97-Alk-T	7	TotalAlkalinity
EPA 310.2	10	TotalAlkalinity
SM2320 B SM	10	TotalAlkalinity
200.7	3	TotalAluminium
EPA 200.8	4	TotalAluminium
EPA Method 200.7 W SOL (ICP)	7	TotalAluminium
200.7	3	TotalAntimony
EPA Method 200.8 SOL	7	TotalAntimony
200.7	3	TotalArsenic
EPA 200.8	4	TotalArsenic
EPA Method 200.8 SOL	7	TotalArsenic
EPA Method 200.8 TOT	7	TotalArsenic
200.7	3	TotalBarium
EPA 200.8	4	TotalBarium

TWDB Direct Potable Reuse Research Study
Available Sampling Methods

SamplingMethod	Sponsor	Parameter
EPA Method 200.7 W SOL (ICP)	7	TotalBarium
200.7	3	TotalBeryllium
EPA Method 200.7 W SOL (ICP)	7	TotalBeryllium
EPA 200.8	4	TotalBoron
EPA Method 200.7 W SOL (ICP)	7	TotalBoron
200.7	3	TotalCadmium
EPA 200.8	4	TotalCadmium
EPA Method 200.8 SOL	7	TotalCadmium
EPA 200.7 ICP	7	TotalCalcium
200.7	3	TotalChromium
EPA 200.8	4	TotalChromium
EPA Method 200.7 W SOL (ICP)	7	TotalChromium
SM 9223 B	4	TotalColiform
SM 9223B Coliforms	10	TotalColiform
SM9223 B	10	TotalColiform
SM 9222A,B,C, SM 9223		TotalColiform
200.7	3	TotalCopper
EPA 200.8	4	TotalCopper
EPA Method 200.7 W SOL (ICP)	7	TotalCopper
SM 2540C	1	TotalDissolvedSolids
SM 2540 C	3	TotalDissolvedSolids
SM 2540C	3	TotalDissolvedSolids
SM 2540 C	4	TotalDissolvedSolids
SM20 2540 C	5	TotalDissolvedSolids
SM 2540 C-97-TDS	7	TotalDissolvedSolids
SM 2540C	9	TotalDissolvedSolids
EPA 130.1 T-HARD	7	TotalHardness
200.7	3	TotalIron
EPA 200.8	4	TotalIron
EPA Method 200.7 W (ICP)	7	TotalIron
EPA Method 200.7 W SOL (ICP)	7	TotalIron
HACH 8008-IRON-Fe	7	TotalIron
200.7	3	TotalLead
EPA 200.8	4	TotalLead
EPA Method 200.8 SOL	7	TotalLead
EPA Method 200.7 W SOL (ICP)	7	TotalLithium
EPA 200.7 ICP	7	TotalMagnesium
200.7	3	TotalManganese
EPA 200.8	4	TotalManganese
EPA Method 200.7 W (ICP)	7	TotalManganese
EPA Method 200.7 W SOL (ICP)	7	TotalManganese
245.1	3	TotalMercury
EPA 245.1 AA-Hg	7	TotalMercury

TWDB Direct Potable Reuse Research Study
Available Sampling Methods

SamplingMethod	Sponsor	Parameter
200.7	3	TotalNickel
EPA Method 200.7 W SOL (ICP)	7	TotalNickel
SM 5310C	1	TotalOrganicCarbon
SM 5310 C	4	TotalOrganicCarbon
SM20 5310 C	5	TotalOrganicCarbon
EPA 415.1	9	TotalOrganicCarbon
SM 5310C	9	TotalOrganicCarbon
SM 5310B	10	TotalOrganicCarbon
SM 5310B TOC/DOC	10	TotalOrganicCarbon
SM 5310B TOC/DOC Screen	10	TotalOrganicCarbon
SM5310B SM	10	TotalOrganicCarbon
SM 5320B TOX	10	TotalOrganicHalides
SM5320 B	10	TotalOrganicHalides
SM20 4500-P B E	5	TotalPhosphorus
EPA 200.7 ICP-Total-P	7	TotalPhosphorus
EPA 200.7 ICP	7	TotalPotassium
200.7	3	TotalSelenium
EPA 200.8	4	TotalSelenium
EPA Method 200.8 SOL	7	TotalSelenium
200.7	3	TotalSilver
EPA Method 200.8 SOL	7	TotalSilver
EPA 200.7 ICP	7	TotalSodium
SM 2540D	1	TotalSuspendedSolids
SM20 2540 D	5	TotalSuspendedSolids
200.7	3	TotalThallium
EPA Method 200.8 SOL	7	TotalTitanium
200.7	3	TotalZinc
EPA 200.8	4	TotalZinc
EPA Method 200.7 W SOL (ICP)	7	TotalZinc
508.1 Rev. 2.0	3	Toxaphene
EPA-525.2	3	Toxaphene
EPA 608	10	Toxaphene
EPA-524	7	trans-1,2-Dichlorethene
EPA 624	4	trans-1,2-Dichloroethene
EPA 524.2 Volatiles	10	trans-1,2-Dichloroethene
EPA 524.2	3	trans-1,2-Dichloroethylene
EPA 524.2	3	trans-1,3-Dichloropropene
EPA 624	4	trans-1,3-Dichloropropene
EPA-524	7	trans-1,3-Dichloropropene
EPA 524.2 Volatiles	10	trans-1,3-Dichloropropene
EPA 525.2	3	trans-Nonachlor
EPA525.2	10	trans-Nonachlor
EPA-524	7	Trichloroethene

TWDB Direct Potable Reuse Research Study
Available Sampling Methods

SamplingMethod	Sponsor	Parameter
EPA 524.2 Volatiles	10	Trichloroethene
EPA 524.2	3	Trichloroethylene
EPA 624	4	Trichloroethylene
EPA 524.2	3	Trichlorofluoromethane
EPA 624	4	Trichlorofluoromethane
EPA-524	7	Trichlorofluoromethane
EPA 524.2 Volatiles	10	Trichlorofluoromethane
EPA 525.2	3	Trifluralin
EPA525.2	10	Trifluralin
EPA 524.2	1	Trihalomethanes
EPA 524.2	5	Trihalomethanes
EPA-524	7	Trihalomethanes
EPA 524.2 Volatiles	10	Trihalomethanes
SM 2130B	1	Turbidity
SM 2130 B	3	Turbidity
SM20 2130 B	5	Turbidity
SM 2130 B-01-Turb	7	Turbidity
SM 2130B Turbidity	7	Turbidity
SM2130 B	10	Turbidity
EPA 200.8	1	Uranium
EPA 908.0	3	Uranium
SM 5910 B	4	UV254
SM 5910B UV254	4	UV254
SM 5910B UV254 Screen	4	UV254
SM5910 B	10	UV254
SM5910 B SM	10	UV254
SM 5910B		UV254
EPA 524.2	3	Vinylacetate
EPA 524.2	3	Vinylchloride
EPA 624	4	Vinylchloride
EPA-524	7	Vinylchloride
EPA 524.2 Volatiles	10	Vinylchloride
EPA 524.2	1	VolatileOrganicCompound
EPA 524.2	3	Xylenes(total)
EPA-524	7	Xylenes(total)
EPA 524.2 Volatiles	10	Xylenes(total)
EPA 200.7	1	Zinc
EPA 200.8	3	Zinc

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EXHIBIT D

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	1,1,1,2-Tetrachloroethane µg/L	1,1,1-Trichloroethane µg/L	1,1,2,2-Tetrachloroethane µg/L	1,1,2-Trichloroethane µg/L	1,1-Dichloroethane µg/L	1,1-Dichloroethene µg/L	1,1-Dichloroethylene µg/L	1,1-Dichloropropene µg/L	1,2,3-Trichlorobenzene µg/L	1,2,3-Trichloropropane µg/L
1/A	Groundwater	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
1/B	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
1/C	Groundwater	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
3/A	Groundwater	Average	<1	<0.5	<1	<0.5	<1		<0.5	<1	<1	<1
		Minimum	<1	<0.5	<1	<0.5	<1		<0.5	<1	<1	<1
		Maximum	<1	<0.5	<1	<0.5	<1		<0.5	<1	<1	<1
		Count	1	1	1	1	1		1	1	1	1
		Count - less than	1	1	1	1	1		1	1	1	1
3/B	Groundwater	Average	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1
		Minimum	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1
		Maximum	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1
		Count	1	2	2	2	2	1	1	1	1	1
		Count - less than	1	2	2	2	2	1	1	1	1	1
4/A	Surface Water	Average		<3	<3	<3	<3	<3				
		Minimum		<3	<3	<3	<3	<3				
		Maximum		<3	<3	<3	<3	<3				
		Count		7	7	7	7	7				
		Count - less than		7	7	7	7	7				
4/B	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
5/A	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
5/B	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
5/C	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
5/D	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
5/E	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
5/F	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
5/G	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
6/A	Groundwater	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										

Notes:
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Sponsor/Raw Water Source	Source Water Type	Calculation Type	1,1,1,2-Tetrachloroethane µg/L	1,1,1-Trichloroethane µg/L	1,1,2,2-Tetrachloroethane µg/L	1,1,2-Trichloroethane µg/L	1,1-Dichloroethane µg/L	1,1-Dichloroethene µg/L	1,1-Dichloroethylene µg/L	1,1-Dichloropropene µg/L	1,2,3-Trichlorobenzene µg/L	1,2,3-Trichloropropane µg/L
6/B	Groundwater	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
6/C	Groundwater	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
7/A	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
7/B	Groundwater	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
7/C	Groundwater	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
8/A (same waterbody as 5/D)	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
9/A	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
10/A	Surface Water	Average	<1	<1	<1	<1	<1	<1		<1	<1	<1
		Minimum	<1	<1	<1	<1	<1	<1		<1	<1	<1
		Maximum	<1	<1	<1	<1	<1	<1		<1	<1	<1
		Count	88	88	88	88	88	88		88	88	88
		Count - less than	88	88	88	88	88	88		88	88	88
10/B	Surface Water	Average	<1	<1	<1	<1	<1	<1		<1	0.513	<1
		Minimum	<1	<1	<1	<1	<1	<1		<1	<1	<1
		Maximum	<1	<1	<1	<1	<1	<1		<1	1.360	<1
		Count	66	66	66	66	66	66		66	66	66
		Count - less than	66	66	66	66	66	66		66	65	66
10/C	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
10/D	Surface Water	Average	<1	<1	<1	<1	<1	<1		<1	<1	<1
		Minimum	<1	<1	<1	<1	<1	<1		<1	<1	<1
		Maximum	<1	<1	<1	<1	<1	<1		<1	<1	<1
		Count	32	32	32	32	32	32		32	32	32
		Count - less than	32	32	32	32	32	32		32	32	32
11/A	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
11/B	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
11/C	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										

Notes:
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Sponsor/Raw Water Source	Source Water Type	Calculation Type	1,2,4-Trichlorobenzene µg/L	1,2,4-Trimethylbenzene µg/L	1,2-Dibromo-3-chloropropane µg/L	1,2-Dibromoethane µg/L	1,2-Dichlorobenzene µg/L	1,2-Dichloroethane µg/L	1,2-Dichloroethane-d4 %	1,2-Dichloropropane µg/L	1,3,5-Trimethylbenzene µg/L	1,3-Dichlorobenzene µg/L
1/A	Groundwater	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
1/B	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
1/C	Groundwater	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
3/A	Groundwater	Average	<0.5	<1				<0.5		<0.5	<1	<1
		Minimum	<0.5	<1				<0.5		<0.5	<1	<1
		Maximum	<0.5	<1				<0.5		<0.5	<1	<1
		Count	1	1				1		1	1	1
		Count - less than	1	1				1		1	1	1
3/B	Groundwater	Average	<1	<1		<1		<1		<1	<1	<1
		Minimum	<1	<1		<1		<1		<1	<1	<1
		Maximum	<1	<1		<1		<1		<1	<1	<1
		Count	2	1		1		2		2	1	1
		Count - less than	2	1		1		2		2	1	1
4/A	Surface Water	Average					<5	<3	97.220	<3		<5
		Minimum					<5	<3	86.800	<3		<5
		Maximum					<5	<3	113.800	<3		<5
		Count					7	7	10	7		7
		Count - less than					7	7	0	7		7
4/B	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
5/A	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
5/B	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
5/C	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
5/D	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
5/E	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
5/F	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
5/G	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
6/A	Groundwater	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	1,2,4-Trichlorobenzene µg/L	1,2,4-Trimethylbenzene µg/L	1,2-Dibromo-3-chloropropane µg/L	1,2-Dibromoethane µg/L	1,2-Dichlorobenzene µg/L	1,2-Dichloroethane µg/L	1,2-Dichloroethane-d4 %	1,2-Dichloropropane µg/L	1,3,5-Trimethylbenzene µg/L	1,3-Dichlorobenzene µg/L
6/B	Groundwater	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
6/C	Groundwater	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
7/A	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
7/B	Groundwater	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
7/C	Groundwater	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
8/A (same waterbody as 5/D)	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
9/A	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
10/A	Surface Water	Average	<1	<1	<1	<1	<1	<1		<1	<1	<1
		Minimum	<1	<1	<1	<1	<1	<1		<1	<1	<1
		Maximum	<1	<1	<1	<1	<1	<1		<1	<1	<1
		Count	88	88	88	88	88	88		88	88	88
		Count - less than	88	88	88	88	88	88		88	88	88
10/B	Surface Water	Average	<1	<1	<1	<1	<1	<1		<1	<1	<1
		Minimum	<1	<1	<1	<1	<1	<1		<1	<1	<1
		Maximum	<1	<1	<1	<1	<1	<1		<1	<1	<1
		Count	66	66	66	66	66	66		66	66	66
		Count - less than	66	66	66	66	66	66		66	66	66
10/C	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
10/D	Surface Water	Average	<1	<1	<1	<1	<1	<1		<1	<1	<1
		Minimum	<1	<1	<1	<1	<1	<1		<1	<1	<1
		Maximum	<1	<1	<1	<1	<1	<1		<1	<1	<1
		Count	32	32	32	32	32	32		32	32	32
		Count - less than	32	32	32	32	32	32		32	32	32
11/A	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
11/B	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										
11/C	Surface Water	Average										
		Minimum										
		Maximum										
		Count										
		Count - less than										

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	1,3-Dichloropropane µg/L	1,4-Dichlorobenzene µg/L	2,2',3,3',4,4',6-Heptachlorobiphenyl µg/L	2,2',3,3',4,5',6,6'-Octachlorobiphenyl µg/L	2,2',3',4,6-Pentachlorobiphenyl µg/L	2,2',4,4',5,6'-Hexachlorobiphenyl µg/L	2,2',4,4'-Tetrachlorobiphenyl µg/L	2,2-Dichloropropane µg/L
1/A	Groundwater	Average								
		Minimum								
		Maximum								
		Count								
		Count - less than								
1/B	Surface Water	Average								
		Minimum								
		Maximum								
		Count								
		Count - less than								
1/C	Groundwater	Average								
		Minimum								
		Maximum								
		Count								
		Count - less than								
3/A	Groundwater	Average	<1		<0.5	<0.5	<0.2	<0.2	<0.2	<1
		Minimum	<1		<0.5	<0.5	<0.2	<0.2	<0.2	<1
		Maximum	<1		<0.5	<0.5	<0.2	<0.2	<0.2	<1
		Count	1		1	1	1	1	1	1
		Count - less than	1		1	1	1	1	1	1
3/B	Groundwater	Average	<1							<1
		Minimum	<1							<1
		Maximum	<1							<1
		Count	1							1
		Count - less than	1							1
4/A	Surface Water	Average		<5						
		Minimum		<5						
		Maximum		<5						
		Count		7						
		Count - less than		7						
4/B	Surface Water	Average								
		Minimum								
		Maximum								
		Count								
		Count - less than								
5/A	Surface Water	Average								
		Minimum								
		Maximum								
		Count								
		Count - less than								
5/B	Surface Water	Average								
		Minimum								
		Maximum								
		Count								
		Count - less than								
5/C	Surface Water	Average								
		Minimum								
		Maximum								
		Count								
		Count - less than								
5/D	Surface Water	Average								
		Minimum								
		Maximum								
		Count								
		Count - less than								
5/E	Surface Water	Average								
		Minimum								
		Maximum								
		Count								
		Count - less than								
5/F	Surface Water	Average								
		Minimum								
		Maximum								
		Count								
		Count - less than								
5/G	Surface Water	Average								
		Minimum								
		Maximum								
		Count								
		Count - less than								
6/A	Groundwater	Average								
		Minimum								
		Maximum								
		Count								
		Count - less than								

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	1,3-Dichloropropane µg/L	1,4-Dichlorobenzene µg/L	2,2',3,3',4,4',6-Heptachlorobiphenyl µg/L	2,2',3,3',4,5',6,6'-Octachlorobiphenyl µg/L	2,2',3',4,6-Pentachlorobiphenyl µg/L	2,2',4,4',5,6'-Hexachlorobiphenyl µg/L	2,2',4,4'-Tetrachlorobiphenyl µg/L	2,2-Dichloropropane µg/L
6/B	Groundwater	Average								
		Minimum								
		Maximum								
		Count								
		Count - less than								
6/C	Groundwater	Average								
		Minimum								
		Maximum								
		Count								
		Count - less than								
7/A	Surface Water	Average								
		Minimum								
		Maximum								
		Count								
		Count - less than								
7/B	Groundwater	Average								
		Minimum								
		Maximum								
		Count								
		Count - less than								
7/C	Groundwater	Average								
		Minimum								
		Maximum								
		Count								
		Count - less than								
8/A (same waterbody as 5/D)	Surface Water	Average								
		Minimum								
		Maximum								
		Count								
		Count - less than								
9/A	Surface Water	Average								
		Minimum								
		Maximum								
		Count								
		Count - less than								
10/A	Surface Water	Average	<1	<1						<1
		Minimum	<1	<1						<1
		Maximum	<1	<1						<1
		Count	88	88						88
		Count - less than	88	88						88
10/B	Surface Water	Average	<1	<1						<1
		Minimum	<1	<1						<1
		Maximum	<1	<1						<1
		Count	66	66						66
		Count - less than	66	66						66
10/C	Surface Water	Average								
		Minimum								
		Maximum								
		Count								
		Count - less than								
10/D	Surface Water	Average	<1	<1						<1
		Minimum	<1	<1						<1
		Maximum	<1	<1						<1
		Count	32	32						32
		Count - less than	32	32						32
11/A	Surface Water	Average								
		Minimum								
		Maximum								
		Count								
		Count - less than								
11/B	Surface Water	Average								
		Minimum								
		Maximum								
		Count								
		Count - less than								
11/C	Surface Water	Average								
		Minimum								
		Maximum								
		Count								
		Count - less than								

Notes:
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Sponsor/Raw Water Source	Source Water Type	Calculation Type	2,3-Dichlorobiphenyl µg/L	2,4,5-TP(SILVEX) µg/L	2,4,5-Trichlorobiphenyl µg/L	2,4-D µg/L	2-Butanone(MEK) µg/L	2-Chlorobiphenyl µg/L	2-ChloroethylvinylEther µg/L	2-Chlorotoluene µg/L	2-Hexanone µg/L	2-Isopropyl-3-Methoxypyrazin %	2-Methylisoborneol ng/L	4,4'-DDD µg/L	4,4'-DDE µg/L
1/A	Groundwater	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
1/B	Surface Water	Average					2.194								
		Minimum					0.000								
		Maximum					65.000								
		Count					36								
		Count - less than					0								
1/C	Groundwater	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
3/A	Groundwater	Average	<0.2		<0.2		<10	<0.2		<1	<1				
		Minimum	<0.2		<0.2		<10	<0.2		<1	<1				
		Maximum	<0.2		<0.2		<10	<0.2		<1	<1				
		Count	1		1		1	1		1	1				
		Count - less than	1		1		1	1		1	1				
3/B	Groundwater	Average		<4		<10	<10		<5	<1	<1				
		Minimum		<4		<10	<10		<5	<1	<1				
		Maximum		<4		<10	<10		<5	<1	<1				
		Count		1		1	1		1	1	1				
		Count - less than		1		1	1		1	1	1				
4/A	Surface Water	Average							<3			89.889	8.889		
		Minimum							<3			78.000	<10		
		Maximum							<3			114.000	47.000		
		Count							7			54	54		
		Count - less than							7			0	44		
4/B	Surface Water	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
5/A	Surface Water	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
5/B	Surface Water	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
5/C	Surface Water	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
5/D	Surface Water	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
5/E	Surface Water	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
5/F	Surface Water	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
5/G	Surface Water	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
6/A	Groundwater	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													

Notes:
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Sponsor/Raw Water Source	Source Water Type	Calculation Type	2,3-Dichlorobiphenyl µg/L	2,4,5-TP(SILVEX) µg/L	2,4,5-Trichlorobiphenyl µg/L	2,4-D µg/L	2-Butanone(MEK) µg/L	2-Chlorobiphenyl µg/L	2-ChloroethylvinylEther µg/L	2-Chlorotoluene µg/L	2-Hexanone µg/L	2-Isopropyl-3-Methoxypyrazin %	2-Methylisoborneol ng/L	4,4'-DDD µg/L	4,4'-DDE µg/L
6/B	Groundwater	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
6/C	Groundwater	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
7/A	Surface Water	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
7/B	Groundwater	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
7/C	Groundwater	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
8/A (same waterbody as 5/D)	Surface Water	Average											9.508		
		Minimum											<0		
		Maximum											85.300		
		Count											59		
		Count - less than											26		
9/A	Surface Water	Average											5.785		
		Minimum											<2		
		Maximum											169.000		
		Count											149		
		Count - less than											97		
10/A	Surface Water	Average								<1			7.965	<0.1	<0.1
		Minimum								<1			<5	<0.1	<0.1
		Maximum								<1			56.400	<0.1	<0.1
		Count								88			223	2	2
		Count - less than								88			126	2	2
10/B	Surface Water	Average								<1			9.096		
		Minimum								<1			<5		
		Maximum								<1			128.000		
		Count								66			156		
		Count - less than								66			98		
10/C	Surface Water	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
10/D	Surface Water	Average								<1			10.592		
		Minimum								<1			<5		
		Maximum								<1			55.400		
		Count								32			32		
		Count - less than								32			18		
11/A	Surface Water	Average											<2		
		Minimum											<2		
		Maximum											<2		
		Count											1		
		Count - less than											1		
11/B	Surface Water	Average											4.358		
		Minimum											<2		
		Maximum											16.600		
		Count											24		
		Count - less than											13		
11/C	Surface Water	Average											1.193		
		Minimum											<2		
		Maximum											3.700		
		Count											40		
		Count - less than											35		

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	4,4'-DDT µg/L	4-Chlorotoluene µg/L	4-Isopropyltoluene µg/L	4-Methyl-2-pentanone(MIBK) µg/L	Acenaphthene µg/L	Acenaphthylene µg/L	Acetone µg/L	Acrolein µg/L	Acrylonitrile µg/L	a-Dichlorobenzene µg/L	Alachlor µg/L	Aldrin µg/L	AlgaeCount organisms/mL	alpha-BHC µg/L	alpha-Chlordane µg/L
1/A	Groundwater	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
1/B	Surface Water	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
1/C	Groundwater	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
3/A	Groundwater	Average		<1	<1	<2	<0.2	<0.2	<10		<10	<0.5	<0.2	<0.2			<0.2
		Minimum		<1	<1	<2	<0.2	<0.2	<10		<10	<0.5	<0.2	<0.2			<0.2
		Maximum		<1	<1	<2	<0.2	<0.2	<10		<10	<0.5	<0.2	<0.2			<0.2
		Count		1	1	1	1	1	1		1	1	1	1			1
		Count - less than		1	1	1	1	1	1		1	1	1	1			1
3/B	Groundwater	Average		<1	<1	<2			<10		<10		<0.02				
		Minimum		<1	<1	<2			<10		<10		<0.02				
		Maximum		<1	<1	<2			<10		<10		<0.02				
		Count		1	1	1			1		1		1				
		Count - less than		1	1	1			1		1		1				
4/A	Surface Water	Average								<20	<3						
		Minimum								<20	<3						
		Maximum								<20	<3						
		Count								6	6						
		Count - less than								6	6						
4/B	Surface Water	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
5/A	Surface Water	Average													2,156.775		
		Minimum													0.000		
		Maximum													9,008.000		
		Count													40		
		Count - less than													0		
5/B	Surface Water	Average													1,581.236		
		Minimum													14.000		
		Maximum													8,142.000		
		Count													55		
		Count - less than													0		
5/C	Surface Water	Average													2,778.636		
		Minimum													0.000		
		Maximum													17,323.000		
		Count													55		
		Count - less than													0		
5/D	Surface Water	Average													2,552.042		
		Minimum													69.000		
		Maximum													13,166.000		
		Count													48		
		Count - less than													0		
5/E	Surface Water	Average													2,734.099		
		Minimum													69.000		
		Maximum													15,591.000		
		Count													71		
		Count - less than													0		
5/F	Surface Water	Average													1,460.638		
		Minimum													14.000		
		Maximum													5,994.000		
		Count													47		
		Count - less than													0		
5/G	Surface Water	Average													3,098.400		
		Minimum													0.000		
		Maximum													18,363.000		
		Count													55		
		Count - less than													0		
6/A	Groundwater	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	4,4'-DDT µg/L	4-Chlorotoluene µg/L	4-Isopropyltoluene µg/L	4-Methyl-2-pentanone(MIBK) µg/L	Acenaphthene µg/L	Acenaphthylene µg/L	Acetone µg/L	Acrolein µg/L	Acrylonitrile µg/L	a-Dichlorobenzene µg/L	Alachlor µg/L	Aldrin µg/L	AlgaeCount organisms/mL	alpha-BHC µg/L	alpha-Chlordane µg/L
6/B	Groundwater	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
6/C	Groundwater	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
7/A	Surface Water	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
7/B	Groundwater	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
7/C	Groundwater	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
8/A (same waterbody as 5/D)	Surface Water	Average													29.485		
		Minimum													0.000		
		Maximum													150.000		
		Count													66		
		Count - less than													0		
9/A	Surface Water	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
10/A	Surface Water	Average	<0.1	<1	<1	<1		<1	2.647				<1	<1		<0.05	<1
		Minimum	<0.1	<1	<1	<1		<1	<1				<1	<1		<0.05	<1
		Maximum	<0.1	<1	<1	<1		<1	14.000				<1	<1		<0.05	<1
		Count	2	88	88	88		1	88				1	3		2	1
		Count - less than	2	88	88	88		1	84				1	3		2	1
10/B	Surface Water	Average		<1	<1	<1		<1	2.982				<1	<1			<1
		Minimum		<1	<1	<1		<1	<1				<1	<1			<1
		Maximum		<1	<1	<1		<1	9.280				<1	<1			<1
		Count		66	66	66		1	66				1	1			1
		Count - less than		66	66	66		1	57				1	1			1
10/C	Surface Water	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
10/D	Surface Water	Average		<1	<1	<1			2.725								
		Minimum		<1	<1	<1			<5								
		Maximum		<1	<1	<1			9.700								
		Count		32	32	32			32								
		Count - less than		32	32	32			31								
11/A	Surface Water	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
11/B	Surface Water	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
11/C	Surface Water	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	Aluminium mg/L	Ammonia mg/L	Anthracene µg/L	Antimony mg/L	Aroclor-1016 µg/L	Aroclor-1221 µg/L	Aroclor-1232 µg/L	Aroclor-1242 µg/L	Aroclor-1248 µg/L	Aroclor-1254 µg/L	Aroclor-1260 µg/L	Arsenic mg/L	Atrazine µg/L	Barium mg/L	Benzene µg/L	Benzo(a)anthracene µg/L	Benzo[a]pyrene µg/L
1/A	Groundwater	Average	0.000	0.045		0.000								0.001		0.122			
		Minimum	0.000	0.011		<0.0001								<0.0002		0.018			
		Maximum	0.174	0.400		0.003								0.004		0.170			
		Count	771	772		25								25		25			
		Count - less than	0	0		10								11		0			
1/B	Surface Water	Average	0.003	0.028		0.000								0.003		0.215			
		Minimum	<0	0.006		0.000								<0.0002		0.150			
		Maximum	0.005	0.198		0.001								0.011		0.480			
		Count	49	107		16								16		16			
		Count - less than	28	0		0								2		0			
1/C	Groundwater	Average	<0.12	<1.816		<0.0004								<0.0118		<0.38			
		Minimum	<0.12	<1.816		<0.0004								<0.0118		<0.38			
		Maximum	<0.12	<1.816		<0.0004								<0.0118		<0.38			
		Count	31	35		27								27		27			
		Count - less than	31	35		27								27		27			
3/A	Groundwater	Average	<0.02		<0.2	<0.001								<0.002	<0.1	<0.0762	<0.5	<0.2	<0.02
		Minimum	<0.02		<0.2	<0.001								<0.002	<0.1	<0.0762	<0.5	<0.2	<0.02
		Maximum	<0.02		<0.2	<0.001								<0.002	<0.1	<0.0762	<0.5	<0.2	<0.02
		Count	1		1	1								1	1	1	1	1	1
		Count - less than	1		1	1								1	1	1	1	1	1
3/B	Groundwater	Average													<1		<1		<0.1
		Minimum													<1		<1		<0.1
		Maximum													<1		<1		<0.1
		Count													1		2		1
		Count - less than													1		2		1
4/A	Surface Water	Average		0.069													<3		
		Minimum		<0.02													<3		
		Maximum		0.420													<3		
		Count		39													7		
		Count - less than		12													7		
4/B	Surface Water	Average		0.067															
		Minimum		<0.1															
		Maximum		0.200															
		Count		34															
		Count - less than		26															
5/A	Surface Water	Average		0.181															
		Minimum		<0.02															
		Maximum		1.470															
		Count		170															
		Count - less than		36															
5/B	Surface Water	Average		0.092															
		Minimum		<0.02															
		Maximum		3.110															
		Count		127															
		Count - less than		56															
5/C	Surface Water	Average		0.105															
		Minimum		<0.02															
		Maximum		3.360															
		Count		133															
		Count - less than		60															
5/D	Surface Water	Average		0.077															
		Minimum		<0.02															
		Maximum		1.020															
		Count		128															
		Count - less than		64															
5/E	Surface Water	Average		0.086															
		Minimum		<0.02															
		Maximum		0.650															
		Count		128															
		Count - less than		68															
5/F	Surface Water	Average		0.107															
		Minimum		<0.02															
		Maximum		2.820															
		Count		165															
		Count - less than		85															
5/G	Surface Water	Average		0.124															
		Minimum		<0.02															
		Maximum		3.010															
		Count		165															
		Count - less than		70															
6/A	Groundwater	Average																	
		Minimum																	
		Maximum																	
		Count																	
		Count - less than																	

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	Aluminium mg/L	Ammonia mg/L	Anthracene µg/L	Antimony mg/L	Aroclor-1016 µg/L	Aroclor-1221 µg/L	Aroclor-1232 µg/L	Aroclor-1242 µg/L	Aroclor-1248 µg/L	Aroclor-1254 µg/L	Aroclor-1260 µg/L	Arsenic mg/L	Atrazine µg/L	Barium mg/L	Benzene µg/L	Benzo(a)anthracene µg/L	Benzo[a]pyrene µg/L
6/B	Groundwater	Average																	
		Minimum																	
		Maximum																	
		Count																	
		Count - less than																	
6/C	Groundwater	Average																	
		Minimum																	
		Maximum																	
		Count																	
		Count - less than																	
7/A	Surface Water	Average		0.253															
		Minimum		<0.108															
		Maximum		0.890															
		Count		259															
		Count - less than		253															
7/B	Groundwater	Average																	
		Minimum																	
		Maximum																	
		Count																	
		Count - less than																	
7/C	Groundwater	Average																	
		Minimum																	
		Maximum																	
		Count																	
		Count - less than																	
8/A (same waterbody as 5/D)	Surface Water	Average		0.033															
		Minimum		0.000															
		Maximum		0.232															
		Count		74															
		Count - less than		0															
9/A	Surface Water	Average		0.136															
		Minimum		<0.032															
		Maximum		0.752															
		Count		356															
		Count - less than		38															
10/A	Surface Water	Average			<1		0.318	0.318	0.318	0.318	0.318	0.318	0.318		<1.01		<1	<1	<0.2
		Minimum			<1		<0	<0	<0	<0	<0	<0	<0		<1.01		<1	<1	<0.2
		Maximum			<1		0.500	0.500	0.500	0.500	0.500	0.500	0.500		<1.01		<1	<1	<0.2
		Count			1		11	11	11	11	11	11	11		11		88	1	1
		Count - less than			1		7	7	7	7	7	7	7		11		88	1	1
10/B	Surface Water	Average			<1										<1.01		<1	<1	<0.2
		Minimum			<1										<1.01		<1	<1	<0.2
		Maximum			<1										<1.01		<1	<1	<0.2
		Count			1										11		66	1	1
		Count - less than			1										11		66	1	1
10/C	Surface Water	Average																	
		Minimum																	
		Maximum																	
		Count																	
		Count - less than																	
10/D	Surface Water	Average															<1		
		Minimum															<1		
		Maximum															<1		
		Count															32		
		Count - less than															32		
11/A	Surface Water	Average	11.677	0.846															
		Minimum	0.040	0.200															
		Maximum	592.000	2.501															
		Count	61	993															
		Count - less than	0	0															
11/B	Surface Water	Average	5.382																
		Minimum	0.007																
		Maximum	71.000																
		Count	29																
		Count - less than	0																
11/C	Surface Water	Average	1.139	0.813															
		Minimum	0.075	0.425															
		Maximum	2.830	1.688															
		Count	31	743															
		Count - less than	0	0															

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	Benzo[b]fluoranthene µg/L	Benzo[g,h,i]perylene µg/L	Benzo[k]fluoranthene µg/L	Beryllium mg/L	beta-BHC µg/L	Bicarbonate mg/L	BOD mg/L	Bromacil µg/L	Bromate µg/L	Bromide µg/L	Bromobenzene µg/L	Bromochloromethane µg/L	Bromodichloromethane µg/L	Bromoform µg/L	Bromomethane µg/L
1/A	Groundwater	Average				<0.0009						182.339					
		Minimum				<0.0009						<5					
		Maximum				<0.0009						1,031.000					
		Count				25						31					
		Count - less than				25						22					
1/B	Surface Water	Average				0.000						587.750					
		Minimum				<0.0001						<5					
		Maximum				0.000						920.000					
		Count				16						38					
		Count - less than				1						4					
1/C	Groundwater	Average				<0.0009						<1964					
		Minimum				<0.0009						<1964					
		Maximum				<0.0009						<1964					
		Count				27						36					
		Count - less than				27						36					
3/A	Groundwater	Average	<0.2	<0.2	<0.2	<0.0008		411.000		<0.2			<1	<1	<0.5	<0.5	<2
		Minimum	<0.2	<0.2	<0.2	<0.0008		411.000		<0.2			<1	<1	<0.5	<0.5	<2
		Maximum	<0.2	<0.2	<0.2	<0.0008		411.000		<0.2			<1	<1	<0.5	<0.5	<2
		Count	1	1	1	1		1		1			1	1	1	1	1
		Count - less than	1	1	1	1		0		1			1	1	1	1	1
3/B	Groundwater	Average						337.450					<1	<1	<1	<1	<2
		Minimum						204.900					<1	<1	<1	<1	<2
		Maximum						470.000					<1	<1	<1	<1	<2
		Count						2					1	1	2	2	2
		Count - less than						0					1	1	2	2	2
4/A	Surface Water	Average										105.077			<3	<3	<3
		Minimum										<20			<3	<3	<3
		Maximum										500.000			<3	<3	<3
		Count										39			10	10	7
		Count - less than										7			10	10	7
4/B	Surface Water	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
5/A	Surface Water	Average							3.650						0.156	0.152	
		Minimum							<3						<0.01	<0.01	
		Maximum							10.000						2.210	4.320	
		Count							170						170	170	
		Count - less than							61						168	168	
5/B	Surface Water	Average							3.362						0.163	0.163	
		Minimum							<3						<0.01	<0.01	
		Maximum							9.000						1.340	4.090	
		Count							127						120	120	
		Count - less than							56						117	118	
5/C	Surface Water	Average							3.353						0.143	0.127	
		Minimum							<3						<0.01	<0.01	
		Maximum							15.000						0.780	0.940	
		Count							133						129	129	
		Count - less than							64						128	128	
5/D	Surface Water	Average							4.031						0.259	<0.32	
		Minimum							<3						<0.01	<0.32	
		Maximum							15.000						7.660	<0.32	
		Count							128						120	120	
		Count - less than							52						117	120	
5/E	Surface Water	Average							3.313						<0.368	<0.32	
		Minimum							<3						<0.368	<0.32	
		Maximum							8.000						<0.368	<0.32	
		Count							128						120	120	
		Count - less than							62						120	120	
5/F	Surface Water	Average							3.015						0.149	0.141	
		Minimum							<3						<0.01	<0.01	
		Maximum							11.000						1.610	1.580	
		Count							165						155	155	
		Count - less than							93						153	153	
5/G	Surface Water	Average							3.745						0.153	0.134	
		Minimum							<3						<0.01	<0.01	
		Maximum							15.000						1.610	1.650	
		Count							165						160	160	
		Count - less than							70						158	158	
6/A	Groundwater	Average						275.069									
		Minimum						235.520									
		Maximum						336.810									
		Count						54									
		Count - less than						0									

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	Benzo[b]fluoranthene µg/L	Benzo[g,h,i]perylene µg/L	Benzo[k]fluoranthene µg/L	Beryllium mg/L	beta-BHC µg/L	Bicarbonate mg/L	BOD mg/L	Bromacil µg/L	Bromate µg/L	Bromide µg/L	Bromobenzene µg/L	Bromochloromethane µg/L	Bromodichloromethane µg/L	Bromoform µg/L	Bromomethane µg/L
6/B	Groundwater	Average						265.725									
		Minimum						236.740									
		Maximum						283.120									
		Count						4									
		Count - less than						0									
6/C	Groundwater	Average						358.780									
		Minimum						358.780									
		Maximum						358.780									
		Count						1									
		Count - less than						0									
7/A	Surface Water	Average									<2	68.889					
		Minimum									<2	<50					
		Maximum									<2	160.000					
		Count									6	27					
		Count - less than									6	18					
7/B	Groundwater	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
7/C	Groundwater	Average										56.133					
		Minimum										<0					
		Maximum										160.000					
		Count										150					
		Count - less than										107					
8/A (same waterbody as 5/D)	Surface Water	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
9/A	Surface Water	Average						120.291									
		Minimum						83.000									
		Maximum						155.000									
		Count						69									
		Count - less than						0									
10/A	Surface Water	Average	<1	<1	<1		<0.05			<1	<5	171.533	<1	<1	<1	<1	<1
		Minimum	<1	<1	<1		<0.05			<1	<5	148.000	<1	<1	<1	<1	<1
		Maximum	<1	<1	<1		<0.05			<1	<5	191.000	<1	<1	<1	<1	<1
		Count	1	1	1		2			1	15	15	88	88	89	89	88
		Count - less than	1	1	1		2			1	15	0	88	88	89	89	88
10/B	Surface Water	Average	<1	<1	<1					<1	2.979	169.509	<1	<1	<1	<1	<1
		Minimum	<1	<1	<1					<1	<5	97.900	<1	<1	<1	<1	<1
		Maximum	<1	<1	<1					<1	9.270	210.000	<1	<1	<1	<1	<1
		Count	1	1	1					1	161	161	66	66	66	66	66
		Count - less than	1	1	1					1	143	0	66	66	66	66	66
10/C	Surface Water	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
10/D	Surface Water	Average									<5	115.458	<1	<1	0.538	<1	<1
		Minimum									<5	73.300	<1	<1	<1	<1	<1
		Maximum									<5	152.000	<1	<1	1.170	<1	<1
		Count									33	33	32	32	32	32	32
		Count - less than									33	0	32	32	30	32	32
11/A	Surface Water	Average										99.302			4.400	0.316	
		Minimum										<20			0.700	0.070	
		Maximum										196.000			22.200	1.200	
		Count										825			1,375	215	
		Count - less than										250			0	0	
11/B	Surface Water	Average										68.288					
		Minimum										<70					
		Maximum										133.000					
		Count										59					
		Count - less than										19					
11/C	Surface Water	Average										106.294			3.659	0.276	
		Minimum										<100			0.700	0.080	
		Maximum										820.000			11.150	0.700	
		Count										592			700	67	
		Count - less than										138			0	0	

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	Butachlor µg/L	Butylbenzylphthalate µg/L	Cadmium mg/L	Calcium mg/L	Carbofuran µg/L	Carbonate mg/L	Carbondisulfide µg/L	Carbontetrachloride µg/L	Chlordane µg/L	Chloride mg/L	Chlorine(total) mg/L	ChlorineDioxide mg/L	ChlorineResidual mg/L	Chlorite mg/L	Chlorobenzene µg/L
1/A	Groundwater	Average			<0.0001	50.414						308.645			0.038		
		Minimum			<0.0001	39.400						<0.005			0.000		
		Maximum			<0.0001	75.600						586.000			0.190		
		Count			25	29						31			588		
		Count - less than			25	0						1			0		
1/B	Surface Water	Average			<0.0001	29.280						232.026		0.349	0.123	0.452	
		Minimum			<0.0001	23.200						189.000		0.059	0.000	0.365	
		Maximum			<0.0001	34.500						443.000		0.605	0.400	0.577	
		Count			16	28						38		14	74	14	
		Count - less than			16	0						0		0	0	0	
1/C	Groundwater	Average			<0.0008	<268.2						<54.2					
		Minimum			<0.0008	<268.2						<54.2					
		Maximum			<0.0008	<268.2						<54.2					
		Count			27	31						36					
		Count - less than			27	31						36					
3/A	Groundwater	Average	<0.2	<2	<0.001	2.650		<1	<1	<0.5	<0.2	44.000					
		Minimum	<0.2	<2	<0.001	2.650		<1	<1	<0.5	<0.2	44.000					
		Maximum	<0.2	<2	<0.001	2.650		<1	<1	<0.5	<0.2	44.000					
		Count	1	1	1	1		1	1	1	1	1					
		Count - less than	1	1	1	0		1	1	1	1	0					
3/B	Groundwater	Average				3.000	<0.04	5.250	<1	<1	<0.14	99.500					<1
		Minimum				3.000	<0.04	<1	<1	<1	<0.14	43.000					<1
		Maximum				3.000	<0.04	10.000	<1	<1	<0.14	156.000					<1
		Count				1	1	2	1	2	1	2					1
		Count - less than				0	1	1	1	2	1	0					1
4/A	Surface Water	Average				39.092				<3		18.036					<3
		Minimum				27.500				<3		14.200					<3
		Maximum				56.600				<3		26.400					<3
		Count				39				7		14					7
		Count - less than				0				7		0					7
4/B	Surface Water	Average										57.241					
		Minimum										11.000					
		Maximum										115.000					
		Count										33					
		Count - less than										0					
5/A	Surface Water	Average										26.673					
		Minimum										9.000					
		Maximum										56.000					
		Count										165					
		Count - less than										0					
5/B	Surface Water	Average										19.121					
		Minimum										8.000					
		Maximum										41.000					
		Count										127					
		Count - less than										0					
5/C	Surface Water	Average										44.856					
		Minimum										10.000					
		Maximum										233.000					
		Count										132					
		Count - less than										0					
5/D	Surface Water	Average										29.611					
		Minimum										8.000					
		Maximum										106.000					
		Count										128					
		Count - less than										0					
5/E	Surface Water	Average										33.266					
		Minimum										20.000					
		Maximum										61.000					
		Count										128					
		Count - less than										0					
5/F	Surface Water	Average										15.176					
		Minimum										0.920					
		Maximum										34.000					
		Count										165					
		Count - less than										0					
5/G	Surface Water	Average										17.502					
		Minimum										1.800					
		Maximum										88.000					
		Count										165					
		Count - less than										0					
6/A	Groundwater	Average				80.061		0.000				18.291					
		Minimum				62.300		0.000				12.600					
		Maximum				107.000		0.000				27.800					
		Count				54		54				54					
		Count - less than				0		0				0					

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	Butachlor µg/L	Butylbenzylphthalate µg/L	Cadmium mg/L	Calcium mg/L	Carbofuran µg/L	Carbonate mg/L	Carbondisulfide µg/L	Carbontetrachloride µg/L	Chlordane µg/L	Chloride mg/L	Chlorine(total) mg/L	ChlorineDioxide mg/L	ChlorineResidual mg/L	Chlorite mg/L	Chlorobenzene µg/L
6/B	Groundwater	Average				79.000		0.000				17.800					
		Minimum				69.600		0.000				16.400					
		Maximum				84.300		0.000				21.600					
		Count				4		4				4					
		Count - less than				0		0				0					
6/C	Groundwater	Average				101.000		0.000				25.100					
		Minimum				101.000		0.000				25.100					
		Maximum				101.000		0.000				25.100					
		Count				1		1				1					
		Count - less than				0		0				0					
7/A	Surface Water	Average										109.093					
		Minimum										61.090					
		Maximum										1,270.000					
		Count										259					
		Count - less than										0					
7/B	Groundwater	Average										1,400.586					
		Minimum										<50					
		Maximum										12,500.000					
		Count										203					
		Count - less than										1					
7/C	Groundwater	Average										104.565			0.054		
		Minimum										54.990			<0.1		
		Maximum										169.000			0.200		
		Count										154			301		
		Count - less than										0			281		
8/A (same waterbody as 5/D)	Surface Water	Average				98.804						16.500			0.000		
		Minimum				80.000						15.000			0.000		
		Maximum				124.000						22.300			0.000		
		Count				107						10			85		
		Count - less than				0						0			0		
9/A	Surface Water	Average				47.215						64.761					
		Minimum				28.700						<1					
		Maximum				73.500						474.000					
		Count				108						667					
		Count - less than				0						1					
10/A	Surface Water	Average	<1	<2					<1	<1	<1				0.116		<1
		Minimum	<1	<2					<1	<1	<1				<0.1		<1
		Maximum	<1	<2					<1	<1	<1				0.260		<1
		Count	1	1					88	88	2				8		88
		Count - less than	1	1					88	88	2				4		88
10/B	Surface Water	Average	<1	<2					<1	<1					0.105		<1
		Minimum	<1	<2					<1	<1					<0.1		<1
		Maximum	<1	<2					<1	<1					0.210		<1
		Count	1	1					66	66					8		66
		Count - less than	1	1					66	66					4		66
10/C	Surface Water	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
10/D	Surface Water	Average							<1	<1					0.077		<1
		Minimum							<1	<1					<0.1		<1
		Maximum							<1	<1					0.160		<1
		Count							32	32					7		32
		Count - less than							32	32					5		32
11/A	Surface Water	Average				39.827						32.780	2.397		0.099		
		Minimum				4.970						21.000	0.500		0.010		
		Maximum				50.500						51.900	220.000		0.150		
		Count				1,048						825	1,044		48		
		Count - less than				0						0	0		0		
11/B	Surface Water	Average				18.735						34.289	0.100		0.100		
		Minimum				1.000						9.000	0.100		0.100		
		Maximum				39.000						71.800	0.100		0.100		
		Count				749						59	20		18		
		Count - less than				0						0	0		0		
11/C	Surface Water	Average				38.361						33.329	1.727				
		Minimum				23.000						20.000	0.200				
		Maximum				93.300						53.000	4.650				
		Count				750						592	748				
		Count - less than				0						0	0				

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	Chlorodibromomethane µg/L	Chloroethane µg/L	Chloroform µg/L	Chloromethane µg/L	Chlorophyll mg/m3	Chlorophyll-a mg/m3	Chromium mg/L	Chrysene µg/L	cis-1,2-Dichloroethene µg/L	cis-1,2-Dichloroethylene µg/L	cis-1,3Dichloropropene µg/L	cis-1,3-Dichloropropene µg/L	cis-Nonachlor µg/L
1/A	Groundwater	Average							0.006						
		Minimum							0.001						
		Maximum							0.023						
		Count							25						
		Count - less than							0						
1/B	Surface Water	Average							0.006						
		Minimum							0.000						
		Maximum							0.016						
		Count							16						
		Count - less than							0						
1/C	Groundwater	Average							<0.02						
		Minimum							<0.02						
		Maximum							<0.02						
		Count							27						
		Count - less than							27						
3/A	Groundwater	Average		<2	<0.5	<2			<0.01	<0.2		<0.5		<1	
		Minimum		<2	<0.5	<2			<0.01	<0.2		<0.5		<1	
		Maximum		<2	<0.5	<2			<0.01	<0.2		<0.5		<1	
		Count		1	1	1			1	1		1		1	
		Count - less than		1	1	1			1	1		1		1	
3/B	Groundwater	Average		<2	<1	<2					<1	<0.5		<1	
		Minimum		<2	<1	<2					<1	<0.5		<1	
		Maximum		<2	<1	<2					<1	<0.5		<1	
		Count		2	2	2					1	1		2	
		Count - less than		2	2	2					1	1		2	
4/A	Surface Water	Average		<3	<3	<3								<3	
		Minimum		<3	<3	<3								<3	
		Maximum		<3	<3	<3								<3	
		Count		7	10	7								7	
		Count - less than		7	10	7								7	
4/B	Surface Water	Average					9.825								
		Minimum					2.000								
		Maximum					28.000								
		Count					13								
		Count - less than					0								
5/A	Surface Water	Average			0.227			10.435							
		Minimum			<0.01			<6							
		Maximum			2.010			33.700							
		Count			170			44							
		Count - less than			162			16							
5/B	Surface Water	Average			0.244			8.605							
		Minimum			<0.01			<1.06							
		Maximum			1.930			42.100							
		Count			120			60							
		Count - less than			116			27							
5/C	Surface Water	Average			0.200			13.056							
		Minimum			<0.01			<6							
		Maximum			0.810			74.190							
		Count			129			64							
		Count - less than			128			21							
5/D	Surface Water	Average			0.470			14.239							
		Minimum			<0.01			<6							
		Maximum			14.200			54.200							
		Count			120			60							
		Count - less than			110			21							
5/E	Surface Water	Average			<0.508			16.287							
		Minimum			<0.508			<6							
		Maximum			<0.508			81.030							
		Count			120			80							
		Count - less than			120			19							
5/F	Surface Water	Average			0.204			7.505							
		Minimum			<0.01			<0							
		Maximum			1.490			62.100							
		Count			155			60							
		Count - less than			153			34							
5/G	Surface Water	Average			0.256			22.342							
		Minimum			<0.01			<6							
		Maximum			2.460			91.560							
		Count			160			72							
		Count - less than			152			18							
6/A	Groundwater	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													

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6/B	Groundwater	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
6/C	Groundwater	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
7/A	Surface Water	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
7/B	Groundwater	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
7/C	Groundwater	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
8/A (same waterbody as 5/D)	Surface Water	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
9/A	Surface Water	Average						46.088							
		Minimum						<3							
		Maximum						176.000							
		Count						254							
		Count - less than						4							
10/A	Surface Water	Average	<1	<1	<1	<1				<1	<1		<1		<1
		Minimum	<1	<1	<1	<1				<1	<1		<1		<1
		Maximum	<1	<1	<1	<1				<1	<1		<1		<1
		Count	88	88	89	88				1	88		88		1
		Count - less than	88	88	89	88				1	88		88		1
10/B	Surface Water	Average	<1	<1	<1	<1				<1	<1		<1		<1
		Minimum	<1	<1	<1	<1				<1	<1		<1		<1
		Maximum	<1	<1	<1	<1				<1	<1		<1		<1
		Count	66	66	66	66				1	66		66		1
		Count - less than	66	66	66	66				1	66		66		1
10/C	Surface Water	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
10/D	Surface Water	Average	<1	<1	0.717	<1					<1		<1		
		Minimum	<1	<1	<1	<1					<1		<1		
		Maximum	<1	<1	3.280	<1					<1		<1		
		Count	32	32	32	32					32		32		
		Count - less than	32	32	29	32					32		32		
11/A	Surface Water	Average			9.279										
		Minimum			0.390										
		Maximum			63.160										
		Count			1,377										
		Count - less than			0										
11/B	Surface Water	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
11/C	Surface Water	Average			7.481										
		Minimum			0.600										
		Maximum			54.380										
		Count			700										
		Count - less than			0										

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	Color units	Conductivity µmhos/cm	Copper mg/L	Corrosivity mg/L	Cryptosporidium (Oo) cysts/L	Cyanide µg/L	Dalapon µg/L	delta-BHC µg/L	Di(2-ethylhexyl)adipate µg/L	Di(2-ethylhexyl)phthalate µg/L	Dibenz[a,h]anthracene µg/L	Dibromochloromethane µg/L	Dibromochloropropane µg/L	Dibromomethane µg/L
1/A	Groundwater	Average		1,660.548	0.029											
		Minimum		869.000	0.003											
		Maximum		2,708.000	0.060											
		Count		31	25											
		Count - less than		0	0											
1/B	Surface Water	Average		1,258.316	0.019											
		Minimum		1,059.000	0.004											
		Maximum		1,466.000	0.098											
		Count		38	16											
		Count - less than		0	0											
1/C	Groundwater	Average		<1282	<0.092			<140								
		Minimum		<1282	<0.092			<140								
		Maximum		<1282	<0.092			<140								
		Count		34	27			1								
		Count - less than		34	27			1								
3/A	Groundwater	Average			<0.002						<0.6	<0.6	<0.2	<0.5	<1	<1
		Minimum			<0.002						<0.6	<0.6	<0.2	<0.5	<1	<1
		Maximum			<0.002						<0.6	<0.6	<0.2	<0.5	<1	<1
		Count			1						1	1	1	1	2	1
		Count - less than			1						1	1	1	1	2	1
3/B	Groundwater	Average	<1	653.300		<1		<20	<0.2		<100	<5		<1	<0.1	<1
		Minimum	<1	653.300		<1		<20	<0.2		<100	<5		<1	<0.1	<1
		Maximum	<1	653.300		<1		<20	<0.2		<100	<5		<1	<0.1	<1
		Count	1	1		1		1	1		1	1		2	1	1
		Count - less than	1	0		1		1	1		1	1		2	1	1
4/A	Surface Water	Average												<3		
		Minimum												<3		
		Maximum												<3		
		Count												10		
		Count - less than												10		
4/B	Surface Water	Average														
		Minimum														
		Maximum														
		Count														
		Count - less than														
5/A	Surface Water	Average		375.683										0.124		
		Minimum		279.000										<0.01		
		Maximum		740.000										3.080		
		Count		180										170		
		Count - less than		0										168		
5/B	Surface Water	Average		211.570										0.114		
		Minimum		128.000										<0.01		
		Maximum		1,570.000										1.110		
		Count		135										120		
		Count - less than		0										118		
5/C	Surface Water	Average		426.807										0.105		
		Minimum		66.000										<0.01		
		Maximum		1,139.000										0.820		
		Count		140										129		
		Count - less than		0										128		
5/D	Surface Water	Average		384.824										0.176		
		Minimum		246.000										<0.01		
		Maximum		908.000										6.850		
		Count		136										120		
		Count - less than		0										118		
5/E	Surface Water	Average		361.824										<0.25		
		Minimum		298.000										<0.25		
		Maximum		501.000										<0.25		
		Count		136										120		
		Count - less than		0										120		
5/F	Surface Water	Average		250.637										0.114		
		Minimum		123.000										<0.01		
		Maximum		323.000										1.540		
		Count		171										155		
		Count - less than		0										153		
5/G	Surface Water	Average		249.966										0.113		
		Minimum		140.000										<0.01		
		Maximum		883.000										1.190		
		Count		175										160		
		Count - less than		0										158		
6/A	Groundwater	Average		540.778												
		Minimum		482.000												
		Maximum		628.000												
		Count		54												
		Count - less than		0												

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	Color units	Conductivity µmhos/cm	Copper mg/L	Corrosivity mg/L	Cryptosporidium (Oo) cysts/L	Cyanide µg/L	Dalapon µg/L	delta-BHC µg/L	Di(2-ethylhexyl)adipate µg/L	Di(2-ethylhexyl)phthalate µg/L	Dibenz[a,h]anthracene µg/L	Dibromochloromethane µg/L	Dibromochloropropane µg/L	Dibromomethane µg/L
6/B	Groundwater	Average		531.750												
		Minimum		488.000												
		Maximum		556.000												
		Count		4												
		Count - less than		0												
6/C	Groundwater	Average		660.000												
		Minimum		660.000												
		Maximum		660.000												
		Count		1												
		Count - less than		0												
7/A	Surface Water	Average														
		Minimum														
		Maximum														
		Count														
		Count - less than														
7/B	Groundwater	Average	12.448	4,293.793												
		Minimum	<4	3,050.000												
		Maximum	12.500	5,880.000												
		Count	202	203												
		Count - less than	201	0												
7/C	Groundwater	Average		817.935												
		Minimum		618.000												
		Maximum		1,210.000												
		Count		154												
		Count - less than		0												
8/A (same waterbody as 5/D)	Surface Water	Average	14.618		0.064											
		Minimum	0.000		0.000											
		Maximum	86.000		5.000											
		Count	18		123											
		Count - less than	0		0											
9/A	Surface Water	Average		481.167			0.000									
		Minimum		0.380			0.000									
		Maximum		1,050.000			0.000									
		Count		1,165			28									
		Count - less than		0			0									
10/A	Surface Water	Average						<10		<0.05	<2	<2	<1	<1		<1
		Minimum						<10		<0.05	<2	<2	<1	<1		<1
		Maximum						<10		<0.05	<2	<2	<1	<1		<1
		Count						100		2	1	1	1	1		88
		Count - less than						100		2	1	1	1	1		88
10/B	Surface Water	Average						<10			<2	<2	<1			<1
		Minimum						<10			<2	<2	<1			<1
		Maximum						<10			<2	<2	<1			<1
		Count						62			1	1	1			66
		Count - less than						62			1	1	1			66
10/C	Surface Water	Average														
		Minimum														
		Maximum														
		Count														
		Count - less than														
10/D	Surface Water	Average														<1
		Minimum														<1
		Maximum														<1
		Count														32
		Count - less than														32
11/A	Surface Water	Average	5.294	358.126										1.655		
		Minimum	1.750	1.000										0.090		
		Maximum	51.600	483.000										7.500		
		Count	1,040	593										1,277		
		Count - less than	0	0										0		
11/B	Surface Water	Average	11.058	275.869												
		Minimum	1.000	3.010												
		Maximum	40.000	531.000												
		Count	740	744												
		Count - less than	0	0												
11/C	Surface Water	Average	5.101	362.449										1.357		
		Minimum	2.120	109.000										0.000		
		Maximum	24.000	484.000										4.500		
		Count	742	296										676		
		Count - less than	0	0										0		

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	Dichlorodifluoromethane µg/L	Dichloromethane µg/L	Dieldrin µg/L	Diethylphthalate µg/L	DilutedConductance µmho/cm	Dimethylphthalate µg/L	Di-n-butylphthalate µg/L	Dinoseb µg/L	Diquat µg/L	DissolvedAluminium µg/L	DissolvedArsenic µg/L	DissolvedBarium µg/L	DissolvedBoron µg/L
1/A	Groundwater	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
1/B	Surface Water	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
1/C	Groundwater	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
3/A	Groundwater	Average	<2	<0.5	<0.2	<2	809.000	<2	<2						
		Minimum	<2	<0.5	<0.2	<2	809.000	<2	<2						
		Maximum	<2	<0.5	<0.2	<2	809.000	<2	<2						
		Count	1	1	1	1	1	1	1						
		Count - less than	1	1	1	1	0	1	1						
3/B	Groundwater	Average	<2	<1			894.000			<1	<10				
		Minimum	<2	<1			894.000			<1	<10				
		Maximum	<2	<1			894.000			<1	<10				
		Count	1	2			1			1	1				
		Count - less than	1	2			0			1	1				
4/A	Surface Water	Average	<3									<50	<5	41.276	57.600
		Minimum	<3									<50	<5	17.600	<94.3
		Maximum	<3									<50	<5	54.200	77.360
		Count	7									39	39	13	13
		Count - less than	7									39	39	0	2
4/B	Surface Water	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
5/A	Surface Water	Average										<50	<5	45.127	
		Minimum										<50	<5	34.950	
		Maximum										<50	<5	55.290	
		Count										10	15	15	
		Count - less than										10	15	0	
5/B	Surface Water	Average										<21	<10	63.583	
		Minimum										<21	<10	31.000	
		Maximum										<21	<10	121.000	
		Count										12	12	12	
		Count - less than										12	12	0	
5/C	Surface Water	Average										<50	<5	57.131	
		Minimum										<50	<5	48.380	
		Maximum										<50	<5	93.580	
		Count										5	12	12	
		Count - less than										5	12	0	
5/D	Surface Water	Average										<50	<5	37.668	
		Minimum										<50	<5	27.480	
		Maximum										<50	<5	43.660	
		Count										4	12	12	
		Count - less than										4	12	0	
5/E	Surface Water	Average										<50	<5	46.546	
		Minimum										<50	<5	42.320	
		Maximum										<50	<5	50.690	
		Count										7	12	12	
		Count - less than										7	12	0	
5/F	Surface Water	Average										47.924	<5	46.691	
		Minimum										<50	<5	25.240	
		Maximum										86.780	<5	53.220	
		Count										5	15	15	
		Count - less than										2	15	0	
5/G	Surface Water	Average										<21	4.933	43.267	
		Minimum										<21	<6	19.000	
		Maximum										<21	13.000	65.000	
		Count										15	15	15	
		Count - less than										15	12	0	
6/A	Groundwater	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													

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6/B	Groundwater	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
6/C	Groundwater	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
7/A	Surface Water	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
7/B	Groundwater	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
7/C	Groundwater	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
8/A (same waterbody as 5/D)	Surface Water	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
9/A	Surface Water	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
10/A	Surface Water	Average	<1		<1	<1		<1	<2						
		Minimum	<1		<1	<1		<1	<2						
		Maximum	<1		<1	<1		<1	<2						
		Count	88		3	1		1	1						
		Count - less than	88		3	1		1	1						
10/B	Surface Water	Average	<1		<1	<1		<1	<2						
		Minimum	<1		<1	<1		<1	<2						
		Maximum	<1		<1	<1		<1	<2						
		Count	66		1	1		1	1						
		Count - less than	66		1	1		1	1						
10/C	Surface Water	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
10/D	Surface Water	Average	<1												
		Minimum	<1												
		Maximum	<1												
		Count	32												
		Count - less than	32												
11/A	Surface Water	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
11/B	Surface Water	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
11/C	Surface Water	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	DissolvedCadmium µg/L	DissolvedChromium µg/L	DissolvedCopper µg/L	DissolvedIron µg/L	DissolvedLead µg/L	DissolvedManganese µg/L	DissolvedNickel µg/L	DissolvedOrganicCarbon mg/L	DissolvedOxygen mg/L	DissolvedSelenium µg/L	DissolvedSilver µg/L	DissolvedZinc µg/L
1/A	Groundwater	Average								1.521				
		Minimum								<0				
		Maximum								4.040				
		Count								36				
		Count - less than								18				
1/B	Surface Water	Average								4.400				
		Minimum								3.600				
		Maximum								6.600				
		Count								19				
		Count - less than								0				
1/C	Groundwater	Average												
		Minimum												
		Maximum												
		Count												
		Count - less than												
3/A	Groundwater	Average												
		Minimum												
		Maximum												
		Count												
		Count - less than												
3/B	Groundwater	Average												
		Minimum												
		Maximum												
		Count												
		Count - less than												
4/A	Surface Water	Average	0.164	<5	2.230	<50	<1	30.636		4.860		<5		3.694
		Minimum	<0.3	<5	<1	<50	<1	<1		3.900		<5		<5
		Maximum	0.330	<5	7.470	<50	<1	370.030		5.700		<5		18.020
		Count	13	13	13	13	39	39		40		13		13
		Count - less than	12	13	2	13	39	19		0		13		12
4/B	Surface Water	Average												
		Minimum												
		Maximum												
		Count												
		Count - less than												
5/A	Surface Water	Average	0.168	2.670	5.424		0.577		2.787		8.308	<5	<0.3	12.321
		Minimum	<0.3	<5	<1		<1		2.340		2.830	<5	<0.3	<5
		Maximum	0.420	5.050	35.530		1.660		3.780		13.010	<5	<0.3	24.540
		Count	15	15	15		15		15		180	15	15	15
		Count - less than	14	14	1		14		0		0	15	15	3
5/B	Surface Water	Average	<4	<7	13.417		4.417		<6		8.706	<15	4.583	26.000
		Minimum	<4	<7	9.000		<7		<6		4.550	<15	<2	<16
		Maximum	<4	<7	18.000		7.000		<6		14.750	<15	10.000	68.000
		Count	12	12	12		12		12		135	12	12	12
		Count - less than	12	12	0		10		12		0	12	8	8
5/C	Surface Water	Average	<0.3	2.970	2.914		<1		2.686		9.060	<5	<0.3	12.724
		Minimum	<0.3	<5	<1		<1		1.860		3.370	<5	<0.3	<5
		Maximum	<0.3	5.570	9.160		<1		4.830		13.360	<5	<0.3	42.160
		Count	12	12	12		12		12		141	12	12	12
		Count - less than	12	10	1		12		0		0	12	12	5
5/D	Surface Water	Average	0.224	<5	2.508		<1		2.793		9.497	<5	<0.3	5.965
		Minimum	<0.3	<5	<1		<1		1.790		3.780	<5	<0.3	<5
		Maximum	1.040	<5	5.540		<1		5.110		16.060	<5	<0.3	13.600
		Count	12	12	12		12		12		136	12	12	12
		Count - less than	11	12	3		12		0		0	12	12	6
5/E	Surface Water	Average	<0.3	<5	0.920		<1		2.379		8.954	<5	<0.3	2.727
		Minimum	<0.3	<5	<1		<1		1.880		2.470	<5	<0.3	<5
		Maximum	<0.3	<5	1.490		<1		2.590		12.560	<5	<0.3	5.220
		Count	12	12	12		12		12		136	12	12	12
		Count - less than	12	12	5		12		0		0	12	12	11
5/F	Surface Water	Average	<0.3	<5	1.643		<1		1.882		9.449	<5	<0.3	10.417
		Minimum	<0.3	<5	<1		<1		1.300		5.470	<5	<0.3	<5
		Maximum	<0.3	<5	3.040		<1		2.900		13.680	<5	<0.3	57.800
		Count	15	15	15		15		15		171	15	15	15
		Count - less than	15	15	5		15		0		0	15	15	10
5/G	Surface Water	Average	2.667	<7	10.767		<9		<5		8.665	<15	<2	18.600
		Minimum	<4	<7	<9		<9		<5		2.160	<15	<2	<16
		Maximum	4.000	<7	23.000		<9		<5		14.530	<15	<2	72.000
		Count	15	15	15		15		15		175	15	15	15
		Count - less than	10	15	9		15		15		0	15	15	9
6/A	Groundwater	Average												
		Minimum												
		Maximum												
		Count												
		Count - less than												

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6/B	Groundwater	Average												
		Minimum												
		Maximum												
		Count												
		Count - less than												
6/C	Groundwater	Average												
		Minimum												
		Maximum												
		Count												
		Count - less than												
7/A	Surface Water	Average												
		Minimum												
		Maximum												
		Count												
		Count - less than												
7/B	Groundwater	Average												
		Minimum												
		Maximum												
		Count												
		Count - less than												
7/C	Groundwater	Average												
		Minimum												
		Maximum												
		Count												
		Count - less than												
8/A (same waterbody as 5/D)	Surface Water	Average								5.811	7.321			
		Minimum								3.900	2.480			
		Maximum								60.000	11.460			
		Count								131	188			
		Count - less than								0	0			
9/A	Surface Water	Average									6.355			
		Minimum									0.000			
		Maximum									20.930			
		Count									2,983			
		Count - less than									0			
10/A	Surface Water	Average								4.568				
		Minimum								3.460				
		Maximum								5.470				
		Count								69				
		Count - less than								0				
10/B	Surface Water	Average								4.684				
		Minimum								4.010				
		Maximum								5.390				
		Count								39				
		Count - less than								0				
10/C	Surface Water	Average												
		Minimum												
		Maximum												
		Count												
		Count - less than												
10/D	Surface Water	Average								4.438				
		Minimum								3.620				
		Maximum								7.360				
		Count								12				
		Count - less than								0				
11/A	Surface Water	Average												
		Minimum												
		Maximum												
		Count												
		Count - less than												
11/B	Surface Water	Average												
		Minimum												
		Maximum												
		Count												
		Count - less than												
11/C	Surface Water	Average												
		Minimum												
		Maximum												
		Count												
		Count - less than												

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	E.Coli MPN/100mL	EndosulfanI µg/L	EndosulfanII µg/L	EndosulfanSulfate µg/L	Endothall µg/L	Endrin µg/L	EndrinAldehyde µg/L	EndrinKeton µg/L	EthylBenzene µg/L	Ethylenedibromide µg/L	Ethylmethacrylate µg/L	FecalColiform cfu/100mL	Fluorene µg/L	Fluoride mg/L	FoamingAgents mg/L	FreeCO2 mg/L
1/A	Groundwater	Average														0.826		
		Minimum														0.700		
		Maximum														0.900		
		Count														31		
		Count - less than														0		
1/B	Surface Water	Average														1.201		
		Minimum														1.000		
		Maximum														1.500		
		Count														38		
		Count - less than														0		
1/C	Groundwater	Average														<3.92		
		Minimum														<3.92		
		Maximum														<3.92		
		Count														36		
		Count - less than														36		
3/A	Groundwater	Average						<0.01			<0.5	<1	<1		<0.2	0.270		
		Minimum						<0.01			<0.5	<1	<1		<0.2	0.270		
		Maximum						<0.01			<0.5	<1	<1		<0.2	0.270		
		Count						1			1	2	1		1	1		
		Count - less than						1			1	2	1		1	0		
3/B	Groundwater	Average					<50	<0.06			<1	<0.01	<1			0.530	<0.02	3.800
		Minimum					<50	<0.06			<1	<0.01	<1			<1	<0.02	3.800
		Maximum					<50	<0.06			<1	<0.01	<1			0.560	<0.02	3.800
		Count					1	1			2	1	1			2	1	1
		Count - less than					1	1			2	1	1			1	1	0
4/A	Surface Water	Average	19.230								<5					0.221		
		Minimum	<1								<5					0.200		
		Maximum	687.000								<5					0.300		
		Count	172								7					38		
		Count - less than	49								7					0		
4/B	Surface Water	Average	108.953															
		Minimum	<1															
		Maximum	875.000															
		Count	34															
		Count - less than	2															
5/A	Surface Water	Average	197.503															
		Minimum	<1															
		Maximum	2,419.200															
		Count	170															
		Count - less than	5															
5/B	Surface Water	Average	33.402															
		Minimum	<1															
		Maximum	686.700															
		Count	60															
		Count - less than	12															
5/C	Surface Water	Average	259.102															
		Minimum	<1															
		Maximum	2,419.200															
		Count	65															
		Count - less than	7															
5/D	Surface Water	Average	78.436															
		Minimum	<1															
		Maximum	2,419.200															
		Count	61															
		Count - less than	8															
5/E	Surface Water	Average	25.347															
		Minimum	<1															
		Maximum	261.300															
		Count	32															
		Count - less than	10															
5/F	Surface Water	Average	67.107															
		Minimum	<1															
		Maximum	2,419.200															
		Count	102															
		Count - less than	23															
5/G	Surface Water	Average	202.823															
		Minimum	<1															
		Maximum	2,419.200															
		Count	66															
		Count - less than	12															
6/A	Groundwater	Average														0.214		
		Minimum														0.160		
		Maximum														0.350		
		Count														54		
		Count - less than														0		

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	E.Coli MPN/100mL	EndosulfanI µg/L	EndosulfanII µg/L	EndosulfanSulfate µg/L	Endothall µg/L	Endrin µg/L	EndrinAldehyde µg/L	EndrinKeton µg/L	EthylBenzene µg/L	Ethylenedibromide µg/L	Ethylmethacrylate µg/L	FecalColiform cfu/100mL	Fluorene µg/L	Fluoride mg/L	FoamingAgents mg/L	FreeCO2 mg/L
6/B	Groundwater	Average														0.208		
		Minimum														0.200		
		Maximum														0.220		
		Count														4		
		Count - less than														0		
6/C	Groundwater	Average														0.350		
		Minimum														0.350		
		Maximum														0.350		
		Count														1		
		Count - less than														0		
7/A	Surface Water	Average														0.704		
		Minimum														0.550		
		Maximum														1.830		
		Count														21		
		Count - less than														0		
7/B	Groundwater	Average																
		Minimum																
		Maximum																
		Count																
		Count - less than																
7/C	Groundwater	Average														0.595		
		Minimum														<0.1		
		Maximum														0.750		
		Count														154		
		Count - less than														1		
8/A (same waterbody as 5/D)	Surface Water	Average																
		Minimum																
		Maximum																
		Count																
		Count - less than																
9/A	Surface Water	Average	4.638											8.545		0.305		
		Minimum	<1											<2		0.210		
		Maximum	44.100											94.000		0.630		
		Count	72											101		69		
		Count - less than	27											27		0		
10/A	Surface Water	Average	27.068	<0.1	<0.1	<0.1		<1	<0.1	<0.1	<1			27.448	<1	0.231		
		Minimum	<0	<0.1	<0.1	<0.1		<1	<0.1	<0.1	<1			<1	<1	0.150		
		Maximum	14,100.000	<0.1	<0.1	<0.1		<1	<0.1	<0.1	<1			600.000	<1	0.370		
		Count	1,068	2	2	2		3	2	2	88			1,068	1	31		
		Count - less than	411	2	2	2		3	2	2	88			178	1	0		
10/B	Surface Water	Average	3.190					<1			<1			3.996	<1	0.277		
		Minimum	<1					<1			<1			<0	<1	0.200		
		Maximum	31.000					<1			<1			600.000	<1	1.040		
		Count	735					1			66			736	1	23		
		Count - less than	489					1			66			335	1	0		
10/C	Surface Water	Average																
		Minimum																
		Maximum																
		Count																
		Count - less than																
10/D	Surface Water	Average	5.500								<1			4.186		0.315		
		Minimum	<1								<1			<1		0.240		
		Maximum	200.000								<1			170.000		0.550		
		Count	156								32			156		8		
		Count - less than	110								32			66		0		
11/A	Surface Water	Average	0.655													0.396		
		Minimum	<1													0.114		
		Maximum	63.100													35.000		
		Count	765													1,434		
		Count - less than	758													0		
11/B	Surface Water	Average	35.892											1,710.974		0.225		
		Minimum	<1											<1		<0.01		
		Maximum	1,986.300											2,419.200		0.523		
		Count	497											497		789		
		Count - less than	145											202		1		
11/C	Surface Water	Average	0.639													0.372		
		Minimum	<1													0.097		
		Maximum	35.000													1.700		
		Count	564													1,145		
		Count - less than	535													0		

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1/A	Groundwater	Average								256.897						112.706
		Minimum								195.000						0.000
		Maximum								380.000						3,800.000
		Count								29						245
		Count - less than								0						0
1/B	Surface Water	Average						0.422	0.189	116.586						
		Minimum						0.000	0.000	91.000						
		Maximum						5.800	3.900	135.000						
		Count						36	35	29						
		Count - less than						0	0	0						
1/C	Groundwater	Average								<860						
		Minimum								<860						
		Maximum								<860						
		Count								31						
		Count - less than								31						
3/A	Groundwater	Average		<0.2				<2	<4	6.620	<0.04	<0.02	<0.1	<1	<0.1	
		Minimum		<0.2				<2	<4	6.620	<0.04	<0.02	<0.1	<1	<0.1	
		Maximum		<0.2				<2	<4	6.620	<0.04	<0.02	<0.1	<1	<0.1	
		Count		1				1	1	1	1	1	1	1	1	
		Count - less than		1				1	1	0	1	1	1	1	1	
3/B	Groundwater	Average					<0.1	1.000	2.000	8.500	<0.03	<0.2	<1	<1	<10	
		Minimum					<0.1	<2	<4	8.500	<0.03	<0.2	<1	<1	<10	
		Maximum					<0.1	1.000	2.000	8.500	<0.03	<0.2	<1	<1	<10	
		Count					1	2	2	1	1	1	1	1	1	
		Count - less than					1	1	1	0	1	1	1	1	1	
4/A	Surface Water	Average			191.657					170.000						
		Minimum			<10					170.000						
		Maximum			1,102.000					170.000						
		Count			54					1						
		Count - less than			9					0						
4/B	Surface Water	Average								162.783						
		Minimum								98.000						
		Maximum								230.000						
		Count								35						
		Count - less than								0						
5/A	Surface Water	Average			5.708					137.759						
		Minimum			<1.36					40.000						
		Maximum			13.870					248.000						
		Count			32					170						
		Count - less than			2					0						
5/B	Surface Water	Average			26.250					74.339						
		Minimum			2.680					40.000						
		Maximum			153.000					170.000						
		Count			30					127						
		Count - less than			0					0						
5/C	Surface Water	Average			11.248					152.459						
		Minimum			<1.36					64.000						
		Maximum			73.200					320.000						
		Count			37					133						
		Count - less than			4					0						
5/D	Surface Water	Average			16.256					130.953						
		Minimum			2.050					46.000						
		Maximum			74.860					300.000						
		Count			33					128						
		Count - less than			0					0						
5/E	Surface Water	Average			19.090					132.539						
		Minimum			<1.7					44.000						
		Maximum			96.590					240.000						
		Count			43					128						
		Count - less than			8					0						
5/F	Surface Water	Average			17.069					117.685						
		Minimum			<1.36					54.000						
		Maximum			98.080					232.000						
		Count			41					165						
		Count - less than			4					0						
5/G	Surface Water	Average			21.748					105.606						
		Minimum			<1.36					40.000						
		Maximum			137.000					336.000						
		Count			44					165						
		Count - less than			4					0						
6/A	Groundwater	Average								270.500						
		Minimum								231.000						
		Maximum								322.000						
		Count								36						
		Count - less than								0						

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6/B	Groundwater	Average								280.000						
		Minimum								279.000						
		Maximum								281.000						
		Count								2						
		Count - less than								0						
6/C	Groundwater	Average								329.000						
		Minimum								329.000						
		Maximum								329.000						
		Count								1						
		Count - less than								0						
7/A	Surface Water	Average								213.880						
		Minimum								171.000						
		Maximum								279.000						
		Count								259						
		Count - less than								0						
7/B	Groundwater	Average								502.980						
		Minimum								110.000						
		Maximum								743.000						
		Count								203						
		Count - less than								0						
7/C	Groundwater	Average								81.929						
		Minimum								47.800						
		Maximum								144.000						
		Count								119						
		Count - less than								0						
8/A (same waterbody as 5/D)	Surface Water	Average			10.087					113.771						
		Minimum			<0					92.000						
		Maximum			107.000					136.000						
		Count			68					105						
		Count - less than			22					0						
9/A	Surface Water	Average			24.122	0.000				149.622						
		Minimum			2.300	0.000				0.000						
		Maximum			108.000	0.000				280.000						
		Count			149	28				5,847						
		Count - less than			0	0				0						
10/A	Surface Water	Average	<0.2	<1	11.470						<0.4	<0.2	<1	<1	<1	8,025.000
		Minimum	<0.2	<1	<5						<0.4	<0.2	<1	<1	<1	4,700.000
		Maximum	<0.2	<1	78.400						<0.4	<0.2	<1	<1	<1	12,200.000
		Count	3	1	223						3	3	1	88	1	8
		Count - less than	3	1	59						3	3	1	88	1	0
10/B	Surface Water	Average	<0.2	<1	20.965						<0.4	<0.2	<1	<1	<1	657,842.857
		Minimum	<0.2	<1	<5						<0.4	<0.2	<1	<1	<1	200.000
		Maximum	<0.2	<1	219.000						<0.4	<0.2	<1	<1	<1	4,560,000.000
		Count	1	1	156						1	1	1	66	1	7
		Count - less than	1	1	42						1	1	1	66	1	0
10/C	Surface Water	Average														
		Minimum														
		Maximum														
		Count														
		Count - less than														
10/D	Surface Water	Average			14.006									<1		69,042.857
		Minimum			<5									<1		16,300.000
		Maximum			68.800									<1		168,000.000
		Count			32									32		7
		Count - less than			9									32		0
11/A	Surface Water	Average			<2					116.240						
		Minimum			<2					65.000						
		Maximum			<2					144.800						
		Count			1					1,049						
		Count - less than			1					0						
11/B	Surface Water	Average			1.429					58.417						17,521.739
		Minimum			<2					29.600						<2000
		Maximum			3.300					84.800						209,000.000
		Count			24					70						69
		Count - less than			16					0						11
11/C	Surface Water	Average			1.443					112.978						
		Minimum			<2					71.400						
		Maximum			3.300					144.200						
		Count			40					750						
		Count - less than			29					0						

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1/A	Groundwater	Average					0.052				0.000			31.731	0.002	<0.3	
		Minimum					<0.03				<0.000004			21.600	<0.002	<0.3	
		Maximum					0.378				0.000			46.500	0.009	<0.3	
		Count					25				25			29	25	9	
		Count - less than					12				21			0	6	9	
1/B	Surface Water	Average					0.073				0.002			10.354	0.016	<0.3	
		Minimum					<0.034				<0.0002			8.000	0.001	<0.3	
		Maximum					0.160				0.014			13.000	0.064	<0.3	
		Count					19				16			28	16	4	
		Count - less than					4				1			0	0	4	
1/C	Groundwater	Average					<1.93				<0.0124			<46.2	<0.144	<0.3	
		Minimum					<1.93				<0.0124			<46.2	<0.144	<0.3	
		Maximum					<1.93				<0.0124			<46.2	<0.144	<0.3	
		Count					27				27			31	27	9	
		Count - less than					27				27			31	27	9	
3/A	Groundwater	Average			<0.2	<2	0.016	<1			<0.001	<0.02		<1	0.010	<0.4	<0.1
		Minimum			<0.2	<2	0.016	<1			<0.001	<0.02		<1	0.010	<0.4	<0.1
		Maximum			<0.2	<2	0.016	<1			<0.001	<0.02		<1	0.010	<0.4	<0.1
		Count			1	1	1	1			1	1		1	1	1	1
		Count - less than			1	1	0	1			1	1		1	0	1	1
3/B	Groundwater	Average	<0.05			<2		<1		-0.910		<0.03		<0.001			<0.5
		Minimum	<0.05			<2		<1		-0.910		<0.03		<0.001			<0.5
		Maximum	<0.05			<2		<1		-0.910		<0.03		<0.001			<0.5
		Count	1			1		1		1		1		1			1
		Count - less than	1			1		1		0		1		1			1
4/A	Surface Water	Average											<6	4.692		<0.2	
		Minimum											<6	3.530		<0.2	
		Maximum											<6	6.880		<0.2	
		Count											7	39		12	
		Count - less than											7	0		12	
4/B	Surface Water	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
5/A	Surface Water	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
5/B	Surface Water	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
5/C	Surface Water	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
5/D	Surface Water	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
5/E	Surface Water	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
5/F	Surface Water	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
5/G	Surface Water	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
6/A	Groundwater	Average												15.807			
		Minimum												12.700			
		Maximum												18.400			
		Count												54			
		Count - less than												0			

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6/B	Groundwater	Average												16.575			
		Minimum												16.100			
		Maximum												17.000			
		Count												4			
		Count - less than												0			
6/C	Groundwater	Average												18.400			
		Minimum												18.400			
		Maximum												18.400			
		Count												1			
		Count - less than												0			
7/A	Surface Water	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
7/B	Groundwater	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
7/C	Groundwater	Average								0.051							
		Minimum								-1.100							
		Maximum								0.450							
		Count								154							
		Count - less than								0							
8/A (same waterbody as 5/D)	Surface Water	Average													0.065		
		Minimum													0.002		
		Maximum													0.898		
		Count													148		
		Count - less than													0		
9/A	Surface Water	Average					0.212								0.032		
		Minimum					0.000								0.002		
		Maximum					1.520								0.231		
		Count					108								108		
		Count - less than					0								0		
10/A	Surface Water	Average		<1					<1				<1				<1
		Minimum		<1					<1				<1				<1
		Maximum		<1					<1				<1				<1
		Count		1					88				88				3
		Count - less than		1					88				88				3
10/B	Surface Water	Average		<1					<1				<1				<1
		Minimum		<1					<1				<1				<1
		Maximum		<1					<1				<1				<1
		Count		1					66				66				1
		Count - less than		1					66				66				1
10/C	Surface Water	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
10/D	Surface Water	Average							<1				<1				
		Minimum							<1				<1				
		Maximum							<1				<1				
		Count							32				32				
		Count - less than							32				32				
11/A	Surface Water	Average					0.729							5.486	0.051		
		Minimum					<0.03							2.700	0.010		
		Maximum					3.420							13.400	0.442		
		Count					144							144	144		
		Count - less than					1							0	0		
11/B	Surface Water	Average					0.563			-0.528				3.026	0.162		
		Minimum					0.030			-1.770				0.326	<0.01		
		Maximum					3.010			0.781				8.860	6.590		
		Count					70			484				70	70		
		Count - less than					0			0				0	2		
11/C	Surface Water	Average					0.929							5.294	0.070		
		Minimum					0.140							2.750	0.007		
		Maximum					4.730							12.600	0.278		
		Count					72							72	72		
		Count - less than					0							0	0		

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	Methylenechloride µg/L	Methylisoborneol ng/L	Methylmethacrylate µg/L	Methyl-t-butylether(MTBE) µg/L	Metolachlor µg/L	Metribuzin µg/L	Monochlorobenzene µg/L	Naphthalene µg/L	n-Butylbenzene µg/L	Nickel mg/L	Nitrate mg/L	Nitrate+Nitrite mg/L	Nitrite mg/L	NoncarbonateHardness mg/L
1/A	Groundwater	Average										0.003	1.088		0.064	
		Minimum										<0.002	<0.033		<0.004	
		Maximum										0.031	1.570		1.340	
		Count										25	31		31	
		Count - less than										1	1		26	
1/B	Surface Water	Average										0.003	0.080		0.006	
		Minimum										0.002	<0.015		<0.004	
		Maximum										0.004	0.719		0.014	
		Count										16	38		38	
		Count - less than										0	28		36	
1/C	Groundwater	Average										<0.01	<4.76		<0.028	
		Minimum										<0.01	<4.76		<0.028	
		Maximum										<0.01	<4.76		<0.028	
		Count										27	36		36	
		Count - less than										27	36		36	
3/A	Groundwater	Average			<1	<2	<0.2	<0.2	<0.5	<1	<1	<0.001	<0.01		<0.01	
		Minimum			<1	<2	<0.2	<0.2	<0.5	<1	<1	<0.001	<0.01		<0.01	
		Maximum			<1	<2	<0.2	<0.2	<0.5	<1	<1	<0.001	<0.01		<0.01	
		Count			1	1	1	1	1	2	1	1	2		1	
		Count - less than			1	1	1	1	1	2	1	1	2		1	
3/B	Groundwater	Average	<1		<1	<2			<0.5	<1	<1		<0.5		<0.05	
		Minimum	<1		<1	<2			<0.5	<1	<1		<0.5		<0.05	
		Maximum	<1		<1	<2			<0.5	<1	<1		<0.5		<0.05	
		Count	1		1	1			1	1	1		2		1	
		Count - less than	1		1	1			1	1	1		2		1	
4/A	Surface Water	Average	<3									<0.004	0.099		0.038	
		Minimum	<3									<0.004	<0.05		<0.014	
		Maximum	<3									<0.004	0.370		0.560	
		Count	7									1	39		39	
		Count - less than	7									1	20		35	
4/B	Surface Water	Average											3.930		0.062	
		Minimum											<0.04		<0.04	
		Maximum											12.000		0.300	
		Count											33		32	
		Count - less than											4		23	
5/A	Surface Water	Average		10.068									0.784			
		Minimum		<1.24									<0.07			
		Maximum		49.930									5.500			
		Count		32									165			
		Count - less than		2									7			
5/B	Surface Water	Average		6.026									6.697			
		Minimum		<1.36									<0.07			
		Maximum		18.300									220.000			
		Count		30									119			
		Count - less than		4									32			
5/C	Surface Water	Average		11.645									0.811			
		Minimum		<1.26									<0.07			
		Maximum		59.620									12.300			
		Count		37									125			
		Count - less than		9									18			
5/D	Surface Water	Average		4.856									1.617			
		Minimum		<1.36									<0.07			
		Maximum		17.380									16.200			
		Count		33									120			
		Count - less than		7									12			
5/E	Surface Water	Average		6.752									0.234			
		Minimum		<1.37									<0.07			
		Maximum		32.600									2.000			
		Count		43									120			
		Count - less than		8									13			
5/F	Surface Water	Average		3.690									0.351			
		Minimum		<1.36									<0.07			
		Maximum		16.810									4.000			
		Count		41									155			
		Count - less than		14									20			
5/G	Surface Water	Average		10.301									0.587			
		Minimum		<1.37									<0.07			
		Maximum		264.490									13.690			
		Count		44									160			
		Count - less than		21									29			
6/A	Groundwater	Average											5.425			
		Minimum											0.170			
		Maximum											9.830			
		Count											54			
		Count - less than											0			

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	Methylenechloride µg/L	Methylisoborneol ng/L	Methylmethacrylate µg/L	Methyl-t-butylether(MTBE) µg/L	Metolachlor µg/L	Metribuzin µg/L	Monochlorobenzene µg/L	Naphthalene µg/L	n-Butylbenzene µg/L	Nickel mg/L	Nitrate mg/L	Nitrate+Nitrite mg/L	Nitrite mg/L	NoncarbonateHardness mg/L
6/B	Groundwater	Average											5.665			
		Minimum											0.210			
		Maximum											8.410			
		Count											4			
		Count - less than											0			
6/C	Groundwater	Average											8.770			
		Minimum											8.770			
		Maximum											8.770			
		Count											1			
		Count - less than											0			
7/A	Surface Water	Average											1.326		<0.25	
		Minimum											<0.2		<0.25	
		Maximum											2.670		<0.25	
		Count											21		21	
		Count - less than											1		21	
7/B	Groundwater	Average														
		Minimum														
		Maximum														
		Count														
		Count - less than														
7/C	Groundwater	Average											0.077		0.038	
		Minimum											<0		<0	
		Maximum											3.520		0.150	
		Count											153		154	
		Count - less than											145		147	
8/A (same waterbody as 5/D)	Surface Water	Average											0.281		0.013	
		Minimum											0.000		0.000	
		Maximum											2.300		0.107	
		Count											73		72	
		Count - less than											0		0	
9/A	Surface Water	Average											0.340	0.540	0.016	49.104
		Minimum											<0	0.000	<0	2.000
		Maximum											13.800	13.800	0.113	130.000
		Count											607	80	550	67
		Count - less than											134	0	139	0
10/A	Surface Water	Average	<1			<1	<1	<1		<1	<1		0.179	0.282	0.011	
		Minimum	<1			<1	<1	<1		<1	<1		<0.1	0.238	<0.005	
		Maximum	<1			<1	<1	<1		<1	<1		0.350	0.354	0.039	
		Count	88			99	1	1		88	88		39	7	39	
		Count - less than	88			99	1	1		88	88		7	0	15	
10/B	Surface Water	Average	<1			<1	<1	<1		<1	<1		0.319	0.495	0.025	
		Minimum	<1			<1	<1	<1		<1	<1		<0.1	0.422	<0.005	
		Maximum	<1			<1	<1	<1		<1	<1		0.920	0.586	0.090	
		Count	66			77	1	1		66	66		31	6	31	
		Count - less than	66			77	1	1		66	66		1	0	2	
10/C	Surface Water	Average														
		Minimum														
		Maximum														
		Count														
		Count - less than														
10/D	Surface Water	Average	<1			<1				<1	<1		0.469	0.721	0.041	
		Minimum	<1			<1				<1	<1		<0.1	0.216	<0.005	
		Maximum	<1			<1				<1	<1		1.210	1.230	0.440	
		Count	32			32				32	32		15	5	15	
		Count - less than	32			32				32	32		2	0	8	
11/A	Surface Water	Average											0.285		0.022	
		Minimum											<0.01		<0.01	
		Maximum											1.240		0.210	
		Count											825		825	
		Count - less than											1		549	
11/B	Surface Water	Average											0.235		0.018	
		Minimum											<0.016		<0.01	
		Maximum											0.970		0.040	
		Count											59		59	
		Count - less than											10		41	
11/C	Surface Water	Average											0.273		0.022	
		Minimum											0.022		<0.01	
		Maximum											1.180		0.060	
		Count											592		592	
		Count - less than											0		312	

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	n-Propylbenzene µg/L	o-Dichlorobenzene µg/L	Orthophosphate mg/L	Oxamyl µg/L	o-Xylene µg/L	para-Dichlorobenzene µg/L	p-Bromofluorobenzene %	p-DICHLOROBENZENE µg/L	Pentachlorophenol µg/L	PercentSodium	pH StandardUnits	Phenanthrene µg/L
1/A	Groundwater	Average											8.259	
		Minimum											7.730	
		Maximum											8.750	
		Count											771	
		Count - less than											0	
1/B	Surface Water	Average											8.274	
		Minimum											6.400	
		Maximum											8.930	
		Count											110	
		Count - less than											0	
1/C	Groundwater	Average											<15.2	
		Minimum											<15.2	
		Maximum											<15.2	
		Count											33	
		Count - less than											33	
3/A	Groundwater	Average	<1					<0.5			<0.04		8.100	<0.2
		Minimum	<1					<0.5			<0.04		8.100	<0.2
		Maximum	<1					<0.5			<0.04		8.100	<0.2
		Count	1					1			1		1	1
		Count - less than	1					1			1		0	1
3/B	Groundwater	Average	<1	<1		<100		<0.5		<1	<1		8.115	
		Minimum	<1	<1		<100		<0.5		<1	<1		8.030	
		Maximum	<1	<1		<100		<0.5		<1	<1		8.200	
		Count	1	2		1		1		1	1		2	
		Count - less than	1	2		1		1		1	1		0	
4/A	Surface Water	Average			0.011		<5		112.882					
		Minimum			<0.02		<5		90.800					
		Maximum			0.030		<5		129.340					
		Count			39		7		10					
		Count - less than			37		7		0					
4/B	Surface Water	Average			0.350								7.451	
		Minimum			<0.04								7.000	
		Maximum			1.196								8.400	
		Count			32								35	
		Count - less than			3								0	
5/A	Surface Water	Average			0.149								7.808	
		Minimum			<0.05								6.810	
		Maximum			1.960								9.030	
		Count			160								180	
		Count - less than			52								0	
5/B	Surface Water	Average			0.074								7.850	
		Minimum			<0.05								6.880	
		Maximum			0.730								8.760	
		Count			121								135	
		Count - less than			84								0	
5/C	Surface Water	Average			0.183								8.018	
		Minimum			<0.05								7.150	
		Maximum			5.900								8.920	
		Count			125								141	
		Count - less than			70								0	
5/D	Surface Water	Average			0.251								7.890	
		Minimum			<0.032								5.380	
		Maximum			3.820								10.100	
		Count			124								136	
		Count - less than			64								0	
5/E	Surface Water	Average			0.045								7.956	
		Minimum			<0.05								6.920	
		Maximum			0.250								8.690	
		Count			128								136	
		Count - less than			108								0	
5/F	Surface Water	Average			0.088								7.930	
		Minimum			<0.05								7.040	
		Maximum			1.740								9.050	
		Count			160								170	
		Count - less than			111								0	
5/G	Surface Water	Average			0.480								7.918	
		Minimum			<0.05								6.460	
		Maximum			11.500								9.360	
		Count			149								175	
		Count - less than			76								0	
6/A	Groundwater	Average										7.889	7.132	
		Minimum										6.000	6.940	
		Maximum										11.000	7.350	
		Count										54	54	
		Count - less than										0	0	

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6/B	Groundwater	Average										8.000	7.130	
		Minimum										8.000	7.070	
		Maximum										8.000	7.250	
		Count										4	4	
		Count - less than										0	0	
6/C	Groundwater	Average										7.000	6.920	
		Minimum										7.000	6.920	
		Maximum										7.000	6.920	
		Count										1	1	
		Count - less than										0	0	
7/A	Surface Water	Average			0.649								8.424	
		Minimum			<0.1								7.800	
		Maximum			6.160								8.600	
		Count			259								259	
		Count - less than			1								0	
7/B	Groundwater	Average			0.064								7.654	
		Minimum			<0.1								6.600	
		Maximum			0.800								7.900	
		Count			203								199	
		Count - less than			193								0	
7/C	Groundwater	Average			0.062								8.215	
		Minimum			<-0.02								7.200	
		Maximum			1.000								8.900	
		Count			154								300	
		Count - less than			144								0	
8/A (same waterbody as 5/D)	Surface Water	Average											7.877	
		Minimum											6.200	
		Maximum											10.680	
		Count											200	
		Count - less than											0	
9/A	Surface Water	Average			0.049								7.971	
		Minimum			<0.01								0.000	
		Maximum			1.150								9.600	
		Count			346								6,912	
		Count - less than			115								0	
10/A	Surface Water	Average	<1		<0.1		<1				<4		8.013	<1
		Minimum	<1		<0.1		<1				<4		7.900	<1
		Maximum	<1		<0.1		<1				<4		8.200	<1
		Count	88		6		88				1		8	1
		Count - less than	88		6		88				1		0	1
10/B	Surface Water	Average	<1		<0.1		<1				<4		7.975	<1
		Minimum	<1		<0.1		<1				<4		7.600	<1
		Maximum	<1		<0.1		<1				<4		8.200	<1
		Count	66		4		66				1		8	1
		Count - less than	66		4		66				1		0	1
10/C	Surface Water	Average												
		Minimum												
		Maximum												
		Count												
		Count - less than												
10/D	Surface Water	Average	<1		<0.1		<1						7.929	
		Minimum	<1		<0.1		<1						7.600	
		Maximum	<1		<0.1		<1						8.300	
		Count	32		1		32						7	
		Count - less than	32		1		32						0	
11/A	Surface Water	Average			0.025								7.712	
		Minimum			<0.01								0.010	
		Maximum			0.091								8.830	
		Count			395								1,046	
		Count - less than			243								0	
11/B	Surface Water	Average											7.796	
		Minimum											6.460	
		Maximum											8.820	
		Count											743	
		Count - less than											0	
11/C	Surface Water	Average			0.025								7.723	
		Minimum			<0.01								7.300	
		Maximum			0.168								9.360	
		Count			397								748	
		Count - less than			255								0	

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1/A	Groundwater	Average	0.049		3.080				24.957							
		Minimum	0.000		<0.004				5.500							
		Maximum	11.370		95.000				275.000							
		Count	772		31				29							
		Count - less than	0		30				0							
1/B	Surface Water	Average	0.006		0.020				5.800							
		Minimum	0.000		<0.022				4.300							
		Maximum	0.600		0.165				9.700							
		Count	108		38				28							
		Count - less than	0		37				0							
1/C	Groundwater	Average	<0		<0.872				<23.6							
		Minimum	<0		<0.872				<23.6							
		Maximum	<0		<0.872				<23.6							
		Count	33		36				31							
		Count - less than	33		36				31							
3/A	Groundwater	Average	<1							<0.2	<0.2	<0.2		1.100		
		Minimum	<1							<0.2	<0.2	<0.2		1.100		
		Maximum	<1							<0.2	<0.2	<0.2		1.100		
		Count	1							1	1	1		1		
		Count - less than	1							1	1	1		0		
3/B	Groundwater	Average	4.250				<100	<0.5	1.200				1.200	0.500	76.000	
		Minimum	<1				<100	<0.5	1.200				1.200	0.000	76.000	
		Maximum	8.000				<100	<0.5	1.200				1.200	1.000	76.000	
		Count	2				1	1	1				1	2	1	
		Count - less than	1				1	1	0				0	0	0	
4/A	Surface Water	Average							4.752							
		Minimum							4.070							
		Maximum							5.560							
		Count							13							
		Count - less than							0							
4/B	Surface Water	Average														
		Minimum														
		Maximum														
		Count														
		Count - less than														
5/A	Surface Water	Average		14.380												
		Minimum		<2.2												
		Maximum		49.800												
		Count		44												
		Count - less than		13												
5/B	Surface Water	Average		16.385												
		Minimum		<6												
		Maximum		98.000												
		Count		60												
		Count - less than		20												
5/C	Surface Water	Average		15.573												
		Minimum		<4												
		Maximum		123.000												
		Count		64												
		Count - less than		22												
5/D	Surface Water	Average		21.860												
		Minimum		<6												
		Maximum		83.900												
		Count		60												
		Count - less than		16												
5/E	Surface Water	Average		15.748												
		Minimum		<6												
		Maximum		72.200												
		Count		80												
		Count - less than		20												
5/F	Surface Water	Average		12.683												
		Minimum		<5												
		Maximum		73.000												
		Count		60												
		Count - less than		20												
5/G	Surface Water	Average		16.903												
		Minimum		<6												
		Maximum		113.000												
		Count		72												
		Count - less than		19												
6/A	Groundwater	Average	<2						1.266							0.000
		Minimum	<2						0.970							0.000
		Maximum	<2						2.620							0.010
		Count	54						54							54
		Count - less than	54						0							0

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	PhenolphthaleinAlkalinity mg/L	Pheophytin a mg/m3	Phosphate mg/L	PhytoplanktonCount cells/mL	Picloram µg/L	PolychlorinatedBiphenyls mg/L	Potassium mg/L	Prometon µg/L	Propachlor µg/L	Pyrene µg/L	Radium-226 pCi/L	Radium-228 pCi/L	Radon-222 pCi/L	ResidualSodiumCarbonate
6/B	Groundwater	Average	<2						1.213							0.000
		Minimum	<2						0.970							0.000
		Maximum	<2						1.340							0.000
		Count	4						4							4
		Count - less than	4						0							0
6/C	Groundwater	Average	<2						1.570							0.000
		Minimum	<2						1.570							0.000
		Maximum	<2						1.570							0.000
		Count	1						1							1
		Count - less than	1						0							0
7/A	Surface Water	Average	5.083		0.299											
		Minimum	<1		<0.05											
		Maximum	13.200		3.290											
		Count	259		21											
		Count - less than	34		2											
7/B	Groundwater	Average	0.505													
		Minimum	<1													
		Maximum	1.600													
		Count	203													
		Count - less than	202													
7/C	Groundwater	Average														
		Minimum														
		Maximum														
		Count														
		Count - less than														
8/A (same waterbody as 5/D)	Surface Water	Average														
		Minimum														
		Maximum														
		Count														
		Count - less than														
9/A	Surface Water	Average			0.047	85,686.818										
		Minimum			<0.01	5,000.000										
		Maximum			0.124	431,000.000										
		Count			69	154										
		Count - less than			24	0										
10/A	Surface Water	Average									<1	<1				
		Minimum									<1	<1				
		Maximum									<1	<1				
		Count									1	1				
		Count - less than									1	1				
10/B	Surface Water	Average									<1	<1				
		Minimum									<1	<1				
		Maximum									<1	<1				
		Count									1	1				
		Count - less than									1	1				
10/C	Surface Water	Average														
		Minimum														
		Maximum														
		Count														
		Count - less than														
10/D	Surface Water	Average														
		Minimum														
		Maximum														
		Count														
		Count - less than														
11/A	Surface Water	Average			0.103				5.310							
		Minimum			<0.054				4.060							
		Maximum			0.684				7.240							
		Count			96				144							
		Count - less than			1				0							
11/B	Surface Water	Average			0.528				4.520							
		Minimum			0.066				2.800							
		Maximum			15.400				7.850							
		Count			47				70							
		Count - less than			0				0							
11/C	Surface Water	Average			0.102				5.222							
		Minimum			0.025				4.160							
		Maximum			0.218				7.300							
		Count			48				72							
		Count - less than			0				0							

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	Residue on Evaporation mg/L	sec-Butylbenzene µg/L	SecchiDepth inches	Selenium mg/L	Silica mg/L	Silver mg/L	Simazine µg/L	Sodium mg/L	SodiumAdsorptionRatio	Styrene µg/L	Sulfate mg/L	Sulfide mg/L	SuspendedOrganicCarbon µg/L	Taste & Odor	t-Butylbenzene µg/L	Temperature C
1/A	Groundwater	Average				0.001	24.593	0.000		211.346			164.260					20.666
		Minimum				0.000	17.100	<0.0001		7.100			83.400					12.900
		Maximum				0.002	55.300	0.001		504.000			310.000					25.730
		Count				25	29	25		28			30					772
		Count - less than				0	0	16		0			0					0
1/B	Surface Water	Average				0.002	10.588	0.000		208.741			102.358		0.000			19.217
		Minimum				0.000	0.500	<0.0001		147.000			76.000		0.000			9.600
		Maximum				0.006	56.300	0.000		265.000			125.000		0.000			26.100
		Count				16	32	16		27			38		3			108
		Count - less than				0	0	14		0			0		0			0
1/C	Groundwater	Average				<0.0216	<155.8	<0.0012		<76.4			<105.8		<0			<51.4
		Minimum				<0.0216	<155.8	<0.0012		<76.4			<105.8		<0			<51.4
		Maximum				<0.0216	<155.8	<0.0012		<76.4			<105.8		<0			<51.4
		Count				27	32	27		31			36		1			33
		Count - less than				27	32	27		31			36		1			33
3/A	Groundwater	Average		<1		<0.003		<0.01	<0.07	172.000		<0.5	15.000				<1	
		Minimum		<1		<0.003		<0.01	<0.07	172.000		<0.5	15.000				<1	
		Maximum		<1		<0.003		<0.01	<0.07	172.000		<0.5	15.000				<1	
		Count		1		1		1	1	1		1	1				1	
		Count - less than		1		1		1	1	0		1	0				1	
3/B	Groundwater	Average		<1			12.700		<1	144.200		<50	5.000				<1	38.000
		Minimum		<1			12.700		<1	144.200		<50	<10				<1	38.000
		Maximum		<1			12.700		<1	144.200		<50	5.000				<1	38.000
		Count		1			1		1	1		2	2				1	1
		Count - less than		1			0		1	0		2	1				1	0
4/A	Surface Water	Average								19.977			32.777					
		Minimum								14.800			23.000					
		Maximum								28.800			46.300					
		Count								39			13					
		Count - less than								0			0					
4/B	Surface Water	Average						<0.0005					66.305					
		Minimum						<0.0005					16.000					
		Maximum						<0.0005					105.000					
		Count						12					34					
		Count - less than						12					0					
5/A	Surface Water	Average																
		Minimum																
		Maximum																
		Count																
		Count - less than																
5/B	Surface Water	Average																
		Minimum																
		Maximum																
		Count																
		Count - less than																
5/C	Surface Water	Average																
		Minimum																
		Maximum																
		Count																
		Count - less than																
5/D	Surface Water	Average																
		Minimum																
		Maximum																
		Count																
		Count - less than																
5/E	Surface Water	Average																
		Minimum																
		Maximum																
		Count																
		Count - less than																
5/F	Surface Water	Average																
		Minimum																
		Maximum																
		Count																
		Count - less than																
5/G	Surface Water	Average																
		Minimum																
		Maximum																
		Count																
		Count - less than																
6/A	Groundwater	Average					12.478			10.309	0.272		25.343					24.038
		Minimum					11.600			7.790	0.200		15.600					22.000
		Maximum					13.200			13.700	0.380		48.600					28.000
		Count					54			54	54		54					53
		Count - less than					0			0	0		0					0

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EXHIBIT E

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	Residue on Evaporation mg/L	sec-Butylbenzene µg/L	SecchiDepth inches	Selenium mg/L	Silica mg/L	Silver mg/L	Simazine µg/L	Sodium mg/L	SodiumAdsorptionRatio	Styrene µg/L	Sulfate mg/L	Sulfide mg/L	SuspendedOrganicCarbon µg/L	Taste & Odor	t-Butylbenzene µg/L	Temperature C
6/B	Groundwater	Average					12.900			10.380	0.273		29.250					24.250
		Minimum					12.300			9.720	0.270		15.900					23.000
		Maximum					13.700			10.900	0.280		35.500					26.000
		Count					4			4	4		4					4
		Count - less than					0			0	0		0					0
6/C	Groundwater	Average					10.800			11.800	0.280		26.700					23.000
		Minimum					10.800			11.800	0.280		26.700					23.000
		Maximum					10.800			11.800	0.280		26.700					23.000
		Count					1			1	1		1					1
		Count - less than					0			0	0		0					0
7/A	Surface Water	Average					19.186						152.840					20.129
		Minimum					13.800						<5					18.100
		Maximum					44.100						319.000					23.800
		Count					21						259					21
		Count - less than					0						1					0
7/B	Groundwater	Average					33.397						295.842					25.447
		Minimum					25.200						<25					6.000
		Maximum					45.000						2,680.000					26.900
		Count					203						203					200
		Count - less than					0						2					0
7/C	Groundwater	Average					33.857						147.697					24.078
		Minimum					26.500						75.370					14.700
		Maximum					47.500						268.000					29.500
		Count					154						154					301
		Count - less than					0						0					0
8/A (same waterbody as 5/D)	Surface Water	Average											28.936	0.008				21.803
		Minimum											0.000	0.000				8.600
		Maximum											36.700	0.029				31.100
		Count											11	132				200
		Count - less than											0	0				0
9/A	Surface Water	Average	313.235		18.806		6.669			38.409			554.571			16.983		20.045
		Minimum	172.000		3.000		<2			14.200			16.800			1.000		0.000
		Maximum	604.000		42.000		10.500			127.000			43,500.000			70.000		31.660
		Count	68		162		69			109			530			161		6,810
		Count - less than	0		0		5			0			0			0		0
10/A	Surface Water	Average		<1					<1			<1	21.740					15.650
		Minimum		<1					<1			<1	10.500					11.100
		Maximum		<1					<1			<1	26.700					18.600
		Count		88					1			88	5					8
		Count - less than		88					1			88	0					0
10/B	Surface Water	Average		<1					<1			<1	22.767					16.800
		Minimum		<1					<1			<1	20.800					13.500
		Maximum		<1					<1			<1	26.200					19.600
		Count		66					1			66	3					8
		Count - less than		66					1			66	0					0
10/C	Surface Water	Average																
		Minimum																
		Maximum																
		Count																
		Count - less than																
10/D	Surface Water	Average		<1								<1						17.886
		Minimum		<1								<1						14.500
		Maximum		<1								<1						21.000
		Count		32								32						7
		Count - less than		32								32						0
11/A	Surface Water	Average					7.196			28.300			39.264					22.387
		Minimum					0.790			11.000			<0.04					11.000
		Maximum					14.300			47.600			67.700					33.000
		Count					105			144			825					1,036
		Count - less than					0			0			1					0
11/B	Surface Water	Average					5.553			32.827			9.931					21.638
		Minimum					0.910			5.000			0.163					2.000
		Maximum					18.800			80.300			16.600					29.000
		Count					45			70			59					675
		Count - less than					0			0			0					0
11/C	Surface Water	Average					7.845			28.767			37.946					22.280
		Minimum					0.940			11.000			19.000					7.900
		Maximum					18.900			46.500			59.200					31.700
		Count					46			72			592					743
		Count - less than					0			0			0					0

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	tert-Butylbenzene µg/L	Tetrachloroethene µg/L	Tetrachloroethylene µg/L	Tetrahydrofuran µg/L	Thallium mg/L	Titanium mg/L	Toluene µg/L	Toluene-d8 %	TotalAlkalinity mg/L	TotalAluminium mg/L	TotalAntimony mg/L	TotalArsenic mg/L	TotalBarium mg/L	TotalBeryllium mg/L	TotalBoron mg/L
1/A	Groundwater	Average						<0.0002			186.076						
		Minimum						<0.0002			166.900						
		Maximum						<0.0002			443.300						
		Count						25			771						
		Count - less than						25			0						
1/B	Surface Water	Average						<0.0002			177.395						
		Minimum						<0.0002			151.000						
		Maximum						<0.0002			221.000						
		Count						16			109						
		Count - less than						16			0						
1/C	Groundwater	Average						<0.0002			<600						
		Minimum						<0.0002			<600						
		Maximum						<0.0002			<600						
		Count						27			34						
		Count - less than						27			34						
3/A	Groundwater	Average			<0.5	<5	<0.0004		<0.5		337.000						
		Minimum			<0.5	<5	<0.0004		<0.5		337.000						
		Maximum			<0.5	<5	<0.0004		<0.5		337.000						
		Count			1	1	1		1		1						
		Count - less than			1	1	1		1		0						
3/B	Groundwater	Average		<1	<0.5	<5			<1		285.000	0.016	<0.005	<0.003	0.086	0.002	
		Minimum		<1	<0.5	<5			<1		168.000	0.016	<0.005	<0.003	0.086	0.002	
		Maximum		<1	<0.5	<5			<1		402.000	0.016	<0.005	<0.003	0.086	0.002	
		Count		1	1	1			2		2	1	1	1	1	1	
		Count - less than		1	1	1			2		0	0	1	1	0	0	
4/A	Surface Water	Average			<5				<3	97.530	102.976	0.169		0.003	0.053		0.062
		Minimum			<5				<3	86.880	75.000	0.025		<0.005	0.045		0.051
		Maximum			<5				<3	101.600	133.000	0.942		0.008	0.063		0.072
		Count			7				7	10	42	39		39	13		13
		Count - less than			7				7	0	0	0		33	0		0
4/B	Surface Water	Average									108.956	4.862		0.003			
		Minimum									73.000	<0.2		<0.003			
		Maximum									154.000	20.000		0.006			
		Count									36	11		11			
		Count - less than									0	2		5			
5/A	Surface Water	Average									108.860						
		Minimum									78.000						
		Maximum									729.000						
		Count									165						
		Count - less than									0						
5/B	Surface Water	Average									37.504						
		Minimum									18.000						
		Maximum									104.000						
		Count									127						
		Count - less than									0						
5/C	Surface Water	Average									132.967						
		Minimum									81.000						
		Maximum									285.000						
		Count									133						
		Count - less than									0						
5/D	Surface Water	Average									98.842						
		Minimum									58.000						
		Maximum									177.000						
		Count									128						
		Count - less than									0						
5/E	Surface Water	Average									101.647						
		Minimum									60.000						
		Maximum									171.360						
		Count									128						
		Count - less than									0						
5/F	Surface Water	Average									99.605						
		Minimum									24.000						
		Maximum									274.000						
		Count									165						
		Count - less than									0						
5/G	Surface Water	Average									84.630						
		Minimum									45.000						
		Maximum									170.000						
		Count									165						
		Count - less than									0						
6/A	Groundwater	Average									225.407						
		Minimum									193.000						
		Maximum									276.000						
		Count									54						
		Count - less than									0						

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6/B	Groundwater	Average									217.750						
		Minimum									194.000						
		Maximum									232.000						
		Count									4						
		Count - less than									0						
6/C	Groundwater	Average									294.000						
		Minimum									294.000						
		Maximum									294.000						
		Count									1						
		Count - less than									0						
7/A	Surface Water	Average									188.432	0.386	0.008	<0.01	0.143	<0.004	
		Minimum									116.000	0.386	<0.01	<0.01	0.054	<0.004	
		Maximum									2,110.000	0.386	0.049	<0.01	0.287	<0.004	
		Count									259	1	21	21	21	21	
		Count - less than									0	0	19	21	0	21	
7/B	Groundwater	Average									84.946			13.012			
		Minimum									72.100			8.330			
		Maximum									190.000			58.500			
		Count									203			201			
		Count - less than									0			0			
7/C	Groundwater	Average									84.471	0.013	0.800	13.725	0.031	<0.002	0.124
		Minimum									59.300	<0.02	0.800	10.200	<0.01	<0.002	<0.02
		Maximum									138.000	0.068	0.800	17.800	0.046	<0.002	0.150
		Count									154	35	1	303	35	35	35
		Count - less than									0	33	0	0	1	35	1
8/A (same waterbody as 5/D)	Surface Water	Average									98.932						
		Minimum									78.000						
		Maximum									128.000						
		Count									73						
		Count - less than									0						
9/A	Surface Water	Average									106.546			0.003	0.057		
		Minimum									0.000			<0.00194	0.041		
		Maximum									170.000			0.013	0.083		
		Count									5,825			69	69		
		Count - less than									0			48	0		
10/A	Surface Water	Average	<1	<1		<5			<1		114.514						
		Minimum	<1	<1		<5			<1		80.400						
		Maximum	<1	<1		<5			<1		147.000						
		Count	88	88		88			88		73						
		Count - less than	88	88		88			88		0						
10/B	Surface Water	Average	<1	<1		<5			<1		104.556						
		Minimum	<1	<1		<5			<1		80.200						
		Maximum	<1	<1		<5			<1		133.000						
		Count	66	66		66			66		47						
		Count - less than	66	66		66			66		0						
10/C	Surface Water	Average															
		Minimum															
		Maximum															
		Count															
		Count - less than															
10/D	Surface Water	Average	<1	<1		<5			<1		98.116						
		Minimum	<1	<1		<5			<1		75.300						
		Maximum	<1	<1		<5			<1		134.000						
		Count	32	32		32			32		19						
		Count - less than	32	32		32			32		0						
11/A	Surface Water	Average									89.257						
		Minimum									48.000						
		Maximum									120.100						
		Count									1,049						
		Count - less than									0						
11/B	Surface Water	Average									68.136						
		Minimum									22.000						
		Maximum									135.100						
		Count									748						
		Count - less than									0						
11/C	Surface Water	Average									88.659						
		Minimum									52.000						
		Maximum									116.100						
		Count									750						
		Count - less than									0						

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	TotalCadmium mg/L	TotalCalcium mg/L	TotalChromium mg/L	TotalColiform MPN/100mL	TotalCopper mg/L	TotalDissolvedSolids mg/L	TotalIron mg/L	TotalKjeldahlNitrogen mg/L	TotalLead mg/L	TotalMagnesium mg/L	TotalManganese mg/L	TotalMercury mg/L	TotalMolybdenum mg/L	TotalNickel mg/L
1/A	Groundwater	Average				55.980		935.387								
		Minimum				<0		548.000								
		Maximum				2,800.000		1,555.000								
		Count				299		31								
		Count - less than				2		0								
1/B	Surface Water	Average				5.731		698.122								
		Minimum				<1		574.000								
		Maximum				52.000		818.000								
		Count				13		41								
		Count - less than				7		0								
1/C	Groundwater	Average						<796								
		Minimum						<796								
		Maximum						<796								
		Count						33								
		Count - less than						33								
3/A	Groundwater	Average						460.000								
		Minimum						460.000								
		Maximum						460.000								
		Count						1								
		Count - less than						0								
3/B	Groundwater	Average	<0.005		<0.005		0.001	441.000	0.046		<0.005		0.011	<0.0002		<0.005
		Minimum	<0.005		<0.005		0.001	392.000	0.046		<0.005		0.011	<0.0002		<0.005
		Maximum	<0.005		<0.005		0.001	490.000	0.046		<0.005		0.011	<0.0002		<0.005
		Count	1		1		1	2	1		1		1	1		1
		Count - less than	1		1		0	0	0		1		0	1		1
4/A	Surface Water	Average	<0.001		<0.001	1,161.015	0.005	195.000	0.321		0.001		0.222			
		Minimum	<0.001		<0.001	<1	0.001	158.000	0.109		<0.001		0.030			
		Maximum	<0.001		<0.001	4,839.000	0.020	271.000	0.776		0.009		1.685			
		Count	13		13	171	13	13	13		39		47			
		Count - less than	13		13	34	0	0	0		30		0			
4/B	Surface Water	Average	0.000		0.010		0.014	345.278	5.578		0.007		0.147			0.021
		Minimum	<0.0003		<0.01		<0.003	154.000	0.356		<0.001		0.038			<0.01
		Maximum	0.001		0.033		0.052	530.000	25.900		0.025		0.580			0.039
		Count	10		11		12	36	12		12		11			11
		Count - less than	6		8		1	0	0		4		0			2
5/A	Surface Water	Average						335.582								
		Minimum						28.000								
		Maximum						8,207.000								
		Count						170								
		Count - less than						0								
5/B	Surface Water	Average						122.150								
		Minimum						32.000								
		Maximum						353.000								
		Count						127								
		Count - less than						0								
5/C	Surface Water	Average						288.451								
		Minimum						10.000								
		Maximum						1,228.000								
		Count						133								
		Count - less than						0								
5/D	Surface Water	Average						250.469								
		Minimum						119.000								
		Maximum						663.000								
		Count						128								
		Count - less than						0								
5/E	Surface Water	Average						246.953								
		Minimum						132.000								
		Maximum						1,195.000								
		Count						128								
		Count - less than						0								
5/F	Surface Water	Average						175.503								
		Minimum						59.000								
		Maximum						485.000								
		Count						165								
		Count - less than						0								
5/G	Surface Water	Average						167.230								
		Minimum						49.000								
		Maximum						521.000								
		Count						165								
		Count - less than						0								
6/A	Groundwater	Average						307.630								
		Minimum						262.000								
		Maximum						358.000								
		Count						54								
		Count - less than						0								

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	TotalCadmium mg/L	TotalCalcium mg/L	TotalChromium mg/L	TotalColiform MPN/100mL	TotalCopper mg/L	TotalDissolvedSolids mg/L	TotalIron mg/L	TotalKjeldahlNitrogen mg/L	TotalLead mg/L	TotalMagnesium mg/L	TotalManganese mg/L	TotalMercury mg/L	TotalMolybdenum mg/L	TotalNickel mg/L
6/B	Groundwater	Average						306.000								
		Minimum						272.000								
		Maximum						323.000								
		Count						4								
		Count - less than						0								
6/C	Groundwater	Average						382.000								
		Minimum						382.000								
		Maximum						382.000								
		Count						1								
		Count - less than						0								
7/A	Surface Water	Average	<0.003	64.177	0.006		0.010	620.869	4.269		0.008	13.654	0.216	<0.2	<0.01	0.006
		Minimum	<0.003	23.600	<0.01		<0.01	454.000	0.200		<0.005	1.800	0.034	<0.2	<0.01	<0.01
		Maximum	<0.003	90.600	0.016		0.022	1,220.000	20.500		0.017	19.900	0.482	<0.2	<0.01	0.018
		Count	21	259	21		21	259	42		21	259	21	21	21	21
		Count - less than	21	0	20		10	0	0		4	0	0	21	21	19
7/B	Groundwater	Average		131.708				2,468.177	0.084			34.552	0.046			
		Minimum		<50				1,610.000	<0.02			<2.5	0.025			
		Maximum		212.000				3,610.000	2.050			60.000	0.173			
		Count		203				203	406			203	203			
		Count - less than		3				0	159			2	0			
7/C	Groundwater	Average	<0.5	27.387	<0.005		<0.01	495.338	<0.02		<0.5	2.069	0.005	<0.2		<0.01
		Minimum	<0.5	13.300	<0.005		<0.01	356.000	<0.02		<0.5	0.600	<0.01	<0.2		<0.01
		Maximum	<0.5	50.400	<0.005		<0.01	962.000	<0.02		<0.5	4.100	0.014	<0.2		<0.01
		Count	35	154	35		35	154	35		35	154	35	35		35
		Count - less than	35	0	35		35	0	35		35	0	33	35		35
8/A (same waterbody as 5/D)	Surface Water	Average						193.625	0.189							
		Minimum						44.000	<0							
		Maximum						440.000	3.300							
		Count						96	151							
		Count - less than						0	1							
9/A	Surface Water	Average	<0.005	48.154	0.002		0.011	302.320	0.282	0.726	0.001	6.113	0.030	<0.0000003		0.004
		Minimum	<0.005	28.700	<0.001		0.002	102.000	<0.104	<0.344	<0.000035	2.300	0.002	<0.0000003		<0.0049
		Maximum	<0.005	69.200	0.013		0.072	638.000	1.000	1.760	0.005	13.600	0.231	<0.0000003		0.006
		Count	69	69	69		69	593	138	476	69	69	69	69		69
		Count - less than	69	0	68		0	0	64	165	53	0	0	69		1
10/A	Surface Water	Average				7,724.459										
		Minimum				<1										
		Maximum				199,000.000										
		Count				1,068										
		Count - less than				45										
10/B	Surface Water	Average				2,095.381										
		Minimum				<1										
		Maximum				77,000.000										
		Count				735										
		Count - less than				22										
10/C	Surface Water	Average														
		Minimum														
		Maximum														
		Count														
		Count - less than														
10/D	Surface Water	Average				1,632.554										
		Minimum				<1										
		Maximum				15,500.000										
		Count				156										
		Count - less than				1										
11/A	Surface Water	Average				13.941										
		Minimum				<1										
		Maximum				2,419.170										
		Count				762										
		Count - less than				668										
11/B	Surface Water	Average														
		Minimum														
		Maximum														
		Count														
		Count - less than														
11/C	Surface Water	Average				26.603										
		Minimum				<1										
		Maximum				2,419.170										
		Count				565										
		Count - less than				178										

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	TotalOrganicCarbon mg/L	TotalOrganicHalides µg/L	TotalOrganicNitrogen mg/L	TotalPhosphorus mg/L	TotalPotassium mg/L	TotalSelenium mg/L	TotalSilver mg/L	TotalSodium mg/L	TotalStrontium mg/L	TotalSuspendedSolids mg/L	TotalThallium mg/L	TotalTitanium mg/L	TotalVanadium mg/L
1/A	Groundwater	Average	1.815									6.806			
		Minimum	0.321									<1			
		Maximum	9.263									40.000			
		Count	767									31			
		Count - less than	0									6			
1/B	Surface Water	Average	4.978									2.838			
		Minimum	3.400									<0			
		Maximum	7.415									10.000			
		Count	95									40			
		Count - less than	0									19			
1/C	Groundwater	Average	<1.56									<160			
		Minimum	<1.56									<160			
		Maximum	<1.56									<160			
		Count	34									33			
		Count - less than	34									33			
3/A	Groundwater	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
3/B	Groundwater	Average						<0.005	<0.005				0.004		
		Minimum						<0.005	<0.005				0.004		
		Maximum						<0.005	<0.005				0.004		
		Count						1	1				1		
		Count - less than						1	1				0		
4/A	Surface Water	Average	5.314					<0.005							
		Minimum	4.100					<0.005							
		Maximum	9.900					<0.005							
		Count	44					13							
		Count - less than	0					13							
4/B	Surface Water	Average				0.573		0.002				115.971			
		Minimum				0.157		<0.002				18.000			
		Maximum				1.360		0.004				1,016.000			
		Count				36		11				35			
		Count - less than				0		7				0			
5/A	Surface Water	Average	5.564			0.253						20.073			
		Minimum	1.800			<0.05						4.000			
		Maximum	8.870			2.290						99.000			
		Count	170			155						170			
		Count - less than	0			7						0			
5/B	Surface Water	Average	7.649			0.132						10.490			
		Minimum	5.000			<0.05						<0.2			
		Maximum	13.923			0.950						71.000			
		Count	127			123						127			
		Count - less than	0			35						12			
5/C	Surface Water	Average	5.632			0.306						31.644			
		Minimum	3.500			<0.05						<5			
		Maximum	10.900			9.100						888.000			
		Count	133			121						133			
		Count - less than	0			23						4			
5/D	Surface Water	Average	6.038			0.366						23.385			
		Minimum	2.200			<0.05						<5			
		Maximum	10.400			4.460						171.000			
		Count	128			124						128			
		Count - less than	0			32						1			
5/E	Surface Water	Average	5.060			0.116						21.298			
		Minimum	1.800			<0.05						<5			
		Maximum	9.700			0.470						191.000			
		Count	128			128						128			
		Count - less than	0			34						3			
5/F	Surface Water	Average	5.921			0.136						19.290			
		Minimum	1.300			<0.05						<0.2			
		Maximum	13.100			1.860						278.000			
		Count	165			155						165			
		Count - less than	0			59						7			
5/G	Surface Water	Average	7.707			0.583						25.775			
		Minimum	2.100			<0.05						<5			
		Maximum	16.000			12.100						498.000			
		Count	165			150						165			
		Count - less than	0			14						2			
6/A	Groundwater	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													

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6/B	Groundwater	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
6/C	Groundwater	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
7/A	Surface Water	Average				0.520	8.454	0.006	0.359	118.050	0.901			<0.01	0.031
		Minimum				<0.2	2.300	<0.01	<0.01	80.700	0.741			<0.01	0.022
		Maximum				2.000	18.900	0.012	1.260	303.000	1.120			<0.01	0.051
		Count				21	259	21	21	259	21			21	21
		Count - less than				1	0	19	19	0	0			21	0
7/B	Groundwater	Average					16.916			690.325					
		Minimum					<9.4			152.000					
		Maximum					67.500			950.000					
		Count					203			203					
		Count - less than					9			0					
7/C	Groundwater	Average				0.098	2.618	0.848	<0.5	133.994				<0.5	
		Minimum				<0	<2	<0.5	<0.5	102.000				<0.5	
		Maximum				0.100	4.000	1.500	<0.5	177.000				<0.5	
		Count				154	154	35	35	154				1	
		Count - less than				151	5	2	35	0				1	
8/A (same waterbody as 5/D)	Surface Water	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
9/A	Surface Water	Average	4.802			0.066	4.833	0.001	0.000	43.655		17.477			
		Minimum	0.000			0.014	2.430	<0.001	<0.000013	14.200		0.930			
		Maximum	9.520			0.512	7.090	0.003	0.003	127.000		133.000			
		Count	1,181			471	69	69	69	69		481			
		Count - less than	0			0	0	62	67	0		0			
10/A	Surface Water	Average	5.127	60.021											
		Minimum	3.020	6.560											
		Maximum	6.830	252.000											
		Count	292	17											
		Count - less than	0	0											
10/B	Surface Water	Average	5.041	49.255											
		Minimum	2.070	<20											
		Maximum	7.750	192.000											
		Count	192	11											
		Count - less than	0	2											
10/C	Surface Water	Average													
		Minimum													
		Maximum													
		Count													
		Count - less than													
10/D	Surface Water	Average	4.817												
		Minimum	3.890												
		Maximum	8.110												
		Count	43												
		Count - less than	0												
11/A	Surface Water	Average	5.995		5.326	0.099						16.074			
		Minimum	3.400		4.000	0.020						4.000			
		Maximum	46.000		8.000	0.200						47.000			
		Count	1,034		86	49						144			
		Count - less than	0		0	0						0			
11/B	Surface Water	Average	8.825		17.408	0.229						14.657			
		Minimum	5.660		8.000	0.140						5.000			
		Maximum	16.100		20.000	0.370						30.000			
		Count	728		98	23						70			
		Count - less than	0		0	0						0			
11/C	Surface Water	Average	6.059		5.786	0.112						23.333			
		Minimum	4.360		4.000	0.030						6.000			
		Maximum	12.300		8.000	0.170						185.000			
		Count	735		42	24						72			
		Count - less than	0		0	0						0			

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1/A	Groundwater	Average												1.041
		Minimum												0.000
		Maximum												14.440
		Count												433
		Count - less than												0
1/B	Surface Water	Average												0.005
		Minimum												0.000
		Maximum												0.400
		Count												74
		Count - less than												0
1/C	Groundwater	Average												<4.52
		Minimum												<4.52
		Maximum												<4.52
		Count												34
		Count - less than												34
3/A	Groundwater	Average		<1			<0.5	<1	<0.2		<0.5	<2	<0.2	
		Minimum		<1			<0.5	<1	<0.2		<0.5	<2	<0.2	
		Maximum		<1			<0.5	<1	<0.2		<0.5	<2	<0.2	
		Count		1			1	1	1		1	1	1	
		Count - less than		1			1	1	1		1	1	1	
3/B	Groundwater	Average	0.002	<2.4	<1		<0.5	<1		<1	<0.5	<2		<1
		Minimum	0.002	<2.4	<1		<0.5	<1		<1	<0.5	<2		<1
		Maximum	0.002	<2.4	<1		<0.5	<1		<1	<0.5	<2		<1
		Count	1	1	1		1	2		1	1	2		1
		Count - less than	0	1	1		1	2		1	1	2		1
4/A	Surface Water	Average	0.022			<3		<3			<3	<3		
		Minimum	0.005			<3		<3			<3	<3		
		Maximum	0.183			<3		<3			<3	<3		
		Count	13			7		7			7	7		
		Count - less than	0			7		7			7	7		
4/B	Surface Water	Average												
		Minimum												
		Maximum												
		Count												
		Count - less than												
5/A	Surface Water	Average												0.294
		Minimum												<0
		Maximum												7.400
		Count												170
		Count - less than												75
5/B	Surface Water	Average												0.314
		Minimum												<0
		Maximum												4.870
		Count												124
		Count - less than												56
5/C	Surface Water	Average												0.218
		Minimum												<0
		Maximum												3.350
		Count												129
		Count - less than												59
5/D	Surface Water	Average												0.637
		Minimum												<0
		Maximum												28.700
		Count												120
		Count - less than												45
5/E	Surface Water	Average												0.197
		Minimum												<0
		Maximum												0.450
		Count												128
		Count - less than												68
5/F	Surface Water	Average												0.275
		Minimum												<0
		Maximum												6.220
		Count												160
		Count - less than												83
5/G	Surface Water	Average												0.276
		Minimum												<0
		Maximum												5.940
		Count												165
		Count - less than												75
6/A	Groundwater	Average												
		Minimum												
		Maximum												
		Count												
		Count - less than												

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	TotalZinc mg/L	Toxaphene µg/L	trans-1,2-Dichlorethene µg/L	trans-1,2-Dichloroethene µg/L	trans-1,2-Dichloroethylene µg/L	trans-1,3-Dichloropropene µg/L	trans-Nonachlor µg/L	Trichloroethene µg/L	Trichloroethylene µg/L	Trichlorofluoromethane µg/L	Trifluralin µg/L	Trihalomethanes µg/L
6/B	Groundwater	Average												
		Minimum												
		Maximum												
		Count												
		Count - less than												
6/C	Groundwater	Average												
		Minimum												
		Maximum												
		Count												
		Count - less than												
7/A	Surface Water	Average	0.025											
		Minimum	<0.02											
		Maximum	0.094											
		Count	21											
		Count - less than	9											
7/B	Groundwater	Average												
		Minimum												
		Maximum												
		Count												
		Count - less than												
7/C	Groundwater	Average	<0.02											
		Minimum	<0.02											
		Maximum	<0.02											
		Count	35											
		Count - less than	35											
8/A (same waterbody as 5/D)	Surface Water	Average												
		Minimum												
		Maximum												
		Count												
		Count - less than												
9/A	Surface Water	Average	0.005											
		Minimum	<0.005											
		Maximum	0.031											
		Count	69											
		Count - less than	49											
10/A	Surface Water	Average		<5		<1		<1	<1	<1		<1	<1	<2
		Minimum		<5		<1		<1	<1	<1		<1	<1	<2
		Maximum		<5		<1		<1	<1	<1		<1	<1	<2
		Count		2		88		88	1	88		88	1	88
		Count - less than		2		88		88	1	88		88	1	88
10/B	Surface Water	Average				<1		<1	<1	<1		<1	<1	<2
		Minimum				<1		<1	<1	<1		<1	<1	<2
		Maximum				<1		<1	<1	<1		<1	<1	<2
		Count				66		66	1	66		66	1	66
		Count - less than				66		66	1	66		66	1	66
10/C	Surface Water	Average												
		Minimum												
		Maximum												
		Count												
		Count - less than												
10/D	Surface Water	Average				<1		<1		<1		<1		1.240
		Minimum				<1		<1		<1		<1		<2
		Maximum				<1		<1		<1		<1		4.450
		Count				32		32		32		32		32
		Count - less than				32		32		32		32		29
11/A	Surface Water	Average												11.925
		Minimum												0.000
		Maximum												76.300
		Count												905
		Count - less than												0
11/B	Surface Water	Average												
		Minimum												
		Maximum												
		Count												
		Count - less than												
11/C	Surface Water	Average												10.016
		Minimum												0.700
		Maximum												27.600
		Count												465
		Count - less than												0

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	Turbidity NTU	Uranium pCi/L	UV254 cm-1	Vinylacetate µg/L	Vinylchloride µg/L	VolatileOrganicCompound µg/L	VolatileSuspendedSolids mg/L	Xylenes(total) µg/L	Zinc mg/L
1/A	Groundwater	Average	5.972		0.033			1.171			0.011
		Minimum	0.783		0.011			0.000			0.003
		Maximum	39.500		0.066			3.700			0.044
		Count	769		18			30			25
		Count - less than	0		0			0			0
1/B	Surface Water	Average	1.905	0.523	0.054			0.357			0.019
		Minimum	0.206	0.000	0.043			0.000			0.002
		Maximum	38.400	7.370	0.068			4.000			0.060
		Count	110	36	18			35			16
		Count - less than	0	0	0			0			0
1/C	Groundwater	Average	<5.72					<11.96			<0.2392
		Minimum	<5.72					<11.96			<0.2392
		Maximum	<5.72					<11.96			<0.2392
		Count	33					34			27
		Count - less than	33					34			27
3/A	Groundwater	Average				<10	<0.5			<0.5	<0.005
		Minimum				<10	<0.5			<0.5	<0.005
		Maximum				<10	<0.5			<0.5	<0.005
		Count				1	1			1	1
		Count - less than				1	1			1	1
3/B	Groundwater	Average	<1	0.400		<10	<2			<1	
		Minimum	<1	0.400		<10	<2			<1	
		Maximum	<1	0.400		<10	<2			<1	
		Count	1	1		1	2			2	
		Count - less than	1	0		1	2			2	
4/A	Surface Water	Average			0.105		<3				
		Minimum			0.086		<3				
		Maximum			0.153		<3				
		Count			40		7				
		Count - less than			0		7				
4/B	Surface Water	Average	109.618								0.054
		Minimum	12.000								0.014
		Maximum	782.000								0.198
		Count	34								12
		Count - less than	0								0
5/A	Surface Water	Average	14.622								
		Minimum	2.600								
		Maximum	95.000								
		Count	165								
		Count - less than	0								
5/B	Surface Water	Average	8.308								
		Minimum	2.100								
		Maximum	50.000								
		Count	127								
		Count - less than	0								
5/C	Surface Water	Average	25.933								
		Minimum	1.100								
		Maximum	800.000								
		Count	131								
		Count - less than	0								
5/D	Surface Water	Average	19.816								
		Minimum	3.400								
		Maximum	120.000								
		Count	125								
		Count - less than	0								
5/E	Surface Water	Average	13.181								
		Minimum	2.000								
		Maximum	60.000								
		Count	124								
		Count - less than	0								
5/F	Surface Water	Average									
		Minimum									
		Maximum									
		Count									
		Count - less than									
5/G	Surface Water	Average	16.222								
		Minimum	2.400								
		Maximum	190.000								
		Count	165								
		Count - less than	0								
6/A	Groundwater	Average									
		Minimum									
		Maximum									
		Count									
		Count - less than									

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Sponsor/Raw Water Source	Source Water Type	Calculation Type	Turbidity NTU	Uranium pCi/L	UV254 cm-1	Vinylacetate µg/L	Vinylchloride µg/L	VolatileOrganicCompound µg/L	VolatileSuspendedSolids mg/L	Xylenes(total) µg/L	Zinc mg/L
6/B	Groundwater	Average									
		Minimum									
		Maximum									
		Count									
		Count - less than									
6/C	Groundwater	Average									
		Minimum									
		Maximum									
		Count									
		Count - less than									
7/A	Surface Water	Average	198.530								
		Minimum	14.000								
		Maximum	3,821.000								
		Count	259								
		Count - less than	0								
7/B	Groundwater	Average	0.929								
		Minimum	<0.1								
		Maximum	28.000								
		Count	207								
		Count - less than	1								
7/C	Groundwater	Average	0.165								
		Minimum	<0.1								
		Maximum	0.850								
		Count	154								
		Count - less than	22								
8/A (same waterbody as 5/D)	Surface Water	Average	6.652		0.087						
		Minimum	0.000		0.020						
		Maximum	26.500		0.110						
		Count	151		133						
		Count - less than	0		0						
9/A	Surface Water	Average	19.052						6.284		
		Minimum	0.900						<2.08		
		Maximum	532.000						55.500		
		Count	5,850						293		
		Count - less than	0						92		
10/A	Surface Water	Average	7.743		0.096		<1			<1	
		Minimum	1.600		0.052		<1			<1	
		Maximum	88.000		0.142		<1			<1	
		Count	1,071		86		88			53	
		Count - less than	0		0		88			53	
10/B	Surface Water	Average	5.333		0.079		<1			<1	
		Minimum	0.500		0.049		<1			<1	
		Maximum	43.000		0.128		<1			<1	
		Count	738		50		66			33	
		Count - less than	0		0		66			33	
10/C	Surface Water	Average									
		Minimum									
		Maximum									
		Count									
		Count - less than									
10/D	Surface Water	Average	4.386		0.092		<1			<1	
		Minimum	0.650		0.076		<1			<1	
		Maximum	25.000		0.098		<1			<1	
		Count	156		5		32			29	
		Count - less than	0		0		32			29	
11/A	Surface Water	Average	17.180		0.167						
		Minimum	0.010		0.091						
		Maximum	61.700		1.500						
		Count	1,049		1,040						
		Count - less than	0		0						
11/B	Surface Water	Average	17.120		0.729						
		Minimum	0.010		0.009						
		Maximum	59.400		313.000						
		Count	751		741						
		Count - less than	0		0						
11/C	Surface Water	Average	17.832		0.164						
		Minimum	0.010		0.093						
		Maximum	65.700		1.090						
		Count	750		743						
		Count - less than	0		0						

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Sponsor/Reclaimed Water Source	Calculation Type	1,1,1-Trichloroethane µg/L	1,1,2,2-Tetrachloroethane µg/L	1,1,2-Trichloroethane µg/L	1,1,2-Trichloroethylene µg/L	1,1-Dichloroethane µg/L	1,1-Dichloroethylene µg/L	1,2,4,5-Tetrachlorobenzene µg/L	1,2,4-Trichlorobenzene µg/L	1,2-Dibromoethane µg/L
1i	Average	<10	<10	<10		<10	<10	<20	<10	<2
	Minimum	<10	<10	<10		<10	<10	<20	<10	<2
	Maximum	<10	<10	<10		<10	<10	<20	<10	<2
	Count	3	2	3		2	2	3	3	3
	Count - less than	3	2	3		2	2	3	3	3
3i	Average	<5	<5	<5		<5	<5	<20	<10	<2
	Minimum	<5	<5	<5		<5	<5	<20	<10	<2
	Maximum	<5	<5	<5		<5	<5	<20	<10	<2
	Count	1	1	1		1	1	1	1	1
	Count - less than	1	1	1		1	1	1	1	1
3ii	Average	<5	<5	<5		<5	<5	<20	<10	<2
	Minimum	<5	<5	<5		<5	<5	<20	<10	<2
	Maximum	<5	<5	<5		<5	<5	<20	<10	<2
	Count	1	1	1		1	1	1	1	1
	Count - less than	1	1	1		1	1	1	1	1
4i	Average	<10	<10		<10	<10	<10	<20	<10	<2
	Minimum	<10	<10		<10	<10	<10	<20	<10	<2
	Maximum	<10	<10		<10	<10	<10	<20	<10	<2
	Count	6	6		6	6	6	6	6	6
	Count - less than	6	6		6	6	6	6	6	6
4ii	Average	<10	<10	<10		<10	<10	<20	<10	<2
	Minimum	<10	<10	<10		<10	<10	<20	<10	<2
	Maximum	<10	<10	<10		<10	<10	<20	<10	<2
	Count	1	1	1		1	1	1	1	1
	Count - less than	1	1	1		1	1	1	1	1
5i	Average	<10	<10	<10		<10	<10	<20	<10	<2
	Minimum	<10	<10	<10		<10	<10	<20	<10	<2
	Maximum	<10	<10	<10		<10	<10	<20	<10	<2
	Count	6	6	6		6	6	6	6	6
	Count - less than	6	6	6		6	6	6	6	6
5ii	Average	<10	<10	<10		<10	<10	<20	<10	<5
	Minimum	<10	<10	<10		<10	<10	<20	<10	<5
	Maximum	<10	<10	<10		<10	<10	<20	<10	<5
	Count	6	6	6		6	6	6	6	6
	Count - less than	6	6	6		6	6	6	6	6
6i	Average	<5	<5	<5		<5		<10	<10	<5
	Minimum	<5	<5	<5		<5		<10	<10	<5
	Maximum	<5	<5	<5		<5		<10	<10	<5
	Count	6	6	6		6		6	6	6
	Count - less than	6	6	6		6		6	6	6
7i	Average	<5	<5	<5		<5	<5	<20	<20	<2
	Minimum	<5	<5	<5		<5	<5	<20	<20	<2
	Maximum	<5	<5	<5		<5	<5	<20	<20	<2
	Count	6	6	6		6	6	6	6	6
	Count - less than	6	6	6		6	6	6	6	6
7ii	Average	<5	<5	<5		<5	<5	<20	<5	<2
	Minimum	<5	<5	<5		<5	<5	<20	<5	<2
	Maximum	<5	<5	<5		<5	<5	<20	<5	<2
	Count	6	6	6		6	6	6	6	6
	Count - less than	6	6	6		6	6	6	6	6

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Sponsor/Reclaimed Water Source	Calculation Type	1,1,1-Trichloroethane µg/L	1,1,2,2-Tetrachloroethane µg/L	1,1,2-Trichloroethane µg/L	1,1,2-Trichloroethylene µg/L	1,1-Dichloroethane µg/L	1,1-Dichloroethylene µg/L	1,2,4,5-Tetrachlorobenzene µg/L	1,2,4-Trichlorobenzene µg/L	1,2-Dibromoethane µg/L
7iii	Average	<5	<5	<5		<5	<5	<20	<5	<2
	Minimum	<5	<5	<5		<5	<5	<20	<5	<2
	Maximum	<5	<5	<5		<5	<5	<20	<5	<2
	Count	6	6	6		6	6	6	6	6
	Count - less than	6	6	6		6	6	6	6	6
8i	Average	<10	<10	<10		<10	<10	<20	<10	<2
	Minimum	<10	<10	<10		<10	<10	<20	<10	<2
	Maximum	<10	<10	<10		<10	<10	<20	<10	<2
	Count	6	6	6		6	6	6	6	6
	Count - less than	6	6	6		6	6	6	6	6
9i	Average	<10	<10	<10		<10	<10	<20	<10	<2
	Minimum	<10	<10	<10		<10	<10	<20	<10	<2
	Maximum	<10	<10	<10		<10	<10	<20	<10	<2
	Count	4	4	4		4	4	4	4	4
	Count - less than	4	4	4		4	4	4	4	4
9ii	Average	<10	<10	<10		<10	<10	<20	<10	<2
	Minimum	<10	<10	<10		<10	<10	<20	<10	<2
	Maximum	<10	<10	<10		<10	<10	<20	<10	<2
	Count	4	4	4		4	4	4	4	4
	Count - less than	4	4	4		4	4	4	4	4
9iii	Average	<10	<10	<10		<10	<10	<20	<10	<2
	Minimum	<10	<10	<10		<10	<10	<20	<10	<2
	Maximum	<10	<10	<10		<10	<10	<20	<10	<2
	Count	4	4	4		4	4	4	4	4
	Count - less than	4	4	4		4	4	4	4	4
10i	Average	<5	<5	<5		<14.4	<5	<20	<10	<5
	Minimum	<5	<5	<5		<14.4	<5	<20	<10	<5
	Maximum	<5	<5	<5		<14.4	<5	<20	<10	<5
	Count	26	26	26		26	26	22	22	22
	Count - less than	26	26	26		26	26	22	22	22
11i	Average	<10	<10	<10		<10	<10	<20	<10	<2
	Minimum	<10	<10	<10		<10	<10	<20	<10	<2
	Maximum	<10	<10	<10		<10	<10	<20	<10	<2
	Count	3	3	3		3	3	3	3	3
	Count - less than	3	3	3		3	3	3	3	3
11ii	Average	<10	<10	<10		<10	<10	<20	<10	<2
	Minimum	<10	<10	<10		<10	<10	<20	<10	<2
	Maximum	<10	<10	<10		<10	<10	<20	<10	<2
	Count	6	6	6		6	6	6	6	6
	Count - less than	6	6	6		6	6	6	6	6
11iii	Average	<10	<10	<10		<10	<10	<20	<10	<2
	Minimum	<10	<10	<10		<10	<10	<20	<10	<2
	Maximum	<10	<10	<10		<10	<10	<20	<10	<2
	Count	6	6	6		6	6	6	6	6
	Count - less than	6	6	6		6	6	6	6	6

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Sponsor/Reclaimed Water Source	Calculation Type	1,2-Dichlorobenzene µg/L	1,2-Dichloroethane µg/L	1,2-Dichloropropane µg/L	1,2-DiphenylHydrazine µg/L	1,2-Transdichloroethylene µg/L	1,3-Dichlorobenzene µg/L	1,3-Dichloropropylene µg/L	1,4-Dichlorobenzene µg/L	2,4,5-T µg/L	2,4,5-TP(Silvex) µg/L
1i	Average	<10	<10	<10	<20	<10	<10	<10	<10		<20
	Minimum	<10	<10	<10	<20	<10	<10	<10	<10		<20
	Maximum	<10	<10	<10	<20	<10	<10	<10	<10		<20
	Count	2	2	2	3	3	2	2	3		3
	Count - less than	2	2	2	3	3	2	2	3		3
3i	Average	<10	<5	<10	<20	<5	<10	<5	<10		<2
	Minimum	<10	<5	<10	<20	<5	<10	<5	<10		<2
	Maximum	<10	<5	<10	<20	<5	<10	<5	<10		<2
	Count	1	1	1	1	1	1	1	1		1
	Count - less than	1	1	1	1	1	1	1	1		1
3ii	Average	<10	<5	<10	<20	<5	<10	<5	<10		<2
	Minimum	<10	<5	<10	<20	<5	<10	<5	<10		<2
	Maximum	<10	<5	<10	<20	<5	<10	<5	<10		<2
	Count	1	1	1	1	1	1	1	1		1
	Count - less than	1	1	1	1	1	1	1	1		1
4i	Average	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Minimum	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Maximum	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Count	6	6	6	6	6	6	6	6		6
	Count - less than	6	6	6	6	6	6	6	6		6
4ii	Average	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Minimum	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Maximum	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Count	1	1	1	1	1	1	1	1		1
	Count - less than	1	1	1	1	1	1	1	1		1
5i	Average	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Minimum	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Maximum	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Count	6	6	6	6	6	6	6	6		6
	Count - less than	6	6	6	6	6	6	6	6		6
5ii	Average	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Minimum	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Maximum	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Count	6	6	6	6	6	6	6	6		6
	Count - less than	6	6	6	6	6	6	6	6		6
6i	Average	<10		<5	<10	<5	<10	8.450	<10	<0.5	<0.5
	Minimum	<10		<5	<10	<5	<10	<5	<10	<0.5	<0.5
	Maximum	<10		<5	<10	<5	<10	14.400	<10	<0.5	<0.5
	Count	6		6	3	6	6	6	6	6	6
	Count - less than	6		6	3	6	6	3	6	6	6
7i	Average	<5	<5	<5	<5	<5	1.600	<5	<5		<1
	Minimum	<5	<5	<5	<5	<5	<1	<5	<5		<1
	Maximum	<5	<5	<5	<5	<5	2.500	<5	<5		<1
	Count	6	6	6	6	6	6	6	6		6
	Count - less than	6	6	6	6	6	5	6	6		6
7ii	Average	<5	<5	<5	<5	<5	<5	<5	<5		<1
	Minimum	<5	<5	<5	<5	<5	<5	<5	<5		<1
	Maximum	<5	<5	<5	<5	<5	<5	<5	<5		<1
	Count	6	6	6	6	6	6	6	6		6
	Count - less than	6	6	6	6	6	6	6	6		6

Notes:
1) For parameters with sampling data both less than and greater than the detection value, values that are less than the detection value are included in the analysis as one-half the detection value.
2) For parameters with all sample points below the detection value, the results are reported as less than the highest detection value reported.
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Sponsor/Reclaimed Water Source	Calculation Type	1,2-Dichlorobenzene µg/L	1,2-Dichloroethane µg/L	1,2-Dichloropropane µg/L	1,2-DiphenylHydrazine µg/L	1,2-Transdichloroethylene µg/L	1,3-Dichlorobenzene µg/L	1,3-Dichloropropylene µg/L	1,4-Dichlorobenzene µg/L	2,4,5-T µg/L	2,4,5-TP(Silvex) µg/L
7iii	Average	<5	<5	<5	<5	<5	<5	<5	<5		<1
	Minimum	<5	<5	<5	<5	<5	<5	<5	<5		<1
	Maximum	<5	<5	<5	<5	<5	<5	<5	<5		<1
	Count	6	6	6	6	6	6	6	6		6
	Count - less than	6	6	6	6	6	6	6	6		6
8i	Average	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Minimum	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Maximum	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Count	6	6	6	6	6	6	6	6		6
	Count - less than	6	6	6	6	6	6	6	6		6
9i	Average	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Minimum	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Maximum	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Count	4	4	4	4	4	4	4	4		4
	Count - less than	4	4	4	4	4	4	4	4		4
9ii	Average	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Minimum	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Maximum	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Count	4	4	4	4	4	4	4	4		4
	Count - less than	4	4	4	4	4	4	4	4		4
9iii	Average	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Minimum	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Maximum	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Count	4	4	4	4	4	4	4	4		4
	Count - less than	4	4	4	4	4	4	4	4		4
10i	Average	<5	<5	<5	<20		<5	<10	<5		<2
	Minimum	<5	<5	<5	<20		<5	<10	<5		<2
	Maximum	<5	<5	<5	<20		<5	<10	<5		<2
	Count	27	26	26	26		27	26	27		23
	Count - less than	27	26	26	26		27	26	27		23
11i	Average	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Minimum	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Maximum	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Count	3	3	3	3	3	3	3	3		3
	Count - less than	3	3	3	3	3	3	3	3		3
11ii	Average	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Minimum	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Maximum	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Count	6	6	6	6	6	6	6	6		6
	Count - less than	6	6	6	6	6	6	6	6		6
11iii	Average	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Minimum	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Maximum	<10	<10	<10	<20	<10	<10	<10	<10		<2
	Count	6	6	6	6	6	6	6	6		6
	Count - less than	6	6	6	6	6	6	6	6		6

Notes:
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Sponsor/Reclaimed Water Source	Calculation Type	2,4,5-Trichlorophenol µg/L	2,4,6-Trichlorophenol µg/L	2,4-D µg/L	2,4-DB µg/L	2,4-Dichlorophenol µg/L	2,4-Dimethylphenol µg/L	2,4-Dinitrophenol µg/L	2,4-Dinitrotoluene µg/L	2,6-Dinitrotoluene µg/L	2-ChloroethylvinylEther µg/L	2-Chloronaphthalene µg/L
1i	Average	<50	<10	<10		<10	<10	<50	<10	<10	<50	<10
	Minimum	<50	<10	<10		<10	<10	<50	<10	<10	<50	<10
	Maximum	<50	<10	<10		<10	<10	<50	<10	<10	<50	<10
	Count	3	3	3		3	3	3	3	3	2	2
	Count - less than	3	3	3		3	3	3	3	3	2	2
3i	Average	<50	<10	<10		<10	<10	<50	<10	<10	<5	<10
	Minimum	<50	<10	<10		<10	<10	<50	<10	<10	<5	<10
	Maximum	<50	<10	<10		<10	<10	<50	<10	<10	<5	<10
	Count	1	1	1		1	1	1	1	1	1	1
	Count - less than	1	1	1		1	1	1	1	1	1	1
3ii	Average	<50	<10	<10		<10	<10	<50	<10	<10	<5	<10
	Minimum	<50	<10	<10		<10	<10	<50	<10	<10	<5	<10
	Maximum	<50	<10	<10		<10	<10	<50	<10	<10	<5	<10
	Count	1	1	1		1	1	1	1	1	1	1
	Count - less than	1	1	1		1	1	1	1	1	1	1
4i	Average	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Minimum	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Maximum	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Count	6	6	6		6	6	6	6	6	6	6
	Count - less than	6	6	6		6	6	6	6	6	6	6
4ii	Average	<2	<10	<10		<10	<10	<50	<10	<10	<50	<10
	Minimum	<2	<10	<10		<10	<10	<50	<10	<10	<50	<10
	Maximum	<2	<10	<10		<10	<10	<50	<10	<10	<50	<10
	Count	1	1	1		1	1	1	1	1	1	1
	Count - less than	1	1	1		1	1	1	1	1	1	1
5i	Average	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Minimum	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Maximum	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Count	6	6	6		6	6	6	6	6	6	6
	Count - less than	6	6	6		6	6	6	6	6	6	6
5ii	Average	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Minimum	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Maximum	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Count	6	6	6		6	6	6	6	6	6	6
	Count - less than	6	6	6		6	6	6	6	6	6	6
6i	Average	<10	<10	<1	<1	<10	<10	<10	<10	<10	<5	<10
	Minimum	<10	<10	<1	<1	<10	<10	<10	<10	<10	<5	<10
	Maximum	<10	<10	<1	<1	<10	<10	<10	<10	<10	<5	<10
	Count	6	6	6	6	6	6	6	6	6	6	6
	Count - less than	6	6	6	6	6	6	6	6	6	6	6
7i	Average	<50	<5	<1		<5	<10	<25	<5	<5	<5	<5
	Minimum	<50	<5	<1		<5	<10	<25	<5	<5	<5	<5
	Maximum	<50	<5	<1		<5	<10	<25	<5	<5	<5	<5
	Count	6	6	6		6	6	6	6	6	6	6
	Count - less than	6	6	6		6	6	6	6	6	6	6
7ii	Average	<50	<5	<1		<5	<50	<25	<5	<5	<5	<5
	Minimum	<50	<5	<1		<5	<50	<25	<5	<5	<5	<5
	Maximum	<50	<5	<1		<5	<50	<25	<5	<5	<5	<5
	Count	6	6	6		6	6	6	6	6	6	6
	Count - less than	6	6	6		6	6	6	6	6	6	6

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Sponsor/Reclaimed Water Source	Calculation Type	2,4,5-Trichlorophenol µg/L	2,4,6-Trichlorophenol µg/L	2,4-D µg/L	2,4-DB µg/L	2,4-Dichlorophenol µg/L	2,4-Dimethylphenol µg/L	2,4-Dinitrophenol µg/L	2,4-Dinitrotoluene µg/L	2,6-Dinitrotoluene µg/L	2-ChloroethylvinylEther µg/L	2-Chloronaphthalene µg/L
7iii	Average	<50	<5	<1		<5	<10	<25	<5	<5	<5	<5
	Minimum	<50	<5	<1		<5	<10	<25	<5	<5	<5	<5
	Maximum	<50	<5	<1		<5	<10	<25	<5	<5	<5	<5
	Count	6	6	6		6	6	6	6	6	6	6
	Count - less than	6	6	6		6	6	6	6	6	6	6
8i	Average	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Minimum	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Maximum	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Count	6	6	6		6	6	6	6	6	6	6
	Count - less than	6	6	6		6	6	6	6	6	6	6
9i	Average	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Minimum	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Maximum	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Count	4	4	4		4	4	4	4	4	4	4
	Count - less than	4	4	4		4	4	4	4	4	4	4
9ii	Average	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Minimum	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Maximum	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Count	4	4	4		4	4	4	4	4	4	4
	Count - less than	4	4	4		4	4	4	4	4	4	4
9iii	Average	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Minimum	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Maximum	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Count	4	4	4		4	4	4	4	4	4	4
	Count - less than	4	4	4		4	4	4	4	4	4	4
10i	Average	<40	<10	<10		4.600	4.600	<40	<10	<10	<5	<10
	Minimum	<40	<10	<10		<5	<5	<40	<10	<10	<5	<10
	Maximum	<40	<10	<10		5.000	5.000	<40	<10	<10	<5	<10
	Count	23	22	27		25	25	26	23	23	26	23
	Count - less than	23	22	27		26	26	26	23	23	26	23
11i	Average	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Minimum	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Maximum	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Count	3	3	3		3	3	3	3	3	3	3
	Count - less than	3	3	3		3	3	3	3	3	3	3
11ii	Average	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Minimum	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Maximum	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Count	6	6	6		6	6	6	6	6	6	6
	Count - less than	6	6	6		6	6	6	6	6	6	6
11iii	Average	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Minimum	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Maximum	<50	<10	<10		<10	<10	<50	<10	<10	<10	<10
	Count	6	6	6		6	6	6	6	6	6	6
	Count - less than	6	6	6		6	6	6	6	6	6	6

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Sponsor/Reclaimed Water Source	Calculation Type	2-Chlorophenol µg/L	2-methyl-4-chlorophenoxyacetic µg/L	2-Methylphenol (o-Cresol) µg/L	2-Nitrophenol µg/L	3,3-Dichlorobenzidine µg/L	3,4-Benzofluoranthene µg/L	3-Methylphenol (m-Cresol) µg/L	4,4-DDD µg/L	4,4-DDE µg/L	4,4-DDT µg/L	4,4T-DDD µg/L
1i	Average	<10			<20	<50	<10					
	Minimum	<10			<20	<50	<10					
	Maximum	<10			<20	<50	<10					
	Count	3			3	3	2					
	Count - less than	3			3	3	2					
3i	Average	<10		<10	<20	<50	<10	<10	<0.1	<0.1	<0.1	
	Minimum	<10		<10	<20	<50	<10	<10	<0.1	<0.1	<0.1	
	Maximum	<10		<10	<20	<50	<10	<10	<0.1	<0.1	<0.1	
	Count	1		1	1	1	1	1	1	1	1	
	Count - less than	1		1	1	1	1	1	1	1	1	
3ii	Average	<10		<10	<20	<50	<10	<10	<0.1	<0.1	<0.1	
	Minimum	<10		<10	<20	<50	<10	<10	<0.1	<0.1	<0.1	
	Maximum	<10		<10	<20	<50	<10	<10	<0.1	<0.1	<0.1	
	Count	1		1	1	1	1	1	1	1	1	
	Count - less than	1		1	1	1	1	1	1	1	1	
4i	Average	<10			<20	<50	<10		<0.02	<0.02	<0.02	
	Minimum	<10			<20	<50	<10		<0.02	<0.02	<0.02	
	Maximum	<10			<20	<50	<10		<0.02	<0.02	<0.02	
	Count	6			6	6	6		12	12	12	
	Count - less than	6			6	6	6		12	12	12	
4ii	Average	<10			<20	<50	<10		<0.02	<0.02	<0.02	
	Minimum	<10			<20	<50	<10		<0.02	<0.02	<0.02	
	Maximum	<10			<20	<50	<10		<0.02	<0.02	<0.02	
	Count	1			1	1	1		1	1	1	
	Count - less than	1			1	1	1		1	1	1	
5i	Average	<10			<20	<50	<10		<0.1	<0.1	<0.1	
	Minimum	<10			<20	<50	<10		<0.1	<0.1	<0.1	
	Maximum	<10			<20	<50	<10		<0.1	<0.1	<0.1	
	Count	6			6	6	6		6	6	6	
	Count - less than	6			6	6	6		6	6	6	
5ii	Average	<10			<20	<50	<10		<0.1	<0.1	<0.1	
	Minimum	<10			<20	<50	<10		<0.1	<0.1	<0.1	
	Maximum	<10			<20	<50	<10		<0.1	<0.1	<0.1	
	Count	6			6	6	6		6	6	6	
	Count - less than	6			6	6	6		6	6	6	
6i	Average	<10	<50		<10	<10	<10		<0.05	<0.05	<1	
	Minimum	<10	<50		<10	<10	<10		<0.05	<0.05	<1	
	Maximum	<10	<50		<10	<10	<10		<0.05	<0.05	<1	
	Count	6	6		6	6	6		6	6	6	
	Count - less than	6	6		6	6	6		6	6	6	
7i	Average	<5			<5	<10	<5		<0.05	<0.05	<0.05	
	Minimum	<5			<5	<10	<5		<0.05	<0.05	<0.05	
	Maximum	<5			<5	<10	<5		<0.05	<0.05	<0.05	
	Count	6			6	6	6		6	6	6	
	Count - less than	6			6	6	6		6	6	6	
7ii	Average	<5			<5	<10	<5		<0.05	<0.05	<0.05	
	Minimum	<5			<5	<10	<5		<0.05	<0.05	<0.05	
	Maximum	<5			<5	<10	<5		<0.05	<0.05	<0.05	
	Count	6			6	6	6		6	6	6	
	Count - less than	6			6	6	6		6	6	6	

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7iii	Average	<5			<5	<10	<5		<0.05	<0.05	<0.05	
	Minimum	<5			<5	<10	<5		<0.05	<0.05	<0.05	
	Maximum	<5			<5	<10	<5		<0.05	<0.05	<0.05	
	Count	6			6	6	6		6	6	6	
	Count - less than	6			6	6	6		6	6	6	
8i	Average	<10			<20	<50	<10		<0.1	<0.1	<0.1	
	Minimum	<10			<20	<50	<10		<0.1	<0.1	<0.1	
	Maximum	<10			<20	<50	<10		<0.1	<0.1	<0.1	
	Count	6			6	6	6		6	6	6	
	Count - less than	6			6	6	6		6	6	6	
9i	Average	<10			<20	<50	<10		<0.1	<0.1	<0.1	
	Minimum	<10			<20	<50	<10		<0.1	<0.1	<0.1	
	Maximum	<10			<20	<50	<10		<0.1	<0.1	<0.1	
	Count	4			4	4	4		4	4	4	
	Count - less than	4			4	4	4		4	4	4	
9ii	Average	<10			<20	<50	<10		<0.1	<0.1	<0.1	
	Minimum	<10			<20	<50	<10		<0.1	<0.1	<0.1	
	Maximum	<10			<20	<50	<10		<0.1	<0.1	<0.1	
	Count	4			4	4	4		4	4	4	
	Count - less than	4			4	4	4		4	4	4	
9iii	Average	<10			<20	<50	<10		<0.1	<0.1	<0.1	
	Minimum	<10			<20	<50	<10		<0.1	<0.1	<0.1	
	Maximum	<10			<20	<50	<10		<0.1	<0.1	<0.1	
	Count	4			4	4	4		4	4	4	
	Count - less than	4			4	4	4		4	4	4	
10i	Average	4.600			<20	<50	<10					<10
	Minimum	<5			<20	<50	<10					<10
	Maximum	5.000			<20	<50	<10					<10
	Count	25			25	27	23					27
	Count - less than	26			25	27	23					27
11i	Average	<10			<20	<50	<10		<0.1	<0.1	<0.1	
	Minimum	<10			<20	<50	<10		<0.1	<0.1	<0.1	
	Maximum	<10			<20	<50	<10		<0.1	<0.1	<0.1	
	Count	3			3	3	3		3	3	3	
	Count - less than	3			3	3	3		3	3	3	
11ii	Average	<10			<20	<50	<10		<0.1	<0.1	<0.1	
	Minimum	<10			<20	<50	<10		<0.1	<0.1	<0.1	
	Maximum	<10			<20	<50	<10		<0.1	<0.1	<0.1	
	Count	6			6	6	6		6	6	6	
	Count - less than	6			6	6	6		6	6	6	
11iii	Average	<10			<20	<50	<10		<0.1	<0.1	<0.1	
	Minimum	<10			<20	<50	<10		<0.1	<0.1	<0.1	
	Maximum	<10			<20	<50	<10		<0.1	<0.1	<0.1	
	Count	6			6	6	6		6	6	6	
	Count - less than	6			6	6	6		6	6	6	

Notes:
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Sponsor/Reclaimed Water Source	Calculation Type	4,4T-DDE µg/L	4,4T-DDT µg/L	4,6-Dinitro-o-cresol µg/L	4-BromophenylPhenylEther µg/L	4-Chloro-3-MethylPhenol µg/L	4-ChlorophenylPhenylEther µg/L	4-Methylphenol (p-Cresol) µg/L	4-Nitrophenol µg/L	Acenaphthene µg/L	Acenaphthylene µg/L	Acrolein µg/L
1i	Average			<20	<10	<10	<10		<50	<10	<10	<50
	Minimum			<20	<10	<10	<10		<50	<10	<10	<50
	Maximum			<20	<10	<10	<10		<50	<10	<10	<50
	Count			3	2	3	2		3	1	1	2
	Count - less than			3	2	3	2		3	1	1	2
3i	Average			<50	<10		<10	<10	<50	<10	<10	<50
	Minimum			<50	<10		<10	<10	<50	<10	<10	<50
	Maximum			<50	<10		<10	<10	<50	<10	<10	<50
	Count			1	1		1	1	1	1	1	1
	Count - less than			1	1		1	1	1	1	1	1
3ii	Average			<50	<10		<10	<10	<50	<10	<10	<50
	Minimum			<50	<10		<10	<10	<50	<10	<10	<50
	Maximum			<50	<10		<10	<10	<50	<10	<10	<50
	Count			1	1		1	1	1	1	1	1
	Count - less than			1	1		1	1	1	1	1	1
4i	Average			<50	<10		<10		<50	<10	<10	<50
	Minimum			<50	<10		<10		<50	<10	<10	<50
	Maximum			<50	<10		<10		<50	<10	<10	<50
	Count			6	6		6		6	6	6	6
	Count - less than			6	6		6		6	6	6	6
4ii	Average			<50	<10		<10		<50	<10	<10	<50
	Minimum			<50	<10		<10		<50	<10	<10	<50
	Maximum			<50	<10		<10		<50	<10	<10	<50
	Count			1	1		1		1	1	1	1
	Count - less than			1	1		1		1	1	1	1
5i	Average			<50	<10		<10		<50	<10	<10	<50
	Minimum			<50	<10		<10		<50	<10	<10	<50
	Maximum			<50	<10		<10		<50	<10	<10	<50
	Count			6	6		6		6	6	6	6
	Count - less than			6	6		6		6	6	6	6
5ii	Average			<50	<10		<10		<50	<10	<10	<50
	Minimum			<50	<10		<10		<50	<10	<10	<50
	Maximum			<50	<10		<10		<50	<10	<10	<50
	Count			6	6		6		6	6	6	6
	Count - less than			6	6		6		6	6	6	6
6i	Average			<10	<10		<10		<10	<10	<10	<25
	Minimum			<10	<10		<10		<10	<10	<10	<25
	Maximum			<10	<10		<10		<10	<10	<10	<25
	Count			6	6		6		6	6	6	6
	Count - less than			6	6		6		6	6	6	6
7i	Average			<15	<5		<5		<20	<5	<5	<10
	Minimum			<15	<5		<5		<20	<5	<5	<10
	Maximum			<15	<5		<5		<20	<5	<5	<10
	Count			6	6		6		6	6	6	6
	Count - less than			6	6		6		6	6	6	6
7ii	Average			<15	<5		<5		<20	<5	<5	<10
	Minimum			<15	<5		<5		<20	<5	<5	<10
	Maximum			<15	<5		<5		<20	<5	<5	<10
	Count			6	6		6		6	6	6	6
	Count - less than			6	6		6		6	6	6	6

Notes:
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Sponsor/Reclaimed Water Source	Calculation Type	4,4T-DDE µg/L	4,4T-DDT µg/L	4,6-Dinitro-o-cresol µg/L	4-BromophenylPhenylEther µg/L	4-Chloro-3-MethylPhenol µg/L	4-ChlorophenylPhenylEther µg/L	4-Methylphenol (p-Cresol) µg/L	4-Nitrophenol µg/L	Acenaphthene µg/L	Acenaphthylene µg/L	Acrolein µg/L
7iii	Average			<15	<5		<5		<20	<5	<5	<10
	Minimum			<15	<5		<5		<20	<5	<5	<10
	Maximum			<15	<5		<5		<20	<5	<5	<10
	Count			6	6		6		6	6	6	6
	Count - less than			6	6		6		6	6	6	6
8i	Average			<50	<10		<10		<50	<10	<10	<50
	Minimum			<50	<10		<10		<50	<10	<10	<50
	Maximum			<50	<10		<10		<50	<10	<10	<50
	Count			6	6		6		6	6	6	6
	Count - less than			6	6		6		6	6	6	6
9i	Average			<50	<10		<10		<50	<10	<10	<50
	Minimum			<50	<10		<10		<50	<10	<10	<50
	Maximum			<50	<10		<10		<50	<10	<10	<50
	Count			4	4		4		4	4	4	4
	Count - less than			4	4		4		4	4	4	4
9ii	Average			<50	<10		<10		<50	<10	<10	<50
	Minimum			<50	<10		<10		<50	<10	<10	<50
	Maximum			<50	<10		<10		<50	<10	<10	<50
	Count			4	4		4		4	4	4	4
	Count - less than			4	4		4		4	4	4	4
9iii	Average			<50	<10		<10		<50	<10	<10	<50
	Minimum			<50	<10		<10		<50	<10	<10	<50
	Maximum			<50	<10		<10		<50	<10	<10	<50
	Count			4	4		4		4	4	4	4
	Count - less than			4	4		4		4	4	4	4
10i	Average	<10	<10	<40	<10		<10		<40	<10	<10	<5
	Minimum	<10	<10	<40	<10		<10		<40	<10	<10	<5
	Maximum	<10	<10	<40	<10		<10		<40	<10	<10	<5
	Count	27	27	26	23		23		26	23	23	26
	Count - less than	27	27	26	23		23		26	23	23	26
11i	Average			<50	<10		<10		<50	<10	<10	<50
	Minimum			<50	<10		<10		<50	<10	<10	<50
	Maximum			<50	<10		<10		<50	<10	<10	<50
	Count			3	3		3		3	3	3	3
	Count - less than			3	3		3		3	3	3	3
11ii	Average			<50	<10		<10		<50	<10	<10	<50
	Minimum			<50	<10		<10		<50	<10	<10	<50
	Maximum			<50	<10		<10		<50	<10	<10	<50
	Count			6	6		6		6	6	6	6
	Count - less than			6	6		6		6	6	6	6
11iii	Average			<50	<10		<10		<50	<10	<10	<50
	Minimum			<50	<10		<10		<50	<10	<10	<50
	Maximum			<50	<10		<10		<50	<10	<10	<50
	Count			6	6		6		6	6	6	6
	Count - less than			6	6		6		6	6	6	6

Notes:
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Sponsor/Reclaimed Water Source	Calculation Type	Acrylonitrile µg/L	Aldrin µg/L	alpha-BHC µg/L	Alpha-Endosulfan µg/L	Aluminium mg/L	AmenableCyanide µg/L	Ammonia mg/L	Anthracene µg/L	Antimony mg/L	Arsenic mg/L	Azinphos Methyl µg/L	Barium mg/L	Benzene µg/L	Benzidine µg/L	Benzo(a)anthracene µg/L	Benzo(a)pyrene µg/L
1i	Average	<50	<0.05	<0.1	<0.1			1.133	<10					<10	<50	<10	<10
	Minimum	<50	<0.05	<0.1	<0.1			0.030	<10					<10	<50	<10	<10
	Maximum	<50	<0.05	<0.1	<0.1			8.510	<10					<10	<50	<10	<10
	Count	2	2	3	2			104	1					2	2	2	2
	Count - less than	2	2	3	2			0	1					2	2	2	2
3i	Average	<50	<0.05	<0.05		0.040		0.808	<10	<0.06	<0.01		<0.01	<5	<50	<10	<10
	Minimum	<50	<0.05	<0.05		0.040		0.100	<10	<0.06	<0.01		<0.01	<5	<50	<10	<10
	Maximum	<50	<0.05	<0.05		0.040		2.380	<10	<0.06	<0.01		<0.01	<5	<50	<10	<10
	Count	1	1	1		1		36	1	1	1		1	1	1	1	1
	Count - less than	1	1	1		0		0	1	1	1		1	1	1	1	1
3ii	Average	<50	<0.05	<0.05		0.052		0.678	<10	<0.06	<0.01		<0.01	<5	<50	<10	<10
	Minimum	<50	<0.05	<0.05		0.052		0.140	<10	<0.06	<0.01		<0.01	<5	<50	<10	<10
	Maximum	<50	<0.05	<0.05		0.052		2.100	<10	<0.06	<0.01		<0.01	<5	<50	<10	<10
	Count	1	1	1		1		22	1	1	1		1	1	1	1	1
	Count - less than	1	1	1		0		0	1	1	1		1	1	1	1	1
4i	Average	<50	<0.02	<0.02	<0.02	0.031		0.114	<10	<0.001	0.003		0.013	<10	<50	<10	<10
	Minimum	<50	<0.02	<0.02	<0.02	0.020		0.060	<10	<0.001	<0.005		0.010	<10	<50	<10	<10
	Maximum	<50	<0.02	<0.02	<0.02	0.050		0.188	<10	<0.001	0.006		0.018	<10	<50	<10	<10
	Count	6	12	12	12	6		36	6	15	15		6	6	6	6	6
	Count - less than	6	12	12	12	0		0	6	15	14		0	6	6	6	6
4ii	Average	<50	<0.2	<0.2	<0.02	0.029		0.201	<10				0.045	<10	<50	<10	<10
	Minimum	<50	<0.2	<0.2	<0.02	0.029		0.053	<10				0.045	<10	<50	<10	<10
	Maximum	<50	<0.2	<0.2	<0.02	0.029		0.583	<10				0.045	<10	<50	<10	<10
	Count	1	1	1	1	1		36	1				1	1	1	1	1
	Count - less than	1	1	1	1	0		0	1				0	1	1	1	1
5i	Average	<50	<0.05	<0.05	<0.1	0.414			<10				0.026	<50	<50	<10	<10
	Minimum	<50	<0.05	<0.05	<0.1	0.010			<10				<0.01	<50	<50	<10	<10
	Maximum	<50	<0.05	<0.05	<0.1	1.350			<10				0.090	<50	<50	<10	<10
	Count	6	6	6	6	7			6				7	6	6	6	6
	Count - less than	6	6	6	6	0			6				1	6	6	6	6
5ii	Average	<50	<0.05	<0.05	<0.1	0.067			<10				0.021	<10	<50	<10	<10
	Minimum	<50	<0.05	<0.05	<0.1	<0.03			<10				0.016	<10	<50	<10	<10
	Maximum	<50	<0.05	<0.05	<0.1	0.103			<10				0.026	<10	<50	<10	<10
	Count	6	6	6	6	6			6				7	6	6	6	6
	Count - less than	6	6	6	6	1			6				0	6	6	6	6
6i	Average	<25	<10	<0.05	<0.05	0.014		0.733	<10				0.013	<5	<10	<10	<10
	Minimum	<25	<10	<0.05	<0.05	0.007		0.250	<10				0.011	<5	<10	<10	<10
	Maximum	<25	<10	<0.05	<0.05	0.035		2.350	<10				0.016	<5	<10	<10	<10
	Count	6	6	6	6	18		72	6				18	6	6	6	6
	Count - less than	6	6	6	6	0		0	6				0	6	6	6	6
7i	Average	<10	<0.05	<0.05	<0.05	0.033		0.356	<5				0.022	<5	<50	<5	<5
	Minimum	<10	<0.05	<0.05	<0.05	<0.03		<0.102	<5				<0.002	<5	<50	<5	<5
	Maximum	<10	<0.05	<0.05	<0.05	0.072		3.800	<5				0.041	<5	<50	<5	<5
	Count	6	6	6	6	7		187	6				6	6	6	6	6
	Count - less than	6	6	6	6	3		148	6				1	6	6	6	6
7ii	Average	<10	<0.05	<0.05	<0.05	0.032		0.324	<5				0.023	<5	<50	<5	<5
	Minimum	<10	<0.05	<0.05	<0.05	<0.03		<0.074	<5				0.016	<5	<50	<5	<5
	Maximum	<10	<0.05	<0.05	<0.05	0.054		1.500	<5				0.028	<5	<50	<5	<5
	Count	6	6	6	6	7		191	6				7	6	6	6	6
	Count - less than	6	6	6	6	3		139	6				0	6	6	6	6

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Sponsor/Reclaimed Water Source	Calculation Type	Acrylonitrile µg/L	Aldrin µg/L	alpha-BHC µg/L	Alpha-Endosulfan µg/L	Aluminium mg/L	AmenableCyanide µg/L	Ammonia mg/L	Anthracene µg/L	Antimony mg/L	Arsenic mg/L	Azinphos Methyl µg/L	Barium mg/L	Benzene µg/L	Benzidine µg/L	Benzo(a)anthracene µg/L	Benzo(a)pyrene µg/L
7iii	Average	<10	<0.05	<0.05	<0.05	0.055		3.290	<5				0.059	<5	<50	<5	<5
	Minimum	<10	<0.05	<0.05	<0.05	<0.03		<0.24	<5				0.048	<5	<50	<5	<5
	Maximum	<10	<0.05	<0.05	<0.05	0.150		44.000	<5				0.068	<5	<50	<5	<5
	Count	6	6	6	6	7		190	6				7	6	6	6	6
	Count - less than	6	6	6	6	3		44	6				0	6	6	6	6
8i	Average	<50	<0.05	<0.05	<0.1	<0.03			<10					<10	<50	<10	<10
	Minimum	<50	<0.05	<0.05	<0.1	<0.03			<10					<10	<50	<10	<10
	Maximum	<50	<0.05	<0.05	<0.1	<0.03			<10					<10	<50	<10	<10
	Count	6	6	6	6	6			6					6	6	6	6
	Count - less than	6	6	6	6	6			6					6	6	6	6
9i	Average	<50	<0.05	<0.05	<0.1	0.101		0.492	<10				0.020	<10	<50	<10	<10
	Minimum	<50	<0.05	<0.05	<0.1	<0.00511		0.050	<10				<0.01888	<10	<50	<10	<10
	Maximum	<50	<0.05	<0.05	<0.1	0.347		8.290	<10				0.033	<10	<50	<10	<10
	Count	4	4	4	4	4		1,063	4				4	4	4	4	4
	Count - less than	4	4	4	4	3		0	4				2	4	4	4	4
9ii	Average	<50	<0.05	<0.05	<0.1	0.024		1.479	<10				0.022	<10	<50	<10	<10
	Minimum	<50	<0.05	<0.05	<0.1	0.012		0.050	<10				0.016	<10	<50	<10	<10
	Maximum	<50	<0.05	<0.05	<0.1	0.051		12.680	<10				0.028	<10	<50	<10	<10
	Count	4	4	4	4	4		1,032	4				4	4	4	4	4
	Count - less than	4	4	4	4	0		0	4				0	4	4	4	4
9iii	Average	<50	<0.05	<0.05	<0.1	0.011		0.722	<10				0.015	<10	<50	<10	<10
	Minimum	<50	<0.05	<0.05	<0.1	0.008		0.050	<10				0.012	<10	<50	<10	<10
	Maximum	<50	<0.05	<0.05	<0.1	0.015		16.480	<10				0.021	<10	<50	<10	<10
	Count	4	4	4	4	4		1,063	4				4	4	4	4	4
	Count - less than	4	4	4	4	0		0	4				0	4	4	4	4
10i	Average	<5	<0.05	<0.05	<0.1	0.011	<20	0.256	<10	<0.005	0.003	<0.5	0.025	<5	<50	<10	<10
	Minimum	<5	<0.05	<0.05	<0.1	<0.02	<20	<0.1	<10	<0.005	<0.005	<0.5	0.015	<5	<50	<10	<10
	Maximum	<5	<0.05	<0.05	<0.1	0.046	<20	3.490	<10	<0.005	0.008	<0.5	0.051	<5	<50	<10	<10
	Count	26	27	27	27	88	27	896	23	151	152	71	27	26	27	22	23
	Count - less than	26	27	27	27	83	27	179	23	151	132	71	0	26	27	22	23
11i	Average	<50	<0.05	<0.05	<0.1	0.083			<10	<0.06	<0.01		0.020	<10	<50	<10	<10
	Minimum	<50	<0.05	<0.05	<0.1	<0.03			<10	<0.06	<0.01		<0.01	<10	<50	<10	<10
	Maximum	<50	<0.05	<0.05	<0.1	0.266			<10	<0.06	<0.01		0.066	<10	<50	<10	<10
	Count	3	3	3	3	11			3	11	11		11	3	3	3	3
	Count - less than	3	3	3	3	1			3	11	11		1	3	3	3	3
11ii	Average	<50	<0.05	<0.05	<0.1	0.052			<10	<0.06	<0.01		0.025	<10	<50	<10	<10
	Minimum	<50	<0.05	<0.05	<0.1	<0.03			<10	<0.06	<0.01		0.014	<10	<50	<10	<10
	Maximum	<50	<0.05	<0.05	<0.1	0.115			<10	<0.06	<0.01		0.043	<10	<50	<10	<10
	Count	6	6	6	6	12			6	11	11		12	6	6	6	6
	Count - less than	6	6	6	6	1			6	11	11		0	6	6	6	6
11iii	Average	<50	<0.05	<0.05	<0.1	0.101			<10	<0.06	<0.01		0.033	<10	<50	<10	<10
	Minimum	<50	<0.05	<0.05	<0.1	<0.03			<10	<0.06	<0.01		0.024	<10	<50	<10	<10
	Maximum	<50	<0.05	<0.05	<0.1	0.259			<10	<0.06	<0.01		0.047	<10	<50	<10	<10
	Count	6	6	6	6	17			6	17	17		17	6	6	6	6
	Count - less than	6	6	6	6	2			6	17	17		0	6	6	6	6

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Sponsor/Reclaimed Water Source	Calculation Type	Benzo(g,h,i)perylene µg/L	Benzo(k)fluoranthene µg/L	Beryllium mg/L	beta-BHC µg/L	beta-Endosulfan µg/L	Bis(2-chloroethoxy)methane µg/L	Bis(2-chloroethyl)ether µg/L	Bis(2-choloroisopropyl)ether µg/L	Bis(2-ethylhexyl)Phthalate µg/L
1i	Average	<20	<10		<0.1	<0.1	<10	<10	<10	<10
	Minimum	<20	<10		<0.1	<0.1	<10	<10	<10	<10
	Maximum	<20	<10		<0.1	<0.1	<10	<10	<10	<10
	Count	2	2		3	2	2	2	2	2
	Count - less than	2	2		3	2	2	2	2	2
3i	Average	<20	<10	<0.005	<0.05		<10	<10	<10	<10
	Minimum	<20	<10	<0.005	<0.05		<10	<10	<10	<10
	Maximum	<20	<10	<0.005	<0.05		<10	<10	<10	<10
	Count	1	1	1	1		1	1	1	1
	Count - less than	1	1	1	1		1	1	1	1
3ii	Average	<20	<10	<0.005	<0.05		<10	<10	<10	<10
	Minimum	<20	<10	<0.005	<0.05		<10	<10	<10	<10
	Maximum	<20	<10	<0.005	<0.05		<10	<10	<10	<10
	Count	1	1	1	1		1	1	1	1
	Count - less than	1	1	1	1		1	1	1	1
4i	Average	<20	<10	<0.003	0.015	<0.02	<10	<10	<10	<10
	Minimum	<20	<10	<0.003	<0.02	<0.02	<10	<10	<10	<10
	Maximum	<20	<10	<0.003	0.067	<0.02	<10	<10	<10	<10
	Count	6	6	15	12	12	6	6	6	6
	Count - less than	6	6	15	11	12	6	6	6	6
4ii	Average	<20	<10		<0.2	<0.02	<10	<10	<10	<10
	Minimum	<20	<10		<0.2	<0.02	<10	<10	<10	<10
	Maximum	<20	<10		<0.2	<0.02	<10	<10	<10	<10
	Count	1	1		1	1	1	1	1	1
	Count - less than	1	1		1	1	1	1	1	1
5i	Average	<20	<10		<0.05	<0.1	<10	7.333	6.833	<10
	Minimum	<20	<10		<0.05	<0.1	<10	<10	<10	<10
	Maximum	<20	<10		<0.05	<0.1	<10	14.000	11.000	<10
	Count	6	6		6	6	6	6	6	6
	Count - less than	6	6		6	6	6	4	4	6
5ii	Average	<20	<10		<0.05	<0.1	<10	5.833	5.833	18.857
	Minimum	<20	<10		<0.05	<0.1	<10	<10	<10	<10
	Maximum	<20	<10		<0.05	<0.1	<10	10.000	10.000	102.000
	Count	6	6		6	6	6	6	6	7
	Count - less than	6	6		6	6	6	5	5	6
6i	Average	<10	<10		<0.05	<0.05	<10	<10	<10	<10
	Minimum	<10	<10		<0.05	<0.05	<10	<10	<10	<10
	Maximum	<10	<10		<0.05	<0.05	<10	<10	<10	<10
	Count	6	6		6	6	6	6	6	6
	Count - less than	6	6		6	6	6	6	6	6
7i	Average	<5	<5		<0.05	<0.05	<5	<5	<5	6.358
	Minimum	<5	<5		<0.05	<0.05	<5	<5	<5	<5
	Maximum	<5	<5		<0.05	<0.05	<5	<5	<5	13.550
	Count	6	6		6	6	6	6	6	6
	Count - less than	6	6		6	6	6	6	6	3
7ii	Average	<5	<5		<0.05	<0.05	<5	<5	<5	8.067
	Minimum	<5	<5		<0.05	<0.05	<5	<5	<5	<5
	Maximum	<5	<5		<0.05	<0.05	<5	<5	<5	23.700
	Count	6	6		6	6	6	6	6	6
	Count - less than	6	6		6	6	6	6	6	3

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Sponsor/Reclaimed Water Source	Calculation Type	Benzo(g,h,i)perylene µg/L	Benzo(k)fluoranthene µg/L	Beryllium mg/L	beta-BHC µg/L	beta-Endosulfan µg/L	Bis(2-chloroethoxy)methane µg/L	Bis(2-chloroethyl)ether µg/L	Bis(2-choloroisopropyl)ether µg/L	Bis(2-ethylhexyl)Phthalate µg/L
7iii	Average	<5	<5		<0.05	<0.05	<5	<5	<5	7.500
	Minimum	<5	<5		<0.05	<0.05	<5	<5	<5	<5
	Maximum	<5	<5		<0.05	<0.05	<5	<5	<5	19.900
	Count	6	6		6	6	6	6	6	6
	Count - less than	6	6		6	6	6	6	6	3
8i	Average	<20	<10		<0.05	<0.1		<10	<10	<10
	Minimum	<20	<10		<0.05	<0.1		<10	<10	<10
	Maximum	<20	<10		<0.05	<0.1		<10	<10	<10
	Count	6	6		6	6		6	6	6
	Count - less than	6	6		6	6		6	6	6
9i	Average	<20	<10		<0.05	<0.1	<10	<10	<10	<10
	Minimum	<20	<10		<0.05	<0.1	<10	<10	<10	<10
	Maximum	<20	<10		<0.05	<0.1	<10	<10	<10	<10
	Count	4	4		4	4	4	4	4	4
	Count - less than	4	4		4	4	4	4	4	4
9ii	Average	<20	<10		<0.05	<0.1	<10	<10	<10	6.525
	Minimum	<20	<10		<0.05	<0.1	<10	<10	<10	<10
	Maximum	<20	<10		<0.05	<0.1	<10	<10	<10	11.100
	Count	4	4		4	4	4	4	4	4
	Count - less than	4	4		4	4	4	4	4	3
9iii	Average	<20	<10		<0.05	<0.1	<10	<10	<10	<10
	Minimum	<20	<10		<0.05	<0.1	<10	<10	<10	<10
	Maximum	<20	<10		<0.05	<0.1	<10	<10	<10	<10
	Count	4	4		4	4	4	4	4	4
	Count - less than	4	4		4	4	4	4	4	4
10i	Average	<20	<10	<0.004	<0.05	<0.1	<10	<10	<10	6.254
	Minimum	<20	<10	<0.004	<0.05	<0.1	<10	<10	<10	<9.09
	Maximum	<20	<10	<0.004	<0.05	<0.1	<10	<10	<10	28.600
	Count	26	23	151	27	27	23	23	23	23
	Count - less than	26	23	151	27	27	23	23	23	21
11i	Average	<10	<10	<0.005	<0.05	<0.1	<10	<10	<10	<10
	Minimum	<10	<10	<0.005	<0.05	<0.1	<10	<10	<10	<10
	Maximum	<10	<10	<0.005	<0.05	<0.1	<10	<10	<10	<10
	Count	3	3	11	3	3	3	3	3	3
	Count - less than	3	3	11	3	3	3	3	3	3
11ii	Average	<20	<10	<0.005	<0.05	<0.1	<10	<10	<10	<26
	Minimum	<20	<10	<0.005	<0.05	<0.1	<10	<10	<10	<26
	Maximum	<20	<10	<0.005	<0.05	<0.1	<10	<10	<10	<26
	Count	6	6	11	6	6	6	6	6	4
	Count - less than	6	6	11	6	6	6	6	6	4
11iii	Average	<20	<10	<0.005	<0.05	<0.1	<10	<10	<10	5.900
	Minimum	<20	<10	<0.005	<0.05	<0.1	<10	<10	<10	<10
	Maximum	<20	<10	<0.005	<0.05	<0.1	<10	<10	<10	9.500
	Count	6	6	17	6	6	6	6	6	6
	Count - less than	6	6	17	6	6	6	6	6	5

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Sponsor/Reclaimed Water Source	Calculation Type	Bis(chloromethyl)ether µg/L	BOD mg/L	BOD5 mg/L	Boron mg/L	Bromide mg/L	Bromodichloromethane µg/L	Bromoform µg/L	Butylbenzylphthalate µg/L	Cadmium mg/L	Calcium mg/L	Carbaryl µg/L	Carbonaceous BOD mg/L	CarbonTetrachloride µg/L	CBOD5 mg/L	CCC ??
1i	Average		3.627				<10	<10	<10			<5		<10		###
	Minimum		2.000				<10	<10	<10			<5		<10		###
	Maximum		####				<10	<10	<10			<5		<10		###
	Count		727				2	2	2			3		2		486
	Count - less than		0				2	2	2			3		2		0
3i	Average							<5	<10	<0.0005		<2	2.444	<5	5.000	
	Minimum							<5	<10	<0.0005		<2	2.000	<5	5.000	
	Maximum							<5	<10	<0.0005		<2	4.000	<5	5.000	
	Count							2	1	1		1	36	1	1	
	Count - less than							2	1	1		1	0	1	0	
3ii	Average							<5	<10	<0.0005		<2	2.524	<5	5.000	
	Minimum							<5	<10	<0.0005		<2	2.000	<5	5.000	
	Maximum							<5	<10	<0.0005		<2	3.000	<5	5.000	
	Count							2	1	1		1	21	1	1	
	Count - less than							2	1	1		1	0	1	0	
4i	Average							<10	<10	<0.001		<5	1.194	<10		
	Minimum							<10	<10	<0.001		<5	1.000	<10		
	Maximum							<10	<10	<0.001		<5	1.600	<10		
	Count							6	6	15		6	36	6		
	Count - less than							6	6	15		6	0	6		
4ii	Average							<10	<10			<5	1.217	<10		
	Minimum							<10	<10			<5	1.000	<10		
	Maximum							<10	<10			<5	1.600	<10		
	Count							1	1			1	36	1		
	Count - less than							1	1			1	0	1		
5i	Average							8.000	<10			<5		<10		
	Minimum							<10	<10			<5		<10		
	Maximum							16.000	<10			<5		<10		
	Count							6	6			6		6		
	Count - less than							4	6			6		6		
5ii	Average							10.883	<10			<5		<10		
	Minimum							<10	<10			<5		<10		
	Maximum							21.300	<10			<5		<10		
	Count							6	6			6		6		
	Count - less than							3	6			6		6		
6i	Average	<10		2.516	0.254			<5	<10		87.429	<10		<5	2.028	
	Minimum	<10		2.000	0.200			<5	<10		79.000	<10		<5	2.000	
	Maximum	<10		4.970	0.290			<5	<10		96.000	<10		<5	3.000	
	Count	6		72	70			6	6		70	6		6	72	
	Count - less than	6		0	0			6	6		0	6		6	0	
7i	Average		1.621			0.118	12.297	<5	<5		54.207	<5	1.909	<5		
	Minimum		<2			<0.05	8.300	<5	<5		32.200	<5	<2	<5		
	Maximum		4.200			0.250	17.400	<5	<5		76.300	<5	3.000	<5		
	Count		154			152	6	6	6		154	6	33	6		
	Count - less than		97			148	0	6	6		0	6	9	6		
7ii	Average	0.000	1.372			0.154	2.783	1.750	<5		59.315	<5	2.139	<5		
	Minimum	<0	<2			<0.05	<1	<1	<5		<77	<5	2.000	<5		
	Maximum	0.000	####			0.820	8.200	2.500	<5		81.300	<5	3.000	<5		
	Count	0	155			154	6	6	6		155	6	36	6		
	Count - less than	2	125			125	5	5	6		1	6	0	6		

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Sponsor/Reclaimed Water Source	Calculation Type	Bis(chloromethyl)ether µg/L	BOD mg/L	BOD5 mg/L	Boron mg/L	Bromide mg/L	Bromodichloromethane µg/L	Bromoform µg/L	Butylbenzylphthalate µg/L	Cadmium mg/L	Calcium mg/L	Carbaryl µg/L	Carbonaceous BOD mg/L	CarbonTetrachloride µg/L	CBOD5 mg/L	CCC ??
7iii	Average	0.000	4.411			0.152	5.600	<5	<5		63.567	<5	6.000	<5		
	Minimum	<0	<2			<0.05	<2.4	<5	<5		<74.8	<5	6.000	<5		
	Maximum	0.000	####			1.060	17.200	<5	<5		86.500	<5	6.000	<5		
	Count	0	189			152	6	6	6		154	6	1	6		
	Count - less than	4	12			125	2	6	6		1	6	0	6		
8i	Average	16.477						<10	<10			<5		<15		
	Minimum	14.730						<10	<10			<5		<15		
	Maximum	19.070						<10	<10			<5		<15		
	Count	6						6	6			6		6		
	Count - less than	0						6	6			6		6		
9i	Average							<10	<10			<5	2.247	<10		
	Minimum							<10	<10			<5	2.000	<10		
	Maximum							<10	<10			<5	8.400	<10		
	Count							4	4			4	1,028	4		
	Count - less than							4	4			4	0	4		
9ii	Average		2.842					<10	<10			<5	3.065	<10		
	Minimum		2.300					<10	<10			<5	2.100	<10		
	Maximum		6.300					<10	<10			<5	26.100	<10		
	Count		12					4	4			4	1,047	4		
	Count - less than		0					4	4			4	0	4		
9iii	Average							<10	<10			<5	2.282	<10		
	Minimum							<10	<10			<5	2.000	<10		
	Maximum							<10	<10			<5	13.000	<10		
	Count							4	4			4	1,059	4		
	Count - less than							4	4			4	0	4		
10i	Average	<10					12.857	<5	<10	<0.005		<5	1.286	<5		
	Minimum	<10					<5	<5	<10	<0.005		<5	<2	<5		
	Maximum	<10					21.200	<5	<10	<0.005		<5	7.500	<5		
	Count	3					26	26	23	151		27	884	26		
	Count - less than	3					2	26	23	151		27	754	26		
11i	Average							<10	<10	0.001		<5		<10		
	Minimum							<10	<10	<0.001		<5		<10		
	Maximum							<10	<10	0.001		<5		<10		
	Count							3	3	11		3		3		
	Count - less than							3	3	10		3		3		
11ii	Average							<10	<10	<0.001		<5		<10		
	Minimum							<10	<10	<0.001		<5		<10		
	Maximum							<10	<10	<0.001		<5		<10		
	Count							6	6	11		6		6		
	Count - less than							6	6	11		6		6		
11iii	Average							<10	<10	<0.001		<5		<10		
	Minimum							<10	<10	<0.001		<5		<10		
	Maximum							<10	<10	<0.001		<5		<10		
	Count							6	6	17		6		6		
	Count - less than							6	6	17		6		6		

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Sponsor/Reclaimed Water Source	Calculation Type	Chemical Oxygen Demand mg/L	Chlordane µg/L	Chloride mg/L	ChlorineResidual mg/L	Chlorinetotal mg/L	Chlorobenzene µg/L	Chlorodibromomethane µg/L	Chloroethane µg/L	Chloroform µg/L	Chlorpyrifos µg/L	Chromium mg/L	ChromiumHex mg/L	ChromiumTri mg/L	Chrysene µg/L
1i	Average		<0.15			0.033	<10		<10	<10	<0.05		<0.01	0.003	<10
	Minimum		<0.15			0.030	<10		<10	<10	<0.05		<0.01	<0.002	<10
	Maximum		<0.15			0.970	<10		<10	<10	<0.05		<0.01	0.023	<10
	Count		2			517	2		2	2	3		20	20	2
	Count - less than		2			0	2		2	2	3		20	13	2
3i	Average		<0.15	130.000	<0.1		<5	<5	<5	<5	<0.05	<0.0001	<0.0001	<0.0001	<10
	Minimum		<0.15	130.000	<0.1		<5	<5	<5	<5	<0.05	<0.0001	<0.0001	<0.0001	<10
	Maximum		<0.15	130.000	<0.1		<5	<5	<5	<5	<0.05	<0.0001	<0.0001	<0.0001	<10
	Count		1	1	1		1	2	1	2	1	1	1	1	1
	Count - less than		1	0	1		1	2	1	2	1	1	1	1	1
3ii	Average		<0.15	133.000	<0.1		<5	<5	<5	<5	<0.05	<0.0001	<0.0001	<0.0001	<10
	Minimum		<0.15	133.000	<0.1		<5	<5	<5	<5	<0.05	<0.0001	<0.0001	<0.0001	<10
	Maximum		<0.15	133.000	<0.1		<5	<5	<5	<5	<0.05	<0.0001	<0.0001	<0.0001	<10
	Count		1	1	1		1	2	1	2	1	1	1	1	1
	Count - less than		1	0	1		1	2	1	2	1	1	1	1	1
4i	Average		<0.15			0.054	<10	5.933	<50	18.158	<0.05		<0.01	<0.01	<10
	Minimum		<0.15			0.040	<10	<10	<50	<17.1	<0.05		<0.01	<0.01	<10
	Maximum		<0.15			0.070	<10	10.600	<50	24.700	<0.05		<0.01	<0.01	<10
	Count		8			36	6	6	6	6	6		6	6	6
	Count - less than		8			0	6	5	6	1	6		6	6	6
4ii	Average		<0.15				<10	<10		<10			<0.01	<0.01	<10
	Minimum		<0.15				<10	<10		<10			<0.01	<0.01	<10
	Maximum		<0.15				<10	<10		<10			<0.01	<0.01	<10
	Count		1				1	1		1			1	1	1
	Count - less than		1				1	1		1			1	1	1
5i	Average		<0.15				<10	6.333	<50	9.133	<0.05		<0.01	<0.01	<10
	Minimum		<0.15				<10	<10	<50	<10	<0.05		<0.01	<0.01	<10
	Maximum		<0.15				<10	13.000	<50	20.800	<0.05		<0.01	<0.01	<10
	Count		6				6	6	6	6	6		18	18	6
	Count - less than		6				6	5	6	4	6		18	18	6
5ii	Average		<0.15				<10	12.917	<50	18.167	<0.05		<0.01	<0.01	<10
	Minimum		<0.15				<10	<10	<50	<10	<0.05		<0.01	<0.01	<10
	Maximum		<0.15				<10	34.500	<50	34.000	<0.05		<0.01	<0.01	<10
	Count		6				6	6	6	6	6		18	18	6
	Count - less than		6				6	3	6	1	6		18	18	6
6i	Average		<1	144.944			<5	6.455	<5	21.400	<0.05		<0.01	<0.0025	<10
	Minimum		<1	126.000			<5	5.400	<5	19.000	<0.05		<0.01	<0.0025	<10
	Maximum		<1	160.000			<5	7.510	<5	23.800	<0.05		<0.01	<0.0025	<10
	Count		6	72			6	6	6	6	6		18	18	6
	Count - less than		6	0			6	0	6	0	6		18	18	6
7i	Average	23.045	<0.25	163.480			<5	7.667	<5	11.267	<0.05		<0.01	0.000	<5
	Minimum	<20	<0.25	1.000			<5	6.200	<5	7.600	<0.05		<0.01	<0	<5
	Maximum	84.000	<0.25	501.000			<5	10.000	<5	15.100	<0.05		<0.01	0.000	<5
	Count	154	6	220			6	6	6	6	6		12	8	6
	Count - less than	5	6	0			6	0	6	0	6		12	4	6
7ii	Average	20.171	<0.15	284.077			<5	2.717	<5	2.500	<0.05		<0.01	0.001	<5
	Minimum	<5	<0.15	129.000			<5	<1	<5	<1	<0.05		<0.01	<0	<5
	Maximum	70.000	<0.15	607.000			<5	7.800	<5	6.500	<0.05		<0.01	0.003	<5
	Count	155	6	155			6	6	6	6	6		12	7	6
	Count - less than	14	6	0			6	5	6	5	6		12	9	6

Notes:
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Sponsor/Reclaimed Water Source	Calculation Type	Chemical Oxygen Demand mg/L	Chlordane µg/L	Chloride mg/L	ChlorineResidual mg/L	Chlorinetotal mg/L	Chlorobenzene µg/L	Chlorodibromomethane µg/L	Chloroethane µg/L	Chloroform µg/L	Chlorpyrifos µg/L	Chromium mg/L	ChromiumHex mg/L	ChromiumTri mg/L	Chrysene µg/L
7iii	Average	38.922	0.104	237.622			<5	3.933	<5	5.308	<0.05		0.004	0.003	<5
	Minimum	<20	<0.15	1.740			<5	<1	<5	<3.4	<0.05		<0.005	<0.005	<5
	Maximum	76.000	0.250	538.000			<5	9.500	<5	14.200	<0.05		0.012	0.003	<5
	Count	154	6	190			6	6	6	6	6		12	4	6
	Count - less than	2	5	0			6	3	6	2	6		11	12	6
8i	Average		<0.15				<21	<27	<50	7.900	<0.05		<0.01	0.001	<10
	Minimum		<0.15				<21	<27	<50	<10	<0.05		<0.01	<0.001	<10
	Maximum		<0.15				<21	<27	<50	22.400	<0.05		<0.01	0.005	<10
	Count		6				6	6	6	6	6		31	31	6
	Count - less than		6				6	6	6	5	6		31	27	6
9i	Average		<0.15				<10	6.925	<50	18.675	<0.05				<10
	Minimum		<0.15				<10	<10	<50	15.800	<0.05				<10
	Maximum		<0.15				<10	12.700	<50	23.100	<0.05				<10
	Count		4				4	4	4	4	4				4
	Count - less than		4				4	3	4	0	4				4
9ii	Average		<0.15				<10	6.800	<50	11.350	<0.05		0.000	0.000	<10
	Minimum		<0.15				<10	<10	<50	<10	<0.05		0.000	0.000	<10
	Maximum		<0.15				<10	12.200	<50	23.500	<0.05		0.000	0.000	<10
	Count		4				4	4	4	4	4		0	0	4
	Count - less than		4				4	3	4	2	4		0	0	4
9iii	Average		<0.15				<10	<10	<50	<10	<0.05				<10
	Minimum		<0.15				<10	<10	<50	<10	<0.05				<10
	Maximum		<0.15				<10	<10	<50	<10	<0.05				<10
	Count		4				4	4	4	4	4				4
	Count - less than		4				4	4	4	4	4				4
10i	Average	33.124	<10	98.724			<5	9.033	<8.35	9.456	<0.05	0.003	<0.01	<0.01	<10
	Minimum	<20	<10	17.000			<5	<5	<8.35	<5	<0.05	<0.005	<0.01	<0.01	<10
	Maximum	502.000	<10	158.000			<5	20.600	<8.35	15.900	<0.05	0.014	<0.01	<0.01	<10
	Count	299	27	306			26	26	26	26	98	151	6	6	22
	Count - less than	16	27	0			26	3	26	4	98	148	6	6	22
11i	Average		<0.15				<10	<10	<50	7.667	<0.5	<0.01	<0.01	<0.01	<10
	Minimum		<0.15				<10	<10	<50	<10	<0.5	<0.01	<0.01	<0.01	<10
	Maximum		<0.15				<10	<10	<50	13.000	<0.5	<0.01	<0.01	<0.01	<10
	Count		3				3	3	3	3	3	11	11	11	3
	Count - less than		3				3	3	3	2	3	11	11	11	3
11ii	Average		<0.15				<10	7.733	<50	28.183	<0.05	<0.01	<0.01	<0.01	<10
	Minimum		<0.15				<10	<10	<50	<10	<0.05	<0.01	<0.01	<0.01	<10
	Maximum		<0.15				<10	13.400	<50	73.000	<0.05	<0.01	<0.01	<0.01	<10
	Count		6				6	6	6	6	6	11	11	11	6
	Count - less than		6				6	4	6	1	6	11	11	11	6
11iii	Average		<0.15				<10	<10	<50	<10	<0.05	<0.01	<0.01	<0.01	<10
	Minimum		<0.15				<10	<10	<50	<10	<0.05	<0.01	<0.01	<0.01	<10
	Maximum		<0.15				<10	<10	<50	<10	<0.05	<0.01	<0.01	<0.01	<10
	Count		6				6	6	6	6	6	17	17	17	6
	Count - less than		6				6	6	6	6	6	17	17	17	6

Notes:
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2) For parameters with all sample points below the detection value, the results are reported as less than the highest detection value reported.
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Sponsor/Reclaimed Water Source	Calculation Type	Coliform CFU/100mL	Conductivity µmhos/cm	Copper mg/L	Cresols µg/L	Cyanide µg/L	Cyanide, Available µg/L	CyanideAmenabletoChlorination µg/L	CyanideTotal µg/L	Dalapon µg/L	Danitol µg/L	oxin/Fura µg/L	DDD µg/L	DDE µg/L	DDT µg/L	delta-BHC µg/L	Demeton µg/L	Demeton-O µg/L	Demeton-O & S µg/L
1i	Average				<10				<50				<0.1	<0.1	<0.1	<0.1	<0.2		
	Minimum				<10				<50				<0.1	<0.1	<0.1	<0.1	<0.2		
	Maximum				<10				<50				<0.1	<0.1	<0.1	<0.1	<0.2		
	Count				3				24				2	2	2	3	3		
	Count - less than				3				24				2	2	2	3	3		
3i	Average		1,080.000	<0.0005				<20	<20							<0.05			<0.1
	Minimum		1,080.000	<0.0005				<20	<20							<0.05			<0.1
	Maximum		1,080.000	<0.0005				<20	<20							<0.05			<0.1
	Count		1	1				1	1							1			1
	Count - less than		0	1				1	1							1			1
3ii	Average		1,104.000	<0.0005				<20	<20							<0.05			<0.1
	Minimum		1,104.000	<0.0005				<20	<20							<0.05			<0.1
	Maximum		1,104.000	<0.0005				<20	<20							<0.05			<0.1
	Count		1	1				1	1							1			1
	Count - less than		0	1				1	1							1			1
4i	Average			0.004	<50				<20							<0.02	<0.2		
	Minimum			0.002	<50				<20							<0.02	<0.2		
	Maximum			0.008	<50				<20							<0.02	<0.2		
	Count			15	6				28							12	6		
	Count - less than			0	6				28							12	6		
4ii	Average				<50			<20	<20							<0.2			
	Minimum				<50			<20	<20							<0.2			
	Maximum				<50			<20	<20							<0.2			
	Count				1			1	8							1			
	Count - less than				1			1	8							1			
5i	Average				<22		<20		<20							<0.05	<0.2		
	Minimum				<22		<20		<20							<0.05	<0.2		
	Maximum				<22		<20		<20							<0.05	<0.2		
	Count				6		12		12							6	6		
	Count - less than				6		12		12							6	6		
5ii	Average				<10		<20		<20							<0.05	<0.2		
	Minimum				<10		<20		<20							<0.05	<0.2		
	Maximum				<10		<20		<20							<0.05	<0.2		
	Count				6		12		12							6	6		
	Count - less than				6		12		12							6	6		
6i	Average				<30				14.683	<2						<0.05	<0.1		
	Minimum				<30				10.500	<2						<0.05	<0.1		
	Maximum				<30				26.000	<2						<0.05	<0.1		
	Count				6				18	6						6	6		
	Count - less than				6				0	6						6	6		
7i	Average		1,444.118		<10		<20		<20							<0.05	<0.2		
	Minimum		<2500		<10		<20		<20							<0.05	<0.2		
	Maximum		1,920.000		<10		<20		<20							<0.05	<0.2		
	Count		153		8		12		12							6	6		
	Count - less than		16		8		12		12							6	6		
7ii	Average		1,922.258		<5		<20		<20		0.000	0.000				<0.05	<0.2		
	Minimum		<3160		<5		<20		<20		<0	<0				<0.05	<0.2		
	Maximum		2,350.000		<5		<20		<20		0.000	0.000				<0.05	<0.2		
	Count		155		8		12		12		0	0				6	6		
	Count - less than		52		8		12		12		2	4				6	6		

Notes:
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Sponsor/Reclaimed Water Source	Calculation Type	Coliform CFU/100mL	Conductivity µmhos/cm	Copper mg/L	Cresols µg/L	Cyanide µg/L	Cyanide, Available µg/L	CyanideAmenabletoChlorination µg/L	CyanideTotal µg/L	Dalapon µg/L	Danitol µg/L	oxin/Fura µg/L	DDD µg/L	DDE µg/L	DDT µg/L	delta-BHC µg/L	Demeton µg/L	Demeton-O µg/L	Demeton-O & S µg/L
7iii	Average		1,747.597		<10		11.667		14.167		0.000	0.000				<0.05	<0.2		
	Minimum		1,080.000		<10		<20		<20		<0	<0				<0.05	<0.2		
	Maximum		2,040.000		<10		30.000		30.000		0.000	0.000				<0.05	<0.2		
	Count		154		8		12		12		0	0				6	6		
	Count - less than		0		8		11		9		6	6				6	6		
8i	Average				<10											<0.05	<0.2		
	Minimum				<10											<0.05	<0.2		
	Maximum				<10											<0.05	<0.2		
	Count				6											6	6		
	Count - less than				6											6	6		
9i	Average	2.288		0.001	<50				<10							<0.05	<0.2		
	Minimum	<2		0.000	<50				<10							<0.05	<0.2		
	Maximum	12.000		0.001	<50				<10							<0.05	<0.2		
	Count	12		28	4				8							4	4		
	Count - less than	6		0	4				8							4	4		
9ii	Average			2.052	<50				6.625							<0.05	<0.2		
	Minimum			0.007	<50				<10							<0.05	<0.2		
	Maximum			48.500	<50				12.000							<0.05	<0.2		
	Count			175	4				8							4	4		
	Count - less than			0	4				6							4	4		
9iii	Average	9.191		0.000	<50				5.727							<0.05	<0.2		
	Minimum	<2		0.000	<50				<10							<0.05	<0.2		
	Maximum	90.000		0.000	<50				13.000							<0.05	<0.2		
	Count	28		28	4				11							4	4		
	Count - less than	12		0	4				10							4	4		
10i	Average			0.003	5.489				<24							<0.05	<2	<0.5	<0.2
	Minimum			<0.005	<9.09				<24							<0.05	<2	<0.5	<0.2
	Maximum			0.007	16.700				<24							<0.05	<2	<0.5	<0.2
	Count			151	23				27							27	27	69	3
	Count - less than			147	22				27							27	27	69	3
11i	Average			0.007	<10	<20										<0.05	<0.2		
	Minimum			<0.01	<10	<20										<0.05	<0.2		
	Maximum			0.016	<10	<20										<0.05	<0.2		
	Count			11	3	11										3	3		
	Count - less than			9	3	11										3	3		
11ii	Average			<0.01	<10	<20										<0.05	<0.2		
	Minimum			<0.01	<10	<20										<0.05	<0.2		
	Maximum			<0.01	<10	<20										<0.05	<0.2		
	Count			11	6	11										6	6		
	Count - less than			11	6	11										6	6		
11iii	Average			0.006	<10	<20										<0.05	<0.2		
	Minimum			<0.01	<10	<20										<0.05	<0.2		
	Maximum			0.011	<10	<20										<0.05	<0.2		
	Count			17	6	17										6	6		
	Count - less than			15	6	17										6	6		

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Sponsor/Reclaimed Water Source	Calculation Type	Demeton-S µg/L	Diazinon µg/L	Dibenzo(a,h)anthracene µg/L	Dibromochloromethane µg/L	Dicamba µg/L	Dichloroprop µg/L	Dicofol µg/L	Dieldrin µg/L	Diethylphthalate µg/L	Dimethylphtalate µg/L	Di-n-butylphthalate µg/L	Di-n-octylphthalate µg/L	DissolvedOxygen mg/L
1i	Average		<0.5	<20	<10			<20	<0.1	<10	<10	<10	<10	6.702
	Minimum		<0.5	<20	<10			<20	<0.1	<10	<10	<10	<10	3.760
	Maximum		<0.5	<20	<10			<20	<0.1	<10	<10	<10	<10	9.110
	Count		3	2	2			3	2	3	3	2	3	1,459
	Count - less than		3	2	2			3	2	3	3	2	3	0
3i	Average		<0.5	<20	<5			<20	<0.1	<10	<10	<10	<10	4.000
	Minimum		<0.5	<20	<5			<20	<0.1	<10	<10	<10	<10	4.000
	Maximum		<0.5	<20	<5			<20	<0.1	<10	<10	<10	<10	4.000
	Count		1	1	2			1	1	1	1	1	1	1
	Count - less than		1	1	2			1	1	1	1	1	1	0
3ii	Average		<0.5	<20	<5			<20	<0.1	<10	<10	<10	<10	5.000
	Minimum		<0.5	<20	<5			<20	<0.1	<10	<10	<10	<10	5.000
	Maximum		<0.5	<20	<5			<20	<0.1	<10	<10	<10	<10	5.000
	Count		1	1	2			1	1	1	1	1	1	1
	Count - less than		1	1	2			1	1	1	1	1	1	0
4i	Average		<0.5	<20	8.408			<20	<0.02	<10	<10	<10	<10	7.703
	Minimum		<0.5	<20	<10			<20	<0.02	<10	<10	<10	<10	6.820
	Maximum		<0.5	<20	12.500			<20	<0.02	<10	<10	<10	<10	9.040
	Count		6	6	6			6	12	6	6	6	6	36
	Count - less than		6	6	3			6	12	6	6	6	6	0
4ii	Average			<20	<10			<20	<0.02	<10	<10	<10	<10	6.978
	Minimum			<20	<10			<20	<0.02	<10	<10	<10	<10	6.310
	Maximum			<20	<10			<20	<0.02	<10	<10	<10	<10	7.860
	Count			1	1			1	1	1	1	1	1	36
	Count - less than			1	1			1	1	1	1	1	1	0
5i	Average		<0.5	<20	7.071			<20	<0.1	<10	<10	<10	<10	
	Minimum		<0.5	<20	<9			<20	<0.1	<10	<10	<10	<10	
	Maximum		<0.5	<20	19.000			<20	<0.1	<10	<10	<10	<10	
	Count		6	6	7			6	6	6	6	6	6	
	Count - less than		6	6	4			6	6	6	6	6	6	
5ii	Average		<0.5	<20	15.000			<20	<0.1	<10	<10	<10	<10	
	Minimum		<0.5	<20	<10			<20	<0.1	<10	<10	<10	<10	
	Maximum		<0.5	<20	21.000			<20	<0.1	<10	<10	<10	<10	
	Count		6	6	6			6	6	6	6	6	6	
	Count - less than		6	6	1			6	6	6	6	6	6	
6i	Average		<0.05	<10	<5	<0.5	<1	<0.05	<0.05	<10	<10	<10	<10	
	Minimum		<0.05	<10	<5	<0.5	<1	<0.05	<0.05	<10	<10	<10	<10	
	Maximum		<0.05	<10	<5	<0.5	<1	<0.05	<0.05	<10	<10	<10	<10	
	Count		6	6	6	6	6	6	6	6	6	6	6	
	Count - less than		6	6	6	6	6	6	6	6	6	6	6	
7i	Average		<0.5	<5				<2	<0.05	<5	<5	<5	<7	8.418
	Minimum		<0.5	<5				<2	<0.05	<5	<5	<5	<7	6.400
	Maximum		<0.5	<5				<2	<0.05	<5	<5	<5	<7	11.000
	Count		12	6				6	6	6	6	6	6	33
	Count - less than		12	6				6	6	6	6	6	6	0
7ii	Average		<0.5	<5				<2	<0.05	<5	<5	<5	<7	6.978
	Minimum		<0.5	<5				<2	<0.05	<5	<5	<5	<7	6.400
	Maximum		<0.5	<5				<2	<0.05	<5	<5	<5	<7	7.600
	Count		8	6				6	6	6	6	6	6	36
	Count - less than		8	6				6	6	6	6	6	6	0

Notes:
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Sponsor/Reclaimed Water Source	Calculation Type	Demeton-S µg/L	Diazinon µg/L	Dibenzo(a,h)anthracene µg/L	Dibromochloromethane µg/L	Dicamba µg/L	Dichloroprop µg/L	Dicofol µg/L	Dieldrin µg/L	Diethylphthalate µg/L	Dimethylphtalate µg/L	Di-n-butylphthalate µg/L	Di-n-octylphthalate µg/L	DissolvedOxygen mg/L
7iii	Average		<0.5	<5				<2	<0.05	<5	<5	<5	<7	6.794
	Minimum		<0.5	<5				<2	<0.05	<5	<5	<5	<7	6.000
	Maximum		<0.5	<5				<2	<0.05	<5	<5	<5	<7	7.700
	Count		6	6				6	6	6	6	6	6	36
	Count - less than		6	6				6	6	6	6	6	6	0
8i	Average		<0.5	<20	5.933			<20	<0.1	<10	<10	<10	<10	
	Minimum		<0.5	<20	<10			<20	<0.1	<10	<10	<10	<10	
	Maximum		<0.5	<20	10.600			<20	<0.1	<10	<10	<10	<10	
	Count		6	6	6			6	6	6	6	6	6	
	Count - less than		6	6	5			6	6	6	6	6	6	
9i	Average		<0.5	<20	9.600			<20	<0.1	<10	<10	<10	<10	
	Minimum		<0.5	<20	<10			<20	<0.1	<10	<10	<10	<10	
	Maximum		<0.5	<20	16.200			<20	<0.1	<10	<10	<10	<10	
	Count		4	4	4			4	4	4	4	4	4	
	Count - less than		4	4	2			4	4	4	4	4	4	
9ii	Average		<0.5	<20	7.950			<20	<0.1	6.500	<10	<10	<10	
	Minimum		<0.5	<20	<10			<20	<0.1	<10	<10	<10	<10	
	Maximum		<0.5	<20	16.800			<20	<0.1	11.000	<10	<10	<10	
	Count		4	4	4			4	4	4	4	4	4	
	Count - less than		4	4	3			4	4	3	4	4	4	
9iii	Average		<0.5	<20	<10			<20	<0.1	<10	<10	<10	<10	
	Minimum		<0.5	<20	<10			<20	<0.1	<10	<10	<10	<10	
	Maximum		<0.5	<20	<10			<20	<0.1	<10	<10	<10	<10	
	Count		4	4	4			4	4	4	4	4	4	
	Count - less than		4	4	4			4	4	4	4	4	4	
10i	Average	<0.5	0.026	<20				<20	<10	<10	<10	<10	<10	
	Minimum	<0.5	<0.05	<20				<20	<10	<10	<10	<10	<10	
	Maximum	<0.5	0.090	<20				<20	<10	<10	<10	<10	<10	
	Count	69	98	26				27	27	23	23	23	23	
	Count - less than	69	97	26				27	27	23	23	23	23	
11i	Average		<0.5	<20	<10			<20	<0.1	<10	<10	<10	<10	
	Minimum		<0.5	<20	<10			<20	<0.1	<10	<10	<10	<10	
	Maximum		<0.5	<20	<10			<20	<0.1	<10	<10	<10	<10	
	Count		3	3	3			3	3	3	3	3	3	
	Count - less than		3	3	3			3	3	3	3	3	3	
11ii	Average		<0.5	<20	8.700			<20	<0.1	<10	<10	<10	<10	
	Minimum		<0.5	<20	<10			<20	<0.1	<10	<10	<10	<10	
	Maximum		<0.5	<20	20.200			<20	<0.1	<10	<10	<10	<10	
	Count		6	6	6			6	6	6	6	6	6	
	Count - less than		6	6	4			6	6	6	6	6	6	
11iii	Average		<0.5	<20	<10			<20	<0.1	<10	<10	<10	<10	
	Minimum		<0.5	<20	<10			<20	<0.1	<10	<10	<10	<10	
	Maximum		<0.5	<20	<10			<20	<0.1	<10	<10	<10	<10	
	Count		6	6	6			6	6	6	6	6	6	
	Count - less than		6	6	6			6	6	6	6	6	6	

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Sponsor/Reclaimed Water Source	Calculation Type	Disulfoton µg/L	Diuron µg/L	E.coli CFU/100mL	E.coli MPN/100mL	E.coli ??/100mL	Endosulfan I µg/L	Endosulfan II µg/L	EndosulfanSulfate µg/L	Endrin µg/L	EndrinAldehyde µg/L	Enterococci CFU/100mL	EPN µg/L	Ethion µg/L	Ethyl Parathion µg/L	Ethylbenzene µg/L	Fats,Oils,Grease mg/L	FecalColiform CFU/100mL
1i	Average		<0.05	9.051	9.051	9.051			<0.1	<0.1	<0.1					<10	2.811	
	Minimum		<0.05	1.000	1.000	1.000			<0.1	<0.1	<0.1					<10	0.700	
	Maximum		<0.05	142.100	142.100	142.100			<0.1	<0.1	<0.1					<10	15.000	
	Count		3	426	426	426			2	2	2					2	11	
	Count - less than		3	0	0	0			2	2	2					2	0	
3i	Average		<2	36.758	36.758	36.758	<0.1	<0.1	<0.1	<0.1	<0.1	<1				<5	<2	3.000
	Minimum		<2	14.000	14.000	14.000	<0.1	<0.1	<0.1	<0.1	<0.1	<1				<5	<2	3.000
	Maximum		<2	68.000	68.000	68.000	<0.1	<0.1	<0.1	<0.1	<0.1	<1				<5	<2	3.000
	Count		1	36	36	36	1	1	1	1	1	1				1	1	1
	Count - less than		1	0	0	0	1	1	1	1	1	1				1	1	0
3ii	Average		<2	32.333	32.333	32.333	<0.1	<0.1	<0.1	<0.1	<0.1	<1				<5	<2	2.000
	Minimum		<2	8.000	8.000	8.000	<0.1	<0.1	<0.1	<0.1	<0.1	<1				<5	<2	2.000
	Maximum		<2	54.000	54.000	54.000	<0.1	<0.1	<0.1	<0.1	<0.1	<1				<5	<2	2.000
	Count		1	21	21	21	1	1	1	1	1	1				1	1	1
	Count - less than		1	0	0	0	1	1	1	1	1	1				1	1	0
4i	Average		<0.09						<0.02	<0.02	<0.02					<10		
	Minimum		<0.09						<0.02	<0.02	<0.02					<10		
	Maximum		<0.09						<0.02	<0.02	<0.02					<10		
	Count		6						12	12	12					6		
	Count - less than		6						12	12	12					6		
4ii	Average		<0.09	3.543	3.543	3.543			<0.02	<0.02	<0.02					<10	<5	
	Minimum		<0.09	1.000	1.000	1.000			<0.02	<0.02	<0.02					<10	<5	
	Maximum		<0.09	39.000	39.000	39.000			<0.02	<0.02	<0.02					<10	<5	
	Count		1	35	35	35			1	1	1					1	1	
	Count - less than		1	0	0	0			1	1	1					1	1	
5i	Average		<0.09						<0.1	<0.1	<0.1					<10		
	Minimum		<0.09						<0.1	<0.1	<0.1					<10		
	Maximum		<0.09						<0.1	<0.1	<0.1					<10		
	Count		6						6	6	6					6		
	Count - less than		6						6	6	6					6		
5ii	Average		<0.09						<0.1	<0.1	<0.1					<10		
	Minimum		<0.09						<0.1	<0.1	<0.1					<10		
	Maximum		<0.09						<0.1	<0.1	<0.1					<10		
	Count		6						6	6	6					6		
	Count - less than		6						6	6	6					6		
6i	Average		<4						<0.05	<0.05	<0.05					6.150	3.167	
	Minimum		<4						<0.05	<0.05	<0.05					<5	<5	
	Maximum		<4						<0.05	<0.05	<0.05					9.800	6.500	
	Count		6						6	6	6					6	18	
	Count - less than		6						6	6	6					3	15	
7i	Average		<0.1	7.088	7.088	7.088			<0.05	<0.05	<0.05					<5		
	Minimum		<0.1	1.000	1.000	1.000			<0.05	<0.05	<0.05					<5		
	Maximum		<0.1	67.000	67.000	67.000			<0.05	<0.05	<0.05					<5		
	Count		6	27	27	27			6	6	6					6		
	Count - less than		6	0	0	0			6	6	6					6		
7ii	Average		0.074	1.583	1.583	1.583			<0.05	<0.05	<0.05					<5		3.667
	Minimum		<0.09	1.000	1.000	1.000			<0.05	<0.05	<0.05					<5		1.000
	Maximum		0.250	12.000	12.000	12.000			<0.05	<0.05	<0.05					<5		20.000
	Count		7	24	24	24			6	6	6					6		12
	Count - less than		6	0	0	0			6	6	6					6		0

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7iii	Average		<0.1	5.025	5.025	5.025			<0.05	<0.05	<0.05					<5		23.250
	Minimum		<0.1	<0.8	<0.8	<0.8			<0.05	<0.05	<0.05					<5		3.000
	Maximum		<0.1	39.000	39.000	39.000			<0.05	<0.05	<0.05					<5		84.000
	Count		6	28	28	28			6	6	6					6		8
	Count - less than		6	2	2	2			6	6	6					6		0
8i	Average		0.090						<0.1	<0.1	<0.1					<10		
	Minimum		0.090						<0.1	<0.1	<0.1					<10		
	Maximum		0.090						<0.1	<0.1	<0.1					<10		
	Count		6						6	6	6					6		
	Count - less than		0						6	6	6					6		
9i	Average		######						<0.1	<0.1	<0.1					<10		1.192
	Minimum		<0.09						<0.1	<0.1	<0.1					<10		<1
	Maximum		######						<0.1	<0.1	<0.1					<10		36.000
	Count		4						4	4	4					4		250
	Count - less than		3						4	4	4					4		225
9ii	Average		<0.09	15.970	15.970	15.970			<0.1	<0.1	<0.1					<10		
	Minimum		<0.09	<1	<1	<1			<0.1	<0.1	<0.1					<10		
	Maximum		<0.09	2,419.600	2,419.600	2,419.600			<0.1	<0.1	<0.1					<10		
	Count		4	176	176	176			4	4	4					4		
	Count - less than		4	162	162	162			4	4	4					4		
9iii	Average		<0.09	13.707	13.707	13.707			<0.1	<0.1	<0.1					<10		7.109
	Minimum		<0.09	<1	<1	<1			<0.1	<0.1	<0.1					<10		<1
	Maximum		<0.09	2,419.600	2,419.600	2,419.600			<0.1	<0.1	<0.1					<10		547.500
	Count		4	762	762	762			4	4	4					4		92
	Count - less than		4	373	373	373			4	4	4					4		72
10i	Average	<0.5	<0.09	3.692	3.692	3.692			<0.1	<0.1	<0.1		<0.5	<0.5	0.051	<10		69.516
	Minimum	<0.5	<0.09	<1	<1	<1			<0.1	<0.1	<0.1		<0.5	<0.5	<0.1	<10		<1
	Maximum	<0.5	<0.09	84.000	84.000	84.000			<0.1	<0.1	<0.1		<0.5	<0.5	0.129	<10		900.000
	Count	71	27	304	304	304			27	27	27		71	71	71	26		310
	Count - less than	71	27	164	164	164			27	27	27		71	71	70	26		31
11i	Average		<0.1						<0.1	<0.1	<0.1					<10	<0.0085	
	Minimum		<0.1						<0.1	<0.1	<0.1					<10	<0.0085	
	Maximum		<0.1						<0.1	<0.1	<0.1					<10	<0.0085	
	Count		3						3	3	3					3	3	
	Count - less than		3						3	3	3					3	3	
11ii	Average		<0.09						<0.1	<0.1	<0.1					<10	<0.0068	
	Minimum		<0.09						<0.1	<0.1	<0.1					<10	<0.0068	
	Maximum		<0.09						<0.1	<0.1	<0.1					<10	<0.0068	
	Count		6						6	6	6					6	6	
	Count - less than		6						6	6	6					6	6	
11iii	Average		<0.09						<0.1	<0.1	<0.1					<10	0.006	
	Minimum		<0.09						<0.1	<0.1	<0.1					<10	<0.005	
	Maximum		<0.09						<0.1	<0.1	<0.1					<10	0.014	
	Count		6						6	6	6					6	6	
	Count - less than		6						6	6	6					6	4	

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Sponsor/Reclaimed Water Source	Calculation Type	FecalColiform ??/100mL	Fixed TSS mg/L	Fluoranthene µg/L	Fluorene µg/L	Fluoride mg/L	fluroranthene µg/L	gamma-BHC µg/L	Guthion µg/L	Hardness mg/L	Heptachlor µg/L	HeptachlorEpoxide µg/L	Heterotrophic Plate Count CFU/100mL	Hexachlorobenzene µg/L	Hexachlorobutadiene µg/L
1i	Average			<10	<10	<2.48		<0.1	<0.1		<0.05	<1		<10	<10
	Minimum			<10	<10	<2.48		<0.1	<0.1		<0.05	<1		<10	<10
	Maximum			<10	<10	<2.48		<0.1	<0.1		<0.05	<1		<10	<10
	Count			3	3	2		3	3		2	2		3	3
	Count - less than			3	3	2		3	3		2	2		3	3
3i	Average	3.000		<10	<10	<0.5		<0.05	<0.1		<0.05	<1		<10	<10
	Minimum	3.000		<10	<10	<0.5		<0.05	<0.1		<0.05	<1		<10	<10
	Maximum	3.000		<10	<10	<0.5		<0.05	<0.1		<0.05	<1		<10	<10
	Count	1		1	1	1		1	1		1	1		1	1
	Count - less than	0		1	1	1		1	1		1	1		1	1
3ii	Average	2.000		<10	<10	<0.5		<0.05	<0.1		<0.05	<1		<10	<10
	Minimum	2.000		<10	<10	<0.5		<0.05	<0.1		<0.05	<1		<10	<10
	Maximum	2.000		<10	<10	<0.5		<0.05	<0.1		<0.05	<1		<10	<10
	Count	1		1	1	1		1	1		1	1		1	1
	Count - less than	0		1	1	1		1	1		1	1		1	1
4i	Average			<10	<10	0.733		<0.02	<0.1		<0.02	<0.02		<10	<10
	Minimum			<10	<10	0.600		<0.02	<0.1		<0.02	<0.02		<10	<10
	Maximum			<10	<10	1.300		<0.02	<0.1		<0.02	<0.02		<10	<10
	Count			6	6	6		12	6		12	12		6	6
	Count - less than			6	6	0		12	6		12	12		6	6
4ii	Average			<10	<10	0.700		<0.2			<0.02	<0.02		<10	<10
	Minimum			<10	<10	0.700		<0.2			<0.02	<0.02		<10	<10
	Maximum			<10	<10	0.700		<0.2			<0.02	<0.02		<10	<10
	Count			1	1	1		1			1	1		1	1
	Count - less than			1	1	0		1			1	1		1	1
5i	Average			<10	<10	1.201		<0.05	<0.1		<0.05	<1		<10	<10
	Minimum			<10	<10	<1.31		<0.05	<0.1		<0.05	<1		<10	<10
	Maximum			<10	<10	2.300		<0.05	<0.1		<0.05	<1		<10	<10
	Count			6	6	7		6	6		6	6		6	6
	Count - less than			6	6	1		6	6		6	6		6	6
5ii	Average			<10	<10	2.290		<0.05	<0.1		<0.05	<1		<10	<10
	Minimum			<10	<10	1.070		<0.05	<0.1		<0.05	<1		<10	<10
	Maximum			<10	<10	3.380		<0.05	<0.1		<0.05	<1		<10	<10
	Count			6	6	7		6	6		6	6		6	6
	Count - less than			6	6	0		6	6		6	6		6	6
6i	Average			<10	<10	0.566		<0.05	<0.05	287.200	<0.05	<0.05		<10	<10
	Minimum			<10	<10	0.496		<0.05	<0.05	264.000	<0.05	<0.05		<10	<10
	Maximum			<10	<10	0.750		<0.05	<0.05	313.000	<0.05	<0.05		<10	<10
	Count			3	6	18		6	6	70	6	6		6	6
	Count - less than			3	6	0		6	6	0	6	6		6	6
7i	Average			<5	<5	0.823		<0.05	<0.1	192.208	<0.05	<0.05		<5	<5
	Minimum			<5	<5	<0.1		<0.05	<0.1	108.000	<0.05	<0.05		<5	<5
	Maximum			<5	<5	3.430		<0.05	<0.1	247.000	<0.05	<0.05		<5	<5
	Count			6	6	159		6	6	154	6	6		6	6
	Count - less than			6	6	41		6	6	0	6	6		6	6
7ii	Average	3.667		<5	<5	0.800		<0.05	<0.1	200.630	<0.05	<0.05		<5	<5
	Minimum	1.000		<5	<5	<0.001		<0.05	<0.1	62.700	<0.05	<0.05		<5	<5
	Maximum	20.000		<5	<5	1.760		<0.05	<0.1	264.000	<0.05	<0.05		<5	<5
	Count	12		6	6	161		6	6	155	6	6		6	6
	Count - less than	0		6	6	62		6	6	0	6	6		6	6

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Sponsor/Reclaimed Water Source	Calculation Type	FecalColiform ??/100mL	Fixed TSS mg/L	Fluoranthene µg/L	Fluorene µg/L	Fluoride mg/L	fluroranthene µg/L	gamma-BHC µg/L	Guthion µg/L	Hardness mg/L	Heptachlor µg/L	HeptachlorEpoxide µg/L	Heterotrophic Plate Count CFU/100mL	Hexachlorobenzene µg/L	Hexachlorobutadiene µg/L
7iii	Average	23.250		<5	<5	0.713		<0.05	<0.1	224.506	<0.05	<0.05		<5	<5
	Minimum	3.000		<5	<5	<0.26		<0.05	<0.1	145.000	<0.05	<0.05		<5	<5
	Maximum	84.000		<5	<5	1.170		<0.05	<0.1	293.000	<0.05	<0.05		<5	<5
	Count	8		6	6	159		6	6	154	6	6		6	6
	Count - less than	0		6	6	14		6	6	0	6	6		6	6
8i	Average			<10	<10	0.348		<0.05	<0.1		<0.05	<1		<10	<10
	Minimum			<10	<10	<0.0005		<0.05	<0.1		<0.05	<1		<10	<10
	Maximum			<10	<10	0.654		<0.05	<0.1		<0.05	<1		<10	<10
	Count			6	6	6		6	6		6	6		6	6
	Count - less than			6	6	3		6	6		6	6		6	6
9i	Average	1.192		<10	<10	1.936		<0.05	<0.1		<0.05	<1		<10	<10
	Minimum	<1		<10	<10	0.782		<0.05	<0.1		<0.05	<1		<10	<10
	Maximum	36.000		<10	<10	3.240		<0.05	<0.1		<0.05	<1		<10	<10
	Count	250		4	4	4		4	4		4	4		4	4
	Count - less than	225		4	4	0		4	4		4	4		4	4
9ii	Average			<10	<10	0.685		<0.05	<0.1		<0.05	<1		<10	<10
	Minimum			<10	<10	0.580		<0.05	<0.1		<0.05	<1		<10	<10
	Maximum			<10	<10	0.830		<0.05	<0.1		<0.05	<1		<10	<10
	Count			4	4	4		4	4		4	4		4	4
	Count - less than			4	4	0		4	4		4	4		4	4
9iii	Average	7.109		<10	<10	0.873		<0.05	<0.1		<0.05	<1		<10	<10
	Minimum	<1		<10	<10	0.627		<0.05	<0.1		<0.05	<1		<10	<10
	Maximum	547.500		<10	<10	1.120		<0.05	<0.1		<0.05	<1		<10	<10
	Count	92		4	4	4		4	4		4	4		4	4
	Count - less than	72		4	4	0		4	4		4	4		4	4
10i	Average	69.516	0.000	<10	<10	0.676	<10	<0.05	<0.1		<0.05	<0.1	<6000	<10	<10
	Minimum	<1	0.000	<10	<10	<0.66	<10	<0.05	<0.1		<0.05	<0.1	<6000	<10	<10
	Maximum	900.000	0.000	<10	<10	1.000	<10	<0.05	<0.1		<0.05	<0.1	<6000	<10	<10
	Count	310	1	18	22	35	4	27	27		27	27	1	22	22
	Count - less than	31	0	18	22	2	4	27	27		27	27	1	22	22
11i	Average			<10	<10	2.263		<0.05	<0.5		<0.05	<1		<10	<10
	Minimum			<10	<10	1.570		<0.05	<0.5		<0.05	<1		<10	<10
	Maximum			<10	<10	3.510		<0.05	<0.5		<0.05	<1		<10	<10
	Count			3	3	3		3	3		3	3		3	3
	Count - less than			3	3	0		3	3		3	3		3	3
11ii	Average			<10	<10	0.768		<0.05	<0.1		<0.05	<1		<10	<10
	Minimum			<10	<10	0.510		<0.05	<0.1		<0.05	<1		<10	<10
	Maximum			<10	<10	1.090		<0.05	<0.1		<0.05	<1		<10	<10
	Count			6	6	6		6	6		6	6		6	6
	Count - less than			6	6	0		6	6		6	6		6	6
11iii	Average			<10	<10	0.750		<0.05	<0.1		<0.05	<1		<10	<10
	Minimum			<10	<10	0.560		<0.05	<0.1		<0.05	<1		<10	<10
	Maximum			<10	<10	1.090		<0.05	<0.1		<0.05	<1		<10	<10
	Count			6	6	6		6	6		6	6		6	6
	Count - less than			6	6	0		6	6		6	6		6	6

Notes:
1) For parameters with sampling data both less than and greater than the detection value, values that are less than the detection value are included in the analysis as one-half the detection value.
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Sponsor/Reclaimed Water Source	Calculation Type	Hexachlorocyclopentadiene µg/L	Hexachloroethane µg/L	Hexachlorophene µg/L	Indeno(1,2,3-cd)pyrene µg/L	Iron mg/L	Isophorone µg/L	Lead mg/L	Magnesium mg/L	Malathion µg/L	Manganese µg/L	Mercury µg/L	meta-Chlorophenylpiperazine µg/L	Methoxychlor µg/L
1i	Average	<10	<20	<20	<20		<10			<0.1				<2
	Minimum	<10	<20	<20	<20		<10			<0.1				<2
	Maximum	<10	<20	<20	<20		<10			<0.1				<2
	Count	3	3	3	3		3			3				3
	Count - less than	3	3	3	3		3			3				3
3i	Average	<10	<20	<10	<20		<10	0.003		<0.1		<0.2		<2
	Minimum	<10	<20	<10	<20		<10	0.003		<0.1		<0.2		<2
	Maximum	<10	<20	<10	<20		<10	0.003		<0.1		<0.2		<2
	Count	1	1	1	1		1	1		1		1		1
	Count - less than	1	1	1	1		1	0		1		1		1
3ii	Average	<10	<20	<10	<20		<10	0.002		<0.1		<0.2		<2
	Minimum	<10	<20	<10	<20		<10	0.002		<0.1		<0.2		<2
	Maximum	<10	<20	<10	<20		<10	0.002		<0.1		<0.2		<2
	Count	1	1	1	1		1	1		1		1		1
	Count - less than	1	1	1	1		1	0		1		1		1
4i	Average	<10	<20	<10	<20		<10	<0.001		<0.1		<0.2		<2
	Minimum	<10	<20	<10	<20		<10	<0.001		<0.1		<0.2		<2
	Maximum	<10	<20	<10	<20		<10	<0.001		<0.1		<0.2		<2
	Count	6	6	6	6		6	15		6		15		6
	Count - less than	6	6	6	6		6	15		6		15		6
4ii	Average	<10	<20	<10	<20		<10							<2
	Minimum	<10	<20	<10	<20		<10							<2
	Maximum	<10	<20	<10	<20		<10							<2
	Count	1	1	1	1		1							1
	Count - less than	1	1	1	1		1							1
5i	Average	<10	<20	<10	<20		<10			<0.1				<2
	Minimum	<10	<20	<10	<20		<10			<0.1				<2
	Maximum	<10	<20	<10	<20		<10			<0.1				<2
	Count	6	6	6	6		6			6				6
	Count - less than	6	6	6	6		6			6				6
5ii	Average	<10	<20	<10	<20		<10			<0.1				<2
	Minimum	<10	<20	<10	<20		<10			<0.1				<2
	Maximum	<10	<20	<10	<20		<10			<0.1				<2
	Count	6	6	6	6		6			6				6
	Count - less than	6	6	6	6		6			6				6
6i	Average	<10	<10	<10	<10	0.090	<10		16.749	<0.05			<100	<0.05
	Minimum	<10	<10	<10	<10	0.000	<10		14.400	<0.05			<100	<0.05
	Maximum	<10	<10	<10	<10	0.180	<10		19.000	<0.05			<100	<0.05
	Count	6	6	6	6	70	6		70	6			6	6
	Count - less than	6	6	6	6	0	6		0	6			6	6
7i	Average	<5	<5	<10	<5		<5		13.088	<0.1				<0.2
	Minimum	<5	<5	<10	<5		<5		8.900	<0.1				<0.2
	Maximum	<5	<5	<10	<5		<5		16.700	<0.1				<0.2
	Count	6	6	6	6		6		154	6				6
	Count - less than	6	6	6	6		6		0	6				6
7ii	Average	<5	<5	<10	<5		<5		11.751	<0.1				<0.2
	Minimum	<5	<5	<10	<5		<5		7.700	<0.1				<0.2
	Maximum	<5	<5	<10	<5		<5		16.900	<0.1				<0.2
	Count	6	6	6	6		6		155	6				6
	Count - less than	6	6	6	6		6		0	6				6

Notes:
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Sponsor/Reclaimed Water Source	Calculation Type	Hexachlorocyclopentadiene µg/L	Hexachloroethane µg/L	Hexachlorophene µg/L	Indeno(1,2,3-cd)pyrene µg/L	Iron mg/L	Isophorone µg/L	Lead mg/L	Magnesium mg/L	Malathion µg/L	Manganese µg/L	Mercury µg/L	meta-Chlorophenylpiperazine µg/L	Methoxychlor µg/L
7iii	Average	<5	<5	<10	<5		<5		15.706	<0.1				<0.2
	Minimum	<5	<5	<10	<5		<5		7.900	<0.1				<0.2
	Maximum	<5	<5	<10	<5		<5		19.200	<0.1				<0.2
	Count	6	6	6	6		6		154	6				6
	Count - less than	6	6	6	6		6		0	6				6
8i	Average	<10	<20	<10	<20		<10			<0.1				<2
	Minimum	<10	<20	<10	<20		<10			<0.1				<2
	Maximum	<10	<20	<10	<20		<10			<0.1				<2
	Count	6	6	6	6		6			6				6
	Count - less than	6	6	6	6		6			6				6
9i	Average	<10	<20	<10	<20		<10			<0.1				<2
	Minimum	<10	<20	<10	<20		<10			<0.1				<2
	Maximum	<10	<20	<10	<20		<10			<0.1				<2
	Count	4	4	4	4		4			4				4
	Count - less than	4	4	4	4		4			4				4
9ii	Average	<10	<20	<10	<20		<10			<0.1				<2
	Minimum	<10	<20	<10	<20		<10			<0.1				<2
	Maximum	<10	<20	<10	<20		<10			<0.1				<2
	Count	4	4	4	4		4			4				4
	Count - less than	4	4	4	4		4			4				4
9iii	Average	<10	<20	<10	<20		<10			<0.1				<2
	Minimum	<10	<20	<10	<20		<10			<0.1				<2
	Maximum	<10	<20	<10	<20		<10			<0.1				<2
	Count	4	4	4	4		4			4				4
	Count - less than	4	4	4	4		4			4				4
10i	Average	<10	<20	31.325	<20	0.095	<10	<0.005		<0.05	14.481			<1
	Minimum	<10	<20	<9.5	<20	<0.075	<10	<0.005		<0.05	3.000			<1
	Maximum	<10	<20	100.000	<20	0.487	<10	<0.005		<0.05	47.000			<1
	Count	22	25	18	25	64	22	151		98	27			23
	Count - less than	22	25	20	25	11	22	151		98	0			23
11i	Average	<10	<20	<10	<20		<10	<0.005		<0.5		<0.2		<2
	Minimum	<10	<20	<10	<20		<10	<0.005		<0.5		<0.2		<2
	Maximum	<10	<20	<10	<20		<10	<0.005		<0.5		<0.2		<2
	Count	3	3	3	3		3	11		3		11		3
	Count - less than	3	3	3	3		3	11		3		11		3
11ii	Average	<10	<20	<10	<20		<10	<0.005		<0.5		<0.2		<2
	Minimum	<10	<20	<10	<20		<10	<0.005		<0.5		<0.2		<2
	Maximum	<10	<20	<10	<20		<10	<0.005		<0.5		<0.2		<2
	Count	6	6	6	6		6	11		6		11		6
	Count - less than	6	6	6	6		6	11		6		11		6
11iii	Average	<10	<20	<10	<20		<10	<0.005		<0.1		<2		<2
	Minimum	<10	<20	<10	<20		<10	<0.005		<0.1		<2		<2
	Maximum	<10	<20	<10	<20		<10	<0.005		<0.1		<2		<2
	Count	6	6	6	6		6	17		6		17		6
	Count - less than	6	6	6	6		6	17		6		17		6

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Sponsor/Reclaimed Water Source	Calculation Type	Methyl Parathion µg/L	MethylBromide µg/L	MethylChloride µg/L	MethyleneChloride µg/L	MethylEthylKetone µg/L	Mirex µg/L	Molybdenum µg/L	Naphthalene µg/L	Nickel mg/L	Nitrate mg/L	Nitrite mg/L	Nitrite+Nitrate mg/L	Nitrobenzene µg/L	Nitrogen(N2) mg/L
1i	Average		<20	<20	<20	<50	<0.02		<10		8.532	0.875		<10	11.704
	Minimum		<20	<20	<20	<50	<0.02		<10		<0.136	0.068		<10	4.758
	Maximum		<20	<20	<20	<50	<0.02		<10		14.720	4.308		<10	28.601
	Count		2	2	2	3	3		3		107	103		3	104
	Count - less than		2	2	2	3	3		3		2	0		3	0
3i	Average		<5	<5	<5	<50	<0.2		<10	<0.001	6.050			<10	
	Minimum		<5	<5	<5	<50	<0.2		<10	<0.001	4.200			<10	
	Maximum		<5	<5	<5	<50	<0.2		<10	<0.001	7.900			<10	
	Count		1	1	1	1	1		1	1	2			1	
	Count - less than		1	1	1	1	1		1	1	0			1	
3ii	Average		<5	<5	<5	<50	<0.2		<10	<0.001	5.850			<10	
	Minimum		<5	<5	<5	<50	<0.2		<10	<0.001	5.400			<10	
	Maximum		<5	<5	<5	<50	<0.2		<10	<0.001	6.300			<10	
	Count		1	1	1	1	1		1	1	2			1	
	Count - less than		1	1	1	1	1		1	1	0			1	
4i	Average		<50	<50	<20	<50	<0.2	4.775	<10	0.008	14.927			<10	
	Minimum		<50	<50	<20	<50	<0.2	3.400	<10	0.006	12.490			<10	
	Maximum		<50	<50	<20	<50	<0.2	8.900	<10	0.014	17.640			<10	
	Count		6	6	6	6	6	12	6	15	6			6	
	Count - less than		6	6	6	6	6	0	6	0	0			6	
4ii	Average		<50	<50	<20	<50	<0.2	10.000	<10		2.730			<10	
	Minimum		<50	<50	<20	<50	<0.2	10.000	<10		2.730			<10	
	Maximum		<50	<50	<20	<50	<0.2	10.000	<10		2.730			<10	
	Count		1	1	1	1	1	1	1		1			1	
	Count - less than		1	1	1	1	1	0	1		0			1	
5i	Average		<50	<50	<20	<50	<0.2		<10		15.300			<10	
	Minimum		<50	<50	<20	<50	<0.2		<10		7.700			<10	
	Maximum		<50	<50	<20	<50	<0.2		<10		24.700			<10	
	Count		6	6	6	6	6		6		7			6	
	Count - less than		6	6	6	6	6		6		0			6	
5ii	Average		<50	<50	<20	<50	<0.2		<10		10.349			<10	
	Minimum		<50	<50	<20	<50	<0.2		<10		2.700			<10	
	Maximum		<50	<50	<20	<50	<0.2		<10		20.500			<10	
	Count		6	6	6	6	6		6		7			6	
	Count - less than		6	6	6	6	6		6		0			6	
6i	Average		<5	<5	<5	<50	<0.05		<10		19.117	0.232	19.188	<10	
	Minimum		<5	<5	<5	<50	<0.05		<10		14.300	0.000	15.200	<10	
	Maximum		<5	<5	<5	<50	<0.05		<10		22.000	1.240	25.160	<10	
	Count		6	6	6	6	6		6		18	72	72	6	
	Count - less than		6	6	6	6	6		6		0	0	0	6	
7i	Average		<5	<5	<5	<25	<0.2		<5		10.714	0.120		<5	
	Minimum		<5	<5	<5	<25	<0.2		<5		<0.1	<0.05		<5	
	Maximum		<5	<5	<5	<25	<0.2		<5		16.000	0.250		<5	
	Count		6	6	6	6	6		6		158	153		6	
	Count - less than		6	6	6	6	6		6		5	147		6	
7ii	Average		<5	<5	<5	<25	<0.2		<5		11.563	0.177		<5	
	Minimum		<5	<5	<5	<25	<0.2		<5		<0.5	<0.05		<5	
	Maximum		<5	<5	<5	<25	<0.2		<5		22.400	1.860		<5	
	Count		6	6	6	6	6		6		161	155		6	
	Count - less than		6	6	6	6	6		6		4	133		6	

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Sponsor/Reclaimed Water Source	Calculation Type	Methyl Parathion µg/L	MethylBromide µg/L	MethylChloride µg/L	MethyleneChloride µg/L	MethylEthylKetone µg/L	Mirex µg/L	Molybdenum µg/L	Naphthalene µg/L	Nickel mg/L	Nitrate mg/L	Nitrite mg/L	Nitrite+Nitrate mg/L	Nitrobenzene µg/L	Nitrogen(N2) mg/L
7iii	Average		<5	<5	1.600	<25	<0.2		<5		14.072	0.834		<5	
	Minimum		<5	<5	<1	<25	<0.2		<5		<0.1	<0.05		<5	
	Maximum		<5	<5	2.500	<25	<0.2		<5		28.200	11.600		<5	
	Count		6	6	6	6	6		6		159	153		6	
	Count - less than		6	6	5	6	6		6		4	74		6	
8i	Average		<50	<50	<20	<50	<0.2		<10		7.790			<10	
	Minimum		<50	<50	<20	<50	<0.2		<10		1.120			<10	
	Maximum		<50	<50	<20	<50	<0.2		<10		10.700			<10	
	Count		6	6	6	6	6		6		6			6	
	Count - less than		6	6	6	6	6		6		0			6	
9i	Average		<50	<50	<20	<50	<0.2		<10		9.086			<10	
	Minimum		<50	<50	<20	<50	<0.2		<10		<0.05			<10	
	Maximum		<50	<50	<20	<50	<0.2		<10		15.300			<10	
	Count		4	4	4	4	4		4		4			4	
	Count - less than		4	4	4	4	4		4		1			4	
9ii	Average		<50	<50	<20	<50	<0.2		<10		9.880			<10	
	Minimum		<50	<50	<20	<50	<0.2		<10		7.440			<10	
	Maximum		<50	<50	<20	<50	<0.2		<10		11.200			<10	
	Count		4	4	4	4	4		4		4			4	
	Count - less than		4	4	4	4	4		4		0			4	
9iii	Average		<50	<50	<20	<50	<0.2		<10		10.245			<10	
	Minimum		<50	<50	<20	<50	<0.2		<10		9.380			<10	
	Maximum		<50	<50	<20	<50	<0.2		<10		11.000			<10	
	Count		4	4	4	4	4		4		4			4	
	Count - less than		4	4	4	4	4		4		0			4	
10i	Average	0.051	<10	<5	<5	<5	<2	4.059	<10	0.004	16.736	0.080	13.534	<10	
	Minimum	<0.1	<10	<5	<5	<5	<2	<5	<10	<0.005	<0.0001	<0.005	2.850	<10	
	Maximum	0.106	<10	<5	<5	<5	<2	8.000	<10	0.029	43.400	3.530	21.400	<10	
	Count	71	26	26	26	23	23	152	22	153	263	237	76	22	
	Count - less than	70	26	26	26	23	23	102	22	111	1	116	0	22	
11i	Average		<20	<50	<20	<50	<0.2		<10	0.006	8.503			<10	
	Minimum		<20	<50	<20	<50	<0.2		<10	<0.01	2.710			<10	
	Maximum		<20	<50	<20	<50	<0.2		<10	0.018	11.600			<10	
	Count		3	3	3	3	3		3	11	3			3	
	Count - less than		3	3	3	3	3		3	10	0			3	
11ii	Average		<20	<50	<20	<50	<0.2		<10	0.006	34.490			<10	
	Minimum		<20	<50	<20	<50	<0.2		<10	<0.01	5.930			<10	
	Maximum		<20	<50	<20	<50	<0.2		<10	0.014	149.000			<10	
	Count		6	6	6	6	6		6	11	6			6	
	Count - less than		6	6	6	6	6		6	9	0			6	
11iii	Average		<20	<50	<20	<50	<0.2		<10	0.007	12.057			<10	
	Minimum		<20	<50	<20	<50	<0.2		<10	<0.01	7.480			<10	
	Maximum		<20	<50	<20	<50	<0.2		<10	0.012	16.400			<10	
	Count		6	6	6	6	6		6	17	6			6	
	Count - less than		6	6	6	6	6		6	12	0			6	

Notes:
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3) Metals are listed as total or dissolved when specified. When not specified by sponsor, metals are included in table, but not specified.

Sponsor/Reclaimed Water Source	Calculation Type	n-Nitrosodiethylamine µg/L	n-Nitrosodimethylamine µg/L	N-Nitroso-di-n-Butylamine µg/L	n-Nitrosodi-n-propylamine µg/L	n-Nitrosodiphenylamine µg/L	Orthophosphate mg/L	Outfall ??	Parathion µg/L	Parathionethyl µg/L	PCB 1016 µg/L	PCB 1221 µg/L
1i	Average	<20	<50	<20	<20	<20		0.019	<0.1			
	Minimum	<20	<50	<20	<20	<20		0.010	<0.1			
	Maximum	<20	<50	<20	<20	<20		0.070	<0.1			
	Count	3	3	3	3	3		486	3			
	Count - less than	3	3	3	3	3		0	3			
3i	Average	<20	<50	<20	<20	<20				<0.05	<1	<1
	Minimum	<20	<50	<20	<20	<20				<0.05	<1	<1
	Maximum	<20	<50	<20	<20	<20				<0.05	<1	<1
	Count	1	1	1	1	1				1	1	1
	Count - less than	1	1	1	1	1				1	1	1
3ii	Average	<20	<50	<20	<20	<20				<0.05	<1	<1
	Minimum	<20	<50	<20	<20	<20				<0.05	<1	<1
	Maximum	<20	<50	<20	<20	<20				<0.05	<1	<1
	Count	1	1	1	1	1				1	1	1
	Count - less than	1	1	1	1	1				1	1	1
4i	Average	<20	<50	<20	<20	<20			<0.1			
	Minimum	<20	<50	<20	<20	<20			<0.1			
	Maximum	<20	<50	<20	<20	<20			<0.1			
	Count	6	6	6	6	6			6			
	Count - less than	6	6	6	6	6			6			
4ii	Average	<20	<20	<20	<20	<20						
	Minimum	<20	<20	<20	<20	<20						
	Maximum	<20	<20	<20	<20	<20						
	Count	1	1	1	1	1						
	Count - less than	1	1	1	1	1						
5i	Average	<20	<50	<20	<20	<20			<0.1			
	Minimum	<20	<50	<20	<20	<20			<0.1			
	Maximum	<20	<50	<20	<20	<20			<0.1			
	Count	6	6	6	6	6			6			
	Count - less than	6	6	6	6	6			6			
5ii	Average	<20	<50	<20	<20	<20			<0.1			
	Minimum	<20	<50	<20	<20	<20			<0.1			
	Maximum	<20	<50	<20	<20	<20			<0.1			
	Count	6	6	6	6	6			6			
	Count - less than	6	6	6	6	6			6			
6i	Average	<10	<10	<10	<10	<10			<0.05			
	Minimum	<10	<10	<10	<10	<10			<0.05			
	Maximum	<10	<10	<10	<10	<10			<0.05			
	Count	6	6	6	6	6			6			
	Count - less than	6	6	6	6	6			6			
7i	Average	<20	<10	<20	<5	<5	2.149		<0.1			
	Minimum	<20	<10	<20	<5	<5	<0.05		<0.1			
	Maximum	<20	<10	<20	<5	<5	6.240		<0.1			
	Count	6	6	6	6	6	153		6			
	Count - less than	6	6	6	6	6	6		6			
7ii	Average	<20	<10	<20	<5	<5	1.428		<0.1			
	Minimum	<20	<10	<20	<5	<5	<0.2		<0.1			
	Maximum	<20	<10	<20	<5	<5	5.380		<0.1			
	Count	6	6	6	6	6	155		6			
	Count - less than	6	6	6	6	6	14		6			

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Sponsor/Reclaimed Water Source	Calculation Type	n-Nitrosodiethylamine µg/L	n-Nitrosodimethylamine µg/L	N-Nitroso-di-n-Butylamine µg/L	n-Nitrosodi-n-propylamine µg/L	n-Nitrosodiphenylamine µg/L	Orthophosphate mg/L	Outfall ??	Parathion µg/L	Parathionethyl µg/L	PCB 1016 µg/L	PCB 1221 µg/L
7iii	Average	<20	<10	<20	<10	<5	2.997		<0.1			
	Minimum	<20	<10	<20	<10	<5	<0.05		<0.1			
	Maximum	<20	<10	<20	<10	<5	6.000		<0.1			
	Count	6	6	6	6	6	153		6			
	Count - less than	6	6	6	6	6	2		6			
8i	Average	<20	<20	<20	<20	<20			<0.1			
	Minimum	<20	<20	<20	<20	<20			<0.1			
	Maximum	<20	<20	<20	<20	<20			<0.1			
	Count	6	6	6	6	6			6			
	Count - less than	6	6	6	6	6			6			
9i	Average	<20	<50	<20	<20	<20			<0.1			
	Minimum	<20	<50	<20	<20	<20			<0.1			
	Maximum	<20	<50	<20	<20	<20			<0.1			
	Count	4	4	4	4	4			4			
	Count - less than	4	4	4	4	4			4			
9ii	Average	<20	<50	<20	<20	<20			<0.1			
	Minimum	<20	<50	<20	<20	<20			<0.1			
	Maximum	<20	<50	<20	<20	<20			<0.1			
	Count	4	4	4	4	4			4			
	Count - less than	4	4	4	4	4			4			
9iii	Average	<20	<50	<20	<20	<20			<0.1			
	Minimum	<20	<50	<20	<20	<20			<0.1			
	Maximum	<20	<50	<20	<20	<20			<0.1			
	Count	4	4	4	4	4			4			
	Count - less than	4	4	4	4	4			4			
10i	Average	<20	<40	<20	<20	<20	1.752		<0.1	<0.1		
	Minimum	<20	<40	<20	<20	<20	0.510		<0.1	<0.1		
	Maximum	<20	<40	<20	<20	<20	2.720		<0.1	<0.1		
	Count	22	26	22	25	25	43		7	16		
	Count - less than	22	26	22	25	25	0		7	16		
11i	Average	<20	<50	<20	<20	<20			<0.1			
	Minimum	<20	<50	<20	<20	<20			<0.1			
	Maximum	<20	<50	<20	<20	<20			<0.1			
	Count	3	3	3	3	3			3			
	Count - less than	3	3	3	3	3			3			
11ii	Average	<20	<50	<20	<20	<20			<0.1			
	Minimum	<20	<50	<20	<20	<20			<0.1			
	Maximum	<20	<50	<20	<20	<20			<0.1			
	Count	6	6	6	6	6			6			
	Count - less than	6	6	6	6	6			6			
11iii	Average	<20	<50	<20	<20	<20			<10			
	Minimum	<20	<50	<20	<20	<20			<10			
	Maximum	<20	<50	<20	<20	<20			<10			
	Count	6	6	6	6	6			6			
	Count - less than	6	6	6	6	6			6			

Notes:
1) For parameters with sampling data both less than and greater than the detection value, values that are less than the detection value are included in the analysis as one-half the detection value.
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Sponsor/Reclaimed Water Source	Calculation Type	PCB 1232 µg/L	PCB 1242 µg/L	PCB 1248 µg/L	PCB 1254 µg/L	PCB 1260 µg/L	PCB-1016 µg/L	PCB-1221 µg/L	PCB-1232 µg/L	PCB-1242 µg/L	PCB-1248 µg/L	PCB-1254 µg/L	PCB-1260 µg/L	P-Chloro-m-Cresol µg/L	Pentachlorobenzene µg/L	Pentachlorophenol µg/L	pH StandardUnits
1i	Average						<1	<1	<1	<1	<1	<1	<1		<20	<50	7.671
	Minimum						<1	<1	<1	<1	<1	<1	<1		<20	<50	6.900
	Maximum						<1	<1	<1	<1	<1	<1	<1		<20	<50	7.950
	Count						4	4	4	4	4	4	4		3	3	731
	Count - less than						4	4	4	4	4	4	4		3	3	0
3i	Average	<1	<1	<1	<1	<1								<10	<20	<1	7.800
	Minimum	<1	<1	<1	<1	<1								<10	<20	<1	7.800
	Maximum	<1	<1	<1	<1	<1								<10	<20	<1	7.800
	Count	1	1	1	1	1								1	1	1	1
	Count - less than	1	1	1	1	1								1	1	1	0
3ii	Average	<1	<1	<1	<1	<1								<10	<20	<1	8.200
	Minimum	<1	<1	<1	<1	<1								<10	<20	<1	8.200
	Maximum	<1	<1	<1	<1	<1								<10	<20	<1	8.200
	Count	1	1	1	1	1								1	1	1	1
	Count - less than	1	1	1	1	1								1	1	1	0
4i	Average						<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<10	<20	<50	
	Minimum						<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<10	<20	<50	
	Maximum						<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<10	<20	<50	
	Count						6	6	6	6	6	6	6	6	6	6	
	Count - less than						6	6	6	6	6	6	6	6	6	6	
4ii	Average						<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<10	<20	<50	
	Minimum						<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<10	<20	<50	
	Maximum						<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<10	<20	<50	
	Count						1	1	1	1	1	1	1	1	1	1	
	Count - less than						1	1	1	1	1	1	1	1	1	1	
5i	Average						<1	<1	<1	<1	<1	<1	<1	<10	<20	<50	
	Minimum						<1	<1	<1	<1	<1	<1	<1	<10	<20	<50	
	Maximum						<1	<1	<1	<1	<1	<1	<1	<10	<20	<50	
	Count						6	6	6	6	6	6	6	6	6	6	
	Count - less than						6	6	6	6	6	6	6	6	6	6	
5ii	Average						<1	<1	<1	<1	<1	<1	<1	<10	<20	<50	
	Minimum						<1	<1	<1	<1	<1	<1	<1	<10	<20	<50	
	Maximum						<1	<1	<1	<1	<1	<1	<1	<10	<20	<50	
	Count						6	6	6	6	6	6	6	6	6	6	
	Count - less than						6	6	6	6	6	6	6	6	6	6	
6i	Average						<0.25	<0.5	<0.5	<0.25	<0.25	<0.25	<0.25	<10	<10	<10	
	Minimum						<0.25	<0.5	<0.5	<0.25	<0.25	<0.25	<0.25	<10	<10	<10	
	Maximum						<0.25	<0.5	<0.5	<0.25	<0.25	<0.25	<0.25	<10	<10	<10	
	Count						6	6	6	6	6	6	6	6	6	6	
	Count - less than						6	6	6	6	6	6	6	6	6	6	
7i	Average						<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<5	<20	<15	6.812
	Minimum						<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<5	<20	<15	6.200
	Maximum						<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<5	<20	<15	7.800
	Count						6	6	6	6	6	6	6	7	6	6	66
	Count - less than						6	6	6	6	6	6	6	7	6	6	0
7ii	Average						<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<5	<20	<15	7.258
	Minimum						<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<5	<20	<15	6.900
	Maximum						<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<5	<20	<15	7.500
	Count						6	6	6	6	6	6	6	8	6	6	36
	Count - less than						6	6	6	6	6	6	6	8	6	6	0

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Sponsor/Reclaimed Water Source	Calculation Type	PCB 1232 µg/L	PCB 1242 µg/L	PCB 1248 µg/L	PCB 1254 µg/L	PCB 1260 µg/L	PCB-1016 µg/L	PCB-1221 µg/L	PCB-1232 µg/L	PCB-1242 µg/L	PCB-1248 µg/L	PCB-1254 µg/L	PCB-1260 µg/L	P-Chloro-m-Cresol µg/L	Pentachlorobenzene µg/L	Pentachlorophenol µg/L	pH StandardUnits
7iii	Average						<1	<1	<1	<1	<0.5	<0.5	<0.5	<5	<20	<15	6.811
	Minimum						<1	<1	<1	<1	<0.5	<0.5	<0.5	<5	<20	<15	6.600
	Maximum						<1	<1	<1	<1	<0.5	<0.5	<0.5	<5	<20	<15	7.000
	Count						6	6	6	6	6	6	6	7	6	6	36
	Count - less than						6	6	6	6	6	6	6	7	6	6	0
8i	Average						<1	<1	<1	<1	<1	<1	<1	<10	<20	<50	
	Minimum						<1	<1	<1	<1	<1	<1	<1	<10	<20	<50	
	Maximum						<1	<1	<1	<1	<1	<1	<1	<10	<20	<50	
	Count						6	6	6	6	6	6	6	6	6	6	
	Count - less than						6	6	6	6	6	6	6	6	6	6	
9i	Average						<1	<1	<1	<1	<1	<1	<1	<10	<20	<50	
	Minimum						<1	<1	<1	<1	<1	<1	<1	<10	<20	<50	
	Maximum						<1	<1	<1	<1	<1	<1	<1	<10	<20	<50	
	Count						4	4	4	4	4	4	4	4	4	4	
	Count - less than						4	4	4	4	4	4	4	4	4	4	
9ii	Average						<1	<1	<1	<1	<1	<1	<1	<10	<20	<50	
	Minimum						<1	<1	<1	<1	<1	<1	<1	<10	<20	<50	
	Maximum						<1	<1	<1	<1	<1	<1	<1	<10	<20	<50	
	Count						4	4	4	4	4	4	4	4	4	4	
	Count - less than						4	4	4	4	4	4	4	4	4	4	
9iii	Average						<1	<1	<1	<1	<1	<1	<1	<10	<20	<50	
	Minimum						<1	<1	<1	<1	<1	<1	<1	<10	<20	<50	
	Maximum						<1	<1	<1	<1	<1	<1	<1	<10	<20	<50	
	Count						4	4	4	4	4	4	4	4	4	4	
	Count - less than						4	4	4	4	4	4	4	4	4	4	
10i	Average						<1	<1	<1	<1	<1	<1	<1	<10	<20	<40	7.313
	Minimum						<1	<1	<1	<1	<1	<1	<1	<10	<20	<40	6.700
	Maximum						<1	<1	<1	<1	<1	<1	<1	<10	<20	<40	7.920
	Count						27	27	27	27	27	27	27	22	22	26	784
	Count - less than						27	27	27	27	27	27	27	22	22	26	0
11i	Average						<1	<1	<1	<1	<1	<1	<1	<10	<20	<50	
	Minimum						<1	<1	<1	<1	<1	<1	<1	<10	<20	<50	
	Maximum						<1	<1	<1	<1	<1	<1	<1	<10	<20	<50	
	Count						3	3	3	3	3	3	3	3	3	3	
	Count - less than						3	3	3	3	3	3	3	3	3	3	
11ii	Average						<1	<1	<1	<1	<1	<1	<1	<10	<20	<50	
	Minimum						<1	<1	<1	<1	<1	<1	<1	<10	<20	<50	
	Maximum						<1	<1	<1	<1	<1	<1	<1	<10	<20	<50	
	Count						6	6	6	6	6	6	6	6	6	6	
	Count - less than						6	6	6	6	6	6	6	6	6	6	
11iii	Average						<1	<1	<1	<1	<1	<1	<1	<10	<20	<50	
	Minimum						<1	<1	<1	<1	<1	<1	<1	<10	<20	<50	
	Maximum						<1	<1	<1	<1	<1	<1	<1	<10	<20	<50	
	Count						6	6	6	6	6	6	6	6	6	6	
	Count - less than						6	6	6	6	6	6	6	6	6	6	

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1) For parameters with sampling data both less than and greater than the detection value, values that are less than the detection value are included in the analysis as one-half the detection value.
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Sponsor/Reclaimed Water Source	Calculation Type	Phenanthrene µg/L	Phenols µg/L	Phosphate mg/L	Potassium mg/L	Pyrene µg/L	Pyridine µg/L	Selenium mg/L	Settleable Solids ml/L	Silica mg/L	Silver mg/L	Sodium mg/L	SodiumAdsorptionRatio 0	Sulfate mg/L	Temperature ºC	Tetrachloroethylene µg/L	Thallium mg/L
	Average	<10	4.773			<10	<20									<10	
	Minimum	<10	<5			<10	<20									<10	
1i	Maximum	<10	9.000			<10	<20									<10	
	Count	3	11			3	3									2	
	Count - less than	3	8			3	3									2	
	Average	<10	<10			<10	<20	<0.01			<0.0005			184.000		<5	<0.01
	Minimum	<10	<10			<10	<20	<0.01			<0.0005			184.000		<5	<0.01
3i	Maximum	<10	<10			<10	<20	<0.01			<0.0005			184.000		<5	<0.01
	Count	1	1			1	1	1			1			1		1	1
	Count - less than	1	1			1	1	1			1			0		1	1
	Average	<10	<10			<10	<20	<0.01			<0.0005			163.000		<5	<0.01
	Minimum	<10	<10			<10	<20	<0.01			<0.0005			163.000		<5	<0.01
3ii	Maximum	<10	<10			<10	<20	<0.01			<0.0005			163.000		<5	<0.01
	Count	1	1			1	1	1			1			1		1	1
	Count - less than	1	1			1	1	1			1			0		1	1
	Average	<10	4.286			<10	<20	<0.005			<0.001					<10	<0.002
	Minimum	<10	<5			<10	<20	<0.005			<0.001					<10	<0.002
4i	Maximum	<10	15.000			<10	<20	<0.005			<0.001					<10	<0.002
	Count	6	21			6	6	15			15					6	15
	Count - less than	6	20			6	6	15			15					6	15
	Average	<10	<10	1.000		<10	<20							67.100		<10	
	Minimum	<10	<10	0.090		<10	<20							67.100		<10	
4ii	Maximum	<10	<10	2.660		<10	<20							67.100		<10	
	Count	1	2	36		1	1							1		1	
	Count - less than	1	2	0		1	1							0		1	
	Average	<10	6.667			<10	<20									<10	
	Minimum	<10	<10			<10	<20									<10	
5i	Maximum	<10	10.000			<10	<20									<10	
	Count	6	6			6	6									6	
	Count - less than	6	4			6	6									6	
	Average	<10	5.833			<10	<20									<10	
	Minimum	<10	<10			<10	<20									<10	
5ii	Maximum	<10	10.000			<10	<20									<10	
	Count	6	6			6	6									6	
	Count - less than	6	5			6	6									6	
	Average	<10	5.500		14.627	<10	<10					98.543	2.532	64.194		<5	
	Minimum	<10	<5		10.600	<10	<10					72.000	1.860	56.000		<5	
6i	Maximum	<10	21.500		17.000	<10	<10					108.000	3.000	80.000		<5	
	Count	6	24		70	6	6					70	70	72		6	
	Count - less than	6	21		0	6	6					0	0	0		6	
	Average	<5	<5		17.246	<5	<20			32.134		212.052		170.152		<5	
	Minimum	<5	<5		7.800	<5	<20			17.500		127.000		66.000		<5	
7i	Maximum	<5	<5		21.200	<5	<20			47.800		257.000		291.000		<5	
	Count	6	6		154	6	6			154		154		154		6	
	Count - less than	6	6		0	6	6			0		0		0		6	
	Average	<5	<5		12.461	<5	<20			36.957		326.871		335.659	24.500	<5	
	Minimum	<5	<5		<17.8	<5	<20			22.400		236.000		<5	20.000	<5	
7ii	Maximum	<5	<5		16.800	<5	<20			52.800		456.000		637.000	28.700	<5	
	Count	6	6		155	6	6			155		155		154	36	6	
	Count - less than	6	6		1	6	6			0		0		1	0	6	

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Sponsor/Reclaimed Water Source	Calculation Type	Phenanthrene µg/L	Phenols µg/L	Phosphate mg/L	Potassium mg/L	Pyrene µg/L	Pyridine µg/L	Selenium mg/L	Settleable Solids ml/L	Silica mg/L	Silver mg/L	Sodium mg/L	SodiumAdsorptionRatio 0	Sulfate mg/L	Temperature ºC	Tetrachloroethylene µg/L	Thallium mg/L
7iii	Average	<5	<5		19.816	<5	<20			30.519		260.669		236.010		<5	
	Minimum	<5	<5		<20	<5	<20			13.900		159.000		87.000		<5	
	Maximum	<5	<5		31.300	<5	<20			54.100		345.000		543.000		<5	
	Count	6	6		154	6	6			154		154		154		6	
	Count - less than	6	6		1	6	6			0		0		0		6	
8i	Average	<10	<10			<10	<20									<10	
	Minimum	<10	<10			<10	<20									<10	
	Maximum	<10	<10			<10	<20									<10	
	Count	6	6			6	6									6	
	Count - less than	6	6			6	6									6	
9i	Average	<10	<10	0.787		<10	<20									<10	
	Minimum	<10	<10	0.100		<10	<20									<10	
	Maximum	<10	<10	3.650		<10	<20									<10	
	Count	4	12	1,035		4	4									4	
	Count - less than	4	12	0		4	4									4	
9ii	Average	<10	3.542	0.232		<10	<20									<10	
	Minimum	<10	<5	0.100		<10	<20									<10	
	Maximum	<10	5.000	0.810		<10	<20									<10	
	Count	4	12	31		4	4									4	
	Count - less than	4	11	0		4	4									4	
9iii	Average	<10	3.500	0.247		<10	<20									<10	
	Minimum	<10	<5	0.030		<10	<20									<10	
	Maximum	<10	5.000	2.950		<10	<20									<10	
	Count	4	15	1,035		4	4									4	
	Count - less than	4	13	0		4	4									4	
10i	Average	<10	4.865			<10	<20	<0.005	0.251		<0.002			64.711	21.431	<5	<0.002
	Minimum	<10	<1			<10	<20	<0.005	<0.5		<0.002			<5	20.000	<5	<0.002
	Maximum	<10	11.500			<10	<20	<0.005	0.500		<0.002			137.000	24.900	<5	<0.002
	Count	22	48			21	22	151	430		151			319	67	26	151
	Count - less than	22	46			21	22	151	429		151			1	0	26	151
11i	Average	<10	5.607			<10	<20	<0.01			<0.002					<10	<0.01
	Minimum	<10	<5			<10	<20	<0.01			<0.002					<10	<0.01
	Maximum	<10	11.000			<10	<20	<0.01			<0.002					<10	<0.01
	Count	3	14			3	3	11			11					3	11
	Count - less than	3	10			3	3	11			11					3	11
11ii	Average	<10	5.088			<10	<20	<0.01			<0.002					<10	<0.01
	Minimum	<10	<5			<10	<20	<0.01			<0.002					<10	<0.01
	Maximum	<10	15.000			<10	<20	<0.01			<0.002					<10	<0.01
	Count	6	17			6	6	11			11					6	11
	Count - less than	6	14			6	6	11			11					6	11
11iii	Average	<10	5.761			<10	<20	0.006			<0.002					<10	<0.01
	Minimum	<10	<5			<10	<20	<0.01			<0.002					<10	<0.01
	Maximum	<10	36.000			<10	<20	0.010			<0.002					<10	<0.01
	Count	6	23			6	6	17			17					6	17
	Count - less than	6	19			6	6	15			17					6	17

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Sponsor/Reclaimed Water Source	Calculation Type	Toluene µg/L	TotalAlkalinity mg/L	TotalAluminium mg/L	TotalAntimony mg/L	TotalArsenic mg/L	TotalBarium mg/L	TotalBeryllium mg/L	TotalCadmium mg/L	TotalChromium mg/L	TotalColiform MPN/100mL	TotalCopper mg/L	TotalCyanide mg/L	TotalDissolvedSolids mg/L
1i	Average	<10		0.036	<0.02	0.003	0.072	<0.005	<0.001	0.003		0.009		1,020.962
	Minimum	<10		<0.01	<0.02	<0.002	0.029	<0.005	<0.001	<0.002		<0.004		760.000
	Maximum	<10		0.114	<0.02	0.005	0.144	<0.005	<0.001	0.023		0.079		1,760.000
	Count	3		20	20	20	20	20	20	24		24		104
	Count - less than	3		2	20	14	0	20	20	17		11		0
3i	Average	<5												575.054
	Minimum	<5												530.000
	Maximum	<5												704.000
	Count	1												37
	Count - less than	1												0
3ii	Average	<5												720.000
	Minimum	<5												720.000
	Maximum	<5												720.000
	Count	1												1
	Count - less than	1												0
4i	Average	<10				0.003			<0.001	0.001		0.004		
	Minimum	<10				<0.005			<0.001	<0.001		0.002		
	Maximum	<10				0.006			<0.001	0.002		0.008		
	Count	6				13			13	28		13		
	Count - less than	6				12			13	23		0		
4ii	Average	<10				0.003		<0.003	<0.001	0.001		0.006		564.000
	Minimum	<10				<0.005		<0.003	<0.001	<0.001		0.004		564.000
	Maximum	<10				0.004		<0.003	<0.001	0.002		0.009		564.000
	Count	1				8		1	8	8		8		1
	Count - less than	1				7		1	8	6		0		0
5i	Average	<10			<0.02	<0.01		<0.005	0.001	<0.01		0.032	<0.02	
	Minimum	<10			<0.02	<0.01		<0.005	<0.001	<0.01		<0.01	<0.02	
	Maximum	<10			<0.02	<0.01		<0.005	0.002	<0.01		0.135	<0.02	
	Count	6			18	18		18	19	18		21	6	
	Count - less than	6			18	18		18	18	18		3	6	
5ii	Average	<10			0.013	0.005		<0.005	0.001	<0.01		0.029	<0.02	
	Minimum	<10			<0.02	<0.01		<0.005	<0.001	<0.01		<0.01	<0.02	
	Maximum	<10			0.045	0.013		<0.005	0.002	<0.01		0.091	<0.02	
	Count	6			19	18		18	19	18		21	6	
	Count - less than	6			17	17		18	18	18		2	6	
6i	Average	<5	187.778	0.000	<0.000625	<0.00125		<0.000625	<0.00375	<0.0025		0.012		680.167
	Minimum	<5	158.000	0.000	<0.000625	<0.00125		<0.000625	<0.00375	<0.0025		0.009		611.000
	Maximum	<5	210.000	0.000	<0.000625	<0.00125		<0.000625	<0.00375	<0.0025		0.013		764.000
	Count	6	72	0	18	18		18	18	18		18		72
	Count - less than	6	0	0	18	18		18	18	18		0		0
7i	Average	1.833	126.058		<0.01	0.004		<0.002	<0.001	<0.005		<0.01		865.636
	Minimum	<1	101.000		<0.01	<0.005		<0.002	<0.001	<0.005		<0.01		666.000
	Maximum	2.500	163.000		<0.01	0.008		<0.002	<0.001	<0.005		<0.01		1,090.000
	Count	6	154		12	12		12	12	12		12		154
	Count - less than	5	0		12	7		12	12	12		12		0
7ii	Average	<5	136.206		<0.01	0.005		<0.002	<0.001	<0.005		0.006		1,206.077
	Minimum	<5	97.800		<0.01	<0.005		<0.002	<0.001	<0.005		<0.01		982.000
	Maximum	<5	247.000		<0.01	0.008		<0.002	<0.001	<0.005		0.011		1,450.000
	Count	6	155		12	12		12	12	12		12		155
	Count - less than	6	0		12	5		12	12	12		10		0

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Sponsor/Reclaimed Water Source	Calculation Type	Toluene µg/L	TotalAlkalinity mg/L	TotalAluminium mg/L	TotalAntimony mg/L	TotalArsenic mg/L	TotalBarium mg/L	TotalBeryllium mg/L	TotalCadmium mg/L	TotalChromium mg/L	TotalColiform MPN/100mL	TotalCopper mg/L	TotalCyanide mg/L	TotalDissolvedSolids mg/L
7iii	Average	<5	102.007		<0.01	0.005		<0.002	<0.001	<0.005		0.008		1,053.195
	Minimum	<5	47.600		<0.01	<0.005		<0.002	<0.001	<0.005		<0.01		622.000
	Maximum	<5	265.000		<0.01	0.008		<0.002	<0.001	<0.005		0.016		1,250.000
	Count	6	154		12	12		12	12	12		12		154
	Count - less than	6	0		12	5		12	12	12		8		0
8i	Average	<10			<0.12	0.002		0.001	<0.001	0.001		0.005	<0.02	
	Minimum	<10			<0.12	<0.001		0.000	<0.001	<0.001		<0.00506	<0.02	
	Maximum	<10			<0.12	0.005		0.005	<0.001	0.005		0.009	<0.02	
	Count	6			31	31		31	31	31		31	18	
	Count - less than	6			31	19		0	31	27		6	18	
9i	Average	<10			<0.005	<0.005		<0.001	<0.001	<0.005		0.013		
	Minimum	<10			<0.005	<0.005		<0.001	<0.001	<0.005		0.009		
	Maximum	<10			<0.005	<0.005		<0.001	<0.001	<0.005		0.016		
	Count	4			8	8		8	8	8		8		
	Count - less than	4			8	8		8	8	8		0		
9ii	Average	<10			<0.005	0.004		<0.001	<0.001	<0.005		0.012		
	Minimum	<10			<0.005	<0.005		<0.001	<0.001	<0.005		0.010		
	Maximum	<10			<0.005	0.011		<0.001	<0.001	<0.005		0.015		
	Count	4			7	8		8	8	8		8		
	Count - less than	4			7	7		8	8	8		0		
9iii	Average	<10			<0.005	<0.005		<0.001	<0.001	<0.005		0.010		
	Minimum	<10			<0.005	<0.005		<0.001	<0.001	<0.005		0.003		
	Maximum	<10			<0.005	<0.005		<0.001	<0.001	<0.005		0.054		
	Count	4			11	11		11	11	11		11		
	Count - less than	4			11	11		11	11	11		0		
10i	Average	<5	141.507		<0.005	0.003		<0.004	<0.001	0.003	449.541	0.003		575.521
	Minimum	<5	77.000		<0.005	<0.005		<0.004	<0.001	<0.005	<1	<0.005		109.000
	Maximum	<5	205.000		<0.005	0.006		<0.004	<0.001	0.005	18,500.000	0.006		1,140.000
	Count	26	292		27	27		27	27	27	304	27		746
	Count - less than	26	0		27	25		27	27	26	1	25		0
11i	Average	<10												
	Minimum	<10												
	Maximum	<10												
	Count	3												
	Count - less than	3												
11ii	Average	<10												
	Minimum	<10												
	Maximum	<10												
	Count	6												
	Count - less than	6												
11iii	Average	<10												
	Minimum	<10												
	Maximum	<10												
	Count	6												
	Count - less than	6												

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Sponsor/Reclaimed Water Source	Calculation Type	TotalKjeldahlNitrogen mg/L	TotalLead mg/L	TotalMercury mg/L	TotalMolybdenum mg/L	TotalNickel mg/L	TotalOrganicCarbon mg/L	TotalOrganicNitrogen mg/L	TotalPCBs µg/L	TotalPetroleumHydrocarbons mg/L	TotalPhenols µg/L	TotalPhosphorus mg/L
1i	Average	2.137	0.005	<0.0002	0.013	0.004				1.500		1.951
	Minimum	0.222	<0.001	<0.0002	<0.005	<0.005				1.000		0.074
	Maximum	16.900	0.010	<0.0002	0.017	0.005				3.000		6.300
	Count	104	24	24	24	24				9		104
	Count - less than	0	22	24	17	21				0		0
3i	Average							3.600			<10	1.500
	Minimum							3.600			<10	1.500
	Maximum							3.600			<10	1.500
	Count							1			1	1
	Count - less than							0			1	0
3ii	Average							3.800			<10	0.900
	Minimum							3.800			<10	0.900
	Maximum							3.800			<10	0.900
	Count							1			1	1
	Count - less than							0			1	0
4i	Average		<0.001	<0.0002	0.005	0.008						
	Minimum		<0.001	<0.0002	0.003	0.006						
	Maximum		<0.001	<0.0002	0.009	0.014						
	Count		13	13	13	13						
	Count - less than		13	13	0	0						
4ii	Average		<0.001	0.000	0.007	0.004						0.270
	Minimum		<0.001	<0.000000998	0.007	<0.004						0.270
	Maximum		<0.001	0.000	0.008	0.008						0.270
	Count		8	8	7	8						1
	Count - less than		8	1	0	4						0
5i	Average		0.004	<0.0002		0.005			<1		16.444	
	Minimum		<0.005	<0.0002		<0.01			<1		<10	
	Maximum		0.018	<0.0002		0.012			<1		110.000	
	Count		19	18		18			4		18	
	Count - less than		15	18		17			4		14	
5ii	Average		0.004	<0.0002		0.005			<1		<10	
	Minimum		<0.005	<0.0002		<0.01			<1		<10	
	Maximum		0.027	<0.0002		0.010			<1		<10	
	Count		19	18		18			2		18	
	Count - less than		14	18		17			2		18	
6i	Average	1.879	<0.00125	<0.0002		0.004						1.492
	Minimum	1.000	<0.00125	<0.0002		0.003						0.600
	Maximum	4.360	<0.00125	<0.0002		0.005						2.260
	Count	72	18	18		18						72
	Count - less than	0	18	18		0						0
7i	Average	1.584	0.003	<0.0002		0.003					9.711	2.591
	Minimum	<2	<0.003	<0.0002		<0.005					<6	<0.2
	Maximum	7.800	0.004	<0.0002		0.005					25.000	9.000
	Count	154	12	12		12					12	154
	Count - less than	104	6	12		11					5	2
7ii	Average	1.432	0.003	<0.0002		0.003					26.292	1.537
	Minimum	<2	<0.003	<0.0002		<0.005					<6	<0.2
	Maximum	6.900	0.005	<0.0002		0.005					178.000	6.000
	Count	155	12	12		12					12	155
	Count - less than	114	6	12		11					5	4

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7iii	Average	5.526	0.002	<0.0002		0.003					17.167	2.780
	Minimum	<2	<0.003	<0.0002		<0.005					<6	<0.3
	Maximum	39.800	0.004	<0.0002		0.008					65.000	4.400
	Count	154	12	12		12					12	154
	Count - less than	18	8	12		11					2	1
8i	Average		0.001	<0.0002		0.004					7.944	
	Minimum		<0.0002	<0.0002		<0.00186					<5	
	Maximum		0.003	<0.0002		0.005					62.000	
	Count		31	31		31					18	
	Count - less than		24	31		6					13	
9i	Average		<0.001	<0.0001		0.006						
	Minimum		<0.001	<0.0001		0.004						
	Maximum		<0.001	<0.0001		0.007						
	Count		8	8		8						
	Count - less than		8	8		0						
9ii	Average		<0.001	<0.0001		0.006						
	Minimum		<0.001	<0.0001		0.004						
	Maximum		<0.001	<0.0001		0.012						
	Count		8	8		8						
	Count - less than		8	8		0						
9iii	Average		<0.001	<0.0001		0.006						
	Minimum		<0.001	<0.0001		0.004						
	Maximum		<0.001	<0.0001		0.007						
	Count		10	11		11						
	Count - less than		10	11		0						
10i	Average	1.401	<0.005	<0.002	0.003	0.004	8.320		<1			1.829
	Minimum	0.658	<0.005	<0.002	<0.005	<0.001	5.660		<1			<1
	Maximum	3.860	<0.005	<0.002	0.007	0.016	13.500		<1			7.540
	Count	35	27	27	27	27	108		27			58
	Count - less than	0	27	27	22	23	0		27			9
11i	Average											
	Minimum											
	Maximum											
	Count											
	Count - less than											
11ii	Average											
	Minimum											
	Maximum											
	Count											
	Count - less than											
11iii	Average											
	Minimum											
	Maximum											
	Count											
	Count - less than											

Notes:
1) For parameters with sampling data both less than and greater than the detection value, values that are less than the detection value are included in the analysis as one-half the detection value.
2) For parameters with all sample points below the detection value, the results are reported as less than the highest detection value reported.
3) Metals are listed as total or dissolved when specified. When not specified by sponsor, metals are included in table, but not specified.

Sponsor/Reclaimed Water Source	Calculation Type	TotalResidualSolids mg/L	TotalSelenium mg/L	TotalSilver mg/L	TotalSolids% %	TotalSuspendedSolids mg/L	TotalThallium mg/L	TotalZinc mg/L	Toxaphene µg/L	trans-1,2-Dichloroethylene µg/L	Tributyltin µg/L	Trichloroethylene µg/L	Trihalomethanes µg/L	Turbidity NTU
1i	Average		0.002	<0.002		5.264	<0.01	0.036	<5			<10	<10	
	Minimum		<0.002	<0.002		1.000	<0.01	0.009	<5			<10	<10	
	Maximum		0.003	<0.002		264.000	<0.01	0.148	<5			<10	<10	
	Count		24	24		742	24	24	3			3	3	
	Count - less than		17	24		0	24	0	3			3	3	
3i	Average					4.028			<0.5		<0.01	<5		
	Minimum					<2			<0.5		<0.01	<5		
	Maximum					7.000			<0.5		<0.01	<5		
	Count					36			1		1	1		
	Count - less than					1			1		1	1		
3ii	Average					5.409			<0.5		<0.01	<5		
	Minimum					<2			<0.5		<0.01	<5		
	Maximum					9.000			<0.5		<0.01	<5		
	Count					22			1		1	1		
	Count - less than					1			1		1	1		
4i	Average		<0.005	<0.001		1.164		0.027	<2.5			<10	29.050	
	Minimum		<0.005	<0.001		1.000		0.019	<2.5			<10	17.000	
	Maximum		<0.005	<0.001		2.200		0.041	<2.5			<10	37.700	
	Count		13	13		36		13	6			6	6	
	Count - less than		13	13		0		0	6			6	0	
4ii	Average		<0.005	<0.001		1.343	<0.002	0.038	<0.02			<10		
	Minimum		<0.005	<0.001		<1.2	<0.002	<0.0386	<0.02			<10		
	Maximum		<0.005	<0.001		2.600	<0.002	0.047	<0.02			<10		
	Count		8	8		37	1	8	1			1		
	Count - less than		8	8		1	1	1	1			1		
5i	Average		0.006	0.001			<0.01	0.062	<5			<10	16.571	
	Minimum		<0.01	<0.002			<0.01	<0.01	<5			<10	<10	
	Maximum		0.010	0.004			<0.01	0.199	<5			<10	46.000	
	Count		19	19			18	21	6			6	7	
	Count - less than		17	14			18	1	6			6	2	
5ii	Average		0.005	0.001			<0.01	0.058	<5			<10	50.333	
	Minimum		<0.01	<0.002			<0.01	<0.01	<5			<10	13.000	
	Maximum		0.012	0.003			<0.01	0.302	<5			<10	111.000	
	Count		18	19			18	21	6			6	6	
	Count - less than		17	15			18	1	6			6	0	
6i	Average	747.556	<0.003125	<0.00125		1.858	<0.0025	0.017	<2			<5	39.950	1.002
	Minimum	675.000	<0.003125	<0.00125		1.000	<0.0025	0.014	<2			<5	34.200	0.600
	Maximum	845.000	<0.003125	<0.00125		5.300	<0.0025	0.020	<2			<5	45.700	2.040
	Count	72	18	18		144	18	18	6			6	6	72
	Count - less than	0	18	18		0	18	0	6			6	0	0
7i	Average		<0.005	<0.001		3.789	<0.005	0.032	<3			<5	29.983	3.847
	Minimum		<0.005	<0.001		<1	<0.005	<0.01	<3			<5	16.100	0.160
	Maximum		<0.005	<0.001		14.000	<0.005	0.048	<3			<5	41.800	249.000
	Count		12	12		187	12	12	6			6	6	154
	Count - less than		12	12		22	12	1	6			6	0	0
7ii	Average		0.003	<0.001		1.788	<0.005	0.043	<3		0.000	<5	5.500	0.994
	Minimum		<0.005	<0.001		<1	<0.005	0.032	<3		<0	<5	<1	0.450
	Maximum		0.005	<0.001		22.000	<0.005	0.072	<3		0.000	<5	24.500	2.700
	Count		12	12		191	12	12	6		0	6	6	155
	Count - less than		11	12		64	12	0	6		6	6	5	0

Notes:
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2) For parameters with all sample points below the detection value, the results are reported as less than the highest detection value reported.
3) Metals are listed as total or dissolved when specified. When not specified by sponsor, metals are included in table, but not specified.

Sponsor/Reclaimed Water Source	Calculation Type	TotalResidualSolids mg/L	TotalSelenium mg/L	TotalSilver mg/L	TotalSolids% %	TotalSuspendedSolids mg/L	TotalThallium mg/L	TotalZinc mg/L	Toxaphene µg/L	trans-1,2-Dichloroethylene µg/L	Tributyltin µg/L	Trichloroethylene µg/L	Trihalomethanes µg/L	Turbidity NTU
7iii	Average		0.004	<0.001		7.774	<0.005	0.054	<3		0.000	<5	13.100	4.036
	Minimum		<0.005	<0.001		<4	<0.005	0.037	<3		<0	<5	<5	1.000
	Maximum		0.006	<0.001		30.000	<0.005	0.075	<3		0.000	<5	40.900	16.000
	Count		12	12		190	12	12	6		0	6	6	154
	Count - less than		8	12		4	12	0	6		6	6	2	0
8i	Average		0.002	<0.002			<0.01	0.027	<5			<10	10.750	
	Minimum		<0.0015	<0.002			<0.01	0.017	<5			<10	<10	
	Maximum		0.005	<0.002			<0.01	0.042	<5			<10	33.000	
	Count		31	31			31	31	6			6	6	
	Count - less than		30	31			31	0	6			6	4	
9i	Average		0.001	<0.001		1.374	<0.001	0.015	<5			<10	25.975	1.283
	Minimum		<0.001	<0.001		0.500	<0.001	0.011	<5			<10	<10	0.100
	Maximum		0.002	<0.001		10.000	<0.001	0.019	<5			<10	52.000	4.830
	Count		8	8		1,063	8	8	4			4	4	288
	Count - less than		5	8		0	8	0	4			4	1	0
9ii	Average		0.001	<0.001		2.850	<0.001	0.030	<5			<10	18.575	
	Minimum		<0.001	<0.001		0.500	<0.001	0.015	<5			<10	<10	
	Maximum		0.002	<0.001		26.300	<0.001	0.049	<5			<10	52.400	
	Count		8	8		1,063	8	8	4			4	4	
	Count - less than		6	8		0	8	0	4			4	2	
9iii	Average		0.001	<0.001		2.448	<0.001	0.014	<5			<10	<10	
	Minimum		<0.001	<0.001		0.500	<0.001	0.011	<5			<10	<10	
	Maximum		0.002	<0.001		18.800	<0.001	0.021	<5			<10	<10	
	Count		11	11		1,063	11	11	4			4	4	
	Count - less than		6	11		0	11	0	4			4	4	
10i	Average		<0.005	<0.005	<1	264.697	<0.002	0.021	<5	<5		<5	1,713.472	
	Minimum		<0.005	<0.005	<1	<2	<0.002	0.000	<5	<5		<5	<5	
	Maximum		<0.005	<0.005	<1	1,140.000	<0.002	0.039	<5	<5		<5	25,800.000	
	Count		27	27	60	1,628	27	27	27	26		26	25	
	Count - less than		27	27	60	747	27	0	27	26		26	2	
11i	Average								<5			<10	<10	
	Minimum								<5			<10	<10	
	Maximum								<5			<10	<10	
	Count								3			3	3	
	Count - less than								3			3	3	
11ii	Average								<5			<10	6.000	
	Minimum								<5			<10	<10	
	Maximum								<5			<10	11.000	
	Count								6			6	6	
	Count - less than								6			6	5	
11iii	Average								<5			<10	<10	
	Minimum								<5			<10	<10	
	Maximum								<5			<10	<10	
	Count								6			6	6	
	Count - less than								6			6	6	

Notes:
1) For parameters with sampling data both less than and greater than the detection value, values that are less than the detection value are included in the analysis as one-half the detection value.
2) For parameters with all sample points below the detection value, the results are reported as less than the highest detection value reported.
3) Metals are listed as total or dissolved when specified. When not specified by sponsor, metals are included in table, but not specified.

Sponsor/Reclaimed Water Source	Calculation Type	VinylChloride µg/L	VolatileSuspendedSolids mg/L	VolatileSuspendedSolids% %	Zinc µg/L
1i	Average	<10			
	Minimum	<10			
	Maximum	<10			
	Count	3			
	Count - less than	3			
3i	Average	<5			1.800
	Minimum	<5			1.800
	Maximum	<5			1.800
	Count	1			1
	Count - less than	1			0
3ii	Average	<5			3.200
	Minimum	<5			3.200
	Maximum	<5			3.200
	Count	1			1
	Count - less than	1			0
4i	Average	<10			27.193
	Minimum	<10			18.700
	Maximum	<10			41.000
	Count	6			15
	Count - less than	6			0
4ii	Average	<10			
	Minimum	<10			
	Maximum	<10			
	Count	1			
	Count - less than	1			
5i	Average	<10			
	Minimum	<10			
	Maximum	<10			
	Count	6			
	Count - less than	6			
5ii	Average	<10			
	Minimum	<10			
	Maximum	<10			
	Count	6			
	Count - less than	6			
6i	Average	<5			
	Minimum	<5			
	Maximum	<5			
	Count	6			
	Count - less than	6			
7i	Average	<5	3.133		
	Minimum	<5	<1		
	Maximum	<5	11.000		
	Count	6	154		
	Count - less than	6	28		
7ii	Average	<5	1.348		
	Minimum	<5	<1		
	Maximum	<5	5.000		
	Count	6	155		
	Count - less than	6	77		

Notes:
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2) For parameters with all sample points below the detection value, the results are reported as less than the highest detection value reported.
3) Metals are listed as total or dissolved when specified. When not specified by sponsor, metals are included in table, but not specified.

Sponsor/Reclaimed Water Source	Calculation Type	VinylChloride µg/L	VolatileSuspendedSolids mg/L	VolatileSuspendedSolids% %	Zinc µg/L
7iii	Average	<5	6.708		
	Minimum	<5	<4		
	Maximum	<5	25.000		
	Count	6	154		
	Count - less than	6	6		
8i	Average	<10			
	Minimum	<10			
	Maximum	<10			
	Count	6			
	Count - less than	6			
9i	Average	<10			
	Minimum	<10			
	Maximum	<10			
	Count	4			
	Count - less than	4			
9ii	Average	<10			
	Minimum	<10			
	Maximum	<10			
	Count	4			
	Count - less than	4			
9iii	Average	<10			
	Minimum	<10			
	Maximum	<10			
	Count	4			
	Count - less than	4			
10i	Average	<5	25.550	61.314	27.342
	Minimum	<5	<2.2	<0	<20
	Maximum	<5	50.000	900.000	######
	Count	26	2	1,494	154
	Count - less than	26	1	3	9
11i	Average	<10			53.609
	Minimum	<10			42.300
	Maximum	<10			98.700
	Count	3			11
	Count - less than	3			0
11ii	Average	<10			42.318
	Minimum	<10			27.400
	Maximum	<10			66.800
	Count	6			11
	Count - less than	6			0
11iii	Average	<10			36.282
	Minimum	<10			17.500
	Maximum	<10			79.200
	Count	6			17
	Count - less than	6			0

Notes:
1) For parameters with sampling data both less than and greater than the detection value, values that are less than the detection value are included in the analysis as one-half the detection value.
2) For parameters with all sample points below the detection value, the results are reported as less than the highest detection value reported.
3) Metals are listed as total or dissolved when specified. When not specified by sponsor, metals are included in table, but not specified.

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EXHIBIT F

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Table 1: Stream sampling sites analyzed for selected antibiotic compounds (Method1) in 1999 and 2000 (From Barnes and others, 2002).

Site code	TX01 (USGS Trinity River below Dallas)
Date (month-day-year)	8/9/1999
Time (24-hour)	830
Type of sample	do.
Carbodox (6804-07-5)	<.10
Chlor-tetra-cycline (57-62-5)	<.05
Cipro-floxacin (85721-33-1)	<.02
Doxy-cycline (564-25-0)	<.10
Enrofloxacin (93106-60-6)	<.02
Erythromycin-H_20 (114-07-8)	<.05
Lincomycin (154-21-2)	<.05
Norfloxacin (70458-96-7)	<.02
Oxytetracycline (79-57-2)	<.10
Roxithromycin (80214-83-1)	<.03
Sarafloxacin (98105-99-8)	<.02
Sulfadimethoxine (122-11-2)	<.05
Sulfamerazine (127-79-7)	<.05
Sulfamethazine (57-68-1)	<.05
Sulfamethizole (144-82-1)	<.10
Sulfamethoxazole (723-46-6)	<.10
Sulfathiazole (72-14-0)	<.10
Tetracycline (60-54-8)	<.05
Trimethoprim (738-70-5)	<.03
Tylosin (1401-69-0)	0.12
Virginiamycin (21411-53-0)	<.10

*All concentrations are in micrograms per liter.
<, less than indicated detected limit;
E, estimated;
--*, data not yet analyzed;
Number in parentheses () is the Chemistry Abstracts Service Registry Number

Table 2: Stream sampling sites analyzed for selected human pharmaceutical compounds (Method 3) in 1999 and 2000 (From Barnes and others, 2002).

Site code	TX01
Date (month-day-year)	8/9/1999
Time (24-hour)	830
Type of sample	do.
Acetaminophen (103-90-2)	<.009
Caffeine (58-08-2)	0.05
Cimetidine (51481-61-9)	<.007
Codeine (76-57-3)	--
Cotinine (486-56-6)	0.059
Dehydronifedipine (67035-22-7)	0.027
Digoxigenin (1672-46-4)	<.008
Digoxin (20830-75-5)	--
Diltiazem (42399-41-7)	<.012
1,7-Dimethylxanthine (611-59-6)	<.018
Enalaprilat (76420-72-9)	<.152
Fluoxetine (54910-89-3)	<.018
Gemfibrozil (25812-30-0)	<.015
Ibuprofen (15687-27-1)	<.018
Metformin (657-24-9)	<.003
Paroxetine metabolite	<.26
Ranitidine (66357-35-5)	<.01
Albuterol (18559-94-9)	<.029
Sulfamethoxazole (723-46-6)	<.023
Trimethoprim (738-70-5)	<.014
Warfarin (81-81-2)	<.001

Table 3: Stream sampling sites analyzed for selected organic wastewater compounds (Method 4) in 1999 and 2000 (From Barnes and others, 2002).

Site code	TX01
Date (month-day-year)	8/9/1999
Time (24-hour)	830
Type of sample	do.
1,4-dichlorobenzene (106-46-7)	0.08
2,6-di-*tert*-butyl-phenol (128-39-2)	<.090
2,6-di-*tert*-p-benzoquinone (719-22-2)	0.22
3-*tert*-butyl-4-hydroxy anisole (25013-16-5)	<.100
4-methyl phenol (106-44-5)	<.030
4-nonylphenol(84852-15-3)	E1
4-nonylphenol monoethoxylate (NA)	E.9
4-nonylphenol diethoxylate (NA)	E.6
4-octylphenol monoethoxylate (26636-32-8)	E.4
4-octylphenol diethoxylate (26636-32-8)	E.1
5-methyl-1H-benzo-triazle (136-85-6)	--
Aceto-phenone (98-86-2)	<.150
Anthra-cene (120-12-7)	<.050
Benzo (a) pyrene (50-32-8)	<.050
Bis (2-ethylhexyl) adipate (103-23-1)	E.7
Bis (2-ethylhexyl) phthalate (117-81-7)	E2
Bis-phenol A (80-05-7)	<.090
Butylated hydroxy toluene (128-37-0)	<.080
Caffeine (58-08-2)	0.17
Carbaryl (63-25-2)	<.060
cis-Chlordane (5103-71-9)	<.040
Chlor-pyrifos (2921-88-2)	<.020
Cholesterol (57-88-5)	E2
Codeine (76-57-3)	<.100
Coprostanol (360-68-9)	E.4
Cotinine (486-56-6)	--
Diazinon (333-41-5)	<.030
Dieldrin (60-57-1)	<.080
Diethyl-phthalate (84-66-2)	--
N,N-di-ethyl-toluamide (134-62-3)	--
17β-estradiol (50-28-2)	<.500
Ethanol, 2-butoxy phosphate (78-51-3)	0.75
Fluoranthene (206-44-0)	<.030

Lindane (58-89-9)	E.02
Methyl parathion (298-00-0)	<.060
Naphthalene (91-20-3)	<.030
Phenanthrene (85-01-8)	<.060
Phenol (108-95-2)	<.150
Phthalic anhydride (85-44-9)	E.8
Pyrene (129-00-0)	<.030
Stigmastanol (19466-47-8)	--
Tetra-chloroethylene (127-18-4)	<.030
Triclosan (3380-34-5)	0.3
Tri (2-chloro-ethyl) phosphate (115-96-8)	0.42
Tri (di-chloriso-propyl) phosphate (13674-87-8)	<.100
Triphenyl phosphate (115-86-6)	<.100

All concentrations are in micrograms per liter.
<, less than indicated detected limit;
E, estimated;
--, data not collected;
Number in parentheses is the Chemical Abstracts Registry Number

Table 4: Stream sampling sites analyzed for selected steroid and hormone compounds (Method 5) in 1999 and 2000 (From Barnes and others, 2002).

Site code	TX01
Date (month-day-year)	8/9/1999
Time (24-hour)	830
Type of sample	do.
cis-Androsterone (53-41-8)	<.005
Cholesterol (57-88-5)	0.518
Coprostanol (360-68-9)	0.158
Equilenin (517-09-9)	<.005
Equilin (474-86-2)	<.005
17α-estradiol (57-91-0)	<.005
17α-ethynyl estradiol (57-63-6)	<.005
17β-estradiol (50-28-2)	<.005
Estriol (50-27-1)	<.005
Estrone (53-16-7)	<.005
Mestranol (72-33-3)	<.005
19-norethisterone (68-22-4)	<.005
Progesterone (57-83-0)	<.005
Testosterone (58-22-0)	<.005

All concentrations are in micrograms per liter.
<, less than indicated detected limit;
E, estimated;
--, data not collected;
--*, data not yet analyzed;
**, Primary sample was lost. Results shown are for the duplicate sample;
Number in parentheses () is the Chemical Abstracts Service Registry Number;
***, because of low-level detections in blanks, value set to less than reporting limit for summary in Kolpin and others, 2002

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Table 5: Concentrations (μg/L) of PPCPs in wastewater (Table from Karnjanapiboonwong, A and Anderson, T., 2010)

Compound	Date	Bar rack	Aeration basin		Chlorine Contact Chamber	Effluent	
			Plant 3	Plant 4		Station I	Station II
E1	12/16/08	3.25	3.18	3.67	*	1.43	1.82
	3/11/09	1.47	0.74	1.63	0.42	0.49	0.59
	6/3/09	ND	0.22	2.82	1.54	0.33	0.48
	9/9/09	1.29	ND	ND	ND	ND	ND
E2	12/16/08	4.62	1.30	1.38	*	ND	1.37
	3/11/09	2.29	ND	1.12	0.36	0.50	ND
	6/3/09	0.90	1.66	1.58	0.80	0.26	0.75
	9/9/09	1.58	0.73	0.50	ND	ND	0.67
E3	12/16/08	0.68	7.45	13.97	*	0.25	7.60
	3/11/09	110.71	126.53	29.19	86.71	83.43	59.23
	6/3/09	ND	37.51	7.29	7.66	13.08	2.76
	9/9/09	25.71	ND	ND	ND	ND	ND
EE2	12/16/08	ND	ND	ND	*	0.08	0.39
	3/11/09	7.89	ND	ND	0.16	ND	ND
	6/3/09	ND	ND	0.12	0.81	0.26	ND
	9/9/09	ND	ND	ND	ND	ND	ND
Triclosan	12/16/08	5.10	0.12	ND	*	0.26	0.13
	3/11/09	8.12	ND	0.77	ND	ND	ND
	6/3/09	1.90	0.44	ND	0.14	0.15	0.17
	9/9/09	0.70	ND	ND	1.41	0.18	0.35
Caffeine	12/16/08	23.60	ND	ND	*	N	ND
	3/11/09	41.04	0.35	ND	0.12	0.17	0.34
	6/3/09	45.48	5.35	ND	ND	ND	ND
	9/9/09	53.43	ND	ND	ND	ND	ND

*No sample
ND = Not detectable
E1=Estrone (E1);
E2= 17β-estradiol,
E3=estriol,
EE2=17α-ethynylestradiol

Table 6: Concentrations (ng/L) of PPCPs in groundwater (Table from Karnjanapiboonwong, A and Anderson, T., 2010)

Compound	Sampling Date	CL-11[a]	CL-29[b]	CL-43[a]	CL048[b]
E1	3/9/09	*	79.15	75.15	61.74
	6/30/09	ND	ND	ND	ND
	9/16/09	ND	ND	ND	ND
E2	3/9/09	*	12.16	146.54	34.3
	6/30/09	39.4	ND	ND	77.51
	9/16/09	ND	ND	ND	ND
E3	3/9/09	*	1744.62	874.16	538.32
	6/30/09	685.68	321.83	1660.75	675.96
	9/16/09	ND	ND	ND	ND
EE2	3/9/09	*	ND	230.32	101.66
	6/30/09	14.51	ND	ND	ND
	9/16/09	ND	ND	ND	10.87
Triclosan	3/9/09	*	16.69	15.74	11.57
	6/30/09	ND	44.73	53.27	ND
	9/16/09	ND	ND	ND	ND
Caffeine	3/9/09	*	118.57	166.17	163.52
	6/30/09	ND	ND	ND	ND
	9/16/09	16.03	ND	ND	ND
	9/16/09	ND	ND	ND	ND

* No sample
ND = Not detectable
[a] inside pivot irrigation
[b] outside pivot irrigation

Table 7: Range of measured pesticide concentrations in micrograms per liter, by site, for stream samples collected in Texas in 2003-2004 (From Battalin and others 2008).

Pesticide	Action	Beaver Creek near Electra, Texas	Sabana River near DeLeon, Texas	San Miguel Creek near Tilden, Texas
Chlorothalonil	Fungicide	ND	ND	ND
4-hydroxy-chlorothalonil	Fungicide TP	ND	ND	ND
1-amide-4-hydroxy chlorothalonil	Fungicide TP	ND	ND	ND
Diamide chlorothalonil	Fungicide TP	ND	ND	ND
2,4-D	Herbicide	NA	NA	NA
Atrazine	Herbicide	0.024	ND	0.008 – 0.122
Bentazon	Herbicide	NA	NA	NA
Carbaryl	Insecticide	ND	ND	E 0.27
Deethylatrazine	Herbicide TP	0.006	ND	0.040
Deisopropylatrazine	Herbicide TP	NA	NA	NA
Hydroxyatrazine	Herbicide TP	NA	NA	NA
2-hydroxyatrazine	Herbicide TP	NA	NA	NA
Malathion	Insecticide	0.033	ND	ND
Metolachlor	Herbicide	ND	E 0.010 – 0.019	E 0.007 – 0.019
Oryzalin	Herbicide	NA	NA	NA
Pendimethalin	Herbicide	ND	ND	ND
Prometon	Herbicide	ND	ND	ND
Propargite	Insecticide	ND	ND	ND
Simazine	Herbicide	ND	ND	ND
buthiuron	Herbicide	ND	ND	0.008
Terbacil	Herbicide	ND	ND	ND
Triclopyr	Herbicide	NA	NA	NA

E, estimated concentration;
ND, not detected;
NA, not analyzed;
TP, transformation product

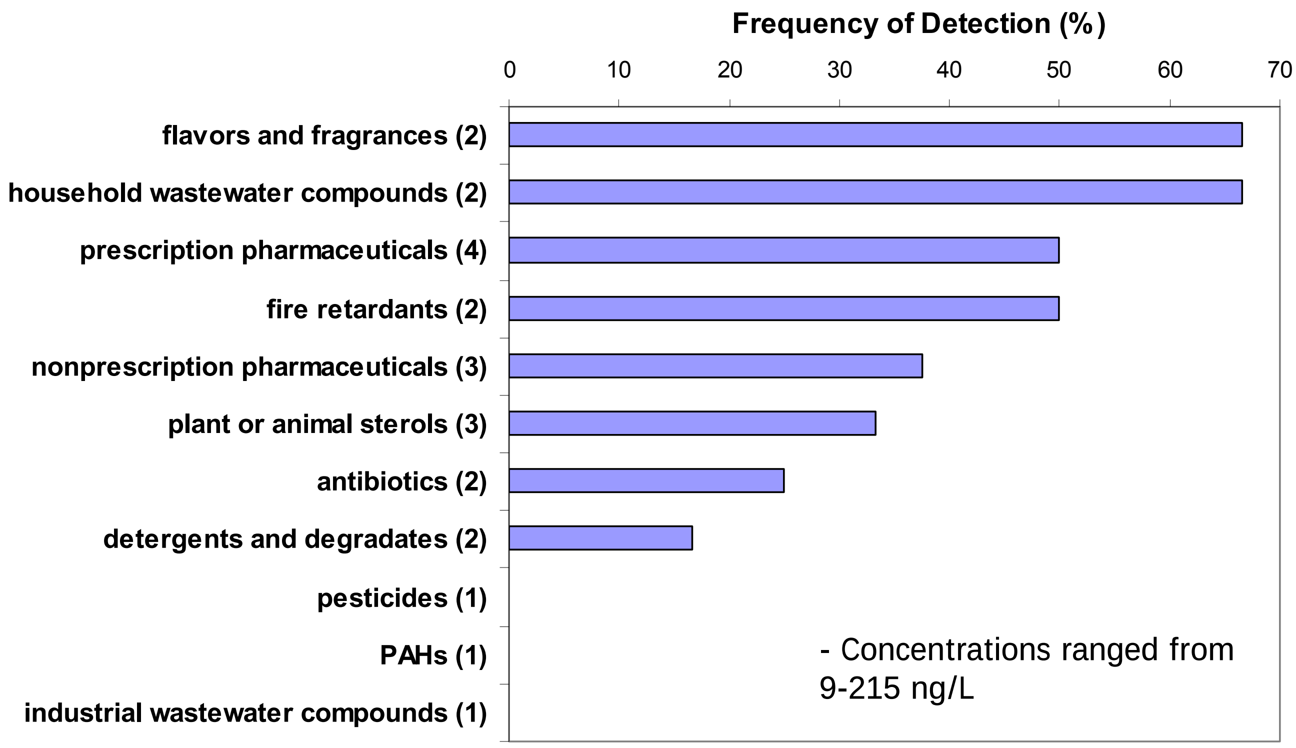

Figure 1: San Marcos WWTP Effluent Samples (From Foster, 2007)

Table 8: Table1 from Ging and others, 2009.

Table 1. One hundred three of 277 organic compounds were detected frequently (in at least 20 percent of the samples) in source water or finished water, or both. Forty-two compounds were detected in source water, and about 90 percent of these compounds (38) also were detected frequently in finished water. The diversity of compounds indicates a variety of different uses (including industrial, agricultural, and domestic) and different pathways (including treated wastewater outfalls located upstream, overland runoff, and groundwater discharge) of the compounds entering drinking-water supplies.

[Black text, compounds detected in source and finished water; blue text, compounds detected in source water only; green text, compounds detected in finished water only; ESA, ethane sulfonic acid; OA, oxanilic acid; MCPA, 2-methyl-4-chlorophenoxyacetic acid; AHTN, acetyl hexamethyl tetrahydronaphthalene; HHCB, hexadydrohexamethyl cyclopentabenzopyran]

Herbicides and herbicide degradates	Manufacturing additives	Disinfection by-products
2,4–D	Bisphenol A	Bromodichloromethane
2-Hydroxyatrazine	Tri(2-butoxyethyl)phosphate	Bromoform
3,4-Dichloroaniline	Tri(2-chloroethyl)phosphate	Chloroform
Alachlor	Tributyl phosphate	Dibromochloromethane
Alachlor ESA	Triphenyl phosphate	**Solvents**
Alachlor OA	Tris(dichlorisopropyl)phosphate	Acetone
Atrazine	**Personal-care and domestic-use products**	Carbon tetrachloride
Deethylatrazine (DEA)	AHTN	Methyl ethyl ketone
Deisopropylatrazine (DIA)	Caffeine	Methylene chloride
Diuron	Camphor	**Gasoline hydrocarbons and oxygenates**
MCPA	HHCB	Benzene
Metolachlor	Methyl salicylate	Methyl *tert*-butyl ether (MTBE)
Metolachlor OA	Triethyl citrate	*tert*-Butyl alcohol
Prometon	**Insecticides and insecticide degradates**	Toluene
Simazine	Carbaryl	**Organic synthesis compounds**
Tebuthiuron	Desulfinylfipronil	Chloromethane
	Diazinon	**Fumigant-related compounds**
	Fipronil	1,4-Dichlorobenzene

Table 9: Table 2 from Ging and others, 2009.

Table 2. Fewer than 20 compounds that were detected frequently in source or finished water, or both, had concentrations greater than 0.1 microgram per liter. None of these concentrations exceeded a human-health benchmark; however, benchmarks are only available for 11 of the 19 compounds included in this table.

[µg/L, micrograms per liter; MCL, maximum contaminant level; HBSL, health-based screening level; THMs, trihalomethanes; ND, not detected; E, estimated; --, no data; OA, oxanilic acid; HHCB, hexadydrohexamethyl cyclopentabenzopyran]

Name of compound	Number of samples		Percentage occurrence[1]		Reporting level[2] (µg/L)	MCL or HBSL[3] (µg/L)	Maximum concentration (µg/L)	
	Source water	Finished water	Source water	Finished water			Source water	Finished water
Disinfection by-products								
Bromodichloromethane	30	13	13	100	0.04	**80 for total THMs[4]**	0.28	18.85
Bromoform	30	13	0	100	.10		ND	1.07
Chloroform	30	13	50	100	.02		.56	23.52
Dibromochloromethane	30	13	3	100	.18		E.165	10.57
Gasoline hydrocarbons and oxygenates								
Methy *tert*-butyl ether	30	13	80	77	.1	--	3.44	.56
tert-Butyl alcohol	23	6	35	0	1.0	--	1.05	ND
Herbicides and herbicide degradates								
2,4–D	30	13	27	15	.040	**70**	4.78	.459
2-Hydroxyatrazine	30	13	100	69	.080	70	.68	.301
Alachlor OA	13	13	38	15	.020	--	.26	.120
Atrazine	30	13	100	100	.007	**3**	1.37	.706
Deethylatrazine (DEA)	30	13	27	23	.014	--	.136	.105
Simazine	30	13	100	100	.006	**4**	1.75	.454
Manufacturing additives								
Bisphenol A	29	12	17	25	1.0	400	E.32	E.44
Tri(2-butoxyethyl)phosphate	30	13	43	23	.5	--	.93	.56
Tri(2-chloroethyl)phosphate	30	13	30	15	.5	--	E.16	E.13
Personal-care and domestic-use products								
Caffeine	30	13	17	38	.04	--	.58	.22
HHCB	30	13	50	0	.50	--	E.26	E.096
Solvents								
Acetone	30	13	7	100	6	6,000	E1.55	11.19
Methyl ethyl ketone	30	13	0	31	2	4,000	ND	E .98

[1] Percentage occurrence of samples with concentrations equal to or greater than 0.1 µg/L.

[2] Reporting level shown is higher value of either source or finished water.

[3] MCL in bold (U.S. Environmental Protection Agency, 2007a); HBSL from Toccalino and others (2007).

[4] Total THMs include bromodichloromethane, bromoform, chloroform, and dibromochloromethane.

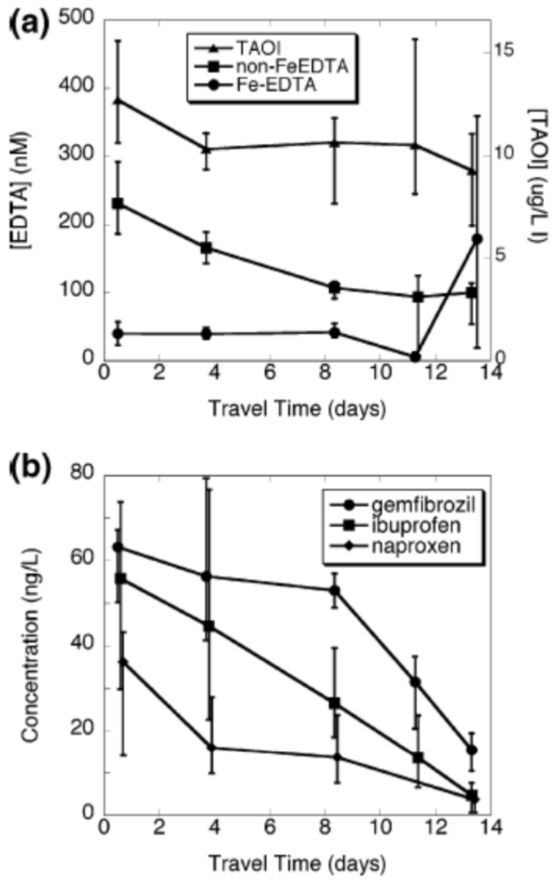

FIGURE 2. Average (symbols) and range (bars) of concentrations of WWDCs in the Trinity River. All data are included in Table SI 2.

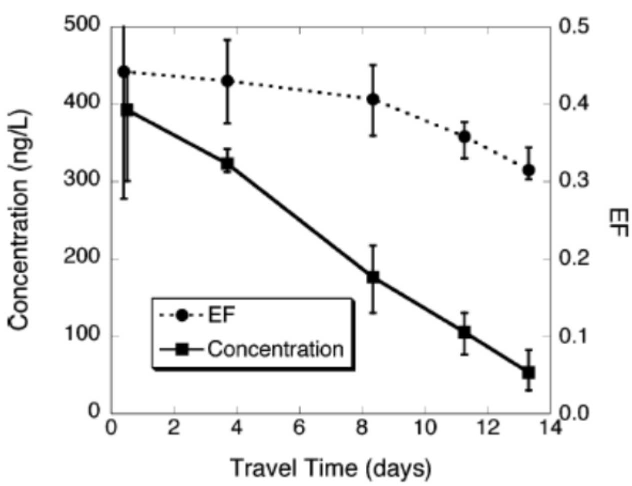

FIGURE 3. Average (symbols) and range (bars) of concentrations and enantiomer fractions (EFs) of metoprolol in the Trinity River.

Figure 2: Figures 1, 2, and 3 from Fono and others, 2006

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B2 Appendix:

Characterizing Wastewater Effluent Quality (Texas Commission on Environmental Quality document)

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This document was prepared by the TCEQ to provide information on recommended monitoring for public water systems interested in DPR. It is a draft document; prior to pursuing a project, the TCEQ should be contacted for updated information.

Characterizing Wastewater Effluent Water Quality

Purpose of wastewater characterization

The Texas rules require that any entity proposing to use a new source of water for a public water system (PWS) must identify the quality of that source water. Wastewater effluent is by definition impacted by fecal microbes and chemicals of human origin. Therefore, it is critical that the quality of wastewater effluent be characterized before use as a drinking water source.

Texas adopts specific rules under Title 30 Texas Administrative Code (30 TAC) Chapter 210 for reclaimed water quality. However, the 30 TAC 210 standards do not address all of the chemical and microbial constituents of concern in drinking water. Drinking water rules in 30 TAC 290 are based on removal of constituents at levels found in ambient water, which is different than wastewater effluent.

The lists presented here are for planning purposes only and is subject to change.

Locations

The wastewater effluent that is intended as a new source of drinking water should be characterized. It is required that any water streams intended for blending with the wastewater be characterized as well. Likewise, any raw water used for treatment as surface water should be sampled. Treated water should be analyzed in accordance with the site-specific requirements applied by the TCEQ.

Sample site map: Sampling at various stages in the process allows a PWS to demonstrate the source of any pathogens or chemical contaminants. A map showing the sampling locations, and a list describing the sample location(s) should be provided to the TCEQ when the sampling regime is proposed.

Frequency

A single 'snapshot' view of water quality is not sufficient; instead multiple samples are needed to provide statistically representative samples.

Wastewater effluent site schedule: Wastewater effluent should be sampled at least 24 times at approximately equal intervals over a period of at least one year for the microbes shown in Table 1, nitrate, and nitrite. On a monthly basis, the wastewater effluent should be analyzed for ammonia, trihalomethanes, hardness, total dissolved solids, and alkalinity. Temperature and pH data should be provided with all samples. Additionally, any available data collected for compliance with the wastewater permit should be provided.

The TCEQ requires that wastewater intended for use as a drinking water source be characterized over a period of time that includes seasonal variation. Without seasonal data, changes in quality cannot be scientifically factored into treatment plant design. For example, people drink and flush more water in the summer so the contaminant levels in summer may be less than those in the winter.

To characterize seasonal variation, wastewater effluent should be tested for the other chemicals and water quality parameters a minimum of four times over the same one year period: once in the summer at the hottest temperature, once in the winter at the lowest temperature, and once in spring and fall at the midpoints.

These schedules are summarized in Tables 1 and 2, below.

Additional sample site schedule: Samples should be collected from other locations, such as at proposed blending points or surface water intakes, at least four times at approximately equal intervals over the same one year period.

PWSs often use different initial sources of raw water on a seasonal basis, so that the baseline water quality characteristics can change seasonally. A system may use surface water as their initial source, but also use well water during the high-demand summer periods. Samples characterizing various changes in source should be collected and documented to clearly show what source they represent.

Sample types

The constituents of concern in wastewater effluent can be broadly grouped as microbes or chemicals and other constituents such as hardness and pH.

The constituents of greatest concern are those with documented, immediate negative health effects ("acute" health effects), such as pathogens and nitrate/nitrite. It may be acceptable for a system to perform sampling for constituents that have long-term health effects, like regulated organics, less frequently than sampling for pathogens or nitrate/nitrite.

A basic level of sampling must be completed before a wastewater effluent source can be considered for use as a drinking water source. Table 1, below, lists the required sampling that must be performed; the two subsequent tables list recommended sampling. The intent of the sampling is to establish what microbial and chemical contaminants are present in order to protect public health. An acceptable sampling program will ensure that characterization is accomplished.

Although the lists of recommended sampling are not exhaustive, they provide a starting place for planning.

Required and Recommended Sampling Tables

The requirements and recommendations presented here are intended to help a PWS pre-plan for a potable reuse project. Before sampling, a PWS should work with TCEQ to ensure that any applicable site-specific sampling is scheduled.

Required Sampling

Before beginning to sample the parameters in Table 1, a PWS should determine whether TCEQ requires any additional sampling based on the system's site-specific conditions.

Table 1. Required Samples (One Year)[1]

Microbes	**Method [2]**	**Frequency**
Bacteria		
Total coliform	EPA Method 1604	Twice a month
Escherichia coli (E. coli)		
Heterotrophic plate count (HPC)	EPA Method 9215	
Viruses		
Total culturable viruses	EPA Method 1615	Twice a month
Enterovirus		
Norovirus		
Protozoans:		
Cryptosporidium	EPA Method 1623	Twice a month
Giardia		
Chemicals	**Method [2]**	**Frequency**
Disinfection byproducts		
Total trihalomethanes	EPA Method 524	Monthly [4]
Haloacetic acids [3]	EPA Method 552	
Inorganic chemicals		
Nitrate and nitrite (as nitrogen)	EPA Method 200.5[5]	Monthly
Metals [6]	EPA Method 200.5[5]	
Minerals [7]	EPA Method 300.0[5]	
Cyanide	EPA Method 335.4	
Free available ammonia (as nitrogen)	PWS's method [8]	
Asbestos [9]	EPA Method 100.2	
Disinfectant residual (if wastewater is disinfected)	Applicable method	Daily
Organic chemicals		
Volatile organic chemicals (VOCs) [10]	EPA Method 524.4	Twice
Synthetic organic chemical (SOC) Semivolatiles Group [11]	EPA Method 525.3	Twice during probable application periods [12]
SOC Chlorinated Acid Group [13]	EPA Method 515.4	
SOC N-Methylcarbamoyloximes and N-Methylcarbamates Group [14]	EPA Method 531.2	
EDP/DBCP (ethylene dibromide and 1,2-dichloro-3-propane)	EPA Method 504.1	
Glyphosate	EPA Method 547	
2,3,7,8-TCDD (Dioxin)	EPA Method 1613	
Diquat	EPA Method 549.2	
Endothall	EPA Method 548.1	
Other constituents	**Method [2]**	**Frequency**
Alkalinity, hardness, total suspended solids	30 TAC 290/ 40 CFR 141.23 [15]	Monthly
pH and temperature		With every sample

1 Before performing wastewater characterization, a PWS must provide the sampling plan to TCEQ for review and approval.
2 Methods listed here are recommended, based on common, approved methods as of 2014.

Table 1. Required Samples (One Year)[1]

Methods may change, and new methods may periodically be approved by EPA. Therefore, a PWS may propose to use any EPA-approved method in their sampling plan submittal.

3. Haloacetic acids including the group of five regulated species plus bromodichloramethane must be measured.
4. Quarterly means that samples should be collected at roughly equal intervals representing hottest, coldest, and average water temperatures.
5. Either EPA Method 100 or any of the appropriate methods approved in Title 40 Code of Federal Regulations (40 CFR) Section 141.23 may be used for analysis.
6. Regulated primary metals include antimony, arsenic, barium, beryllium, cadmium, chromium, mercury, selenium, and thallium. Regulated secondary metals include aluminum, copper, iron, manganese, silver, zinc.
7. The regulated primary mineral is fluoride. Regulated secondary minerals are fluoride, chloride, sulfate, and total dissolved solids.
8. No free available ammonia methods are specifically approved by the EPA as of 2014. A PWS should propose their specific desired method.
9. If asbestos/cement pipe is used in drinking water distribution, wastewater collection, or associated piping.
10. VOCs include 1,1,1,2-Tetrachloroethane, 1,1,2,2-Tetrachloroethane, 1,1-Dichloroethylene, 1,2-dichloroethane, 1,2-dichloropropane, 1,2,4-trichlorobenzene, benzene, carbon tetrachloride, cis-1,2-dichloroethylene, dichloromethane, ethylbenzene, monochlorobenzene, o-dichlorobenzene, para-dichlorobenzene, styrene, tetrachloroethylene, toluene, trans-1,2-dichloroethylene, trichloroethylene, vinyl chloride, and xylenes.
11. Semivolatile SOCs include: alachlor, atrazine, benzo(a)pyrene, di(ethylhexyl)-adipate, di(ethylhexyl)-phthalate, endrin, heptachlor, heptachlor epoxide, hexachlorobenzere (HCB), hexachlorocyclopentadiene, lindane, methoxychlor, pentachlorophenol (PCP), and simazine.
12. SOC groups representing herbicides should be collected during the periods of time when they are most likely to be applied in the local area of the PWS.
13. Chlorinated acid SOCs include: 2,4-D, 2,4,5-TP (Silvex), Dalapon, Dinoseb, pentachlorophenol (PCP), picloram, and dicamba.
14. Methylcarbamoyloximes and N-Methylcarbamates include Aldicarb, Aldicarb sulfone, Aldicarb sulfoxide. Carbaryl, Carbofuran, 3-Hydroxycarbofuran, Methiocarb, Methomyl, 1-Naphthol, oxamyl (Vydate), and Propoxur.
15. The methods approved in the system's TCEQ-approved Monitoring Plan (30 TAC 290.121) should be utilized. Instruments used for 'approved-laboratory' analyte testing must be maintained in accordance with the minimum operating conditions and calibration frequency (30 TAC 290.46).

The constituents listed in Table 1 have regulatory source water monitoring requirements—for any water source—listed in 30 TAC Chapter 290.

Recommended Sampling

There are multiple parameters that the TCEQ highly recommends sampling in wastewater effluent proposed for use as a drinking water source.

Table 2. Recommended Samples

Microbes		
Bacteria	**Method**	**Frequency**
Enterococci	EPA Method 1600	Monthly/Quarterly
Aeromonas	EPA Method 1605	
Viruses	**Method**	**Frequency**
Rotavirus,	TBD[1]	Monthly/Quarterly
Poliovirus		
Echovirus		
Coxsackievirus		
Adenovirus		
Hepatitis A		
Protozoa	**Method**	**Frequency**

Table 2. Recommended Samples

Salmonella, Shigella, Campylobacter, and Pseudomonas	EPA Method 1200	Monthly/Quarterly
Naegleria fowlerii	TBD[1]	
Cyclospora		
Fungi	**Method**	**Frequency**
Microsporidia	TBD[1]	Monthly/Quarterly
Chemicals		
Disinfection byproducts	**Method**	**Frequency**
N-Nitroso-dimethylamine (NDMA) and N-Nitroso-pyrrolidine (NPYR)	EPA Method 521	Monthly/Quarterly
Inorganic chemicals	**Method**	**Frequency**
Perchlorate	EPA Method 314	Quarterly
Sodium	EPA Method 200.7	Quarterly
Organic chemicals	**Method**	**Frequency**
Pharmaceutical indicators [2]	EPA Method 537	Monthly/Quarterly
Chemicals of human origin [3]		
1,4 dioxane	EPA Method 522	
N,N-Diethyl-meta-toluamide (DEET)	EPA Method 633	
Caffeine, Gemfibrozil, and Iopromide	EPA Method 1694	
Sucralose	TBD [4]	Monthly

1. Methods are under development. The PWS should propose a method for TCEQ's review and approval.
2. Including 17-α-ethynylestradiol (ethinyl estradiol), 16-α-hydroxyestradiol (estriol), equilin, estrone, testosterone, 4-androstene-3,17-dione.
3. Including Perfluorooctanesulfonic sulfonate (PFOS), perfluorooctanoic acid (PFOA) perfluorononanoic acid (PFNA) perfluorohexanesulfonic acid (PFHxS) perfluoroheptanoic acid (PFHpA) perfluorobutanesulfonic acid (PFBS).
4. Methods for sucralose analysis are widely available but have not been approved by the EPA for use specifically in drinking water sources. The PWS should propose a method for TCEQ's review and approval.

Sucralose as an indicator of chemicals of human origin

New research has identified sucralose as an excellent, conservative, easy-to-measure indicator that water contains chemicals of human origin. Sucralose is not biologically degraded, so it passes through wastewater biological treatment plants unchanged. Several researchers have proposed sucralose as an indicator for other chemicals of human origin that are more difficult or expensive to measure. Sucralose should be quantified in reuse sources.

Contaminants of Emerging Concern

The drinking water industry and the EPA are becoming concerned about contaminants of emerging concern (CECs). Many of the CECs are of human origin, especially pharmaceuticals and personal care products.

Public concern regarding these CECs is very high, and the EPA is researching their presence through the Contaminant Candidate List (CCL) and Unregulated Contaminant Monitoring Regulation (UCMR) process. As of 2014, the EPA has not determined or set health-based maximum contaminant levels (MCLs) for these potentially harmful microbes and chemicals. Additional research into ambient levels of CEC chemicals is ongoing. If the EPA sets MCLs, further characterization may be necessary (see References).

Analytical methods do not yet exist for some of these CEC chemicals. The best current methods for CEC chemicals are described in the EPA's Unregulated Contaminant Monitoring Regulations (UCMRs), 1 through 3.

Although the UCMR contaminants are not required by EPA to be sampled in all direct and indirect reuse sources, the list provides a well-researched source of information for chemicals that EPA is most likely to regulate in the future, and that are most likely to have negative health effects.

Additionally, as interest in chemicals of emerging concern grows, researchers have identified chemicals that can indicate the presence of anthropogenic contamination, but that are not harmful to human health.

Pharmaceutical indicators

The UCMR3 list includes estrogenic hormones used in pharmaceuticals. It is recommended that reuse sources be evaluated for these chemicals using analytical method 537.

Personal care product indicator

The UCMR3 list includes 1,4 dioxane, which is used in personal care products such as soaps and makeup. It is recommended that reuse sources be evaluated for 1,4 dioxane using method EPA 522.

Additionally, EPA identified six perfluorinated compounds that may indicate contamination from human industrial activities. These compounds (perfluorooctanesulfonic sulfonate (PFOS), perfluorooctanoic acid (PFOA), perfluorononanoic acid (PFNA), perfluorohexanesulfonic acid (PFHxS), perfluoroheptanoic acid (PFHpA), and perfluorobutanesulfonic acid (PFBS)) should be quantified using method EPA 537 (1.1).

Disinfection byproducts of emerging concern

Wastewater sources are frequently chlorinated during the wastewater treatment process. Regulated disinfection byproducts (trihalomethanes and haloacetic acids) are known to frequently occur at levels of concern in wastewater. Additionally, the EPA has identified the presence of other potentially carcinogenic disinfection byproducts called nitrosamines. It is recommended that the two most-frequently occurring nitrosamines (nitroso-dimethylamine (NDMA) and nitroso-pyrrolidine (NPYR)) be quantified using method EPA 521.

Sampling costs

The cost of sample analyses may be a concern to a PWS. A system should consider this cost in planning. Based on industry experience, the cost of sampling prior to design is offset by the ability to design treatment based on actual levels of contaminants. If the raw wastewater is not fully characterized, regulators may require additional safety factors which may result in additional treatment needs with their associated additional costs.

In general, analyses should be performed at National Environmental Laboratory Accreditation Program (NELAP)-accredited laboratories using EPA-approved methods. Where those labs or methods are unavailable, a PWS should identify a capable lab and request permission for its use. Methods listed in these tables are recommendations; other approved EPA-methods exist, and may be proposed for use.

Depending on the treatment method selected by the PWS, it may be necessary for a PWS to perform additional sampling to characterize the impact on treatment. For example, selenium interferes with adsorption under some conditions; if adsorption is used for treatment, additional selenium sampling may be required. This is an example of a situation where additional sampling will result in a more efficient design.

Reporting WW Characterization Sample Results

Results should be tabulated in a clear, easy-to-read manner for submittal; analytical detail such as the quality assurance documentation needs to be submitted. The summary tables should be organized with sample sites in order of extent of treatment; for sampling over a period of time, analyses should be presented in the order that the samples were collected. The summary tables should contain the units of measurement. A summary of the quality assurance procedures, methods, laboratories, and standard operating procedures should be included with the report.

References

1. "2012 Guidelines for Water Reuse," (EPA/600/R-12/618); U.S. Environmental Protection Agency, Office of Wastewater Management, Office of Water; September 2012; available at: http://nepis.epa.gov/Adobe/PDF/P100FS7K.pdf
2. "Revisions to the Unregulated Contaminant Monitoring Regulation (UCMR 3) for Public Water Systems," (77 FR 26072); U.S. Environmental Protection Agency; May 5, 2012

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C Appendix:

Water Quality Performance Targets

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C1 Appendix:

Proposed Targets and Background Information

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TECHNICAL MEMORANDUM

Texas Water Development Board
Evaluating the Potential of Direct Potable Reuse in Texas
Workshop #1: Water Quality Performance Targets

Ellen McDonald

Digitally signed by Ellen McDonald
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Project No.: 0866-005-01

Date: April 19, 2015

Prepared For: Workshop Participants

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1 INTRODUCTION

Texas faces many challenges when planning for future water supplies. The population of Texas is expected to increase 82 percent between 2010 and 2060, ongoing droughts have stressed water supplies in many regions of the state, and increasing challenges are associated with acquiring new surface and groundwater supplies. Interest in the direct potable use of reclaimed water continues to grow in Texas, particularly under the recent drought conditions.

The use of reclaimed water for potable purposes by discharging treated wastewater to a water supply source, such as a surface water or groundwater, is referred to as “indirect” potable reuse. The water supply source serves to dilute the reclaimed water and may provide additional treatment through natural processes. The mixed reclaimed and natural water then receive additional treatment before entering the drinking water distribution system. Often this type of reuse occurs incidentally due to a water supply intake being located downstream of a wastewater discharge, and in this case is referred to as “unplanned” or “de facto” indirect potable reuse.

In contrast, “direct” potable reuse (DPR) is typically defined as the introduction of reclaimed water either directly into the potable water system downstream of a water treatment plant or into the raw water supply immediately upstream of a water treatment plant. DPR eliminates or significantly minimizes the use of an environmental buffer and utilizes engineered treatment processes to treat reclaimed water prior to distribution to the potable water distribution system

The primary purpose of the subject project (hereafter referred to as the DPR Study) is to develop a resource document that can be utilized by Texas utilities for future implementation of DPR projects. The

DPR Study is a cooperative effort funded by the Texas Water Development Board (TWDB) and a number of sponsor organizations: Brazos Valley Groundwater Conservation District, El Paso Water Utilities, North Texas Municipal Water District, San Antonio Water System, Trinity River Authority, WateReuse Texas, and the Cities of College Station, Dallas, Fort Worth, Houston, Irving, Lewisville, and Lubbock.

1.1 Purpose of Memorandum

The scope of the DPR Study includes a workshop (Workshop #1) that will focus on a discussion of potential water quality performance targets for DPR projects. The purpose of this technical memorandum is to provide information as background material for workshop participants on categories of contaminants relevant to DPR, approaches and frameworks for regulating potable reuse projects, and strategies for assigning water quality performance targets.

1.2 Performance Targets for Direct Potable Reuse

The concept of developing performance targets is premised on the recognition that, given the absence of an environmental buffer, DPR projects are inherently different than indirect potable reuse projects or conventional water treatment projects in terms of a number of factors including:

- Reduced response times to address potential treatment failures or other compromises to water quality (due to the lack of an environmental buffer);
- Differences in characteristics of source water to be turned into drinking water (e.g., treated wastewater as compared to traditional drinking water sources);
- Need to verify treatment reliability to ensure the quality of the final product water depending on water source, treatment scheme, blending scheme, and other specific aspects of a project; and
- Public acceptance of DPR.

Due to these factors, the implementation and operation of a DPR project will likely need to incorporate some form of "enhanced" performance targets beyond those established under the Safe Drinking Water Act. Each of these issues is discussed further below.

1.2.1 Reduced Response Time

The use of an environmental buffer has historically been utilized for indirect potable reuse systems (typically via groundwater recharge, surface water discharge, or treatment wetlands). With advancements in treatment technologies, the necessity of environmental buffers has been questioned and will be further investigated in Task 7 of the DPR Study. The transport of reclaimed water to and from the environmental buffer can involve significant capital and operational costs. In addition, some communities, particularly in more arid regions, have limited availability of viable environmental buffers. Transition to DPR projects would mean the loss of an environmental buffer, resulting in a reduction in response time prior to distribution to the potable water system. In indirect potable reuse systems, detention times ranging from several months to several years allow operators to identify and respond to operational problems or other situations that may compromise water quality. Although DPR systems could incorporate engineered storage buffers, the concomitant cost could be cost-prohibitive, especially if the goal was to provide the same long-term storage as a water supply reservoir, major river, or aquifer. The DPR Study will investigate the role that "enhanced" performance targets may have in mitigating the risk associated with reduced response time and could include end-of-treatment-based targets, early stage unit process-based targets, or operational/maintenance-based targets.

1.2.2 Differences in Source Water Quality

Due to its size and a very wide range of hydrologic, geologic and ecosystem conditions, source water characteristics in Texas are highly variable, both spatially and temporally. Consequently, water providers have adapted strategies to effectively manage treatment of their specific source waters using a wide variety of water treatment technologies. For DPR systems, reclaimed water becomes another source water and can have significantly different characteristics from traditional source waters. While the quality of any reclaimed water will be closely tied to its originating drinking water source, the introduction of additional microbial and chemical constituents through municipal and industrial use of the water can change its quality characteristics markedly. Performance targets for DPR should take into account the unique quality issues (including both concentrations and variability) associated with using reclaimed water as a source water in comparison to traditional supplies.

1.2.3 Treatment Reliability

Key factors to the success of DPR systems include knowledge and understanding of system reliability and control of variability depending on the raw water source, treatment scheme, blending scheme, use of storage, etc. A basic requirement for drinking water regardless of whether it originates from conventional drinking water sources or from reclaimed water sources, is to limit the risk to a level that has been deemed to be acceptable. This specific issue includes addressing process reliability and robustness, which can be shaped by the development of performance targets.

1.2.4 Public Acceptance

The use of an environmental buffer in indirect potable reuse projects can provide an important physical barrier in the minds of the public, in effect eliminating the association with the wastewater history and resulting in the acceptance of reclaimed water as a source of drinking water. However, a recent research study funded by the WateReuse Research Foundation (WRRF) found that when a focus group understood the "context of the urban water cycle" this understanding had an "immediate, positive impact on the acceptance of drinking water reuse, including what is referenced by water professionals as direct potable reuse." While the focus group was seemingly open to drinking reclaimed water, the study found that the focus group would want assurances about monitoring processes. Notably, study participants were "concerned about the possibility that closing the water loop might create problems. These problems were ill-defined but appeared to include concerns about consistent high-quality water," (Macpherson and Snyder, 2012). Therefore, this study suggests that well-defined performance targets, in association with public education efforts, will aid in the public acceptance of DPR projects.

1.3 WateReuse Research Foundation Project 11-02 Report

In 2011, WRRF approved funding for Project WRRF 11-02 titled "Equivalency of Advanced Treatment Trains for Potable Reuse." One of the goals of this ongoing study, which is being conducted by a team of consultants led by Trussell Technologies, is to develop criteria which are protective of public health and can be used to evaluate the viability of various treatment strategies for potable reuse systems. A second phase of the project will create a toolbox of unit process models that can be combined to model an integrated treatment train. One of the deliverables from this project is a report summarizing the state of the science with respect to potable reuse and the proposed performance "equivalency" criteria to be used as metrics to determine the equivalency of potential treatment schemes in the second phase (Trussell, et al., 2013). Much of the background information provided in this memorandum has been obtained and/or adapted from this report, hereafter referred to as the "WRRF State of Science Report". In addition, since it is so directly relevant to the TWDB DPR Study, a subsequent section of this memorandum will provide a summary of the potable reuse criteria proposed in the WRRF State of Science Report.

2 CONSTITUENTS OF CONCERN FOR POTABLE REUSE

The primary consideration during the implementation of a DPR project is the protection of public health. While the detection of constituents of concern has increased in recent years due to advances in water quality testing technology that enable detection at increasingly lower concentrations, the concentration of constituents of concern in the nation's water supply is generally very low. All DPR Study sponsors and consultants are committed to facilitating a process that will both ensure the protection of public health and provide practical approaches to implementation of DPR projects that are appropriate for Texas water providers. Microbial and chemical contaminants are the primary categories of constituents that are related to human health impacts and include regulated and unregulated parameters. In addition to health-related considerations, aesthetic issues, while largely unregulated, are also an important consideration for the public acceptance of a DPR project.

2.1 Microbial Contaminants

Microbial contaminants in reclaimed water can include bacteria, viruses and protozoan parasites. Pathogenic microorganisms (microorganisms that can cause disease in a host) are widely acknowledged as the most critical element with respect to potential acute impacts on human health in public water supplies. The presence and concentration of pathogens in treated wastewater varies depending on infection patterns in the community tributary to the wastewater management system. Table 1 provides a summary of the fifteen most common illness-causing pathogens in the United States. Although Table 1 represents all cases in the United States (food, personal contact, drinking water, contact with recreational water, fomite[1], etc.), this information does provide a general indication of the pathogens that are most likely to be present in raw wastewater.

Table 1: Fifteen pathogens causing the highest level of illness in the United States annually[a]

Rank	Pathogen	Episodes	Hospitalizations	Deaths
1	*Norovirus*	20,796,079	55,825	569
2	*Giardia intestinalis*	1,121,864	3,289	31
3	*Salmonella* spp. (non-typhoid)	1,095,079	20,608	403
4	*Campylobacter* spp.	1,058,387	10,599	95
5	*Clostridium perfringens*‡	966,120	438	26
6	*Cryptosporidium* spp.	678,828	2,438	42
7	*Shigella* spp.	421,048	4,672	32
8	*Staphylococcus aureus*‡	241,188	1,063	6
9	*Toxoplasma gondii*	173,415	8,859	654
10	*STEC* non–O157	138,063	331	0
11	*Yersinia enterocolitica*	108,490	592	32
12	*STEC* O157	93,094	3,152	30
13	*Bacillus cereus*‡	63,411	20	0
14	*Vibrio parahaemolyticus*	40,309	116	4
15	Diarrheagenic *E. coli* other than STEC and ETEC	39,739	26	0

[a]Source: Trussell, et al., 2013, Table 1.9 (Based on Scallan et al., 2011). The Centers for Disease Control (CDC) compiled these data as part of a foodborne illness study; estimates were possible for 31 pathogens. Three additional viral pathogens (astrovirus, rotavirus, and sapovirus) were measured, but not included in this table due to CDC's assumption that they are only relevant for children under 5 years of age.

The ability to routinely measure specific pathogens in water is limited by the availability of reliable and sensitive analytical methods. Consequently, there is very little specific pathogen data available and surrogate parameters, such as coliforms, must still be used to characterize desired treatment levels. However, with the increased interest in advancing DPR, there has been significant interest in advancing

[1] Any inanimate object or substance capable of carrying infectious organisms and hence transferring them from one individual to another.

capability with respect to monitoring of pathogens and real-time monitoring of surrogate parameters, and research in this area is ongoing.

Most bacteria associated with waterborne diseases are relatively susceptible to chemical disinfection practices such as chlorination and chloramination, or ultraviolet radiation. Viruses typically are more resistant to environmental stresses than bacteria are. Numerous studies have used viruses as model organisms to determine the fate of microorganisms because viruses can be more resistant to disinfection than bacteria and are smaller in size, which makes them more difficult to remove by granular filtration.

Cryptosporidium and *Giardia* are the most common enteric protozoan parasites associated with reported waterborne disease outbreaks. In water and wastewater, protozoa may produce cysts or oocysts that aid in their survival. Consequently, these organisms can be highly resistant to chlorine disinfection and must generally be controlled by other means, such as filtration, ultraviolet radiation, or ozone oxidation (TWDB, 2010).

2.2 Chemical Contaminants

Chemical contaminants can be of concern for acute and chronic exposure effects. The composition of chemical contaminants is unique for every reclaimed water source at any given time. Factors such as industry volume and types, land use, source control programs, and treatment all play an important role in the types and concentrations of chemical contaminants present in reclaimed water. Additionally, naturally occurring inorganic chemicals and salts that are present in source water and the addition of water and wastewater treatment chemicals impact the quality of reclaimed water sources. Categories of chemical contaminants are summarized in Table 2.

2.2.1 The Role of Total Organic Carbon

Monitoring the concentrations and toxicities of thousands of potential organic compounds in a reclaimed water source would be an infeasible task. Total organic carbon (TOC) has been cited as a potential surrogate parameter that could be used to evaluate removal of organic contaminants for potable reuse applications. TOC also has been used for many purposes to gauge the risk from unregulated and unidentified organic compounds. Most recently, TOC has also been used to indicate the potential for disinfection byproduct formation.

Although a useful and well-known parameter, using TOC as a surrogate for trace organics presents some challenges. TOC is often present in source water in a wide range of concentrations. The unidentified bulk of residual TOC in reclaimed water, also called effluent organic matter (EfOM), is comprised largely of humic and fulvic acids, soluble microbial products created during the wastewater treatment process, and natural organic matter (NOM) contributed by drinking water sources (Drewes et al., 2003, 2006; Fox et al., 2001, 2006). The TOC test cannot distinguish between NOM and EfOM. After soil aquifer treatment or advanced treatment, the resulting TOC, which is non-biodegradable, may be a function of the originating drinking water source NOM (Drewes et al, 2000).

A recent study supported by the National Water Research Institute has recommended the use of biodegradable organic carbon (BDOC), combined with a suite of indicators as an alternative approach to the use of TOC for evaluating soil aquifer treatment effectiveness (Drewes et al., 2012). BDOC can serve as a performance surrogate for biodegradable compounds and the suite of indicators provides a means of estimating removal of compounds with a range of physical-chemical properties.

Table 2: Major chemical contaminant categories[2]

Category	Description
Nutrients	Discharge to receiving waters can cause algal blooms and eutrophication (not applicable for direct potable reuse). Some nutrients (i.e., nitrates) do have maximum contaminant levels (MCLs) for drinking water.
Total Dissolved Solids (TDS and associated ions)	The TDS of reclaimed water sources is generally higher than the potable water source in the region, and without treatment to remove dissolved salts, the TDS concentrations in a reclaimed water source could be significant (the secondary MCL for TDS in Texas is 1,000 milligrams per liter (mg/L)). In addition, in a closed-loop, direct potable reuse system, the TDS will become more concentrated over time if none of the dissolved solids are removed in the treatment process.
Metals	Toxic metals are considered priority pollutants and pretreatment programs now regulate industrial discharges to wastewater systems, although they are likely to still be present in raw wastewater streams. Naturally occurring metals can also be a concern, as well as in distribution systems with significant quantities of lead pipe.
Nanomaterials	The increased use of nanomaterials for a wide range of applications in recent years has introduced these contaminants into reclaimed water supplies. Information on the potential risk of nanomaterials in potable reuse applications is limited at this time.
Trace Organic Chemicals	The trace organic chemical category includes compounds that are naturally occurring, synthetically produced, or are formed as a result of chemical reactions and transformations (i.e., disinfection byproducts). Trace organic chemicals are known to occur in traditional and reclaimed water sources, but generally occur at a greater frequency in reclaimed water applications. However, even at the concentrations typical of secondary effluent, many trace organic chemicals pose no risk to human health due to the tremendous volume of water that would have to consumed before any adverse or therapeutic effects would be observed (Snyder et al, 2008). The potential risk of compounds not intended for human consumption (i.e., pesticides and organic solvents) which are present at very low concentrations in most reclaimed water supplies is more difficult to quantify. Critical contaminants for potable reuse include those that are already regulated through the drinking water standards as well as some unregulated contaminants such as unregulated, or "emerging" disinfectant byproducts. Indicator compounds and surrogates can be used to evaluate treatment effectiveness on groups of unregulated compounds with similar structure or reactive properties.

[2] Information from Table 2 adapted from Trussell et al., (2013) and TWDB (2010).

2.3 Aesthetic issues

In addition to public health protection, the aesthetic quality of potable reuse water can be very important, particularly as it relates to public perception. Table 3 includes some metrics and indicator parameters that have recently been identified by regulatory agencies or in the literature related to aesthetics. Establishing targets for aesthetic indicators may be desirable or necessary in order to help obtain public acceptance for a DPR project.

Table 3: Potential metrics and indicator parameters for direct potable reuse aesthetics

Metrics	Indicator Parameters
Organic Matter Concentration	Total Organic Carbon (TOC)
Color	Dissolved Organic Carbon (DOC)
Absorbance	Color
Fluorescence	UV 254 Absorbance (UVA)
Solids Concentration	Specific UV Absorbance (SUVA)
Odor	Total Fluorescence (TF)
Mineralization	Fluorescence Indices/Ratios
	Total Suspended Solids (TSS)
	Turbidity
	Total Dissolved Solids (TDS)
	Conductivity
	Chloride
	Odor
	Hardness

Source: Trussell et al. (2013).

3 CONTAMINANT RISK IN POTABLE REUSE

Risk analysis is a technique used by environmental professionals to quantify the potential for human health effects as the result of an environmental action. Typically, a risk analysis approach includes two distinct phases: risk assessment and risk management. Risk assessment, which includes an analysis of the potential effect of certain hazards to human health, includes the following four steps (Tchobanoglous et al., 2003):

- Hazard identification – includes the examination of evidence and determination of whether a constituent exhibits an adverse health hazard.
- Exposure assessment – includes the identification of exposure pathways and routes and the quantification of exposures.
- Dose response assessment – the definition of the relationship between the amount of a constituent to which a human is exposed and the risk of an unhealthy response.
- Risk characterization – the identification of what segment of the population is affected and what the likely effects are expected to be.

Risk management includes the development of standards, guidelines, and management strategies for specific constituents.

3.1 *De minimis* vs. acceptable risk

Risk is inherent in all human activities. While risk assessment is a powerful tool to reduce risk levels, no human activity should ever be considered to be "risk free." When incorporating risk assessment into a DPR project, it is recommended that the process be made transparent to the general public. Generally, members of the public tend to believe that for potable reuse to be acceptable, water should be guaranteed to be absolutely risk free. However, it is not feasible to make this guarantee. Therefore, the concepts of *de minimis* and acceptable risk are typically used when determining safe levels for regulatory purposes.

De minimis risk, which is defined as a level of risk characterized by the risk being virtually non-existent, is often used in the regulatory realm to describe risks that are "below regulatory concern." While no activity should be considered "risk free," *de minimis* risk levels infer that the activity is essentially "risk free." Traditionally, for drinking water supplies, *de minimis* risk levels are related to health criteria (toxicity of the constituents, the characteristics of the population, and exposure). Different risk levels are used, depending on the specific situation and type of contaminant. The United States Environmental Protection Agency (EPA) Office of Drinking Water uses a "regulatory window" of 10^{-6} to 10^{-4} for evaluation of risk where 10^{-4} is the baseline risk for all regulations and 10^{-6} is the *de minimis* risk level. A specific legal mandate has not been established for acceptable pathogen risk. In the Surface Water Treatment Rule (SWTR), however, EPA first stated its goal to achieve a 10^{-4} annual risk of infection for both *Giardia* and viruses (US EPA 1989a). This goal is also implicit in the log reduction requirements for *Cryptosporidium* in the Long Term 2 Enhanced Surface Water Treatment Rule (LT2). Since the SWTR, this level of risk has served as a *de facto* standard for the industry (CDPH, 2013, NRC, 1998). While this level is not achieved in all regulations, it is frequently used as the target risk level.

Acceptable risk differs from *de minimis* risk in that it incorporates factors beyond health-based criteria alone, such as the technological feasibility or economic impacts of achieving a given level of risk. Under ideal conditions, the acceptable risk would meet the *de minimis* criteria while being technically and economically practical. However, a compromise between the lower levels of risk and the availability of technology and/or economic limitations is sometimes justified.

3.2 Pathogen risk

Modern treatment processes, while capable of substantial reductions, are unable to completely reject pathogens. Additionally, the limits of modern testing methods, which are able to detect pathogens at extremely low, but finite levels, would be unable to confirm the complete eradication of pathogens if accomplished. The WRRF State of Science Report provides a relevant example:

> "To achieve virus concentrations of 10^{-7} per liter (an extremely low concentration, but still greater than no viruses per liter), one would have to be able to detect a single virus in 10^{7} liters of water, a volume equivalent to four Olympic-sized swimming pools. Processing this volume of water to detect that single virus is not feasible with current technology. Even if we could establish that the virus concentration was demonstrated to be below 10^{-7} per liter, the water would still technically not be "free of pathogens."

The commonly used *de minimis* risk level for pathogens, as noted above, is the concentration associated with a 10^{-4} annual individual risk of infection. This level was established by Regli et al. (1991) and is a widely recognized and utilized value. This risk level is consistent with the standards applied to conventional drinking water sources.

3.3 Chemical risk

Thousands of chemicals, with a broad range of sources, characteristics and concentrations, are present in wastewater effluent. For regulated chemicals, a *de minimis or* an acceptable risk level for a given constituent is established as part of developing regulatory limits. These limits are typically based on benchmarks of the *de minimis* risk level, expressed as an acceptable daily dose (mg/kg/d) or as an acceptable concentration in drinking water (mg/L). For regulated chemicals, *acceptable* risk levels have been established and used by the EPA to assign MCLs.[3] For unregulated chemicals, literature information may be available to establish *de minimis* risk levels for some chemicals where toxicity information is available. For those lacking toxicity information, estimates of risk level levels can be made based on similarities of the chemical to the function and structure of chemicals of known toxicity.

4 EXISTING POTABLE REUSE GUIDELINES AND REGULATIONS

4.1 Federal and State Drinking Water Standards

Potable reuse projects include requirements to meet drinking water standards adopted by states under the Safe Drinking Water Act (SDWA).

The SDWA allows the EPA to promulgate national primary drinking water standards specifying MCLs for each contaminant present in a public water system with an adverse effect on human health, taking into consideration cost and technical feasibility. MCLs have been established for approximately 90

[3] The Safe Drinking Water Act also considers other factors when establishing MCLs in addition to risk. The Clean Water Act only considers risk when establishing recommended human health water quality criteria.

contaminants in drinking water.[4] In cases where the MCLs cannot be feasibly ascertained, the EPA may elect to identify and establish a schedule of "treatment techniques" preventing adverse effects on human health to the extent feasible.

Drinking water MCLs are established in two steps. First, the EPA establishes MCL goals, which are the maximum levels of a contaminant in drinking water at which no known or anticipated adverse effect on the health of persons would occur, and which allow an adequate margin of safety. These have been historically set at zero for microbial and carcinogenic contaminants. Once the MCL goal is established, the EPA determines the feasible MCL or treatment technology level that may be achieved with the use of the best available technology and treatment techniques, and taking cost into consideration.

On March 22, 2010, the EPA released a new strategy for drinking water standards development (U.S. EPA, 2010). The shift in drinking water strategy is organized around four key principles: 1) to address contaminants as a group rather than one at a time so that enhancement of drinking water protection can be achieved cost-effectively; 2) to foster development of new drinking water treatment technologies to address health risks posed by a broad array of contaminants; 3) to use the authority of multiple statutes to help protect drinking water; and 4) to partner with states to share more complete data from monitoring of public water systems.

The SDWA includes a process that the EPA must follow to identify and list unregulated contaminants that may require a national drinking water regulation in the future. This process requires the periodic publication of a list of contaminants called the Contaminant Candidate List (CCL). The EPA must then decide whether to regulate at least five or more contaminants on the list. The list is also used by the EPA to prioritize research and data collection efforts to help the agency determine whether it should regulate a specific contaminant. In September 2009, the EPA published the final version of the third CCL (CCL3). The list contains 104 chemicals or chemical groups, including pesticides, disinfection byproducts, chemicals used in commerce, waterborne pathogens, pharmaceuticals, steroid hormones, and biological toxins.[5] Sampling for the third Unregulated Contaminant Monitoring Regulation (UCMR 3) will occur from 2013-2015. Data collected through UCMR are used to support analysis and review of contaminant occurrence, to guide the CCL selection process, and to support the EPA Administrator's determination of whether to regulate a contaminant in the interest of protecting public health. Thus, pharmaceuticals and steroid hormones have the potential to be selected for development of future drinking water standards.

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[4] For a current list of maximum contaminant levels, see http://www.epa.gov/safewater/contaminants/index.html.

[5] For the list of contaminants see http://www.epa.gov/safewater/ccl/ccl3.html

There are also a variety of chemicals of health concern whose occurrence is too infrequent in conventional drinking water sources to justify the establishment of national standards but are addressed using advisory levels. The EPA establishes health advisories (U.S. EPA, 2012a) to address many of these latter chemicals. As another example, in California, Notification Levels and Response Levels established by the California Department of Public Health (CDPH) have been established for chemicals in drinking water without MCLs.[6] If a chemical concentration is greater than its Notification Level in drinking water, the utility must inform its customers and consumers about the presence of the chemical, and about health concerns associated with exposure to it. If a chemical is present in drinking water that is provided to consumers at concentrations greater than the Notification Level (10 to 100 times greater depending on the toxicological endpoint), the CDPH recommends that the source be taken out of service (Response Level).

4.2 Potable Reuse Regulations and Guidance

4.2.1 Direct Potable Reuse

At this time, there are only two operational direct potable reuse projects each of which has project-defined regulatory requirements: the Big Spring, Texas Project and the Windhoek, Namibia Project.[7] To date, no states have developed or proposed regulations or guidelines specifically governing DPR. California has a statutory mandate for CDPH to investigate the feasibility of developing regulatory criteria for DPR and to provide a final report on that investigation to the Legislature by the end of 2016.

The Colorado River Municipal Water District (CRMWD) Project at Big Spring is capturing 2.5 million gallons per day of filtered secondary effluent, treating the effluent with advanced treatment, blending the treated water in the raw water transmission line, and treating the blended water in a water treatment plant before distribution. A schematic of the treatment plant is presented in Attachment A. The Texas Commission on Environmental Quality (TCEQ) has granted an exception request to use membrane treated reclaimed wastewater from the Big Spring Wastewater Treatment Plant as a raw water source for public water systems for the Cities of Big Spring, Snyder, Odessa, Stanton, and Midland (TCEQ, 2010, 2013). This exception includes design, operational, reporting, calibration, and record keeping requirements, including turbidity for the influent to the CRMWD treatment facility (effluent from the City of

[6] See http://www.cdph.ca.gov/certlic/drinkingwater/Pages/NotificationLevels.aspx

[7] This does not include requirements placed on the International Space Station. It is not considered to be a DPR project since it is designed to produce potable water from condensate and urine, and thus does not treat the same source water (municipal wastewater) as municipal DPR projects.

Big Spring WWTP), integrity testing for membranes, continuous monitoring of membrane units, membrane design specifications, and testing, operation and design of the ultraviolet light system. An instantaneous blending ratio of 20% was set. All treatment approved by TCEQ must be applied to all the water and must be operated to the parameters set in the exception letter. A copy of the TCEQ exception letters is provided in Attachment A. Final approval of the project was contingent upon completion of chemical testing. The TCEQ is also considering DPR proposals from other communities and is evaluating each on a case-by-case basis. The only other operational DPR project is in Windhoek, Namibia, where highly treated reclaimed water is put into a drinking water system that serves 250,000 people. The DPR system in Windhoek has been in operation since 1968. The current treatment plant (the New Goreangab Water Reclamation Plant) produces about 5.5 million gallons per day of reclaimed water. A "multiple barrier" approach was used to select the treatment process technology for the plant such that two to five barriers are in place to address microbial and chemical contaminants (Lahnsteiner and Lempert, 2007). The unit processes are shown in Attachment B. Water quality guarantee values have been established for the project based on the World Health Organization (WHO) Guidelines, the Rand Water Guidelines (South Africa), and the Namibian Guidelines for Group A Water (see Attachment B). Water samples are collected every four hours for analysis. The reclaimed water is blended with treated dam water and/or groundwater. The maximum portion of reclaimed water fed into the distribution system is 50 percent in times of low water demand (winter season) (Lahnsteiner and Lempert, 2007).

4.2.2 Indirect Potable Reuse

As of August 2012, nine states had developed regulations (some draft) and/or guidance for indirect potable reuse (U.S. EPA, 2012b): Arizona, California, Florida, Hawaii, Massachusetts, Pennsylvania, Utah, Virginia, and Washington.[8] In looking at the different regulations, there are common elements for all or most states: requirements for source control (industrial pretreatment); treatment requirements; monitoring requirements; and minimum retention time underground prior to withdrawal as a source of drinking water (U.S. EPA, 2012). Several states also specify minimum separation distances between a point of recharge and the point of withdrawal as a source of drinking water or a requirement to conduct pilot studies (U.S. EPA, 2012). A table summarizing the regulations / guidance is provided in Attachment C. It is of interest to note that the CDPH's draft groundwater recharge regulations have proposed establishing specific pathogen reduction treatment requirements in lieu of requiring a minimum underground residence time for pathogen protection and a response retention time (underground

[8] Since the publication of the 2012 *Guidelines for Water Reuse*, the CDPH has revised its draft groundwater recharge regulations (March 2013); however, the revisions are not substantively different than the November 2011 draft.

retention time requirement) to respond to failures and emergencies. The minimum allowed time is 2 months, thereby distinguishing an indirect potable reuse project from a DPR project.[9]

4.3 Frameworks for Control of Unregulated Contaminants

4.3.1 Acceptable Levels for Unregulated Contaminants

There is a distinct possibility that some unregulated chemicals with the potential of producing adverse health effects may occur in the wastewater being treated and possibly in the produced reclaimed water at concentrations that would be of health concern. If such compounds are identified, it is important to establish criteria that would be equally protective of public health as chemicals for which drinking water standards have been established (NWRI, 2013).

As discussed in Section 3.3, one approach to addressing these kinds of chemicals is to use “acceptable” levels for unregulated contaminants that have been developed through studies that look at relevant toxicological endpoints and derive predicted no-effect concentrations. The predicted no-effect concentration is the level below which exposure to a substance is not expected to cause adverse effects.

4.3.2 Technical Framework

Tchobanoglous et al. (2011) identified a number of specific technical issues that should be considered for DPR projects. These kinds of issues (see Table 4) in of themselves provide a framework that can be directly used or customized to address DPR projects for planning and implementation.

Table 4: Technical issues in the implementation of DPR

Consideration	Comments / questions
Source control	• Identification of constituents that may be difficult to remove (depends on technologies used). • Development of baseline sources and concentrations of selected constituents. • Define improvements that need to be made to existing source control programs where DPR is to be implemented.

[9] The 2 month response retention time is not guaranteed and must be approved by the CDPH based on the specifics of a project.

Consideration	Comments / questions
Influent monitoring	• Development of influent monitoring systems, including constituents, parameters, and monitoring recommendations. • Investigate potential benefits of various influent-monitoring schemes that may be used for early detection of constituents. • Consideration of how influent monitoring data could be used to adapt treatment operations depending on variable influent characteristics.
Flow equalization	• Determination of the optimum location and type (in- or off-line) in secondary treatment process with respect to enhanced reliability and removal of trace constituents. • Determination of optimum size of flow equalization before advanced treatment. • Quantify the benefits of flow equalization on the performance and reliability of biological and other pretreatment processes.
Wastewater treatment	• Quantify benefits of optimizing conventional (primary, secondary, and tertiary) processes to improve overall reliability of entire system. • Quantify the benefits of complete nitrification or nitrification and denitrification on the performance of membrane systems used for DPR applications.
Performance monitoring	• Determine monitoring schemes to document reliability of treatment performance for each unit process and validate end-of-process water quality.
Analytical/monitoring requirements	• Selection of constituents and parameters that will require monitoring, including analytical methods, detection limits, quality assurance/quality control methods, and frequency. • Determination of how monitoring systems should be designed in relation to process design. • Development of appropriate monitoring systems for use with alternative buffer designs.
Advanced wastewater treatment (water purification)	• Develop baseline data for treatment processes employing reverse osmosis. The Orange County Water District (California) can be used as a benchmark. • Development of alternative treatment schemes with and without demineralization that can be used for water purification. • Quantify benefit of second stage (redundant) reverse osmosis.
Engineered storage buffer	• Development of sizing guidelines based principally on existing analytical, detection, and monitoring capabilities to assess technical and economic feasibility of utilizing engineered storage buffer. • Characterize the impact of existing monitoring response times on the safety and economic feasibility of implementing an engineered storage buffer.

Consideration	Comments / questions
Balancing mineral content	• Development of recommendations for balancing water supply mineral content in consideration of site-specific factors, such as magnesium and calcium. • Determination of potential impacts of various water chemistries on infrastructure and public acceptance. • Development of specifications for chemicals used for balancing water quality.
Blending	• Development of guidance on what level of blending, if any, is required based on the quality of the purified water and alternative water sources. • Investigation of the significance of and rationale for blend ratios in terms of engineered buffer, protection of public health, public acceptance, and regulatory acceptance. • Investigation of potential impacts of purified water on drinking water distribution system, for example corrosion issues, water quality impacts.
Emergency facilities	• Stand-by power systems in the event of power loss or other emergency. • Availability of all replacement parts and components that would be required in the event of a process breakdown. • Process redundancy so that treatment trains can be taken off-line for maintenance. • Facilities for the by-pass or discharge of off-spec water in the event that the water does not meet the established quality requirements.
Pilot testing	• Utilization of a review panel for advice and recommendations of design, operation, monitoring plan for a project's pilot system to ensure that it will be representative of the proposed full-scale system. • Development of monitoring protocol for collection of baseline data for "raw" water input to an advanced water treatment pilot plant; how much testing and for what duration (for example 6 months to 1 year). • Development of pilot study design so that results can be used to assess reliability with proposed source water.

Source: Tchobanoglous et al., 2011, From Table 4-2.

4.3.3 International Guidelines

To generate a nationally consistent approach to the management of health and environmental risks from water recycling, Australia has developed a suite of documents that make up the Australian Guidelines for Water Reuse. The guidelines were developed by the National Health and Medical Research Council in collaboration with the Natural Resource Management Ministerial Council. Phase 2 of the guidelines covers the use of reclaimed water to augment drinking water supplies and managed aquifer recharge. The guidelines build upon a risk management framework as detailed in the 2004 Australian Drinking Water Guidelines as shown in Figure 1. (Health and Medical Research Council, Natural Resource

Management Ministerial Council, 2004). The framework provides generic guidance based on 12 elements that form a structured and systematic approach for the management of water quality from catchment to consumer, to assure its safety and reliability, rather than relying on verification monitoring. By replacing "drinking" with "reclaimed" these elements apply in exactly the same way to the framework for reclaimed water quality.

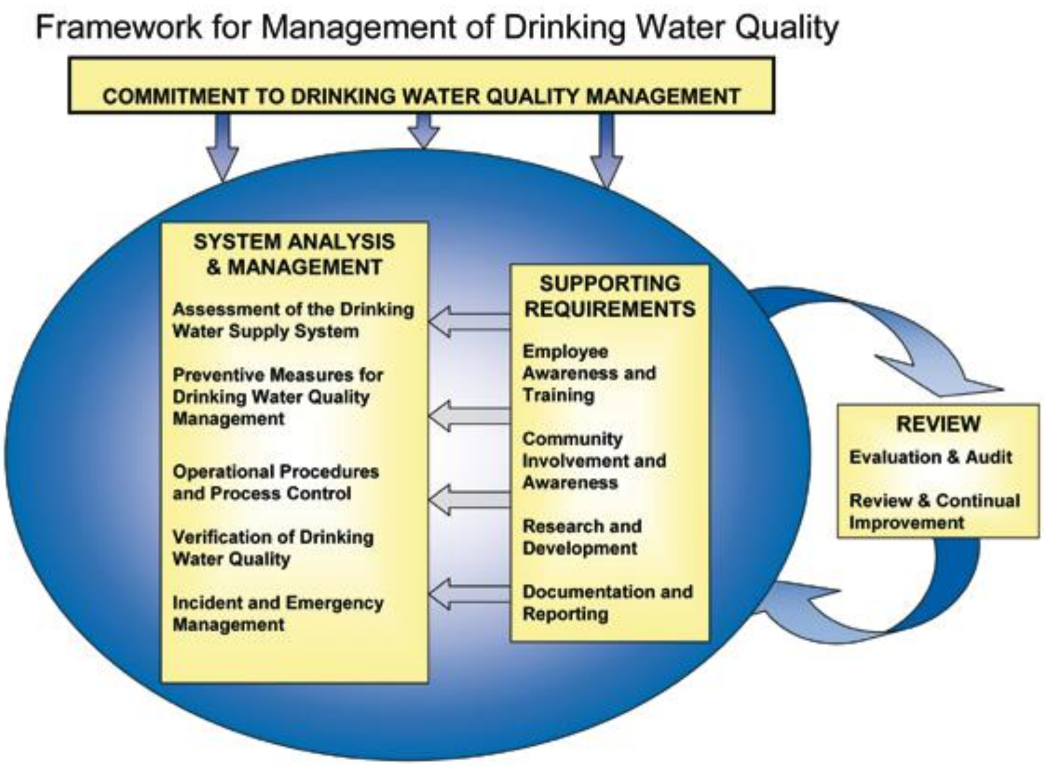


Figure 1: Framework for Australian management of drinking water quality (Source: Lovell and Deere, 2009)

Management of water resources in Australia is the responsibility of the states, rather than the federal government. Thus, the guidelines are not mandatory and have no formal legal status. However, their adoption provides a shared national objective and allows states and/or local jurisdictions to independently adopt them or to use their own legislative and regulatory tools to refine them into their own guidelines. To date, all of the state health regulators have taken and implemented the guidelines either in their entirety or with some minor modifications.[10]

[10] Personal communication from Adam Lovell, Water Services Association of Australia, July 31, 2009.

The United Kingdom's Framework for Developing Water Reuse Criteria was commissioned by the United Kingdom Water Industry Research Limited, the Water Research Foundation, and the WateReuse Foundation. It consists of a framework developed by an international committee of experts as part of a two-day workshop that took place in April 2004 (UKWIR, 2004). The framework is similar to the Australian Guidelines in that it takes a risk management approach as a guide for reuse. The framework includes an overarching component and detailed components for specific uses based on varying levels of treatment. The overarching component consists of identifying hazards, barriers to hazards, and management tools, and verification by independent third parties. Unlike the Australian framework, this approach includes verification monitoring. The United Kingdom framework has not been formally adopted for use.

4.3.4 Hazard Analysis Critical Control Point

The hazard analysis critical control point (HACCP) concept, which originated as a systematic approach to food safety, has the potential to be applied to potable water reuse. The concept involves a number of specific steps as part of its implementation:

- Conduct a hazard analysis
- Identify critical control points
- Establish preventive measures with critical limits
- Establish procedures to monitor critical control points
- Establish corrective actions
- Establish verification procedures
- Establish record keeping procedures

In 2009, the WRRF funded a project (WRRF 09-03) to develop an approach for monitoring and managing microbial water quality in reclaimed water, based on HACCP, to build on the Australian and broader international experience with these types of systems. The final report for the project has not been published. However, preliminary findings highlighted notable differences in the United States regulatory structure compared with some countries where HACCP approaches have been adopted, such as Australia. It is believed that the more prescriptive (statutory-based regulated) approach adopted in the United States does not provide the same degree of flexibility in achieving the desired water quality outcome. For example, in theory the adoption of a hazard analysis critical control point approach should reduce the need for compliance monitoring. However, in the current United States regulatory environment, this may not be easily achieved. There were also concerns that the United States regulators might elect to require a HACCP approach in addition to current requirements. While the HACCP approach is one example of a framework for risk management, well-functioning United States treatment plants have invested considerable effort to implement their own systems that in large part address many of the issues covered as part of a hazard analysis critical control point approach.

4.3.5 CDPH Drinking Water Permitting of Impaired Groundwater Sources

One other framework that may have some application for DPR is the CDPH approach to permitting an extremely impaired groundwater source for a water supply. While the quality of reclaimed water used for DPR will be significantly better than the criteria[11] used to define impaired groundwater, the evaluation approach nevertheless is relevant in that it allows the use of water that has some degree of uncertainty or risk associated with using it to be considered as a drinking water source. Before approving the groundwater permit for this type of water, CDPH conducts an evaluation with information provided by an applicant pursuant to Policy Memo 97-005 *Policy Guidance for Direct Domestic Use of Extremely Impaired Sources*.[12] The evaluation process consists of:

1. A review of a *source water assessment* that has been conducted by the applicant to determine the extent to which the aquifer or surface water is vulnerable to contaminating activities in the area;
2. A review of the *raw water quality* for all regulated and unregulated chemicals;
3. A determination if a *source protection program* is in place to control the level of contamination;
4. A determination if the applicant has an effective *monitoring program* and will provide *treatment* commensurate with the degree of risk associated with the contaminants present;
5. A review of an assessment by the applicant regarding the *risks of failure of the proposed treatment system* and any *potential health risks* that would result; and
6. A review of the *alternatives* to the use of the extremely impaired source and of the *potential health risk* associated with the alternatives in comparison to the risk incurred by using the impaired source.

5 SUMMARY OF CRITERIA FROM “EQUIVALENCY OF ADVANCED TREATMENT TRAINS FOR POTABLE REUSE” (WRRF 11-02)

As noted earlier, in order to address several research priorities for DPR, the WRRF provided funding for WRRF 11-02, entitled “Equivalency of Advanced Treatment Trains for Potable Reuse.” The major

[11] CDPH considers a groundwater source to be extremely impaired if it meets one or more of the following criteria: exceeds 10 times the MCL or Notification Level based on chronic health effects; exceeds 3 times an MCL or Notification Level based on acute health effects; is extremely threatened with contamination due to proximity to known contaminating activities; contains a mixture of contaminants of health concern; and is designed to intercept known contaminants of health concern.

[12] *See* http://www.dhs.ca.gov/ps/ddwem/chemicals/PDFs/memo97-005.pdf

research goals of this project are two-fold. The first is to develop a single set of potable reuse criteria that are protective of public health. Second, these equivalency criteria are then utilized to evaluate treatment trains with the goal of determining which treatment options are capable of satisfying these criteria. Since California is one of the few states that has developed regulations (although still draft) for potable reuse (groundwater recharge) and there is significant interest among California utilities in pursuing DPR, the CDPH draft groundwater recharge regulations[13] and assumptions are referenced for comparison in the WRRF State of Science Report and are also briefly discussed in this section.

This section begins by laying out the thought process used in developing the public health equivalency criteria for WRRF 11-02, including microbial pathogens and chemical contaminants, as well as aesthetic criteria. Key assumptions made in creating these criteria are then highlighted. The safety factors included in both the CDPH draft groundwater recharge regulations and the 11-02 equivalency criteria are explicitly presented to demonstrate the conservatism included in the process. The section concludes with a discussion of the effectiveness of unit processes in achieving pathogen and chemical removal, and considers what removal credit might be expected from regulatory agencies.

5.1 Pathogen Removal Criteria

The process used to develop the pathogen removal criteria for WRRF 11-02 followed four steps:

1. Review the methodology and criteria used in CDPH's draft groundwater recharge (GWR) regulations;
2. Draft public health criteria that address the limitations of the CDPH criteria;
3. Present the draft criteria to an Independent Advisory Panel (IAP); and
4. Develop final public health criteria based on IAP recommendations.

5.1.1 CDPH Draft Groundwater Recharge Regulations

As a starting point for WRRF 11-02, the project team first evaluated CDPH's draft GWR regulations as a basis for the equivalency criteria. The approach CDPH took in creating their criteria was equivalent to the methodology the National Research Council (NRC) first proposed in their 1998 report *Issues in Potable Reuse* (NRC, 1998). This methodology calculates microbial removal requirements based on the difference in microbial densities between wastewater effluents and drinking water. The methodology utilizes the following four steps (Haas and Trussell, 1998; NRC, 1998):

1. Identify target organisms;

[13] See http://www.cdph.ca.gov/healthinfo/environhealth/water/pages/waterrecycling.aspx.

2. Determine maximum concentrations in raw sewage;
3. Define acceptable concentrations in drinking water; and
4. Determine removal goals based on the difference.

Step 1: Identify Target Organisms

The draft GWR regulations require that recycled municipal wastewater receive treatment to reduce the concentrations of a select group of pathogens—viruses, *Giardia* cysts, and *Cryptosporidium* oocysts—to acceptable levels. The EPA also uses the same group of pathogens in drinking water regulations (U.S. EPA 1989a, 1998, 2006). In both cases, the logic for selecting this particular group of pathogens is to ensure adequate removal of a broad range of pathogen types.

Step 2: Determine Maximum Concentrations in Raw Sewage

CDPH utilized a handful of references to select values for pathogen concentrations in raw sewage (Asano et al., 2007, Robertson et al., 2006, Tetra Tech, 2011). While all references provide a range of pathogen concentrations in raw sewage, it should be noted that CDPH selected the **maximum** concentration from each reference to define the raw wastewater levels. For each pathogen, the maximum density was 10^5 infectious units per liter.

Step 3: Determine Acceptable Concentrations in Drinking Water

As discussed in Section 3, the concept of risk is a critical component in the development of drinking water criteria. In the SWTR, the EPA states that providing treatment to ensure less than one case of illness per 10,000 people is a reasonable goal, which achieves a level of risk comparable to other accepted risk levels (Regli et al., 1991, US EPA, 1989a). Since that time, the United States drinking water community has widely accepted this as the *de facto* target for negligible, or *de minimis*, risk (NRC, 1998, CDPH, 2013). Using this risk level as the goal, the methods of quantitative microbial risk assessment (QMRA) can be used to determine appropriate drinking water concentrations (Haas et al., 1999).

QMRA uses a number of inputs to determine what concentrations pose a *de minimis* threat, including risk levels, pathogen infectivity, and assumptions about water consumption. The infectivity of different pathogens can be obtained from dose-response curves that relate the probability of infection to the ingestion of different quantities of pathogens. Pathogen infectivity is highly variable, with the number of pathogens causing an infection ranging from a single organism to tens of thousands. Using QMRA, with assumptions about water consumption, allows for the calculation of acceptable pathogen concentrations in water.

Step 4: Calculate Removal Goals Based on the Difference

The treatment requirements were determined by calculating the difference in the concentrations in the raw sewage (Step 2) and the finished drinking water (Step 3) according to the following formula:

$$Log\ removal = \log\left(\frac{[Pathogens]_{sewage}}{[Pathogens]_{potable}}\right)$$

where $[Pathogens]_{sewage}$ and $[Pathogens]_{potable}$ are the concentrations of pathogens in the raw sewage and potable drinking water, respectively. Table 5 presents the key inputs for each of the four steps in the process, and the resulting pathogen log removal requirements in the CDPH draft GWR regulations: 12-log virus reduction, 10-log *Cryptosporidium* reduction, and 10-log *Giardia* reduction. The draft GWR regulations specify that the treatment system (raw wastewater through soil aquifer treatment) to achieve these reductions must use at least three treatment barriers.[14]

Table 5: Pathogen removal requirements from CDPH draft groundwater recharge regulations

Parameter	**Units**	**Pathogens**		
		Virus	*Cryptosporidium*	*Giardia*
Raw wastewater	IU/L[a]	10^5	10^5	10^5
Drinking water goal	IU/L	2×10^{-7}	3×10^{-5}	6.8×10^{-6}
Ratio	-	5×10^{11}	3×10^9	1.5×10^{10}
Log removal	**-**	**12**	**10**	**10**

[a] IU/L = infectious units per liter

5.1.2 Draft Public Health Criteria for WRRF 11-02

5.1.2.1 Review of CDPH Pathogen Removal Requirements

After analyzing the draft GWR regulations, the WRRF 11-02 team concluded that the CDPH regulations were both rigorous and sound based on the approach methodology, the risk-based goals (10^{-4} annual risk of infection), and the use of QMRA for determining safe drinking water concentrations. While the general findings of the draft GWR regulations were accepted, the team looked further into a number of key elements during the development of the DPR criteria including:

[14] This approach allows credit for conventional wastewater treatment and any above ground treatment processes, as well as soil aquifer treatment. No single process can receive a credit of more than a 6-log reduction.

1. Pathogen concentrations in raw wastewater;
2. Selection of target pathogens; and
3. Estimates of risk during outbreaks.

Pathogen Concentrations in Raw Wastewater

To supplement CDPH's analysis, the WRRF 11-02 team reviewed a wider range of studies looking at raw wastewater concentrations (Trussell et al. 2013). Emphasis in this review was to expand CDPH's work by capturing recent findings, i.e., from studies performed since the year 2000. Multiple factors can impact raw wastewater concentrations, including the characteristics of the populations contributing to the sewershed, the original use of the water, and the detection methods used. To gain the most relevant information, the literature review placed a preference on 1) surveys of raw wastewater pathogen concentrations in the U.S., 2) focusing on domestic wastewaters or blends (vs. studies looking at atypical wastewater streams such as highly concentrated, unblended slaughterhouse wastes), and 3) using the best available detection technologies to overcome limitations of earlier methods.

Selection of Target Pathogens

The WRRF 11-02 team suggested a bacterial requirement as a supplement to the CDPH proposed viral and protozoan requirements. *Salmonella* was chosen based on its importance in acute gastrointestinal illness in the United States (Scallan et al, 2011). Inclusion of a bacterial pathogen falls in line with the Australian water recycling guidelines by using an indicator for each of the main pathogen groups: bacteria, virus, and parasites (protozoa and helminths) (NRMMC/EPHC/NHMRC, 2008).

One pathogen that will be important to evaluate further as greater understanding of its characteristics is developed is norovirus. As shown in Table 1, norovirus is a major source of illness in the U.S., so its occurrence alone would merit additional risk analysis. One of the main reasons that norovirus was not used in the risk assessment for WRRF 11-02 was uncertainty regarding its infectivity. Underlying all QMRAs are dose-response data that relate levels of human infection to pathogen exposure. Because norovirus cannot yet be cultured, traditional risk assessments have not been undertaken. One recent study attempted to overcome this obstacle by linking genome counts with a human feeding study (Teunis et al., 2008). While providing a new and different method to assess norovirus infectivity, it also introduces additional uncertainty[15]. However, the study showed that the infectivity of norovirus is similar to rotavirus (the virus used in the SWTR and WRRF 11-02 risk assessments) (Teunis et al., 2008). Therefore, the proposed requirements should be appropriately conservative based on virus infectivity. The other key component of the calculation—the concentration of viable and infectious viruses in raw wastewater—remains unresolved. While current and future research address these knowledge gaps, additional safety factors may be considered for the existing 12-log virus removal requirements to account for norovirus.

Further characterization of norovirus behavior is clearly an important priority for future research. As new data are developed, the viral removal requirements should be reassessed and appropriately modified (if needed) to ensure that they remain protective of human health.

Estimates of Risk During Outbreaks

One issue that was not specifically addressed in either the CDPH draft GWR regulations or Australian Guidelines was the impact of a waterborne outbreak when the concentrations of pathogens in the raw wastewater would be in excess of their typical levels. This issue was studied based on the WRRF 11-02 team's concern that higher pathogen levels during an outbreak would carry over into the potable water and sustain or worsen an epidemic. Ultimately, the increased public health risk posed by outbreaks, and a lack of clear data on the increase in pathogen concentrations during outbreaks, served as justification to accept the higher levels of conservatism included in the CDPH draft GWR regulatory strategy. The conservatism in this approach is reviewed in Section 5.4.

5.1.2.2 Draft 11-02 Pathogen Removal Requirements

After a thorough analysis of CDPH's proposed pathogen removal requirements, the 11-02 team concluded that their framework and specific removal requirements provide an appropriate level of protection from wastewater pathogens during both endemic and outbreak situations. An additional criterion for *Salmonella* bacteria was also added (Table 6)

[15] The analysis assumes a constant ratio between virus numbers (measured in genome copies using quantitative polymerase chain reaction methods) and virus infectivity. To develop this ratio, the authors calculated genome copies and infectivity using norovirus extracted from the fecal matter of infected hosts. It is not known *how* this ratio changes as fresh fecal matter enters the raw wastewater, travels through the sewer system, and passes through primary and secondary (biological) wastewater treatment. It is likely, however, that this ratio changes as a result of virus inactivation from physical, chemical, and biological processes in the environment. Applying the ratio from this study to a wastewater context may over- or underestimate the actual risk. Given this uncertainty, norovirus was not used for the risk assessment.

Table 6: Draft criteria for pathogen removal for potable reuse projects

Organism	Log removal
Enteric viruses	12
Cryptosporidium oocysts	10
Giardia cysts	10
Salmonella spp. (non-typhoid)	10

5.1.2.3 Final 11-02 Pathogen Removal Requirements

The WRRF 11-02 team presented the draft criteria to an IAP at a workshop organized by the National Water Research Institute. This workshop included experts in the potable reuse field, including scientists, regulators, engineers, administrators, and technology vendors, with the goal of discussing critical issues related to potable reuse and public health. The process led to the publication of an IAP report (Crook et al., 2013), including the final recommended microbial public health criteria (Table 7). Treatment trains that achieve these specific recommended treatment goals are, by definition, deemed protective of human health and therefore appropriate for water production from a municipal reuse project.

Table 7: Final pathogen and total coliform removal requirements from WRRF 11-02

Microbial Group	Criterion ($\log_{10}$ removal)	Possible Surrogates	Sources Used for Criteria
Enteric Virus	12	MS-2 bacteriophage	Surface Water Treatment Rule (U.S. EPA 1989a), CDPH (2011), NRC (2012), NRMMC/EPHC/NHMRC (2008)
Cryptosporidium spp.[1]	10	Latex microspheres, AC fine test dust, inactivated *Cryptosporidium* oocysts, aerobic spores	U.S. EPA (1998, 2006), CDPH (2011)[4], NRC (2012), NRMMC/EPHC/NHMRC (2008)
Total Coliform Bacteria[2]	9	N/A[3]	EPA Drinking Water Rule (U.S. EPA,1989b), NRC (2012) risk assessment for *Salmonella*

[1] Addresses *Giardia* and other protozoa as well.
[2] Addresses enteric pathogenic bacteria, such as *Salmonella* spp.
[3] N/A = not applicable.
[4] The 2011 draft GWR regulations contain the same log reduction requirements as the March 2013 draft GWR regulations.

A few important modifications to the draft criteria were included in the final removal requirements. Notably, the 10-log *Giardia* requirement was removed based on the assumption that the 10-log *Cryptosporidium* requirement addresses *Giardia* and other protozoa as well. Secondly, the 10-log *Salmonella* requirement was adjusted to a 9-log requirement based on the use of a more recent dose-response study for *Salmonella* (WHO and FAO, 2002). Finally, the IAP recommended total coliform (TC) be used in place of *Salmonella*, assuming that TC would address pathogenic enteric bacteria, like *Salmonella*, while being significantly easier to monitor.

One issue that was not specifically addressed was the tolerable level of variation from these requirements, i.e., the frequency and degree to which the treatment can fail to meet the requirements before triggering remedial action. One strategy that has been applied in existing regulations to define these limits is to specify an average (long-term) value along with a not-to-exceed (instantaneous) value. For example, the LT2 provides a 0.5-log *Cryptosporidium* removal credit if all individual filter effluents achieve (1) turbidities less than 0.15 NTU in at least 95% of the maximum daily values in each month (i.e., long-term value), and (2) no individual filter turbidity exceeds 0.3 NTU in two consecutive measurements (i.e., instantaneous value) (US EPA 2010). CDPH's draft groundwater recharge regulations allow 75-80% of the full pathogen reduction for up to 8 hours in one week before initiating an investigation or taking remedial action for an advanced water treatment facility (CDPH, 2013, Hultquist, 2012). The CDPH draft regulations require that groundwater recharge using recycled water be discontinued if the effectiveness of the treatment train is less than 9 logs for virus and less than 8 logs for *Giardia* and *Cryptosporidium*. A similar framework could be applied for DPR scenarios to define the tolerable variation. This subject warrants further discussion as DPR targets are evaluated.

5.2 <u>Chemical Removal Requirements</u>

5.2.1 Draft Chemical Criteria

As with the microbial criteria, a risk-based methodology was used to develop the draft chemical requirements. As noted earlier, the risk from chemical contaminants is substantively different from the microbial contaminants in that the majority of chemicals typically pose a chronic (vs. acute) threat at the concentrations found in wastewater. Because they exert effects over longer exposure periods, brief exposure to elevated levels of chemical contaminants is less important than the overall, lifetime exposure level.

Building upon a review of existing regulations and guidelines for chemical contaminants, the WRRF 11-02 team developed a hierarchical procedure for determining health-risk benchmarks for chemical removal in potable reuse supplies. The selection of chemical removal benchmarks proceeds from the top of the hierarchical structure to the bottom in order of decreasing preference. At the top of the hierarchy are the regulated chemical limits enforced by various regulatory agencies (EPA and state governments), WHO drinking water guidelines (DWG), and similarly reputable benchmarks from EPA and state governments. Limits in this tier generally represent acceptable risk, i.e., risk determined through analysis of health, economic, and technological factors. The next tier includes non-enforceable *de minimis* benchmarks determined through review by recognized authorities such as EPA, state governments, and other federal agencies. A final tier includes criteria for pharmaceuticals and *de minimis* benchmarks proposed by secondary sources. These benchmarks tend to cover chemicals with little to no toxicological information.

5.2.2 Final Proposed WRRF 11-02 Chemical Criteria

Using the WRRF 11-02 literature review, the draft criteria, and additional sources, the IAP developed a proposed set of chemical criteria that are considered to be protective of human health (Table 8). Given the wide diversity of chemicals, the requirements were divided into three sections: 1) disinfection byproducts, 2) chemicals of potential interest (if present in wastewater sources), and 3) chemicals used for evaluating the effectiveness of organic chemical removal by treatment.

While the chemical criteria listed in Table 8 encompass the requirements for WRRF 11-02, the IAP also provided feedback on the chemical framework provided in the draft criteria. The goal of that framework was to provide a general methodology for selecting appropriate concentrations of chemicals, beyond the specific recommendations offered by the IAP. Ultimately, the IAP approved the use of two of the frameworks, namely the highest tier (Framework 1) consisting of EPA and WHO drinking water regulations, in addition to the second tier (Framework 2) containing the unregulated chemicals with *de minimis* benchmarks (Figure 2). An additional tier (Framework 3) was added to include frameworks that require specialists, such as toxicologists, to formulate appropriate drinking water values.

While values in Framework 1 are expressed in terms of mg/L of drinking water, Framework 2 values need the following conversion from their existing form (mg of chemical per kilogram (kg) of body weight per day) into mg/L of drinking water:

$$De\ minimis\ \text{concentration}\ \left[\frac{mg}{L}\right] = \frac{\text{benchmark}\ \left[\frac{\frac{mg}{kg}}{day}\right] x\ \text{weight}\ [kg]\ x\ \text{source contribution}\ [\%]}{\text{daily consumption}\ \left[\frac{L}{day}\right]}$$

where *benchmark* is the *de minimis* benchmark, *weight* is the average body weight of a drinking water consumer (assumed to be 60 kg), *source contribution* is the percentage of the total exposure related to potable reuse water (typically assumed to be 20%) and *daily consumption* is the average daily potable reuse consumption (typically 2 liters (L) per day). The IAP also added EPA's Human Health Benchmarks for Pesticides to Framework 2.

Table 8: Chemical threshold guidelines[16]

Chemical Group	Criterion	Rationale	Sources Used for Criteria
Disinfection Byproducts that should be measured in the evaluation of treatment trains			
THMs	80 µg/L	Prominent chlorination byproducts	MCL
HAA5	60 µg/L	Polar group of chlorination byproducts	MCL
NDMA	10 ng/L	Byproduct of chloramination	CDPH Notification Level
Bromate	10 µg/L	Byproduct of ozonation	MCL / WHO guideline
Chlorate	800 µg/L	Reflective of hypochlorite use	CDPH Notification Level
Non-regulated chemicals of interest from the standpoint of public health (if they are present in wastewater source)			
PFOA	0.4 µg/L	Known to occur, frequency unknown	Provisional short-term EPA Health Advisory
PFOS	0.2 µg/L	Known to occur, frequency unknown	Provisional short-term EPA Health Advisory
Perchlorate	15 µg/L 6 µg/L	Of interest, same analysis as chlorate and bromate	EPA Health Advisory California MCL
1,4-Dioxane	1 µg/L	Occurs at a relatively low frequency in wastewater, but likely to penetrate RO membranes	CDPH notification level
Steroid Hormones			
Ethinyl Estradiol	None, but if established, it will approach detection limit (low ng/L).	Should evaluate presence in source water	Bull et al. (2011)
17-β-estradiol	None, but if established, it will approach detection limit (low ng/L).	Should evaluate presence in source water	Bull et al. (2011)
Chemicals of potential health concern that should be useful for evaluation effectiveness of organic chemical removals by treatment trains			
Pharmaceuticals[1]			
Cotinine/Primidone/ Dilantin	1/10/2 µg/L	Surrogate for low MW partially charged cyclics	Bruce et al. (2010); Bull et al. (2011)
Meprobamate/Atenolol	200/4 µg/L	Occur frequently at ng level	Bull et al. (2011)
Carbamazepine	10 µg/L	Unique structure	Bruce et al. (2010)

[16] Based on Trussell et al. (2013).

Chemical Group	Criterion	Rationale	Sources Used for Criteria
Estrone[2]	320 ng/L	Surrogate for steroids	Based on increased risk of stroke and deep vein thrombosis in women taking the lowest dose (0.625 mg/day) of conjugated estrogens/1000
Other Chemicals			
Sucralose	150 mg/L[3]	Surrogate for water soluble, uncharged chemicals, moderate molecular weight	CFR Title 12, revised 4/1/12[4]
TCEP	5 µg/L	Chemical of interest	Minnesota Dept. of Health (2011) guidance value
DEET	200 µg/L	Chemical of interest	Minnesota Dept. of Health (2011) guidance value
Triclosan	2,100 µg/L	Chemical of interest	Risk-based action level (NRC, 2012)

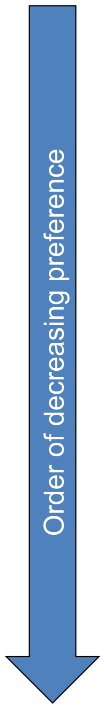
THM – trihalomethane, HAA5 – haloacetic acids, NDMA – N-nitrosodimethylamine, PFOA – perfluorootanoic acid, PFOS - Perfluorooctanesulfonic acid, TCEP - tris (2-chloroethyl) phosphate, DEET - N,N-diethyl-meta-toluamide.

[1] For pharmaceuticals the criterion is given as the drinking water equivalent conc. for the lowest therapeutic dose/1000. For anticonvulsant drugs, the lowest daily maintenance dose in adults/10,000 was used in recognition of the teratogenic potential of these drugs (primidone). However, numbers for carbamazepine and Dilantin (phenytoin) are based on reported carcinogenicity.

[2] Conjugated estrogens (largely estrone conjugates) administered without progestin increased risk of deep vein thrombosis and stroke significantly in a large clinical study of postmenopausal women conducted over 5.1 years (involved groups > 5,000 treated and 5,000 placebo subjects). Cited in RxList (2012).

[3] Sucralose based upon acceptable daily intakes established by the U.S. FDA of 5 mg/kg per day x 60 kg/2 L.

[4] http://www.gpo.gov/fdsys/browse/collectionCfr.action?collectionCode=CFR



Framework 1 – Existing Drinking Water Regulations (in order):

- US EPA MCLs
- State MCLs
- State provisional levels
- *De minimis* concentrations (HAs or PNECs)
- WHO Drinking Water Goals

Framework 2 – de minimis Benchmarks (no order)[1]:

- US EPA Reference dose (RfD)
- ASTDR Minimal Risk Levels (MRL)
- WHO Acceptable Daily Intake (ADI)
- CA EPA OEHHA Acceptable Daily Dose (ADD)
- US EPA Long-term health advisory (LTHA)
- EPA Predicted No-Effect Concentration (PNEC)
- EPA Human Health Benchmarks for Pesticides (HHBP)

Framework 3 – requiring specialist expertise (e.g., toxicologists):

- Pharmaceuticals based on lowest therapeutic dose (LTD)
- De minimis benchmarks from secondary sources

HA – Health advisory, PNEC – Predicted no effect concentration, CA OEHHA – California Office of Environmental Health Hazard
Source: Based on Trussell et al. (2013)

Figure 2: Frameworks approved by 11-02 IAP for calculating chemical concentrations in drinking water

5.3 Aesthetic Criteria for Potable Reuse

As noted earlier, one of the hurdles that the public faces in embracing potable reuse stems from the product water's wastewater origin. The WRRF 11-02 team set out two broad goals for the aesthetic quality of the treated water: it should be free of wastewater properties that are obvious to both 1) the uninformed consumer and 2) the informed consumer. To meet the first goal, the team applied secondary standards established by the EPA for aesthetic properties related to appearance, odor, and taste (Table 9, top).

Table 9: WRRF 11-02 aesthetic criteria for potable reuse

Parameter	Requirements
Aesthetic criteria for uninformed consumer	
• Color	Apparent color units (ACU) ≤ 15[1]
• Odor	
○ Threshold odor number (TON)	≤ 3
○ Flavor profile	No off-flavors
• Mineralization	TDS and hardness similar to local supplies[2]
Aesthetic criteria for informed consumer	
Potable reuse is free of dissolved organic matter (DOM) of wastewater origin	
• TOC concentration	≤ 0.5 mg/L
Or	
• Effluent organic matter	Transformed into a DOM that is more NOM-like based on 90% reduction in excitation-emission matrix total fluorescence
Trace organic chemicals have been reduced to acceptable levels	
• Performance- and health-based chemical indicators	Must achieve chemical criteria established by IAP

[1] This is the state secondary MCL.

[2] In some instances, potable reuse projects may seek to achieve lower TDS and/or hardness levels than local supplies with the goal of improving the water quality of the blended project.

To achieve a water that meets the aesthetic criteria of an informed consumer, the water should be 1) free of dissolved organic matter (DOM) of wastewater origin and 2) trace organic chemicals (TOrCs) should be reduced to acceptable levels (Table 9, lower section). To be free of DOM of wastewater origin, the team proposed either the use of an absolute TOC requirement, or the use of excitation-emission matrices (EEM) to determine when the wastewater identity has been eliminated. Given the difference in TOC values for different source waters based on varying concentrations of NOM, and the fact that NOM does not generally decrease through the treatment train, it is not feasible to select an absolute EEM profile for all waters. Instead, it is recommended that the total fluorescence (measured by EEM) should be reduced by at least 90 percent through the treatment train. Demonstrating that a recycled water has lost its wastewater identity based on EEM, despite the fact that its TOC was greater than 0.5 mg/L, should also be accepted.

5.4 Discussion of Key Assumptions

The overriding goal for all potable reuse projects is that they be protective of human health. In developing the equivalency criteria for potable reuse, a number of conservative assumptions were included to ensure that this critical public health goal is met. In this section, the key assumptions included in the criteria are discussed with a particular emphasis on the pathogen removal requirements.

As discussed earlier, the development of the pathogen criteria involved four steps:

1. Identify target organisms;
2. Determine maximum concentrations in raw wastewater;
3. Define acceptable concentrations in drinking water; and
4. Determine removal goals based on the difference.

Assumptions included in each of these four steps are discussed in the following sections.

5.4.1 Conservatism in Target Pathogen Selection

A wide range of pathogens could have been selected for the equivalency criteria. The WRRF 11-02 team focused primarily on pathogens and/or indicators regulated both by the EPA in the National Primary Drinking Water Regulations (U.S.EPA 1989a, b, 1998, 2006) and the CDPH's draft GWR regulations (CDPH, 2013). The selected viral and protozoan pathogens are understood to be among the more prevalent and resistant pathogens. It is intended that their regulation provides protection against the remainder of the pathogens as well. Their selection is also justified based on their importance in the gastroenteric disease burden in the United States.

A bacterial requirement was also added given the importance of enteric bacterial pathogens in the United States disease burden. The addition of a bacterial indicator to the viral and protozoan requirements is intended to account more broadly for variations in pathogen characteristics, behaviors, and susceptibilities to treatment.

5.4.2 Conservatism in Pathogen Concentrations in Raw Wastewater

One criticism of the CDPH draft GWR regulations is that they are excessively conservative regarding pathogen concentrations in raw wastewater. To address this issue, the WRRF 11-02 team undertook an extensive literature review to develop a dataset with which to evaluate the CDPH approach. The literature review showed a high level of conservatism in the CDPH assumptions, primarily due to two factors. Firstly, CDPH selected the pathogen concentrations from a small subset of the literature, and, from these references, they chose to select the **maximum** raw wastewater concentrations for their calculations. This practice may overemphasize outliers, skewing the results towards higher values.

The literature review undertaken by the WRRF 11-02 team focused on domestic or blended wastewaters to eliminate outliers from atypical wastewaters such as slaughterhouse effluents. To maintain consistency with the CDPH method, the project team focused on the **maximum** pathogen concentrations reported in these studies. Even when comparing maximum values, this analysis showed CDPH values were typically 10 to 100 times higher than the maximum literature values.

The approach of using maximum values is not the only option for the selection of raw wastewater concentrations. For example, the Australian Guidelines for Water Recycling use the 95th percentile value as the wastewater concentration for their calculations. The 95th percentile value can be substantially smaller (i.e., less conservative) than the maximum value depending on the variability in the raw wastewater concentrations. For comparison, Table 10 presents the raw wastewater concentrations used in the Australian, CDPH draft GWR Regulations, and 11-02 proposed guidelines.

Table 10: Raw wastewater pathogen concentrations used in Australian, CDPH, and WRRF 11-02 removal requirements

Organism	Units	95th percentile concentration (Australia)	Maximum concentration (CDPH/ WRRF 11-02)
Cryptosporidium	oocysts/L	2,000	100,000
Enteric virus	infectious units/L	8,000	100,000

In addition to the use of the 95th percentile, other methods could decrease the conservatism in the CDPH / WRRF 11-02 numbers. One option to retain conservatism while utilizing the full data set is to compile the maximum values from the literature, and then take an **average** value of the maximum reported values. To validate such alternative approaches, decisions should be made in conjunction with input from public health and statistical experts.

5.4.3 Conservatism in Acceptable Drinking Water Concentrations

The first assumption used in the calculation of acceptable drinking water concentrations was the *de minimis* level of risk. The 10^{-4} annual risk of infection was selected by the WRRF 11-02 team, given its incorporation into numerous water quality regulations, as well as its standing as the *de facto* U.S. standard.

Other risk-based frameworks exist and could replace the 10^{-4} level. The most notable alternative is the disability adjusted life-years, or DALY framework. The DALY concept is used by the WHO and the Australian Guidelines (Havelaar et al. 2000, NRMMC/EPHC/NHMRC 2008). The DALY framework offers a number of advantages by focusing on levels of human health impairment over levels of infection. This framework allows pathogens of different severities to be normalized to their health impacts, requiring higher removal for pathogens with more severe health tolls, and lower requirements for milder pathogens.

While providing many benefits, the use of DALYs greatly increases the system's complexity due to the increased inputs needed for the modeling. Additional inputs include the dose-response characteristics of all relevant pathogens, and the health outcomes for both immunocompetent and susceptible populations (e.g., probability of infection, severity and duration of infection, case fatality ratio, life expectancy, etc.). Accordingly, a significant research effort would be needed to collect pathogen-specific data to feed the model. While this concept may lead to significant advances in risk assessment in the future, the level of data currently available suggests that implementing such a strategy is not a near-term option.

The DALY concept also leads to different health outcomes than the 10^{-4} infectious risk level. One notable difference is the standard DALY goal of 10^{-6} DALYs/person/year produces a 10^{-3} annual risk of diarrhea disease (McAuliffe and Gregory 2010, NRMMC/EPHC/NHMRC 2008). While providing higher levels of protection from more serious health outcomes, it is less protective than the 10^{-4} risk level for diarrheal disease (acute gastrointestinal illness). Accordingly, the WRRF 11-02 team proposed using the United States *de minimis* standard of 10^{-4} infections/person/year, with the logic that potable reuse projects must meet or exceed the standard applied to local conventional drinking water sources in the United States.

5.4.4 Conservatism in Removal Requirements

The conservatism in the removal requirements is a direct consequence of conservatism in the preceding steps since the removal requirements are simply a calculation based on these inputs. A comparison of the CDPH draft GWR regulations, WRRF 11-02 proposed criteria, and Australian pathogen removal requirements is presented in Table 11.

Table 11: Comparison of various pathogen and total coliform removal requirements

Organism	CDPH Draft GWR Regulations	WateReuse 11-02	Australian Water Recycling Guidelines
Enteric virus	12	12	9.5
Cryptosporidium	10	10	8
Giardia	10	–	–
Campylobacter	–	–	8.1
Total Coliform	–	9	–

The 11-02 team quantified the total conservatism present within their methodology, and found that it incorporated a factor of safety on the order of 100 to 1000 (Table 12)

Given this conservatism, the actual risk of infection from potable reuse consumption is more stringent than the 10^{-4} goal, extending as low as $< 10^{-6}$ annual risk of infection under typical or endemic scenarios.

Table 12: Safety factors inherent in CDPH / WRRF 11-02 risk assessment

Sources of conservatism	***Cryptosporidium***	***Giardia***	**Viruses**
Use of max. vs. avg. concentrations	> 10	> 10	> 10
Maximum #s higher than literature values	> 10	> 10	–
QMRA assumptions	~10	~10	~10
Total conservatism	**~ 1000**	**~ 1000**	**~ 100**

Despite this high level of conservatism, the WRRF 11-02 team concluded that it was justified after evaluating the risk from extreme events, such as outbreaks. During outbreaks, pathogen concentrations exceed the concentrations typically present, but the degree to which they increase is not well documented. Using data from the literature review, the WRRF 11-02 team estimated that concentrations increase at least 10-fold, and may extend as high as 100 times higher than endemic levels. Increasing the wastewater pathogen concentrations by 100-fold has a direct impact on the epidemic risk, raising it by 100-fold as well.

Given the conservatism in the values, however, this 100-fold increase in pathogen concentrations raises the outbreak risk from $< 10^{-6}$ to $< 10^{-4}$ infections per person per year. In other words, the risk of infection during an outbreak remains negligible because it only rises to the 10^{-4} *de minimis* risk level. By incorporating this conservatism, potable reuse projects will be protective of public health even during outbreaks. For this reason, the WRRF 11-02 team did not seek to reduce the CDPH proposed pathogen removal requirements.

5.5 <u>Implications for Treatment</u>

Once pathogen and chemical removal criteria have been developed, treatment trains that achieve these goals must be designed. Typical pathogen and chemical removal efficiencies for a range of unit processes are provided in Table 13 and Table 14. These tables are intended to provide a general sense of the treatment performance of different unit processes. They are not, however, intended to be an exhaustive portrayal of the available literature. Treatment performance is the focus of the next workshop and subsequent project tasks; a more detailed discussion of this topic will be provided at that time.

While Table 13 and Table 14 show contaminant removal from research studies, another important factor is the level of contaminant removal **credit** assigned by regulatory agencies. The difference between these two elements can be illustrated with an example. In theory, reverse osmosis (RO) membranes provide an absolute barrier to all contaminants with the exception of a select set of chemicals with specific physical-chemical properties. In theory, RO should provide an impenetrable barrier to microbial contaminants, such as *Cryptosporidium* oocysts, and thereby achieve the removal requirements by itself. As set forth in the draft CDPH GWR regulations, CDPH will only allow a maximum of 6-log removal credit for any single unit process (CDPH, 2013). Furthermore, in the draft GWR regulations, CDPH requires verification of the effectiveness of each pathogen barrier, but not by monitoring specific pathogens. In the case of RO, membrane performance is demonstrated through decreases in surrogate concentrations—typically TOC or conductivity—from the influent to the RO product water. Because it is typical to only show an approximate 100-fold decrease in these surrogate parameters (e.g., a 99% salt rejection), a 2-log removal credit is considered the practical maximum that can be demonstrated for *Cryptosporidium*, viruses, and bacteria through surrogate monitoring of RO. Less credit was awarded for a recent AWT system expansion that uses reclaimed water for indirect potable reuse, where CDPH approved a 1.5-log pathogen removal credit for RO. New monitoring schemes capable of demonstrating higher levels of removal could potentially be used to seek higher treatment credits. Further dialogue with regulators would be required to obtain such allowances.

Table 13: Log removals for enteric pathogens and indicator organisms

	Indicative Log Reductions[a]						
Treatment	***Escherichia coli***	**Enteric bacteria (e.g., *Campylobacter*)**	**Enteric viruses**	**Phage**	***Giardia***	***Cryptosporidium***	***Clostridium perfringens***
Secondary Treatment	1.0–3.0	1.0–3.0	0.5–2.0	0.5–2.5	0.5–1.5	0.5–1.0	0.5–1.0
Dual Media Filtration[b]	0–1.0	0–1.0	0.5–3.0	1.0–4.0	1.0–3.0	1.5–2.5	0–1.0
MF	3.5–>6.0	3.5–>6.0	0.5–>6.0	3–>6.0	>6.0	>6.0	>6.0
UF, NF, RO	>6.0	>6.0	>6.0	>6.0	>6.0	>6.0	>6.0
Reservoir Storage	1.0–5.0	1.0–5.0	1.0–4.0	1.0–4.0	3.0–4.0	1.0–3.5	N/A
Ozone	2.0–6.0	2.0–6.0	3.0–6.0	2.0–6.0	2.0–4.0	1.0–2.0	0–0.5
Low UV	2.0–>4.0	2.0–>4.0	1.0 – >3.0	3.0–6.0	>3.0	>3.0	N/A
High UV	>6.0	>6.0	>6.0	>6.0	>6.0	>6.0	N/A
AOP	>6.0	>6.0	>6.0	>6.0	>6.0	>6.0	N/A
Chlorination	2.0–6.0	2.0–6.0	1.0–3.0	0–2.5	0.5–1.5	0–0.5	1.0–2.0

N/A - not available, MF – microfiltration, UF – ultrafiltration, NF – nanofiltraiton, UV – ultraviolet radiation, AOP – advanced oxidation
[a]Reductions depend on specific features of the process, including detention times, pore size, filter depths and disinfectant
[b]Including coagulation
Source: NRMMC/EPHC/NHMRC (2008) based on Bitton (1999), U.S. EPA (1999), 2003), 2004), Mara and Horan (2003), NRC (1998), WHO (1989)

Given the lack of existing DPR projects in operation, the credits that may be assigned for DPR unit processes remains uncertain. Insight into the possible credits can be gained by evaluating the credits regulatory agencies have given for applications of a given technology in other settings such as in drinking water, reclaimed water, and indirect potable reuse scenarios. For example, for an expansion of an AWT system that uses reclaimed water for indirect potable reuse, CDPH has agreed to 6-logs pathogen removal credits for reclaimed water that undergoes UV/peroxide treatment. Given that it is not certain whether credits assigned under one setting will also apply to all potable reuse scenarios, it is advisable to consult with the appropriate regulatory body to discuss the requirements for removal credits. In achieving these credits, it is assumed that all unit processes have been appropriately designed and are adequately operated.

Table 14: Expected percent removals of organic chemicals

Treatment	Pharmaceuticals							Hormones		Fragrance	DBPs
	B(a)p	Anti-biotics[a]	DZP	CBZ	DCF	IBP	ACE	Steroid[b]	Anab-olic[c]		NDMA
Secondary	nd	10–50	nd	nd	10–50	>90	nd	>90	nd	50–90	nd
SAT	nd	nd	nd	25–50	>90	>90	>90	>90	nd	>90	>90
Aquifer Storage	nd	50–90	10–50	nd	50–90	50–90	nd	>90	nd	nd	nd
MF	nd	<20	<20	<20	<20	<20	<20	<20	nd	<20	nd
PAC/UF	nd	>90	>90	>90	>90	>90	nd	>90	nd	>90	>90
NF	>80	50–80	50–80	50–80	50–80	50–80	50–80	50–80	50–80	50–80	nd
RO	>80	>95	>95	>95	>95	>95	>95	>95	>95	>95	25–50
PAC	>80	20–>80	50–80	50–80	20–50	<20	50–80	50–80	50–80	50–80	nd
GAC	nd	>90	>90	>90	>90	>90	nd	>90	nd	>90	>90
Ozone	>80	>95	50–80	50–80	>95	50–80	>95	>95	>80	50–90	50–90
AOP	nd	50–80	50–80	>80	>80	>80	>80	>80	>80	50–80	>90
High UV	nd	20–>80	<20	20–50	>80	20–50	>80	>80	20–50	nd	>90
Chlorination	>80	>80	20–50	–<20	>80	<20	>80	>80	<20	20–>80	nd
Combined chlorine	50–80	<20	<20	<20	50–80	<20	>80	>80	<20	<20	nd

ACE = acetaminophen; B(a)p = benz(a)pyrene; CBZ = carbamazepine, DCF = diclofenac; DZP = diazepam; IBP = ibuprofen; nd = no data provided; PAC = powdered activated carbon
[a]erythromycin, sulfamethoxazole, triclosan, and trimethoprim
[b]ethynylestradiol, estrone, estradiol, and estriol
[c]progesterone and testosterone
[d]Removal percentages will vary widely depending on water quality and recharge/recovery cycles

Source: NRMMC/EPHC/NHMRC (2008) based on Snyder et al. (2007), Ternes and Joss (2006)

In general, the removal from a series of unit processes can be added linearly to calculate the overall removal. As stated previously, the CDPH draft GWR regulations allow pathogen removal credit for any unit process providing at least 1 log reduction in pathogen concentrations, but limits the credit to a maximum of 6 logs per unit process.

6 PERFORMANCE TARGET STRATEGIES FOR DPR RESOURCE DOCUMENT

The primary goals of recommending water quality performance targets in the TWDB DPR Resource Document are:

- To provide utilities considering the implementation of DPR projects with suggested targets that are protective of public health, together with the assumptions and justification for each of the targets; and
- To provide a consistent basis for evaluating potential treatment schemes for DPR, also to be addressed in the Resource Document.

The range of options for water quality performance targets is bounded by existing regulatory requirements for drinking water (i.e., SDWA requirements) as a minimum level of protection, and could be expanded to include “enhanced” targets for pathogens and/or chemicals, as illustrated in Figure 3. Given the potential acute impacts of pathogens and selected chemicals, as a straw man and for purposes of discussion, it is presumed that enhanced pathogen targets would be assigned a higher priority than enhanced chemical targets for constituents with chronic toxicity.

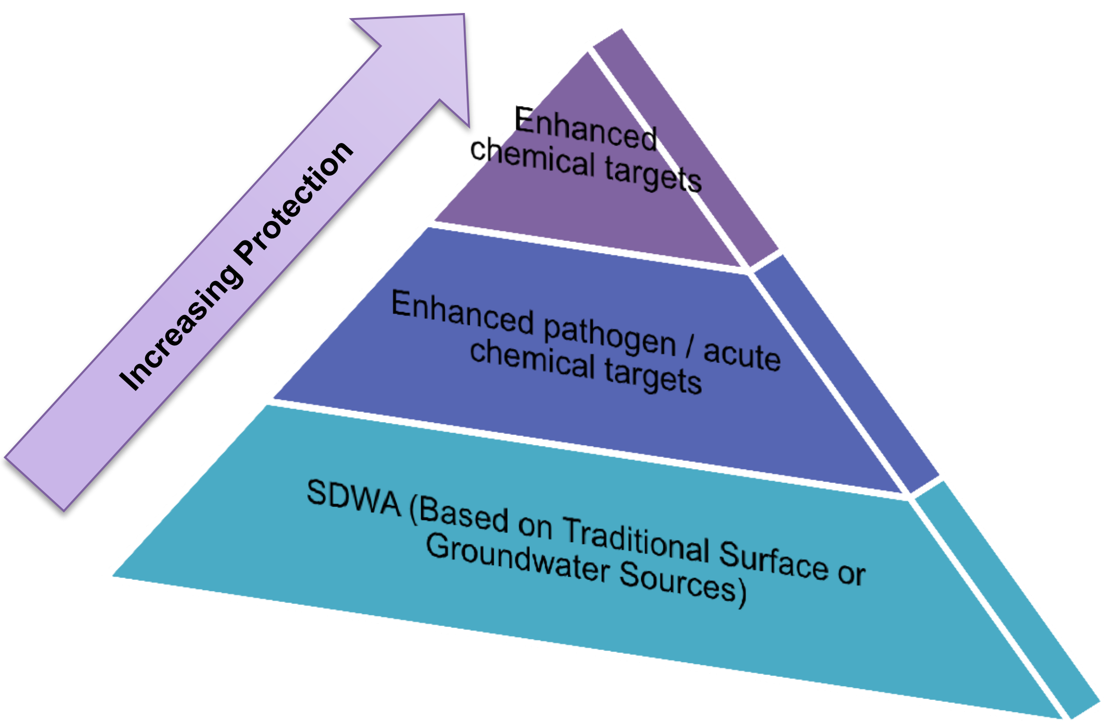


Figure 3: Straw man hierarchy of potential water quality performance targets for DPR projects

As discussed in this memo, there is a range of options that have been explored outside of Texas to develop performance targets for potable reuse. As these and other options are considered during Workshop #1, it is important to consider the goals of establishing the targets noted above, as well as:

- Implications of the selected targets on potential cost and feasibility of implementing DPR projects in Texas, if these targets were to be used;
- Consistency of the selected targets with the existing regulatory framework and protocols;
- Implications of the selected targets on treatment operation and monitoring protocols; and
- Implications of the selected targets on public acceptance of DPR projects.

The primary goal of Workshop #1 is to reach agreement on the recommended approach for establishing water quality performance targets. The approach should consider what level of the hierarchy (as illustrated in Figure 3) is appropriate for Texas and, as appropriate, what methodologies should be considered for establishing enhanced pathogen and chemical targets for DPR. Feedback obtained during the workshop will then be used by the technical team to establish a final set of recommended targets to be included in the Resource Document.

7 ACRONYMS

ACE	Acetaminophen
ACU	Apparent color units
ADD	Acceptable daily dose
ADI	Acceptable daily intake
AOP	Advanced oxidation
AWT	Advanced water treatment
B(a)p	Benz(a)pyrene
BDOC	Biodegradable organic carbon
CA	California
CBZ	Carbamazepine
CCL	Contaminant Candidate List
CDPH	California Department of Public Health
CRMWD	Colorado River Municipal Water District
DALY	Disability adjusted life-years
DCF	Diclofenac
DEET	N,N-diethyl-meta-toluamide
DOC	Dissolved Organic Carbon
DOM	Dissolved organic matter
DPR	Direct Potable Reuse
DWG	Drinking water guidelines
DZP	Diazepam
EEM	Excitation-emission matrices
EfOM	Effluent organic matter
EPA	Environmental Protection Agency
GWR	Groundwater Recharge
HA	Health advisory
HAA5	Haloacetic acids
HACCP	Hazard analysis critical control point
HHBP	Human health benchmarks for pesticides
IAP	Independent Advisory Panel
IBP	Ibuprofen
IU/L	Infectious units per liter
kg	Kilogram
L	Liter

LT2	Long Term 2 Enhanced Surface Water Treatment Rule
LTD	Lowest therapeutic dose
LTHA	Long-term health advisory
MCL	Maximum contaminant level
MF	Microfiltration
mg/L	Miligrams per liter
MRL	Minimal risk level
N/A	Not applicable
nd	No data
NDMA	N-nitrosodimethylamine
NF	Nanofiltration
NOM	Natural organic matter
NRC	National Research Council
NTU	Nephelometric Turbidity Units
OEHHA	Office of Environmental Health Hazard Assessment
PAC	Powdered activated carbon
PFOA	Perfluorootanoic acid
PFOS	Perfluorooctanesulfonic acid
PNEC	Predicted no effect concentration
QMRA	Quantitative microbial risk assessment
RfD	Reference dose
RO	Reverse osmosis
SDWA	Safe Drinking Water Act
SUVA	Specific UV Absorbance
SWTR	Surface Water Treatment Rule
TCEQ	Texas Commission on Environmental Quality
TC	Total coliform
TCEP	Tris (2-chloroethyl) phosphate
TDS	Total Dissolved Solids
TF	Total Fluorescence
THM	Trihalomethane
TOC	Total Organic Carbon
TON	Threshold odor number
TOrCs	Trace organic chemicals
TSS	Total Suspended Solids
TWDB	Texas Water Development Board

UCMR	Unregulated Contaminant Monitoring Regulation
UF	Ultrafiltration
UV	Ultraviolet radiation
UVA	UV 254 Absorbance
WHO	World Health Organization
WRRF	WateReuse Research Foundation

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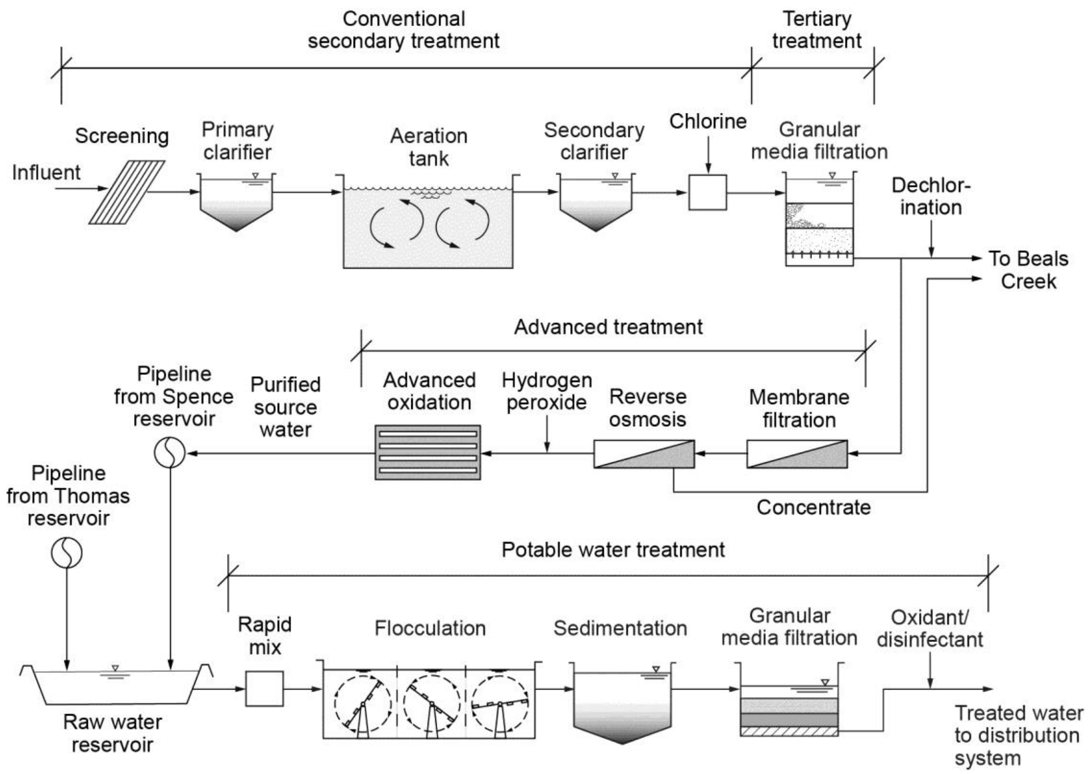
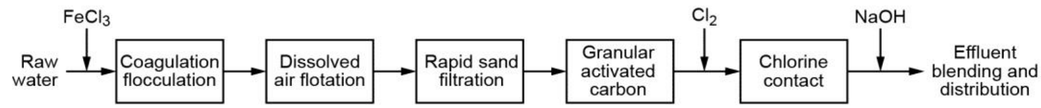
Attachment A – CRMWD at Big Spring Direct Potable Reuse Project

Treatment System (Tchobanoglous et al., 2011)

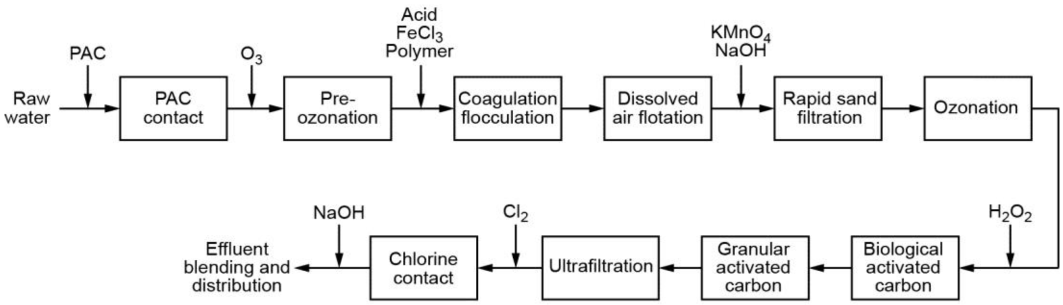


Attachment B – Windhoek Direct Potable Reuse Project

Treatment Processes for the New Goreangab Water Reclamation Plant (Tchobanoglous et al., 2011)



(a)



(b)

Major Water Quality Parameters (Lahnsteiner and Lempert, 2007)

Parameters	Units	Raw water (design value)	Treated water (guarantee value)	WHO Guidelines	EU Directive	Results[1)]
Physical & Chemical						
Turbidity	NTU	53	0.1	0.1[2)]	[3)]	0.08
DOC	mg/l	15	5			1.0
COD (dichromate)	mg/l	43	20			12.6
THM	µg/l	169	20	[4)]	100	11[5)]
Microbiological						
Giardia	per 100 ml	214	0 or log 6 removal			0
Cryptosporidium	per 100 ml	334	0 or log 6 removal			0
E. Coli	per 100 ml	20,347	0		0	0
Heterotrophic Plate Count (37°C)	per 1 ml	332,150	80			8
Elements						
Iron	mg/l	2.8	0.05		0.2	<0.05
Manganese	mg/l	0.9	0.005	0.4	0.05	<0.005

1) Median at Performance Test
2) Recommendation for Effective Disinfection
3) No Abnormal Change
4) Guideline Values: Chloroform 0.2 mg/l, Bromoform 0.1 mg/l, Dibromochloromethane 0.1 mg/l, Bromodichloromethane 0.06 mg/l
5) Currently 4-6 µg/l have been accomplished

mg/l – milligram per liter
ml - mililiter
NTU – Nephelometric Turbidity Units
ug/l – microgram per liter
WHO – World Health Organization

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Attachment C - State Regulations/Guidance for Indirect Potable Reuse (Table 4-16 from U.S. EPA, 2012)

		Arizona[1]	California[2]	Florida[4]	Hawaii	Nevada	New Jersey[7]	North Carolina	Texas	Virginia	Washington		
											Surface Percolation Class A	Direct Groundwater Recharge[8] Class A	Streamflow Augmentation Case-by-case
Treatment (System Design) Requirements	Unit processes	*NR*	Oxidized, coagulated, filtered, disinfected, multiple barriers for pathogen and organics removal	Secondary treatment, filtration, high-level disinfection, multiple barriers for pathogen and organics removal	Case-by-case	*ND*	*NR*	*NR*	Case-by-case	Case-by-case	Oxidized with nitrogen reduction, filtered, disinfected	Oxidized, coagulated, filtered, RO-treated, disinfected	Oxidized, clarified, disinfected
	UV dose, if UV disinfection used	*NR*	NWRI Guidelines[3]	NWRI UV Guidelines enforced, variance allowed	*NS*	*ND*	*NR*	*NR*	*NS*	*NS*	NWRI Guidelines	NWRI Guidelines	NWRI Guidelines
	Chlorine disinfection requirements, if used	*NR*	C_rT > 450 mg·min/L; 90 minutes modal contact time at peak dry weather flow[3]	TRC > 1 mg/L; 15 minutes contact time at peak hr flow[5]	*NS*	*ND*	*NR*	*NR*	*NS*	*NS*	Chlorine residual > 1 mg/L; 30 minutes contact time at peak hr flow	Chlorine residual > 1 mg/L; 30 minutes contact time at peak hr flow	Chlorine residual to comply with NPDES permit
Monitored Reclaimed Water Quality Requirements	BOD_5 (or $CBOD_5$)	*NR*	*NS*	$CBOD_5$: -20 mg/L (ann avg) -30 mg/L (mon avg) -45 mg/L (wk avg) -60 mg/L (max)	*NS*	*ND*	*NR*	*NR*	5 mg/L	*NS*	30 mg/L	5 mg/L	30 mg/L
	TSS	*NR*	*NS*	5 mg/L (max)	*NS*	*ND*	*NR*	*NR*	*NS*	*NS*	30 mg/L	5 mg/L	30 mg/L
	Turbidity	*NR*	-2 NTU (avg) for media filters -10 NTU (max) for media filters -0.2 NTU (avg) for membrane filters -0.5 NTU (max) for membrane filters	Case-by-case (generally 2 to 2.5 NTU) Florida requires continuous on-line monitoring of turbidity as indicator for TSS	*NS*	*ND*	*NR*	*NR*	3 NTU	*NS*	-2 NTU (avg) -5 NTU (max)	-0.1 NTU (avg) -0.5 NTU (max)	*NS*
	Bacterial indicators	*NR*	Total coliform: -2.2/100mL (7-day med) -23/100mL (not more than one sample exceeds this value in 30 d) -240/100mL (max)	Total coliform: -4/100mL (max)	*NS*	*ND*	*NR*	*NR*	Fecal coliform or *E. coli* -20/100mL (30-d geom) -75/100mL (max) Enterococci -4/100mL (30-d geom) -9/100mL (max)	*NS*	Total coliform: -2.2/100 (7-d med) -23/100 (max)	Total coliform: -1/100mL (avg) -5/100mL (max)	Fecal coliform: -200/100mL (avg) -400/100mL (max wk)
	Total Nitrogen	*NR*	10 mg/l (avg of 4 consecutive samples)	10 mg/L (ann avg)	*NS*	*ND*	*NR*	*NR*	*NS*	*NS*	NA	10 mg/L	NPDES requirements to receiving stream
	TOC	*NR*	0.5 mg/L	-3 mg/L (mon avg) -5 mg/L (max); TOX[6]: < 0.2 (mon avg) or 0.3 mg/L (max); alternate limits allowed	*NS*	*ND*	*NR*	*NR*	*NS*	*NS*	NA	1 mg/L	NS
	Primary and Secondary Drinking Water Standards	*NR*	Compliance with most primary and secondary	Compliance with most primary and secondary	*NS*	*ND*	*NR*	*NR*	*NS*	*NS*	Compliance with SDWA MCLs	Compliance with most primary and secondary	NPDES requirements to receiving stream
	Pathogens	*NR*	*TR*	*Giardia*, *Cryptosporidium* sampling quarterly	*NS*	*ND*	*NR*	*NR*	*NS*	*NS*	*NS*	*NS*	*NS*

NS = not specified by the state's reuse regulation; NR = not regulated by the state under the reuse program; ND = regulations have not been developed for this type of reuse; TR = monitoring is not required but virus removal rates are prescribed by treatment requirements

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C2 Appendix:

Final Targets

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TECHNICAL MEMORANDUM

Texas Water Development Board
Evaluating the Potential for Direct Potable Reuse in Texas
Summary of Recommended Water Quality Performance Targets

Project No.: 0866-005-01

Date: April 19, 2015

Prepared For: Project Team and Sponsors

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NOTE: The water quality targets presented in this memorandum represent targets recommended by the technical team to be used as a guideline for public water systems. As noted in the Direct Potable Reuse Resource Document, Volume 1, Chapter 3, the Texas Commission on Environmental Quality has established baseline pathogen targets for direct potable reuse projects that are different than those presented here.

1 INTRODUCTION

As municipal utilities begin to consider pursuing and planning for direct potable reuse (DPR) projects, water quality performance targets need to be considered and ultimately defined. These targets should include not only regulated pathogens and chemicals, but also unregulated contaminants that may have potential human health impacts or serve as treatment performance indicators. The protection of public health is the primary consideration in the development of these targets for municipal utilities in the state. In addition to health-related considerations, aesthetic issues are also of importance as they can aid in the public acceptance of a DPR project. In order to develop recommendations for these targets, the project technical team drew from local, state, national and international studies, current potable reuse projects from around the world, stakeholder input (including the July 9, 2013 Workshop), as well as the project team's own expertise.[1] The goal of this document is to provide a summary of the recommended performance targets to ultimately be included in the DPR Resource Document.

It should be noted that the targets do not specifically address the type of DPR scheme to be implemented (e.g. delivery of reclaimed water directly to the drinking water distribution system vs. reclaimed water blended with raw water and processed through a water treatment plant prior to delivery to the drinking water distribution system). The targets are based on risk thresholds for the drinking water to be supplied to the customer. Safeguards, factors of safety and reliability for different DPR schemes will be addressed as part of a later task.

2 PATHOGENS

The following recommendations are suggested for pathogen performance targets to be used for subsequent project tasks and to be included in the DPR Resource Document.

- The general approach presented in *Potable Reuse: State of the Science Report and Equivalency Criteria for Treatment Trains* (WateReuse Research Foundation Project 11-02[2]; hereafter called WRRF 11-02) will be used. The *State of the Science Report*, which is the first phase of WRRF 11-02, summarizes the state of the science with respect to potable reuse and the proposed performance "equivalency" criteria to be used as metrics to determine the equivalency of potential treatment schemes to be evaluated as part of the second phase of the project. This approach established pathogen $\log_{10}$ reduction requirements for target pathogens in reclaimed water (from raw sewage to final reclaimed water intended for DPR) using available raw wastewater quality data obtained from the literature and established drinking water concentrations needed to meet a 10^{-4} risk level.
- Recommended target pathogens are *Cryptosporidium*, *Giardia*, virus and total coliform (as an indicator). These organisms have been selected due to consistency with the U.S. Environmental Protection Agency's approach in developing drinking water standards under the Safe Drinking Water Act and utility familiarity and confidence with sampling and analytical methods.

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[1] Please refer to the following reference sources: Draft Technical Memorandum Workshop #1: Water Quality Performance Documents (July 1, 2013); Draft Workshop #1 Summary (August 7, 2013); Task 2 Draft Technical Memorandum.

[2] WRRF 11-02: Equivalency of Advanced Treatment Trains for Potable Reuse. Note: the project team had access to the final *State of the Science Report* prior to publication.

- Although there were concerns expressed about the use of maximum raw wastewater concentrations of pathogens in the WRRF 11-02 study, the technical team generally agreed that the quality and quantity of pathogen data was not sufficient to rely on an alternative approach at this time. Ideally, an approach that uses a statistically valid percentile value (e.g., the 95th percentile where 95% of the observations are below this value) was favored by the technical team. However, given the uncertainties associated with the available pathogen datasets, it was recommended that an approach based on either the maximum concentrations or perhaps an average of maximum concentrations be used at this time and periodically revisited to assess the robustness of pathogen data. A comparison of these two approaches and the resulting $\log_{10}$ removals for each target organism is presented below.

2.1 Cryptosporidium

The *Cryptosporidium* data from the *State of Science Report* are presented in **Table 1**.

Table 1: Maximum concentrations of *Cryptosporidium* in raw wastewater. (Adapted from Table 1.1 and Table 1.5 WRRF 11-02 *State of Science Report;* only data from studies 1990 or later using domestic sewage are used)

Maximum Concentration oocysts/L	Reference
2.4×10^{1}	McCuin (2005)
1.2×10^{2}	Rose et al. (1996)
2.6×10^{2}	Gennaccaro et al. (2003)
3.8×10^{2}	Rose et al. (2004)
1.0×10^{5}	Robertson et al. (2006), Tetra Tech (2011)

Maximum concentration: 1.0×10^{5} oocysts/L
Average of maximum concentrations: 2.2×10^{4} oocysts/L

2.2 Giardia

The *Giardia* data from the *State of Science Report* are presented in **Table 2**.

Table 2: Maximum concentrations of *Giardia* in raw wastewater. (Adapted from Table 1.11 WRRF 11-02 *State of Science Report*)

Maximum Concentration cysts/L	Reference
1.2×10^{2}	Rose et al. (1996)
1.3×10^{4}	Rose et al. (2004)
1.4×10^{4}	Sykora et al. (1991)
1.0×10^{5}	NRC (1998)

Maximum concentration: 1.0×10^{5} cysts/L
Average of maximum concentrations: 3.2×10^{4} cysts/L

2.3 Virus

The virus data from the *State of Science Report* are presented in **Table 3**.

Table 3: Maximum concentrations of viruses in raw wastewater. (Adapted from Table 1.11 WRRF 11-02 *State of Science Report*)

Organism	Maximum Concentration	Units	Reference
Enterovirus	4.5×10^{1}	IU/L	Rose et al. (1996)
Enterovirus	1.0×10^{5}	IU/L	NRC (1998)
Enterovirus	1.3×10^{6}	GC/L	Simmons et al. (2011)
Adenovirus	5.0×10^{6}	GC/L	Simmons et al. (2011)
Rotavirus	3.0×10^{3}	IU/L	Rao et al. (1987)
Norovirus GGII	4.0×10^{8}	GC/L	Simmons et al. (2011)

IU/L = Infectious Units/Liter
GC/L = Genome Copies/Liter

As discussed in the *State of Science Report* and the draft Task 3 Workshop Memo, reliable cell culture methods (i.e., those that enumerate infectious units) have not been developed for several of the viruses presented above. Molecular methods alone, such as quantitative polymerase chain reaction (qPCR), cannot distinguish between whole viral particles and fragments, and thus in treated wastewater may overestimate the concentration of virus and thus confound log reduction calculations. In addition, unless combined with cell culture methods (or human feeding studies), it is not possible to use qPCR to determine if the quantified viruses can cause infection. Therefore, only data using culture methods were used to determine maximum concentrations in the *State of the Science Report*.

Using only the data obtained from cell culture methods, the maximum and average maximum concentrations for viruses are:

<u>Maximum concentration:</u> 1.0×10^{5} IU/L
<u>Average of maximum concentrations:</u> 3.4×10^{4} IU/L

As can be seen from the computed maximum and average maximum concentrations above, there is less than an order of magnitude difference between the maximum and average maximum concentration for *Cryptosporidium*, *Giardia*, and virus. Therefore, use of an average maximum instead of the maximum concentration would not have a significant impact on a proposed log removal target for any of the organisms. Based on this evaluation and considering the limitations of the existing pathogen dataset, it is recommended that the targets to be included in the DPR Resource Document be calculated using the maximum concentrations. However, as stated earlier, the Resource Document should clearly discuss the need to obtain additional data and the ultimate goal of establishing a percentile value as the basis for evaluating raw wastewater quality.

2.4 Proposed Log Removal Targets

The following section describes the suggested log removal targets developed by the technical team, as well as the rationale behind the values.

2.4.1 Protozoa and Virus

Proposed log removal targets are computed as the ratio between the maximum raw wastewater concentration and established drinking water goals (based on the 10^{-4} annual risk) for each organism. **Table 4** summarizes these calculations and shows the resulting removal targets.

Table 4: Pathogen removal targets based on maximum raw wastewater concentrations.

Parameter	Units	Pathogens		
		Cryptosporidium	***Giardia***	**Virus**
Raw Wastewater (Maximum Conc.)	IU/L	1×10^5	1×10^5	1×10^5
Drinking Water Goal[3]	IU/L	3×10^{-5}	6.8×10^{-6}	2×10^{-7}
Ratio	--	0.3×10^{10}	1.5×10^{10}	5×10^{11}
Log Removal	--	10	10	12

2.4.2 Total Coliform

The WRRF 11-02 expert panel recommended total coliform as an appropriate indicator for enteric pathogenic bacteria. Total coliform bacteria were selected because they are present in raw wastewater at concentrations that are higher than enteric pathogens and *E. coli*. In addition, they are easy to monitor and are widely used as a surrogate for enteric virus and pathogenic bacteria. The expert panel recommended a $\log_{10}$ removal of 9 for total coliform, which would provide a *de minimis* annual risk of infection from *Salmonella* (the target organism initially recommended) and other enteric bacterial pathogens.

2.5 Summary of Pathogen and Total Coliform Targets

Table 5 summarizes the proposed pathogen removal targets to be included in the DPR Resource Document. Subsequent project tasks will define potential treatment strategies that can be used to meet these targets. However, it is assumed that, if technically justified and properly controlled, credit could be given for any treatment process between the wastewater treatment headworks and the drinking water distribution system.

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[3] Based on CDPH draft groundwater recharge regulations; assumes annual risk of 10^{-4}, infectious dose of 1 organism and 10^3 L/year of water consumed.

Table 5: Proposed pathogen and total coliform $\log_{10}$ removal targets.

Parameter	***Cryptosporidium***	***Giardia***	**Virus**	**Total Coliform**
$\log_{10}$ removal	10	10	12	9

2.6 Norovirus

Given the high numbers of acute gastrointestinal illness attributed to Norovirus in the United States, it is an important pathogen to consider for DPR. Since no method of culturing is available (only qPCR), this presents challenges for evaluating inactivation of the virus. The Resource Document will include information on its importance and potential strategies for developing water quality log reduction targets.

3 CHEMICALS

Recommended water quality targets for chemicals include, at a minimum, compliance with the primary and secondary drinking water maximum contaminant levels (MCLs). In addition to ensuring compliance with the MCLs, it is recommended that utilities pursuing implementation of DPR projects develop a monitoring program using indicators and surrogates, as more fully described in the Task 2 Draft Technical Memorandum[4]. This approach recommends using a combination of indicator compounds and surrogate parameters that are tailored to monitor the removal efficiency of individual unit processes. An indicator compound is an individual constituent that is a regulated compound or a constituent of emerging concern (CEC) that represents certain physicochemical and biodegradable characteristics of a family of trace organic constituents. The indicator compounds are important in terms of human health and/or are relevant to fate and transport of broader classes of chemicals and provide a conservative assessment of removal during treatment. A surrogate parameter is a quantifiable change of a bulk parameter that can measure the performance of individual unit processes (often in real-time) or operations in removing trace organic compounds and/or assuring disinfection.

Recommended indicator chemicals from the Task 2 Draft Technical Memorandum, together with suggested target levels are repeated here for reference (Table 6).

[4] See TWDB Evaluating the Potential for Direct Potable Reuse in Texas Task 2 Technical Memorandum for an expanded explanation of the indicator and surrogate concept.

Table 6: Suggested indicator chemicals to be included in DPR monitoring program.

Constituent	**Rationale**	**Monitoring Trigger Threshold (ng/L)**[1]	**Reporting limit (ng/L)**	**Reference**
Total trihalomethanes (THMs)	Health	80,000	1,000	MCL
Haloacetic acids (HAA5)	Health	60,000	1,000	MCL
N-Nitrosodimethylamine (NDMA)	Health	10	2	CDPH[2] Notification Level[3]
Perfluorooctanoic acid (PFOA)	Health	400	10	Provisional short-term USEPA[4] Health Advisory
Perfluorooctane Sulfonate (PFOS)	Health	200	10	Provisional short-term EPA Health Advisory
Bromate	Health	10,000	1,000	MCL / World Health Organization guideline
Perchlorate	Health	15,000	1,000	EPA Health Advisory
1,4-Dioxane	Health	1,000	100	CDPH Notification Level
17β-Estradiol	Health	<1	0.9	Drewes et al. 2013
Atenolol	Health/ Performance	4,000	100	Bull et al. 2011
Tris(2-chloroethyl)phosphate (TCEP)	Health/ Performance	5,000	100	Minnesota Dept. of Health (2011) guidance value
Caffeine	Performance		50	Drewes et al. 2013
Gemfibrozil	Performance	800,000	10	Schwab 2005
Iopromide	Performance	750,000	50	Australia 2008
Meprobamate	Health/ Performance	200,000	100	Bull et al. 2011
N,N-Diethyl-meta-toluamide (DEET)	Performance	200,000	50	Minnesota Dept. of Health (2011) guidance value
Primidone	Performance	10,000	10	Bruce et al. 2010
Sucralose	Performance	150,000,000	100	CFR Title 21

Constituent	Rationale	Monitoring Trigger Threshold (ng/L)[1]	Reporting limit (ng/L)	Reference
Triclosan	Performance	2,100,000	50	Drewes et al. 2013

1. ng/L – nanograms per liter. The Monitoring Trigger Thresholds (MTTs)are based on primary maximum contaminant levels for regulated chemicals, health advisory levels, and human health relevant drinking water levels from published studies for unregulated chemicals. The MTTs represent the concentration of a substance in drinking water that can be ingested daily over a lifetime without appreciable risk. Additional information is provided in the Task 2 TM.
2. CDPH - California Department of Public Health.
3. CDPH has established Notification Levels for chemicals in drinking water without MCLs. If a chemical concentration is greater than its Notification Level in drinking water, the utility must inform its customers and consumers about the presence of the chemical, and about health concerns associated with exposure to it.
4. USEPA – U.S. Environmental Protection Agency.

As described in the Task 2 Draft Technical Memorandum, suggested surrogates for advanced treatment processes are provided in **Table 7**.

Table 7: Suggested surrogate parameters for advanced water treatment processes to be included in DPR monitoring program.

Surrogate Parameter	Example Unit processes[1]
Total organic carbon (TOC) or dissolved organic carbon (DOC)	RO, NF, GAC, PAC, ozone, AOP
UV absorbance (254 nm)	RO, NF, GAC, PAC, ozone, AOP
Fluorescence indices/ratios	RO, NF, GAC, PAC, ozone, AOP
Total dissolved solids (TDS)/electrical conductivity	RO, NF, EDR
Boron (surrogate for NDMA)	RO, NF
Turbidity	MF, UF
THM Formation Potential	All treatment processes contemplated looking at pre and post-chlorination (free or combined)
NDMA Formation Potential	All treatment processes contemplated looking at pre and post-chlorination (free or combined) and pre and post-ozonation
Aesthetics	
Temperature	RO, NF, GAC, PAC, ozone, AOP
Color (436 nm)	RO, NF, GAC, PAC, ozone, AOP
Odor	RO, NF, GAC, PAC, ozone, AOP
Hardness	RO, NF, CHEM

1. RO – reverse osmosis, NF – nanofiltration, GAC – granular activated carbon, PAC – powdered activated carbon, AOP – advanced oxidation, EDR – electrodialysis reversal, CHEM –chemical precipitation.

In addition to the parameters listed in Table 7, there are currently studies underway to evaluate the use of chloramines as a surrogate for 1,4 dioxane to evaluate the effectiveness of AOP. It is recommended that these efforts be monitored as more information is developed.

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D Appendix:

Source Control

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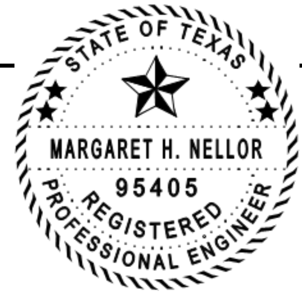
TECHNICAL MEMORANDUM



Texas Water Development Board
Evaluating the Potential for Direct Potable Reuse in Texas
Task 5 Source Control

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1 INTRODUCTION

An important preventative barrier to consider when pursuing and planning for direct potable reuse (DPR) is the implementation of a source control program that limits the discharge of toxic contaminants to the sewerage system from industries, commercial businesses, and homes thereby keeping them out of the reclaimed water supply. All source control programs administer the National Pretreatment Program and local requirements that apply to industries and commercial businesses; some programs may also include elements that address domestic wastewater. The goal of this document is to evaluate source control approaches relevant to potable reuse in light of standard federal pretreatment requirements that are part of the National Pretreatment Program and other methods that have been utilized to enhance source control effectiveness. It will also provide a summary of options for source control approaches for inclusion in the DPR Resource Document.

2 OVERVIEW OF THE NATIONAL PRETREATMENT PROGRAM

Because publicly owned treatment works (POTWs)[1] are generally designed to treat domestic wastewater and not toxics or non-conventional pollutants[2] from industries or commercial businesses, the National

[1] The term POTW means a treatment works as defined by section 212 of the Clean Water Act, which is owned by a State or municipality (as defined by section 502(4) of the Act). This definition includes any devices and systems used in the storage, treatment, recycling and reclamation of municipal sewage or industrial wastes of a liquid nature. It also includes sewers, pipes and other conveyances only if they convey wastewater to a POTW Treatment Plant. The term also means the municipality as defined in section 502(4) of the Act, which has jurisdiction over the Indirect Discharges to and the discharges from such a treatment works (40 Code of Federal Regulations § 403.3(q)).

[2] These are pollutants other than biochemical oxygen demand, total suspended solids, pH, fecal coliform, and oil and grease.

Pretreatment Program was created as part of the Clean Water Act (CWA) to address the discharge of toxics from non-domestic sources. Even if a POTW can remove toxics, many will end up in biosolids or other residuals making them unsuitable for beneficial reuse or disposal. In the National Pretreatment Regulations, industrial and commercial dischargers (non-domestic dischargers) are defined as *industrial users* (IUs). The CWA did not establish the authority for POTWs to control discharges from residential sources. The U.S. Environmental Protection Agency (EPA) promulgated the General Pretreatment Regulations (40 Code of Federal Regulations (CFR) §403) to set responsibilities for federal, state, local government, and industries to achieve the National Pretreatment Program objectives. EPA has also supported the National Pretreatment Program by developing numerous guidance manuals. The term "pretreatment" is defined as the reduction of the amount of pollutants, the elimination of pollutants, or the alteration of the nature of pollutant properties in wastewater prior to or in lieu of discharging or introducing such pollutants into a POTW. An overview of the National Pretreatment Program can be found at: http://www.epa.gov/npdes/pubs/pretreatment_program_intro_2011.pdf (accessed 10/21/14).

In Texas, the National Pretreatment Program is administered by the Texas Commission on Environmental Quality (TCEQ) as part of the Texas Pollutant Discharge Elimination System (TPDES) program.[3] As per 30 Texas Administrative Code (TAC) Chapter 315, TPDES permits, which contain pretreatment requirements to develop and administer an approved pretreatment program, are issued to POTWs that discharge to Texas surface waters.

The objectives of the National Pretreatment Program (40 CFR §403.2) are to:

- Prevent the introduction of pollutants into a POTW that will interfere with the operation of the POTW, including interference with its use or disposal of biosolids. Interference is defined as a discharge which alone or in combination with a discharge or discharges from other sources (1) inhibits or disrupts the POTW, its treatment processes or operations, or its sludge processes, uses or disposal, and (2) is therefore a cause of a violation of any requirement in a POTW's TPDES permit.
- Prevent the introduction of pollutants into a POTW that will pass through the treatment works or otherwise be incompatible with the treatment works. Pass through is defined as a discharge that exits the POTW into waters of the United States in quantities or concentrations, which, alone or in conjunction with a discharge or discharges from other sources, is a cause of a violation of any requirement in a POTW's TPDES permit.

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[3] See http://www.tceq.texas.gov/permitting/wastewater/pretreatment/ (accessed 10/21/2014).

- Improve opportunities to recycle and reclaim municipal and industrial wastewaters and sludges.

The Contributing Industries and Pretreatment Requirements section of the TPDES wastewater discharge permit includes pretreatment requirements for all POTWs regardless of whether or not the POTW has an approved TPDES pretreatment program.[4] For POTWs not required to have an approved pretreatment program, the TPDES permit includes specific prohibitions and notification requirements. For POTWs with approved programs, the pretreatment requirements in the TPDES permit are based on whether or not the POTW has significant industrial users (SIUs) discharging wastewater to the sewer system (see Section 2.2.2).

A POTW not required to implement an approved TPDES pretreatment program should consider developing a local pretreatment program in order to:

- Protect the receiving stream.
- Correct existing problems at the POTW and the collection system.
- Prevent potential problems at the POTW and the collection system.
- Improve opportunities for beneficial sludge reuse.
- Protect the POTW and its personnel.
- Increase options for water recycling or reclamation.
- Protect drinking water supplies by reducing contaminants released into source waters
- Prevent sanitary sewer overflows
- Extend the life of the POTW's wastewater infrastructure

The TCEQ may require the development and implementation of an approved TPDES pretreatment program when the POTW meets the following criteria:

- The total design flow (for all wastewater treatment plants owned by the POTW) is greater than 5 million gallons per day (mgd); and
- Receives wastewater discharges from IUs that contain pollutants that either pass through the treatment plant or interfere with its operation; or
- One or more IUs meet the definition of a categorical industrial user (or CIU, an industry subject to EPA categorical pretreatment standards – see Section 2.2.2).

The TCEQ may also consider additional criteria such as:

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[4] See http://www.tceq.texas.gov/permitting/wastewater/pretreatment/nonapproved_programs_goals.html (accessed 10/21/14).

- The nature and volume of industrial wastewater received by the POTW; or
- Whether contaminants that could have been removed or controlled by pretreatment have prevented sewage sludge from being used or disposed of as intended; or
- Whether a pretreatment program will make significant differences in water quality—for example, in terms of the CWA 303(d)[5] List of Impaired Water Bodies or with respect to a total maximum daily load (TMDL)[6]; or
- The POTW's compliance history.

These local programs must enforce all national pretreatment standards and requirements in addition to any more stringent local requirements necessary to protect site-specific conditions at the POTW.

For non-TPDES permits (e.g., Texas Land Application Permits or TLAP), the TCEQ may require implementation of certain elements of a pretreatment program on a case-by-case basis as a result of an enforcement action or other considerations; however, these programs are not subject to approval by TCEQ (see 40 CFR §403.11 for the procedures that must be followed for approval of pretreatment programs).[7]

2.1 Pretreatment Program Elements

Approved pretreatment programs must contain at a minimum, the following six (6) elements:

- Legal authority (ordinance, rules, multijurisdictional agreements as applicable);
- Procedures, including forms and checklists;
- Funding, including resources and personnel;
- Local limits;
- Enforcement Response Plan, including an Enforcement Response Guide; and
- List of IUs, SIUs, and CIUs.

2.1.1 Legal Authority

The POTW must operate pursuant to legal authority enforceable in federal, state or local courts, which authorizes or enables the POTW to apply and enforce any pretreatment requirements developed pursuant to the CWA. At a minimum, the legal authority must enable the POTW to:

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[5]See http://www.tceq.texas.gov/permitting/wastewater/pretreatment/approved_programs_who.html (accessed 10/21/14)

[6] http://www.tceq.texas.gov/waterquality/tmdl (accessed 10/21/14)

[7] The elements of a pretreatment program that are required to be implemented as a result of an enforcement action may be subject to acceptance by TCEQ.

- Deny or condition discharges to the POTW;
- Require compliance with pretreatment standards and requirements;
- Control industrial discharges through permits, orders, or similar means;
- Require compliance schedules when necessary to meet applicable pretreatment standards and/or requirements and the submission of reports to demonstrate compliance;
- Inspect and monitor industries;
- Obtain remedies for industrial noncompliance;
- Comply with confidentiality requirements; and
- Enter into multijurisdictional agreements with entities that discharge to a POTW, but are outside the POTW's legal jurisdiction to ensure that the entity and its IUs meet the POTW's pretreatment program requirements (fees, inspection rights, limits, monitoring, reporting, etc.).[8]

2.1.2 Procedures

The POTW must develop and implement procedures to ensure compliance with pretreatment requirements, including:

- Identifying and locating all industries subject to the pretreatment program;
- Identifying the character and volume of pollutants contributed by industries;
- Notifying industries of applicable pretreatment standards and requirements;
- Receiving and analyzing reports from industries;
- Sampling and analyzing industrial discharges;
- Evaluating the need for control plans for spills;
- Investigating instances of noncompliance;
- Complying with public participation requirements for changes to the program and publication of industries in significant noncompliance with pretreatment requirements; and
- Developing forms and checklists to implement the pretreatment program.

2.1.3 Funding

The POTW (and multijurisdictional entities) must have sufficient resources and qualified personnel to carry out the authorities and procedures specified in its approved pretreatment program.

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[8] See http://www.epa.gov/npdes/pubs/owm0248.pdf (accessed 10/21/14).

2.1.4 Local Limits

Local limits regulate the discharge of pollutants of concern (POC) from IUs to address the specific needs and concerns of a POTW, its sludge, and its receiving waters. Local limits are applicable at the *end-of-pipe* discharge from an IU's facility (i.e., at the point of IU's connection to the POTW's collection system). These limits must be developed and enforced as part of a public process. Some POTWs establish the legal authority to develop local limits for categories of industries, individual industries, or on a case-by-case basis. For an approved pretreatment program, local limits must be technically based and prepared considering the procedures in EPA's *Local Limits Development Guidance*.[9]If authorized by TCEQ in their approved TPDES pretreatment programs, POTWs can develop and impose best management practices (BMPs) on their IUs, which are considered for enforcement purposes to be local limits/pretreatment standards.

2.1.5 Enforcement Response Plan

The POTW must develop and implement an enforcement response plan that contains detailed procedures indicating how the POTW will investigate and respond to instances of industrial noncompliance. It should include an enforcement response guide, which is a matrix that describes the types of violations and the POTW's range of appropriate enforcement options.[10]

2.1.6 List of Industrial Users

The POTW must prepare, update, and submit to the Approval Authority (the applicable EPA Region or state – for Texas this would be TCEQ) a list of all IUs and identify them by appropriate classification: SIUs, including CIUs; non-significant IUs; non-significant CIUs (NSCIUs)[11]; and middle tier CIUs (MTCIUs)[12]. An SIU is defined as:

- An industry subject to categorical pretreatment standards except NSCIUs;
- Any other IU that:
    (1) discharges an average of 25,000 gallons per day (gpd) or more of process wastewater to

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[9] See http://www.epa.gov/npdes/pubs/final_local_limits_guidance.pdf (accessed 10/21/14).

[10] See http://www.epa.gov/npdes/pubs/owm0015.pdf (accessed 10/21/14).

[11] An IU subject to a categorical pretreatment standard that the POTW has determined is exempt from the definition of SIU on a finding that the IU never discharges more than 100 gpd of total categorical wastewater.

[12] A classification that a POTW may apply to certain IUs, if their discharge of categorical wastewater does not exceed specified percentages of the hydraulic or organic capacity of the treatment plant or loading into the plant.

the POTW;

(2) contributes a process waste stream that makes up 5 percent or more of the average dry-weather hydraulic capacity of the POTW wastewater treatment plant;

(3) contributes a process waste stream that makes up 5 percent or more of the organic capacity of the POTW wastewater treatment plant; or

(4) is designated as an SIU by the POTW based on the reasonable potential for adversely affecting treatment plant operation or violating any pretreatment standard.

2.2 Pretreatment Standards

2.2.1 Prohibitions

The POTW must enforce two types of prohibitions that apply to all non-domestic users: general prohibitions and specific prohibitions. The general prohibitions disallow a user from discharging a pollutant or pollutants that cause pass through or interference (see 40 CFR §403.5(a)). The specific discharge prohibitions listed in 40 CFR §403.5(b) exclude the discharge of:

- Pollutants that may create a fire or explosion hazard in the sewer system or at the POTW.
- Pollutants that are corrosive, including any discharge with a pH of less than five.
- Solid or viscous pollutants, in sufficient amounts, that will cause obstruction or blockage of flow.
- Any pollutants discharged in sufficient quantity to interfere with the operation of the POTW.
- Heat in such quantities that the temperature at the POTW Treatment Plant exceeds 104 °F or is hot enough to interfere with biological treatment processes.
- Petroleum oil, non-biodegradable cutting oil, or other products of mineral oil origin in amounts sufficient to cause interference or pass-through.
- Pollutants that result in the presence of toxic gases, vapors, or fumes at the POTW in sufficient amounts that may cause acute worker health and safety problems.
- Any trucked or hauled pollutants, except at discharge points designated by the POTW.

2.2.2 Categorical Pretreatment Standards

Categorical pretreatment standards are technology-based numeric limits that have been developed in accordance with section 307 of the CWA to limit the pollutant discharges to POTWs from specific process wastewaters from IUs. These national technology-based standards apply to an IU regardless of whether or not the POTW has an approved pretreatment program or the IU has been issued a control mechanism or permit[13]. The standards are established based on the list of priority pollutants in 40 CFR §401.15, which contains 65 entries, some of which are for groups of pollutants.

The list of industrial categories and applicable federal regulations are shown in **Table 1**. Categorical industrial users (CIUs) subject to these regulations must comply with monitoring, reporting, and record keeping requirements in the applicable regulations (as well as local requirements levied by the POTW).[14]

Table 1. EPA Pretreatment Categories and Standards

Category[a]	40 CFR §	Category	40 CFR §
Aluminum Forming	467	Battery Manufacturing	461
Carbon Black Manufacturing (New Sources Only)[b]	458	Centralized Waste Treatment	437
Coil Coating	465	Copper Forming	468
Electrical & Electronic Components	469	Electroplating	413
Feedlots (New Sources Only)	412	Fertilizer Manufacturing (New Sources Only)	418
Glass Manufacturing (New Sources Only)	426	Grain Mills (New Sources Only)	406
Ink Formulating (New Sources Only)	447	Inorganic Chemicals Manufacturing	415
Iron & Steel	420	Leather Tanning & Finishing	425
Metal Finishing	433	Metal Molding & Casting	464
Nonferrous Metals Forming	471	Nonferrous Metal Manufacturing	421
Oil & Gas Extraction	435	Organic Chemicals, Plastics & Synthetic Fibers	414
Paint Formulating (New Sources Only)	446	Paving & Roofing (New Sources Only)	443
Petroleum Refining	419	Pesticide Chemicals Manufacturing	455
Pharmaceuticals	439	Porcelain Enameling	466
Pulp, Paper & Paperboard	430	Rubber Manufacturing (New Sources Only)	428
Soap & Detergent Manufacturing (New Sources Only)	417	Steam Electric	423
Timber Products	429	Transportation Equipment Cleaning	442
Waste Combustors	444		

Source: TCEQ Pretreatment Webpage at: http://www.tceq.texas.gov/permitting/wastewater/pretreatment/EPA_categories_standards.html (accessed 10/21/14)

a. EPA is proposing technology-based pretreatment standards for dental practices that would require dentists to control discharges of dental amalgam and amendments to 40 §CFR 403 to streamline oversight requirements for the dental sector. See http://water.epa.gov/scitech/wastetech/guide/dental/ (accessed 10/21/14).

[13] The TCEQ is authorized to enforce the standards when the CIU discharges directly to waters of the state or discharges to a POTW without an approved pretreatment program.

[14] Non-categorical SIUs and other IUs are subject to monitoring requirements established by the POTW.

b. A new source is any building, structure, facility or installation from which there is a discharge that started after the publication of the proposed pretreatment standards (more detail is provided in 40 §CFR 403.3).

A POTW can calculate an equivalent mass limit for IU's permit (or control mechanism) for those categorical pretreatment standards that are expressed in terms of concentration. Once in the permit, the equivalent limit replaces the promulgated concentration-based pretreatment standard.

The CWA requires EPA to review pretreatment standards every two years and to identify potential new categories for regulation. In some cases in lieu of pretreatment standards, EPA may recommend development of BMPs such as the draft guidance document developed for unused pharmaceutical disposal at hospitals and other health care facilities.[15]

2.3 Hazardous and Toxic Waste and Pollutant Discharge Notification and Monitoring

2.3.1 Hazardous Waste Notification

The pretreatment regulations in 40 CFR §403.12(p) require IUs to notify, in writing, the POTW, EPA, and state hazardous waste authority (in Texas this is the TCEQ) of the discharge into a POTW of a substance, which, if otherwise disposed of, would be a hazardous waste under 40 CFR Part 261. An industrial user is required to submit a one-time notification for discharges of more than 15 kilogram (kg) of hazardous waste in any month, or any amount of acute hazardous waste.[16] If the discharge exceeds 100 kg in any month, the notification should include the hazardous constituents, the constituent mass, and an estimate of the discharge for the next 12 months.

2.3.2 Toxic or Hazardous Waste Pollutant Monitoring

POTWs with approved pretreatment programs may need to monitor influent and effluent for toxic or hazardous pollutants if based upon information available to the POTW, there is reason to suspect the presence of any toxic or hazardous pollutants listed in 40 CFR Part 122, Appendix D, Table V (Toxic Pollutants and Hazardous Substances Required To Be Identified by Existing Dischargers if Expected To Be Present), or any other pollutant, known or suspected to adversely affect treatment plant operation, receiving water quality, or solids disposal procedure.

[15] See http://water.epa.gov/scitech/wastetech/guide/upload/unuseddraft.pdf (accessed 10/21/14).

[16] Acute hazardous waste contains such dangerous chemicals that it could pose a threat to human health and the environment even when properly managed.

2.3.3 Toxics Release Inventory Chemical Discharges to POTWs

Information on some hazardous chemicals manufactured, processed, or otherwise used by industries in specific sectors and discharged to POTWs is available from the EPA's Toxics Release Inventory (TRI). The TRI Program currently covers 683 chemicals and chemical categories including many, but not all, hazardous chemicals. TRI chemicals also include many chemicals not listed as hazardous waste.[17]

Information on the discharge of TRI-listed chemicals to POTWs is available from the EPA's Discharge Monitoring Report (DMR) Pollutant Loading Tool.[18] The TRI program tracks the management of certain toxic chemicals that may pose a threat to human health and the environment. Facilities in different industry sectors must report annually how much of each chemical is released to the environment and/or managed through recycling, energy recovery, and treatment. A "release" of a chemical means that it is discharged to a POTW, emitted to the air or water, or placed in some type of land disposal. In general, chemicals covered by the TRI Program are those that cause chronic or acute human health effects or significant adverse environmental effects.

3 DISCHARGE CONTROL PLANS

POTWs with an approved pretreatment program are required to evaluate if their SIUs need a discharge control plan or other action to control accidental spills, non-customary batch discharges, or non-routine discharges that have a reasonable potential to cause pass through or interference or otherwise violate the POTW's regulations, local limits, or permit conditions. If the POTW determines that a control plan is needed, it must contain the following elements in 40 CFR §403.8(f)(2)(vi):

- Description of discharge practices;
- Description of stored chemicals;
- Procedures to immediately notify the POTW; and
- Procedures to prevent adverse impact from accidental spills (i.e., storage and containment, inspections, maintenance, training, etc.)

[17] See http://www2.epa.gov/toxics-release-inventory-tri-program (last accessed on 2/11/15).

[18] See http://cfpub.epa.gov/dmr/ (last accessed on 2/11/15).

4 SOURCE CONTROL PROGRAM EFFECTIVENESS

A number of approaches have been used to illustrate the effectiveness of source control programs in reducing or controlling the discharge of pollutants.

One example is an evaluation conducted by EPA on the achievements of the National Pretreatment Program (EPA, 2003). This evaluation showed that after 30 years post implementation, the program has resulted in significant reductions (83 percent) in the discharge of toxic chemicals (primarily priority pollutants) to the environment.

Other examples specifically relevant to potable reuse include source control programs that have been implemented for groundwater recharge projects in California involving indirect potable reuse. These programs attribute reductions in toxicity or specific constituents of emerging concern (CECs), such as 1,4-dioxane and N-nitrosodimethylamine (NDMA) to their source control programs.

- Toxicity testing of tertiary treated reclaimed water concentrates has been conducted by the County Sanitation Districts of Los Angeles County using the Ames test, which is a bioassay, used to evaluate the mutagenicity of reclaimed water. Test results from reclaimed water samples evaluated in the mid-1990s showed no Ames test responses, while wastewater concentrates collected in the late 1970s to the early 1980s showed a response. These results indicate that the character of the reclaimed water has substantively changed over time, most likely as a result of increased source control activities (unpublished).
- Certain CECs are not well removed by reverse osmosis membranes, such as NDMA and 1,4-dioxane. In response, through its source control program, the Orange County Sanitation District (OCSD) has been able to reduce the industrial discharge of NDMA and 1,4-dioxane into the wastewater collection system (NRC, 2012). As part of its next local limits evaluation, OCSD will evaluate the need for a limit on 1,4-dioxane.

It is important to note that expectations regarding pollution prevention and source control must be realistic. Source control programs will be effective in achieving reductions if the following conditions can be met:

- The pollutant can be found at measurable levels in the POTW's influent and collection system.
- A single source or group of similar sources accounting for most of the influent loading can be identified, such as the source's relative contributions to the mass loading and concentration of a pollutant or pollutants. The portion of the total influent source that is identified and considered controllable must be greater than the reduction in pollutant levels needed.

- The sources are within the jurisdiction of the POTW to control (or significant outside support/resources are available). For example, industrial sources are more easily controlled because industries are regulated and required to meet sewer use permit requirements, while residential sources are not within the legal jurisdiction of POTWs and, therefore, voluntary behavioral changes must be accomplished. If a pollutant source is a commercial product, such as mercury thermometers or lindane head lice remedies, it may not be within the local agency's power to ban or restrict the use of the product. To be effective, the use of a product must be restricted on a local, regional, statewide, or national basis.

5 EXAMPLE SOURCE CONTROL PROGRAMS RELATED TO POTABLE REUSE

For agencies implementing potable reuse projects, some source control programs have gone beyond the minimum federal requirements. Many agencies have developed local or statewide "no drugs down the drain programs"[19] and/or drug take-back programs and/or household hazardous waste collection programs.

The Code of Management Practices for Silver Dischargers (CMP) was developed by POTWs and industry as an alternative to numerical limits and monitoring for controlling silver discharges. A companion guidance manual to implement and use the CMP was developed by the National Association of Clean Water Agencies (formerly the Association of Metropolitan Sewerage Agencies) and the Silver Council.[20] The CMP is a set of recommended operating procedures using performance-based standards designed to reduce both the amount of silver and the overall volume of photographic processing solutions discharged to POTWs by photo processors, commercial imaging businesses, and diagnostic and industrial x-ray imaging facilities. Each type of facility has a recommended performance category and percentage of silver recovery from their silver-bearing wastes. The CMP has proven successful in reducing the amount of silver discharged to POTWs, increasing the amount of silver recovered; easing the administrative burden on both POTWs and silver users to enforce numerical limits, and encouraging water conservation and pollution prevention efforts.

Another national program is Healthier Hospitals Initiative (HHI) and Practice Greenhealth, These campaigns help facilitate the incorporation of sustainable and environmentally friendly practices into daily operations by participating health care facilities that result in the use, generation, and discharge of harmful

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[19] See http://www.nodrugsdownthedrain.org/ (accessed 10/21/14).

[20] See http://pmairegs.com/silvercouncil/codes/POTW_Guide.pdf (accessed 4/3/15).

and toxic chemicals and wastes.[21]

Other agencies have enhanced pretreatment program elements to augment their pollution prevention efforts. For example, to meet permit conditions imposed by the California State Water Resources Control Board's Division of Drinking Water (DDW, which was formerly the California Department of Public Health), the OCSD, which provides reclaimed water to the Orange County Water District for the Groundwater Replenishment System Project, has instituted program elements that build on the agency's traditional source control program. They consist of a pollutant prioritization scheme that includes chemical fate assessment for a broad range of regulated chemicals, including those with drinking water maximum contaminant levels (MCLs) or advisory health levels; a response plan for constituents of concern based on monitoring results; an outreach program for industries, businesses, and the public; and a toxics inventory that integrates a geographical information system and chemical fact sheets.

Some POTWs have voluntarily established specialized programs for categories of IUs to effectively control discharges rather than issuing discharge and monitoring requirements to each business:

- Dental offices and clinics – the program requires dental offices to use BMPs to reduce the amount of dental amalgam (potentially containing mercury) and other dental wastes (silver from photographic X-ray processing and lead from foil shields) being discharged.
- Dry cleaners – these programs are intended to control and regulate the management and disposal of solvents such as perchloroethylene, solvent waste and separator water from dry cleaners. For example, dry cleaner facilities may be required to either obtain an industrial discharge permit if they intend to discharge to the sewer, or to self-certify that they do not discharge dry cleaning waste to the sewer. For these kinds of program, solvent contaminated wastewater must be properly disposed (e.g., by evaporation or removed from a dry cleaning facility by a certified waste hauler (with records retained for verification)).
- Pharmaceutial manufactuers – in addition to compliance with federal categorical pretreatment standards and local limits, companies are asked to segregate, minimize, and separatly dispose of wastes containing pharmaceuticals so that they are not discharges to the sewer.
- Food Service Establishments – programs requiring control of fats, oil, and grease discharges. These programs are primarily implemented to prevent sewer blockages or overflows, but are an example of programs that can be implemented by POTWs for a general business class.

Some POTWs have voluntarily implemented outreach programs including:

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[21] See http://healthierhospitals.org/ (last accessed 2/11/15) and https://practicegreenhealth.org/ (last accessed 2/11/15).

- Educational programs affiliated with school districts – one example is the Sewer Science Program, a comprehensive high school science laboratory that teaches students about municipal wastewater treatment using specially designed tanks and standard testing equipment. It is an inter-disciplinary microbiology, chemistry, physics, and environmental curriculum designed to stress the importance of pollution prevention to high school students. The Sewer Science curriculum began in 1997 through collaboration between the City of Palo Alto, California's Regional Water Quality Control Plant, San Jose State University, and Menlo-Atherton High School, Menlo Park, California. Since 1997, numerous school districts including Dallas, Texas have adopted the program. Program materials are available at: http://www.calfog.org/cleanbay/sewerscience/hsduplicate.html (accessed 10/21/14). Besides increasing environmental awareness, the program grooms future environmental professionals and leaders.
- Industry advisory councils to provide a forum for the POTW and their regulated industries to address issues that are of concern to each group, including feedback on program modifications. As an example see http://www.lacsd.org/wastewater/industrial_waste/advisorycouncil.asp (accessed 10/21/14).
- Training courses, workshops, and outreach materials for industrial compliance. As an example see https://www.phoenix.gov/waterservices/envservices/indpretreatmentprog/compliance-academy (accessed 10/21/14).
- Technical assistance center/hot line for industries and businesses.

5.1 California Groundwater Replenishment Regulations

The June 2014 California Groundwater Replenishment (GWR) Regulations established requirements for source control programs.[22] Entities that supply recycled water to a GWR project must administer a comprehensive source control program to prevent undesirable chemicals from entering wastewater. The source control program must include:

- An assessment of the fate of DDW-specified contaminants through the wastewater and reclaimed water treatment systems;
- Provisions for contaminant source investigations and contaminant monitoring that focus on DDW-specified contaminants;
- An outreach program to industrial, commercial, and residential communities; and
- An up-to-date inventory of contaminants.

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[22] See http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/RecycledWater.shtml (accessed 10/21/14).

5.2 Oregon Priority Persistent Pollutants

Oregon has developed a program that requires POTWs to develop toxics reduction plans for priority persistent pollutants.[23] In 2007, the Oregon Legislature passed Senate Bill (SB) 737 that required the Oregon Department of Environmental Quality (DEQ) to consult with all interested parties by June 1, 2009 to develop a list of priority persistent pollutants (the "P3 list") that have a documented effect on human health, wildlife and aquatic life. By June 1, 2010, DEQ was required to issue a final report to the Legislature about the sources of priority persistent pollutants "from existing data" and identify source reduction and control methods that can reduce discharges. SB 737 also requires Oregon's 52 largest municipal wastewater treatment plants to develop plans by July 1, 2011 for reducing priority persistent pollutants through pollution prevention and toxics reduction. The municipalities or districts are required to develop toxics reduction plans for any of the pollutants on the "P3 list" that are present in the treatment plant discharge at levels greater than MCLs or an initiation level established by DEQ. The list was derived with input from expert workgroups.

The P3 list is comprised of pesticides, industrial chemicals, poly aromatic hydrocarbons, metals, and perfluorinated surfactants. Of the 118 listed pollutants, 33 pollutants have established MCLs; the remainder have a DEQ initiation level.[24] An initiation level is the concentration of a pollutant in municipal wastewater treatment plant effluent that, if exceeded, triggers the need for a priority persistent reduction plan for that pollutant. DEQ developed an implementation plan (sampling and quality assurance and quality control) to assist the municipalities in preparing plans.[25]

During the regulatory adoption process, some stakeholders expressed concern that although initiation levels are not water quality standards, they may be used as such. Senate Bill 737 specifically precludes the use of initiation levels as water quality standards (c.f., Section 4(1)(b)) and DEQ has repeated in the regulation the language from Senate Bill 737 stating that initiation levels are not water quality standards under state or federal law.

Sampling conducted in 2010 showed that municipal wastewater treatment plants routinely exceed initiation levels for cholesterol and coprostanol, two naturally occurring human digestion by-products (and thus pollutants with no feasible municipal pollution prevention activities or cost-effective treatment options). In 2011, DEQ adopted a rule so the wastewater agencies didn't have to develop reduction plans for cholesterol and coprostanol.

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[23] See http://www.deq.state.or.us/wq/SB737/ (accessed10/21/14).

[24] See http://www.deq.state.or.us/about/eqc/agendas/attachments/2011oct/G-Att-Div045.pdf (accessed 10/21/14).

[25] See http://www.deq.state.or.us/wq/SB737/docs/QAPPf.pdf (accessed 10/21/14).

6 SOURCE CONTROL RECOMMENDATIONS FOR POTABLE REUSE

A key factor for creating an effective source control program for potable reuse is the recognition that the program is a critical sentinel in creating a safe water supply and no longer is strictly focused on just wastewater compliance. The following recommendations are provided on how to structure a pretreatment program to provide an effective barrier for DPR that are voluntary program elements (and not intended to be part of approved programs). It should be noted that these recommendations could impact pretreatment program resources and budgets in terms of staffing, technical skills, and operating procedures.

- Implement a proactive source control program tailored to your service area's industrial and commercial business inventory and wastewater treatment system.
- Ensure that a source control program's legal authority has sufficient power to develop and implement source control measures to protect reclaimed water quality and the ability of the treatment facility to produce reclaimed water; including establishing local limits to control POCs and provisions to take actions as necessary to protect a DPR project.
- Develop and maintain a frequently updated comprehensive inventory of industries and businesses, which may use products or chemicals that contain POCs or that could generate intermediate compounds of concern.
- Assist and encourage industries and businesses, which use chemicals that contain POCs for DPR, to identify source control options, such as chemical substitution.
- For development of local limits, consider including as POCs a broader spectrum of regulated and non-regulated constituents that are relevant for DPR, such as drinking water contaminants, or CECs.
- Ensure that IU discharge permits and other control mechanisms can effectively regulate and reduce the discharge of POCs for DPR, and permits are reviewed and revised to adapt to any changing conditions, as needed.
- Consider alternative control mechanisms, such as BMPs or self-certification for zero discharge of pollutants for classes of industries or commercial businesses.
- Ensure that monitoring programs conducted by the POTW and IUs address POCs for DPR.
- Ensure that the enforcement response program can rapidly identify and respond to discharges of POCs for DPR.
- For projects with multiple agency involvement (in particular when a separate agency treats the wastewater supplied to the agency that produces the reclaimed water used for DPR), consider entering into a memorandum of understanding or other contractual agreement so that appropriate source control actions can be taken if necessary to protect reclaimed water quality.

- Provide outreach to industries on DPR, source control practices and compliance assistance, and permit assistance to support the DPR program.
- Provide outreach to the public regarding proper disposal of pharmaceuticals and household products that contain chemicals that may also be POCs; consider developing household hazardous waste collection programs; and consider developing school education programs for the wastewater management program that addresses potable reuse.
- Ensure that there is communication between the POTW operations and source control staff of the POTW supplying wastewater to the DPR water reclamation facility in situations where the treated wastewater quality appears to be impacted by (or is believed to be impacted) by an industrial discharge. This communication will ensure that the source control program can rapidly respond to correct a problem, and if necessary the effluent flow can be discharged instead of diverted to DPR water reclamation facility until the situation is stabilized.

7 ACRONYMS

BMP	Best management practice
CEC	Constituent of emerging concern
CFR	Code of Federal Regulations
CIU	Categorical industrial user
CMP	Code of Management Practice for Silver Dischargers
CWA	Clean Water Act
DDW	California Division of Drinking Water
DEQ	Department of Environmental Quality
DMR	Discharge Monitoring Report
DPR	Direct potable reuse
EPA	U.S. Environmental Protection Agency
gpd	gallons per day
GWR	Groundwater recharge
HHI	Healthier Hospitals Initiative
IU	Industrial user
kg	kilogram
MCL	Maximum contaminant level
mgd	Million gallons per day
MTCIU	Middle tier categorical industrial user
NSCIU	Non significant categorical industrial user
OCSD	Orange County Sanitation District

POC	Pollutant of concern
POTW	Publicly owned treatment works
SB	Senate Bill
SIU	Significant industrial user
TAC	Texas Administrative Code
TCEQ	Texas Commission on Environmental Quality
TLAP	Texas Land Application Permit
TMDL	Total Maximum Daily Load
TPDES	Texas Pollutant Discharge Elimination System
TRI	Toxics Release Inventory
§	Section

8 REFERENCES

EPA, 2003, EPA's National Pretreatment Program, 1973-2003: Thirty Years of Protecting the Environment. Available at http://www.epa.gov/npdes/pubs/pretreatment_thirtyyears.pdf (accessed 10/21/14).

NRC, 2012, Water Reuse: Expanding the Nation's Water Supply Through Reuse of Municipal Wastewater. National Academies Press, Washington, D.C.

E Appendix:
Evaluation of Treatment Technologies

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TECHNICAL MEMORANDUM

Texas Water Development Board
Evaluating the Potential for Direct Potable Reuse in Texas
Task 6: Evaluation of Treatment Technologies

Project No.: 0866-005-01

Date: April 15, 2015

Ellen McDonald

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NOTE: The information presented in this technical memorandum (TM) is based on the water quality performance targets summarized in Appendix C. As noted in the Direct Potable Reuse Resource Document, Volume 1, Chapter 3, the Texas Commission on Environmental Quality has established baseline pathogen targets for direct potable reuse projects that are different than those presented in Appendix C and summarized in this TM. The TCEQ also grants different log removal credits for some processes than those presented here. TCEQ log removal credits are presented in Chapter 5 of the Direct Potable Reuse Resource Document, Volume 1.

1 INTRODUCTION

An integral component of Direct Potable Reuse (DPR) projects[1] is a multi-barrier treatment system capable of reliably achieving the desired water quality goals. The treatment system must be robust to effectively remove a wide range of targets including regulated constituents (i.e., pathogens and other

[1] For this project, DPR has been defined as the introduction of advanced treated reclaimed water either directly into the potable water system downstream of a water treatment plant or into the raw water supply immediately upstream of a water treatment plant.

chemical constituents). The treatment system must also provide redundancy to maintain consistent performance. Other components of the DPR treatment strategy include financial considerations (both capital and operational costs), treatment process residuals management, regulatory permitting, and stabilization of the final product water.

The purpose of this technical memorandum (TM) is to identify and summarize performance characteristics of potential treatment strategies for production of reclaimed water intended for DPR to achieve reclaimed water with concentrations at or below the Water Quality Performance Targets developed during Task 3 of this project. A summary of conceptual capital and Operation and Maintenance (O&M) costs for the potential treatment strategies will also be included.

2 WATER QUALITY PERFORMANCE TARGETS

In Task 3, Water Quality Performance Targets for unregulated constituents were developed that will be included in the DPR Resource Document; a *de facto* minimum requirement for DPR treatment systems in Texas is that they must produce reclaimed water that meets drinking water standards. The targets (indicators and surrogates) for unregulated constituents were either based on protection of human health or ensuring that a treatment system is properly operating. Chemical targets were also developed taking into consideration aesthetic issues as they can aid in the public acceptance of a DPR project. The chemical targets developed for this project focus on health and aesthetics, but targets related to operational performance may also be needed depending on the specific treatment process being used. In order to develop recommendations for these targets, the project technical team drew from local, state, national and international studies, current potable reuse projects from around the world, stakeholder input (including the July 9, 2013 Workshop), as well as the project team's own expertise. It should be noted that the targets do not specifically address the type of DPR scheme to be implemented (e.g., delivery of reclaimed water directly to the drinking water distribution system vs. reclaimed water blended with raw water and processed through a water treatment plant prior to delivery to the drinking water distribution system).

2.1 Pathogens

Pathogen and treatment reduction targets were selected to meet an acceptable risk threshold. **Table 1** summarizes the proposed pathogen and total coliform removal targets (between raw wastewater and the drinking water distribution system) developed in the Task 3 TM. Evaluation of the *Cryptosporidium*, *Giardia*, and virus targets is not based on direct measurement of the specific pathogens, but evaluating appropriate surrogates for treatment unit processes.

Table 1: Proposed pathogen and total coliform $\log_{10}$ removal targets.

Parameter	***Cryptosporidium***	***Giardia***	**Virus**	**Total Coliform**
$\log_{10}$ removal	10	10	12	9

2.2 Chemicals

Recommended water quality targets for chemicals include, at a minimum, compliance with the primary and secondary drinking water Maximum Contaminant Levels (MCLs). However, the Task 3 Draft TM recommended that additional chemical targets be established to ensure that removal of a wide range of chemical types is achieved. The chemical indicator targets were selected (1) by comparing their measured environmental concentrations in water and/or reclaimed water to human health benchmarks or (2) on the basis that they are present in sufficient concentrations to assess unit process reductions. In addition to ensuring compliance with the MCLs, it is recommended that utilities pursuing implementation of DPR projects develop a monitoring program using indicators and surrogates, as more fully described in the Task 2 Draft TM.

Recommended indicator chemicals from the Task 2 Draft Technical Memorandum, together with suggested target levels (monitoring trigger thresholds) are repeated here for reference (**Table 2**). The constituents with MCLs, which are disinfection byproducts (DBPs), have been specifically included to emphasize that they should be monitored throughout a treatment scheme to ensure that formation is controlled during treatment.

Table 2: Suggested indicator chemicals to be included in DPR monitoring program.

Constituent	Rationale	Monitoring Trigger Threshold (ng/L)[1]	Reporting Limit (ng/L)	Task 2 Draft Technical Memorandum Reference
Total trihalomethanes (THMs)	Health	80,000	1,000	MCL
Haloacetic acids (HAA5)	Health	60,000	1,000	MCL
N-Nitrosodimethylamine (NDMA)	Health	10	2	CDPH[2] Notification Level[3]
Perfluorooctanoic acid (PFOA)	Health	400	10	Provisional short-term USEPA[4] Health Advisory
Perfluorooctane Sulfonate (PFOS)	Health	200	10	Provisional short-term EPA Health Advisory
Bromate	Health	10,000	1,000	MCL / World

Constituent	Rationale	Monitoring Trigger Threshold (ng/L)[1]	Reporting Limit (ng/L)	Task 2 Draft Technical Memorandum Reference
				Health Organization guideline
Perchlorate	Health	15,000	1,000	EPA Health Advisory
1,4-Dioxane	Health	1,000	100	CDPH Notification Level
17 α-ethinyl estradiol (EE2)	Health	280	28	USEPA CCL3[5] List
Atenolol	Health/ Performance	4,000	100	Bull et al. 2011
Tris(2-chloroethyl)phosphate (TCEP)	Health/ Performance	5,000	100	Minnesota Dept. of Health (2011) guidance value
Caffeine	Performance	--	50	Drewes et al. 2013
Gemfibrozil	Performance	800,000	10	Schwab 2005
Iopromide	Performance	750,000	50	Australia 2008
Meprobamate	Health/ Performance	200,000	100	Bull et al. 2011
N,N-Diethyl-meta-toluamide (DEET)	Performance	200,000	50	Minnesota Dept. of Health (2011) guidance value
Primidone	Performance	10,000	10	Bruce et al. 2010
Sucralose	Performance	150,000,000	100	CFR Title 21
Triclosan	Performance	2,100,000	50	Drewes et al. 2013

1. ng/L – nanograms per liter. The Monitoring Trigger Thresholds (MTTs) are based on primary MCLs for regulated chemicals, health advisory levels, and human health relevant drinking water levels from published studies for unregulated chemicals. The MTTs represent the concentration of a substance in drinking water that can be ingested daily over a lifetime without appreciable risk. Additional information is provided in the Task 2 TM.
2. CDPH - California Department of Public Health.
3. CDPH has established Notification Levels for chemicals in drinking water without MCLs. If a chemical concentration is greater than its Notification Level in drinking water, the utility must inform its customers and consumers about the presence of the chemical, and about health concerns associated with exposure to it.
4. USEPA – U.S. Environmental Protection Agency.
5. Contaminant Candidate List 3

As described in the Task 2 Draft TM, suggested surrogates for advanced treatment processes are provided in **Table 3**.

Table 3: Suggested surrogate parameters for advanced water treatment processes to be included in DPR monitoring program.

Surrogate Parameter	Example Unit Processes[1]
Performance	
Total organic carbon (TOC) or dissolved organic carbon (DOC)	RO, NF, GAC, PAC, ozone, AOP
UV absorbance (254 nm[2])	RO, NF, GAC, PAC, ozone, AOP
Fluorescence indices/ratios	RO, NF, GAC, PAC, ozone, AOP
Total dissolved solids (TDS)/electrical conductivity	RO, NF, EDR
Boron (surrogate for NDMA)	RO, NF
Turbidity	MF, UF, GAC, PAC
THM Formation Potential	All treatment processes contemplated looking at pre and post-chlorination (free or combined)
NDMA Formation Potential	All treatment processes contemplated looking at pre and post-chlorination (free or combined) and pre and post-ozonation
Aesthetics	
Temperature	RO, NF, GAC, PAC, ozone, AOP
Color (436 nm)	RO, NF, GAC, PAC, ozone, AOP
Odor	RO, NF, GAC, PAC, ozone, AOP
Hardness	RO, NF, CHEM

1. RO – reverse osmosis, NF – nanofiltration, GAC – granular activated carbon, PAC – powdered activated carbon, AOP – advanced oxidation, EDR – electrodialysis reversal, CHEM –chemical precipitation.
2. nm – nanometers.

3 TREATMENT TECHNOLOGIES

A variety of treatment technologies are available to treat wastewater for reuse. Many of these technologies have been employed in full scale applications to generate reclaimed water for non-potable use, and more recently, for indirect potable reuse (IPR). Other technologies have either limited full scale applications or have not resulted in efficient or effective treatment for producing reclaimed water. Site- and project-specific attributes can be a factor in selecting the appropriate treatment process for a reuse project.

A brief description of the technologies considered for DPR treatment strategies in this report are described in the following sections; the order does not imply the order of a specific treatment scheme.

Secondary/Tertiary Treatment - The feed water for IPR or DPR systems is typically secondary effluent or tertiary effluent from a wastewater treatment plant (WWTP). Treatment at the WWTP typically includes headworks, primary clarification, and a secondary biological process followed by secondary clarifiers. The secondary biological process generally consists of aerated lagoons, rotating biological contactors, trickling filters, or conventional activated sludge processes (with or without nutrient removal). For reuse applications, modifications to improve the final effluent quality can be implemented at the WWTP such as (1) improved primary treatment performance via chemical addition; and (2) secondary treatment alterations, including, but not limited to increased solids retention times (SRTs), and the addition of microbial selectors to achieve nitrification, denitrification, and/or biological phosphorus removal. Particle settling or phosphorus removal can be enhanced with chemical addition such as alum or polymers.

Since many WWTPs produce water for non-potable reuse, tertiary treatment is often utilized via filtration including granular media filtration (sand, anthracite or multi-media filters) and cloth-media filtration. Secondary effluent and tertiary effluent are typically disinfected using free chlorine, chloramine, ozone, UV, or other disinfectants. Selection of disinfected or undisinfected effluent prior to advanced treatment should be considered in light of pathogen reduction objectives, maintenance of the distribution system from the WWTP to the advanced treatment facility, formation of disinfection byproducts for treatment at the advanced treatment facility, and other factors.

It should be noted that the Texas Commission on Environmental Quality (TCEQ) does not typically allow pathogen removal or chemical constituent removal credit for treatment prior to advanced treatment or a potable water treatment plant. However, both pathogens and chemical constituents can be removed by the WWTP processes. For this TM, treatment schemes were assembled assuming that both pathogen and chemical constituent removal credits would be allowed for the WWTP in order to assist with achieving the Water Quality Performance Targets.

Microfiltration or Ultrafiltration (MF/UF) – Membrane filtration is a water treatment process that is being used extensively for potable use or reuse. MF/UF is typically employed in the Advanced Water Treatment (AWT) component of a reuse project. The purpose of the membrane filtration system is to remove suspended and colloidal solids, including target pathogens from a water stream. Consistent water quality is produced while achieving particle, pathogen and turbidity removal that meets treatment goals. These systems can be configured with a high level of automation to minimize staffing requirements and operate reliably.

Various membrane materials are utilized in membrane water treatment including polyvinylidene fluoride (PVDF), polyether sulfone (PES), polysulfone (PS), and other similar materials. Most commercially available MF/UF membranes are extruded into hollow fiber tubes. Each hollow fiber tube has size controlled pores in the material to achieve the appropriate level of filtration without jeopardizing the strength of the membrane fiber. The membranes operate as a sieve using size exclusion to filter out the debris in the water. MF and UF membranes are differentiated by their pore size. MF has a larger pore size, ranging from about 0.1 to 3 microns, while UF pore sizes range from 0.01 to 0.1 microns.

The pathogen removal credit allowed is typically awarded based on a challenge study for the membrane product, or based on the removal that can be verified by a direct integrity test, whichever value is lowest. MF and UF membranes can provide virus removal, with UF capable of achieving up to 4-log reduction. However, the TCEQ does not currently allow this reduction credit due to concerns with integrity testing verification. For this memorandum, it was conservatively assumed that MF and UF membranes would not have a log reduction credit for viruses.

Membrane Bioreactor (MBR) - An MBR essentially combines the biological treatment process of a conventional wastewater treatment plant with a membrane filtration process. An MBR is typically employed in the AWT component of a reuse project. An MBR-based WWTP typically consists of headworks, a bioreactor, and membrane filtration. The membrane filtration in an MBR system essentially replaces the solids separation function of secondary clarifiers and tertiary filters used following a conventional activated sludge WWTP. An MBR is capable of producing consistent water quality while achieving Biochemical Oxygen Demand (BOD), ammonia, pathogen and turbidity treatment goals for reuse. Similar to the MF/UF membranes discussed above, the pathogen removal credits are determined by a challenge study and/or direct integrity verification. TCEQ also does not allow a virus reduction credit for MBR membranes.

The bioreactor configuration generally includes anoxic tanks followed by aeration tanks. The mixed liquor from the aeration tanks flows to the membrane tanks where filtration occurs with membranes submerged in the mixed liquor. MBRs are typically operated with long SRTs to help achieve nitrification, which assists with the performance of the membrane filtration by minimizing the fouling potential of the water to be filtered. MBR membranes can be either MF or UF membranes. An advantage of MBR over conventional wastewater treatment processes is a smaller overall plant footprint. Existing activated sludge wastewater plants can be retrofitted to an MBR plant by adding the membrane filtration process along with minor modifications to the existing processes.

Reverse Osmosis (RO) – RO is a process that uses semi-permeable spiral wound membranes to separate and remove dissolved solids, organics, pesticides, pharmaceutical compounds and other constituents of emerging concern (CECs). RO is typically employed in the AWT component of a reuse project. RO does most of the work in removing the dissolved solids, organics and pathogens that remain after upstream treatment processes. Feed water is delivered under pressure to the semi-permeable membrane, where water permeates through the membrane and is collected. This purified water stream is called permeate. Impurities in the water are rejected by the membrane, concentrated, and collected for disposal. This stream is called the concentrate or brine. An important aspect of the RO process is that not all of the feed water is recovered as permeate. The percentage of permeate in relation to the feed water is called the recovery. For reuse applications, the RO recovery typically ranges from 75 – 85%. It is possible to add a third stage RO unit to improve recovery up to 90%. Thus, considerations for treating a larger feed flow and disposal of the RO concentrate must be accounted for in a treatment scheme that includes RO.

Common RO membrane materials include polyamide thin film composites, cellulose acetate and cellulose triacetate with the membrane material being spiral wound around a tube to produce an RO element. RO elements are loaded into pressure vessels and multiple pressure vessels comprise an RO unit.

An RO pretreatment system consists of chemical dosing and cartridge filtration. Acid is typically used to lower the pH to assist with scaling and fouling control of the RO system. Antiscalant is also dosed to the RO feed stream to assist with scaling control. The cartridge filters remove any particle material from the stream before the RO system.

After pretreatment, the feed water is pumped to the RO units with high pressure pumps. RO units are typically arranged in multiple stages to achieve the desired recovery. For example in a two stage system, the concentrate from the first stage becomes the feed water for the second stage and permeate from the second stage is blended with the permeate from the first stage.

The disposal of RO brine or concentrate can be a challenging issue that needs to be addressed at an early stage in the design of a membrane treatment system. Addressing RO brine disposal issues early in a project is necessary because without an acceptable method for disposal of the concentrate generated by the plant, it cannot be built or operated. Brine disposal options can be costly, land intensive and in some cases maintenance intensive. Some common brine disposal options include disposal at a WWTP, disposal to surface water, evaporation ponds, and deep well injection.

An alternative membrane process to RO that is seeing increased evaluation and consideration for reuse applications is Nanofiltration (NF). NF is a pressure driven separation process that employs a semi-permeable membrane and the principles of cross-flow filtration treat water for reuse. NF removes organic constituents, viruses, Natural Organic Matter (NOM), and divalent ions that comprise hard water. NF is less efficient at removing dissolved salts and nitrate in comparison to RO. Concentrate from NF is less problematic for treatment or disposal compared to RO concentrate. NF is configured and operated similar to RO, but might provide the opportunity to reduce feed pressure and operating costs compared to RO. Although NF might be a viable treatment process for DPR, it is mentioned in this TM but not included in any of the treatment schemes due to limited full scale application for reclaimed water production.

Ultraviolet (UV) Disinfection and Ultraviolet/Advanced Oxidation Process (UV/AOP) – UV or UV/AOP is typically employed in the AWT component of a reuse project. UV disinfection is a physical process that transfers electromagnetic energy from a mercury arc lamp to an organism's genetic material (DNA and

RNA). When UV radiation penetrates the cell wall of an organism, it destroys the cell's ability to reproduce. UV radiation can also destroy other components of an organism when applied over a range of wavelengths. The effectiveness of a UV disinfection system depends on the characteristics of the water, the intensity of UV radiation, the amount of time the microorganisms are exposed to the radiation, and the reactor configuration. UV disinfection is more effective for water with low suspended solids concentrations. A UV validation study per EPA rules or using National Water Research Institute guidance is required to determine the log inactivation credit for UV equipment.

The main components of a UV disinfection system are mercury arc lamps, a reactor, and ballasts. The source of UV radiation is either the low-pressure or medium-pressure mercury arc lamp with low or high intensities. Low-pressure lamps produce virtually all of their UV output at a wavelength of 254 nanometers (nm). Medium pressure UV lamps produce output over a range of 200 to 300 nm.

The UV disinfection system can be utilized to photolysize chemicals such as NDMA. It also is used for AOP by adding an oxidant, typically hydrogen peroxide, upstream of the UV system. UV and hydrogen peroxide together form free hydroxyl radicals, which are powerful oxidizing agents. Hydroxyl radicals are short lived but can oxidize trace levels of organics. The UV/AOP process is particularly effective at removing NDMA and 1,4-Dioxane from water. The UV dose required for photolysis or AOP is typically higher than the dose required for disinfection. Medium pressure UV lamps are typically more effective for NDMA removal since NDMA absorbs UV light at about 228 nm.

Ozone - Ozone is produced when oxygen molecules are dissociated by an energy source into oxygen atoms that subsequently collide with an oxygen molecule to form an ozone gas. Ozone is generated by most facilities by imposing a high voltage alternating current (6 to 20 kilovolts) across a dielectric discharge gap that contains an oxygen-bearing gas. Ozone is generated onsite because it is unstable and decomposes to elemental oxygen in a short amount of time after generation. Ozone is a very strong oxidant and disinfectant. The amount of disinfection can be estimated using EPA CT tables.

When ozone decomposes in water, the free radicals that are formed have great oxidizing capacity and play an active role in the oxidation and disinfection process. The effectiveness of disinfection depends on the susceptibility of the target organisms, the contact time, and the concentration of the ozone. Oxidation of organic contaminants show similar dependencies. Ozone is typically employed in the AWT component of a reuse project.

The components of an ozone system include feed-gas preparation, ozone generation, ozone contacting, and ozone destruction. Air or pure oxygen is used as the feed-gas source and is passed to the ozone generator at a set flow rate. The energy source for production is generated by electrical discharge in a gas that contains oxygen.

After generation, ozone is injected into the water stream which then flows to an ozone contact chamber or contactor. The primary purpose of the contactor is to provide sufficient contact time for oxidation and disinfection. Since ozone is consumed quickly, it must be contacted uniformly in a contactor that approximates plug flow. The key process control parameters are dose, mixing, and contact time.

The off-gases from the contactor must be treated to destroy any remaining ozone before release into the atmosphere. Therefore, it is essential to maintain an optimal ozone dosage for better efficiency. When pure oxygen is used as the feed-gas, the off-gases from the contactor can be recycled to generate ozone or for reuse in the aeration tank. The ozone off gases that are not used are sent to the ozone destruction unit or are recycled.

Ozone and AOP can result in formation of undesirable chemical by-products including NDMA and bromate which may be difficult to remove with downstream treatment processes. A treatment scheme employing ozone or AOP should consider the benefits of ozone versus the potential drawbacks from formation of by-products. Ozone is often used in conjunction with Biological Activated Carbon (BAC) to remove some of the by-products and the Assimilable Organic Carbon (AOC) that results from the ozonation. A thorough assessment of the ozone/AOP by-product formation, which may include bench scale or pilot studies, should be conducted to assist with confirmation of the overall treatment scheme.

Granular Activated Carbon (GAC) - GAC is used to adsorb organic compounds, taste and odor compounds, and synthetic organic chemicals in water treatment. Adsorption is a physical and chemical process that results in accumulation of a substance at the interface between liquid and solids phases. Activated carbon is an effective adsorbent because it is a highly porous material and provides a large surface area to which contaminants may adsorb. GAC systems generally consist of fixed bed contactors and a backwash system. When the adsorptive capacity of the GAC is exhausted, the GAC must be replaced. Depending on the treatment application, the replacement GAC can be unused (virgin) or regenerated carbon produced by off-site processing the spent GAC. Depending on the adsorptive capacity for constituents in the stream to be treated, GAC can be an expensive treatment process if frequent replacement or regeneration of the GAC is required. GAC is most effective for removing chemical constituents and has limited effectiveness for pathogen removal. GAC might be a viable treatment process for DPR schemes that require additional assistance with removal of trace chemical constituents. However, it is not included in any of the treatment schemes due to the cost considerations as well as the availability of other treatment processes for trace chemical constituent removal.

Biological Activated Carbon (BAC) - BAC is a modification of conventional media filtration and is typically employed in the AWT component of a reuse project. BAC is GAC that has not been replaced and is allowed to exhaust which then promotes biological activity on the GAC to assist with removal of dissolved organic constituents, including CECs, DBP precursors, and AOC. BAC can be enhanced by pre-ozonation. Biological growth can be supported on BAC because of the surface area available to the bacteria. In the absence of a sustained disinfection residual in the filter feed water or backwash water, bacteria attach to the media and grow using the low levels of organic compounds present in water as a food source. Unlike GAC, the media is not regenerated.

BAC has been shown to remove synthetic organic compounds, iron, manganese, taste, odors and biodegradable organic carbon. BAC offers several advantages over conventional filtration such as reduced chlorine demand of the filtered water, enhanced biostability of water in the distribution system, and removal of many ozone byproducts.

Chlorine - Chlorine is a widely used disinfectant as it kills most bacteria, viruses, and other microorganisms that cause disease. Chlorine is typically employed in the AWT component of a reuse project. Water is dosed with chlorine and rapidly mixed before entering a baffled contact chamber to allow time for disinfection to occur. The disinfected effluent is then conveyed to downstream facilities for reuse.

Chlorine can be dosed as either free chlorine or combined chlorine. Free chlorine is introduced to water in the form of gas or liquid hypochlorite. Combined chlorine is formed by reacting free chlorine with ammonia to form chloramines. For most wastewater applications, ammonia may be present in the wastewater effluent that can react with dosed free chlorine to form chloramines. Free chlorine is a more powerful oxidant than chloramines and is thus used as a primary disinfectant for the treatment schemes developed in this TM. For reuse applications that employ RO, chloramines are an important secondary disinfectant that assist with maintaining a disinfectant residual to control biofouling on the RO membranes.

The effectiveness of chlorination depends on the dose, the chlorine demand of the water, the chlorine residual, and the amount of time the water is in contact with the chlorine. The required degree of disinfection can be achieved by varying the dose and the contact time for any chlorine disinfection system. Chlorine is not effective at inactivating protozoa and helminths. Free chlorine use with water that has organic constituents can result in formation of Disinfection By-Products (DBPs) such as THM and HAA5. Combined chlorine can result in formation of NDMA.

Hypochlorite degrades as a function of time and temperature and can result in formation of chlorate and perchlorate degradation byproducts. Hypochlorite can be generated on-site to avoid degradation and formation of byproducts.

Stabilization - Stabilization of the treated water is sometimes needed to prevent corrosion of any downstream treatment or distribution facilities. Stabilization is typically employed in the AWT component of a reuse project. RO permeate typically has a very low level of total dissolved solids (TDS) and corresponding low levels of calcium, magnesium, and alkalinity. This water matrix results in low Langelier Saturation Index (LSI) or calcium carbonate precipitation potential (CCPP) values.

The dissolved carbon dioxide associated with the addition of acid to the feed water passes through the RO membranes and results in a permeate pH of about 5.5. These characteristics cause the RO permeate to be corrosive and require further treatment. Stabilization can be performed using a packed tower decarbonator to remove most of the carbon dioxide, followed by dosing with an alkaline source (sodium hydroxide or sodium carbonate) and a calcium source (lime, calcium chloride) for hardness and alkalinity. The alkaline source assists with adding alkalinity back into the water and adjusting the pH, while the calcium source assists with adding hardness and/or alkalinity back into the water. The product water is typically stabilized to adjust the LSI to around 0 and pH to a range of 7-9.

Engineered Storage - Storage buffers can be environmental (natural) or engineered (i.e., constructed) facilities used between the AWT and potable water systems to compensate for process variability, reliability, and unknowns. The engineered storage consists of a well-defined, constructed, storage facility. Important features of the engineered storage include a fully controlled environment, containment to prevent contamination and evaporative losses, and no source of contamination from within the storage. Engineered storage can allow for additional measurement of specific constituents to confirm the quality of water prior to discharge to downstream facilities.

Engineered storage can be standalone facilities or can be incorporated into the transport and distribution system. Examples of engineered storage include above ground tanks, covered and lined surface storage reservoirs, large diameter subsurface pipes, enclosed subsurface reservoirs, and confined aquifers.

Engineered storage has not been required by TCEQ for reuse applications. However, it can be an important component of a reuse strategy. For this TM, engineered storage was included in several of the treatment schemes.

Water Treatment Plant (WTP) – As a baseline case, a conventional surface WTP was assumed for this TM. This type of WTP generally consists of pretreatment, filtration and disinfection. A coagulant is dosed to the raw water and then mixed in a rapid mix chamber. The water is then conveyed to the flocculators and on to the sedimentation step. After sedimentation the water is treated with granular media filtration to remove particles. The final water is generally disinfected with chlorine (free or combined).

4 TREATMENT STRATEGIES

The intent of developing treatment schemes for the DPR Resource Document is to provide a prospective list of treatment schemes that can be used as a basis for further consideration by entities interested in pursuing a DPR project. The treatment schemes are comprised of technology options that have proven effectiveness for full scale applications, or show promise from pilot study results at achieving the Water Quality Performance Targets. Additional assumptions for development of the treatment schemes include:

- The treatment scheme represents the entire DPR process from the WWTP to the AWT and WTP (if applicable), to the potable water distribution system (raw wastewater to treated drinking water).

- The pathogen log removal targets in Table 1 were used as a guide for developing the treatment schemes. Only treatment schemes that were able to achieve the required pathogen log removal targets were included for discussion. For some treatment schemes, Engineered Storage and a WTP were included to assist with achieving the required pathogen log removal targets. The Engineered Storage would provide for additional monitoring to confirm the quality of water prior to discharge to downstream facilities For other treatment schemes, the Engineered Storage and WTP were not included because the WWTP and AWT treatment processes were able to achieve the required pathogen log removal targets. However, the figures for these treatment schemes show the Engineered Storage and WTP as optional treatment components.

- A conventional surface water WTP (coagulation/flocculation/sedimentation/filtration/free chlorine disinfection) was assumed for some of the schemes as a baseline. A WTP with more advanced technology could be employed to garner additional removal of target constituents and provide additional barriers of constituent removal.

- The process sequence of MF, RO and UV/AOP is utilized in several of the treatment schemes. This approach is being used for the operational DPR project in Texas - the Colorado River Municipal Water District (CRMWD) at Big Spring project. It has also been successfully employed for several IPR projects in California, as well as internationally.

- The treatment schemes that do not include Engineered Storage and a WTP may need to consider post disinfection to prevent biological regrowth in the drinking water distribution system. It is assumed that a chemical such as chlorine would be added to the reclaimed water to maintain a disinfection residual. However, since this chemical would be added only to provide a disinfection residual, it was conservatively assumed that this chemical would not have significant impacts on the pathogen log removal and chemical constituent removal and was thus not included in the discussion and evaluation of the treatment schemes. However, any post chlorination credits should be evaluated on a case-by-case basis depending on the individual project as well as any impacts on DBPs in the distribution system.

- For treatment schemes that include MF/UF, chlorine and ammonia (if not already present in the feed water) is typically dosed to the MF/UF feed water in order to form chloramines for biological growth control in the MF/UF process. Although dosing of this secondary disinfectant may result in some pathogen removal (Giardia and Cryptosporidium), it was assumed to be insignificant compared to the pathogen removal by the other WWTP and AWT processes and free chlorine disinfection, where applicable.

- For some applications, the WWTP may be operated to achieve denitrification or phosphorus removal by biological or chemical means. Although these processes might result in additional pathogen removal or chemical constituent removal, it was assumed to be insignificant compared to the pathogen and chemical constituent removal by the other WWTP and AWT processes. Project-specific evaluations would need to be conducted to assess the removal efficiencies of these processes for the overall treatment scheme.

4.1 Treatment Scheme No. 1

Figure 1 presents Treatment Scheme No.1, which includes ozonation prior to the MF/UF-RO-UV/AOP process sequence. Engineered Storage and a WTP are shown as optional components as this scheme meets the Water Quality Performance Targets without these components.

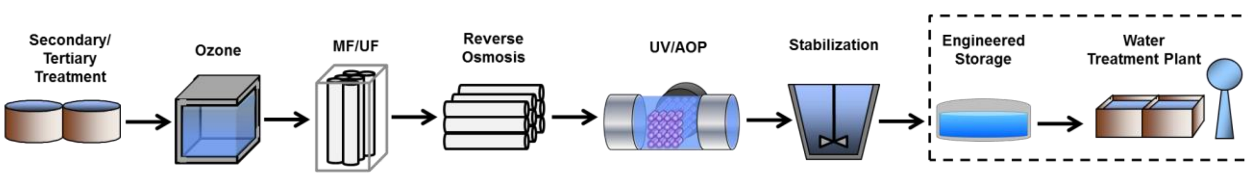

Figure 1: Treatment Scheme No. 1

For this treatment scheme, disinfected secondary or tertiary effluent from a WWTP would be dosed with ozone for pathogen removal and to oxidize the organics in the wastewater effluent. Ozonation can result in formation of undesirable chemical by-products such as NDMA and bromate that may be difficult to remove with downstream AWT treatment processes. The ozone dose/contact time should be considered in order to minimize formation of chemical by-products. The production of AOC from ozonation may contribute to biofouling of downstream membranes if chloramination is not maintained.

After the ozone pretreatment, the water is treated with MF/UF, RO, and UV/AOP (using hydrogen peroxide prior to UV). The final treatment step is post-treatment or stabilization.

Major residuals from this treatment scheme include MF/UF backwash, cleaning chemicals, and RO concentrate or brine. Depending on the capacity of the DPR facility, these residual streams (except RO concentrate) may be recycled back to the WWTP. For facilities located inland, a variety of disposal strategies must be evaluated for the RO brine. The availability of a cost-effective disposal strategy for an inland facility is an extremely important consideration for the feasibility of this scheme.

Treatment Scheme No. 1 is similar to the West Basin Municipal Water District's (WBMWD) Edward C. Little Water Recycling Facility in El Segundo, CA. This facility has operated for nearly a decade and produces a variety of custom made, or "designer" reclaimed waters for potable and industrial uses. One of the reclaimed water streams is injected into a seawater barrier to prevent seawater intrusion into groundwater aquifers as well as to replenish the water that is extracted by potable water wells. Ozonation prior to MF was recently piloted and the process added to the full scale plant during an upgrade project.

4.2 Treatment Scheme No. 2

Figure 2 presents Treatment Scheme No. 2, which includes the MF/UF-RO-UV/AOP process sequence. AWT effluent flows to Engineered Storage and a WTP before the reclaimed water enters the drinking water distribution system. The WTP is needed to assist with achieving pathogen reduction targets.

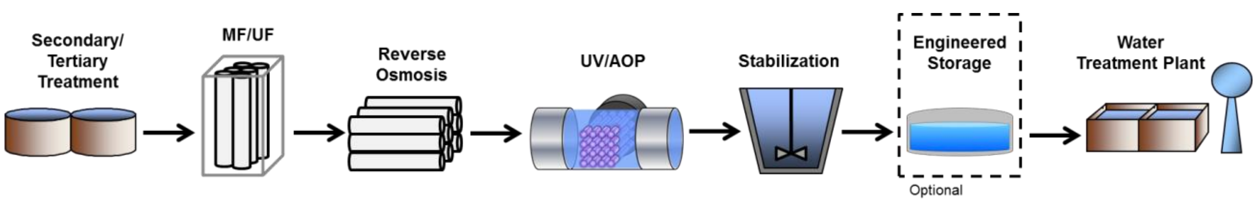

Figure 2: Treatment Scheme No. 2

This treatment scheme is similar to Treatment Scheme No. 1 without the ozone pretreatment and with the addition of Engineered Storage and a WTP. At the heart of this scheme is the MF-RO-UV/AOP process sequence.

After stabilization as described for Treatment Scheme No. 1, the water is conveyed to Engineered Storage and then to a WTP for additional treatment before distribution.

Major residuals from this treatment scheme include MF/UF backwash, cleaning chemicals, and RO concentrate or brine. Depending on the capacity of the DPR facility, these residual streams (except RO concentrate) may be recycled back to the WWTP. For facilities located inland, a variety of disposal strategies must be evaluated for the RO brine. The availability of a cost-effective disposal strategy for an inland facility is an extremely important consideration for the feasibility of this scheme.

It should be noted that Treatment Scheme No. 2 shares some characteristics with the CRMWD at Big Spring, Texas project. The CRMWD project treats disinfected tertiary effluent with the MF/UF-RO-UV/AOP process sequence. The reclaimed water is then blended with raw surface water and treated at a conventional WTP. The CRMWD project began operation in 2013.

4.3 Treatment Scheme No. 3

Treatment Scheme No. 3 is presented in **Figure 3.** This treatment scheme includes and MBR instead of a WWTP to treat raw wastewater ahead of the RO-UV/AOP process sequence.

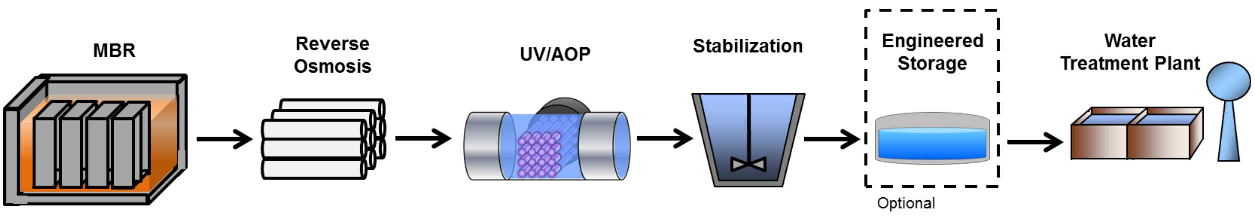

Figure 3: Treatment Scheme No. 3

The first step in this scheme is treatment of primary-treated wastewater with MBR operated with full nitrification. MBR filtrate would be dosed with chloramines and then flow to a filtrate tank before being pumped to the downstream RO and UV/AOP processes. The RO, UV/AOP and stabilization processes would be as described for Treatment Scheme No. 1. Similar to Treatment Scheme No. 2, Engineered Storage and a WTP would comprise the final processes before distribution. The WTP is needed to assist with achieving pathogen reduction targets.

Residuals from the process include wasted sludge, MBR membrane cleaning waste, and RO brine. The waste sludge would be processed in a typical WWTP solids handling facility. The MBR cleaning wastes would be neutralized and slowly fed back into the head of the MBR treatment plant. RO brine would need to be addressed as described in Treatment Scheme No. 1.

A variation of this treatment scheme that could possibly achieve lower overall energy consumption and less brine would be to direct a portion of the MBR filtrate around the RO for treatment using Ozone/BAC. The BAC effluent could then be blended with the RO permeate upstream of the UV/AOP process. This process configuration would allow removal of some of the CECs and other chemical constituents by Ozone/BAC at a lower energy consumption rather than relying on RO for treatment of the entire flow.

Treatment Scheme No. 3 is similar to the Village of Cloudcroft, NM PUReWater Project. The Cloudcroft project is an IPR project that has been constructed but is not yet operational. The IPR treatment system capacity is 0.1 mgd.

4.4 Treatment Scheme No. 4

Figure 4 presents a treatment scheme that is similar to Treatment Scheme No. 1, but with the addition of BAC between ozone and MF/UF, as well as UV disinfection followed by free chlorine instead of UV/AOP. Treatment Scheme No. 4 eliminates RO from the treatment process train which would help alleviate RO brine disposal issues for inland DPR facilities as well as the need to produce a larger flow of RO feed water.

Similar to Treatment Scheme No. 1, Engineered Storage and a WTP would not need to be an integral part of Treatment Scheme No. 4 to meet the Water Quality Performance Targets. However, these processes are shown as optional and would provide additional barriers, if desired.

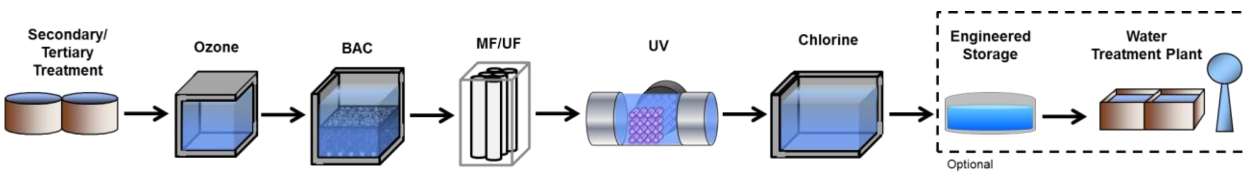

Figure 4: Treatment Scheme No. 4

The BAC will assist with removal of dissolved organic constituents from the feed stream. As with Treatment Scheme No. 1, ozone chemical by-products could be an issue for this treatment scheme if formation levels are such that downstream processes cannot adequately remove them.

The MF/UF filtrate would be disinfected with UV and free chlorine before conveyance to the distribution system.

Major residuals from this treatment scheme include BAC backwash and MF/UF backwash and cleaning chemicals. The BAC backwash would be clarified and the decant stream recycled back to the head of the treatment plant or sent to the WWTP. The MF/UF residual streams may be recycled back to the WWTP.

4.5 Treatment Scheme No. 5

Treatment Scheme No. 5 is presented in **Figure 5.** This treatment scheme reverses the order of MF/UF and Ozone/BAC treatment compared to Treatment Scheme No. 4, and does not use UV. Engineered Storage and a WTP are required components of Treatment Scheme No. 5. The WTP is needed to assist with achieving pathogen reduction targets.

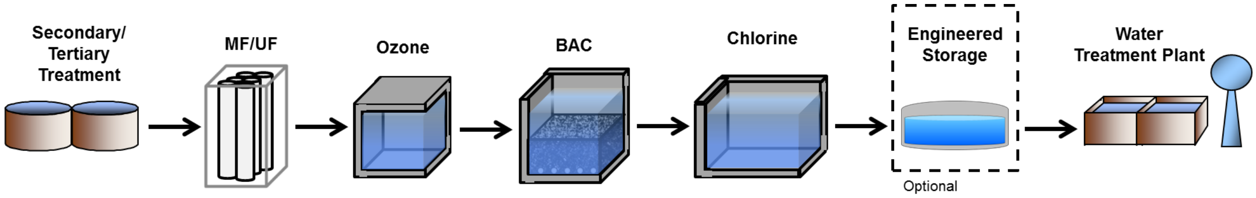

Figure 5: Treatment Scheme No. 5

Disinfected secondary or tertiary effluent would be treated with MF/UF followed by Ozone/BAC. Ozone/BAC would serve the purpose of removing organic constituents from the MF/UF filtrate. Since Ozone/BAC would be employed downstream of MF/UF, the ozone dose and BAC loading could be lower compared to pre-Ozone/BAC because the MF/UF would remove particles and other filterable materials that could present an ozone demand or be filtered by the BAC.

The BAC effluent would be dosed with free chlorine to achieve additional virus removal before the water would be conveyed to the Engineered Storage. This treatment scheme could have limited success for treating water with the potential for formation of ozone by-products. Chlorination and a conventional WTP may not adequately remove these by-products. It would be important to assess the ozone by-product formation via bench or pilot studies before proceeding with design of this treatment scheme. Major residuals from this treatment scheme are similar to those for Treatment Scheme No. 4.

4.6 Treatment Scheme No. 6

Figure 6 presents Treatment Scheme No.6. This treatment scheme would not employ membranes as part of the treatment process. This treatment scheme includes Engineered Storage and a WTP.

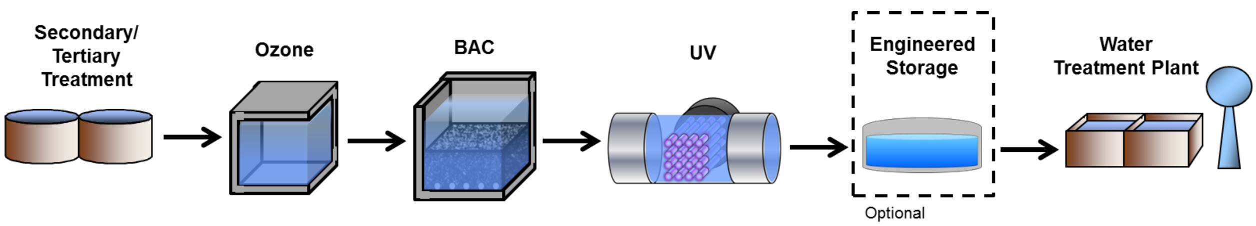

Figure 6: Treatment Scheme No. 6

Disinfected secondary or tertiary effluent would be treated by Ozone/BAC followed by UV. Since this DPR treatment process does not use a filtration process other than BAC it would be most applicable to well-clarified wastewater. The BAC effluent would be treated with UV before conveyance to the Engineered Storage and a WTP. The major residual would be BAC backwash which would be clarified and the decant stream recycled back to the head of the treatment plant or sent to the WWTP.

This treatment scheme is similar to the Landsborough, Queensland, Australia IPR process.

5 TREATMENT REMOVAL PERFORMANCE

Each of the treatment schemes developed in the previous section could provide a multiple barrier treatment system for DPR. However, the number of barriers varies between the schemes and the ability of each scheme to achieve the Water Quality Performance Targets differs. In this section, each scheme will be assessed for its performance at achieving the pathogen and chemical Water Quality Performance Targets.

5.1 Pathogens

The individual treatment processes that comprise the treatment schemes have demonstrated varied performance for removing *Cryptosporidium*, *Giardia*, viruses and Total Coliform. In order to assess the treatment scheme's anticipated log reduction of these constituents, the log reduction range of the individual treatment processes was estimated and the results presented in Table 4**.** It should be noted that the log reduction ranges shown are based on available data from various pilot- and full-scale installations that were summarized in the indicated reference. Actual log removal credits will be subject to TCEQ approval and may need to be adjusted for specific DPR projects.

As indicated in Table 4, each treatment component exhibits variability with respect to the pathogen log reduction values. This variability can be due to water quality and site specific considerations, as well as characteristics of the technology. The treatment processes that rely on physical separation or removal, such as MF/UF or RO, produce consistent performance unless there is an integrity issue with the membranes. Performance of chemical processes, such as Ozone or UV/AOP, is typically dependent on the applied dose and constituent concentrations.

Table 4: Treatment component pathogen and total coliform log reduction.

Treatment Component	Pathogen Log Reduction[1]			
	Cryptosporidium	*Giardia*	Viruses[2]	Total Coliform
Secondary/Tertiary	0.5 - 2.0	0.5 - 2.5	0.5 - 2.5	1.0 - 3.0
MBR	> 6.0	> 6.0	0	3.5 - > 6.0
Ozone	1.0 - 2.0	2.0 - 4.0	4.0 - 6.0	2.0 - 6.0
Ozone/BAC	2.0 - 4.0	3.0 - 5.0	4.0 - 6.0	3.0 -> 6.0
MF/UF	> 6.0	> 6.0	0	3.5 - > 6.0
RO	2.0 - > 6.0	2.0 - > 6.0	2.0 - > 6.0	3.0 - > 6.0
UV/AOP	> 6.0	> 6.0	> 6.0	> 6.0
UV	3.0 - > 6.0	3.0 - > 6.0	3.0 - > 6.0	2.0 - > 6.0
Chlorine	0 - 0.5	0.5 - 1.5	1.0 - 3.0	2.0 - 6.0
Stabilization	--	--	--	--
Engineered Storage	--	--	--	--
WTP	0 - 3.5	0.5 - 4.5	1.0 - 4.5	2.0 - 6.0

1. Source: Trussell, R. et al. (2013)
2. MBR and MF/UF can achieve virus removal. However, regulatory agencies may not allow reduction credits due to concerns with integrity testing verification. Currently the TCEQ does not allow virus removal credit for RO, also due to concerns with integrity testing verification. However, 2 log credit is assumed for RO with the assumption that this concern can be addressed through improved testing methods.

The pathogen log reduction values for the individual processes were then used to generate pathogen log reduction totals for each of the treatment schemes. For the purpose of comparing the treatment schemes, a nominal value was assigned for each of the treatment components in **Table 4. Table 5** summarizes the pathogen log reduction for each of the treatment schemes.

The results show that all of the treatment schemes meet or exceed the log reduction targets. Some schemes, such as Treatment Schemes No. 5 and 6, just achieve the log reduction targets. Treatment Schemes No. 1 through 4 yield excess log reduction credits, particularly for *Cryptosporidium*, *Giardia* and Total Coliform. This is a conservative assessment since higher credits may be achieved by some of the individual unit processes than those shown. Nevertheless, the information presented is significant and consistent with the multi-barrier approach for a DPR treatment system. If an individual treatment process does not operate effectively, the target log reduction values may still be achievable by the other treatment processes.

Table 5: Treatment Scheme Pathogen and Total Coliform Log Reduction.

Treatment Scheme		Pathogen Log Reduction			
		Cryptosporidium	*Giardia*	Viruses	Total Coliform
1	Secondary/Tertiary	2	2	1	2
	Ozone	3	3	5	3
	MF/UF	4	4	0	3
	RO	2	2	2	4
	UV/AOP	6	6	6	6
	Stabilization	--	--	--	--
	Total	**17**	**17**	**14**	**18**
2	Secondary/Tertiary	2	2	1	2
	MF/UF	4	4	0	3
	RO	2	2	2	4
	UV/AOP	6	6	6	6
	Stabilization	--	--	--	--
	Engineered Storage	--	--	--	--
	WTP	3	3	4	5
	Total	**17**	**17**	**13**	**20**
3	MBR	4	4	0	3
	RO	2	2	2	4
	UV/AOP	6	6	6	6
	Stabilization	--	--	--	--
	Engineered Storage	--	--	--	--
	WTP	3	3	4	5
	Total	**15**	**15**	**12**	**18**
4	Secondary/Tertiary	2	2	1	2
	Ozone BAC	3	4	5	4
	MF/UF	4	4	0	3
	UV	4	4	4	5
	Chlorine	0	1	3	3
	Total	**13**	**15**	**13**	**17**
5	Secondary/Tertiary	2	2	1	2
	MF/UF	4	4	0	3
	Ozone BAC	3	4	5	4
	Chlorine	0	1	3	3
	Engineered Storage	--	--	--	--
	WTP	3	3	4	5
	Total	**12**	**14**	**13**	**17**
6	Secondary/Tertiary	2	2	1	2
	Ozone BAC	3	4	5	4
	UV	4	4	4	5
	Engineered Storage	--	--	--	--
	WTP	3	3	4	5
	Total	**12**	**13**	**14**	**16**
Target		**10**	**10**	**12**	**9**

However, the cost to build and operate a facility to provide excess reduction credits may impede certain projects from moving forward. Alternatively, treatment schemes like Treatment Schemes No. 5 and 6 could be employed but would need to be provided with a robust monitoring system as well as adequate reliability and redundancy to maintain efficient operation of all of the treatment processes. These two schemes would provide a less conservative multi-barrier approach and use less energy to achieve reclaimed water intended for potable reuse. Although all of the treatment schemes need a robust monitoring system, the schemes with fewer barriers would need additional monitoring and control provisions in order to ensure that water that does not meet the Water Quality Performance Targets is not discharged to the distribution system. If a treatment process fails, the reuse plant may have to cease sending water to the distribution system until the process issues is resolved. An evaluation of the water quality, risks and controls would need to be conducted to ensure protection of the potable water consumer.

Treatment schemes that include membranes or UV/AOP generally result in higher pathogen log reduction, particularly for *Cryptosporidium* and *Giardia* which are constituents that are readily removed by these processes. MF, UF, and RO membranes can also provide virus removal, with UF capable of achieving up to 4-log reduction. However, the TCEQ does not currently allow this reduction credit due to concerns with integrity testing verification. For this memorandum, it was conservatively assumed that MF/UF and MBR would not have a log reduction credit for viruses.

5.2 Chemicals

Similar to pathogens, the various treatment processes considered for the treatment schemes have varied performance with respect to the chemical Water Quality Performance Targets. Each treatment process was evaluated for removal of target chemical constituents included in Table 2. The treatment processes were also evaluated for removal of secondary constituents categorized as Particles and Aesthetics. **Table 6** presents the results of this evaluation. Approximate removal percentages based on literature review are shown for each constituent for each treatment process**.**

For removal of CECs, RO and Ozone/BAC provide the best performance. RO achieves this removal by rejection of the organic molecule from the membrane, while Ozone/BAC achieves this removal by oxidation of the organic to smaller components that may then be adsorbed or degraded on the BAC. UV/AOP can also achieve removal of specific CECs such as NDMA and 1, 4-Dioxane.

Table 6: Treatment Scheme Qualitative Chemical Removal Efficiency.

Treatment Scheme		Chemicals Removal Efficiency[1]																			
		THM	HAA5	NDMA	PFOS	Bromate	Perchlorate	1,4-Dioxane	17ß-Estradiol	Atenolol	TCEP	Caffeine	Gemfibrozil	Iopromide	Meprobamate	DEET	Primidone	Sucralose	Triclosan	Particles	Aesthetics
1	Secondary/Tertiary	P	P	P	P	P	P	P	E	L	L	E	L	L	L	F	L	L	L	L	P
	Ozone	P	P	L	P	P	P	L	G	E	P	E	E	F	F	G	P	P	E	P	G
	MF/UF	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	E	P
	RO	G	G	L	E	E	E	L	E	E	E	E	E	E	E	E	E	E	E	G	F
	UV/AOP	P	P	E	L	P	P	G	G	F	L	G	E	E	G	G	L	L	E	P	F
	Stabilization	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	L
2	Secondary/Tertiary	P	P	P	P	P	P	P	E	L	L	E	L	L	L	F	L	L	L	L	P
	MF/UF	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	E	P
	RO	G	G	L	E	E	E	L	E	E	E	E	E	E	E	E	E	E	E	G	F
	UV/AOP	P	P	E	L	P	P	G	G	F	L	G	E	E	G	G	L	L	E	P	F
	Stabilization	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	L
	Engineered Storage	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	WTP	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	G	G	L
3	MBR	P	P	P	P	P	P	P	G	G	L	E	E	L	G	L	F	L	G	E	P
	RO	G	G	L	E	E	E	L	E	E	E	E	E	E	E	E	E	E	E	G	F
	UV/AOP	P	P	E	L	P	P	G	G	F	L	G	E	E	G	G	L	L	E	P	F
	Stabilization	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	L
	Engineered Storage	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	WTP	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	G	G	L
4	Secondary/Tertiary	P	P	P	P	P	P	P	E	L	L	E	L	L	L	F	L	L	L	L	P
	Ozone BAC	E	G	G	P	P	P	G	E	E	L	E	E	F	F	F	L	L	E	G	G
	MF/UF	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	E	P
	UV	P	P	E	P	P	P	L	L	P	P	P	L	F	L	L	P	P	G	P	P
	Chlorine	P	P	P	P	P	P	P	G	L	P	P	F	P	P	P	P	L	G	P	P
5	Secondary/Tertiary	P	P	P	P	P	P	P	E	L	L	E	L	L	L	F	L	L	L	L	P
	MF/UF	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	E	P
	Ozone BAC	E	G	G	P	P	P	G	E	E	L	E	E	F	F	F	L	L	E	G	G
	Chlorine	P	P	P	P	P	P	P	G	L	P	P	F	P	P	P	P	L	G	P	P
	Engineered Storage	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	WTP	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	G	G	L
6	Secondary/Tertiary	P	P	P	P	P	P	P	E	L	L	E	L	L	L	F	L	L	L	L	P
	Ozone BAC	E	G	G	P	P	P	G	E	E	L	E	E	F	F	F	L	L	E	G	G
	UV	P	P	E	P	P	P	L	L	P	P	P	L	F	L	L	P	P	G	P	P
	Engineered Storage	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	WTP	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	G	G	L

1. E = Excellent = > 90%; G = Good = 70-90%; F = Fair = 40-70%; L = Low = 20-40%; P = Poor = < 20% 2.
2. Sources: Aga, D. (2008); Carollo Engineers (2011); Johnson, B. et. al. (2009); Lee, C. et. al. (2010); Mofidi, A. et. al. (2002); Munakata, N. et. al. (2011); MWH (2009); Rojas, M. et. al. (2012); Stanford, B. et. al. (2012); Sundaram, V. (2011); Trussell, R. et. al. (2013); U.S. Department of the Interior Bureau of Reclamation (2009).

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The treatment schemes that employ MF/UF would provide the best performance for removal of particles from the wastewater stream. Some processes, such as UV or UV/AOP, do not achieve removal of particles and are processes that can also be impaired by the presence of particles.

Ozone and Ozone/BAC would provide the best performance for aesthetic constituents such as color, taste and odor. These processes remove the constituents by oxidation and/or adsorption.

Overall, each of the treatment schemes could provide sufficient treatment to achieve the Water Quality Performance Targets. However, the treatment schemes that do not employ RO (Treatment Schemes 4-6) will not be as efficient at removing CECs that are difficult to oxidize and are not biodegradable, such as PFOS, bromate and perchlorate. In contrast with the pathogen removal performance of the various treatment processes, there is less redundancy for removal of chemical constituents by the treatment processes. For example, MF/UF is effective at removing *Cryptosporidium*, *Giardia* and Total Coliform, but for chemical constituents it is most effective at removing only particles. Other treatment processes exhibit similar characteristics. For chemical constituents it is thus important to provide sufficient monitoring, redundancy and controls for each treatment process to ensure reliable treatment.

6 TREATMENT COSTS

Conceptual level capital and O&M costs were summarized for each of the treatment schemes. The estimates are considered Level 4 conceptual or planning level estimates as defined by AACE International. Level 4 estimates have an accuracy of +50%, -30%. Cost curves for estimating both capital and O&M costs (Stanford, B. et al. (2013)) were used as a basis for developing the conceptual level estimates. The curves were adjusted based on cost information from recent studies and full scale facility costs.

Costs only include the core DPR treatment processes and do not include Secondary/Tertiary Treatment, Engineered Storage, residual/brine disposal, and Water Treatment Plant components. The costs do not include contractor's overhead and profit nor a project contingency, as the percentages used for these items are typically site specific. A summary of the capital and O&M costs expressed as million dollars per mgd is presented in **Table 7.**

Table 7: Treatment Scheme General Comparative Costs.

Capacity (MGD)	Treatment Scheme	Capital Cost ($M/MGD)	O&M Cost ($M/MGD)
1	1	$ 9.43	$ 1.000
	2	$ 7.54	$ 0.992
	3	$ 7.89	$ 1.048
	4	$ 7.18	$ 0.537
	5	$ 6.93	$ 0.499
	6	$ 4.75	$ 0.153
5	1	$ 6.27	$ 0.778
	2	$ 5.38	$ 0.771
	3	$ 5.63	$ 0.810
	4	$ 4.04	$ 0.398
	5	$ 3.81	$ 0.362
	6	$ 2.32	$ 0.125
10	1	$ 5.30	$ 0.700
	2	$ 4.66	$ 0.693
	3	$ 4.88	$ 0.727
	4	$ 3.21	$ 0.350
	5	$ 2.98	$ 0.315
	6	$ 1.72	$ 0.115
25	1	$ 5.13	$ 0.610
	2	$ 4.63	$ 0.603
	3	$ 4.84	$ 0.631
	4	$ 2.89	$ 0.297
	5	$ 2.63	$ 0.263
	6	$ 1.42	$ 0.103

1. Source: Stanford, B. et al. (2012)

The costs exhibit economy of scale as the unit cost in $M/mgd decreases with increasing treatment plant capacity. Both the capital and O&M costs are generally a function of the number of treatment processes in the scheme, with the larger number of treatment processes resulting in higher costs.

RO has the largest impact on the treatment scheme costs, as the treatment schemes that do not employ RO had comparably lower capital and O&M costs. Treatment schemes that employ RO have higher energy usage due to the pumping energy for the RO process. Furthermore, since RO recovery for reclaimed water production is typically 75-85%, pretreatment processes must treat a larger flow to provide adequate feed water for the RO process.

It should be noted that entities considering a DPR project must consider all of the components of the DPR treatment strategy including pathogen removal, chemical constituent removal, treatment process residuals management and regulatory permitting as well as costs, before selecting a DPR treatment strategy to move forward with. The lowest cost option may not be the most viable strategy to pursue.

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F Appendix:

Quantitative Relative Risk Assessment Examples

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TECHNICAL MEMORANDUM

STATE OF TEXAS
MARGARET H. NELLOR
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Texas Water Development Board
Evaluating the Potential for Direct Potable Reuse in Texas
Task 8: Quantitative Relative Risk Assessment

Margaret H. Nellor

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Project No.: 0866-005-01

Date: April 19, 2015

Prepared For: Project Team and Sponsors

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1 EXECUTIVE SUMMARY

1.1 Purpose

The purpose of the Texas Water Development Board Resource Document Task 8 was to conduct and document an example quantitative relative risk assessment (QRRA) for two direct potable reuse (DPR) case studies. Each case study compares a No Project Alternative (raw surface water that has undergone drinking water treatment) with a potential DPR Alternative (treated wastewater that has undergone advanced water treatment and drinking water treatment). Neither DPR scenario accounts for blending with raw drinking water prior to drinking water treatment, blending after drinking water treatment in the distribution system or directly distributing the purified reclaimed water into a drinking water distribution system. The QRRA focuses on chemicals that are currently regulated and chemicals that are not yet regulated but are of broad interest such as pharmaceuticals and personal care products. This analysis focused on chemical rather than pathogen risk since the Texas Commission on Environmental Quality (TCEQ) currently applies a set of guidelines for pathogen reduction for DPR applications. Pathogen risk evaluation could follow a similar approach as that described in this technical memorandum (TM).

A QRRA does not evaluate the absolute risk from ingestion of water “at the tap”, but rather a relative comparison based on an assumed quantity of water ingested and its estimated water quality. This approach eliminates difficulties in quantifying specific exposure to contaminants that occur as a result of population mobility, where tap water is consumed (home versus work), bottled water consumption, and other factors. Thus, actual exposures to drinking water are likely to be different from those assumed for the QRRA; however, the difficulties with assessing absolute exposure highlight the benefits of the relative risk approach.

1.2 Case Studies

The two case studies were selected to illustrate real situations that could occur in Texas in terms of water treatment, wastewater treatment, and advanced water treatment to produce reclaimed water. For water treatment, we deliberately included additional treatment processes (ozone and biologically activated carbon (BAC)[1]) at the water treatment plant (WTP) for one of the case studies to represent a treatment scheme that addresses taste and odor, iron and manganese, and/or the need to reduce disinfection byproduct (DBP) formation, which are common issues in parts of the State. For advanced water treatment for DPR, we deliberately included one advanced treatment facility (AWTF) with reverse osmosis (RO) for one of the case studies and an AWTF without RO for the other case study. As discussed in earlier phases of this project, it is of significant interest to identify and evaluate treatment schemes that do not include RO due to the difficulty and costs associated with disposal of brine concentrate, particularly in inland areas of the State.

Case Study 1 (Non-RO AWTF/Enhanced WTP):

- No Project Alternative: Raw source water is treated by an enhanced WTP, consisting of ozone, BAC, flocculation-sedimentation, media filtration, and chlorination with free chlorine.
- DPR Project Alternative: Secondary/tertiary wastewater treatment plant (WWTP) effluent is the feed water to an AWTF that consists of microfiltration (MF) or ultrafiltration (UF), ozone, BAC, and chlorination (Figure E-1). This product water is then treated by the enhanced WTP consisting of ozone, BAC, flocculation-sedimentation, media filtration, and chlorination.

[1] While in some parts of Texas ozone and BAC are commonly used drinking water treatment processes, for this TM we have used the term “enhanced WTP” to distinguish the water treatment scheme from what is considered conventional drinking water treatment (flocculation-sedimentation, media filtration, and chlorination).

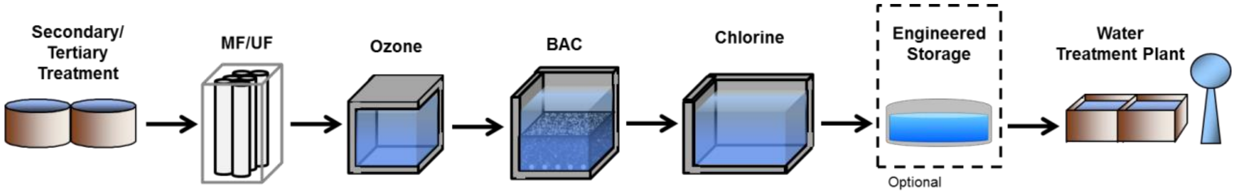

Figure E-1. Case Study 1 Advanced Water Treatment Facility

Case Study 2: (Membrane AWTF/Conventional WTP):

- No Project Alternative: Raw source water is treated by a conventional WTP consisting of flocculation-sedimentation, media filtration, and chlorination with free chlorine.
- DPR Project Alternative: Secondary/tertiary WWTP effluent is the feed water to an AWTF that consists of UF, RO, and advanced oxidation (ultraviolet (UV) irradiation and hydrogen peroxide) (Figure E-2). This product water is then treated by a WTP consisting of flocculation-sedimentation, media filtration, and chlorination.

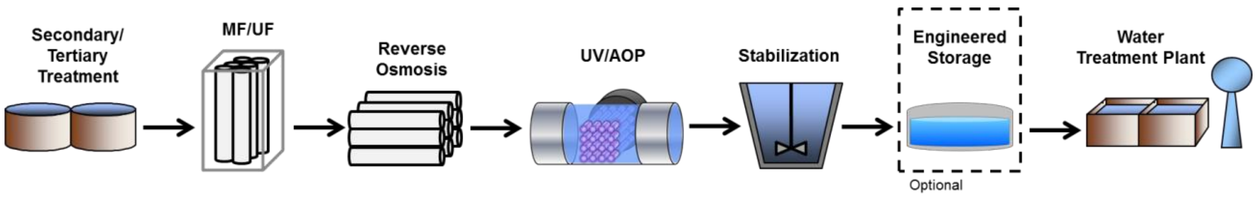

Figure E-2. Case Study 2 Advanced Water Treatment Facility

1.3 Risk Assessment

1.3.1 Data Collection and Estimates

To simulate the case studies for the QRRA, monthly samples were collected from two Texas raw drinking waters and disinfected filtered secondary effluent (tertiary effluent) from two WWTPs for the period December 2013 through May 2014. Samples were analyzed for regulated constituents (priority pollutants, constituents with drinking water maximum contaminant levels (MCLs), constituents with other regulatory recommendations or guidelines), and unregulated constituents (for example, prescription drugs, over-the-counter drugs, and personal care products). For the QRRA, "detected compounds" are those that were found in at least one sample at or above the compound-specific Minimum Reporting Level (MRL). The MRL represents an estimate of the lowest concentration of a compound that can be quantitatively measured. For each constituent, if the concentration in at least one sample was at or above the MRL it was deemed to be "detected." If the other sample concentrations were reported to be below the MRL, for calculation of the average concentration for the QRRA, the constituent was assumed to be present at the

MRL. This averaging approach is likely to overestimate the concentration of any observation reported below the MRL and provides an added layer of conservatism to the risk assessment.

Detected constituents were divided into two categories:

- Constituents of Potential Concern (CPCs) are detected compounds that are regulated or currently under consideration for regulation and had associated health-based criteria that could be used to quantify the estimated relative potential health risk.
- Constituents of Emerging Concern (CECs) are detected compounds that are unregulated with published toxicity information to evaluate their health significance. The Eurofins Eaton Analytical method was used for analysis because it is capable of reliably testing for more than 90 CECs in a single method at low levels (nanogram per liter or ηg/L).

For the No Project Alternatives, estimated WTP removal efficiencies were applied to the CPCs and CECs in the raw waters to estimate drinking water concentrations. For the DPR Alternatives, estimated AWTF and WTP removal efficiencies were applied to the CPCs and CECs in the secondary wastewaters to estimate drinking water concentrations. This assessment accounts for DBPs already present in the water samples, but did not account for formation of DBPs, such as trihalomethanes or N-nitrosodimethylamine through the various water treatment processes.

1.4 Quantitative Relative Risk Assessment Results for Constituents of Potential Concern

For CPCs, QRRAs were conducted for noncarcinogenic and carcinogenic risk. The results showed that a properly designed and operated DPR treatment system can provide protection from CPCs that are comparable to or better than the No Project Alternatives.

For noncarcinogenic risk, the QRRA evaluated the cumulative hazard index (the sum of hazard quotients for each CPC) for each case study alternative. A hazard quotient is the ratio of the CPC and its applicable reference dose (the toxicity value used to evaluate its health effect). A hazard index less than 1 would indicate that the person's dose of each CPC is below its respective "safe dose" or reference dose (RfD), and that the additive potential does not exceed a "total safe dose." The EPA considers a hazard index less than 1 to indicate that there is no increased health risk. In other words, a hazard index less than 1 indicates that all contaminants are present at concentrations below those that could cause effects in humans, even if the chemicals have additive effects.

As shown in Table E-1, for each No Project Alternative and DPR Alternative, the cumulative hazard index was less than 1. However, for the Case Study 1 DPR Alternative (the non-RO AWTF), the cumulative hazard index was close to 1, with most of the contributions coming from nitrate and fluoride.[2] However, none of the CPCs were detected at levels that exceeded MCLs for any of the alternatives. The higher cumulative hazard index for the Case Study 1 DPR Alternative in comparison to the Case Study 2 DPR Alternative illustrates the role of RO membranes in removing nitrogen and its risk contribution. This result also suggests that better removal of nitrogen at the WWTP or an added nitrogen barrier as part of the AWTF would reduce risk for both DPR Alternatives.

Table E-1. Summary of Noncarcinogenic Risk Assessment

	Case Study 1		**Case Study 2**	
	No Project Alternative	**DPR Alternative**	**No Project Alternative**	**DPR Alternative**
Hazard Index (HI)	0.13	**0.89**	0.20	0.05
# CPCs present with RfD[1]	16	27	9	22
Any Single Constituent with HI > 1	No	No	No	No
Major Contributors to Overall HI	**Fluoride (58%)**[2] Nitrate (34%) Aluminum (5%)	**Nitrate (73%)** Fluoride (22%)[2] Monochloroacetic Acid (2%) Strontium (2%)	**Fluoride (61%)**[2] Nitrate (31%) Arsenic (6%)	**Fluoride (37%)**[2] **Nitrite (28%)** Manganese (11%) Molybdenum (7%) Cyanide (7%)
Any Constituent > MCLs	No	No	No	No

1. RfD – reference dose.
2. The fluoride concentration was below its MCL. The RfD is based on prevention of dental fluorosis, which is a change in the appearance of the tooth's enamel.

Carcinogenic risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to a potential carcinogen based on its cancer slope factor (SF). Cancer SFs are based on experimental animal data and limited epidemiological studies, when available. The model generally used by the U.S. Environmental Protection Agency (U.S. EPA) to calculate numerical cancer potency values overpredicts risk in comparison to average population risk.

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[2] Fluoride can occur naturally in drinking water or can be added to public drinking water supplies as a public health measure to reduce cavities. For the Case Study 1 DPR Alternative, both nitrate and fluoride were below their respective MCLs. Fluoridation of water has benefits in the prevention of tooth decay. The RfD for fluoride is based on prevention of dental fluorosis, which is a change in the appearance of the tooth's enamel.

The results of the carcinogenic QRRA are shown in Table E-2. Similar to the noncarcinogenic risk assessment, concentrations of CPCs were below MCLs and health advisory levels. The carcinogenic risks for the Case Study 1 No Project Alternative, Case Study 1 DPR Alternative, and Case Study 2 No Project Alternative were in approximately the same range. The carcinogenic risk for the Case Study 2 DPR Alternative (the membrane AWTF), however, is about an order of magnitude lower. For each alternative, arsenic and DBPs are the major contributors to risk. For the Case Study 2 DPR Alternative, RO and UV/AOP play an important role in reducing risk through removal of these CPCs. These results highlight the need to consider prevention of DBP formation or removal of DBPs as part of a DPR treatment scheme (beginning with the WWTP through AWTF and WTP).

Table E-2. Summary of Carcinogenic Risk Assessment

	Case Study 1		Case Study 2	
	No Project Alternative	**DPR Alternative**	**No Project Alternative**	**DPR Alternative**
Drinking Water Risk (Point Estimate)[1]	1.3E-06	3.9E-06	7.0E-06	7.3E-07
# CPCs with SF	4	8	4	3
Major Risk Contributors	Arsenic (24%) NDMA[2] (74%)	Arsenic (12%) BDCM[3] (20%) CDBM[4] (18%) NDMA (60%)	Arsenic (85%) BDCM (8%) CDBM (13%)	Arsenic (59%) NDMA (22%) TCA[5] (19%)
Any Constituent Present at Levels > MCLs or Advisory Levels	No	No	No	No

1. The point estimate represents the most conservative estimate of risk.
2. NDMA – N-nitrosodimethylamine
3. BDCM – Bromodichloromethane
4. CDBM – Chlorodibromomethane
5. TCA – Trichloroacetic Acid

1.5 Risk Exemplar Results for Constituents of Emerging Concern

For CECs, the 2012 National Research Council (NRC) risk exemplar approach was utilized to assess risk (NRC, 2012). The results show that a properly designed and operated DPR treatment system can provide protection from CECs that are comparable to the No Project Alternatives.

The risk exemplar approach relies on estimates of the amount of a substance in drinking water that can be ingested daily over a lifetime without appreciable risk. These “safe” levels are called Drinking Water Equivalent Levels (DWELs), Predicted No Effect Concentrations (PNECs), or Drinking Water Guidelines (DWGs). For each of the detected CECs, potential lifetime health risks were assessed by calculating margins of safety (MOSs). A MOS is the ratio of a risk-based action level (RBAL) based on a DWEL, PNEC, DWG or other available heath benchmark, divided by the estimated concentration of the constituent in water. In using the risk exemplar approach, the NRC opined that an MOS lower than 1 for a specific CEC posed a potential concern from that CEC. This interpretation was made in light of the multiple safety factors, such as the application of uncertainty factors, included in the derivation of the RBALs.

A summary of the CEC risk for both Case Studies is presented in Table E-3. With one exception, for all of the alternatives, all of the CECs have MOSs greater than 1. The exception is quinoline with an MOS in the range of 1 for the Case Study 1 No Project Alternative and DPR Alternative. For Case Study 2, quinoline was not found in the No Project Alternative raw drinking water, but was found in the secondary wastewater for the DPR Alternative, and is removed by RO.

Table E-3. Summary of Constituents of Emerging Concern Risk Exemplar

	Case Study 1		Case Study 2	
	No Project Alternative	**DPR Alternative**	**No Project Alternative**	**DPR Alternative**
# CECs present >MRL	32	46	5	53
MOS Range	1.6 - 10,500,000,000	0.9 - 59,000,000,000	3,600 - 16,000,000	13 - 6,000,000,000
# CECs with MOS 1-10	1	1	0	0
CECs with MOS 1-10	Quinoline	Quinoline	---	0

The RBAL for quinoline, a probable human carcinogen, is based on U.S. EPA's PNEC of 10 ŋg/L. Quinoline has specific industrial sources (it is used in the production of dyes, paints, pharmaceuticals, and fragrances), but also has ubiquitous sources including automobile exhaust. Quinoline is biodegradable, removed by RO, and can be photolysized. Thus, if the Case Study 1 DPR Alternative utilized photolysis or RO, it is likely that the concentration would have been further reduced and the MOS greater than 1.

For CEC assessments it is important to acknowledge that over time new and updated RBALs are likely to be developed that would further inform risk evaluations, as well as additional information on advanced treatment process performance from research, piloting, or full-scale operations.

1.6 Treatment and Management Considerations for Direct Potable Reuse Applications

Source control is the first important preventative barrier for DPR, and source control programs have been very successful in limiting the discharge of toxic contaminants from industries and commercial businesses thereby keeping them out of the reclaimed water supply. However, expectations regarding source control effectiveness must be realistic in terms of what constituents can be directly controlled versus those that cannot. Additional information on source control is presented in TM 5.

An important consideration for DPR projects is quality of the treated wastewater that undergoes advanced treatment. The current focus of operating WWTPs is to meet discharge or non-potable reuse requirements. Because a higher quality wastewater can improve the quality of the final DPR product water and the operations of the AWTF, a shift in thinking about the function of the WWTP is worthwhile as it now is part of an integrated treatment system to produce a potable drinking water supply. A number of process modifications can be implemented at existing WWTPs to improve the final effluent quality prior to advanced treatment. Additional information is presented in TM 6.

The overarching goal for an integrated DPR treatment system is to reliably achieve the desired water quality, where reliability is a function of both treatment and management. In terms of treatment, reliability depends on (1) redundancy - the use of multiple barriers for the same contaminant, so that if one fails or performs ineffectively, risk is reduced; (2) robustness - the use of a combination of treatment technologies to address a broad variety of contaminants and changes in concentration in source water; and resilience - protocols and strategies to address failures and bring systems back on-line. Reliability also depends on a project sponsor having the managerial and technical capability to operate and maintain the integrated system, including providing certified operators, training, and emergency response.

1.7 Practical Applications

The results of this investigation indicate that a QRRA can inform decisions that are made with respect to source control, wastewater treatment, water treatment, and advanced treatment for DPR. Information from a QRRA can be used to:

- Assist with decisions on the need for bench scale and/or pilot testing of advanced treatment technologies, potentially including evaluation of CPCs (for example DBP removal efficiency and DBP formation during water/wastewater treatment) or CECs.
- Assist with decisions on the components to include in a DPR treatment scheme – this could be done as a screening framework similar to the approach used for this QRRA or as a site-specific study based on the results of bench scale or pilot testing.
- Modify or tailor monitoring programs to ensure that data for the most relevant contaminants are collected rather than compounds that have little impact on evaluating overall risk. This approach is complimentary to the indicator surrogate framework described in TM 2.
- Focus on specific source control and/or treatment options in cases where the relative risk may increase over time or reach a level of potential concern.
- Inform the public about the safety of DPR by using the results of a QRRA for public outreach efforts - this will become more important over time as analytical methodology becomes more sensitive and more constituents are found in water even after advanced treatment.
- Assess the risks and benefits of using DPR as a short-term drought mitigation measure as

opposed to a long-term water supply solution by comparing acute and chronic health risks.

1.8 Research Needs

A QRRA is a useful tool for decision makers when evaluating water supply options. For DPR, the output of a QRRA could advance and benefit from more reliable information on the following topic areas, which could be obtained through targeted research.

- Develop better-defined and additional RBALs for CECs that are not removed by treatment.
- Develop a better understanding of the removal or formation of CPCs and CECs through advanced treatment of reclaimed water and through water treatment facilities.
- Enhance the methods for quantifying health effects of chemical mixtures as part of risk assessments.

2 INTRODUCTION

Direct potable reuse (DPR) can be defined as the introduction of reclaimed water either directly into the potable water system downstream of a water treatment plant (WTP) or into the raw water supply immediately upstream of a WTP. Management decisions regarding implementation of a DPR project will likely be weighed against available alternatives for conventional drinking water supplies.

The purpose of this memorandum is to:

- Conduct demonstration quantitative relative risk assessments (QRRA) for two hypothetical DPR projects (case studies) to illustrate how the assessment can be conducted.
- Summarize how the information can be applied to provide a human health context to monitoring data for chemicals that are currently regulated or are unregulated. This analysis focused on chemical rather than pathogen risk since the Texas Commission on Environmental Quality (TCEQ) currently applies a set of guidelines for pathogen reduction for DPR applications. Pathogen risk evaluation could follow as similar approach as that described in this technical memorandum (TM).

2.1 Scope

The goal of a risk assessment is to estimate the severity and likelihood of harm to human health or the environment occurring from exposure to a risk agent (Cohrssen & Covello, 1989). The assessment described herein uses accepted risk assessment methodologies to provide a relative comparison of health risks for two case studies from consumption of existing drinking water for a representative time period compared to consumption of drinking water under a DPR alternative. In this evaluation the absolute risk from ingestion of water "at the tap" was not assessed, but rather a relative comparison was made based on an assumed quantity of water consumed and the estimated water quality associated with the scenarios under consideration. The methodology employed in this assessment is based on an approach that has been used successfully for previous indirect potable reuse (IPR) assessments (Cooper et al[3]., 1992, 1997 Soller et al., 2000, Soller and Nellor, 2011, a, b).

The QRRA compares the relative human health risk from drinking water for a "No Project" Alternative to a DPR Alternative for each case study. Each No Project Alternative assumes that the raw source water is

[3] These two studies can be difficult to find. Results are also documented here: *City of San Diego Health Effects Study of Potable Water Reuse*; and Olivieri, A.W., D.M. Eisenberg and R.C. Cooper, Chapter 12, pp. 521-580 of *Wastewater Reclamation and Reuse*, edited by Takashi Asano, Technomic Publishing, Co. Inc., 1998.

treated at a drinking water treatment plant (WTP). The DPR alternatives use wastewater treatment plant (WWTP) effluent as a starting point, assume treatment through an advanced water treatment facility (AWTF) to produce reclaimed water, and then further treatment through a drinking WTP. For simplicity, the DPR alternatives in this evaluation do not include blending with conventional raw source waters prior to treatment at the WTP, blending within the drinking water distribution system after water treatment, or introduction of reclaimed water directly into the drinking water distribution system.[4]

The case studies were selected to illustrate real situations that could occur in Texas: (1) a potential scenario where advanced treatment used to produce reclaimed water would not include reverse osmosis (RO) based on local challenges for disposal of the brine concentrate; (2) a potential scenario where advanced treatment would include RO; (3) a potential scenario where the WTP provides typical water treatment (flocculation-sedimentation, media filtration, and chlorination); and (4) a potential scenario, common in some parts of Texas, where the WTP provides additional treatment, such as ozone and biologically activated carbon (BAC), to address taste and odor issues, to treat iron and manganese, and/or to reduce Total Organic Carbon to address disinfection byproduct (DBP) formation. This water treatment scheme is called “enhanced WTP” to distinguish it from the more conventional WTP.

Case Study 1 (Non-RO AWTF/Enhanced WTP):

- No Project Alternative: Raw source water is treated by an enhanced WTP, consisting of ozone, BAC, flocculation-sedimentation, media filtration, and chlorination with free chlorine.
- DPR Project Alternative: Secondary/tertiary WWTP effluent is the feed water to an AWTF that consists of microfiltration (MF) or ultrafiltration (UF), ozone, BAC, and chlorination (Figure 1). This is Treatment Scheme #5 from Technical Memorandum (TM) *Evaluating the Potential for Direct Potable Reuse in Texas Evaluation of Treatment Technologies* (TM 6). This product water is then treated by the enhanced WTP consisting of ozone, BAC, flocculation-sedimentation, media filtration, and chlorination.

[4] As part of the operation of the currently running Texas DPR projects, blending of reclaimed water and raw surface water occurs before the WTP, and for one project further blending occurs as the treated water moves through the drinking water distribution system.

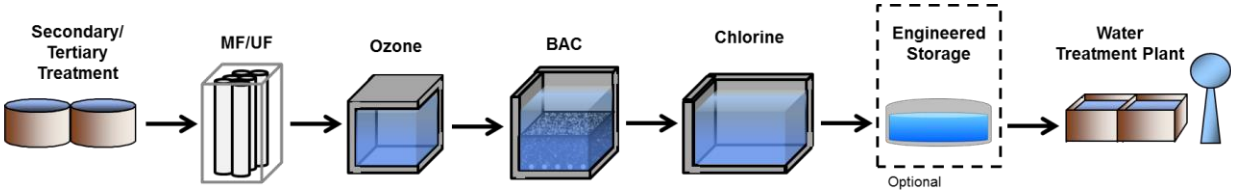

Figure 1. Case Study 1 Advanced Water Treatment Facility

Case Study 2: (AWTF with RO/ WTP):

- No Project Alternative: Raw source water is treated by a conventional surface WTP consisting of flocculation-sedimentation, media filtration, and chlorination with free chlorine.
- DPR Project Alternative: Secondary/tertiary WWTP effluent is the feed water to an AWTF that consists of UF, reverse osmosis (RO), and advanced oxidation (ultraviolet (UV) irradiation and hydrogen peroxide) (Figure 2). This is Treatment Scheme #2 from TM 6, which produces a brine concentrate from the RO process. The product water is then treated by a WTP consisting of flocculation-sedimentation, media filtration, and chlorination.

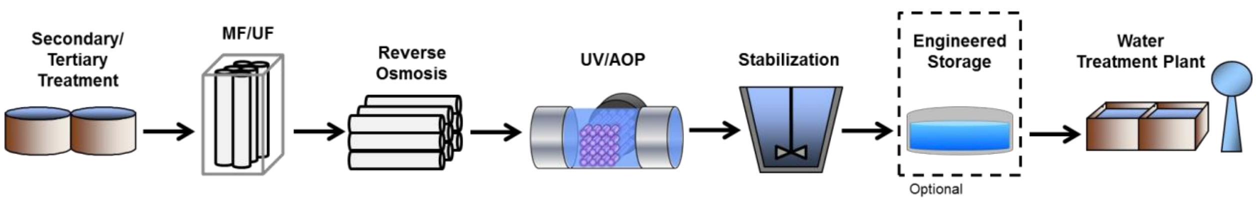

Figure 2. Case Study 2 Advanced Water Treatment Facility

Since the DPR alternatives have not yet been built, actual water quality monitoring data for the DPR alternatives were not available. To collect data for the QRRA, a source water quality monitoring program was designed and implemented that encompassed the collection of monthly samples for six months (starting December 2013) from two raw drinking waters and two wastewater treatment plant (WWTP) effluents located in Texas. The source waters are intended to be representative of the two case studies.

The water quality monitoring program data collection included both regulated constituents (priority pollutants, constituents with drinking water maximum contaminant levels (MCLs), constituents with other regulatory recommendations or guidelines), and constituents not regulated in drinking water (prescription drugs, chemotherapy agents, drugs of abuse, over-the-counter drugs, and personal care products).

The results of the water quality monitoring program were used to identify ***detected compounds*** that could be used to represent the potential hazard posed by the test waters. Detected compounds are defined as those that were found to be present in at least one sample at or above the compound's Minimum Reporting Level (MRL), which represents an estimate of the lowest concentration of a compound that can be quantitatively measured. For each compound, if the other samples yielded concentrations below the MRL, the compound was assumed to be present at the MRL for the purpose of obtaining average concentrations for the QRRA. Detected constituents are referred to herein as constituents of potential concern (CPCs) or constituents of emerging concern (CECs) defined as follows:

- CPCs are contaminants that are regulated or currently under consideration for regulation that were found in the raw drinking waters or wastewater effluents above MRLs and had associated health-based criteria such as noncarcinogenic reference doses (RfDs) and/or oral cancer slope factors (SFs) that could be used to quantify the estimated relative potential risk.
- CECs are unregulated contaminants that were found in the raw drinking waters or wastewater effluents above MRLs with published toxicity information to evaluate their health significance. CECs are of national interest to the reclaimed water community because they have been found in raw drinking waters or wastewater effluents. For this study, the Eurofins Eaton Analytical method was used to evaluate unregulated contaminants because it is capable of reliably testing for more than 90 herbicides, pharmaceuticals, hormones and personal care products in a single method at low part per trillion levels (nanogram per liter or ηg/L).

The following general approach was used for the QRRA:

For the No Project Alternatives, raw (source) water data (CPCs and CECs) were used to represent the feed water to the WTPs. Estimated removal efficiencies for the WTPs were used to calculate estimated concentrations of water to be used for drinking. For CPCs (regulated constituents), a QRRA was conducted. Because many CECs do not have established drinking water standards or formal advisory levels, researchers have developed a method to describe an estimate of the amount of a substance in drinking water that can be ingested daily over a lifetime without appreciable risk. These "safe" levels are called Drinking Water Equivalent Levels (DWELs) or Predicted No Effect Concentrations (PNECs). Other researchers have developed Recommended Drinking Water Guidelines (DWGs) for CECs often based on therapeutic doses or classification models. For CECs, the 2012 National Research Council (NRC) risk exemplar was utilized (NRC, 2012). Namely, for each of the detected CECs, potential lifetime health risks were assessed by calculating margins of safety (MOSs). The MOS is the ratio of a benchmark risk value, which is the risk-based action level (RBAL) based on a DWEL, PNEC, DWG or other available value, divided by the estimated concentration of the constituent in water).

In the DPR alternatives, WWTP effluent data (CPCs and CECs) were used to represent the feed water to the AWT schemes. Estimated removal efficiencies for the two proposed AWT schemes were derived. The removal efficiencies are from and extensions of the approach used in Table 6 in TM 6. For any constituents not addressed in TM 6, known or estimated removal efficiencies were provided by SPI using the same approach used in TM 6. A summary of the removal efficiencies and an explanation of how these efficiencies were derived are provided in the exhibits at the end of this TM. The output from the AWTFs was then assumed to be the feed water to the WTPs, and the projected WTP removal efficiencies were applied to derive estimated concentrations of water to be used for drinking. For CPCs (regulated constituents), a QRRA was conducted. For CECs, MOSs were derived by comparing the estimated concentrations in the drinking water to the RBALs.

2.2 Technical Approach

For the QRRA, four fundamental steps were carried out during the course of this assessment. Those steps follow the general guidance provided by the U.S. Environmental Protection Agency (U.S. EPA) for chemical risk assessment (NRC, 1983; U.S. EPA, 1989b) and are as follows:

1. Evaluate data and identify detected chemicals that can be used to represent the potential carcinogenic and noncarcinogenic hazard posed by the test waters;
2. Conduct a toxicity assessment of the potential carcinogenicity and noncarcinogenic effects of the chemicals of concern;
3. Conduct an exposure assessment, which for this study involves calculating potential doses based on estimated concentrations and an assumed standard intake; and
4. Characterize the potential health risks associated with the test waters.

3 WATER QUALITY MONITORING AND DATA CONSOLIDATION

An overview of the water quality monitoring program results is provided in Table 1. The specific analytes included in the program are shown in Table 2. As shown in Table 1, two source waters and two wastewater effluents were monitored. In total, over 7,500 observations were included. Raw waters had fewer observations at or above MRLs than effluent waters, and fewer constituents with observations at or above MRLs than effluent waters. Taken together, there were a total of 119 unique analytes that were detected at least once.

Table 1. Overview of Water Quality Monitoring Program Results

Water	# Analytes	Total # Observations	# Observations > MRL	# Constituents with Observations >MRL
Case Study #1 Raw Source Water	347	1868	212	55
Case Study #1 WWTP Effluent	367	1898	351	97
Case Study #2 Raw Source Water	308	1861	55	17
Case Study #2 WWTP Effluent	373	1901	321	90

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Table 2. Analytes Included in Water Quality Monitoring Program

1,1,1,2-Tetrachloroethane	4-tert-Octylphenol	Bromomethane (Methyl Bromide)	Diazepam	Hexachlorobutadiene	N-Nitroso-dimethylamine (NDMA)	Sulfamethizole
1,1,1-Trichloroethane	Acenaphthene-d10-%	Butachlor	Diazinon (Qualitative)	Hexachlorocyclopentadiene	Norethisterone	Sulfamethoxazole
1,1,2,2-Tetrachloroethane	Acenaphthylene	Butalbital	Dibenz(a,h)Anthracene	Ibuprofen	n-Propylbenzene	Sulfate
1,1,2-Trichloro-1,2,2-trifluoroethane	Acesulfame-K	Butylbenzylphthalate	Dibromoacetic acid	Indeno(1,2,3,c,d)Pyrene	o-Chlorotoluene	Sulfathiazole
1,1,2-Trichloroethane	Acetaminophen	Butylparaben	Dibromochloromethane	Iodomethane	o-Dichlorobenzene (1,2-DCB)	TCEP
1,1-Dichloroethane	Acetone	c-1,2-Dichloroethene	Dibromochloropropane (DBCP)	Iohexal	Orthophosphate as P	TCPP
1,1-Dichloroethene	Acetonitrile	c-1,3-Dichloropropene	Dibromomethane	Iopromide	Orthophosphate as PO4	TDCPP
1,1-Dichloroethylene	Acifluorfen	C12-2,3,7,8-TCDD-%	Dicamba	Iron Total ICAP	Oxamyl (Vydate)	tert-amyl Methyl Ether
1,1-Dichloropropene	Acrolein	Cadmium dissolved ICAP/MS	Dichloroacetic acid	Isobutylparaben	Oxolinic acid	Tert-Butyl Alcohol (TBA)
1,2,3-Trichlorobenzene	Acrylonitrile	Cadmium Total ICAP/MS	Dichlorodifluoromethane	Isophorone	o-Xylene	tert-Butyl Ethyl Ether
1,2,3-Trichloropropane	Alachlor	Caffeine	Dichlorodifluoromethane (Freon 12)	Isopropylbenzene	Paraquat	tert-Butylbenzene
1,2,3-Trichloropropane-%	Alachlor (Alanex)	Caffeine by method 525mod	Dichloromethane	Isoproturon	PCB 1016 Aroclor	Testosterone
1,2,4-Trichlorobenzene	Albuterol	Calcium Total ICAP	Dichlorprop	Ketoprofen	PCB 1221 Aroclor	Tetrachloroethene
1,2,4-Trimethylbenzene	Aldicarb (Temik)	Carbadox	Diclofenac	Ketorolac	PCB 1232 Aroclor	Tetrachloroethylene (PCE)
1,2-Dibromo-3-chloropropane	Aldicarb sulfone	Carbamazepine	Dieldrin	Lead dissolved ICAP/MS	PCB 1242 Aroclor	Tetrachlorometaxylene-%
1,2-Dibromoethane	Aldicarb sulfoxide	Carbaryl	Diethyl Ether	Lead Total ICAP/MS	PCB 1248 Aroclor	Tetrahydrofuran
1,2-Dibromopropane-%	Aldrin	Carbofuran (Furadan)	Diethylphthalate	Lidocaine	PCB 1254 Aroclor	Thallium Total ICAP/MS
1,2-Dichlorobenzene	Alkalinity in CaCO3 units	Carbon disulfide	Di-isopropyl ether	Lincomycin	PCB 1260 Aroclor	Theobromine
1,2-Dichlorobenzene-d4	Allyl chloride	Carbon Tetrachloride	Diisopropyl Ether (DIPE)	Lindane	p-Chlorotoluene	Theophylline
1,2-Dichlorobenzene-d4-%	alpha-Chlordane	Carisoprodol	Dilantin	Lindane (gamma-BHC)	p-Dichlorobenzene (1,4-DCB)	Thiobencarb (ELAP)
1,2-Dichloroethane	Aluminum dissolved ICAP/MS	Chloramphenicol	Diltiazem	Linuron	Pentachloroethane	Toluene
1,2-Dichloroethane-d4	Aluminum Total ICAP/MS	Chlordane	Dimethoate	Lopressor	Pentachlorophenol	Toluene-d8-%
1,2-Dichloroethane-d4-%	Ammonia Nitrogen	Chloridazon	Dimethylphthalate	m,p-Xylene	Pentoxifylline	Tot DCPA Mono&Diacid Degradate
1,2-Dichloropropane	Amoxicillin (semi-quantitative)	Chloride	Di-n-Butylphthalate	m,p-Xylenes	Perchlorate	Total 1,3-Dichloropropene
1,3,5-Trimethylbenzene	Andorostenedione	Chlorobenzene	Dinoseb	Magnesium Total ICAP	Perylene-d12-%	Total Dissolved Solids (TDS)
1,3-Dichlorobenzene	Anthracene	Chlorodibromomethane	Dioxane-d8-%	Manganese Total ICAP	Phenanthrene	Total Haloacetic Acids (HAA5)
1,3-Dichloropropane	Antimony Total ICAP/MS	Chloroethane	Diquat	Manganese Total ICAP/MS	Phenanthrene-d10-%	Total Organic Carbon
1,3-Dimethyl-2-nitrobenzene-%	Arsenic dissolved ICAP/MS	Chloroform	Dissolved Organic Carbon	m-Dichlorobenzene (1,3-DCB)	Phenazone	Total PCBs
1,4-Bromofluorobenzene-%	Arsenic Total ICAP/MS	Chloroform (Trichloromethane)	Diuron	Meclofenamic Acid	Picloram	Total phosphorus as P
1,4-Dichlorobenzene	Atenolol	Chloromethane	Endothall	Meprobamate	p-Isopropyltoluene	Total phosphorus as PO4- Calc.
1,4-Dioxane	Atrazine	Chloromethane(Methyl Chloride)	Endrin	Mercury	Potassium Total ICAP	Total Suspended Solids (TSS)
1,7-Dimethylxanthine	Azithromycin	Chlorotoluron	Erythromycin	Metazachlor	Primidone	Total THM
2,2-Dichloropropane	Barium Total ICAP/MS	Chromium dissolved ICAP/MS	Estradiol	Methacrylonitrile	Progesterone	Total Xylene
2,3,7,8-TCDD	Baygon	Chromium Total ICAP/MS	Estrone	Methiocarb	Propachlor	Total xylenes
2,3-Dibromopropionic acid-%	Bendroflumethiazide	Chrysene	Ethanol	Methomyl	Propazine	Toxaphene
2,4,5-T	Bentazon	Chrysene-d12-%	Ethinyl Estradiol - 17 alpha	Methoxychlor	Propylparaben	trans-1,2-Dichloroethene
2,4,5-TP (Silvex)	Benz(a)Anthracene	Cimetidine	Ethyl benzene	Methyl Methacrylate	Pyrene	trans-1,2-Dichloroethylene
2,4-D	Benzene	cis-1,2-Dichloroethylene	Ethyl methacrylate	Methyl Tert-butyl ether (MTBE)	Quinoline	trans-1,3-Dichloropropene
2,4-DB	Benzo(a)pyrene	cis-1,3-Dichloropropene	Ethylbenzene	Methylene chloride	sec-Butylbenzene	trans-1,4-dichloro-2-butene
2,4-Dichlorophenyl acetic acid-%	Benzo(b)Fluoranthene	Clofibric Acid	Ethylene Dibromide (EDB)	Methylparaben	Selenium Low Level ICAP/MS	trans-Nonachlor
2,4-Dinitrotoluene	Benzo(g,h,i)Perylene	Cobalt Total ICAP/MS	Ethylparaben	Metolachlor	Selenium Total ICAP/MS	Trichloroacetic acid
2-Butanone	Benzo(k)Fluoranthene	Copper dissolved ICAP/MS	Ethyl-t-Butyl Ether (ETBE)	Metribuzin	Silica	Trichloroethene
2-Butanone (MEK)	Beryllium Total ICAP/MS	Copper Total ICAP/MS	Flumeqine	Molinate	Silver dissolved ICAP/MS	Trichloroethylene (TCE)
2-Chloroethyl vinyl ether	Bezafibrate	Cotinine	Fluoranthene	Molybdenum Total ICAP/MS	Silver Total ICAP/MS	Trichlorofluoromethane
2-Chlorotoluene	BPA	Cyanazine	Fluorene	Monobromoacetic acid	Simazine	Trichlorotrifluoroethane(Freon 113)
2-Hexanone	Bromacil	Cyanide	Fluoride	Monochloroacetic acid	Sodium Total ICAP	Triclocarban
3,5-Dichlorobenzoic acid	Bromate by UV/VIS	Cyanide by manual distillation	Fluoxetine	Naphthalene	Strontium ICAP	Triclosan
3-Hydroxycarbofuran	Bromide	DACT	gamma-Chlordane	Naproxen	Strontium Total ICAP	Trifluralin
4,4-Dibromooctafluorobiphenyl-%	Bromobenzene	Dalapon	Gemfibrozil	n-Butylbenzene	Styrene	Trimethoprim
4-Bromo-3,5-dimethylphenyl-N-methy	Bromochloroacetic acid	DEA	Glyphosate	NDMA-D6	Sucralose	Triphenylphosphate-%
4-Bromofluorobenzene-%	Bromochloromethane	DEET	Heptachlor	NDMA-D6-%	Sulfachloropyridazine	Uranium ICAP/MS
4-chlorotoluene	Bromodichloromethane	Dehydronifedipine	Heptachlor Epoxide	Nickel Total ICAP/MS	Sulfadiazine	Vinyl Acetate
4-methyl-2-Pentanone	Bromoethane	Di-(2-Ethylhexyl)adipate	Heptachlor Epoxide (isomer B)	Nifedipine	Sulfadimethoxine	Vinyl chloride
4-Methyl-2-Pentanone (MIBK)	Bromoform	Di(2-Ethylhexyl)phthalate	Hexachloro-1,3-Butadiene	Nitrate as NO3 (calc)	Sulfamerazine	Vinyl chloride (VC)
4-nonylphenol - semi quantitative	Bromomethane	DIA	Hexachlorobenzene	Nitrite Nitrogen by IC	Sulfamethazine	Warfarin
						Zinc Total ICAP/MS

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The analytes detected in each of the evaluated waters are summarized in Tables 3 through 6. These detected analytes form the foundation of all subsequent QRRA work. Review of Tables 3 through 6 indicates that a wide range of contaminants was detected in the evaluated waters. In some cases, constituents were detected at or above MRLs only once, and in other cases in most or all of the evaluated samples. More constituents were detected in the secondary effluent samples (Tables 4 and 6) than in the raw source waters (Tables 3 and 5). These observations regarding occurrence are only provided to illustrate differences in the types of samples evaluated. Response actions based on the results of the QRRA, such as source control to reduce occurrence or concentrations of CPCs and/or CECs, are discussed in a later section of the TM.

Table 3. Summary of Analytes Detected in Case Study 1 Raw Water

Analyte	# Obs	# >MRL	Analyte	# Obs	# >MRL
2,4-D	12	5	Dicamba	6	1
2-Butanone (MEK)	5	1	Diuron	6	3
Acesulfame-K	6	6	Fluoride	6	6
Acetaminophen	6	1	Fluoxetine	6	2
Albuterol	6	4	Gemfibrozil	6	4
Aluminum Total ICAP/MS	6	5	Iohexal	6	6
Amoxicillin (semi-quantitative)	6	3	Lead Total ICAP/MS	6	3
Arsenic Total ICAP/MS	6	5	Lidocaine	6	4
Atenolol	6	2	Lopressor	6	1
Atrazine	12	12	Meprobamate	6	6
Barium Total ICAP/MS	6	6	Metolachlor	11	1
Benzo(b)Fluoranthene	6	1	Nitrate as NO3 (calc)	6	6
BPA	6	1	Nitrite Nitrogen by IC	6	1
Bromacil	12	4	N-Nitroso-dimethylamine (NDMA)	6	1
Caffeine	6	6	Primidone	6	4
Caffeine by method 525mod	6	5	Propazine	6	1
Carbamazepine	6	6	Quinoline	6	1
Carisoprodol	6	1	Simazine	12	12
Chloride	3	3	Sucralose	6	6
Chromium Total ICAP/MS	6	2	Sulfamethoxazole	6	6
Copper Total ICAP/MS	6	1	Sulfate	3	3
Cotinine	6	6	TCEP	6	6
DACT	6	6	TCPP	6	3
DEA	6	6	Theobromine	6	2
DEET	6	6	Theophylline	6	2
Dehydronifedipine	6	4	Tot DCPA Mono&Diacid Degradate	6	1
Di(2-Ethylhexyl)phthalate	6	1	Triclocarban	6	1
DIA	6	6	Trimethoprim	6	4

#Obs – number of observations

Table 4. Summary of Analytes Detected in Case Study 1 Effluent

Analyte	# Obs	# >MRL	Analyte	# Obs	# >MRL
1,2-Dichlorobenzene-d4	1	1	Fluoride	6	6
1,2-Dichloroethane-d4	5	5	Fluoxetine	6	6
1,7-Dimethylxanthine	6	1	Gemfibrozil	6	4
2,4-D	12	3	Ibuprofen	6	2
3-Hydroxycarbofuran	6	1	Iohexal	6	6
4-tert-Octylphenol	6	1	Iopromide	6	3
Acesulfame-K	6	6	Iron Total ICAP	2	2
Acetaminophen	6	2	Ketoprofen	6	4
Albuterol	6	4	Lidocaine	6	4
Aldicarb sulfone	6	5	Lopressor	6	6
Alkalinity in CaCO3 units	2	2	Magnesium Total ICAP	2	2
Aluminum Total ICAP/MS	6	5	Manganese Total ICAP	1	1
Amoxicillin (semi-quantitativ	6	1	Manganese Total ICAP/MS	1	1
Antimony Total ICAP/MS	6	1	Meprobamate	6	6
Arsenic Total ICAP/MS	6	4	Methomyl	6	1
Atenolol	6	5	Monobromoacetic acid	6	2
Atrazine	12	10	Monochloroacetic acid	6	1
Azithromycin	6	2	Naproxen	6	2
Barium Total ICAP/MS	6	5	NDMA-D6	6	6
Bezafibrate	6	1	Nickel Total ICAP/MS	6	1
Bromacil	12	1	Nitrate as NO3 (calc)	6	6
Bromide	2	2	N-Nitroso-dimethylamine (NDM	6	6
Bromochloroacetic acid	6	6	Orthophosphate as P	1	1
Bromodichloromethane	6	6	Orthophosphate as PO4	1	1
Bromoform	6	3	Potassium Total ICAP	2	2
Caffeine	6	5	Primidone	6	6
Caffeine by method 525mod	6	3	Propazine	6	2
Calcium Total ICAP	2	2	Quinoline	6	3
Carbamazepine	6	6	Silica	2	2
Carisoprodol	6	5	Simazine	12	10
Chloride	3	3	Sodium Total ICAP	2	2
Chlorodibromomethane	5	4	Strontium ICAP	1	1
Chloroform	1	1	Strontium Total ICAP	1	1
Chloroform (Trichloromethar	5	5	Sucralose	6	6
Copper Total ICAP/MS	6	5	Sulfamethazine	6	2
Cotinine	6	5	Sulfamethoxazole	6	4
Cyanide by manual distillatio	6	4	Sulfate	3	3
DACT	6	6	TCEP	6	6
DEA	6	6	TCPP	6	6
DEET	6	3	TDCPP	6	6
Dehydronifedipine	6	6	Theobromine	6	2
DIA	6	6	Theophylline	6	1
Dibromoacetic acid	6	5	Toluene	6	2
Dibromochloromethane	1	1	Total Haloacetic Acids (HAA5)	6	6
Dichloroacetic acid	6	6	Total Organic Carbon	1	1
Diclofenac	6	2	Total phosphorus as P	1	1
Dilantin	6	6	Total phosphorus as PO4- Calc.	1	1
Diltiazem	6	3	Total THM	6	6
Dissolved Organic Carbon	1	1	Trichloroacetic acid	6	6
Diuron	6	2	Triclocarban	6	2
Erythromycin	6	2	Triclosan	6	1
Estrone	6	3	Trimethoprim	6	3

Table 5. Summary of Analytes Detected in Case Study 2 Raw Water

Analyte	# Obs	# >MRL
Aluminum Total ICAP/MS	6	6
Barium Total ICAP/MS	6	6
Chromium Total ICAP/MS	6	6
Copper Total ICAP/MS	6	6
Fluoride	6	6
Nitrate as NO3 (calc)	6	6
Arsenic Total ICAP/MS	6	5
Chloride	3	3
Sulfate	3	3
Albuterol	6	1
Bromodichloromethane	6	1
Bromoform	6	1
Caffeine	6	1
Chlorodibromomethane	6	1
DEA	6	1
DEET	6	1
Sulfamethoxazole	6	1

Table 6. Summary of Analytes Detected in Case Study 2 Effluent

Analyte	# Obs	# >MRL	Analyte	# Obs	# >MRL
1,7-Dimethylxanthine	6	1	Lidocaine	6	6
2,4-D	12	2	Lincomycin	6	6
Acesulfame-K	6	6	Lopressor	6	6
Acetaminophen	6	2	Magnesium Total ICAP	2	2
Albuterol	6	4	Manganese Total ICAP	2	2
Aldicarb sulfone	6	6	Manganese Total ICAP/MS	1	1
Alkalinity in CaCO3 units	2	2	Meprobamate	6	6
Aluminum Total ICAP/MS	6	6	Methomyl	6	1
Amoxicillin (semi-quantitative)	6	6	Metolachlor	12	1
Antimony Total ICAP/MS	6	2	Molybdenum Total ICAP/MS	1	1
Arsenic Total ICAP/MS	6	6	Naproxen	6	3
Atenolol	6	6	Nifedipine	6	1
Atrazine	12	5	Nitrate as NO3 (calc)	5	5
Azithromycin	6	2	Nitrite Nitrogen by IC	5	3
Barium Total ICAP/MS	6	6	N-Nitroso-dimethylamine (NDMA)	6	6
BPA	6	2	Orthophosphate as P	1	1
Bromacil	12	3	Orthophosphate as PO4	1	1
Bromide	2	2	p-Dichlorobenzene (1,4-DCB)	5	1
Butalbital	6	2	Pentoxifylline	6	2
Caffeine	6	6	Potassium Total ICAP	2	2
Caffeine by method 525mod	6	1	Primidone	6	6
Calcium Total ICAP	2	2	Quinoline	6	2
Carbamazepine	6	6	Silica	2	2
Carisoprodol	6	6	Simazine	12	2
Chloride	3	3	Sodium Total ICAP	2	2
Cimetidine	6	1	Strontium ICAP	2	2
Copper Total ICAP/MS	6	4	Sucralose	6	6
Cotinine	6	6	Sulfadimethoxine	6	2
Cyanide	3	2	Sulfamerazine	6	1
DEET	6	6	Sulfamethoxazole	5	5
Dehydronifedipine	6	6	Sulfate	2	2
Diclofenac	6	3	Sulfathiazole	6	1
Dilantin	6	6	TCEP	6	6
Diltiazem	6	6	TCPP	6	6
Diuron	6	2	TDCPP	6	6
Erythromycin	6	4	Theobromine	6	2
Estrone	6	6	Theophylline	6	2
Fluoride	6	6	Tot DCPA Mono&Diacid Degradate	6	1
Fluoxetine	6	6	Total phosphorus as P	1	1
Gemfibrozil	6	6	Total phosphorus as PO4- Calc.	1	1
Ibuprofen	6	1	Trichloroacetic acid	6	4
Iohexal	6	6	Triclocarban	6	4
Iopromide	6	5	Triclosan	6	6
Iron Total ICAP	2	2	Trimethoprim	6	6
Ketoprofen	6	2	Uranium ICAP/MS	1	1
Ketorolac	6	3	Warfarin	6	3

4 TOXICITY ASSESSMENT

The purpose of the toxicity assessment is to weigh available evidence regarding the potential for a particular chemical to cause adverse health effects in exposed individuals and to provide, where possible, an estimate of the relationship between the extent of exposure to a chemical and the increased likelihood and/or severity of adverse health effects (Cooper et al., 1997). Detected chemical constituents were evaluated for their carcinogenic and noncarcinogenic potential based on a hazard identification and a dose–response evaluation. From this evaluation, toxicity values for CPCs (characterized in terms of reference doses [RfDs] for noncarcinogenic effects and carcinogenic oral slope factors (SFs) for carcinogenic effects) were identified to estimate the potential for adverse effects as a function of human exposure to a given constituent. In addition, RBALs were collated from the literature for CECs (discussed in detail below).

Hazard evaluation involves gathering and evaluating data on the types of human health injury that may be produced by a chemical and the conditions of exposure under which injury or disease is produced. Characterization of the behavior of a chemical within the body and the interactions it undergoes with organs, cells, or even parts of cells may also be required. Data of the latter type may be useful in determining whether the forms of toxicity produced by a chemical in one experimental setting are likely to be produced in humans.

The health-based criteria presented in this section were used as input to the QRRA to quantify the estimates of relative potential risk from the No Project and DPR Alternatives. The health-based criteria for CPCs used for this assessment include RfDs for the noncarcinogenic effects, oral SFs for carcinogenic effects, and RBALs for CECs.

4.1 Categorizing Detected Analytes as Potential Constituents of Potential Concern or Constituents of Emerging Concern

As described above, there were a total of 119 unique analytes that were detected in one or more of the waters evaluated.

The sources for determining whether an analyte would be a potential CPC included:

1. US EPA's National Primary Drinking Water Regulation summary which includes all primary and secondary MCLs;
2. TCEQ's Public Water Supply Program summary which lists all State MCLs for drinking water;
3. US EPA's list of Priority Pollutants;
4. US EPA's 2012 Edition of the Drinking Water Standards and Health Advisories;
5. State of California Department of Public Health Drinking Water Notification Level list; and

6. State of California Department of Public Health's Archived Advisory Levels for Drinking Water.

Based on this review, 48 analytes are considered potential CPCs for this assessment and 71 are considered potential CECs for this assessment. A summary of the potential CPCs is provided in Table 7 and a summary of the potential CECs is provided in Table 8.

Table 7. Summary of Potential Constituents of Potential Concern

Class	Potential CPC	Federal or State MCL
Regulated	1,2-Dichlorobenzene	yes
	1,2-Dichloroethane	yes
	2,4-D	yes
	Aluminum Total ICAP/MS	yes
	Antimony Total ICAP/MS	yes
	Arsenic Total ICAP/MS	yes
	Atrazine	yes
	Barium Total ICAP/MS	yes
	Benzo(b)Fluoranthene	yes
	Chloride	yes
	Chromium Total ICAP/MS	yes
	Copper Total ICAP/MS	yes
	Cyanide	yes
	Di(2-Ethylhexyl)phthalate	yes
	Fluoride	yes
	Iron Total ICAP	yes
	Lead Total ICAP/MS	yes
	Manganese Total ICAP	yes
	Nickel Total ICAP/MS	yes
	Nitrate as NO3 (calc)	yes
	Nitrite Nitrogen by IC	yes
	p-Dichlorobenzene (1,4-DCB)	yes
	Simazine	yes
	Sulfate	yes
	Toluene	yes
	Total Haloacetic Acids (HAA5)	yes
	Total THM	yes
	Uranium ICAP/MS	yes
Individual chemical of Regulated Group	Bromodichloromethane	Sub(THM)
	Bromoform	Sub(THM)
	Chlorodibromomethane	Sub(THM)
	Chloroform	Sub(THM)
	Dibromoacetic acid	Sub(HAA)
	Dichloroacetic acid	Sub(HAA)
	Monobromoacetic acid	Sub(HAA)
	Monochloroacetic acid	Sub(HAA)
	Trichloroacetic acid	Sub(HAA)
Unregulated with Notification Level, Health Advisory, or Water Quality Critiria Value	2-Butanone (MEK)	no
	Aldicarb sulfone	no
	Bromacil	no
	Dicamba	no
	Diuron	no
	Methomyl	no
	Molybdenum Total ICAP/MS	no
	N-Nitroso-dimethylamine (NDMA	no
	Propazine	no
	Sodium Total ICAP	no
	Strontium ICAP	no

Note that Sub(THM or HAA) means that there is a federal or state regulation that regulates a group of contaminants together and the corresponding chemical is one of the components that makes up that group.

Table 8. Summary of Potential Constituents of Emerging Concern

1,7-Dimethylxanthine	Ketoprofen
3-Hydroxycarbofuran	Ketorolac
4-tert-Octylphenol	Lidocaine
Acesulfame-K	Lincomycin
Acetaminophen	Lopressor
Albuterol	Magnesium Total
Alkalinity in CaCO3 units	Meprobamate
Amoxicillin (semi-quantitative)	Metolachlor
Atenolol	Naproxen
Azithromycin	Nifedipine
Bezafibrate	Orthophosphate as P
BPA	Orthophosphate as PO4
Bromide	Pentoxifylline
Bromochloroacetic acid	Potassium Total ICAP
Butalbital	Primidone
Caffeine	Quinoline
Calcium	Silica
Carbamazepine	Sucralose
Carisoprodol	Sulfadimethoxine
Cimetidine	Sulfamerazine
Cotinine	Sulfamethazine
DACT	Sulfamethoxazole
DEA	Sulfathiazole
DEET	TCEP
Dehydronifedipine	TCPP
DIA	TDCPP
Diclofenac	Theobromine
Dilantin	Theophylline
Diltiazem	Tot DCPA Mono&Diacid Degradate
Erythromycin	Total Organic Carbon
Estrone	Total phosphorus as P
Fluoxetine	Triclocarban
Gemfibrozil	Triclosan
Ibuprofen	Trimethoprim
Iohexal	Warfarin
Iopromide	

4.2 Toxicity Evaluation

The toxicity evaluation was used to determine which of the potential CPCs and CECs have associated health based values that can be used to evaluate the potential risk associated with each of the alternatives. Sources used for the CPC toxicity evaluation were as follows:

1. The U.S. EPA Integrated Risk Information System (IRIS) database (U.S. EPA, 2007b) or documentation available from the U.S. EPA Office of Pesticide Programs (OPP), accessed electronically August, 2014;
2. The Provisional Peer Reviewed Toxicity Values (PPRTVs) and cited references developed for the U.S. EPA Office of Solid Waste and Emergency Response (OSWER) Office of Superfund Remediation and Technology Innovation (OSRTI) programs;
3. The California Office of Environmental Health Hazard Assessment (OEHHA) Toxicity Criteria Database, electronically accessed August, 2014;
4. US EPA's Health Effects Assessment Summary Tables (HEAST) accessed electronically August, 2014; and
5. The Agency for Toxic Substances and Disease Registry (ATSDR) Minimal Risk Levels (ATSDR, 2009, 2012).

4.2.1 Noncarcinogenic Effects

Reference doses are established based on reported results from human epidemiological data, chronic animal studies, and other previously published toxicological information. The RfD is based on the assumption that thresholds exist for certain toxic effects but may not exist for other effects, such as carcinogenicity. In general, the RfD is an estimate of the daily exposure to the human population (including sensitive subgroups) that is likely not to result in an appreciable risk of deleterious effects during a lifetime (U.S. EPA, 1989b).

The RfD is used as a reference point for gauging the potential effects of doses associated with specific exposures. As the frequency of exposure approaches and/or exceeds the RfD, the probability increases that adverse health effects may be observed in a human population. The RfD is derived as follows:

RfD = NOAEL or LOAEL or BMDL/(UF)

Where:

NOAEL is the No observable adverse effect level;
LOAEL is the Lowest observable adverse effect level;
BMDL is the Lower confidence bound on the benchmark dose; and
UF is an Uncertainty factor.

In this equation, UFs are based on experimental species and effects, as well as on the duration of study. The LOAEL is used only when a suitable NOAEL or BMDL is unavailable.

4.2.2 Carcinogenic Effects

In assessing the carcinogenic potential of a chemical, the U.S. EPA uses a cancer weight-of-evidence (WOE) descriptor to describe a substance's potential to cause cancer in humans and the conditions under which the carcinogenic effects may be expressed. Under the U.S. EPA's 1986 guidelines for carcinogen risk assessment, the WOE was described by categories:

Group A:	Known Human Carcinogen
Group B:	Probable Human Carcinogen
	B1: Indicates that limited data are available
	B2: Indicates sufficient evidence on animals and inadequate or no evidence in humans
Group C:	Possible Human Carcinogen
Group D:	Not Classifiable as to Human Carcinogenicity
Group E:	Evidence of Noncarcinogenicity for Humans

Under the U.S. EPA's 2005 guidelines for carcinogen risk assessment, a narrative approach, rather than categories, is used to characterize carcinogenicity. Five standard weight of evidence descriptors (Carcinogenic to Humans, Likely to Be Carcinogenic to Humans, Suggestive Evidence of Carcinogenic Potential, Inadequate Information to Assess Carcinogenic Potential, and Not Likely to Be Carcinogenic to Humans) are used as part of the narrative. (U.S. EPA, 2007a). Cancer slope factors are estimated through the use of mathematical extrapolation models for estimating the largest possible linear slope at low doses that is consistent with the data. Slope factors are characterized as a conservative upper-bound estimate, meaning that the true risk to humans (although not directly identifiable) is not likely to exceed the upper-bound estimate and may in fact be lower. In this investigation oral SFs are used because the exposure is assumed to occur through ingestion rather than inhalation.

4.2.3 Risk Based Action Levels for Constituents of Emerging Concern

The RBALs used for the assessment were derived using the following approaches.

Tolerable Daily Intakes (TDIs)/Acceptable Daily Intakes (ADIs)[5] represent a level of daily intake of a constituent in water that should not result in an adverse health effect from direct exposure in a population,

[5] These terms are often used synonymously.

including sensitive population groups, such as pregnant women, children, and people with immune compromised systems, or for sensitive endpoints such as reproductive and developmental toxicity, carcinogenicity, and endocrine-mediated toxicity. Bruce et al., (2010a,b) developed either ADIs or TDIs using different heath endpoints with different ranges of uncertainty factors to develop TDIs/ADIs. The endpoints include:

- Non-carcinogenic effects based on the no observable effect level (NOAEL) or lowest observed adverse effect level (LOAEL).

$$\text{ADI or TDI (µg/kg-day)} = \frac{\text{NOAEL or LOAEL (mg/kg-day)}}{\text{UFs}} \times \frac{\text{1,000 µg}}{\text{mg}}$$

  Where:

  kg is kilograms;

  UFs are uncertainty factors;

  mg is milligram;

  µg is microgram; and

  1,000 is a conversion factor (from mg to µg)

- Minimum inhibitory concentrations (MICs) to human gastrointestinal flora.

$$\text{Upper limit of TDI (µg/kg-day)} = \frac{\text{MIC}_{50}\text{ (µg/g) x MCC (g/day)}}{\text{FA x Sf x BW (kg)}}$$

  Where:

  MIC_{50} is the minimum inhibitory concentration of 50 percent of strains of the most sensitive relevant organism (µg per gram [g], equivalent to µg per milliliter [mL]);

  MCC is the mass of colonic contents (in gram per day [g/day]);

  FA is the fraction available of the dose to the gastrointestinal microflora;

  Sf is the safety factor where the magnitude depends on the quality and quantity of the microbiological data available; and

  BW is body weight (kg).

- Endocrine-mediated effects in animals or humans, estrogenic, androgenic, or mediated by thyroid hormones (fertility, sexual behavior, ovulation, maintenance of pregnancy, development of specific tissues and organs, growth and viability of offspring, lactation, and maternal behavior) based on NOAELs or LOAELs for non-carcinogenic effects or tumor incidence data and cancer SFs for carcinogenic effects.

- Therapeutic dose. This approach assumes that the lower end of a drug's therapeutic range represents a threshold for appreciable biological activity in target populations, and therefore may be considered a threshold for potential adverse effects (such as an LOAEL).

$$\text{ADI or TDI } (\mu g/kg\text{-day}) = \frac{\text{Minimum therapeutic dose } (\mu g/kg\text{-day})}{\text{UFs}}$$

- Cancer consisting of both genotoxic (gene damage) and non-genotoxic (produces cancer by a mechanism other than gene damage) effects.

$$\text{ADI or TDI } (\mu g/kg\text{-day}) = \frac{10^{-6}}{\text{SF } (mg/kg\text{-day})^{-1}} \times 1{,}000 \ \mu g/mg$$

PNECs represent the concentration in water at or below which no adverse human health effects are expected based on the ADI. Schwab et al., 2005 developed PNECs based on lowest therapeutic dose and MICs.

$$PNEC_{DW} \ (\mu g/kg/day) = \frac{1{,}000 \times ADI \times BW \times AT}{IngR_{DW} \times EF \times ED}$$

Where:

AT is the averaging time in days;

$IngR_{DW}$ is the child or adult drinking water ingestion rate (L/person/day)

EF is the exposure frequency (in days per year); and

ED is the exposure duration (year).

DWELs represent the concentration in water at or below which no adverse human health effects are expected based on the TDI/ADI (Bruce et al, 2010a,b) and drinking two liters (L) per day of water.

$$\text{DWEL } (\mu g/L) = \frac{\text{TDI } (\mu g/kg\text{-day}) \times 70 \text{ kg}}{2 \text{ L/day}}$$

Recommended DWGs, are similar to DWELs, but consider the relative contribution from water (Environment Protection and Heritage Council et al., 2008).

$$\text{DWG } (\mu g/L) = \frac{\text{ADI } (mg/kg\text{-day}) \times \text{BW (kg)} \times P \times 10^{-3}}{\text{V (L/day)}}$$

Where:

ADI = NOAEL ÷ UF (up to 10,000);

P = Proportion ADI from water = 100 percent;

V = Volume of water consumed (2L/day); and

10^{-3} = Unit conversion from mg/L to μg/L.

Sources used for the CEC toxicity evaluation included Anderson, et al. (2010) and other studies. Anderson et al. reported the outcome of an expert panel convened by the California State Water Resources Control Board to develop monitoring recommendations for CECs in reclaimed water. Appendix J in the report contained a compendium of PNECs, DWGs, DWELs, Guideline Values from U.S. EPA and Australia, and studies funded by water and water reuse research foundations. In addition, the Anderson et al. (2010) compendium was updated using results from other studies including DWELs from Intertox (2009), DWELs from Bruce et al., (2010), ADIs converted to DWELs from the Food and Drug Administration, ADIs converted to DWELs from the Emergency Medicine Journal (online ADIs), PNECs from the World Health Organization (WHO), and No Significant Risk Levels (NSRLs) from OEHHA. The NSRLs, which are developed for consumer products, are designated as “safe harbors” for carcinogens.

4.2.4 Toxicity Summaries

Summary chemical toxicity information was sought for each potential CPC and CEC (as defined above). The summaries are compilations of information that are available from the sources identified above. A synopsis of the toxicity assessment results is presented in Table 9 for CPCs and Table 10 for CECs.

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Table 9. Constituents of Potential Concern Toxicity Evaluation

Class	Potential CPC	IRIS, OPP, OEHHA Documentation	CPC - Sufficient Information to Characterize Health Effects or Basis to develop DWELs	RfD (mg/kg-day)	Oral Slope Factor (mg/kg-day)
Regulated	1,2-Dichlorobenzene	Yes	Yes	0.09	NA - Class D
	1,2-Dichloroethane	Yes	Yes	No data	0.091
	2,4-D	Yes	Yes	0.01	NA - Not assessed
	Aluminum Total	No (IRIS, OEHHA)	Yes (PPRTV)	1	NA - Not assesed
	Antimony Total	Yes	Yes	0.0004	NA - Not assessed
	Arsenic Total	Yes	Yes	0.0003	1.5
	Atrazine	Yes	Yes	0.035	NA - Not assessed
	Barium Total	Yes	Yes	0.2	NA - Class D
	Benzo(b)Fluoranthene	Yes	No	NA - Not assessed	NA - Class B2 Not assessed
	Chloride	No (IRIS, OEHHA, PPRTV, HEAST)	Yes	NA - Not assessed	NA - Not assessed
	Chromium Total	Yes	Yes	1.5 / 0.003 (CrIII/CrIV)	NA - Class D (oral route - Class A inhalation)
	Copper Total	Yes	No	NA - Not assessed	NA - Class D
	Cyanide	Yes	Yes	0.0006	NA - Class D
	Di(2-Ethylhexyl)phthalate	Yes	Yes	0.02	0.014
	Fluoride	Yes	Yes	0.06	NA - Not assessed
	Iron Total	No (IRIS, OEHHA)	Yes (PPRTV)	0.7	NA - Not assessed
	Lead Total	Yes	Yes	NA - Not estimated	0.0085 OEHHA
	Manganese Total	Yes	Yes	0.14	NA - Class D
	Nickel Total	Yes	Yes	0.02	NA - Not assessed (soluble salts)
	Nitrate as NO3	Yes	Yes	1.6	NA - Not assessed
	Nitrite Nitrogen	Yes	Yes	0.1	NA - Not assessed
	p-Dichlorobenzene (1,4-DCB)	Yes	Yes	0.8	NA - Not assessed
	Simazine	Yes	Yes	0.005	NA - Not assessed
	Sulfate	No (IRIS, OEHHA, PPRTV, HEAST)	No	NA	NA
	Toluene	Yes	Yes	0.08	NA - Not assessed
	Total Haloacetic Acids (HAA5)	No (IRIS, OEHHA, PPRTV, HEAST)	No	NA	NA
	Total THM	No (IRIS, OEHHA, PPRTV, HEAST)	No	NA	NA
	Uranium	Yes	No (natural Uranium), Yes (soluble salts)	0.003	NA - Not assessed
Individual chemical of Regulated Group	Bromodichloromethane	Yes	Yes	0.02	0.062
	Bromoform	Yes	Yes	0.02	0.0079
	Chlorodibromomethane	Yes	Yes	0.02	0.084
	Chloroform	Yes	Yes	0.01	0.000023
	Dibromoacetic acid	No (IRIS, OEHHA, PPRTV, HEAST)	No	NA	NA
	Dichloroacetic acid	Yes	Yes	0.004	0.05
	Monobromoacetic acid	No (IRIS, OEHHA, PPRTV, HEAST)	No	NA	NA
	Monochloroacetic acid	No (IRIS, OEHHA, PPRTV)	Yes (HEAST)	0.002	NA
	Trichloroacetic acid	Yes	Yes	0.02	0.07
Unregulated with Notification Level, Health Advisory, or Water Quality Critiria Value	2-Butanone (MEK)	Yes	Yes	0.6	Inadequate data
	Aldicarb sulfone	Yes	Yes	0.001	NA - Not assessed
	Bromacil	Yes	Yes	0.1	NA - Class C (EPA HA document)
	Dicamba	Yes	Yes	0.03	NA - Not assessed
	Diuron	Yes	Yes	0.002	NA - Not assessed
	Methomyl	Yes	Yes	0.025	NA - Not assessed
	Molybdenum Total	Yes	Yes	0.005	NA - Not assessed
	N-Nitroso-dimethylamine (NDMA)	Yes	Yes	NA - Not assessed	51
	Propazine	Yes	Yes	0.02	NA - Not assessed
	Sodium Total	No (IRIS, OEHHA, PPRTV, HEAST)	No	NA	NA
	Strontium	Yes	Yes	0.6	NA - Not assessed

Table 10. Constituents of Emerging Concern Toxicity Evaluation

Potential CEC	Basis to develop DWELs	DWEL or PNEC (ng/L)	DWEL/PNEC or best available data source	Comment	Type
1,7-Dimethylxanthine (Paraxanthine)	Yes	-	EPHC (2008)	7.0E+02 (ng/L) DWG; Cramer Class III, 5th percentile NOEL SF =100	Caffeine metabolite
3-Hydroxycarbofuran	Yes	4.2E+02	USEPA CCL3		Metabolite of carbofuran, pesticide
4-tert-Octylphenol	Yes	-	EPHC (2008)	5.0E+04 (ng/L) DWG; NOAEL w/ derived ADI and UF =1,000	Chem intermediate for phenolic resins
Acesulfame-K	Yes	5.3E+08	53 FR 28379, July 28, 1988 (FDA)	Based on ADI 15 mg/kg bw/day and no UF=(15)(E06)(70)/2=5.3E+08	Non calorie sweetner
Acetaminophen	Yes	1.2E+07	Intertox (2009)	Also 3.5E+05 (ng/L) PNEC USEPA CCL3	Analgesic
Albuterol	Yes	4.1E+04	Schwab (2005)		Bronchodilator
Amoxicillin (semi-quantitative)	Yes	-	EPHC (2008)	1.5+E03 (ng/L) DWG	Antibiotic
Atenolol	Yes	7.0E+04	AwwaRF (2008)		Beta blocker; blood pressure med
Azithromycin	Yes	-	EPHC (2008)	3.9+E03 (ng/L) DWG	Anitbiotic
Bezafibrate	Yes	3.5E+05	EPHC (2008)	3.0+E05 (ng/L) DWG	Chloesterol med
BPA	Yes	3.5E+05	USEPA CCL3		Used in the production of polycarbonate plastics and epoxy resins
Butalbital	Yes	1.8E+08	http://www.fda.gov/aboutfda/centersoffices/officeofmedicalproductsandtobacco/cder/ucm092199.htm	Based on 5.0 mg/kg-bw/day FDA MRTD and no UF	Barbiturate
Caffeine	Yes	8.7E+07	Intertox (2009)	Also 3.5E2 (ng/L) DWG EPHC (2008) based on Cramer Classification	Stimulant
Carbamazepine	Yes	1.2E+04	Intertox (2009)	1.0E3 (ng/L) PGV Sshriks (2009)	Anti-seizure med
Carisoprodol (SOMA)	Yes	2.6E+05	NA	Use MRTD for Meprobate which is 40 mg/kd-bw/day. http://www.fda.gov/aboutfda/centersoffices/officeofmedicalproductsandtobacco/cder/ucm092	Skeletal muscle relaxant
Cimetidine	Yes	-	EPHC (2008)	2.0E5 (ng/L) DWG	Heartburn med, histamine H2-blocker
Cotinine	Yes	-	EPHC (2008)	1.0E4 (ng/L) DWG	Metabolite of nicotine
Diethanolamine (DEA)	Yes	-	Schriks (2009)	7.5E5 (ng/L) PGV	Ingredient in soaps, cosmetics, shampoos
DEET	Yes	8.1E+04	Intertox (2009)	2.5E3 (ng/L) DWG -EPHC (2008)	Insecticide
Dehydronifedipine	Yes	-	EPHC (2008)	2.0E4 (ng/L) DWG	Metabolite of Nifedipine,calcium channel blocker
DIA	Yes	3.0E3, 1.5E2	Intertox (2009)	Atrazine MCL used as basis for DWEL, 2.0E3 (ng/L) Cotruvo (2010)	Metabolite of atrazine
Diclofenac	Yes	2.3E+06	AwwaRF (2008), Intertox (2009)	1.8E3 (ng/L) DWG -EPHC (2008)	NSAID
Dilantin	Yes	6.7E+03	Intertox (2009)	6.8E3 (ng/L) DWEL AwwaRF (2008)	Anti-seizure med
Diltiazem	Yes	-	EPHC (2008)	6.0E4 (ng/L) DWG	Blood pressure med; calcium channel blocker
Erythromycin	Yes	4.9E+03	USEPA CCL3		Antibiotic
Estrone	Yes	4.6E+02	Intertox (2009), AwwaRF (2008)	3.5E2 (ng/L) PNEC USEPA CCL3	Estrogenic hormone
Fluoxetine (Prozac)	Yes	-	EPHC (2008)	1.0E4 (ng/L) DWG	Anti-depressant
Gemfibrozil	Yes	4.6E+04	Intertox (2009), AwwaRF (2008)		Chloesterol med
Ibuprofen	Yes	3.4E+04	Intertox (2009), Nellor (2010)		NSAID
Iohexal	Yes	-	EPHC (2008)	7.2E5 (ng/L) DWG	Imaging contrast agent
Iopromide	Yes	-	EPHC (2008)	7.5E5 (ng/L) DWG	Imaging contrast agent
Ketoprofen	Yes	1.3E+04	Nellor (2010)	3.5E3 (ng/L) DWG EPHC (2008)	NSAID
Ketorolac	Yes	8.8E+07	http://www.fda.gov/aboutfda/centersoffices/officeofmedicalproductsandtobacco/cder/ucm092199.htm	Based on 2.5 mg/kg-bw/day FDA MRTD and no UF	NSAID
Lidocaine	Yes	1.1E+08	Emerg Med J 2004;21:249-250 doi:10.1136/emj.2003.008730, http://emj.bmj.com/content/21/2/249/T1.expansion.html	Based on 3 mg/kg-bw/day therapeutic dose and no UF	OTC pain reliever
Lincomycin	Yes	3.7E+05	Schwab (2005)		Antibiotic
Lopressor (Metoprolol)	Yes	2.3E+08	http://www.fda.gov/aboutfda/centersoffices/officeofmedicalproductsandtobacco/cder/ucm092199.htm	Based on 6.67 mg/kg-bw/day FDA MRTD and no UF	Beta blocker; blood pressure med
Meprobamate	Yes	2.6E+05	AwwaRF (2008)		Skeletal muscle relaxant
Metolachlor	Yes	7.0E+06	USEPA CCL3		Herbicide
Naproxen	Yes	2.2E+05	EPHC (2008)		NSAID
Nifedipine	Yes	1.1E+09	http://www.accessdata.fda.gov/drugsatfda_docs/label/2011/020198s023lbl.pdf	Based on 30 mg/kg-bw/day and no UF	Blood pressure and angina med
Pentoxifylline	Yes	1.3E+05	Nellor (2010)		Blood circulation med
Primidone	Yes	8.4E+02	Intertox (2009), Nellor (2010)		Anti-seizure med
Quinoline	Yes	1.0E+01	USEPA CCL3		Intermediate in the manufacture of other products
Sucralose	Yes	1.7E+05	http://www.fda.gov/OHRMS/DOCKETS/98fr/cf9947.pdf	Based on 5 mg/kd-bw/day and no UF	Artificial sweetner
Sulfadimethoxine	Yes	-	EPHC (2008)	3.5E4 (ng/L) DWG	Anitbiotic
Sulfamerazine	Yes	2.3E+06	http://www.accessdata.fda.gov/drugsatfda_docs/label/2011/020198s023lbl.pdf	Based on 66.7 mg/kg-bw/day and no UF	Antibiotic
Sulfamethazine	Yes	7.7E+04	Nellor (2010)	3.5E4 (ng/L) DWG EPHC (2008)	Antibacterial
Sulfamethoxazole	Yes	1.8E+07	Intertox (2009)	3.5E4 (ng/L) DWG EPHC (2008)	Antibiotic
Sulfathiazole	Yes	7.3E+05	Schwab (2005)		Antibacterial
TCEP	Yes	4.4E+03	Nellor (2010)	2.5E3 (ng/L) PNEC USEPA CCL3	Flame retardant
TCPP	Yes	1.0E+04	tp://whqlibdoc.who.int/ehc/WHO_EHC_209.p	10 ug/L PNEC for organisms (no human tox data) with SF 100	Flame retardant
TDCPP	Yes	2.7E+03	tps://dtsc.ca.gov/SCP/upload/ProfileTDCCP.p	OEHHA No Significant Risk Level 5.4 ug/d = 2.7 ug/L ;	Flame retardant
Theobromine (Xantheose)	Yes	2.8E+10	http://toxnet.nlm.nih.gov/cgi-bin/sis/search/a?dbs+hsdb:@term+@DOCNO+7332	Based on 0.8g/kg-gw/day and no UF	Ingredient in chocolate
Theophylline	Yes	3.0E+08	http://www.accessdata.fda.gov/drugsatfda_docs/label/2011/020198s023lbl.pdf	Based on 8.67 mg/kg-bw/day and no UF	Bronchodilator
Tot DCPA Mono&Diacid Degradate	Yes	3.5E+05	http://www.epa.gov/safewater/ccl/pdfs/reg_determine2/report_ccl2-reg2_supportdocument_ch04_dcpa.pdf	RfD of 0.01 mg/kg/day for DCPA	Degradation products of herbicide DCPA
Triclocarban	Yes	8.8E+08	http://oehha.ca.gov/multimedia/biomon/pdf/HenkelLANXESSTCCcomments052410.pdf	NOEL 25 mg/kg bw/day and no UF	Antibacterial
Triclosan	Yes	2.6E+06	Intertox (2009)	3.5E2 (ng/L) DWG EPHC (2008)	Antibacterial
Trimethoprim	Yes	6.1E+04	Schwab (2005)		Antibacterial
Warfarin	Yes	2.3E+03	Schwab (2005)		Blood thinner

5 QUANTITATIVE RELATIVE RISK ASSESSMENT

5.1 Concentrations of Constituents of Potential Concern and Constituents of Emerging Concern in Evaluated Waters

A summary and comparison of CPC and CEC average concentrations in the four evaluated waters is presented in Tables 11 through 16. As a conservative approach, data that were reported to be below MRLs were assumed to be present at the MRLs for the purposes of the QRRA. A constituent concentration at or below its MRL could mean that the constituent is present, but cannot be quantified reliably or not present (for example below the method detection limit). Thus, the approach used is likely to overestimate the concentration of any observation reported below the MRL, and any subsequent risk estimates that are developed based on observations below MRLs or analytical method detection limits are likely biased on the high side.[6]

For each constituent the following information is presented in Tables 11 through 16:

- The number of observations collected.
- The number of observations above the MRL for that constituent.
- The average concentration[7] and units.
- Associated health based criteria values (RfDs, Oral SFs, and/or RBALs).

[6] The Method Detection Limit (MDL) for an analytical method is based solely on the standard deviation of repeated measurement of low-level spikes. The MRL differs from the MDL by considering not only the standard deviation of low concentration analyses (precision) but also the accuracy of the measurements.

[7] Averages were calculated as follows: for detected constituents (at least one sample at or above the MRL) if any other data were reported below MRLs, the concentrations were set at the MRL.

Table 11. Average Concentrations of Constituents of Potential Concern and Constituents of Emerging Concern in Case Study 1 Raw Water

Analyte	# Obs	# >MRL	Avg	Units	RfD (mg/kg-day)	Oral Slope Factor (mg/kg-day)	RBAL (ng/L)
2,4-D	12	5	93.1	ng/L	0.01	-	NA
2-Butanone (MEK)	5	1	5.0	ug/L	0.6	-	NA
Aluminum Total	6	5	388.3	ug/L	1	-	NA
Arsenic Total	6	5	2.3	ug/L	0.003	1.5	NA
Atrazine	12	12	277.9	ng/L	0.035	-	NA
Barium Total	6	6	50.7	ug/L	0.2	-	NA
Benzo(b)Fluoranthene	6	1	0.02	ug/L	-	-	NA
Bromacil	6	4	17.2	ng/L	0.1	-	NA
Chloride	3	3	58.7	mg/L	0.1	-	NA
Chromium Total	6	2	1.2	ug/L	1.5 / 0.003 (CrIII/Cr VI)	-	NA
Copper Total	6	1	2.1	ug/L	-	-	NA
Di(2-Ethylhexyl)phthalate	6	1	0.6	ug/L	0.02	0.014	NA
Dicamba	6	1	0.1	ug/L	0.03	-	NA
Diuron	6	3	16.0	ng/L	0.002	-	NA
Fluoride	6	6	0.5	mg/L	0.06	-	NA
Lead Total	6	3	0.7	ug/L	-	0.0085	NA
Nitrate as NO3 (calc)	6	6	4.0	mg/L	1.6	-	NA
Nitrite Nitrogen	6	1	0.06	mg/L	0.1	-	NA
N-Nitroso-dimethylamine (NDMA)	6	1	2.3	ng/L	-	51	NA
Propazine	6	1	5.5	ng/L	0.02	-	NA
Simazine	12	12	422.3	ng/L	0.005	-	NA
Sulfate	3	3	141.7	mg/L	-	-	NA
Acesulfame-K	6	6	1298.3	ng/L	NA	NA	5.3E+08
Acetaminophen	6	1	8.7	ng/L	NA	NA	3.5E+05
Albuterol	6	4	7.3	ng/L	NA	NA	4.1E+04
Amoxicillin (semi-quantitative)	6	3	45.2	ng/L	NA	NA	1.5E+03
Atenolol	6	2	9.3	ng/L	NA	NA	7.0E+04
BPA	6	1	10.7	ng/L	NA	NA	3.5E+05
Caffeine	12	11	87.2	ng/L	NA	NA	8.7E+07
Carbamazepine	6	6	14.4	ng/L	NA	NA	1.2E+04
Carisoprodol	6	1	5.4	ng/L	NA	NA	2.6E+05
Cotinine	6	6	28.5	ng/L	NA	NA	1.0E+04
DACT	6	6	46.2	ng/L	NA	NA	
DEA	6	6	76.3	ng/L	NA	NA	7.5E+05
DEET	6	6	80.7	ng/L	NA	NA	8.1E+04
Dehydronifedipine	6	4	14.8	ng/L	NA	NA	2.0E+04
DIA	6	6	111.7	ng/L	NA	NA	1.5E+02
Fluoxetine	6	2	10.7	ng/L	NA	NA	1.0E+04
Gemfibrozil	6	4	12.5	ng/L	NA	NA	4.6E+04
Iohexal	6	6	145.5	ng/L	NA	NA	7.2E+05
Lidocaine	6	4	11.1	ng/L	NA	NA	1.1E+08
Lopressor	6	1	21.5	ng/L	NA	NA	2.3E+08
Meprobamate	6	6	15.5	ng/L	NA	NA	2.6E+05
Metolachlor	5	1	5.5	ng/L	NA	NA	7.0E+06
Primidone	6	4	11.3	ng/L	NA	NA	8.4E+02
Quinoline	6	1	6.3	ng/L	NA	NA	1.0E+01
Sucralose	6	6	5966.7	ng/L	NA	NA	1.7E+05
Sulfamethoxazole	6	6	52.0	ng/L	NA	NA	1.8E+07
TCEP	6	6	33.3	ng/L	NA	NA	4.4E+03
TCPP	6	3	110.0	ng/L	NA	NA	1.0E+04
Theobromine	6	2	53.3	ng/L	NA	NA	2.8E+10
Theophylline	6	2	29.7	ng/L	NA	NA	3.0E+08
Tot DCPA Mono&Diacid Degradate	6	1	0.1	ug/L	NA	NA	3.5E+05
Triclocarban	6	1	32.5	ng/L	NA	NA	8.8E+08
Trimethoprim	6	4	7.6	ng/L	NA	NA	6.1E+04

Table 12. Average Concentrations of Constituents of Potential Concern in Case Study 1 Effluent

Analyte	# Obs	# >MRL	Avg	Units	RfD (mg/kg-day)	Oral Slope Factor (mg/kg-day)	RBAL (ng/L)
2,4-D	7	3	47.1	ng/L	0.01	-	NA
Aldicarb sulfone	6	5	0.6	ug/L	0.01	-	NA
Aluminum Total	6	5	31.3	ug/L	1	-	NA
Antimony Total	6	1	1.0	ug/L	0.0004	-	NA
Arsenic Total	6	4	1.7	ug/L	0.0003	1.5	NA
Atrazine	12	10	151.7	ng/L	0.035	-	NA
Barium Total	6	5	9.7	ug/L	0.2	-	NA
Bromacil	6	1	7.3	ng/L	0.1	-	NA
Bromodichloromethane	6	6	7.8	ug/L	0.02	0.062	NA
Bromoform	6	3	1.1	ug/L	0.02	0.0079	NA
Chloride	3	3	100.7	mg/L	0.1	-	NA
Chlorodibromomethane	6	5	5.4	ug/L	0.02	0.084	NA
Chloroform (Trichloromethane)	6	6	5.8	ug/L	0.01	0.000023	NA
Copper Total	6	5	4.7	ug/L	-	-	NA
Cyanide (manual distillation)	6	4	0.0	mg/L	0.0006	-	NA
Dibromoacetic acid	6	5	2.3	ng/L	-	-	NA
Dichloroacetic acid	6	6	9.9	ug/L	0.004	0.05	NA
Diuron	6	2	6.9	ng/L	0.002	-	NA
Fluoride	6	6	1.2	mg/L	0.06	-	NA
Iron Total ICAP	2	2	0.2	mg/L	0.7	-	NA
Manganese Total	2	2	38.5	ug/L	0.14	-	NA
Methomyl	6	1	0.5	ug/L	0.025	-	NA
Monobromoacetic acid	6	2	1.2	ug/L	-	-	NA
Monochloroacetic acid	6	1	2.1	ug/L	0.002	-	NA
Nickel Total	6	1	5.1	ug/L	0.02	-	NA
Nitrate as NO3 (calc)	6	6	79.3	mg/L	0.1	-	NA
N-Nitroso-dimethylamine (NDMA)	6	6	11.7	ng/L	-	51	NA
Propazine	6	2	5.4	ng/L	0.02	-	NA
Simazine	12	10	168.5	ng/L	0.005	-	NA
Sodium Total	2	2	103.0	mg/L	-	-	NA
Strontium	2	2	0.6	mg/L	0.6	-	NA
Sulfate	3	3	150.0	mg/L	-	-	NA
Toluene	6	2	0.5	ug/L	0.08	-	NA
Total Haloacetic Acids (HAA5)	6	6	23.5	ug/L	-	-	NA
Total THM	6	6	19.7	ug/L	-	-	NA
Trichloroacetic acid	6	6	10.7	ug/L	0.02	0.07	NA

Table 13. Average Concentrations of Constituents of Emerging Concern in Case Study 1 Effluent

Analyte	# Obs	# >MRL	Avg	Units	RfD (mg/kg-day)	Oral Slope Factor (mg/kg-day)	RBAL (ng/L)
1,7-Dimethylxanthine	6	1	63.3	ng/L	NA	NA	7.0E+02
3-Hydroxycarbofuran	6	1	0.5	ug/L	NA	NA	4.2E+02
4-tert-Octylphenol	6	1	71.7	ng/L	NA	NA	5.0E+04
Acesulfame-K	6	6	3080.0	ng/L	NA	NA	5.3E+08
Acetaminophen	6	2	42.5	ng/L	NA	NA	3.5E+05
Albuterol	6	4	14.5	ng/L	NA	NA	4.1E+04
Alkalinity in CaCO3 units	2	2	52.0	mg/L	NA	NA	NA
Amoxicillin (semi-quantitative)	6	1	24.0	ng/L	NA	NA	1.5E+03
Atenolol	6	5	50.3	ng/L	NA	NA	7.0E+04
Azithromycin	6	2	368.3	ng/L	NA	NA	3.9E+03
Bezafibrate	6	1	5.7	ng/L	NA	NA	3.5E+05
Bromide	2	2	215.0	ug/L	NA	NA	NA
Bromochloroacetic acid	6	6	6.1	ug/L	NA	NA	NA
Caffeine	12	8	181.7	ng/L	NA	NA	8.7E+07
Calcium Total ICAP	2	2	71.5	mg/L	NA	NA	NA
Carbamazepine	6	6	98.3	ng/L	NA	NA	1.2E+04
Carisoprodol	6	5	19.3	ng/L	NA	NA	2.6E+05
Cotinine	6	5	41.7	ng/L	NA	NA	1.0E+04
DACT	6	6	54.0	ng/L	NA	NA	NA
DEA	6	6	124.5	ng/L	NA	NA	7.5E+05
DEET	6	3	13.7	ng/L	NA	NA	8.1E+04
Dehydronifedipine	6	6	112.3	ng/L	NA	NA	2.0E+04
DIA	6	6	161.7	ng/L	NA	NA	1.5E+02
Diclofenac	6	2	8.3	ng/L	NA	NA	2.3E+06
Dilantin	6	6	60.7	ng/L	NA	NA	6.7E+03
Diltiazem	6	3	11.7	ng/L	NA	NA	6.0E+04
Erythromycin	6	2	14.5	ng/L	NA	NA	4.9E+03
Estrone	6	3	10.1	ng/L	NA	NA	4.6E+02
Fluoxetine	6	6	17.2	ng/L	NA	NA	1.0E+04
Gemfibrozil	6	4	32.9	ng/L	NA	NA	4.6E+04
Ibuprofen	6	2	19.0	ng/L	NA	NA	3.4E+04
Iohexal	6	6	5183.3	ng/L	NA	NA	7.2E+05
Iopromide	6	3	28.5	ng/L	NA	NA	7.5E+05
Ketoprofen	6	4	10.0	ng/L	NA	NA	1.3E+04
Lidocaine	6	4	60.5	ng/L	NA	NA	1.1E+08
Lopressor	6	6	223.3	ng/L	NA	NA	2.3E+08
Magnesium Total ICAP	2	2	10.2	mg/L	NA	NA	NA
Meprobamate	6	6	62.3	ng/L	NA	NA	2.6E+05
Naproxen	6	2	18.0	ng/L	NA	NA	2.2E+05
Orthophosphate as P	1	1	2.6	mg/L	NA	NA	NA
Orthophosphate as PO4	1	1	8.0	mg/L	NA	NA	NA
Potassium Total ICAP	2	2	17.5	mg/L	NA	NA	NA
Primidone	6	6	52.7	ng/L	NA	NA	8.4E+02
Quinoline	6	3	11.3	ng/L	NA	NA	1.0E+01
Silica	2	2	7.0	mg/L	NA	NA	NA
Sucralose	6	6	27333.3	ng/L	NA	NA	1.7E+05
Sulfamethazine	6	2	5.5	ng/L	NA	NA	2.3E+06
Sulfamethoxazole	6	4	175.8	ng/L	NA	NA	7.7E+04
TCEP	6	6	178.3	ng/L	NA	NA	4.4E+03
TCPP	6	6	333.3	ng/L	NA	NA	1.0E+04
TDCPP	6	6	211.7	ng/L	NA	NA	2.7E+03
Theobromine	6	2	190.0	ng/L	NA	NA	2.8E+10
Theophylline	6	1	83.3	ng/L	NA	NA	3.0E+08
Total Organic Carbon	1	1	7.4	mg/L	NA	NA	NA
Total phosphorus as P	1	1	2.7	mg/L	NA	NA	NA
Total phosphorus as PO4- Calc.	1	1	8.3	mg/L	NA	NA	NA
Triclocarban	6	2	39.3	ng/L	NA	NA	8.8E+08
Triclosan	6	1	11.3	ng/L	NA	NA	2.6E+06
Trimethoprim	6	3	94.5	ng/L	NA	NA	6.1E+04

Table 14. Average Concentrations of Constituents of Potential Concern and Constituents of Emerging Concern in Case Study 2 Raw Water

Analyte	# Obs	# >MRL	Avg	Units	Type	RfD (mg/kg-day)	Oral Slope Factor (mg/kg-day)	RBAL (ng/L)
Aluminum Total	6	6	42.3	ug/L	CPC	1	-	NA
Arsenic Total	6	5	2.1	ug/L	CPC	0.0003	1.5	NA
Barium Total	6	6	87.0	ug/L	CPC	0.2	-	NA
Bromodichloromethane	6	1	0.5	ug/L	CPC	0.02	0.062	NA
Bromoform	6	1	0.6	ug/L	CPC	0.02	0.0079	NA
Chloride	3	3	216.7	mg/L	CPC	0.1	-	NA
Chlorodibromomethane	6	1	0.6	ug/L	CPC	0.02	0.084	NA
Chromium Total	6	6	1.9	ug/L	CPC	1.5 / 0.003 (CrIII/Cr VI)	-	NA
Copper Total	6	6	8.0	ug/L	CPC	-	-	NA
Fluoride	6	6	0.8	mg/L	CPC	0.06	-	NA
Nitrate as NO3 (calc)	6	6	5.7	mg/L	CPC	1.6	-	NA
Sulfate	3	3	83.7	mg/L	CPC	-	-	NA
Albuterol	6	1	11.3	ng/L	CEC	NA	NA	4.1E+04
Caffeine	6	1	7.7	ng/L	CEC	NA	NA	8.7E+07
DEA	6	1	7.2	ng/L	CEC	NA	NA	7.50E+05
DEET	6	1	10.0	ng/L	CEC	NA	NA	8.1E+04
Sulfamethoxazole	6	1	5.5	ng/L	CEC	NA	NA	1.8E+07

Table 15. Average Concentrations of Constituents of Potential Concern in Case Study 2 Effluent

Analyte	# Obs	# >MRL	Avg	Units	RfD (mg/kg-day)	Oral Slope Factor (mg/kg-day)	RBAL (ng/L)
2,4-D	6	2	31.7	ng/L	0.01	-	NA
Aldicarb sulfone	6	6	0.7	ug/L	0.001	-	NA
Aluminum Total	6	6	33.2	ug/L	1	-	NA
Antimony Total	6	2	1.1	ug/L	0.0004	-	NA
Arsenic Total	6	6	3.5	ug/L	0.0003	1.5	NA
Atrazine	6	5	19.4	ng/L	0.035	-	NA
Barium Total	6	6	56.5	ug/L	0.2	-	NA
Bromacil	6	2	62.7	ng/L	0.1	-	NA
Chloride	3	3	310.0	mg/L	0.1	-	NA
Copper Total	6	4	2.2	ug/L	-	-	NA
Cyanide	3	2	0.045	mg/L	0.0006	-	NA
Diuron	6	2	22.8	ng/L	0.002	-	NA
Fluoride	6	6	2.3	mg/L	0.06	-	NA
Iron Total	2	2	0.09	mg/L	0.7	-	NA
Manganese Total	3	3	2803.0	ug/L	0.14	-	NA
Methomyl	6	1	0.5	ug/L	0.025	-	NA
Molybdenum Total	1	1	8.4	ug/L	0.005	-	NA
Nitrate as NO3 (calc)	5	5	33.8	mg/L	1.6	-	NA
Nitrite Nitrogen	5	3	0.7	mg/L	0.1	-	NA
N-Nitroso-dimethylamine (NDMA)	6	6	10.8	ng/L	-	51	NA
p-Dichlorobenzene (1,4-DCB)	5	1	0.5	ug/L	0.8	-	NA
Simazine	6	2	5.8	ng/L	0.005	-	NA
Sodium Total	2	2	230.0	mg/L	-	-	NA
Strontium	2	2	1.4	mg/L	0.6	-	NA
Sulfate	2	2	135.0	mg/L	-	-	NA
Trichloroacetic acid	6	4	1.3	ug/L	0.02	0.07	NA
Uranium ICAP/MS	1	1	5.8	ug/L	0.003	-	NA

Table 16. Average Concentrations of Constituents of Emerging Concern in Case Study 2 Effluent

Analyte	# Obs	# >MRL	Avg	Units	RfD (mg/kg-day)	Oral Slope Factor (mg/kg-day)	RBAL (ng/L)
1,7-Dimethylxanthine	6	1	28.3	ng/L	NA	NA	7.0E+02
Acesulfame-K	6	6	1313.3	ng/L	NA	NA	5.3E+08
Acetaminophen	6	2	33.5	ng/L	NA	NA	3.5E+05
Albuterol	6	4	24.2	ng/L	NA	NA	4.1E+04
Alkalinity in CaCO3 units	2	2	190.0	mg/L	NA	NA	NA
Amoxicillin (semi-quantitative)	6	6	2331.7	ng/L	NA	NA	1.5E+03
Atenolol	6	6	146.7	ng/L	NA	NA	7.0E+04
Azithromycin	6	2	713.3	ng/L	NA	NA	3.9E+03
BPA	6	2	17.8	ng/L	NA	NA	3.5E+05
Bromide	2	2	320.0	ug/L	NA	NA	NA
Butalbital	6	2	21.7	ng/L	NA	NA	1.8E+08
Caffeine	6	6	51.2	ng/L	NA	NA	8.7E+07
Calcium Total ICAP	2	2	59.0	mg/L	NA	NA	NA
Carbamazepine	6	6	225.0	ng/L	NA	NA	1.2E+04
Carisoprodol	6	6	65.2	ng/L	NA	NA	2.6E+05
Cimetidine	6	1	40.8	ng/L	NA	NA	2.0E+05
Cotinine	6	6	35.8	ng/L	NA	NA	1.0E+04
DEET	6	6	88.3	ng/L	NA	NA	8.1E+04
Dehydronifedipine	6	6	368.3	ng/L	NA	NA	2.0E+04
Diclofenac	6	3	19.2	ng/L	NA	NA	2.3E+06
Dilantin	6	6	187.3	ng/L	NA	NA	6.7E+03
Diltiazem	6	6	58.5	ng/L	NA	NA	6.0E+04
Erythromycin	6	4	72.2	ng/L	NA	NA	4.9E+03
Estrone	6	6	102.2	ng/L	NA	NA	4.6E+02
Fluoxetine	6	6	37.8	ng/L	NA	NA	1.0E+04
Gemfibrozil	6	6	412.2	ng/L	NA	NA	4.6E+04
Ibuprofen	6	1	10.7	ng/L	NA	NA	3.4E+04
Iohexal	6	6	10700.0	ng/L	NA	NA	7.2E+05
Iopromide	6	5	231.0	ng/L	NA	NA	7.5E+05
Ketoprofen	6	2	5.7	ng/L	NA	NA	1.3E+04
Ketorolac	6	3	12.0	ng/L	NA	NA	8.8E+07
Lidocaine	6	6	225.0	ng/L	NA	NA	1.1E+08
Lincomycin	6	6	79.0	ng/L	NA	NA	3.7E+05
Lopressor	6	6	533.3	ng/L	NA	NA	2.3E+08
Magnesium Total ICAP	2	2	31.0	mg/L	NA	NA	NA
Meprobamate	6	6	102.0	ng/L	NA	NA	2.6E+05
Metolachlor	6	1	5.2	ng/L	NA	NA	7.0E+06
Naproxen	6	3	11.8	ng/L	NA	NA	2.2E+05
Nifedipine	6	1	20.2	ng/L	NA	NA	1.1E+09
Orthophosphate as P	1	1	0.1	mg/L	NA	NA	NA
Orthophosphate as PO4	1	1	0.2	mg/L	NA	NA	NA
Pentoxifylline	6	2	6.5	ng/L	NA	NA	1.3E+05
Potassium Total ICAP	2	2	19.0	mg/L	NA	NA	NA
Primidone	6	6	155.0	ng/L	NA	NA	8.4E+02
Quinoline	6	2	10.8	ng/L	NA	NA	1.0E+01
Silica	2	2	36.0	mg/L	NA	NA	NA
Sucralose	6	6	43500.0	ng/L	NA	NA	1.7E+05
Sulfadimethoxine	6	2	9.8	ng/L	NA	NA	3.5E+04
Sulfamerazine	6	1	18.0	ng/L	NA	NA	2.3E+06
Sulfamethoxazole	5	5	1676.0	ng/L	NA	NA	1.8E+07
Sulfathiazole	6	1	5.7	ng/L	NA	NA	7.3E+05
TCEP	6	6	216.7	ng/L	NA	NA	4.4E+03
TCPP	6	6	356.7	ng/L	NA	NA	1.0E+04
TDCPP	6	6	425.0	ng/L	NA	NA	2.7E+03
Theobromine	6	2	88.3	ng/L	NA	NA	2.8E+10
Theophylline	6	2	140.5	ng/L	NA	NA	3.0E+08
Tot DCPA Mono&Diacid Degradate	6	1	0.1	ug/L	NA	NA	3.5E+05
Total phosphorus as P	1	1	0.2	mg/L	NA	NA	NA
Total phosphorus as PO4- Calc.	1	1	0.6	mg/L	NA	NA	NA
Triclocarban	6	4	21.3	ng/L	NA	NA	8.8E+08
Triclosan	6	6	76.7	ng/L	NA	NA	2.6E+06
Trimethoprim	6	6	158.2	ng/L	NA	NA	6.1E+04
Warfarin	6	3	6.5	ng/L	NA	NA	2.3E+03

5.2 Exposure Assessment

The objective of an exposure assessment is to estimate the type and magnitude of exposure to the constituents of concern. For this relative risk assessment study, which strictly focused on exposure through drinking water, a hypothetical exposure was calculated based on observed average concentrations of the CPCs and CECs in raw water or wastewater and their predicted concentrations in drinking water taking into consideration removal efficiencies of treatment processes through water treatment and combined advanced treatment and water treatment, and a standard ingestion volume to compare the various scenarios under investigation.

Risk assessment methods used in this study compare water sources where the hypothetical exposures used in the assessment are not expected to actually occur, but are used to “normalize” exposure. This is done because estimating situational exposure can involve a high degree of uncertainty since there is no direct method of determining the uptake of chemicals in a drinking water supply that represents long-term, realistic consumption. There are also many confounding factors that impact exposure and public health that cannot be quantified, such as bottled water usage, smoking, diet, exercise regimen, etc.

Other routes of exposure, such as dermal absorption and inhalation may also be valid, but are not the focus of this investigation. Common household water-use activities such as showering, bathing, and washing clothes or dishes are potentially important contributors to individual exposure to trihalomethanes (THMs) and other volatile organic compounds via inhalation and dermal absorption routes of exposure (Gordon et al., 2006). There have been numerous laboratory-based studies of controlled exposure to THMs from showering, bathing, or other household activities (Andelman, 1985; Jo et al., 1990a, b; Weisel & Jo, 1996; Gordon et al., 1998; Olson & Corsi, 2004). Overall, this body of work indicates that showering and bathing are two common household water-use activities that can cause increases in exposure to volatile organic compounds from water over and above exposures due to ingestion of drinking water. However, previous QRRA work for recycled water indicates that adjusting exposure estimates to account for inhalation and dermal exposure routes does not substantially change the relative risk between various scenarios. Therefore, this work focuses on ingestion, however the potential for adverse health effects from inhalation or dermal exposure are routes of exposure that could be considered as part of a QRRA depending on the characteristics of potential CPCs or CECs that may be present. The inhalation route of exposure is discussed in more detail in Section 6.1.

The exposure to a particular constituent is a function of the concentration of that constituent in the drinking water and the volume of water consumed. Estimated concentrations in drinking water are computed based on the concentrations of CPCs and CECs reported above reduced by the expected removals across advanced water treatment and/or drinking water treatment, as appropriate for each scenario evaluated. The estimated reductions of each constituent across each treatment unit process are provided in the exhibits of this TM along with associated references on how they were derived.

The following equation is used to calculate the assumed dose for the exposure assessment (where 70 kg approximates the average weight of an exposed individual).

Dose (mg/kg-day) = Estimated concentration in drinking water (mg/L) x Volume ingested (L/day) / 70 kg

For the purposes of this exposure assessment for CPCs, the daily volume of water ingested is assumed to be a constant 1.2 L (U.S Department of Agriculture, 1998; U.S. EPA, 2006). The water volume used for this assessment is based on the intake of an average adult. In this respect it differs from the approach U.S. EPA uses to protect the high end consumer. Additional information on the basis for daily water consumption is presented in Section 5.4 of the TM.

Based on the hypothetical exposure scenario described above, the exposure assessment is summarized in Tables 17 – 22 for the Case Study 1 No Project Alternative scenario, Case Study 1 DPR Alternative, Case Study 2 No Project Alternative, and Case Study 2 DPR Alternative. The data presented in Tables 17 - 22 summarize the relative levels of CPCs and CECs in each of the waters at each point in the evaluated treatment processes, the estimated average concentration in the finished drinking water for the scenario, and the exposure dose to each constituent for an assumed daily ingestion volume of 1.2 liters. (As noted above, for simplicity, the DPR alternatives in this evaluation do not include blending raw or finished drinking water).

Table 17. Exposure Assessment for Case Study 1 No Project Alternative

						Water Treatment Plant										
						Ozone/BAC		Floc/Sed		Media Filtration		Chlorine Disinfection				
Type	Analyte	# Obs	# >MRL	Avg	Units	Removal %	Outlet Conc.	Removal %	Outlet Conc.	Removal %	Outlet Conc.	Removal %	Outlet Conc.	Estimated Conc in Drinking Water	Units	Estimated Dose (mg/kg-day)
CPC	2,4-D	12	5	93.1	ng/L	50%	46.5	0%	46.5	0%	46.5	0%	46.5	46.5	ng/L	8.0E-07
	2-Butanone (MEK)	5	1	5.0	ug/L	0%	5.0	0%	5.0	0%	5.0	0%	5.0	5.0	ug/L	8.6E-05
	Aluminum Total	6	5	388.3	ug/L	0%	388.3	0%	388.3	0%	388.3	0%	388.3	388.3	ug/L	6.7E-03
	Arsenic Total	6	5	2.3	ug/L	95%	0.1	90%	0.01	0%	0.01	0%	0.01	0.012	ug/L	2.0E-07
	Atrazine	12	12	277.9	ng/L	81%	52.8	0%	52.8	0%	52.8	20%	42.2	42.2	ng/L	7.2E-07
	Barium Total	6	6	50.7	ug/L	0%	50.7	80%	10.1	0%	10.1	0%	10.1	10.1	ug/L	1.7E-04
	Bromacil	6	4	17.2	ng/L	0%	17.2	0%	17.2	0%	17.2	0%	17.2	17.2	ng/L	2.9E-07
	Chloride	3	3	58.7	mg/L	0%	58.7	0%	58.7	0%	58.7	0%	58.7	58.7	mg/L	1.01E+00
	Chromium Total	6	2	1.2	ug/L	0%	1.2	95%	0.1	0%	0.1	0%	0.1	0.1	ug/L	9.9E-07
	Di(2-Ethylhexyl)phthalate	6	1	0.62	ug/L	68%	0.20	60%	0.08	0%	0.08	0%	0.08	0.08	ug/L	1.4E-06
	Dicamba	6	1	0.1	ug/L	0%	0.1	0%	0.1	0%	0.1	0%	0.1	0.1	ug/L	1.8E-06
	Diuron	6	3	16.0	ng/L	95%	0.8	0%	0.8	0%	0.8	0%	0.8	0.8	ng/L	1.4E-08
	Fluoride	6	6	0.5	mg/L	0%	0.5	45%	0.3	0%	0.3	0%	0.3	0.3	mg/L	4.46E-03
	Lead Total	6	3	0.65	ug/L	95%	0.03	0%	0.03	67%	0.011	0%	0.011	0.011	ug/L	1.8E-07
	Nitrate as NO3 (calc)	6	6	4.0	mg/L	0%	4.0	0%	4.0	0%	4.0	0%	4.0	4.0	mg/L	6.91E-02
	Nitrite Nitrogen	6	1	0.06	mg/L	35%	0.04	0%	0.04	0%	0.04	95%	0.002	0.002	mg/L	3.53E-05
	N-Nitroso-dimethylamine (NDMA)	6	1	2.3	ng/L	46%	1.2	9%	1.1	0%	1.1	0%	1.1	1.1	ng/L	1.9E-08
	Propazine	6	1	5.5	ng/L	0%	5.5	0%	5.5	0%	5.5	0%	5.5	5.5	ng/L	9.4E-08
	Simazine	12	12	422.3	ng/L	0%	422.3	0%	422.3	0%	422.3	0%	422.3	422.3	ng/L	7.2E-06
CEC	Acesulfame-K	6	6	1298.3	ng/L	42%	753.0	0%	753.0	0%	753.0	0%	753.0	753.0	ng/L	1.3E-05
	Acetaminophen	6	1	8.7	ng/L	54%	4.0	0%	4.0	0%	4.0	80%	0.8	0.8	ng/L	1.4E-08
	Albuterol	6	4	7.3	ng/L	95%	0.4	0%	0.4	0%	0.4	0%	0.4	0.4	ng/L	6.2E-09
	Amoxicillin (semi-quantitative)	6	3	45.2	ng/L	95%	2.3	0%	2.3	0%	2.3	0%	2.3	2.3	ng/L	3.9E-08
	Atenolol	6	2	9.3	ng/L	95%	0.5	0%	0.5	0%	0.5	30%	0.3	0.3	ng/L	5.6E-09
	BPA	6	1	10.7	ng/L	0%	10.7	0%	10.7	0%	10.7	58%	4.4	4.4	ng/L	7.6E-08
	Caffeine	12	11	87.2	ng/L	92%	7.0	0%	7.0	0%	7.0	30%	4.9	4.9	ng/L	8.4E-08
	Carbamazepine	6	6	14.4	ng/L	95%	0.7	0%	0.7	0%	0.7	20%	0.6	0.6	ng/L	9.8E-09
	Carisoprodol	6	1	5.4	ng/L	95%	0.3	0%	0.3	0%	0.3	0%	0.3	0.3	ng/L	4.6E-09
	Cotinine	6	6	28.5	ng/L	88%	3.4	0%	3.4	0%	3.4	0%	3.4	3.4	ng/L	5.9E-08
	DEA	6	6	76.3	ng/L	0%	76.3	0%	76.3	0%	76.3	0%	76.3	76.3	ng/L	1.3E-06
	DEET	6	6	80.7	ng/L	95%	4.0	0%	4.0	0%	4.0	22%	3.1	3.1	ng/L	5.4E-08
	Dehydronifedipine	6	4	14.8	ng/L	95%	0.7	0%	0.7	0%	0.7	14%	0.6	0.6	ng/L	1.1E-08
	DIA	6	6	111.7	ng/L	88%	13.4	0%	13.4	0%	13.4	0%	13.4	13.4	ng/L	2.3E-07
	Fluoxetine	6	2	10.7	ng/L	95%	0.5	0%	0.5	0%	0.5	66%	0.2	0.2	ng/L	3.1E-09
	Gemfibrozil	6	4	12.5	ng/L	95%	0.6	0%	0.6	0%	0.6	83%	0.1	0.11	ng/L	1.8E-09
	Iohexal	6	6	145.5	ng/L	42%	84.4	0%	84.4	0%	84.4	0%	84.4	84.4	ng/L	1.4E-06
	Lidocaine	6	4	11.1	ng/L	95%	0.6	0%	0.6	0%	0.6	0%	0.6	0.6	ng/L	9.5E-09
	Lopressor	6	1	21.5	ng/L	75%	5.4	0%	5.4	0%	5.4	0%	5.4	5.4	ng/L	9.2E-08
	Meprobamate	6	6	15.5	ng/L	95%	0.8	0%	0.8	0%	0.8	11%	0.7	0.7	ng/L	1.2E-08
	Metolachlor	5	1	5.5	ng/L	0%	5.5	0%	5.5	0%	5.5	0%	5.5	5.5	ng/L	9.5E-08
	Primidone	6	4	11.3	ng/L	95%	0.6	0%	0.6	0%	0.6	89%	0.1	0.1	ng/L	1.1E-09
	Quinoline	6	1	6.3	ng/L	0%	6.3	0%	6.3	0%	6.3	0%	6.3	6.3	ng/L	1.1E-07
	Sucralose	6	6	5966.7	ng/L	57%	2565.7	0%	2565.7	0%	2565.7	30%	1796.0	1796.0	ng/L	3.1E-05
	Sulfamethoxazole	6	6	52.0	ng/L	95%	2.6	0%	2.6	0%	2.6	49%	1.3	1.3	ng/L	2.3E-08
	TCEP	6	6	33.3	ng/L	95%	1.7	0%	1.7	0%	1.7	20%	1.3	1.3	ng/L	2.3E-08
	TCPP	6	3	110.0	ng/L	95%	5.5	0%	5.5	0%	5.5	0%	5.5	5.5	ng/L	9.4E-08
	Theobromine	6	2	53.3	ng/L	95%	2.7	0%	2.7	0%	2.7	0%	2.7	2.7	ng/L	4.6E-08
	Theophylline	6	2	29.7	ng/L	95%	1.5	0%	1.5	0%	1.5	0%	1.5	1.5	ng/L	2.5E-08
	Tot DCPA Mono&Diacid Degradate	6	1	0.1	ug/L	0%	0.1	0%	0.1	0%	0.1	0%	0.1	0.1	ug/L	1.8E-06
	Triclocarban	6	1	32.5	ng/L	0%	32.5	0%	32.5	0%	32.5	0%	32.5	32.5	ng/L	5.6E-07
	Trimethoprim	6	4	7.6	ng/L	95%	0.4	0%	0.4	0%	0.4	95%	0.02	0.02	ng/L	3.3E-10

Table 18. Exposure Assessment for Case Study 1 DPR Alternative – Constituents of Potential Concern

					Advanced Water Treatment and Drinking Water Treatment Processes														Estimated		
					MF/UF		Ozone/BAC		Chlorine Disinfection		Ozone/BAC		Floc/Sed		Media Filtration		Chlorine Disinfection		Conc in		Estimated
					Removal	Outlet	Removal	Outlet	Removal	Outlet	Removal	Outlet	Removal	Outlet	Removal	Outlet	Removal	Outlet	Drinking		Dose
Analyte	# Obs	# >MRL	Avg	Units	%	Conc.	%	Conc.	%	Conc.	%	Conc.	%	Conc.	%	Conc.	%	Conc.	Water	Units	(mg/kg-day)
2,4-D	7	3	47.1	ng/L	0%	47.1	50%	23.55	0%	23.6	50%	11.8	0%	11.8	0%	11.8	0%	11.8	11.8	ng/L	2.0E-07
Aldicarb sulfone	6	5	0.6	ug/L	0%	0.6	0%	0.64	0%	0.6	0%	0.6	0%	0.6	0%	0.6	0%	0.6	0.6	ug/L	1.1E-05
Aluminum Total	6	5	31.3	ug/L	19%	25.4	0%	25.41	0%	25.4	0%	25.4	0%	25.4	0%	25.4	0%	25.4	25.4	ug/L	4.4E-04
Antimony Total	6	1	1.0	ug/L	1%	1.0	0%	1.00	0%	1.0	0%	1.0	90%	0.1	0%	0.1	0%	0.1	0.1	ug/L	1.7E-06
Arsenic Total	6	4	1.7	ug/L	5%	1.6	95%	0.08	0%	0.08	95%	0.004	90%	0.0004	0%	0.0004	0%	0.0004	0.0004	ug/L	7.1E-09
Atrazine	12	10	151.7	ng/L	8%	140.0	81%	26.60	20%	21.3	81%	4.0	0%	4.0	0%	4.0	20%	3.2	3.2	ng/L	5.5E-08
Barium Total	6	5	9.7	ug/L	0%	9.7	0%	9.70	0%	9.7	0%	9.7	80%	1.9	0%	1.9	0%	1.9	1.9	ug/L	3.3E-05
Bromacil	6	1	7.3	ng/L	0%	7.3	0%	7.30	0%	7.3	0%	7.3	0%	7.3	0%	7.3	0%	7.3	7.3	ng/L	1.3E-07
Bromodichloromethane	6	6	7.8	ug/L	0%	7.8	70%	2.35	0%	2.35	70%	0.71	0%	0.71	0%	0.71	0%	0.71	0.71	ug/L	1.2E-05
Bromoform	6	3	1.1	ug/L	0%	1.1	70%	0.33	0%	0.33	70%	0.10	0%	0.10	0%	0.10	0%	0.10	0.10	ug/L	1.7E-06
Chloride	3	3	100.7	mg/L	0%	100.7	0%	100.67	0%	100.7	0%	100.7	0%	100.7	0%	100.7	0%	100.7	100.7	mg/L	1.7E+00
Chlorodibromomethane	6	5	5.4	ug/L	0%	5.4	70%	1.6	0%	1.6	70%	0.49	0%	0.49	0%	0.49	0%	0.49	0.49	ug/L	8.3E-06
Chloroform (Trichloromethane)	6	6	5.8	ug/L	0%	5.8	70%	1.74	0%	1.7	70%	0.52	0%	0.52	0%	0.52	0%	0.52	0.52	ug/L	8.9E-06
Cyanide (manual distillation)	6	4	0.03	mg/L	0%	0.03	22%	0.02	95%	0.001	22%	0.001	0%	0.001	0%	0.001	95%	0.00005	0.00005	mg/L	8.1E-07
Dichloroacetic acid	6	6	9.9	ug/L	0%	9.9	95%	0.49	0%	0.49	95%	0.025	0%	0.025	0%	0.025	0%	0.025	0.025	ug/L	4.2E-07
Diuron	6	2	6.9	ng/L	0%	6.9	95%	0.34	0%	0.3	95%	0.02	0%	0.02	0%	0.02	0%	0.0	0.02	ng/L	2.9E-10
Fluoride	6	6	1.2	mg/L	0%	1.2	0%	1.23	0%	1.2	0%	1.2	45%	0.7	0%	0.7	0%	0.7	0.7	mg/L	1.2E-02
Iron Total ICAP	2	2	0.2	mg/L	0%	0.2	0%	0.16	0%	0.2	0%	0.2	0%	0.2	67%	0.1	0%	0.1	0.1	mg/L	8.8E-04
Manganese Total	2	2	38.5	ug/L	8%	35.4	0%	35.37	0%	35.4	0%	35.4	0%	35.4	67%	11.7	0%	11.7	11.7	ug/L	2.0E-04
Methomyl	6	1	0.5	ug/L	0%	0.5	0%	0.50	0%	0.5	0%	0.5	0%	0.5	0%	0.5	0%	0.5	0.5	ug/L	8.6E-06
Monochloroacetic acid	6	1	2.1	ug/L	0%	2.1	0%	2.12	0%	2.1	0%	2.1	0%	2.1	0%	2.1	0%	2.1	2.1	ug/L	3.6E-05
Nickel Total	6	1	5.1	ug/L	6%	4.7	0%	4.73	0%	4.7	0%	4.7	80%	0.9	0%	0.9	0%	0.9	0.9	ug/L	1.6E-05
Nitrate as NO3 (calc)	6	6	79.3	mg/L	24%	60.4	0%	60.42	0%	60.4	0%	60.4	0%	60.4	0%	60.4	0%	60.4	60.4	mg/L	1.0E+00
N-Nitroso-dimethylamine (NDMA)	6	6	11.7	ng/L	17%	9.8	46%	5.27	0%	5.3	46%	2.8	9%	2.6	0%	2.6	0%	2.6	2.6	ng/L	4.4E-08
Propazine	6	2	5.4	ng/L	0%	5.4	0%	5.43	0%	5.4	0%	5.4	0%	5.4	0%	5.4	0%	5.4	5.4	ng/L	9.3E-08
Simazine	12	10	168.5	ng/L	33%	113.1	0%	113.07	0%	113.1	0%	113.1	0%	113.1	0%	113.1	0%	113.1	113.1	ng/L	1.9E-06
Strontium	2	2	0.6	mg/L	0%	0.6	0%	0.61	0%	0.6	0%	0.6	0%	0.6	0%	0.6	0%	0.6	0.6	mg/L	1.0E-02
Toluene	6	2	0.5	ug/L	0%	0.5	0%	0.54	0%	0.5	0%	0.5	0%	0.5	0%	0.5	0%	0.5	0.5	ug/L	9.2E-06
Trichloroacetic acid	6	6	10.7	ug/L	1%	10.6	95%	0.53	0%	0.53	95%	0.03	0%	0.03	0%	0.03	0%	0.03	0.03	ug/L	4.5E-07

Table 19. Exposure Assessment for Case Study 1 DPR Alternative – Constituents of Emerging Concern

Analyte	# Obs	# >MRL	Avg	Units	MF/UF Removal %	MF/UF Outlet Conc.	Ozone/BAC Removal %	Ozone/BAC Outlet Conc.	Chlorine Disinfection Removal %	Chlorine Disinfection Outlet Conc.	Ozone/BAC Removal %	Ozone/BAC Outlet Conc.	Floc/Sed Removal %	Floc/Sed Outlet Conc.	Media Filtration Removal %	Media Filtration Outlet Conc.	Chlorine Disinfection Removal %	Chlorine Disinfection Outlet Conc.	Estimated Conc in Drinking Water	Units	Estimated Dose (mg/kg-day)
					Advanced Water Treatment and Drinking Water Treatment Processes																
1,7-Dimethylxanthine	6	1	63.3	ng/L	0%	63.3	95%	3.17	0%	3.2	95%	0.2	0%	0.2	0%	0.2	0%	0.2	0.2	ng/L	2.7E-09
3-Hydroxycarbofuran	6	1	0.5	ug/L	0%	0.5	0%	0.50	0%	0.5	0%	0.5	0%	0.5	0%	0.5	0%	0.5	0.5	ug/L	8.6E-06
4-tert-Octylphenol	6	1	71.7	ng/L	0%	71.7	95%	3.58	0%	3.6	95%	0.2	0%	0.2	0%	0.2	0%	0.2	0.2	ng/L	3.1E-09
Acesulfame-K	6	6	3080.0	ng/L	0%	3080.0	42%	1786.40	0%	1786.4	42%	1036.1	0%	1036.1	0%	1036.1	0%	1036.1	1036.1	ng/L	1.8E-05
Acetaminophen	6	2	42.5	ng/L	50%	21.3	54%	9.78	80%	2.0	54%	0.9	0%	0.9	0%	0.9	80%	0.2	0.2	ng/L	3.1E-09
Albuterol	6	4	14.5	ng/L	31%	10.0	95%	0.50	0%	0.5	95%	0.02	0%	0.02	0%	0.02	0%	0.02	0.02	ng/L	4.3E-10
Amoxicillin (semi-quantitative)	6	1	24.0	ng/L	0%	24.0	95%	1.20	0%	1.2	95%	0.1	0%	0.1	0%	0.1	0%	0.1	0.1	ng/L	1.0E-09
Atenolol	6	5	50.3	ng/L	95%	2.5	95%	0.13	30%	0.1	95%	0.004	0%	0.0	0%	0.004	30%	0.003	0.003	ng/L	5.3E-11
Azithromycin	6	2	368.3	ng/L	0%	368.3	95%	18.42	0%	18.4	95%	0.9	0%	0.9	0%	0.9	0%	0.9	0.9	ng/L	1.6E-08
Bezafibrate	6	1	5.7	ng/L	0%	5.7	0%	5.67	0%	5.7	0%	5.7	0%	5.7	0%	5.7	0%	5.7	5.7	ng/L	9.7E-08
Caffeine	12	8	181.7	ng/L	49%	92.7	92%	7.41	30%	5.2	92%	0.4	0%	0.4	0%	0.4	30%	0.3	0.3	ng/L	5.0E-09
Carbamazepine	6	6	98.3	ng/L	95%	4.9	95%	0.25	20%	0.2	95%	0.01	0%	0.01	0%	0.01	20%	0.01	0.01	ng/L	1.3E-10
Carisoprodol	6	5	19.3	ng/L	0%	19.3	95%	0.97	0%	1.0	95%	0.05	0%	0.05	0%	0.05	0%	0.05	0.05	ng/L	8.3E-10
Cotinine	6	5	41.7	ng/L	42%	24.2	88%	2.90	0%	2.9	88%	0.3	0%	0.3	0%	0.3	0%	0.3	0.3	ng/L	6.0E-09
DEA	6	6	124.5	ng/L	0%	124.5	0%	124.50	0%	124.5	0%	124.5	0%	124.5	0%	124.5	0%	124.5	124.5	ng/L	2.1E-06
DEET	6	3	13.7	ng/L	54%	6.3	95%	0.31	22%	0.2	95%	0.01	0%	0.0	0%	0.01	22%	0.01	0.01	ng/L	1.6E-10
Dehydronifedipine	6	6	112.3	ng/L	3%	108.4	95%	5.42	14%	4.6	95%	0.2	0%	0.2	0%	0.2	14%	0.2	0.2	ng/L	3.4E-09
DIA	6	6	161.7	ng/L	0%	161.7	88%	19.40	0%	19.4	0%	19.4	0%	19.4	0%	19.4	0%	19.4	19.4	ng/L	3.3E-07
Diclofenac	6	2	8.3	ng/L	95%	0.4	92%	0.03	47%	0.0	92%	0.001	3%	0.001	0%	0.001	47%	0.001	0.001	ng/L	1.2E-11
Dilantin	6	6	60.7	ng/L	89%	6.7	95%	0.33	20%	0.3	95%	0.01	0%	0.01	0%	0.01	20%	0.01	0.01	ng/L	1.8E-10
Diltiazem	6	3	11.7	ng/L	0%	11.7	0%	11.72	0%	11.7	0%	11.7	0%	11.7	0%	11.7	0%	11.7	11.7	ng/L	2.0E-07
Erythromycin	6	2	14.5	ng/L	57%	6.2	64%	2.24	95%	0.1	64%	0.04	0%	0.04	0%	0.04	95%	0.002	0.002	ng/L	3.5E-11
Estrone	6	3	10.1	ng/L	94%	0.6	95%	0.03	74%	0.0	95%	0.0004	38%	0.0002	0%	0.0002	74%	0.0001	0.0001	ng/L	1.1E-12
Fluoxetine	6	6	17.2	ng/L	95%	0.9	95%	0.04	66%	0.0	95%	0.001	0%	0.001	0%	0.001	66%	0.0002	0.0002	ng/L	4.3E-12
Gemfibrozil	6	4	32.9	ng/L	95%	1.6	95%	0.08	83%	0.0	95%	0.001	0%	0.001	0%	0.001	83%	0.0001	0.0001	ng/L	2.0E-12
Ibuprofen	6	2	19.0	ng/L	8%	17.5	95%	0.88	28%	0.6	95%	0.03	31%	0.02	0%	0.02	28%	0.02	0.02	ng/L	2.7E-10
Iohexal	6	6	5183.3	ng/L	8%	4746.8	42%	2753.17	0%	2753.2	42%	1596.8	0%	1596.8	0%	1596.8	0%	1596.8	1596.8	ng/L	2.7E-05
Iopromide	6	3	28.5	ng/L	95%	1.4	95%	0.07	55%	0.0	95%	0.002	0%	0.0	0%	0.002	55%	0.001	0.001	ng/L	1.2E-11
Ketoprofen	6	4	10.0	ng/L	37%	6.3	69%	1.96	80%	0.4	69%	0.1	0%	0.1	0%	0.1	80%	0.02	0.02	ng/L	4.2E-10
Lidocaine	6	4	60.5	ng/L	0%	60.5	95%	3.03	0%	3.0	95%	0.2	0%	0.2	0%	0.2	0%	0.2	0.2	ng/L	2.6E-09
Lopressor	6	6	223.3	ng/L	25%	167.5	75%	41.88	0%	41.9	75%	10.5	0%	10.5	0%	10.5	0%	10.5	10.5	ng/L	1.8E-07
Meprobamate	6	6	62.3	ng/L	70%	18.7	95%	0.94	11%	0.8	95%	0.04	0%	0.04	0%	0.04	11%	0.04	0.04	ng/L	6.3E-10
Naproxen	6	2	18.0	ng/L	95%	0.9	95%	0.05	95%	0.0	95%	0.0001	12%	0.0001	0%	0.0001	95%	0.000005	0.000005	ng/L	8.5E-14
Primidone	6	6	52.7	ng/L	13%	46.0	95%	2.30	89%	0.3	95%	0.01	0%	0.01	0%	0.01	89%	0.001	0.001	ng/L	2.4E-11
Quinoline	6	3	11.3	ng/L	0%	11.3	0%	11.33	0%	11.3	0%	11.3	0%	11.3	0%	11.3	0%	11.3	11.3	ng/L	1.9E-07
Sucralose	6	6	27333.3	ng/L	58%	11388.9	57%	4897.22	30%	3428.1	57%	1474.1	0%	1474.1	0%	1474.1	30%	1031.8	1031.8	ng/L	1.8E-05
Sulfamethazine	6	2	5.5	ng/L	0%	5.5	95%	0.28	0%	0.3	95%	0.01	0%	0.01	0%	0.01	0%	0.01	0.01	ng/L	2.4E-10
Sulfamethoxazole	6	4	175.8	ng/L	95%	8.8	95%	0.44	49%	0.2	95%	0.01	0%	0.01	0%	0.01	49%	0.01	0.01	ng/L	9.8E-11
TCEP	6	6	178.3	ng/L	2%	174.4	95%	8.72	20%	7.0	95%	0.3	0%	0.3	0%	0.3	20%	0.3	0.3	ng/L	4.8E-09
TCPP	6	6	333.3	ng/L	0%	333.3	95%	16.67	0%	16.7	95%	0.8	0%	0.8	0%	0.8	0%	0.8	0.8	ng/L	1.4E-08
TDCPP	6	6	211.7	ng/L	17%	176.4	15%	149.93	0%	149.9	15%	127.4	0%	127.4	0%	127.4	0%	127.4	127.4	ng/L	2.2E-06
Theobromine	6	2	190.0	ng/L	0%	190.0	95%	9.50	0%	9.5	95%	0.5	0%	0.5	0%	0.5	0%	0.5	0.5	ng/L	8.1E-09
Theophylline	6	1	83.3	ng/L	16%	70.2	95%	3.51	0%	3.5	95%	0.2	0%	0.2	0%	0.2	0%	0.2	0.2	ng/L	3.0E-09
Triclocarban	6	2	39.3	ng/L	0%	39.3	0%	39.33	0%	39.3	0%	39.3	0%	39.3	0%	39.3	0%	39.3	39.3	ng/L	6.7E-07
Triclosan	6	1	11.3	ng/L	95%	0.6	95%	0.03	79%	0.0	95%	0.0003	0%	0.0003	0%	0.0003	79%	0.0001	0.0001	ng/L	1.1E-12
Trimethoprim	6	3	94.5	ng/L	95%	4.7	95%	0.24	95%	0.0	95%	0.001	0%	0.001	0%	0.001	95%	0.00003	0.00003	ng/L	5.1E-13

Table 20. Exposure Assessment Case Study 2 No Project Alternative

						Water Treatment								
						Floc/Sed		Media Filtration		Chlorine Disinfection		Estimated		Estimated Dose
Type	Analyte	# Obs	# >MRL	Avg	Units	Removal %	Outlet Conc.	Removal %	Outlet Conc.	Removal %	Outlet Conc.	Conc in Drinking	Units	(mg/kg-day)
CPC	Aluminum Total	6	6	42.3	ug/L	0%	42.3	0%	42.3	0%	42.3	42.3	ug/L	7.3E-04
	Arsenic Total	6	5	2.1	ug/L	90%	0.2	0%	0.2	0%	0.2	0.2	ug/L	3.5E-06
	Barium Total	6	6	87.0	ug/L	80%	17.4	0%	17.4	0%	17.4	17.4	ug/L	3.0E-04
	Bromodichloromethane	6	1	0.5	ug/L	0%	0.5	0%	0.5	0%	0.5	0.5	ug/L	8.9E-06
	Bromoform	6	1	0.6	ug/L	0%	0.6	0%	0.6	0%	0.6	0.6	ug/L	9.5E-06
	Chloride	3	3	216.7	mg/L	0%	216.7	0%	216.7	0%	216.7	216.7	mg/L	3.7E+00
	Chlorodibromomethane	6	1	0.6	ug/L	0%	0.6	0%	0.6	0%	0.6	0.6	ug/L	1.0E-05
	Chromium Total	6	6	1.9	ug/L	95%	0.1	0%	0.1	0%	0.1	0.1	ug/L	1.6E-06
	Fluoride	6	6	0.8	mg/L	45%	0.4	0%	0.4	0%	0.4	0.4	mg/L	7.2E-03
	Nitrate as NO3 (calc)	6	6	5.7	mg/L	0%	5.7	0%	5.7	0%	5.7	5.7	mg/L	9.8E-02
CEC	Albuterol	6	1	11.3	ng/L	0%	11.3	0%	11.3	0%	11.3	11.3	ng/L	1.9E-07
	Caffeine	6	1	7.7	ng/L	0%	7.7	0%	7.7	30%	5.4	5.4	ng/L	9.2E-08
	DEA	6	1	7.2	ng/L	0%	7.2	0%	7.2	0%	7.2	7.2	ng/L	1.2E-07
	DEET	6	1	10.0	ng/L	0%	10.0	0%	10.0	22%	7.8	7.8	ng/L	1.3E-07
	Sulfamethoxazole	6	1	5.5	ng/L	0%	5.5	0%	5.5	0%	5.5	5.5	ng/L	9.3E-08

Table 21. Exposure Assessment for Case Study 2 DPR Alternative – Constituents of Potential Concern

					Advanced Water Treatment and Drinking Water Processes														
					MF/UF		RO		UV/AOP		Floc/Sed		Media Filtration		Chlorine Disinfection		Estimated Conc in		Estimated
Analyte	# Obs	# >MRL	Avg	Units	Removal %	Outlet Conc.	Removal %	Outlet Conc.	Removal %	Outlet Conc.	Removal %	Outlet Conc.	Removal %	Outlet Conc.	Removal %	Outlet Conc.	Drinking Water	Units	Dose (mg/kg-
2,4-D	6	2	31.7	ng/L	0%	32	95%	1.6	0%	1.6	0%	1.6	0%	1.6	0%	1.6	1.6	ng/L	2.7E-08
Aldicarb sulfone	6	6	0.7	ug/L	0%	1	95%	0.03	0%	0.03	0%	0.03	0%	0.03	0%	0.03	0.03	ug/L	5.8E-07
Aluminum Total	6	6	33.2	ug/L	19%	27	95%	1.3	0%	1.3	0%	1.3	0%	1.3	0%	1.3	1.3	ug/L	2.3E-05
Antimony Total	6	2	1.1	ug/L	1%	1	95%	0.1	0%	0.1	90%	0.01	0%	0.01	0%	0.01	0.01	ug/L	9.4E-08
Arsenic Total	6	6	3.5	ug/L	5%	3	95%	0.2	0%	0.2	90%	0.02	0%	0.02	0%	0.02	0.02	ug/L	2.8E-07
Atrazine	6	5	19.4	ng/L	8%	18	95%	0.9	60%	0.4	0%	0.4	0%	0.4	20%	0.3	0.3	ng/L	4.9E-09
Barium Total	6	6	56.5	ug/L	0%	57	95%	2.8	0%	2.8	80%	0.6	0%	0.6	0%	0.6	0.6	ng/L	9.7E-09
Bromacil	6	2	62.7	ng/L	0%	63	0%	62.7	84%	10.0	0%	10.0	0%	10.0	0%	10.0	10.0	ng/L	1.7E-07
Chloride	3	3	310.0	mg/L	0%	310	95%	15.5	0%	15.5	0%	15.5	0%	15.5	0%	15.5	15.5	mg/L	2.7E-01
Cyanide	3	2	0.045	mg/L	0%	0.045	95%	0.002	0%	0.002	0%	0.002	0%	0.002	95%	0.0001	0.0001	mg/L	1.9E-06
Diuron	6	2	22.8	ng/L	0%	23	95%	1.1	0%	1.1	0%	1.1	0%	1.1	0%	1.1	1.1	ng/L	2.0E-08
Fluoride	6	6	2.3	mg/L	0%	2	95%	0.1	0%	0.1	45%	0.1	0%	0.1	0%	0.1	0.1	mg/L	1.1E-03
Iron Total	2	2	0.09	mg/L	0%	0.09	95%	0.005	0%	0.005	0%	0.005	67%	0.002	0%	0.002	0.002	mg/L	2.6E-05
Manganese Total	3	3	2803.0	ug/L	8%	2575	95%	128.8	0%	128.8	0%	128.8	67%	42.5	0%	42.5	42.5	ug/L	7.3E-04
Methomyl	6	1	0.5	ug/L	0%	1	0%	0.5	0%	0.5	0%	0.5	0%	0.5	0%	0.5	0.5	ug/L	8.7E-06
Molybdenum Total	1	1	8.4	ug/L	0%	8	88%	1.0	0%	1.0	0%	1.0	0%	1.0	0%	1.0	1.0	ug/L	1.8E-05
Nitrate as NO3 (calc)	5	5	33.8	mg/L	24%	26	95%	1.3	0%	1.3	0%	1.3	0%	1.3	0%	1.3	1.3	mg/L	2.2E-02
Nitrite Nitrogen	5	3	0.7	mg/L	0%	0.7	92%	0.06	0%	0.06	0%	0.06	0%	0.06	95%	0.003	0.0028	mg/L	4.8E-05
N-Nitroso-dimethylamine (NDMA)	6	6	10.8	ng/L	17%	9.0	56%	4.0	95%	0.20	9%	0.18	0%	0.18	0%	0.18	0.18	ng/L	3.1E-09
p-Dichlorobenzene (1,4-DCB)	5	1	0.5	ug/L	0%	1	61%	0.2	0%	0.2	0%	0.2	0%	0.2	0%	0.2	0.2	ug/L	3.5E-06
Simazine	6	2	5.8	ng/L	33%	4	95%	0.2	0%	0.2	0%	0.2	0%	0.2	0%	0.2	0.2	ng/L	3.3E-09
Strontium	2	2	1.4	mg/L	0%	1	95%	0.1	0%	0.1	0%	0.1	0%	0.1	0%	0.1	0.1	mg/L	1.2E-03
Trichloroacetic acid	6	4	1.3	ug/L	1%	1.2	90%	0.12	15%	0.11	0%	0.11	0%	0.11	0%	0.11	0.11	ug/L	1.8E-06
Uranium ICAP/MS	1	1	5.8	ug/L	0%	6	95%	0.3	0%	0.3	70%	0.1	0%	0.1	0%	0.1	0.1	ug/L	1.5E-06

Table 22. Exposure Assessment for Case Study 2 DPR Alternative – Constituents of Emerging Concern

					Advanced Water Treatment and Drinking Water Processes												Estimated		
					MF/UF		RO		UV/AOP		Floc/Sed		Media Filtration		Chlorine Disinfection		Conc in		Estimated
Analyte	# Obs	# >MRL	Avg	Units	Removal %	Outlet Conc.	Removal %	Outlet Conc.	Removal %	Outlet Conc.	Removal %	Outlet Conc.	Removal %	Outlet Conc.	Removal %	Outlet Conc.	Drinking Water	Units	Dose (mg/kg-
1,7-Dimethylxanthine	6	1	28.3	ng/L	0%	28	91%	2.5	0%	2.5	0%	2.5	0%	2.5	0%	2.5	2.5	ng/L	4.2E-08
Acesulfame-K	6	6	1313.3	ng/L	0%	1313	95%	65.7	50%	32.8	0%	32.8	0%	32.8	0%	32.8	32.8	ng/L	5.6E-07
Acetaminophen	6	2	33.5	ng/L	50%	17	95%	0.8	0%	0.8	0%	0.8	0%	0.8	80%	0.2	0.2	ng/L	2.9E-09
Albuterol	6	4	24.2	ng/L	31%	17	95%	0.8	0%	0.8	0%	0.8	0%	0.8	0%	0.8	0.8	ng/L	1.4E-08
Amoxicillin (semi-quantitative)	6	6	2331.7	ng/L	0%	2332	95%	116.6	0%	116.6	0%	116.6	0%	116.6	0%	116.6	116.6	ng/L	2.0E-06
Atenolol	6	6	146.7	ng/L	95%	7	95%	0.4	40%	0.2	0%	0.2	0%	0.2	30%	0.2	0.2	ng/L	2.6E-09
Azithromycin	6	2	713.3	ng/L	0%	713	95%	35.7	0%	35.7	0%	35.7	0%	35.7	0%	35.7	35.7	ng/L	6.1E-07
BPA	6	2	17.8	ng/L	76%	4	95%	0.2	0%	0.2	0%	0.2	0%	0.2	58%	0.1	0.1	ng/L	1.5E-09
Butalbital	6	2	21.7	ng/L	0%	22	95%	1.1	0%	1.1	0%	1.1	0%	1.1	0%	1.1	1.1	ng/L	1.9E-08
Caffeine	6	6	51.2	ng/L	49%	26	95%	1.3	95%	0.1	0%	0.1	0%	0.1	30%	0.05	0.05	ng/L	7.8E-10
Carbamazepine	6	6	225.0	ng/L	95%	11	95%	0.6	45%	0.3	0%	0.3	0%	0.3	20%	0.2	0.2	ng/L	4.2E-09
Carisoprodol	6	6	65.2	ng/L	0%	65	95%	3.3	0%	3.3	0%	3.3	0%	3.3	0%	3.3	3.3	ng/L	5.6E-08
Cimetidine	6	1	40.8	ng/L	0%	41	95%	2.0	0%	2.0	0%	2.0	0%	2.0	0%	2.0	2.0	ng/L	3.5E-08
Cotinine	6	6	35.8	ng/L	42%	21	95%	1.0	0%	1.0	0%	1.0	0%	1.0	0%	1.0	1.0	ng/L	1.8E-08
DEET	6	6	88.3	ng/L	54%	41	95%	2.0	95%	0.1	0%	0.1	0%	0.1	22%	0.1	0.1	ng/L	1.4E-09
Dehydronifedipine	6	6	368.3	ng/L	3%	356	95%	17.8	0%	17.8	0%	17.8	0%	17.8	14%	15.2	15.2	ng/L	2.6E-07
Diclofenac	6	3	19.2	ng/L	95%	1	95%	0.05	34%	0.03	3%	0.03	0%	0.03	47%	0.02	0.02	ng/L	2.8E-10
Dilantin	6	6	187.3	ng/L	89%	21	95%	1.0	60%	0.4	0%	0.4	0%	0.4	20%	0.3	0.3	ng/L	5.7E-09
Diltiazem	6	6	58.5	ng/L	0%	59	0%	58.5	0%	58.5	0%	58.5	0%	58.5	0%	58.5	58.5	ng/L	1.0E-06
Erythromycin	6	4	72.2	ng/L	57%	31	95%	1.6	50%	0.8	0%	0.8	0%	0.8	95%	0.04	0.04	ng/L	6.6E-10
Estrone	6	6	102.2	ng/L	94%	6	95%	0.3	95%	0.02	38%	0.01	0%	0.01	74%	0.002	0.002	ng/L	4.2E-11
Fluoxetine	6	6	37.8	ng/L	95%	2	95%	0.1	0%	0.1	0%	0.1	0%	0.1	66%	0.03	0.03	ng/L	5.5E-10
Gemfibrozil	6	6	412.2	ng/L	95%	21	95%	1.0	80%	0.2	0%	0.2	0%	0.2	83%	0.04	0.04	ng/L	6.0E-10
Ibuprofen	6	1	10.7	ng/L	8%	10	95%	0.5	95%	0.0	31%	0.0	0%	0.0	28%	0.01	0.01	ng/L	2.1E-10
Iohexal	6	6	10700.0	ng/L	8%	9799	95%	489.9	0%	489.9	0%	489.9	0%	489.9	0%	489.9	489.9	ng/L	8.4E-06
Iopromide	6	5	231.0	ng/L	95%	12	95%	0.6	95%	0.03	0%	0.03	0%	0.03	55%	0.01	0.01	ng/L	2.2E-10
Ketoprofen	6	2	5.7	ng/L	37%	4	95%	0.2	0%	0.2	0%	0.2	0%	0.2	80%	0.04	0.04	ng/L	6.2E-10
Ketorolac	6	3	12.0	ng/L	0%	12	0%	12.0	0%	12.0	0%	12.0	0%	12.0	0%	12.0	12.0	ng/L	2.1E-07
Lidocaine	6	6	225.0	ng/L	0%	225	95%	11.3	0%	11.3	0%	11.3	0%	11.3	0%	11.3	11.3	ng/L	1.9E-07
Lincomycin	6	6	79.0	ng/L	0%	79	95%	4.0	0%	4.0	0%	4.0	0%	4.0	0%	4.0	4.0	ng/L	6.8E-08
Lopressor	6	6	533.3	ng/L	25%	400	95%	20.0	0%	20.0	0%	20.0	0%	20.0	0%	20.0	20.0	ng/L	3.4E-07
Meprobamate	6	6	102.0	ng/L	70%	31	95%	1.5	70%	0.5	0%	0.5	0%	0.5	11%	0.4	0.4	ng/L	7.0E-09
Metolachlor	6	1	5.2	ng/L	56%	2	95%	0.1	0%	0.1	0%	0.1	0%	0.1	20%	0.1	0.1	ng/L	1.6E-09
Naproxen	6	3	11.8	ng/L	95%	1	95%	0.03	1%	0.03	12%	0.03	0%	0.03	95%	0.001	0.001	ng/L	2.2E-11
Nifedipine	6	1	20.2	ng/L	0%	20	95%	1.0	0%	1.0	0%	1.0	0%	1.0	0%	1.0	1.0	ng/L	1.7E-08
Pentoxifylline	6	2	6.5	ng/L	10%	6	95%	0.3	35%	0.2	0%	0.2	0%	0.2	50%	0.1	0.1	ng/L	1.6E-09
Primidone	6	6	155.0	ng/L	13%	135	95%	6.8	35%	4.4	0%	4.4	0%	4.4	89%	0.5	0.5	ng/L	8.3E-09
Quinoline	6	2	10.8	ng/L	0%	11	95%	0.5	0%	0.5	0%	0.5	0%	0.5	0%	0.5	0.5	ng/L	9.3E-09
Sucralose	6	6	43500.0	ng/L	58%	18125	95%	906.3	55%	407.8	0%	407.8	0%	407.8	30%	285.5	285.5	ng/L	4.9E-06
Sulfadimethoxine	6	2	9.8	ng/L	0%	10	0%	9.8	0%	9.8	0%	9.8	0%	9.8	0%	9.8	9.8	ng/L	1.7E-07
Sulfamerazine	6	1	18.0	ng/L	25%	14	0%	13.5	0%	13.5	0%	13.5	0%	13.5	0%	13.5	13.5	ng/L	2.3E-07
Sulfamethoxazole	5	5	1676.0	ng/L	95%	84	95%	4.2	58%	1.8	0%	1.8	0%	1.8	49%	0.9	0.9	ng/L	1.5E-08
Sulfathiazole	6	1	5.7	ng/L	0%	6	0%	5.7	0%	5.7	0%	5.7	0%	5.7	0%	5.7	5.7	ng/L	9.7E-08
TCEP	6	6	216.7	ng/L	2%	212	95%	10.6	36%	6.8	0%	6.8	0%	6.8	20%	5.4	5.4	ng/L	9.3E-08
TCPP	6	6	356.7	ng/L	0%	357	95%	17.8	0%	17.8	0%	17.8	0%	17.8	0%	17.8	17.8	ng/L	3.1E-07
TDCPP	6	6	425.0	ng/L	17%	354	95%	17.7	28%	12.8	0%	12.8	0%	12.8	0%	12.8	12.8	ng/L	2.2E-07
Theobromine	6	2	88.3	ng/L	0%	88	95%	4.4	0%	4.4	0%	4.4	0%	4.4	0%	4.4	4.4	ng/L	7.6E-08
Theophylline	6	2	140.5	ng/L	16%	118	95%	5.9	0%	5.9	0%	5.9	0%	5.9	0%	5.9	5.9	ng/L	1.0E-07
Tot DCPA Mono&Diacid Degradate	6	1	0.1	ug/L	0%	0	0%	0.1	0%	0.1	0%	0.1	0%	0.1	0%	0.1	0.1	ug/L	2.0E-06
Triclocarban	6	4	21.3	ng/L	0%	21	95%	1.1	0%	1.1	0%	1.1	0%	1.1	0%	1.1	1.1	ng/L	1.8E-08
Triclosan	6	6	76.7	ng/L	95%	4	95%	0.2	95%	0.01	0%	0.01	0%	0.01	79%	0.002	0.002	ng/L	3.5E-11
Trimethoprim	6	6	158.2	ng/L	95%	8	95%	0.4	40%	0.2	0%	0.2	0%	0.2	95%	0.01	0.01	ng/L	2.0E-10
Warfarin	6	3	6.5	ng/L	0%	6	0%	6.5	0%	6.5	0%	6.5	0%	6.5	0%	6.5	6.5	ng/L	1.1E-07

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5.3 Quantitative Relative Risk Assessment for Noncarcinogenic Constituents of Concern

The hazard index method was used for assessing the overall potential for noncarcinogenic effects posed by the CPCs in the study waters. In this approach, it is assumed that exposures to multiple constituents, some of which may be below a no-effect threshold (subthreshold exposure), could result in an adverse health effect. A simplifying and health-protective assumption is made that the magnitude of that adverse health effect will be the sum of the ratios of the subthreshold exposures to acceptable exposure limits. In this assessment, the hazard index is defined as that sum.

For a single compound there may be a potential adverse health effect when the hazard quotient exceeds unity. Similarly, for multiple compound exposures, if the sum of the hazard quotients exceed unity, the exposure may also result in potential adverse health effects. Such multiple compound exposures may be particularly relevant if multiple compounds act on the same target organ.

Hazard indices were computed for each of the alternatives investigated based on the detected CPCs. An overview of the noncarcinogenic risk assessment results for both Case Studies is presented in Table 23. The results for each of the test waters are presented in Tables 24- 27.

Table 23. Summary of Noncarcinogenic Risk Assessment

	Case Study 1		**Case Study 2**	
	No Project Alternative	**DPR Alternative**	**No Project Alternative**	**DPR Alternative**
Hazard Index (HI)	0.13	0.89	0.20	0.05
# CPCs present with RfD	16	27	9	22
Any Single Constituent with HI > 1	No	No	No	No
Major Contributors to Overall HI	Fluoride (58%) Nitrate (34%) Aluminum (5%)	Nitrate (73%) Fluoride (22%) Monochloroacetic Acid (2%) Strontium (2%)	Fluoride (61%) Nitrate (31%) Arsenic (6%)	Fluoride (37%) Nitrite (28%) Manganese (11%) Molybdenum (7%) Cyanide (7%)
Any Constituent > MCLs	No	No	No	No

The results indicate that the cumulative hazard index for the Case Study 1 and Case Study 2 No Project Alternatives and the Case Study 2 DPR Alternative are substantially lower than 1, which is considered the threshold for potential adverse health effects. For the Case Study 1 DPR Alternative, the cumulative hazard index is close to 1. Most of the cumulative hazard for the Case Study 1 DPR Alternative comes from nitrate and fluoride with smaller contributions from monochloroacetic acid and strontium. Although none of the CPCs were detected at levels that exceeded MCLs, the higher cumulative hazard index for the Case Study 1 DPR in comparison to the Case Study 2 DPR illustrates the effectiveness of RO membranes in removing constituents that can contribute to risk with the caveat that more information is known on membrane performance than ozone/BAC for an AWTF. This information also suggests that better removal of nitrogen or an added nitrogen barrier as part of the WWTP would also reduce risk for both DPR alternatives.

Table 24. Noncarcinogenic Risk Assessment for Case Study 1 No Project Alternative

Analyte	Estimated Conc in Drinking Water	Units	Estimated Dose (mg/kg-day)	RfD (mg/kg-day)	Hazard Index
2,4-D	46.5	ng/L	8.0E-07	0.01	8.0E-05
2-Butanone (MEK)	5.0	ug/L	8.6E-05	0.6	1.4E-04
Aluminum Total	388.3	ug/L	6.7E-03	1	6.7E-03
Arsenic Total	0.012	ug/L	2.0E-07	0.003	6.6E-05
Atrazine	42.2	ng/L	7.2E-07	0.035	2.1E-05
Barium Total	10.1	ug/L	1.7E-04	0.2	8.7E-04
Bromacil	17.2	ng/L	2.9E-07	0.1	2.9E-06
Chromium Total	0.1	ug/L	9.9E-07	1.5 / 0.003 (CrIII/Cr VI)	3.3E-04
Di(2-Ethylhexyl)phthalate	0.08	ug/L	1.4E-06	0.02	6.8E-05
Dicamba	0.1	ug/L	1.8E-06	0.03	6.1E-05
Diuron	0.8	ng/L	1.4E-08	0.002	6.9E-06
Fluoride	0.3	mg/L	4.46E-03	0.06	7.4E-02
Nitrate as NO3 (calc)	4.0	mg/L	6.91E-02	1.6	4.3E-02
Nitrite Nitrogen	0.002	mg/L	3.53E-05	0.1	3.5E-04
Propazine	5.5	ng/L	9.4E-08	0.02	4.7E-06
Simazine	422.3	ng/L	7.2E-06	0.005	1.4E-03
Total					0.13

Note: Hazard Index for Chromium conservatively computed based on Chromium IV RfD.

Table 25. Noncarcinogenic Risk Assessment for Case Study 1 DPR Alternative

Analyte	Estimated Conc in Drinking Water	Units	Estimated Dose (mg/kg-day)	RfD (mg/kg-day)	Hazard Index
2,4-D	11.8	ng/L	2.0E-07	0.01	2.0E-05
Aldicarb sulfone	0.6	ug/L	1.1E-05	0.01	1.1E-03
Aluminum Total	25.4	ug/L	4.4E-04	1	4.4E-04
Antimony Total	0.1	ug/L	1.7E-06	0.0004	4.3E-03
Arsenic Total	0.0004	ug/L	7.1E-09	0.0003	2.4E-05
Atrazine	3.2	ng/L	5.5E-08	0.035	1.6E-06
Barium Total	1.9	ug/L	3.3E-05	0.2	1.7E-04
Bromacil	7.3	ng/L	1.3E-07	0.1	1.3E-06
Bromodichloromethane	0.71	ug/L	1.2E-05	0.02	6.0E-04
Bromoform	0.10	ug/L	1.7E-06	0.02	8.4E-05
Chlorodibromomethane	0.49	ug/L	8.3E-06	0.02	4.2E-04
Chloroform (Trichloromethane)	0.52	ug/L	8.9E-06	0.01	8.9E-04
Cyanide (manual distillation)	0.00005	mg/L	8.1E-07	0.0006	1.3E-03
Dichloroacetic acid	0.025	ug/L	4.2E-07	0.004	1.1E-04
Diuron	0.02	ng/L	2.9E-10	0.002	1.5E-07
Fluoride	0.7	mg/L	1.2E-02	0.06	1.9E-01
Iron Total ICAP	0.1	mg/L	8.8E-04	0.7	1.3E-03
Manganese Total	11.7	ug/L	2.0E-04	0.14	1.4E-03
Methomyl	0.5	ug/L	8.6E-06	0.025	3.4E-04
Monochloroacetic acid	2.1	ug/L	3.6E-05	0.002	1.8E-02
Nickel Total	0.9	ug/L	1.6E-05	0.02	8.1E-04
Nitrate as NO3 (calc)	60.4	mg/L	1.0E+00	1.6	6.5E-01
Propazine	5.4	ng/L	9.3E-08	0.02	4.7E-06
Simazine	113.1	ng/L	1.9E-06	0.005	3.9E-04
Strontium	0.6	mg/L	1.0E-02	0.6	1.7E-02
Toluene	0.5	ug/L	9.2E-06	0.08	1.1E-04
Trichloroacetic acid	0.03	ug/L	4.5E-07	0.02	2.3E-05
					0.89

Table 26. Noncarcinogenic Risk Assessment for Case Study 2 No Project Alternative

Analyte	**Estimated Conc in Drinking Water**	**Units**	**Estimated Dose (mg/kg-day)**	**RfD (mg/kg-day)**	**Hazard Index**
Aluminum Total	42.3	ug/L	7.3E-04	1	7.3E-04
Arsenic Total	0.2	ug/L	3.5E-06	0.0003	1.2E-02
Barium Total	17.4	ug/L	3.0E-04	0.2	1.5E-03
Bromodichloromethane	0.5	ug/L	8.9E-06	0.02	4.5E-04
Bromoform	0.6	ug/L	9.5E-06	0.02	4.8E-04
Chlorodibromomethane	0.6	ug/L	1.0E-05	0.02	5.1E-04
Chromium Total	0.1	ug/L	1.6E-06	1.5 / 0.003 (CrIII/Cr VI)	5.4E-04
Fluoride	0.4	mg/L	7.2E-03	0.06	1.2E-01
Nitrate as NO3 (calc)	5.7	mg/L	9.8E-02	1.6	6.1E-02
Total					**0.20**

Note: Hazard Index for Chromium conservatively computed based on Chromium IV RfD.

Table 27. Noncarcinogenic Risk Assessment for Case Study 2 DPR Alternative

Analyte	Estimated Conc in Drinking Water	Units	Estimated Dose (mg/kg-day)	RfD (mg/kg-day)	Hazard Index
2,4-D	1.6	ng/L	2.7E-08	0.01	2.7E-06
Aldicarb sulfone	0.03	ug/L	5.8E-07	0.001	5.8E-04
Aluminum Total	1.3	ug/L	2.3E-05	1	2.3E-05
Antimony Total	0.01	ug/L	9.4E-08	0.0004	2.4E-04
Arsenic Total	0.02	ug/L	2.8E-07	0.0003	9.4E-04
Atrazine	0.3	ng/L	4.9E-09	0.035	1.4E-07
Barium Total	0.6	ng/L	9.7E-09	0.2	4.8E-08
Bromacil	10.0	ng/L	1.7E-07	0.1	1.7E-06
Cyanide	0.0001	mg/L	1.9E-06	0.0006	3.2E-03
Diuron	1.1	ng/L	2.0E-08	0.002	9.8E-06
Fluoride	0.1	mg/L	1.1E-03	0.06	1.8E-02
Iron Total	0.002	mg/L	2.6E-05	0.7	3.7E-05
Manganese Total	42.5	ug/L	7.3E-04	0.14	5.2E-03
Methomyl	0.5	ug/L	8.7E-06	0.025	3.5E-04
Molybdenum Total	1.0	ug/L	1.8E-05	0.005	3.6E-03
Nitrate as NO3 (calc)	1.3	mg/L	2.2E-02	1.6	1.4E-02
Nitrite Nitrogen	0.003	mg/L	4.8E-05	0.1	4.8E-04
p-Dichlorobenzene (1,4-DCB)	0.2	ug/L	3.5E-06	0.8	4.4E-06
Simazine	0.2	ng/L	3.3E-09	0.005	6.7E-07
Strontium	0.1	mg/L	1.2E-03	0.6	1.9E-03
Trichloroacetic acid	0.1	ug/L	1.8E-06	0.02	9.0E-05
Uranium ICAP/MS	0.1	ug/L	1.5E-06	0.003	5.0E-04
Total					0.05

Nitrate: The most significant health effect associated with nitrate ingestion is the specific condition of methemoglobinemia in infants under six months of age. This condition results from the presence of high nitrite levels in the blood. Untreated, severe methemoglobinemia can result in brain damage and even death. Infants in the first six months of life are particularly susceptible to nitrite induced methemoglobinemia. Infants have a higher intake of water for their weight than adults, so consequently, they ingest a relatively higher amount of nitrate. In addition to small infants, some adults may be particularly susceptible to nitrite-induced methemoglobinemia. These include pregnant women with a particular enzyme deficiency, adults with reduced stomach acidity, and those with a deficiency in the enzyme needed to change methemoglobin back to normal hemoglobin, a condition which can be hereditary.

Human exposure to nitrates occurs primarily through the diet because nitrate is a natural substance found in both water and plants. In the United States, the average dietary intake of nitrate is about 75 to 100 mg per day. About 80 to 90 percent of this amount comes from vegetables. Some common vegetables with high nitrate content are beets, celery, lettuce, and spinach. People following a vegetarian diet may have nitrate intakes of up to 250 mg per day.

Drinking water generally accounts for 5 to 10 percent of nitrates consumed. However, where drinking water is contaminated to a level of 50 mg/L as nitrogen (a concentration five times the MCL), it may supply as much as half of the total daily intake.

Fluoride: Fluoride can occur in drinking water naturally as a result of the geological composition of soils and bedrock. Some areas of the country have high levels of naturally occurring fluoride which can dissolve easily into ground water as it moves through gaps and pore spaces between rocks. Fluoride can also be added to public drinking water supplies as a public health measure for reducing cavities among the treated population.

The most common adverse health effect associated with fluoride exposure is dental fluorosis. Dental fluorosis results from excess exposure to fluoride during the age of calcification of the teeth (up to about 8 years of age for anterior teeth). Dental fluorosis in its mild form is characterized by white opaque areas covering 50 percent of a given tooth; in its severe form, dental fluorosis is characterized by brown to black stains and pitting. There is considerable controversy over whether objectionable dental fluorosis (moderate and severe) is a toxic and/or adverse health effect.

Hodge (1950) studied children consuming fluoride in their drinking water at levels ranging from 0 to14 mg/L. Fluoride levels of 2 to10 mg/L produced a linear dose- response curve (increasing mottling with increasing dose). Fluoride levels of 0.1 to1.0 mg/L produced no observable effect.

Another potential adverse health effect of concern is skeletal fluorosis. It has been estimated that the development of crippling skeletal fluorosis requires the consumption of 20 mg or more of fluoride per person per day over a 20-year period. No cases of crippling skeletal fluorosis have been observed in the United States associated with the consumption of 2 L of water per day containing 4 mg/L fluoride.

5.4 Quantitative Relative Risk Assessment for Constituents of Potential Concern

Carcinogenic risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to a potential carcinogen. The numerical estimate of excess lifetime cancer risk is calculated by multiplying the average chemical intake averaged over a lifetime by the oral SF as follows:

$$\text{Risk} = \text{Chemical intake (mg/kg-day)} \times \text{SF (mg/kg-day)}^{-1}$$

The U.S. EPA SFs are the upper 95th percentile limits of the probability of response per unit intake of the chemical over a lifetime. Cancer SFs are based on experimental animal data and epidemiological studies, when available. A linear non-threshold mathematical model for low-dose extrapolation, the linearized multistage model, is generally used by the U.S. EPA to calculate numerical cancer potency values. The U.S. EPA states that carcinogenic risks estimated using this approach are upper-bound estimates, which means that the actual risk is likely to be less than the predicted risk.

For this investigation, risk is computed using several methods. First, point estimate values are used for each of the model parameters (estimated average concentration of the constituent in drinking water, volume of water ingested daily, and SF). Second, to provide refinement of the risk assessment precision, the various sources of uncertainty are assessed. Once the effects of individual sources of uncertainty are assessed, probabilistic numerical simulation procedures are used to produce an overall analysis of uncertainties and highlight areas where uncertainty might be appreciably reduced by further study. In the probabilistic simulation scheme, the combined effects of different sources of uncertainty are assessed by randomly drawing values from distributions representing different uncertain parameters that impact the risk. Model parameters that contain uncertainty include the volume of water consumed, the cancer SF, and the concentration of each pollutant present in the water. For example, if uncertainty is assumed in all three variables, each probabilistic simulation would require randomly selected values for the concentration of the constituent, SF, and volume of water ingested. Each simulation trial results in a prediction of cancer risk from the water source for that trial. By repeating this procedure thousands of times, a distribution of risk is generated. For each of the four waters evaluated in this study, the total cancer risk is estimated by summing the risk estimated for each CPC.

The following is a brief description of the distributions used to represent each of the variables in the probabilistic simulations.

- Slope Factor: An important issue surrounding the SFs is whether these factors should be characterized as a distribution rather than the standard upper-confidence-limit value (point estimate) representing the 95th percentile of cancer potency. For this investigation, the same approach was used as in prior recycled water QRRAs (Cooper et al., 1992,1997; Soller et al., 2000; Soller and Nellor, 2011a,b). In this approach, the SF is represented as a lognormal distribution with a geometric mean equal to 0.072 times the SF (U.S. EPA upper confidence limit) and a geometric standard deviation of 4.93 (Hattis & Wasson, 1987; Hattis, 1991). For arsenic and a small number of other human carcinogens, the U.S. EPA cancer potency estimates are based on human epidemiological data and, therefore, are effectively maximum likelihood estimates for the median. The SF for arsenic has, however, been the subject of ongoing and substantial controversy in the technical literature and the regulatory environment. For this analysis, the arsenic SF is represented as a lognormal distribution with a geometric mean equal to 0.072 times the current U.S. EPA IRIS SF (1.5 per mg/kg-day) and a geometric standard deviation of 4.93. This approach accounts for the substantial uncertainty in the SF and yields a distribution that encompasses the values reported in a meta-analysis by Chu and Crawford-Brown (2006) of 0.03 (units of probability per mg/kg-day) based on bladder cancer, the current U.S. EPA IRIS estimate of 1.5 per mg/kg-day based on skin cancer, and the value reported in the OEHHA toxicity criteria database (assuming that value represents an upper bound estimate) of 9.5 per mg/kg-day.

- Volume of water ingested: The volume of water ingested is based upon the U.S. EPA's evaluation of data collected by the U.S. Department of Agriculture's 1994–1996 and 1998 Continuing Survey of Food Intakes by Individuals (U.S Dept. of Agriculture, 1998). That analysis indicates the following estimates of water consumption in the U.S. (U.S. EPA, 2004):
    - On average, the estimated daily per capita ingestion of community water is 926 mL per person per day;
    - Considering water from all sources, the mean per capita daily total water ingestion is 1.233 L (75 percent from community water, 13 percent from bottled water, 10 percent from other sources (well, spring and cistern, etc.), and 2 percent from non-identified sources);
    - The estimated 90th percentiles of the distributions of daily average per capita water ingestion by the U.S. population are 2.014 L of community water and 2.341 L of water from all sources;
    - Two liters per person per day has been used as the default value for water ingestion by the U.S. EPA, other Federal agencies, and the WHO. The estimated 90th percentile of community water ingestion for the general population (males and females of all ages) is 2 L per day (2.1 L for males, and 1.9 L for females), and the estimated 90th percentile of total water ingestion is 2.3 L per day (2.5 L for males and 2.2 L for females);
    - The mean community and total water ingestion for males are statistically significantly higher than for females in all age groups except for individuals younger than 1 year of age; and
    - Lactating women have the highest community water ingestion of any subpopulation identified in the sample with an estimated mean 2-day average ingestion of 1.379 L and an estimated 90th percentile of 2.872 L/day. For lactating women, 2 L per day corresponds to the estimated 67th percentile of community water ingestion and the estimated 62nd percentile ingestion of water from all sources.

Based on the above information, a lognormal distribution of consumption is employed in this analysis with a geometric mean of 1.23 L/day and a 90th percentile of 2.34 L/day.

- Concentration: In prior QRRAs, the concentration of each CPC with a SF identified in the toxicity assessment has been treated as a log normally distributed random variable. However, in those QRRAs (Soller et al., 2000, Soller and Nellor, 2011a,b), the concentrations of each CPC were measured directly, as compared to this study in which the concentrations are predicted for drinking water using measured water and wastewater concentrations and treatment efficacy estimates. Because the treatment reductions used in this study represent screening level estimates rather than rigorous statistical estimates, it was not possible to model CPC concentrations in drinking water with a statistical distribution. Therefore in this study average concentrations are used as point estimate values in the carcinogenic risk assessment calculations.[8]

A summary of the concentration, SF, and volume ingested parameters used in the carcinogenic risk assessment is presented in Table 28.

[8] A point estimate of a parameter is a single number that can be regarded as a sensible value for the parameter.

Table 28. Summary of Variables Used in the Carcinogenic Risk Assessment

	Estimated Mean Concentration in Drinking Water (ug/L)	Reported Cancer Slope Factor	Estimated Geometric Mean Slope Factor Estimate	Estimated Geometric Standard Deviation SF	Geometric Mean Water Ingestion (L)	90th %ile Water Ingestion (L)
Case Study 1 No Project Alternative						
Arsenic Total	0.01	1.5	0.108	4.93	1.23	2.34
Di(2-Ethylhexyl)phthalate	0.08	0.014	0.001	4.93	1.23	2.34
Lead Total	0.01	0.009	0.0006	4.93	1.23	2.34
N-Nitroso-dimethylamine (NDMA)[1]	1.10	51	3.7	4.93	1.23	2.34
Case Study 1 DPR Alternative						
Arsenic Total	0.0004	1.5	0.108	4.93	1.23	2.34
Bromodichloromethane	0.71	0.062	0.004	4.93	1.23	2.34
Bromoform	0.10	0.0079	0.001	4.93	1.23	2.34
Chlorodibromomethane	0.49	0.084	0.006	4.93	1.23	2.34
Chloroform	0.52	0.000023	0.0000017	4.93	1.23	2.34
Dichloroacetic acid	0.025	0.05	0.004	4.93	1.23	2.34
NDMA[1]	2.6	51	3.7	4.93	1.23	2.34
Trichloroacetic acid	0.03	0.07	0.005	4.93	1.23	2.34
Case Study 2 No Project Alternative						
Arsenic Total	0.21	1.5	0.108	4.93	1.23	2.34
Bromodichloromethane	0.52	0.062	0.004	4.93	1.23	2.34
Bromoform	0.56	0.0079	0.001	4.93	1.23	2.34
Chlorodibromomethane	0.60	0.084	0.006	4.93	1.23	2.34
Case Study 2 DPR Alternative						
Arsenic Total	0.016	1.5	0.108	4.93	1.23	2.34
NDMA[1]	0.18	51	3.672	4.93	1.23	2.34
Trichloroacetic acid	0.11	0.07	0.005	4.93	1.23	2.34

[1] ng/L

5.4.1 Carcinogenic Quantitative Relative Risk Assessment Results

An overview of the carcinogenic QRRA results is presented in Table 29.

Table 29. Summary of Carcinogenic Risk Assessment

	Case Study 1		Case Study 2	
	No Project Alternative	**DPR Alternative**	**No Project Alternative**	**DPR Alternative**
Drinking Water Risk (Point Estimate)	1.3E-06	3.9E-06	7.0E-06	7.3E-07
# CPCs with SF	4	8	4	3
Major Risk Contributors	Arsenic (24%) NDMA[1] (74%)	Arsenic (12%) BDCM[2] (20%) CDBM[3] (18%) NDMA (60%)	Arsenic (85%) BDCM (8%) CDBM (13%)	Arsenic (59%) NDMA (22%) TCA[4] (19%)
Any Constituent Present at Levels > MCLs or Advisory Levels	No	No	No	No

1. NDMA – N-nitrosodimethylamine
2. BDCM – Bromodichloromethane
3. CDBM – Chlorodibromomethane
4. TCA – Trichloroacetic Acid

Detailed results of the carcinogenic QRRA are provided in Table 30. As described above, point estimate calculations and probabilistic simulations were conducted to estimate the carcinogenic risk associated with drinking water exposure for the four scenarios under investigation. Twenty-five thousand (25,000) individual simulations were carried out for each water. Summary results included in Table 30 are the median, the mean, and the 95th percentiles of the resultant risk distributions for each chemical and for the total risk associated with each water scenario. The median represents the middle value (50th percentile) of each distribution, and the mean value is the arithmetic average of all 25,000 simulation values. Point estimate risk results are also presented for each constituent based on (1) the average concentration, the upper 95th percentile SF and the geometric mean ingestion volume, and (2) the average concentration, the estimated median SF and the geometric mean ingestion volume.

Similar to the noncarcinogenic risk assessment, concentrations of CPCs are below MCLs or health advisory levels. As shown in Table 30, the carcinogenic risks for the Case Study 1 No Project Alternative and DPR Alternative are in approximately the same range, ~10^{-6}. The carcinogenic risk for the Case Study 2 No Project Alternative is also in that same range, with the Case Study 2 DPR Alternative about an order of magnitude lower than the No Project Alternative. In each instance, arsenic and DBPs are the major contributors to risk.

For the Case Study 2 DPR alternative, the relatively high removals (95 percent) of arsenic and haloacetic acids (HAAs) and moderate removals of NDMA through RO in combination with relatively high removals (95 percent) of NDMA through UV/AOP, results in the observed risk reduction. The Case Study 1 DPR Alternative has DBPs as the major contributors to risk, suggesting that further evaluation of the prevention of DBP formation or treatment may be warranted.

Table 30. Carcinogenic Risk Assessment Results

Water	Estimated Mean Concentration in Drinking Water (ug/L)	Geometric Mean Slope Factor	Geometric Mean Volume Ingested (L)	Mean Risk	Median Risk	95th %ile Risk	Point Estimate Risk[1]	Point Estimate Risk[2]
Case Study 1 No Project Alternative								
Arsenic	0.01	0.108	1.23	8.5E-08	2.2E-08	3.5E-07	3.2E-07	2.3E-08
Di(2-Ethylhexyl)phthalate	0.08	0.0010	1.23	5.6E-09	1.4E-09	2.2E-08	2.0E-08	1.4E-09
Lead Total	0.01	0.0006	1.23	4.8E-10	1.2E-10	1.8E-09	1.6E-09	1.2E-10
N-Nitroso-dimethylamine (NDMA)[3]	1.10	3.672	1.23	2.9E-07	7.0E-08	1.1E-06	9.9E-07	7.1E-08
Total				3.8E-07	1.4E-07	1.3E-06	1.3E-06	9.6E-08
Case Study 1 DPR Alternative								
Arsenic	0.0004	0.108	1.23	2.9E-09	7.8E-10	1.2E-08	1.1E-08	7.8E-10
Bromodichloromethane	0.71	0.004	1.23	2.2E-07	5.5E-08	8.4E-07	7.7E-07	5.5E-08
Bromoform	0.10	0.001	1.23	3.8E-09	9.7E-10	1.5E-08	1.4E-08	9.8E-10
Chlorodibromomethane	0.49	0.006	1.23	2.1E-07	5.2E-08	8.0E-07	7.2E-07	5.2E-08
Chloroform	0.52	0.0000017	1.23	6.4E-11	1.6E-11	2.4E-10	2.1E-10	1.5E-11
Dichloroacetic acid	0.025	0.004	1.23	6.2E-09	1.6E-09	2.4E-08	2.2E-08	1.6E-09
NDMA	2.6	3.672	1.23	6.6E-07	1.7E-07	2.6E-06	2.3E-06	1.7E-07
Trichloroacetic acid	0.03	0.005	1.23	9.6E-09	2.4E-09	3.7E-08	3.3E-08	2.4E-09
Total				1.1E-06	5.0E-07	3.8E-06	3.9E-06	2.8E-07
Case Study 2 No Project Alternative								
Arsenic	0.21	0.108	1.23	1.5E-06	3.8E-07	5.9E-06	5.4E-06	3.9E-07
Bromodichloromethane	0.52	0.0045	1.23	1.6E-07	4.1E-08	6.2E-07	5.7E-07	4.1E-08
Bromoform	0.56	0.0006	1.23	2.2E-08	5.6E-09	8.5E-08	7.7E-08	5.6E-09
Chlorodibromomethane	0.60	0.0060	1.23	2.5E-07	6.2E-08	9.8E-07	8.9E-07	6.4E-08
Total				1.9E-06	7.5E-07	6.9E-06	7.0E-06	5.0E-07
Case Study 2 DPR Alternative								
Arsenic	0.016	0.108	1.23	1.3E-07	3.1E-08	5.0E-07	4.4E-07	3.1E-08
NDMA	0.18	3.672	1.23	4.4E-08	1.1E-08	1.7E-07	1.6E-07	1.2E-08
Trichloroacetic acid	0.11	0.005	1.23	3.8E-08	9.7E-09	1.5E-07	1.4E-07	9.8E-09
Total				2.1E-07	9.1E-08	7.3E-07	7.3E-07	5.3E-08

1. Based on estimated mean concentration, upper 95% SF, and geometric mean ingestion volume
2. Based on estimated mean concentration, median SF, and geometric mean ingestion volume
3. ng/L

5.5 Qualitative Analysis for Health Effects Associated with Constituents of Emerging Concern

For CECs, the 2012 NRC risk exemplar approach was utilized (NRC, 2012) for each of the CECs detected in the test waters. The concentrations in the finished drinking water were estimated after treatment, and the potential for adverse health effects were assessed by calculating the MOSs with each of the CECs in each of the test waters. The MOSs are computed as the ratio of the RBAL (which is the DWEL, PNEC, DWG or other benchmark) divided by the estimated concentration of the constituent in finished drinking water.

A summary of the CEC risk for both Case Studies is presented in Table 31 and detailed results are presented in Tables 32 - 35. In using the risk exemplar approach, the NRC looked at the MOS for each CEC and opined that an MOS lower than 1 for a specific CEC posed a potential concern from that CEC. This interpretation was made in light of the multiple safety factors, such as the application of uncertainty factors, included in the derivation of the RBALs.

Table 31. Summary of Constituents of Emerging Concern Risk Exemplar

	Case Study 1		Case Study 2	
	No Project Alt.	**DPR**	**No Project Alt.**	**DPR**
# CECs present >MDL	32	46	5	53
MOS Range	1.6 - 10,500,000,000	0.9 - 59,000,000,000	3,600 - 16,000,000	13 - 6,000,000,000
# CECs with MOS 1-10	1	1	0[1]	0[2]
CECs with MOS <1-10	Quinoline	Quinoline	---	0

1. Quinoline was not detected the raw water.
2. Quinoline was detected in the secondary effluent, and removed via RO.

For the Case Studies in this investigation, all of the CECs except for one have MOSs greater than 1. The Case Study 2 No Project Alternative had MOSs all greater than 3,000. As summarized in Table 31, these results identified one specific CEC, quinoline, with an MOS in the range of 1 for Case Study 1.

Information on chronic, reproductive, developmental or carcinogenic effects of quinoline in humans is not available. There is increased evidence of liver vascular tumors in rats and mice orally exposed to quinoline. The U.S. EPA has provisionally classified it as a possible human carcinogen. For the Third Contaminant Candidate List (CCL3), U.S. EPA established a PNEC of 10 ηg/L, which was used as the RBAL.

Sources of quinoline include petroleum, coal processing, wood preservation, production and use facilities and shale oil (U.S. EPA, 2001). It is used in the production of dyes, paints, pharmaceuticals, and fragrances, and is a solvent for resins and terpenes (U.S. EPA, 2001; Health Canada, 2005). It is also formed during the incomplete combustion of petroleum and coal and is dispersed into the environment as a component of suspended particulate matter emitted from sources such as automobile exhaust and petroleum or coal refining facilities (Health Canada, 2005). Thus, there may be some opportunity for source control of quinoline (see Section 6.6 of the TM). When released to aquatic systems, quinoline will biodegrade and can be photolysized (U.S. EPA, 2001). Thus if the Case Study 1 DPR Alternative utilized photolysis or RO, it is likely that the concentration would have been further reduced and the MOS greater than 1.

Over time, new or updated RBALs are likely to be developed that would further inform this evaluation as well as additional information on advanced treatment process performance from research, piloting, or full-scale operations. Despite the uncertainties inherent in this type of assessment, the results show that a properly designed and operated DPR treatment system can provide protection from CECs comparable to the No Project Alternatives. As noted by the NRC, as a general rule, DBPs and perfluorinated chemicals deserve continued scrutiny in all drinking water supplies.

Table 32. Margin of Safety for Constituents of Emerging Concern in Cast Study 1 No Project Alternative

Analyte	Estimated Conc in Drinking Water	Units	RBAL (ng/L)	Estimated Margin of Safety
Acesulfame-K	753.0	ng/L	5.3E+08	703820
Acetaminophen	0.8	ng/L	3.5E+05	438963
Albuterol	0.4	ng/L	4.1E+04	112586
Amoxicillin (semi-quantitative)	2.3	ng/L	1.5E+03	664
Atenolol	0.3	ng/L	7.0E+04	214286
BPA	4.4	ng/L	3.5E+05	78750
Caffeine	4.9	ng/L	8.7E+07	17816186
Carbamazepine	0.6	ng/L	1.2E+04	20906
Carisoprodol	0.3	ng/L	2.6E+05	965944
Cotinine	3.4	ng/L	1.0E+04	2924
DEA	76.3	ng/L	7.5E+05	9825
DEET	3.1	ng/L	8.1E+04	25747
Dehydronifedipine	0.6	ng/L	2.0E+04	31532
DIA	13.4	ng/L	1.5E+02	11.2
Fluoxetine	0.2	ng/L	1.0E+04	55147
Gemfibrozil	0.1	ng/L	4.6E+04	432941
Iohexal	84.4	ng/L	7.2E+05	8532
Lidocaine	0.6	ng/L	1.1E+08	197604790
Lopressor	5.4	ng/L	2.3E+08	42790698
Meprobamate	0.7	ng/L	2.6E+05	378168
Metolachlor	5.5	ng/L	7.0E+06	1263538
Primidone	0.1	ng/L	8.4E+02	13516
Quinoline	6.3	ng/L	1.0E+01	1.6
Sucralose	1796.0	ng/L	1.7E+05	95
Sulfamethoxazole	1.3	ng/L	1.8E+07	13574661
TCEP	1.3	ng/L	4.4E+03	3300
TCPP	5.5	ng/L	1.0E+04	1818
Theobromine	2.7	ng/L	2.8E+10	10500000000
Theophylline	1.5	ng/L	3.0E+08	202247191
Tot DCPA Mono&Diacid Degradate	0.1	ug/L	3.5E+05	3333333
Triclocarban	32.5	ng/L	8.8E+08	27076923
Trimethoprim	0.02	ng/L	6.1E+04	3196507

Table 33. Margin of Safety for Constituents of Emerging Concern in Case Study 1 Direct Potable Reuse Alternative

Analyte	Estimated Conc in Drinking Water	Units	RBAL (ng/L)	Estimated Margin of Safety
1,7-Dimethylxanthine	0.2	ng/L	7.0E+02	4421
3-Hydroxycarbofuran	0.5	ug/L	4.2E+02	837
4-tert-Octylphenol	0.2	ng/L	5.0E+04	279070
Acesulfame-K	1036.1	ng/L	5.3E+08	506702
Acetaminophen	0.2	ng/L	3.5E+05	1944433
Albuterol	0.02	ng/L	4.1E+04	1645141
Amoxicillin (semi-quantitative)	0.1	ng/L	1.5E+03	25000
Atenolol	0.003	ng/L	7.0E+04	22705771
Azithromycin	0.9	ng/L	3.9E+03	4235
Bezafibrate	5.7	ng/L	3.5E+05	61765
Caffeine	0.3	ng/L	8.7E+07	299376768
Carbamazepine	0.01	ng/L	1.2E+04	1525424
Carisoprodol	0.05	ng/L	2.6E+05	5379310
Cotinine	0.3	ng/L	1.0E+04	28704
DEA	124.5	ng/L	7.5E+05	6024
DEET	0.01	ng/L	8.1E+04	8471013
Dehydronifedipine	0.2	ng/L	2.0E+04	100424
DIA	2.3	ng/L	1.5E+02	64
Diclofenac	0.001	ng/L	2.3E+06	3168482007
Dilantin	0.01	ng/L	6.7E+03	627498
Diltiazem	11.7	ng/L	6.0E+04	5121
Erythromycin	0.002	ng/L	4.9E+03	2425574
Estrone	0.0001	ng/L	4.6E+02	7227819
Fluoxetine	0.0002	ng/L	1.0E+04	40313098
Gemfibrozil	0.00012	ng/L	4.6E+04	387627519
Ibuprofen	0.02	ng/L	3.4E+04	2152716
Iohexal	1596.8	ng/L	7.2E+05	451
Iopromide	0.001	ng/L	7.5E+05	1039028508
Ketoprofen	0.02	ng/L	1.3E+04	535467
Lidocaine	0.2	ng/L	1.1E+08	694214876
Lopressor	10.5	ng/L	2.3E+08	21970149
Meprobamate	0.04	ng/L	2.6E+05	7021206
Naproxen	0.000005	ng/L	2.2E+05	44325925926
Primidone	0.001	ng/L	8.4E+02	604143
Quinoline	11.3	ng/L	1.0E+01	0.9
Sucralose	1031.8	ng/L	1.7E+05	165
Sulfamethazine	0.01	ng/L	2.3E+06	166265060
Sulfamethoxazole	0.01	ng/L	7.7E+04	13469118
TCEP	0.3	ng/L	4.4E+03	15771
TCPP	0.8	ng/L	1.0E+04	12000
TDCPP	127.4	ng/L	2.7E+03	21
Theobromine	0.5	ng/L	2.8E+10	58947368421
Theophylline	0.2	ng/L	3.0E+08	1727100000
Triclocarban	39.3	ng/L	8.8E+08	22245763
Triclosan	0.0001	ng/L	2.6E+06	41616646659
Trimethoprim	0.00003	ng/L	6.1E+04	2065608466

Table 34. Margin of Safety for Constituents of Emerging Concern in Case Study 2 No Project Alternative

Analyte	Estimated Conc in Drinking Water	Units	RBAL (ng/L)	Estimated Margin of Safety
Albuterol	11.3	ng/L	4.1E+04	3618
Caffeine	5.4	ng/L	8.7E+07	16211180
DEA	7.2	ng/L	7.5E+05	104651
DEET	7.8	ng/L	8.1E+04	10385
Sulfamethoxazole	5.5	ng/L	1.8E+07	3302752

Table 35. Margin of Safety for Constituents of Emerging Concern in West Texas Direct Potable Reuse Alternative

Analyte	Estimated Conc in Drinking Water	Units	RBAL (ng/L)	Estimated Margin of Safety
1,7-Dimethylxanthine	2.5	ng/L	7.0E+02	284
Acesulfame-K	32.8	ng/L	5.3E+08	15989848
Acetaminophen	0.2	ng/L	3.5E+05	2089552
Albuterol	0.8	ng/L	4.1E+04	49354
Amoxicillin (semi-quantitative)	116.6	ng/L	1.5E+03	13
Atenolol	0.2	ng/L	7.0E+04	454545
Azithromycin	35.7	ng/L	3.9E+03	109
BPA	0.1	ng/L	3.5E+05	3925234
Butalbital	1.1	ng/L	1.8E+08	161538462
Caffeine	0.05	ng/L	8.7E+07	1905126872
Carbamazepine	0.2	ng/L	1.2E+04	48485
Carisoprodol	3.3	ng/L	2.6E+05	79795
Cimetidine	2.0	ng/L	2.0E+05	97959
Cotinine	1.0	ng/L	1.0E+04	9612
DEET	0.1	ng/L	8.1E+04	1022276
Dehydronifedipine	15.2	ng/L	2.0E+04	1313
Diclofenac	0.02	ng/L	2.3E+06	141600672
Dilantin	0.3	ng/L	6.7E+03	20321
Diltiazem	58.5	ng/L	6.0E+04	1026
Erythromycin	0.04	ng/L	4.9E+03	126323
Estrone	0.002	ng/L	4.6E+02	185777
Fluoxetine	0.03	ng/L	1.0E+04	310961
Gemfibrozil	0.04	ng/L	4.6E+04	1313004
Ibuprofen	0.01	ng/L	3.4E+04	2760858
Iohexal	489.9	ng/L	7.2E+05	1470
Iopromide	0.01	ng/L	7.5E+05	57720058
Ketoprofen	0.04	ng/L	1.3E+04	361111
Ketorolac	12.0	ng/L	8.8E+07	7291667
Lidocaine	11.3	ng/L	1.1E+08	9333333
Lincomycin	4.0	ng/L	3.7E+05	93671
Lopressor	20.0	ng/L	2.3E+08	11500000
Meprobamate	0.4	ng/L	2.6E+05	636459
Metolachlor	0.1	ng/L	7.0E+06	77228597
Naproxen	0.001	ng/L	2.2E+05	170008452
Nifedipine	1.0	ng/L	1.1E+09	1041322314
Pentoxifylline	0.1	ng/L	1.3E+05	1360544
Primidone	0.5	ng/L	8.4E+02	1737
Quinoline	0.5	ng/L	1.0E+01	18
Sucralose	285.5	ng/L	1.7E+05	596
Sulfadimethoxine	9.8	ng/L	3.5E+04	3559
Sulfamerazine	13.5	ng/L	2.3E+06	170370
Sulfamethoxazole	0.9	ng/L	1.8E+07	20055755
Sulfathiazole	5.7	ng/L	7.3E+05	128824
TCEP	5.4	ng/L	4.4E+03	811
TCPP	17.8	ng/L	1.0E+04	561
TDCPP	12.8	ng/L	2.7E+03	212
Theobromine	4.4	ng/L	2.8E+10	6339622642
Theophylline	5.9	ng/L	3.0E+08	51218861
Tot DCPA Mono&Diacid Degradate	0.1	ug/L	3.5E+05	2957746
Triclocarban	1.1	ng/L	8.8E+08	820312500
Triclosan	0.002	ng/L	2.6E+06	1291925466
Trimethoprim	0.01	ng/L	6.1E+04	5142255
Warfarin	6.5	ng/L	2.3E+03	356

6 DISCUSSION OF RISK ASSESSMENT RESULTS

6.1 Potential Impact of Inhalation and Dermal Exposure on the Carcinogenic Risk Assessment

Common household water-use activities such as showering, bathing, and washing clothes or dishes are potentially important contributors to individual exposure to THMs and other volatile organic compounds via inhalation and dermal absorption routes of exposure (Gordon et al., 2006). There have been numerous laboratory-based studies of controlled exposure to THMs, especially chloroform, from showering, bathing, or other household activities (Andelman, 1985; Jo et al., 1990a, b; Weisel & Jo, 1996; Gordon et al., 1998; Olson & Corsi, 2004). There have also been a few studies conducted in normal residential settings, but these typically have been restricted to one or two common water-use activities and to measurements of chloroform and bromodichloromethane concentrations in indoor air or exhaled breath (May et al., 1995; Kerger et al., 2000; Egorov et al., 2003; Gordon et al., 2006). Overall, this body of work indicates that showering and bathing are two common household water-use activities that can cause significant increases in exposure to volatile organic compounds from water over and above exposures due to ingestion of drinking water.

The results from the work of Jo (1990a, b) provide a good estimate of dermal exposure and inhalation to chloroform from showering in relation to ingestion. The results can be used to calculate a reasonable estimate of the contribution of these exposure pathways from volatile organics present in the waters under study in this investigation. For the purposes of previous QRRAs the exposure by these other routes for volatile organic compounds was estimated as approximately 142 percent of the median water ingestion exposure (Cooper et al., 1992; Soller et al., 2000).

Given the exposure estimates for CPCs in Case Study 1 No Project Alternative, Case Study 2 No Project Alternative, and Case Study 2 DPR Alternative (Table 30), the carcinogenic risks presented above are not expected to change substantially if dermal exposure and inhalation are accounted for. However, the Case Study 1 DPR alternative contains several volatile organic compounds with corresponding risk levels that contribute meaningfully to the total risk. Therefore, accounting for dermal exposure and inhalation would increase the risks proportionally in this water compared to the other test waters. This finding stems from the risk estimation process in which each simulation would generate the dose of each of the volatile organic constituents (sample concentration multiplied by sample volume) multiplied by 1.42 to generate an estimated exposure dose for the combined exposures due to ingestion, inhalation, and dermal contact. That product would then be multiplied by a sampled SF value to generate a probability of adverse health effect.

Similar to the results of the noncarcinogenic risk assessment, these results illustrate the potential importance of RO membranes in removing constituents that contribute to risk in a DPR application.

6.2 Sensitive Subpopulations and Younger Age Groups

Another important exposure scenario to consider is exposure of sensitive subpopulations and younger age-groups. With respect to exposure of these groups, several important aspects of the assessment methodology should be considered.

First, the U.S. EPA approach to evaluating carcinogenicity data follows the general format set forth by the National Academy of Sciences in its description of the risk assessment process (NRC, 1983, 1994). The dose-response assessment step in carcinogenic risk assessment is used to define the relationship between the dose of an agent and the likelihood of a carcinogenic effect. Dose-response assessment usually entails an extrapolation from the generally high doses administered to experimental animals or exposures noted in epidemiologic studies to those expected from human contact with the agent in the environment. The choice of a low-dose extrapolation method in U.S. EPA assessments depends on chemical specific information on the mechanism of carcinogenesis and other relevant biological information. The SF is the cancer risk per unit of dose appropriate for calculating upper-bound risks for drinking water (U.S. EPA, 2007b). Typically, carcinogenic risk is assessed based on lifetime (70 years) exposure and alternative SFs are not developed for younger age groups. One exception to this statement is for mutagenic carcinogens like the nitrosamines in which age specific adjustment factors guidelines (U.S. EPA, 2005) permit SF adjustment for early life exposures and exposures for a portion of a lifetime.

Second, the RfD is an estimate of daily exposure to the human population that is likely to be without an appreciable risk of deleterious (noncarcinogenic) effects. The RfD includes exposure to sensitive subgroups (U.S. EPA, 2007a), younger age groups, and takes into consideration all applicable endpoints.

Based on the information presented above, it is reasonable to conclude that the relative assessment of water qualities employed during this study is a valid and protective metric from which a risk management decision may be made for the population as a whole. Further, it may be inferred that the magnitude of risks to sensitive subpopulations and younger age-groups may be different from that presented herein (because of a different volume consumed and/or body weight); however, the ratio of relative risks to sensitive subpopulations and younger age-groups presented by the hypothetical exposure to water from the four waters under investigation is not likely to be significantly different from that presented above.

6.3 Actual Exposures are Likely Different from Those Used for the QRRA

There are a number of factors that can cause actual exposure to drinking water to be different from the assumptions used for this assessment. These include but are not limited to:

- Mobility of the population – the population in the United States typically moves frequently, thus limiting exposure to local drinking water and making it difficult to tie residence to exposure without great uncertainty. A survey of 1,243 women who lived in Los Angeles County in 1981 showed that 57 percent of respondents lived at their present addresses less than 10 years (Nellor et al., 1984).
- Bottled water usage – if the study population drinks bottled water, then exposure to local drinking water is decreased. For example, a survey showed that 28 percent of respondents purchased bottled water (Nellor et al., 1984). Based on the current marketing for bottled water, it is expected that this percentage is higher than in 1981 (even though the most recent trend is towards increased consumption of tap water).
- Point of use treatment – this refers to a treatment device applied to a single point, such as a water faucet, for the purpose of reducing constituents in drinking water prior to its use. A number of treatment devices are currently available ranging from filtration to reverse osmosis units. If the study population drinks water that has been treated by point of use devices in the home, the exposure to specific constituents that might have been present in the untreated water could be different. A 2006 Survey showed that 30 percent of the respondents drank filtered tap water (UCLA, 2006).
- Place of residence vs. place of work – if the study population works outside of the residential area, then exposure to local drinking water is limited, and the individual can be exposed to other CPCs in the workplace drinking water supply.

Based on the above discussion, it is clear that actual exposures to drinking water are likely to be different from those used in the QRRA. Nevertheless, the information presented is pertinent and appropriate for the purposes of this investigation, and these issues highlight the benefits of the relative risk approach (as opposed to an approach based on absolute risk) employed herein.

6.4 Constituents Not Monitored

To provide a relative comparison of health risks related to the quality of representative water from the two No Project Alternative / DPR Alternative case studies, this investigation was based on the use of data that could be collected relatively quickly and efficiently. Those data included analyses for approximately 350 constituents and 2,000 individual data points for each of the test waters. The constituents analyzed represent a broad range of chemicals and chemical categories, including compounds with drinking water MCLs and those identified by U.S. EPA as “priority pollutants.” These analyses provide a reasonable basis for completing a relative comparison and to support risk management considerations, which requires timely action within reasonable time frames and budgets. Such decisions must always balance the remaining level of uncertainty against the need and value associated with additional monitoring.

This study was not intended to be exhaustive, nor was the intent to try to eliminate all uncertainty regarding the level of risk attributable to drinking water. There are potential pollutants for which data were not available, however the CECs evaluated in this investigation included many of the constituents that have been observed in water supplies or wastewater, and were evaluated based on a reliable analytical method. As new methods mature and other CECs emerge as potential constituents of concern, the methods employed herein can be extended to include additional constituents.

6.5 Disinfection Byproduct Formation

The generation or formation of DBPs (trihalomethanes, haloacetic acids, and NDMA) can occur during conventional drinking water treatment, conventional wastewater treatment, and advanced water treatment. This assessment did not account for formation of DBPs during treatment. These compounds can contribute to health risk and depending on the source water and treatment methods utilized could be the major contributors to risk. This suggests that formation of DBPs for DPR is an area deserving scrutiny for projects on a case-by-case basis. Bench and pilot studies should be considered for DPR systems that employ technologies (such ozone and/or chlorination) that have high potential for DBP formation.

The QRRA results clearly illustrate that for the specific constituents in the risk assessment, RO and UV/AOP can be important treatment processes for the removal and control of DBPs including NDMA.

6.6 Treatment Considerations for Direct Potable Reuse Applications

While the TCEQ’s current approach for DPR does not provide credit for wastewater management prior to advanced treatment, including source control and secondary treatment performance, these activities warrant further consideration as barriers for reducing risk.

6.6.1 Source Control

The first important preventative barrier for DPR is the implementation of a source control program that shifts its focus from the current approach of meeting wastewater permit limits and protecting receiving waters to protecting a raw water source for drinking water. Source control programs have been very successful in limiting the discharge of toxic contaminants to the sewerage system from industries and commercial businesses thereby keeping them out of the reclaimed water supply. However, expectations regarding source control effectiveness must be realistic. Source control programs will be successful in achieving reductions if:

- The pollutant can be found at measurable levels in the wastewater influent and/or collection system. If a pollutant is only found sporadically it is very difficult in most cases to identify the source.

- A single source or group of similar sources accounting for most of the influent loading can be identified, such as the source's relative contributions to the mass loading and concentration of a pollutant or pollutants. The portion of the total influent source that is identified and considered "controllable" must be greater than the reduction in pollutant levels needed.
- The sources are within the jurisdiction of the wastewater management agency to control. For example, wastewater management agencies do not have the legal authority to regulate discharges from homes. In addition, pollutants that are banned, used in consumer products, or are components of environmental emissions, such as auto exhaust or power plants, are not typically viewed as "controllable" by the wastewater management agency. Control efforts require voluntary behavioral changes effectuated via public outreach or regional, statewide, or national actions to ban or control a pollutant.

6.6.2 Secondary Wastewater Treatment

A crucial consideration for DPR projects is quality of the treated wastewater that undergoes advanced treatment. The current focus of operating WWTPs is to meet discharge or non-potable reuse requirements. Because a higher quality wastewater can improve the quality of the final DPR product water and the operations of the AWTF, a shift in thinking about the function of the WWTP is worthwhile as it now is part of an integrated treatment system to produce a potable drinking water supply. A number of process modifications can be implemented at existing WWTPs or WRPs to improve the final effluent quality, including (1) influent wastewater flow equalization; (2) improved primary treatment performance via chemical addition such as alum or polymers; (3) improved secondary treatment performance via increased solids retention times (SRTs), and the addition of microbial selectors to achieve nitrification, denitrification, and/or biological phosphorus removal; (4) enhanced secondary particle settling or phosphorus removal with chemical addition such as alum or polymers; and (5) alternative management of return flows from solids processing facilities including flow equalization, treatment, and/or elimination. For nitrogen removal, a project may want to consider using de-nitrifying filters as an additional barrier for not just nitrogen but also for pathogens. For any systems change, such as chemical addition using polymers, consideration should be given to the type of polymer used since it could contain precursors for formation of DBPs.

6.6.3 Reliability

The overarching goal for an integrated DPR treatment system is to reliably achieve the desired water quality, where reliability is a function of both treatment and management. In terms of treatment, reliability depends on (1) redundancy - the use of multiple barriers for the same contaminant, so that if one fails or performs ineffectively, risk is reduced; (2) robustness - the use of a combination of treatment technologies to address a broad variety of contaminants and changes in concentration in source water; and resilience - protocols and strategies to address failures and bring systems back on-line. Reliability also depends on a project sponsor having the managerial and technical capability to operate and maintain the integrated system, including providing certified operators, training, and emergency response.

6.7 DPR Implementation Other Than Those Considered for the Quantitative Relative Risk Assessment

This investigation comprised two case studies, each of which considered a No Project Alternative (use of surface water as the drinking water source) and a DPR Alternative. In both DPR Alternatives, the product water from the AWTF was assumed to be subsequently treated at a drinking water facility (although the specific treatment unit processes at the drinking water facilities varied significantly between the case studies).

There are numerous locations in the Southwestern United States that are considering DPR as an alternative/supplemental source for their water supplies. Each of these communities has specific financial and logistical constraints that are aspects of their risk management considerations. In some cases, communities may be considering DPR options in which the product water from the AWTF is being considered as a direct component of the drinking water supply rather than as a source water to be subsequently treated at a drinking water facility prior to distribution. This study does not address the relative risks of implementing DPR in this way. However, the approach described and illustrated here could serve as a template for evaluating the relative risks of implementing DPR in ways not specifically evaluated herein.

7 PRACTICAL APPLICATIONS OF QRRA

The results of this investigation indicate that various choices that are made with respect to WWTP, WTP, and DPR treatment can have meaningful long-term public health implications. For example, the No Project Alternatives for Case Studies 1 and 2 presented carcinogenic risks that were primarily driven by a small number of constituents. The risks associated with the two DPR Alternatives were strongly influenced by the same constituents (NDMA for Case Study 1 and Arsenic in Case Study 2). However, the formation of DBPs during AWTF treatment was also shown to be an important consideration from a human health risk perspective. In considering the potential long term public health implications of choices that are made in DPR implementation, the results presented here are informative for risk management decision-making and interesting from a scientific point of view. Risk managers can use this type of information to consider the potential public health benefits, costs, and logistical constraints of source control, improved wastewater treatment, and specific AWTF unit processes for their communities as they consider DPR as a potential component to their water resource needs. For example, use of RO can be complicated by the need for a brine concentrate disposal solution. Thus, the approach and methods described in this report are useful for helping to balance the various and potentially competing issues that risk managers face.

In a related way, risk managers may use the results of a study such as this one to balance the potentially competing issues related to the potential benefits of using DPR as a short term drought mitigation measure as opposed to a long term water supply solution. In this light, some risk managers might consider the potential public health benefits, costs, and logistical constraints of specific AWTF unit processes differently for short-term drought mitigation compared to a long-term water supply enhancement perspective. For example, differences in long term (a 70 year basis) carcinogenic risks associated with some potential DPR treatment train alternatives may be acceptable on a short term basis, particularly when considered in light of some of the potential logistical challenges associated with membrane treatment unit processes or the need for additional operator expertise and training for advanced treatment systems. Each community will need to balance these complex issues, but nevertheless, the approach described and illustrated herein can be used to assimilate a wide array of data and information so that decision makers can use the best available scientific information to make informed decisions that are appropriate for their specific needs.

Information from a QRRA can also be used to:

- Assist with decisions on the need for bench scale and/or pilot testing advanced treatment technologies, potentially including evaluation of CPCs (for example DBP removal efficiency and DBP formation during water/wastewater treatment) and CECs.
- Assist with decisions on the components to include in DPR treatment schemes. This could be done as a screening framework similar to the approach used for this QRRA or as a site-specific study based on the results of bench scale or pilot testing.
- Modify or tailor monitoring programs to ensure that data for the most relevant contaminants are collected rather than compounds that have little impact on evaluating overall risk. This approach is complementary to the framework for monitoring CEC indicators and surrogate compounds presented in TM 2.
- Focus on specific source control and/or treatment options in cases where the relative risk may increase over time or reach a level of potential concern; and
- Inform public outreach. The results of QRRAs can be used for public outreach efforts to provide further understanding of the potential impacts of reclaimed water on drinking water sources. This will become more important over time as analytical methodology becomes more sensitive and more constituents are found in water even after advanced treatment.

8 RESEARCH NEEDS

A QRRA is a useful tool for decision makers when evaluating water supply options. For DPR, the output of a QRRA could advance and benefit from more reliable information on the following topic areas, which could be obtained through targeted research.

- Develop better defined and additional RBALs for CECs that are not removed by treatment.
- Develop a better understanding of the removal or formation of CPCs and CECs through advanced treatment of reclaimed water and through water treatment facilities.
- Enhance the methods for quantifying health effects of chemical mixtures as part of risk assessments.

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ACRONYMS

#Obs	Number of Observations
ADI	Acceptable Daily Intake
AT	Averaging Time
ATSDR	Agency For Toxic Substances And Disease Registry
AWTF	Advanced Water Treatment Facility

BAC	Biological Activated Carbon
BDCM	Bromodichloromethane
BMDL	Lower confidence bound on the benchmark dose
BW	Body Weight
CDBM	Chlorodibromomethane
CEC	Constituent Of Emerging Concern
CPC	Constituent Of Potential Concern
DBP	Disinfection Byproduct
DPR	Direct Potable Reuse
DWEL	Drinking Water Equivalent Levels
DWG	Drinking Water Guidelines
ED	Exposure Duration
EF	Exposure Frequency
FA	Fraction Available
g	Gram
HEAST	Health Effects Assessment Summary Tables
HAA	Haloacetic Acids
HI	Hazard Index
IngRDW	Drinking Water Ingestion Rate
IPR	Indirect Potable Reuse
IRIS	Integrated Risk Information System
kg	Kilogram
L	Liter
LOAEL	Lowest Observable Adverse Effect Level
MCC	Mass of Colonic Contents
MCL	Maximum Contaminant Level
MDL	Method Detection Limit
MF	Membrane Filtration
mg	Milligram
mg/L	Milligram per Liter
MIC	Minimum Inhibitory Concentrations
mL	Milliliter
MOS	Margin of Safety
MRL	Minimum Reporting Level
NDMA	N-nitrosodimethylamine
ŋg/L	Nanogram Per Liter
NOAEL	No Observable Adverse Effect Level
NRC	National Research Council
NSRL	No Significant Risk Levels
OEHHA	California Office of Health Hazard Assessment
OPP	Office of Pesticide Programs

OSRTI	Office of Superfund Remediation and Technology Innovation
OSWER	Office of Solid Waste and Emergency Response
P	Proportion from Water
PNEC	Predicted No Effect Concentrations
PPRTV	Provisional Peer Reviewed Toxicity Value
QRRA	Quantitative Relative Risk Assessment
RBAL	Risk Based Action Level
RfD	Reference Dose
RO	Reverse Osmosis
Sf	Safety Factor
SF	Slope Factor
TCA	Trichloroacetic Acid
TCEQ	Texas Commission on Environmental Quality
TDI	Tolerable Daily Intake
THMs	Trihalomethanes
TM	Technical Memo
UF	Ultrafiltration or Uncertainty Factor
µg	Microgram
µg/L	Microgram per Liter
U.S. EPA	United States Environmental Protection Agency
UV	Ultraviolet Irradiation
V	Volume
WHO	World Health Organization
WOE	Weight-of-Evidence
WTP	Conventional Water Treatment Plant
WWTP	Wastewater Treatment Plant

EXHIBITS

Following is a summary of the removals of each constituent for each treatment technology used in the QRRA. These removal data were generated and supplied by SPI for the purposes of this QRRA. The removal percentages were determined from a literature search of studies conducted with the applicable technologies. Data from recent water reuse studies or projects was also used to determine treatment removal percentages for the constituents. In some cases, constituents were removed to non-detectable levels. The removal percentages for these cases were conservatively set to 95 percent removal. A removal percentage of 0 percent was assumed if no data was found.

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Ozone/BAC

	Removal Percentage						Reference No.					
Constituent	Conc. In	units	Conc. Out	units	% Removal	Assigned Value				Reference Name	Reference Link	Notes
1,2-Dichlorobenzene-d4						0%	OB	-				
1,2-Dichloroethane-d4						0%	OB	-				
1,7-Dimethylxanthine	46	mg/L	BDL	mg/L	100%	95%	OB	-	8	OB - 08 - UNM Howe Final PPCP Ozone-Biofiltration Report		
2,4-D					50%	50%	OB	-	10	OB - 10 - www.urbanwateralliance.o... - 20 June 2012 DKB		
2-Butanone (MEK)						0%	OB	-				
3-Hydroxycarbofuran						0%	OB	-				
4-tert-Octylphenol	270	mg/L		mg/L	100%	95%	OB	-	8	OB - 08 - UNM Howe Final PPCP Ozone-Biofiltration Report		
Acesulfame-K					42%	42%	OB	-	9	OB - 09 - GWR_AWTF_BODR Draft (2014.07		
Acetaminophen	13	ng/L	6	ng/L	54%	54%	OB	-	1	OB - 01 -SROG Concentrate Mgmt Study Pilot Testing Summary Final Report - 1		
Albuterol	6.2	mg/L		mg/L	100%	95%	OB	-	8	OB - 08 - UNM Howe Final PPCP Ozone-Biofiltration Report		
Aldicarb sulfone						0%	OB	-				
Aluminum Total ICAP/MS						0%	OB	-				
Amoxicillin (semi-quantitative)	485	mg/L		mg/L	100%	95%	OB	-	8	OB - 08 - UNM Howe Final PPCP Ozone-Biofiltration Report		
Antimony Total ICAP/MS						0%	OB	-				
Arsenic Total ICAP/MS						95%	OB	-	14	OB - 14 - Evaluation of Treatment Systems for the Removal of Arsenic from Groundwater		
Atenolol	1297	ng/L			99%	95%	OB	-	2	OB - 02 - Gerrity et al 2011		
Atrazine	1.0	mg/L	0.19	mg/L	81%	81%	OB	-	6	OB - 06 - AppendicesPthroughU		Ozone Only
Azithromycin	55	ng/L		ng/L	99%	95%	OB	-	3	OB - 03 - Hollender et al (2009)		Ozone followed by Sand
Barium Total ICAP/MS						0%	OB	-				
Bezafibrate						0%	OB	-				
BPA						0%	OB	-				
Bromacil						0%	OB	-				
Bromodichloromethane					70%	50%	OB	-	18	OB - 18 - Pilot study on the removal of TOC, THMs, and HAAs in drinking water using ozone/UV–BAC		
Bromoform					70%	50%	OB	-	18	OB - 18 - Pilot study on the removal of TOC, THMs, and HAAs in drinking water using ozone/UV–BAC		
Butalbital	34	mg/L		mg/L	100%	95%	OB	-	8	OB - 08 - UNM Howe Final PPCP Ozone-Biofiltration Report		
Caffeine	24	ng/L	2	ng/L	92%	92%	OB	-	1	OB - 01 -SROG Concentrate Mgmt Study Pilot Testing Summary Final Report - 1		
Carbamazepine	877	ng/L	ND	ng/L	100%	95%	OB	-	1	OB - 01 -SROG Concentrate Mgmt Study Pilot Testing Summary Final Report - 1		
Carisoprodol	48.5	mg/L		mg/L	100%	95%	OB	-	8	OB - 08 - UNM Howe Final PPCP Ozone-Biofiltration Report		
Chloride						0%	OB	-				
Chlorodibromomethane					70%	50%	OB	-	18	OB - 18 - Pilot study on the removal of TOC, THMs, and HAAs in drinking water using ozone/UV–BAC		
Chloroform					70%	50%	OB	-	18	OB - 18 - Pilot study on the removal of TOC, THMs, and HAAs in drinking water using ozone/UV–BAC		
Chromium Total ICAP/MS						0%	OB	-				
Cimetidine					93%	93%	OB	-	9	OB - 09 - GWR_AWTF_BODR Draft (2014.07		
Cotinine	230	ng/L	28	ng/L	88%	88%	OB	-	1	OB - 01 -SROG Concentrate Mgmt Study Pilot Testing Summary Final Report - 1		
Cyanide					22%	22%	OB	-	12	OB - 12 - USEPA Drinking Water Treatability Database		
DEA						0%	OB	-				
DEET	905	ng/L	3	ng/L	100%	95%	OB	-	1	OB - 01 -SROG Concentrate Mgmt Study Pilot Testing Summary Final Report - 1		
Dehydronifedipine		mg/L		mg/L	100%	95%	OB	-	8	OB - 08 - UNM Howe Final PPCP Ozone-Biofiltration Report		
Di(2-Ethylhexyl)phthalate					68%	68%	OB	-	17	OB - 17 - Experimental study of behavior of endocrine-disrupting chemicals in leachate treatment process and evaluation of removal efficiency		
DIA	237	ng/L	29	ng/L	88%	88%	OB	-	11	OB - 11 - Ozone oxidation of pharmaceuticals, endocrine disruptors and pesticides during drinking water treatment		
Dicamba						0%	OB	-				
Dichloroacetic acid					100%	95%	OB	-	15	OB- - 15 - Removal of haloacetic acids by ozone and biologically active carbon		
Diclofenac					92%	92%	OB	-	4	OB - 04 - Removal of micropollutants and reduction of biological		
Dilantin	466	ng/L	2	ng/L	100%	95%	OB	-	1	OB - 01 -SROG Concentrate Mgmt Study Pilot Testing Summary Final Report - 1		
Diltiazem						0%	OB	-				
Diuron	139	ng/L	ND	ng/L	100%	95%	OB	-	1	OB - 01 -SROG Concentrate Mgmt Study Pilot Testing Summary Final Report - 1		
Erythromycin	19	ng/L		ng/L	64%	64%	OB	-	3	OB - 03 - Hollender et al (2009)		Ozone followed by Sand
Estrone	3	ng/L	ND	ng/L	100%	95%	OB	-	1	OB - 01 -SROG Concentrate Mgmt Study Pilot Testing Summary Final Report - 1		
Fluoride						0%	OB	-				
Fluoxetine	192	ng/L	ND	ng/L	100%	95%	OB	-	1	OB - 01 -SROG Concentrate Mgmt Study Pilot Testing Summary Final Report - 1		
Gemfibrozil	62	ng/L	ND	ng/L	100%	95%	OB	-	1	OB - 01 -SROG Concentrate Mgmt Study Pilot Testing Summary Final Report - 1		
Ibuprofen	34	ng/L	ND	ng/L	100%	95%	OB	-	1	OB - 01 -SROG Concentrate Mgmt Study Pilot Testing Summary Final Report - 1		
Iohexal	560	mg/L		mg/L	42%	42%	OB	-	8	OB - 08 - UNM Howe Final PPCP Ozone-Biofiltration Report		
Iopromide	10	ng/L			99%	95%	OB	-	2	OB - 02 - Gerrity et al 2011		
Iron Total ICAP						0%	OB	-				
Ketoprofen	98	ng/L		ng/L	69%	69%	OB	-	3	OB - 03 - Hollender et al (2009)		Ozone followed by Sand
Ketorolac					50%	50%	OB	-	9	OB - 09 - GWR_AWTF_BODR Draft (2014.07		
Lead Total ICAP/MS						95%	OB	-	16	OB - 16 - Evaluation of Activated Carbon for Treating Heavy Metals in Aquaculture		
Lidocaine	19	ng/L		ng/L	98%	95%	OB	-	3	OB - 03 - Hollender et al (2009)		Ozone followed by Sand
Lincomycin					65%	65%	OB	-	9	OB - 09 - GWR_AWTF_BODR Draft (2014.07		
Lopressor					75%	75%	OB	-	9	OB - 09 - GWR_AWTF_BODR Draft (2014.07		
Manganese Total ICAP/MS						0%	OB	-				
Meprobamate	603	ng/L			97%	95%	OB	-	2	OB - 02 - Gerrity et al 2011		
Methomyl						0%	OB	-				
Metolachlor	1.0	mg/L	0.16	mg/L	84%	84%	OB	-	6	OB - 06 - AppendicesPthroughU		Ozone Only
Molybdenum Total ICAP/MS						0%	OB	-				
Monochloroacetic acid						0%	OB	-				
Naproxen	13	ng/L	ND	ng/L	100%	95%	OB	-	1	OB - 01 -SROG Concentrate Mgmt Study Pilot Testing Summary Final Report - 1		
Nickel Total ICAP/MS						0%	OB	-				
Nifedipine					86%	86%	OB	-	9	OB - 09 - GWR_AWTF_BODR Draft (2014.07		
Nitrate as NO3 (calc)						0%	OB	-				
Nitrite Nitrogen by IC						35%	OB	-	13	Effect of ozone on the performance of a hybrid ceramic membrane-biological activated carbon process		
N-Nitroso-dimethylamine (NDMA	1.0	mg/L	0.54	mg/L	46%	46%	OB	-	6	OB - 06 - AppendicesPthroughU		Ozone Only
p-Dichlorobenzene (1,4-DCB)						0%	OB	-				
Pentoxifylline					62%	62%	OB	-	9	OB - 09 - GWR_AWTF_BODR Draft (2014.07		
Primidone	1260	ng/L	12	ng/L	99%	95%	OB	-	1	OB - 01 -SROG Concentrate Mgmt Study Pilot Testing Summary Final Report - 1		
Propazine						0%	OB	-				
Quinoline						0%	OB	-				
Simazine						0%	OB	-				
Strontium ICAP						0%	OB	-				
Sucralose	43000	mg/L		mg/L	57%	57%	OB	-	8	OB - 08 - UNM Howe Final PPCP Ozone-Biofiltration Report		
Sulfadimethoxine						0%	OB	-				
Sulfamerazine						0%	OB	-				
Sulfamethazine	9.15	mg/L		mg/L	100%	95%	OB	-	8	OB - 08 - UNM Howe Final PPCP Ozone-Biofiltration Report		
Sulfamethoxazole	465	ng/L	1	ng/L	100%	95%	OB	-	1	OB - 01 -SROG Concentrate Mgmt Study Pilot Testing Summary Final Report - 1		
Sulfathiazole	1400	ng/L	25	ng/L	98%	95%	OB	-	5	OB - 05 - 2013EckenfelderPresentation_Stanford		
TCEP	543	ng/L			95%	95%	OB	-	2	OB - 02 - Gerrity et al 2011		
TCPP	3750	ng/L			96%	95%	OB	-	2	OB - 02 - Gerrity et al 2011		
TDCPP					15%	15%	OB	-	9	OB - 09 - GWR_AWTF_BODR Draft (2014.07		
Theobromine	62.5	mg/L		mg/L	100%	95%	OB	-	8	OB - 08 - UNM Howe Final PPCP Ozone-Biofiltration Report		
Theophylline	98	mg/L		mg/L	100%	95%	OB	-	8	OB - 08 - UNM Howe Final PPCP Ozone-Biofiltration Report		
Toluene						0%	OB	-				
Tot DCPA Mono&Diacid Degradate						0%	OB	-				
Trichloroacetic acid					100%	95%	OB	-	15	OB- - 15 - Removal of haloacetic acids by ozone and biologically active carbon		
Triclocarban						0%	OB	-				
Triclosan	12	ng/L	ND	ng/L	100%	95%	OB	-	1	OB - 01 -SROG Concentrate Mgmt Study Pilot Testing Summary Final Report - 1		
Trimethoprim	80	ng/L	ND	ng/L	100%	95%	OB	-	1	OB - 01 -SROG Concentrate Mgmt Study Pilot Testing Summary Final Report - 1		
Uranium ICAP/MS						0%	OB	-				
Warfarin					24%	24%	OB	-	9	OB - 09 - GWR_AWTF_BODR Draft (2014.07		

Floc/Sed

Constituent	Removal Percentage						Reference No.			Reference Name	Reference Link	Notes
	Conc. In	units	Conc. Out	units	% Removal	Assigned Value						
1,2-Dichlorobenzene-d4						0%	FS	-				
1,2-Dichloroethane-d4						0%	FS	-				
1,7-Dimethylxanthine						0%	FS	-				
2,4-D						0%	FS	-				
2-Butanone (MEK)						0%	FS	-				
3-Hydroxycarbofuran						0%	FS	-				
4-tert-Octylphenol						0%	FS	-				
Acesulfame-K						0%	FS	-				
Acetaminophen						0%	FS	-				
Albuterol						0%	FS	-				
Aldicarb sulfone						0%	FS	-				
Aluminum Total ICAP/MS						0%	FS	-				
Amoxicillin (semi-quantitative)						0%	FS	-				
Antimony Total ICAP/MS					90%	90%	FS	-	4	USBOR Antimony Fact Sheet		
Arsenic Total ICAP/MS					90%	90%	FS	-	3	Best Practice Guide on Metals Removal from Drinking Water by Treatment		
Atenolol						0%	FS	-				
Atrazine						0%	FS	-	7	Atrazine and Its Metabolites in Drinking-water		
Azithromycin						0%	FS	-				
Barium Total ICAP/MS					80%	80%	FS	-	3	Best Practice Guide on Metals Removal from Drinking Water by Treatment		
Bezafibrate						0%	FS	-				
BPA						0%	FS	-				
Bromacil						0%	FS	-				
Bromodichloromethane						0%	FS	-				
Bromoform						0%	FS	-				
Butalbital						0%	FS	-				
Caffeine						0%	FS	-				
Carbamazepine						0%	FS	-				
Carisoprodol						0%	FS	-				
Chloride						0%	FS	-				
Chlorodibromomethane						0%	FS	-				
Chloroform						0%	FS	-				
Chromium Total ICAP/MS					95%	95%	FS	-	3	Best Practice Guide on Metals Removal from Drinking Water by Treatment		
Cimetidine						0%	FS	-				
Cotinine						0%	FS	-				
Cyanide						0%	FS	-				
DEA						0%	FS	-				
DEET						0%	FS	-				
Dehydronifedipine						0%	FS	-				
Di(2-Ethylhexyl)phthalate					50-70%	60%	FS	-	8	Experimental study of behavior of endocrine-disrupting chemicals in leachate treatment process and evaluation of removal efficiency		
DIA						0%	FS	-				
Dicamba						0%	FS	-				
Dichloroacetic acid						0%	FS	-				
Diclofenac	485	ng/L	470	ng/L	3%	3%	FS	-	1	ZoritaEtal2009	01 ConstituentRemovalReferences\02 FS\Gaby\FS-1 ZoritaEtal2009.pdf	
Dilantin						0%	FS	-				
Diltiazem						0%	FS	-				
Diuron						0%	FS	-				
Erythromycin						0%	FS	-				
Estrone	70	ng/L	43.5	ng/L	38%	38%	FS	-	1	ZoritaEtal2009	01 ConstituentRemovalReferences\02 FS\Gaby\FS-1 ZoritaEtal2009.pdf	
Fluoride					45%	45%	FS	-	5	Fluoride Removal in Small Water Systems: A Coagulation Lawler		
Fluoxetine						0%	FS	-				
Gemfibrozil						0%	FS	-				
Ibuprofen	88.5	ng/L	61.5	ng/L	31%	31%	FS	-	1	ZoritaEtal2009	01 ConstituentRemovalReferences\02 FS\Gaby\FS-1 ZoritaEtal2009.pdf	
Iohexal						0%	FS	-				
Iopromide						0%	FS	-				
Iron Total ICAP						0%	FS	-				
Ketoprofen						0%	FS	-				
Ketorolac						0%	FS	-				
Lead Total ICAP/MS					95%	95%	FS	-	3	Best Practice Guide on Metals Removal from Drinking Water by Treatment		
Lidocaine						0%	FS	-				
Lincomycin						0%	FS	-				
Lopressor						0%	FS	-				
Manganese Total ICAP/MS						0%	FS	-				
Meprobamate						0%	FS	-				
Methomyl						0%	FS	-				
Metolachlor						0%	FS	-				
Molybdenum Total ICAP/MS						0%	FS	-				
Monochloroacetic acid						0%						
Naproxen	340	ng/L	300	ng/L	12%	12%	FS	-	1	ZoritaEtal2009	01 ConstituentRemovalReferences\02 FS\Gaby\FS-1 ZoritaEtal2009.pdf	
Nickel Total ICAP/MS					80%	80%	FS	-	6	Drinking Water Quality: Problems and Solutions Gray		
Nifedipine						0%	FS	-				
Nitrate as NO3 (calc)						0%	FS	-				
Nitrite Nitrogen by IC						0%	FS	-				
N-Nitroso-dimethylamine (NDMA)					< 10%	9%	FS	-	9	Removal of radio N -nitrosodimethylamine (NDMA) from drinking water by coagulation and Powdered Activated Carbon (PAC) adsorption		
p-Dichlorobenzene (1,4-DCB)						0%	FS	-				
Pentoxifylline						0%	FS	-				
Primidone						0%	FS	-				
Propazine						0%	FS	-				
Quinoline						0%	FS	-				
Simazine						0%	FS	-				
Strontium ICAP						0%	FS	-				
Sucralose						0%	FS	-				
Sulfadimethoxine						0%	FS	-				
Sulfamerazine						0%	FS	-				
Sulfamethazine						0%	FS	-				
Sulfamethoxazole						0%	FS	-				
Sulfathiazole						0%	FS	-				
TCEP						0%	FS	-				
TCPP						0%	FS	-				
TDCPP						0%	FS	-				
Theobromine						0%	FS	-				
Theophylline						0%	FS	-				
Toluene						0%	FS	-				
Tot DCPA Mono&Diacid Degradate						0%	FS	-				
Trichloroacetic acid						0%	FS	-				
Triclocarban						0%	FS	-				
Triclosan						0%	FS	-				
Trimethoprim						0%	FS	-				
Uranium ICAP/MS					70%	70%	FS	-	2	Clifford University of Houston		
Warfarin						0%	FS	-				

Media Filtration

	Removal Percentage						Reference No.			Reference Name	Reference Link	Notes
Constituent	Conc. In	units	Conc. Out	units	% Removal	Assigned Value						
1,2-Dichlorobenzene-d4						0%	GMF	-				
1,2-Dichloroethane-d4						0%	GMF	-				
1,7-Dimethylxanthine						0%	GMF	-				
2,4-D						0%	GMF	-				
2-Butanone (MEK)						0%	GMF	-				
3-Hydroxycarbofuran						0%	GMF	-				
4-tert-Octylphenol						0%	GMF	-				
Acesulfame-K						0%	GMF	-				
Acetaminophen						0%	GMF	-				
Albuterol						0%	GMF	-				
Aldicarb sulfone						0%	GMF	-				
Aluminum Total ICAP/MS						0%	GMF	-				
Amoxicillin (semi-quantitative)						0%	GMF	-				
Antimony Total ICAP/MS						0%	GMF	-				
Arsenic Total ICAP/MS						0%	GMF	-				
Atenolol						0%	GMF	-				
Atrazine						0%	GMF	-	2	Atrazine and Its Metabolites in Drinking-water		
Azithromycin						0%	GMF	-				
Barium Total ICAP/MS						0%	GMF	-				
Bezafibrate						0%	GMF	-				
BPA						0%	GMF	-				
Bromacil						0%	GMF	-				
Bromodichloromethane						0%	GMF	-				
Bromoform						0%	GMF	-				
Butalbital						0%	GMF	-				
Caffeine						0%	GMF	-				
Carbamazepine						0%	GMF	-				
Carisoprodol						0%	GMF	-				
Chloride						0%	GMF	-				
Chlorodibromomethane						0%	GMF	-				
Chloroform						0%	GMF	-				
Chromium Total ICAP/MS						0%	GMF	-				
Cimetidine						0%	GMF	-				
Cotinine						0%	GMF	-				
Cyanide						0%	GMF	-				
DEA						0%	GMF	-				
DEET						0%	GMF	-				
Dehydronifedipine						0%	GMF	-				
Di(2-Ethylhexyl)phthalate						0%	GMF	-				
DIA						0%	GMF	-				
Dicamba						0%	GMF	-				
Dichloroacetic acid						0%	GMF	-				
Diclofenac						0%	GMF	-				
Dilantin						0%	GMF	-				
Diltiazem						0%	GMF	-				
Diuron						0%	GMF	-				
Erythromycin						0%	GMF	-				
Estrone						0%	GMF	-				
Fluoride						0%	GMF	-				
Fluoxetine						0%	GMF	-				
Gemfibrozil						0%	GMF	-				
Ibuprofen						0%	GMF	-				
Iohexal						0%	GMF	-				
Iopromide						0%	GMF	-				
Iron Total ICAP					67%	67%	GMF	-	1	GMF - 1 - OT_TB_summer00.doc - slow_sand_filtration_dwfsom40		Slow Sand Filtration
Ketoprofen						0%	GMF	-				
Ketorolac						0%	GMF	-				
Lead Total ICAP/MS					50%	50%	GMF	-	1	GMF - 1 - OT_TB_summer00.doc - slow_sand_filtration_dwfsom40		Slow Sand Filtration
Lidocaine						0%	GMF	-				
Lincomycin						0%	GMF	-				
Lopressor						0%	GMF	-				
Manganese Total ICAP/MS					67%	67%	GMF	-	1	GMF - 1 - OT_TB_summer00.doc - slow_sand_filtration_dwfsom40		Slow Sand Filtration
Meprobamate						0%	GMF	-				
Methomyl						0%	GMF	-				
Metolachlor						0%	GMF	-				
Molybdenum Total ICAP/MS						0%	GMF	-				
Monochloroacetic acid						0%	GMF	-				
Naproxen						0%	GMF	-				
Nickel Total ICAP/MS						0%	GMF	-				
Nifedipine						0%	GMF	-				
Nitrate as NO3 (calc)						0%	GMF	-				
Nitrite Nitrogen by IC						0%	GMF	-				
N-Nitroso-dimethylamine (NDMA)						0%	GMF	-				
p-Dichlorobenzene (1,4-DCB)						0%	GMF	-				
Pentoxifylline						0%	GMF	-				
Primidone						0%	GMF	-				
Propazine						0%	GMF	-				
Quinoline						0%	GMF	-				
Simazine						0%	GMF	-				
Strontium ICAP						0%	GMF	-				
Sucralose						0%	GMF	-				
Sulfadimethoxine						0%						
Sulfamerazine						0%	GMF	-				
Sulfamethazine						0%	GMF	-				
Sulfamethoxazole						0%	GMF	-				
Sulfathiazole						0%	GMF	-				
TCEP						0%	GMF	-				
TCPP						0%	GMF	-				
TDCPP						0%	GMF	-				
Theobromine						0%	GMF	-				
Theophylline						0%	GMF	-				
Toluene						0%	GMF	-				
Tot DCPA Mono&Diacid Degradate						0%	GMF	-				
Trichloroacetic acid						0%	GMF	-				
Triclocarban						0%	GMF	-				
Triclosan						0%	GMF	-				
Trimethoprim						0%	GMF	-				
Uranium ICAP/MS						0%	GMF	-				
Warfarin						0%	GMF	-				

Chlorine Disinfection

	Removal Percentage						erence I			Reference Name	Reference Link	Notes
Constituent	Conc. In	units	Conc. Out	units	% Removal	Assigned Value						
1,2-Dichlorobenzene-d4		ng/L		ng/L		0%	CH	-				
1,2-Dichloroethane-d4		ng/L		ng/L		0%	CH	-				
1,7-Dimethylxanthine		ng/L		ng/L		0%	CH	-				
2,4-D		ng/L		ng/L		0%	CH	-				
2-Butanone (MEK)		ng/L		ng/L		0%	CH	-				
3-Hydroxycarbofuran		ng/L		ng/L		0%	CH	-				
4-tert-Octylphenol		ng/L		ng/L		0%	CH	-				
Acesulfame-K		ng/L		ng/L		0%	CH	-				
Acetaminophen		ng/L		ng/L	>80%	80%	CH	-	1	Secondary Constituents	CH-1 SecondaryConstituents.pdf	
Albuterol		ng/L		ng/L		0%	CH	-				
Aldicarb sulfone		ng/L		ng/L		0%	CH	-				
Aluminum Total ICAP/MS		ng/L		ng/L		0%	CH	-				
Amoxicillin (semi-quantitative)		ng/L		ng/L		0%	CH	-				
Antimony Total ICAP/MS		ng/L		ng/L		0%	CH	-				
Arsenic Total ICAP/MS		ng/L		ng/L		0%	CH	-				
Atenolol		ng/L		ng/L		30%	CH	-		Task 6 technical memo :Table 6		
Atrazine		ng/L		ng/L	<20	20%	CH	-	1	Secondary Constituents	CH-1 SecondaryConstituents.pdf	
Azithromycin		ng/L		ng/L		0%	CH	-				
Barium Total ICAP/MS		ng/L		ng/L		0%	CH	-				
Bezafibrate		ng/L		ng/L		0%	CH	-				
BPA	108	ng/L	45	ng/L	58%	58%	CH	-	4	Stackelberg et al 2007	CH-4 stackelberg et al 2007.pdf	
Bromacil		ng/L		ng/L		0%	CH	-				
Bromodichloromethane		ng/L		ng/L		0%	CH	-				
Bromoform		ng/L		ng/L		0%	CH	-				
Butalbital		ng/L		ng/L		0%	CH	-				
Caffeine		ng/L		ng/L	30%	30%	CH	-	3	CEC Literature	CH-3 cecliterature.pdf	
Carbamazepine		ng/L		ng/L	<20	20%	CH	-	1	Secondary Constituents	CH-1 SecondaryConstituents.pdf	
Carisoprodol		ng/L		ng/L		0%	CH	-				
Chloride		ng/L		ng/L		0%	CH	-				
Chlorodibromomethane		ng/L		ng/L		0%	CH	-				
Chloroform		ng/L		ng/L		0%	CH	-				
Chromium Total ICAP/MS		ng/L		ng/L		0%	CH	-				
Cimetidine		ng/L		ng/L		0%	CH	-				
Cotinine		ng/L		ng/L		0%	CH	-				
Cyanide		ng/L		ng/L	95%	95%	CH	-	5	USEPA Drinking Water Treatability Database		
DEA		ng/L		ng/L		0%	CH	-				
DEET		ng/L		ng/L	22%	22%	CH	-	3	CEC Literature	CH-3 cecliterature.pdf	
Dehydronifedipine	0.7	ng/L	0.6	ng/L	14%	14%	CH	-	4	Stackelberg et al 2007	CH-4 stackelberg et al 2007.pdf	
Di(2-Ethylhexyl)phthalate		ng/L		ng/L		0%	CH	-				
DIA		ng/L		ng/L		0%	CH	-				
Dicamba		ng/L		ng/L		0%	CH	-				
Dichloroacetic acid		ng/L		ng/L		0%	CH	-				
Diclofenac		ng/L		ng/L	47%	47%	CH	-	3	CEC Literature	CH-3 cecliterature.pdf	
Dilantin		ng/L		ng/L	<20	20%	CH	-	1	Secondary Constituents	CH-1 SecondaryConstituents.pdf	
Diltiazem		ng/L		ng/L		0%	CH	-				
Diuron		ng/L		ng/L		0%	CH	-				
Erythromycin		ng/L		ng/L	99%	95%	CH	-	3	CEC Literature	CH-3 cecliterature.pdf	
Estrone		ng/L		ng/L	74%	74%	CH	-	3	CEC Literature	CH-3 cecliterature.pdf	
Fluoride		ng/L		ng/L		0%	CH	-				
Fluoxetine		ng/L		ng/L	66%	66%	CH	-	3	CEC Literature	CH-3 cecliterature.pdf	
Gemfibrozil		ng/L		ng/L	83%	83%	CH	-	3	CEC Literature	CH-3 cecliterature.pdf	
Ibuprofen		ng/L		ng/L	28%	28%	CH	-	3	CEC Literature	CH-3 cecliterature.pdf	
Iohexal		ng/L		ng/L		0%	CH	-				
Iopromide		ng/L		ng/L	55%	55%	CH	-	3	CEC Literature	CH-3 cecliterature.pdf	
Iron Total ICAP		ng/L		ng/L		0%	CH	-				
Ketoprofen		ng/L		ng/L	80%	80%	CH	-	3	CEC Literature	CH-3 cecliterature.pdf	
Ketorolac		ng/L		ng/L		0%	CH	-				
Lead Total ICAP/MS		ng/L		ng/L		0%	CH	-				
Lidocaine		ng/L		ng/L		0%	CH	-				
Lincomycin		ng/L		ng/L		0%	CH	-				
Lopressor		ng/L		ng/L		0%	CH	-				
Manganese Total ICAP/MS		ng/L		ng/L		0%	CH	-				
Meprobamate		ng/L		ng/L	11%	11%	CH	-	3	CEC Literature	CH-3 cecliterature.pdf	
Methomyl		ng/L		ng/L		0%	CH	-				
Metolachlor		ng/L		ng/L	<20	20%	CH	-	1	Secondary Constituents	CH-1 SecondaryConstituents.pdf	
Molybdenum Total ICAP/MS		ng/L		ng/L		0%	CH	-				
Monochloroacetic acid		ng/L		ng/L		0%	CH	-				
Naproxen		ng/L		ng/L	98%	95%	CH	-	3	CEC Literature	CH-3 cecliterature.pdf	
Nickel Total ICAP/MS		ng/L		ng/L		0%	CH	-				
Nifedipine		ng/L		ng/L		0%	CH	-				
Nitrate as NO3 (calc)		ng/L		ng/L		0%	CH	-				
Nitrite Nitrogen by IC	0.227	mg/L	0.007	mg/L	97%	95%	CH	-	6	Breakpoint Chlorination...Do you Really Have a Free Chlorine Residual?		
N-Nitroso-dimethylamine (NDMA)		ng/L		ng/L		0%	CH	-				
p-Dichlorobenzene (1,4-DCB)		ng/L		ng/L		0%	CH	-				
Pentoxifylline		ng/L		ng/L	<50	50%	CH	-	1	Secondary Constituents	CH-1 SecondaryConstituents.pdf	
Primidone		ng/L		ng/L	89%	89%	CH	-	3	CEC Literature	CH-3 cecliterature.pdf	
Propazine		ng/L		ng/L		0%	CH	-				
Quinoline		ng/L		ng/L		0%	CH	-				
Simazine		ng/L		ng/L		0%	CH	-				
Strontium ICAP		ng/L		ng/L		0%	CH	-				
Sucralose		ng/L		ng/L		30%	CH	-		Task 6 technical memo :Table 6		
Sulfadimethoxine		ng/L		ng/L		0%						
Sulfamerazine		ng/L		ng/L		0%	CH	-				
Sulfamethazine		ng/L		ng/L		0%	CH	-				
Sulfamethoxazole		ng/L		ng/L	49%	49%	CH	-	3	CEC Literature	CH-3 cecliterature.pdf	
Sulfathiazole		ng/L		ng/L		0%	CH	-				
TCEP		ng/L		ng/L	<20	20%	CH	-	1	Secondary Constituents	CH-1 SecondaryConstituents.pdf	
TCPP		ng/L		ng/L		0%	CH	-				
TDCPP		ng/L		ng/L		0%	CH	-				
Theobromine		ng/L		ng/L		0%	CH	-				
Theophylline		ng/L		ng/L		0%	CH	-				
Toluene		ng/L		ng/L		0%	CH	-				
Tot DCPA Mono&Diacid Degradate		ng/L		ng/L		0%	CH	-				
Trichloroacetic acid		ng/L		ng/L		0%	CH	-				
Triclocarban		ng/L		ng/L		0%	CH	-				
Triclosan		ng/L		ng/L	79%	79%	CH	-	3	CEC Literature	CH-3 cecliterature.pdf	
Trimethoprim		ng/L		ng/L	96%	95%	CH	-	3	CEC Literature	CH-3 cecliterature.pdf	
Uranium ICAP/MS		ng/L		ng/L		0%	CH	-				
Warfarin		ng/L		ng/L		0%	CH	-				

UV/AOP

	Removal Percentage						Reference No.			Reference Name	Reference Link	Notes
Constituent	Conc. In	units	Conc. Out	units	% Removal	Assigned Value						
1,2-Dichlorobenzene-d4						0%	UV	-				
1,2-Dichloroethane-d4						0%	UV	-				
1,7-Dimethylxanthine						0%	UV	-				Compound tested in study - levels in and out below detection limit
2,4-D						0%	UV	-				
2-Butanone (MEK)						0%	UV	-				
3-Hydroxycarbofuran						0%	UV	-				
4-tert-Octylphenol						0%	UV	-				
Acesulfame-K	40	ng/L	<20	ng/L	50%	50%	UV	-	1	UV01 - awpfappendixb		
Acetaminophen						0%	UV	-				Compound tested in study - levels in and out below detection limit
Albuterol						0%	UV	-				Compound tested in study - levels in and out below detection limit
Aldicarb sulfone						0%	UV	-				
Aluminum Total ICAP/MS						0%	UV	-				
Amoxicillin (semi-quantitative)						0%	UV	-				Compound tested in study - levels in and out below detection limit
Antimony Total ICAP/MS						0%	UV	-				
Arsenic Total ICAP/MS						0%	UV	-				
Atenolol					40%	40%	UV	-	6	Rosario-Ortiz/Snyder		Compound tested in study - levels in and out below detection limit
Atrazine					60%	60%	UV	-	3	UV03 - coastal-wetlands-process-technology		
Azithromycin						0%	UV	-				Compound tested in study - levels in and out below detection limit
Barium Total ICAP/MS						0%	UV	-				
Bezafibrate						0%	UV	-				Compound tested in study - levels in and out below detection limit
BPA						0%	UV	-				Compound tested in study - levels in and out below detection limit
Bromacil					84%	84%	UV	-	3	UV03 - coastal-wetlands-process-technology		
Bromodichloromethane						0%	UV	-				
Bromoform						0%	UV	-				
Butalbital						0%	UV	-				Compound tested in study - levels in and out below detection limit
Caffeine					98.00%	95%	UV	-	5	san diego		
Carbamazepine					45%	45%	UV	-	6	Rosario-Ortiz/Snyder		
Carisoprodol						0%	UV	-				Compound tested in study - levels in and out below detection limit
Chloride						0%	UV	-				
Chlorodibromomethane						0%	UV	-				
Chloroform						0%	UV	-				
Chromium Total ICAP/MS						0%	UV	-				
Cimetidine						0%	UV	-				Compound tested in study - levels in and out below detection limit
Cotinine						0%	UV	-				Compound tested in study - levels in and out below detection limit
Cyanide						0%	UV	-				
DEA						0%	UV	-				
DEET					99%	95%	UV	-	5	san diego		
Dehydronifedipine						0%	UV	-				Compound tested in study - levels in and out below detection limit
Di(2-Ethylhexyl)phthalate					74%	74%	UV	-	9	The Oxidation of Di-(2-Ethylhexyl) Phthalate (DEHP) in Aqueous Solution by UV/H2O2 Photolysis		
DIA						0%	UV	-				Compound tested in study - levels in and out below detection limit
Dicamba						0%	UV	-				
Dichloroacetic acid					85%	85%	UV	-	10	Advanced oxidation processes of decomposing dichloroacetic acid and trichloroacetic acid in water		
Diclofenac					34%	34%	UV	-	4	UV04 - cec literature review		
Dilantin					60%	60%	UV	-	6	Rosario-Ortiz/Snyder		Compound tested in study - levels in and out below detection limit
Diltiazem						0%	UV	-				
Diuron						0%	UV	-				Compound tested in study - levels in and out below detection limit
Erythromycin					50%	50%	UV	-	3	UV03 - coastal-wetlands-process-technology		
Estrone					98%	95%	UV	-	5	san diego		
Fluoride						0%	UV	-				
Fluoxetine						0%	UV	-				Compound tested in study - levels in and out below detection limit
Gemfibrozil					80%	80%	UV	-	5	san diego		
Ibuprofen					99%	95%	UV	-	5	san diego		
Iohexal						0%	UV	-				Compound tested in study - levels in and out below detection limit
Iopromide					99%	95%	UV	-	5	san diego		
Iron Total ICAP						0%	UV	-				
Ketoprofen						0%	UV	-				Compound tested in study - levels in and out below detection limit
Ketorolac						0%	UV	-				Compound tested in study - levels in and out below detection limit
Lead Total ICAP/MS						0%	UV	-				
Lidocaine						0%	UV	-				Compound tested in study - levels in and out below detection limit
Lincomycin						0%	UV	-				
Lopressor						0%	UV	-				Compound tested in study - levels in and out below detection limit
Manganese Total ICAP/MS						0%	UV	-				
Meprobamate					70	70%	UV	-	6	Rosario-Ortiz/Snyder		
Methomyl						0%	UV	-				
Metolachlor						0%	UV	-				
Molybdenum Total ICAP/MS						0%	UV	-				
Monochloroacetic acid						0%	UV	-				
Naproxen					0.85%	0.85%	UV	-	4	UV04 - cec literature review		
Nickel Total ICAP/MS						0%	UV	-				
Nifedipine						0%	UV	-				Compound tested in study - levels in and out below detection limit
Nitrate as NO3 (calc)						0%	UV	-	2	UV02 - NDMA removal by RO and UV treatment		
Nitrite Nitrogen by IC						0%	UV	-				
N-Nitroso-dimethylamine (NDMA	200	ng/L	2	ng/L	99%	95%	UV	-	5	SD Miami Dade		
p-Dichlorobenzene (1,4-DCB)						0%	UV	-				
Pentoxifylline					20 - 50%	35%	UV	-	3	UV03 - coastal-wetlands-process-technology		
Primidone					35%	35%	UV	-	6	Rosario-Ortiz/Snyder		Compound tested in study - levels in and out below detection limit
Propazine						0%	UV	-				Compound tested in study - levels in and out below detection limit
Quinoline						0%	UV	-				Compound tested in study - levels in and out below detection limit
Simazine						0%	UV	-				Compound tested in study - levels in and out below detection limit
Strontium ICAP						0%	UV	-				
Sucralose					55%	55%	UV	-	7	Good & Bowen		Compound tested in study - levels in and out below detection limit
Sulfadimethoxine						0%	UV					Compound tested in study - levels in and out below detection limit
Sulfamerazine						0%	UV	-				Compound tested in study - levels in and out below detection limit
Sulfamethazine						0%	UV	-				Compound tested in study - levels in and out below detection limit
Sulfamethoxazole					58%	58%	UV	-	5	san diego		
Sulfathiazole						0%	UV	-				Compound tested in study - levels in and out below detection limit
TCEP					36	36%	UV	-	5	san diego		
TCPP						0%	UV	-				Compound tested in study - levels in and out below detection limit
TDCPP	250	ng/L	180	ng/L	28%	28%	UV	-	8	Workshop to Address Critical Surface Water Issues Facing Northern Colorado Municipal Suppliers		Compound tested in study - levels in and out below detection limit
Theobromine						0%	UV	-				Compound tested in study - levels in and out below detection limit
Theophylline						0%	UV	-				Compound tested in study - levels in and out below detection limit
Toluene						0%	UV	-				
Tot DCPA Mono&Diacid Degradate						0%	UV	-				
Trichloroacetic acid					15%	15%	UV	-	10	Advanced oxidation processes of decomposing dichloroacetic acid and trichloroacetic acid in water		
Triclocarban						0%	UV	-				
Triclosan	20	ng/L	6.3	ng/L	99%	95%	UV	-	5	San diego		
Trimethoprim					40	40%	UV	-	5	San diego		
Uranium ICAP/MS						0%	UV	-				
Warfarin						0%	UV	-				Compound tested in study - levels in and out below detection limit

RO

	Removal Percentage						Reference No.			Reference Name	Reference Link	Notes
Constituent	Conc. In	units	Conc. Out	units	% Removal	Assigned Value						
1,2-Dichlorobenzene-d4		ng/L		ng/L	92%	92%	RO	-	9	NWRIRejectionofPharmaceuticalsbyRevers	RO-9 NWRIRejectionofPharmaceuticalsbyReverseOsmosisMembranesRidgway.pdf	
1,2-Dichloroethane-d4		ng/L		ng/L	71%	71%	RO	-	8	treatment_b&v_final08_rpt	RO-8 treatment_b&v_final08_rpt.pdf	
1,7-Dimethylxanthine	46	ng/L	4	ng/L	91%	91%	RO	-	14	UNM Howe Final	RO-14 UNM Howe Final PPCP Ozone-Biofiltration Report.pdf	
2,4-D	2200	ng/L	6.4	ng/L	100%	95%	RO	-	6	awpfappendixb	RO-6 awpfappendixb.pdf	
2-Butanone (MEK)		ng/L		ng/L	73%	73%	RO	-	12	Chemical Data	RO-12 ChemicalData.pdf	
3-Hydroxycarbofuran		ng/L		ng/L	90%	90%	RO	-	10	membranes for removing organics from dri	RO-10 Membranes for Removing Organics from Drinking Water.PDF	
4-tert-Octylphenol	220	ng/L	BDL	ng/L	100%	95%	RO	-	1	Yucaipa Emerging Constituents	RO-1 Yucaipa Emerging constituents_2013 results.pdf	
Acesulfame-K	33000	ng/L	69	ng/L	100%	95%	RO	-	6	awpfappendixb	RO-6 awpfappendixb.pdf	
Acetaminophen	8.3	ng/L	BDL	ng/L	100%	95%	RO	-	6	awpfappendixb	RO-6 awpfappendixb.pdf	
Albuterol	34	ng/L	BDL	ng/L	100%	95%	RO	-	1	Yucaipa Emerging Constituents	RO-1 Yucaipa Emerging constituents_2013 results.pdf	
Aldicarb sulfone		ng/L		ng/L	96%	95%	RO	-	10	membranes for removing organics from dri	RO-10 Membranes for Removing Organics from Drinking Water.PDF	
Aluminum Total ICAP/MS		ng/L		ng/L	99%	95%	RO	-	16	Solute	RO-16 Solute.pdf	
Amoxicillin (semi-quantitative)	3300	ng/L	BDL	ng/L	100%	95%	RO	-	1	Yucaipa Emerging Constituents	RO-1 Yucaipa Emerging constituents_2013 results.pdf	
Antimony Total ICAP/MS	13200	ng/L	100	ng/L	99%	95%	RO	-	13	Arsenic and Antimony Removal from Drinki	RO-13 Arsenic and Antimony Removal from Drinking Water.pdf	
Arsenic Total ICAP/MS		ng/L		ng/L	99%	95%	RO	-	7	ETV Arsenic Removal	RO-7 ETVArsenicRemoval.pdf	
Atenolol	74	ng/L	BDL	ng/L	100%	95%	RO	-	1	Yucaipa Emerging Constituents	RO-1 Yucaipa Emerging constituents_2013 results.pdf	
Atrazine		ng/L		ng/L	99%	95%	RO	-	11	Water Quality & Treatment: Chapter 11	RO-11 Water Quality & Treatment-Chapter 11.pdf	
Azithromycin	240	ng/L	BDL	ng/L	100%	95%	RO	-	1	Yucaipa Emerging Constituents	RO-1 Yucaipa Emerging constituents_2013 results.pdf	
Barium Total ICAP/MS		ng/L		ng/L	98%	95%	RO	-	16	Solute	RO-16 Solute.pdf	
Bezafibrate	6	ng/L	BDL	ng/L	100%	95%	RO	-	6	awpfappendixb	RO-6 awpfappendixb.pdf	
BPA	81	ng/L	BDL	ng/L	100%	95%	RO	-	6	awpfappendixb	RO-6 awpfappendixb.pdf	
Bromacil		ng/L		ng/L	#DIV/0!	0%	RO	-				
Bromodichloromethane		ng/L		ng/L	79%	79%	RO	-	23	Rejection of Pharmaceuticals by Reverse Osmosis Membranes: Quantitative Structure Activity Relationship (QSAR) Analysis		
Bromoform	-	ng/L	-	ng/L	67%	67%	RO	-	3	Quinoline DOW FILMTEC	RO-3 Quinoline DOW FILMTEC Membran Produktinformationen.pdf	
Butalbital	49	ng/L	BDL	ng/L	100%	95%	RO	-	1	Yucaipa Emerging Constituents	RO-1 Yucaipa Emerging constituents_2013 results.pdf	
Caffeine	-	ng/L	-	ng/L	99%	95%	RO	-	3	Quinoline DOW FILMTEC	RO-3 Quinoline DOW FILMTEC Membran Produktinformationen.pdf	
Carbamazepine	309	ng/L	2.4	ng/L	99%	95%	RO	-	4	San Diego - advancedfinalrpt	RO-4 San Diego - advancedfinalrpt.pdf	
Carisoprodol	200	ng/L	BDL	ng/L	100%	95%	RO	-	6	awpfappendixb	RO-6 awpfappendixb.pdf	
Chloride	260	ng/L	2.2	ng/L	99%	95%	RO	-	6	awpfappendixb	RO-6 awpfappendixb.pdf	
Chlorodibromomethane		ng/L		ng/L	79%	79%	RO	-	12	Chemical Data	RO-12 ChemicalData.pdf	
Chloroform		ng/L		ng/L	95%	95%	RO	-	24	Removal of Humic Acid and Chloroform from Drinking Water Using Commercial NF and RO Membranes		
Chromium Total ICAP/MS		ng/L		ng/L	#DIV/0!	0%	RO	-				
Cimetidine	970	ng/L	BDL	ng/L	100%	95%	RO	-	1	Yucaipa Emerging Constituents	RO-1 Yucaipa Emerging constituents_2013 results.pdf	
Cotinine	72	ng/L	BDL	ng/L	100%	95%	RO	-	1	Yucaipa Emerging Constituents	RO-1 Yucaipa Emerging constituents_2013 results.pdf	
Cyanide		ng/L		ng/L	95%	95%	RO	-	20	Dow Filmtec		
DEA		ng/L		ng/L	#DIV/0!	0%	RO	-				
DEET	375	ng/L	2.6	ng/L	99%	95%	RO	-	4	San Diego - advancedfinalrpt	RO-4 San Diego - advancedfinalrpt.pdf	
Dehydronifedipine	320	ng/L	BDL	ng/L	100%	95%	RO	-	1	Yucaipa Emerging Constituents	RO-1 Yucaipa Emerging constituents_2013 results.pdf	
Di(2-Ethylhexyl)phthalate		ng/L		ng/L	94%	94%	RO	-	12	Chemical Data	RO-12 ChemicalData.pdf	
DIA	16	ng/L	BDL	ng/L	100%	95%	RO	-	1	Yucaipa Emerging Constituents	RO-1 Yucaipa Emerging constituents_2013 results.pdf	
Dicamba		ng/L		ng/L	#DIV/0!	0%	RO	-				
Dichloroacetic acid	8	ng/L	0.2	ng/L	98%	95%	RO	-	6	awpfappendixb	RO-6 awpfappendixb.pdf	
Diclofenac	27	ng/L	BDL	ng/L	100%	95%	RO	-	1	Yucaipa Emerging Constituents	RO-1 Yucaipa Emerging constituents_2013 results.pdf	
Dilantin	144	ng/L	1	ng/L	99%	95%	RO	-	4	San Diego - advancedfinalrpt	RO-4 San Diego - advancedfinalrpt.pdf	
Diltiazem		ng/L		ng/L	#DIV/0!	0%	RO	-				
Diuron	47	ng/L		ng/L	100%	95%	RO	-	6	awpfappendixb	RO-6 awpfappendixb.pdf	
Erythromycin	375	ng/L	BDL	ng/L	100%	95%	RO	-	4	San Diego - advancedfinalrpt	RO-4 San Diego - advancedfinalrpt.pdf	
Estrone	182	ng/L	BDL	ng/L	100%	95%	RO	-	4	San Diego - advancedfinalrpt	RO-4 San Diego - advancedfinalrpt.pdf	
Fluoride	0.6	ng/L		ng/L	100%	95%	RO	-	6	awpfappendixb	RO-6 awpfappendixb.pdf	
Fluoxetine	180	ng/L	BDL	ng/L	100%	95%	RO	-	1	Yucaipa Emerging Constituents	RO-1 Yucaipa Emerging constituents_2013 results.pdf	
Gemfibrozil	1700	ng/L	1.3	ng/L	100%	95%	RO	-	4	San Diego - advancedfinalrpt	RO-4 San Diego - advancedfinalrpt.pdf	
Ibuprofen	27	ng/L	BDL	ng/L	100%	95%	RO	-	4	San Diego - advancedfinalrpt	RO-4 San Diego - advancedfinalrpt.pdf	
Iohexal	3300	ng/L	BDL	ng/L	100%	95%	RO	-	1	Yucaipa Emerging Constituents	RO-1 Yucaipa Emerging constituents_2013 results.pdf	
Iopromide	681	ng/L	1.4	ng/L	100%	95%	RO	-	4	San Diego - advancedfinalrpt	RO-4 San Diego - advancedfinalrpt.pdf	
Iron Total ICAP	63	ng/L	BDL	ng/L	100%	95%	RO	-	6	awpfappendixb	RO-6 awpfappendixb.pdf	
Ketoprofen	24	ng/L		ng/L	100%	95%	RO	-	6	awpfappendixb	RO-6 awpfappendixb.pdf	
Ketorolac		ng/L		ng/L	#DIV/0!	0%	RO	-				
Lead Total ICAP/MS		ng/L		ng/L	#DIV/0!	95%	RO	-	22	Water Treatment Guide	http://www.watertreatmentguide.com/Membrane_Rejection.htm	
Lidocaine	310	ng/L		ng/L	100%	95%	RO	-	6	awpfappendixb	RO-6 awpfappendixb.pdf	
Lincomycin	17	ng/L	BDL	ng/L	100%	95%	RO	-	1	Yucaipa Emerging Constituents	RO-1 Yucaipa Emerging constituents_2013 results.pdf	
Lopressor	1300	ng/L	BDL	ng/L	100%	95%	RO	-	1	Yucaipa Emerging Constituents	RO-1 Yucaipa Emerging constituents_2013 results.pdf	
Manganese Total ICAP/MS	62	ng/L	BDL	ng/L	100%	95%	RO	-	6	awpfappendixb	RO-6 awpfappendixb.pdf	
Meprobamate	279	ng/L	1.5	ng/L	99%	95%	RO	-	4	San Diego - advancedfinalrpt	RO-4 San Diego - advancedfinalrpt.pdf	
Methomyl		ng/L		ng/L	#DIV/0!	0%	RO	-				
Metolachlor		ng/L		ng/L	100%	95%	RO	-	10	membranes for removing organics from dri	RO-10 Membranes for Removing Organics from Drinking Water.PDF	
Molybdenum Total ICAP/MS	3210	ng/L	400	ng/L	88%	88%	RO	-	18	Lab Sample Results	Lab Sample Results.xlsx	
Monochloroacetic acid		ng/L		ng/L	#DIV/0!	0%	RO	-				
Naproxen	479	ng/L	1.2	ng/L	100%	95%	RO	-	4	San Diego - advancedfinalrpt	RO-4 San Diego - advancedfinalrpt.pdf	
Nickel Total ICAP/MS		ng/L		ng/L	#DIV/0!	0%	RO	-				
Nifedipine	58	ng/L	BDL	ng/L	100%	95%	RO	-	1	Yucaipa Emerging Constituents	RO-1 Yucaipa Emerging constituents_2013 results.pdf	
Nitrate as NO3 (calc)		ng/L		ng/L	96%	95%	RO	-	16	Solute	RO-16 Solute.pdf	
Nitrite Nitrogen by IC		ng/L		ng/L	92%	92%	RO	-	21	USEPA Reverse Osmosis Treatment to Remove Inorganic Contaminants from Drinking Water		
N-Nitroso-dimethylamine (NDMA	45	ng/L	20	ng/L	56%	56%	RO	-	2	NDMA rremoval by RO and UV treatment	RO-2 NDMA removal by RO and UV treatment.pdf	
p-Dichlorobenzene (1,4-DCB)		ng/L		ng/L	61%	61%	RO	-	12	Chemical Data	RO-12 ChemicalData.pdf	
Pentoxifylline	12	ng/L	BDL	ng/L	100%	95%	RO	-	4	San Diego - advancedfinalrpt	RO-4 San Diego - advancedfinalrpt.pdf	
Primidone	140	ng/L	BDL	ng/L	100%	95%	RO	-	1	Yucaipa Emerging Constituents	RO-1 Yucaipa Emerging constituents_2013 results.pdf	
Propazine		ng/L		ng/L		0%	RO	-				
Quinoline	-	ng/L	-	ng/L	97%	95%	RO	-	3	Quinoline DOW FILMTEC	RO-3 Quinoline DOW FILMTEC Membran Produktinformationen.pdf	
Simazine	17	ng/L	BDL	ng/L	100%	95%	RO	-	1	Yucaipa Emerging Constituents	RO-1 Yucaipa Emerging constituents_2013 results.pdf	
Strontium ICAP		ng/L		ng/L	98%	95%	RO	-	16	Solute	RO-16 Solute.pdf	
Sucralose	69000	ng/L	BDL	ng/L	100%	95%	RO	-	1	Yucaipa Emerging Constituents	RO-1 Yucaipa Emerging constituents_2013 results.pdf	
Sulfadimethoxine		ng/L		ng/L	#DIV/0!	0%						
Sulfamerazine		ng/L		ng/L	#DIV/0!	0%	RO	-				
Sulfamethazine		ng/L		ng/L	99%	95%	RO	-	17	UNM Howe PPCP Final Report	RO-17 UNM Howe PPCP Final Report.pdf	
Sulfamethoxazole	997	ng/L	2.2	ng/L	100%	95%	RO	-	4	San Diego - advancedfinalrpt	RO-4 San Diego - advancedfinalrpt.pdf	
Sulfathiazole		ng/L		ng/L	#DIV/0!	0%	RO	-				
TCEP	880	ng/L	BDL	ng/L	100%	95%	RO	-	1	Yucaipa Emerging Constituents	RO-1 Yucaipa Emerging constituents_2013 results.pdf	
TCPP	540	ng/L	BDL	ng/L	100%	95%	RO	-	1	Yucaipa Emerging Constituents	RO-1 Yucaipa Emerging constituents_2013 results.pdf	
TDCPP	270	ng/L	BDL	ng/L	100%	95%	RO	-	1	Yucaipa Emerging Constituents	RO-1 Yucaipa Emerging constituents_2013 results.pdf	
Theobromine	400	ng/L	19	ng/L	95%	95%	RO	-	6	awpfappendixb	RO-6 awpfappendixb.pdf	
Theophylline	130	ng/L	BDL	ng/L	100%	95%	RO	-	1	Yucaipa Emerging Constituents	RO-1 Yucaipa Emerging constituents_2013 results.pdf	
Toluene		ng/L		ng/L	94%	94%	RO	-	9	NWRIRejectionofPharmaceuticalsbyRevers	RO-9 NWRIRejectionofPharmaceuticalsbyReverseOsmosisMembranesRidgway.pdf	
Tot DCPA Mono&Diacid Degradate		ng/L		ng/L	#DIV/0!	0%	RO	-				
Trichloroacetic acid		ng/L		ng/L	90%	90%	RO	-	25	Rejection of Trace Organic Compounds by Reverse Osmosis and Nanofiltration Membranes		
Triclocarban	233	ng/L	5	ng/L	98%	95%	RO	-	15	FSAWWA Presentation slides	RO-15 fsawwa presentation slides.pdf	
Triclosan	60	ng/L	12	ng/L	80%	95%	RO	-	6	awpfappendixb	RO-6 awpfappendixb.pdf	
Trimethoprim	427	ng/L	2.2	ng/L	99%	95%	RO	-	4	San Diego - advancedfinalrpt	RO-4 San Diego - advancedfinalrpt.pdf	
Uranium ICAP/MS		ng/L		ng/L	99%	95%	RO	-	19	Clifford University of Houston		
Warfarin		ng/L		ng/L	#DIV/0!	0%	RO	-				

MF/UF

	Removal Percentage						Reference No.			Reference Name	Reference Link	Notes
Constituent	Conc. In	units	Conc. Out	units	% Removal	Assigned Value						
1,2-Dichlorobenzene-d4						0%	MF	-				
1,2-Dichloroethane-d4						0%	MF	-				
1,7-Dimethylxanthine						0%	MF	-				
2,4-D						0%	MF	-				
2-Butanone (MEK)						0%	MF	-				
3-Hydroxycarbofuran						0%	MF	-				
4-tert-Octylphenol						0%	MF	-				
Acesulfame-K						0%	MF	-				
Acetaminophen					50%	50%	MF	-	1	CEC Literature	MF-1 cecliterature.pdf	
Albuterol	9.6	ng/L	6.6	ng/L	31%	31%	MF	-	3	awpfappendixb	MF-3 awpfappendixb.pdf	
Aldicarb sulfone		ng/L		ng/L		0%	MF	-				
Aluminum Total ICAP/MS	16400	ng/L	13300	ng/L	19%	19%	MF	-	2	San Diego- advancedfinalrpt	MF-2 San Diego - advancedfinalrpt.pdf	
Amoxicillin (semi-quantitative)		ng/L		ng/L		0%	MF	-				
Antimony Total ICAP/MS	622	ng/L	614	ng/L	1%	1%	MF	-	2	San Diego- advancedfinalrpt	MF-2 San Diego - advancedfinalrpt.pdf	
Arsenic Total ICAP/MS	2030	ng/L	1930	ng/L	5%	5%	MF	-	2	San Diego- advancedfinalrpt	MF-2 San Diego - advancedfinalrpt.pdf	
Atenolol		ng/L		ng/L	100%	95%	MF	-	1	CEC Literature	MF-1 cecliterature.pdf	
Atrazine		ng/L		ng/L	8%	8%	MF	-	1	CEC Literature	MF-1 cecliterature.pdf	
Azithromycin		ng/L		ng/L		0%	MF	-				
Barium Total ICAP/MS		ng/L		ng/L		0%	MF	-				
Bezafibrate		ng/L		ng/L		0%	MF	-				
BPA		ng/L		ng/L	76%	76%	MF	-	1	CEC Literature	MF-1 cecliterature.pdf	
Bromacil		ng/L		ng/L		0%	MF	-				
Bromodichloromethane		ng/L		ng/L		0%	MF	-				
Bromoform		ng/L		ng/L		0%	MF	-				
Butalbital		ng/L		ng/L		0%	MF	-				
Caffeine		ng/L		ng/L	49%	49%	MF	-	1	CEC Literature	MF-1 cecliterature.pdf	
Carbamazepine		ng/L		ng/L	100%	95%	MF	-	1	CEC Literature	MF-1 cecliterature.pdf	
Carisoprodol		ng/L		ng/L		0%	MF	-				
Chloride		ng/L		ng/L		0%	MF	-				
Chlorodibromomethane		ng/L		ng/L		0%	MF	-				
Chloroform		ng/L		ng/L		0%	MF	-				
Chromium Total ICAP/MS		ng/L		ng/L		0%	MF	-				
Cimetidine		ng/L		ng/L		0%	MF	-				
Cotinine	31	ng/L	18	ng/L	42%	42%	MF	-	3	awpfappendixb	MF-3 awpfappendixb.pdf	
Cyanide		ng/L		ng/L		0%	MF	-				
DEA		ng/L		ng/L		0%	MF	-				
DEET		ng/L		ng/L	54%	54%	MF	-	1	CEC Literature	MF-1 cecliterature.pdf	
Dehydronifedipine	374	ng/L	361	ng/L	3%	3%	MF	-	3	awpfappendixb	MF-3 awpfappendixb.pdf	
Di(2-Ethylhexyl)phthalate	2.76	ng/L	2.2	ng/L	20%	20%	MF	-	4	Wastewater NOM Composition Following Chemically Enhanced Primary Treatment and Microfiltration		
DIA		ng/L		ng/L		0%	MF	-				
Dicamba		ng/L		ng/L		0%	MF	-				
Dichloroacetic acid		ng/L		ng/L		0%	MF	-				
Diclofenac		ng/L		ng/L	100%	95%	MF	-	1	CEC Literature	MF-1 cecliterature.pdf	
Dilantin		ng/L		ng/L	89%	89%	MF	-	1	CEC Literature	MF-1 cecliterature.pdf	
Diltiazem		ng/L		ng/L		0%	MF	-				
Diuron		ng/L		ng/L		0%	MF	-				
Erythromycin		ng/L		ng/L	57%	57%	MF	-	1	CEC Literature	MF-1 cecliterature.pdf	
Estrone		ng/L		ng/L	94%	94%	MF	-	1	CEC Literature	MF-1 cecliterature.pdf	
Fluoride		ng/L		ng/L		0%	MF	-				
Fluoxetine		ng/L		ng/L	99%	95%	MF	-	1	CEC Literature	MF-1 cecliterature.pdf	
Gemfibrozil		ng/L		ng/L	99%	95%	MF	-	1	CEC Literature	MF-1 cecliterature.pdf	
Ibuprofen		ng/L		ng/L	8%	8%	MF	-	1	CEC Literature	MF-1 cecliterature.pdf	
Iohexal	9500	ng/L	8700	ng/L	8%	8%	MF	-	3	awpfappendixb	MF-3 awpfappendixb.pdf	
Iopromide		ng/L		ng/L	95%	95%	MF	-	1	CEC Literature	MF-1 cecliterature.pdf	
Iron Total ICAP		ng/L		ng/L		0%	MF	-				
Ketoprofen	38	ng/L	24	ng/L	37%	37%	MF	-	3	awpfappendixb	MF-3 awpfappendixb.pdf	
Ketorolac		ng/L		ng/L		0%	MF	-				
Lead Total ICAP/MS		ng/L		ng/L		0%	MF	-				
Lidocaine		ng/L		ng/L		0%	MF	-				
Lincomycin		ng/L		ng/L		0%	MF	-				
Lopressor	400	ng/L	300	ng/L	25%	25%	MF	-	3	awpfappendixb	MF-3 awpfappendixb.pdf	
Manganese Total ICAP/MS	123000	ng/L	113000	ng/L	8%	8%	MF	-	2	San Diego- advancedfinalrpt	MF-2 San Diego - advancedfinalrpt.pdf	
Meprobamate		ng/L		ng/L	70%	70%	MF	-	1	CEC Literature	MF-1 cecliterature.pdf	
Methomyl		ng/L		ng/L		0%	MF	-				
Metolachlor		ng/L		ng/L	56%	56%	MF	-	1	CEC Literature	MF-1 cecliterature.pdf	
Molybdenum Total ICAP/MS		ng/L		ng/L		0%	MF	-				
Monochloroacetic acid		ng/L		ng/L		0%	MF	-				
Naproxen		ng/L		ng/L	98%	95%	MF	-	1	CEC Literature	MF-1 cecliterature.pdf	
Nickel Total ICAP/MS	4680	ng/L	4380	ng/L	6%	6%	MF	-	2	San Diego- advancedfinalrpt	MF-2 San Diego - advancedfinalrpt.pdf	
Nifedipine		ng/L		ng/L		0%	MF	-				
Nitrate as NO3 (calc)	47400	ng/L	36100	ng/L	24%	24%	MF	-	2	San Diego- advancedfinalrpt	MF-2 San Diego - advancedfinalrpt.pdf	
Nitrite Nitrogen by IC		ng/L		ng/L		0%	MF	-				
N-Nitroso-dimethylamine (NDMA	4.2	ng/L	3.5	ng/L	17%	17%	MF	-	3	awpfappendixb	MF-3 awpfappendixb.pdf	
p-Dichlorobenzene (1,4-DCB)		ng/L		ng/L		0%	MF	-				
Pentoxifylline		ng/L		ng/L	10%	10%	MF	-	1	CEC Literature	MF-1 cecliterature.pdf	
Primidone	110	ng/L	96	ng/L	13%	13%	MF	-	3	awpfappendixb	MF-3 awpfappendixb.pdf	
Propazine		ng/L		ng/L		0%	MF	-				
Quinoline		ng/L		ng/L		0%	MF	-				
Simazine	7.6	ng/L	5.1	ng/L	33%	33%	MF	-	3	awpfappendixb	MF-3 awpfappendixb.pdf	
Strontium ICAP		ng/L		ng/L		0%	MF	-				
Sucralose	48000	ng/L	20000	ng/L	58%	58%	MF	-	3	awpfappendixb	MF-3 awpfappendixb.pdf	
Sulfadimethoxine		ng/L		ng/L		0%						
Sulfamerazine		ng/L		ng/L	25%	25%	MF	-	1	CEC Literature	MF-1 cecliterature.pdf	
Sulfamethazine		ng/L		ng/L		0%	MF	-				
Sulfamethoxazole		ng/L		ng/L	99%	95%	MF	-	1	CEC Literature	MF-1 cecliterature.pdf	
Sulfathiazole		ng/L		ng/L		0%	MF	-				
TCEP	225	ng/L	220	ng/L	2%	2%	MF	-	2	San Diego- advancedfinalrpt	MF-2 San Diego - advancedfinalrpt.pdf	
TCPP		ng/L		ng/L		0%	MF	-				
TDCPP	720	ng/L	600	ng/L	17%	17%	MF	-	3	awpfappendixb	MF-3 awpfappendixb.pdf	
Theobromine		ng/L		ng/L		0%	MF	-				
Theophylline	57	ng/L	48	ng/L	16%	16%	MF	-	3	awpfappendixb	MF-3 awpfappendixb.pdf	
Toluene		ng/L		ng/L		0%	MF	-				
Tot DCPA Mono&Diacid Degradate		ng/L		ng/L		0%	MF	-				
Trichloroacetic acid	1480	ng/L	1470	ng/L	1%	1%	MF	-	2	San Diego- advancedfinalrpt	MF-2 San Diego - advancedfinalrpt.pdf	
Triclocarban		ng/L		ng/L		0%	MF	-				
Triclosan		ng/L		ng/L	98%	95%	MF	-	1	CEC Literature	MF-1 cecliterature.pdf	
Trimethoprim		ng/L		ng/L	97%	95%	MF	-	1	CEC Literature	MF-1 cecliterature.pdf	
Uranium ICAP/MS		ng/L		ng/L		0%	MF	-				
Warfarin		ng/L		ng/L		0%	MF	-				

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Appendix:

Example Pilot Protocols

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TECHNICAL MEMORANDUM

Digitally signed by Alan E. Davis
DN: cn=Alan E. Davis, o=Alan Plummer Associates, Inc, ou, email=adavis@apaienv.com, c=US
Date: 2015.04.28 16:29:01 -05'00'

Texas Water Development Board
Evaluating the Potential for Direct Potable Reuse in Texas
Task 9: Sample Pilot Protocols

Project No.: 0866-005-01

Date: April 19, 2015

Prepared For: Project Team and Sponsors

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1 Pilot Testing Protocol Outline – Supplemental Information

The intent of this section is to provide general guidelines and considerations for the development of a DPR pilot testing protocol. The information presented will most likely require modification to suit project and utility needs on a case-by-case basis. Consultation with the TCEQ is recommended to verify that the pilot testing protocol is acceptable for the proposed DPR project.

- Introduction
  - Identify the affiliation of and the relationship between the parties involved in the pilot study; the name and location of the facility where the testing will be conducted; and the purpose of the pilot study. Provide an overview of the water source, pretreatment processes and overall treatment scheme, anticipated pilot testing duration, and testing stages.
- Background
  - Existing Facility Description
    - Describe the existing WWTP inclusive of primary, secondary, and tertiary treatment processes and chemical additions (as applicable). Define the location and hydraulic condition of the feed water source for the pilot equipment. Provide a process flow diagram of the existing WWTP.
  - Feed Water Quality Data
    - Present a summary of historical water quality data (as available, a minimum of 1 to 2 years is preferred) to characterize the wastewater treatment plant (WWTP) effluent at the test location. The historical data should include parameters that affect the proposed

advanced treatment equipment. It may be useful to conduct a series of effluent sampling events to establish values for water quality parameters that are not normally collected during routine process monitoring and compliance testing activities. Collected parameters should include typical wastewater effluent parameters (i.e. BOD, TSS, NH_3, DO, pH, alkalinity, chlorine residual, etc.) as well as parameters that are relevant to the advanced treatment processes being considered for the full-scale facility (i.e. total hardness, TDS, TOC, DOC, metals, sulfate, CECs etc.).

  - Proposed Treatment Scheme
    - Describe the planned DPR expansion and any modifications to existing WWTP processes (if applicable) inclusive of timeline, capacity, pretreatment processes, and anticipated water quality changes.
    - Provide a process flow description for the pilot system inclusive of pretreatment processes, sampling locations, and waste discharge locations.
- Objectives
  - Define and prioritize pilot testing objectives. Typical pilot testing objectives include:
    - Establishing design criteria for full-scale facility design;
    - Establishing operating parameters for sustainable and efficient equipment operation;
    - Satisfying TCEQ and pilot testing protocol requirements;
    - Identifying operational challenges and developing solutions;
    - Determining design criteria for ancillary equipment and systems;
    - Familiarizing staff with equipment operation and maintenance activities;
    - Determining size of treatment equipment;
    - Developing opinions of probable construction cost and operating cost for a full-scale system; and/or
    - Determining the effects of the piloted treatment process on downstream processes via coordination between other pilot and/or bench-scale studies.
- Site Description
  - Describe and prepare a site plan of the pilot testing site inclusive of shelter; feed and waste piping; electrical and communication wiring/conduits; and the maximum footprint for the complete pilot system with break tanks, air compressors, cleaning solutions, etc.
- Equipment Requirements
  - Define equipment specifications and the vendor’s scope of supply with respect to pilot testing equipment, ancillary equipment, instrumentation, etc. Coordinate with vendors to determine requirements for feed, waste, electrical, and communication connections to the pilot systems.
- Division of Responsibilities

  - Define the roles and responsibilities of each party involved in the pilot study. Items to consider include:
    - Pilot equipment shipping, unloading and unpacking, installation, pipe and wiring connections, startup and commissioning, operation, cleaning, maintenance, repair, disconnection, packing, loading, and return shipping;
    - Provision of chemicals, electricity, and data transfer service;
    - Water quality sampling, shipping, and laboratory analysis;
    - Data collection and analysis; and
    - Draft pilot report preparation, incorporation of comments, and final report submission.
- Performance Requirements
  - Define the performance criteria and goals to be achieved by the equipment during pilot testing. Applicable performance criteria are dependent on the technology and may include items such as process cleaning frequency, effluent water quality, loading rates, allowable fouling, etc.
- Test Stages
  - Define testing stages such that design criteria and operating parameters may be established and regulatory requirements satisfied.
- Test Schedule
  - Prioritize and sequence pilot testing tasks according to project goals, project constraints, task duration, and task interdependency. Consideration should be given to seasonal water quality variability when establishing the pilot study schedule.
- Data Collection
  - Establish a data collection plan to satisfy the pilot testing objectives and verify the achievement of performance requirements.
    - Process Data
      - Specify the process parameters to be monitored with instruments, the recording frequency, the recording method, and the frequency of data collection and reporting. Applicable performance criteria are dependent on the technology and may include items such as temperature, pH, turbidity, conductivity, pressure, flow, chemical consumption, etc.
    - Water Quality Data
      - Specify the water quality parameters to be sampled and tested, the sampling locations, and the sampling frequencies. Consider seasonal and diurnal water quality variability when developing the sampling plan. It may be beneficial to collect samples for pretreatment processes in addition to the process streams of the piloted

equipment. Applicable water quality parameters are dependent on the technology and may include items such as total alkalinity, total organic carbon, chlorine, ammonia, iron, etc.

- Assign sampling and testing responsibilities and determine sampling costs.

- Quality Assurance/Quality Control Procedures
    - Establish quality assurance/quality control (QA/QC) procedures to verify the accuracy of pilot testing results. A QA/QC program should consider pilot equipment inspection frequency, routine equipment maintenance frequency, equipment repair and emergency response protocols, instrument calibration and verification frequency, laboratory certifications, sample collection procedures, analytical methods, etc.
- Progress Updates, Meetings, and Reports
    - Progress Updates
        - Specify the frequency and contents of routine progress updates. Consider requiring vendors to provide regular data analysis summaries (in addition to independent analyses performed by the engineer) so that testing protocol compliance may be monitored on a regular basis.
    - Meetings and Conference Calls
        - Specify the frequency and purpose of routine meetings and conference calls to review pilot testing progress and address issues.
    - Reports
        - Specify the frequency and contents of reports to be provided by the vendor(s). At a minimum, vendor reports should include a detailed analysis and discussion of the pilot testing data; explanations for and durations of downtime; conclusions concerning equipment performance and reliability; and recommended design and operating criteria for a full-scale system. The individual vendor reports will be attached as appendices to a final report incorporating water quality data, equipment descriptions, layout and schematics, QA/QC information, calibration documentation, and the engineer's independent analysis of process data and equipment performance.

2 Bench-Scale Testing Protocol Outline – Supplemental Information

The intent of this section is to provide general guidelines and considerations for the development of a DPR bench-scale test. The information presented will most likely require modification to suit project and utility needs on a case-by-case basis. Consultation with the TCEQ is recommended to verify that the bench-scale testing protocol is acceptable for the proposed DPR project.

- Introduction
  - Identify the affiliation of and the relationship between the parties involved in the bench-scale test and the purpose of the bench-scale test.
- Background
  - Existing Facility Description
    - Describe the existing WWTP treatment scheme inclusive of collection system chemical feed and primary, secondary, and tertiary treatment processes (as applicable).
  - Water Quality Data
    - Characterize the WWTP effluent by presenting historic water quality data. The data should include parameters that affect the proposed advanced treatment equipment to be tested. Additional effluent sampling may be useful in order to establish baseline values for water quality parameters not routinely collected at the WWTP during monitoring and compliance testing.
- Objectives
  - Define and prioritize the bench-scale test objectives. Some typical bench-scale test objectives include:
    - Identifying contaminant removal efficiency;
    - Assessing byproduct formation (i.e. bromate formation for ozone);
    - Determining design criteria for full-scale treatment equipment;
    - Satisfying regulatory requirements; and/or
    - Developing opinions of probable construction and operating cost.
- Equipment and Methods
  - Describe the bench-scale testing equipment, define the test method(s), and specify the source water.
- Division of Responsibilities
  - Define the roles and responsibilities of each party involved in the bench-scale study. Items to consider include:
    - Provision of water quality samples to an external laboratory and identification of the scope of services (if bench-scale testing is performed by a third party);
    - Acquisition of bench-scale equipment and supplies including shipping, unloading and unpacking, installation, pipe and wiring connections, startup and commissioning,

operation, cleaning, maintenance, repair, disconnection, packing, loading, and return shipping (if testing performed by owner);
        - Provision of chemicals and electricity (as applicable);
        - Water quality sampling, shipping, and laboratory analysis;
        - Data collection and analysis; and
        - Draft bench-scale report preparation, incorporation of comments, and final report submission.
- Test Plan
    - Define the bench-scale test matrix and sequence of testing.
- Sample Plan
    - Specify the water quality parameters to be sampled, sampling frequencies, and sampling locations. Consider variations due to seasonal and diurnal water quality when developing the sampling plan as well as impacts from variable sources such as industry, resorts, hospitals, WTP waste streams, sludge recycle streams, etc.
- Quality Assurance/Quality Control Procedures
    - Establish procedures to verify the accuracy of the sample analyses during the bench-scale test. All labs should provide certifications, analytical methods used, maximum sample holding times, blanks, etc.
- Final Report
    - A report should include (at a minimum) a detailed analysis and discussion of the bench-scale test results; conclusions concerning treatment performance and reliability; and recommended design criteria for a full-scale system.

3 Example Scenario I - Example Protocol[1]

3.1 Introduction

For this example scenario, a North Texas municipality (City) is assumed to be conducting a pilot-scale UF study, a pilot-scale ozone study, a pilot-scale BAC filter study, and a bench-scale chlorine study at a

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[1] For Example Scenario I, Treatment Scheme No. 5, which consists of UF, ozone, BAC filter, and chlorine disinfection processes in series upstream of a WTP, has been selected for the development of a sample DPR treatment protocol. The protocol is intended to provide a reference tool for use by practitioners during the development of project-specific testing protocols. Accordingly, the protocol contains general pilot- and bench-scale testing considerations and does not reference project-specific contaminants or treatment considerations. It is assumed that a robust sampling plan to identify contaminants (refer to Tasks 2 and 3 of this project) and risk assessment (refer to Task 8 of this project) have been performed and that the selected treatment scheme is applicable for treatment of the hypothetical North Texas source water. It is recommended that DPR treatment study protocols be developed on a case-by-case basis to address project-specific treatment goals and requirements.

WWTP. The purpose of the four studies is to satisfy TCEQ testing requirements, establish process design criteria, evaluate contaminant reduction efficiency, assist with procurement activities, and familiarize operators with new technologies and equipment. It is assumed that an engineering firm (Engineer) would be retained by the City to conduct the studies in coordination with the individual vendors.

3.2 Background

This section contains background information concerning the existing facility, effluent water quality, and the DPR treatment scheme.

3.2.1 Existing Facility Description

The WWTP is an activated sludge nitrification facility that traditionally discharges a portion of the effluent to a nearby stream. Existing full-scale treatment consists of screens, grit removal, primary clarifiers, aeration basins, secondary clarifiers, tertiary filters, chlorine gas disinfection, and dechlorination.

3.2.2 Tertiary Effluent Water Quality

The advanced treatment system will treat tertiary effluent prior to chlorine disinfection. The following generic assumptions concerning tertiary effluent water quality are provided:

- Biological nutrient removal (BNR) is added to the existing WWTP to reduce effluent nitrogen and phosphorous concentrations;
- The total dissolved solids concentration is less than 1000 mg/L; and
- Industrial inputs into the waste collection system are minimal and an effective source control program has been implemented (refer to Task 5 of this project).

3.2.3 Treatment Scheme

Treatment Scheme No. 5 (Figure 1) was selected for Example Scenario I. The treatment scheme consists of MF or UF, ozone, BAC filter, and chlorine disinfection processes in series upstream of a WTP. The MF/UF process could be utilized downstream of the BAC filter rather than upstream of ozonation if suitable for site-specific feed water quality and project-specific goals and requirements. Please refer to Task 6 of this project for additional information on Treatment Scheme No. 5. It is assumed that an adsorption process is not needed to remove contaminants from the source water that would pass through this treatment scheme.

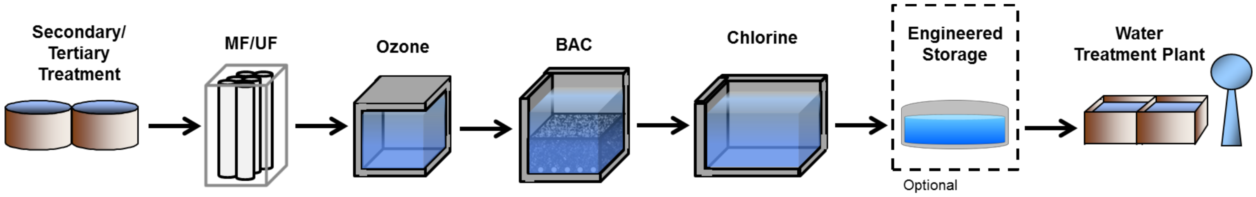

Figure 1: Example Scenario I – Treatment Scheme No. 5

3.3 UF Pilot-Scale Testing Protocol

This section presents a sample UF pilot-scale testing protocol[2].

3.3.1 Objectives

The objectives of the UF pilot test are as follows:

- Satisfy TCEQ pilot testing requirements;
- Determine design flux, recovery, chemically enhanced backwash (CEB) frequency and regime, chemical clean-in-place (CIP) frequency and regime(s), chemical usage, electrical usage, as well as other design parameters for full-scale process design;
- Collect water quality data and determine treatment efficiency;
- Identify multiple successful membrane Vendors as evaluated on the basis of demonstrated flux, recovery, backwash frequency, chemical cleaning frequency, and other considerations;
- Determine design criteria for ancillary systems such as chemical feed and CIP systems;
- Identify potential fouling issues and develop mitigation or cleaning solutions; and
- Familiarize staff with the operation and maintenance of the UF process and ancillary equipment.

3.3.2 Pilot Testing Site Description

The pilot units will be housed in an indoor structure that is heated during the winter months. A rollup door will provide access to the testing site for equipment installation and removal. Feed and waste piping, as well as communication and electrical connections will be provided for Vendor use. Compressed air is not available at the test site. Vendors requiring compressed air shall furnish their own equipment suitable to their individual needs.

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[2] The sample UF protocol should be modified or augmented to suit project specific needs. Additional resources for pilot protocol development include TCEQ guidance and the USEPA *Membrane Filtration Guidance Manual* (USEPA, 2005).

3.3.3 Equipment Requirements

Vendor equipment shall satisfy the following minimum requirements:

General Equipment Requirements:

- Provide a positive pressure-driven, hollow-fiber UF membrane system that operates in a direct ("dead end") mode of filtration;
- Provide a complete, automated, and fully functional pilot system capable of completing the testing requirements outlined in this protocol. The pilot system shall include all pre-screens, pumps, piping, valves, tanks, air compressors, instruments, PLCs, sample panels, ancillary equipment, and spare parts required to perform filtration, backwash, CEB, CIP, data recording, and other applicable activities during the pilot study. The City will not furnish feed water booster pumps or air compressors; and
- Provide the capability for remote, real-time monitoring, downloading, and trending of pilot system data for use by the City, Engineer, and Vendor.

Membrane Requirements:

- Provide at least one new, full-sized membrane for the pilot study. The composition, size, and design of the membrane modules/fibers used for the pilot system shall be the exact same as those that will be proposed for the planned full-scale system;
- Provide a membrane that has an active material of either polyethersulfone (PES) or polyvinylidene difluoride (PVDF) and achieves a high oxidant tolerance;
- Present documentation that the piloted membrane and equipment conform to American National Standards Institute/National Sanitation Foundation (ANSI/NSF) Standard 61 and have been certified by a testing organization accredited by ANSI; and
- Have obtained or submitted an application to obtain TCEQ approval of challenge testing for the removal of microbial contaminants to achieve a minimum $LRV_{C\text{-}Test}$ value of 4-log;

Instrumentation Requirements:

Provide instrumentation to measure and record parameters in accordance with Table 1 (as applicable).

Instrumentation shall also be provided to measure and record UF system power consumption.

Table 1: UF Pilot Instrumentation Requirements

Parameter	Feed	Filtrate	Backwash/CEB	Air Scour
Flow Meter		X	X	X
Pressure Gauge (Bourdon Type)	X	X	X	X

Parameter	Feed	Filtrate	Backwash/CEB	Air Scour
Pressure Transmitter	X	X	X	X
Turbidity Meters[3]	X	X		
pH Meter	X		X	
Temperature Meter	X		X	

Specific details required for the City to complete pilot system installation, such as pilot system connection sizes and electrical specifications, shall be collected from the Vendors selected for pilot testing. All instruments shall transmit data to the pilot system PLC and be calibrated within 30 days prior to startup.

3.3.4 Division of Responsibilities

The City shall:

- Unload the pilot equipment and unpack or remove shipping crates (retain for return of equipment) at the test site and install the equipment with the assistance of the Vendor;
- Provide shelter for the pilot equipment;
- Furnish and install piping to supply tertiary effluent to each Vendor's feed tank;
- Furnish and install waste piping for the pilot skids and overflow connections to the vendor supplied feed and filtrate tanks;
- Furnish and install electrical, and communication connections to the pilot system;
- Operate the pilot systems and perform routine maintenance on the pilot systems as directed by and in conjunction with the Vendors and Engineer;
- Furnish, handle, and distribute ANSI/NSF Standard 60 certified chemicals for the pilot system per Vendor specifications as requested by each Vendor prior to the start of the pilot study and agreed to by the City;
- Collect and analyze, or make arrangements (inclusive of shipping) for a third party laboratory to analyze, water quality samples in accordance with the sampling plan;
- Calibrate pilot system turbidity and pH instrumentation per pilot protocol requirements and instrument manufacturer instructions;

[3] Feed turbidity meter shall be Hach 1720 series or TCEQ approved equal. Filtrate turbidity meter shall be Hach FilterTrak Model 660 laser turbidimeter or TCEQ approved equal.

- Participate in conference calls with Engineer and each Vendor every two weeks. Additional calls may be scheduled upon agreement between the City, Engineer, and Vendor. Emergency calls will be required in the event of any equipment malfunction that stops testing;
- Remove, pack, ship and furnish services for the autopsies of one pilot tested membrane module per Vendor; and
- Disconnect, pack, and load pilot system equipment onto a truck furnished by the Vendor.

The Vendors shall:

- Furnish and deliver a complete, automated UF pilot system inclusive of feed and filtrate tanks;
- Provide installation supervision, equipment startup services, and operator training on the operation and routine maintenance of the pilot system;
- Conduct the pilot test, perform CIPs, and select operating parameters and cleaning regimes in accordance with the test stages and test schedule (defined later in this protocol) to achieve optimal performance;
- Provide timely consultation, equipment repair, and replacement services during the pilot study;
- Calibrate pilot system flow and pressure instrumentation per the pilot protocol requirements and instrument manufacturer instructions;
- Compile, analyze, and summarize all pilot data on a weekly basis and provide to the City and Engineer in a database file format;
- Participate in a conference call every two weeks to discuss the pilot study. Additional calls may be scheduled upon agreement between the City, Engineer, and Vendor. Emergency calls will be required in the event of any equipment malfunction that stops testing;
- Furnish a final pilot testing report;
- Provide one membrane module (used during the pilot study) to the City for autopsy;
- Remove the pilot system from City property following completion of pilot testing.

The Engineer shall:

- Review weekly progress updates provided by Vendors.
- Compile, analyze, and summarize water quality data and process data and provide to the City and Vendors on a monthly basis.
- Provide monthly pilot testing progress reports to the City.
- Participate in conference calls with City and each Vendor every two weeks. Additional calls may be scheduled upon agreement between the City, Engineer, and Vendor. Emergency calls will be required in the event of any equipment malfunction that stops testing.

- Provide a draft pilot study report to the City and a final report to the City and the TCEQ.

3.3.5 Performance Criteria

The minimum performance criteria for the pilot test are provided below. Compliance with the listed performance criteria will be considered by the City when evaluating pilot study outcomes.

- Achieve a filtrate turbidity of less than *Turbidity A*[4], measured in nephelometric turbidity units (NTU), 100 percent of the time;
- Achieve a CIP frequency interval of no less than *CIP Frequency A*[4];
- Achieve a maximum decrease in specific flux (corrected to 20°C) relative to baseline clean water flux conditions (as measured following each CIP) of less than *Decrease A*[4];
- Pass daily direct integrity tests (DITs) and DITs following CIPs that are performed in accordance with the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) and TCEQ requirements;
- Achieve a maximum fiber breakage for the pilot study of no more than *Breakage A*[4] excluding any broken fibers that may occur during the two week startup and testing period;
- Achieve a CEB frequency interval of no less than *CEB Frequency A*[4];
- Achieve a monthly average process recovery of no less than *Recovery A*[4] (accounting for all operations including forward flushes, backwashes, CEBs, CIPs, etc.).

3.3.6 Test Stages

The pilot study will consist of three stages with an optional fourth stage. The first three stages are intended to satisfy typical TCEQ pilot testing criteria for drinking water treatment[5], and the optional fourth stage is reserved for additional testing. A description of each stage is provided in the following sections. If a Vendor is unable to start a test stage at the appointed start date, the Vendor may be considered unsuccessful and disqualified from further testing at the discretion of the City and Engineer.

[4] Select turbidity, CIP frequency, specific flux decrease, fiber breakage, CEB frequency, and recovery requirements appropriate to the application and anticipated full-scale design. These parameters are typically established by the engineer in coordination with the utility and manufacturer(s).

[5] The TCEQ may require a different testing protocol as determined on a case-by-case basis.

3.3.6.1 Stage 1 – Optimization

Stage 1 establishes site-specific operating parameters for each membrane pilot system. This stage is used to select a set of optimized operating conditions to be used in Stages 2 and 3. The operating parameters shall be documented and include, but not be limited to, the following:

- Pretreatment requirements;
- Flux;
- Backwash frequency, duration, flux rate;
- CEB frequency, duration, flux rate, soak time;
- CIP procedure;
- Recovery.

Stage 1 will last approximately 30 days. The pilot systems will start up at typical flux rates, and then slowly increase the flux rates to the Vendor determined optimum values. The goals of Stage 1 testing include maximizing flux and recovery while minimizing CEB/CIP frequency. If the TMP escalates to an unacceptable threshold per predetermined Vendor guidelines, the pilot system will undergo a CIP followed by a DIT, and the flux rate will be reduced. An account of each CIP (for all stages) should be documented in the Vendor's pilot study report. If Stage 1 testing reveals site-specific conditions that require modifications to the pilot study protocol, the pilot study protocol may be changed by the City and Engineer. Vendors will be notified of pilot study protocol changes in a timely manner. A CIP will be conducted at the end of Stage 1, and a clean water flux test will be performed to assess cleaning performance. The CIP procedure will be followed by a DIT.

3.3.6.2 Stage 2 – Operation

Stage 2 tests each membrane module using the optimized set of operating parameters determined during Stage 1. The pilot system shall operate for a minimum of 30 days using the selected set of operating parameters and procedures without adjustment and without the need to conduct a CIP. Stage 2 will conclude with a CIP, and cleaning performance will be assessed using a clean water flux test. The CIP procedure will be followed by a DIT.

Stage 2 results are used to determine the total time a membrane system is in filtrate production, backwash, and CEB modes as well as any other production limiting modes during the test period. Operating procedures that result in time out-of-production shall be taken into account when calculating the TCEQ's approved net capacity. For any unscheduled downtime greater than 24 hours, the Vendor shall notify the City and Engineer prior to restarting the pilot system. If the specific flux or TMP of a membrane pilot system reaches unacceptable levels before the end of the test period, the Vendor may be eliminated from further consideration and testing at the discretion of the City and Engineer.

3.3.6.3 Stage 3 – Irreversible Fouling Assessment

Stage 3 of testing establishes the percent loss of the original specific flux for each membrane module and determines if irreversible fouling has occurred. Stage 3 involves operating the membrane modules at the simulated full-scale operating conditions from Stage 2 for at least 10 days.

3.3.6.4 Stage 4 – Additional Testing (Optional)

The City and Engineer will determine whether or not to conduct the optional fourth stage[6]. Stage 4 testing, if conducted, will evaluate additional items such as alternative pretreatment schemes, operating parameter configurations, and/or water quality variability impacts to process performance. The Stage 4 scope will determine the required testing duration.

3.3.7 Membrane Autopsy

After the completion of the pilot study, one UF module will be removed for autopsy. The membrane autopsy will include the following tests:

- Visual examination;
- Performance of membrane flux testing;
- Collection and analysis of surface foulants;
- Analytical forensics; and
- Cleaning tests.

3.3.8 Test Schedule

Table 2 presents a preliminary test schedule for the pilot study. The schedule is subject to change at the discretion of the City and Engineer.

Table 2: Preliminary UF Pilot Testing Schedule

Event	Approximate Duration	Sequence Order
Installation, Startup, and Testing	2 weeks	1
Pilot Testing Stage 1 – Optimization	30 days	2
Pilot Testing Stage 2 – Operation	30 days	3

[6] Stage 4 testing, along with any subsequent testing stages, may be used to collect additional data and should be customized to project-specific goals and requirements.

Pilot Testing Stage 3 – Irreversible Fouling	10 days	4
Pilot Testing Stage 4 – Optional	To Be Determined	5
Disconnect, Pack, Ship Equipment from Site	1 week	6
Membrane Autopsy[7]	30 days	6
Vendor Final Report Preparation and Review[7]	30 days	6
Vendor Final Report Submittal Deadline	2 weeks	7

3.3.9 Indirect Integrity Monitoring

Continuous indirect integrity monitoring of the filtrate is required for each membrane system. Indirect integrity monitoring shall be accomplished with Hach FilterTrak (FT660) laser turbidimeters (or TCEQ approved equivalent).

3.3.10 Direct Integrity Testing

DITs will be conducted on each membrane module once per day and after each CIP. DITs shall be performed in accordance with the LT2ESWTR and TCEQ requirements. The DIT method used during the pilot study shall be the pressure decay test, also known as the air integrity test. The membrane pilot system shall be off-line during the test.

3.3.11 Data Collection

The subsequent sections outline the frequency at which process and water quality data shall be recorded.

A. Continuous Monitoring (Responsibility of Vendor) - At a minimum, the following data shall be continuously recorded electronically (at 5-minute intervals) by each Vendor's equipment and be remotely accessible for real-time monitoring. Data for intermittent operations, such as backwashes and CEBs shall be recorded at least once per event.
   1. Date (Day, Month, Year) and Time (Hour, Minute, Second)
   2. Feed pressure, turbidity, pH, and temperature
   3. Filtrate flow rate, pressure, and turbidity
   4. Transmembrane pressure (TMP)
   5. Backwash flow rate, volume, duration, and pressure
   6. Chemically enhanced backwash flow rate, volume, pressure, pH, duration, and temperature
   7. Air scour flow rate, volume, duration, and pressure (if applicable)
   8. Forward flush flow rate, volume, duration, and pressure (if applicable)

[7] May be conducted concurrently with demobilization.

9. Elapsed run time for filtration, backwash, and chemical cleaning systems
10. Totalized volume and corresponding run time from each flow monitoring device

B. Water Quality Sampling (Responsibility of City) - The following water quality data shall be sampled, tested, and recorded at the specified frequency indicated in Table 3[8]. Samples shall be collected as grab samples. Daily tests shall be performed either by online instrumentation or plant operators. Weekly and monthly tests shall be performed by the plant operators or sent to an outside laboratory for analysis. Sample collection procedures and volumes will be conducted per the recommendations of the testing laboratory.

[8] This sampling plan is primarily focused on process evaluation. Regulatory sampling and monitoring requirements may also apply. Please refer to Section H.5 of this Appendix for additional information.

Table 3: UF Pilot Water Quality Sampling Matrix

Parameter	Feed	Filtrate
Alkalinity, Total	W	W
Aluminum	W	
Conductivity	M	
Dissolved Organic Carbon	W	
Free Chlorine Residual[9]	D	
Heterotrophic Plate Count	W	
Iron, Total	W	
Manganese, Total	W	
Nitrate	D	D
pH		W
Sulfate	W	
Temperature		
Total Chlorine Residual[9]	D	
Total Dissolved Solids	M	
Total Hardness	W	W
Total Organic Carbon	W	W
Total Suspended Solids	M	
Turbidity		
UV-254	W	W
Project-Specific Contaminants	As Needed	As Needed

C. Daily Wastewater Treatment Plant Data Recording (Responsibility of City) - The following wastewater treatment plant data shall be recorded daily and any time the doses are changed:
1. Influent flow rate
2. Chemical dose(s) (if applicable)
3. Rainfall volume (if applicable)

D. Weekly Quality Control Sampling (Responsibility of City) - The following water quality parameters hall be sampled, measured, and recorded weekly using handheld or laboratory instruments for the purpose of checking onboard pilot instrument readings:
1. Feed pH, temperature, and turbidity
2. Filtrate turbidity
3. Chemically enhanced backwash pH, temperature, and disinfectant residual (free chlorine, total chlorine, etc.)

[9] Record if chlorine is fed upstream of the membranes.

E. Daily Log Sheet (Responsibility of City) – The following online instrument data shall be hand recorded daily on log sheets:
   1. Date (Day, Month, Year) and Time (Hour, Minute)
   2. Feed pressure, turbidity, pH, and temperature
   3. Filtrate flow rate, pressure, and turbidity
   4. Transmembrane pressure (TMP)
   5. Backwash flow rate, volume, duration, and pressure
   6. Chemically enhanced backwash flow rate, volume, pressure, pH, duration, and temperature (if applicable)
   7. Air scour flow rate, volume, duration, and pressure (if applicable)
   8. Forward flush flow rate, volume, duration, and pressure (if applicable)
   9. Totalized volume from each flow monitoring device

F. Additional Data Recording (Responsibility of City) – The following report shall be completed monthly for the UF process per TCEQ instructions.
   1. Surface Water Monthly Operating Report Alternate (SMWOR-Alt)

G. Direct Integrity Testing Data Recording (Responsibility of Vendor) – The following data shall be recorded for each DIT.
   1. Initial pressure, final pressure, duration, and pressure loss per minute

H. Backwash Waste Sampling (Responsibility of City) – The following backwash water quality data shall be collected and recorded monthly:
   1. pH, temperature, total organic carbon, total suspended solids, total iron, total manganese, turbidity

I. CIP Water Quality Sampling and Data Recording (Responsibility of City) - The following water quality data shall be collected and recorded for each CIP
   1. CIP solution pH, temperature, concentration, and disinfectant residual (free chlorine, total chlorine, etc.)
   2. CIP chemical, flow rate, volume, duration, pressure

3.3.12 Quality Assurance/Quality Control

Quality assurance/quality control (QA/QC) measures shall be taken by the Vendors and City during the pilot study. The City shall be responsible for regularly calibrating online turbidity, pH, and temperature instruments associated with the pilot system in accordance with the recommendations of the instrument manufacturer following initial calibration by the Vendor. The Vendor shall calibrate flow and pressure instruments for the entire pilot study duration in accordance with the recommendations of the instrument manufacturer. The City shall incorporate QA/QC measures into the sampling and analysis of water quality data. Refer to the 22nd Edition of *Standard Methods for the Examination of Water and Wastewater* (APHA, AWWA, WEF 2012) for QA/QC guidelines on water sample collection and water quality data analysis.

The following procedures shall be used for monitoring pilot equipment and verifying instrument readings:

- Daily visual inspection of pilot equipment to check for leaks or equipment malfunctions by City;

- Weekly pH and turbidity measurement verification with calibrated handheld or laboratory instruments by City;
- Monthly verification of filtrate flow rate (5 gallon bucket test) by City;
- Weekly verification of chemical feed pump flow rates (calibration column drawdown) by City;
- Weekly verification of pressure transmitter readings using Bourdon type pressure gauges mounted to each pilot system by City;
- Weekly cleaning of equipment and instruments by City (as needed);
- Monthly valve actuation (by City); and
- Instrument maintenance and calibration per manufacturer recommendations (by City and Vendors).

The analytical methods applied during the pilot study shall conform to the following requirements.

- Analytical procedures, calibration procedures, frequency, and accuracy of measurement requirements shall comply with Title 30 Texas Administrative Code 290.46(s), 290.110(d), 290.111(d), and 290.119.

3.3.13 Report

A pilot study report will be prepared by each Vendor for their respective membrane unit to report, summarize, and interpret the data and findings from the pilot study. The pilot study report will undergo review by the City and Engineer. The TCEQ may request a meeting with the Vendor during the review of the pilot study report. In the event the TCEQ makes this request, the Vendor will be required to participate in the meeting in a timely manner and to coordinate with the Engineer in setting up the meeting. The pilot study report will consist of, but is not limited to, the content outlined below and should include the data recorded during the test phases. Refer to TCEQ guidance for additional report requirements. The Vendor supplied report will be attached as an appendix to an independent pilot study report prepared by the engineer.

- Pilot System Description
  - Membrane model information, physical characteristics, and operating limits
  - Pilot system operating procedures
- Analytical Methods
  - Pilot system instrumentation and calibration procedures/records
  - Applicable water quality sampling and laboratory analysis procedures
- Results and Discussion
  - Graphs of feed turbidity, filtrate turbidity, feed temperature, flux, TMP, and specific flux as a function of pilot system runtime for each test stage
  - CIP procedures
  - CIP results including a graph showing the percent recovery of specific flux following each CIP

  - Operating parameters and procedures for each test stage. Indicate operating parameter/protocol changes on performance graphs. Discuss the effects of process changes on system performance and membrane fouling.
- Recommendations
  - Pretreatment
  - Operating flux demonstrated during Stage 2 testing
  - Maximum instantaneous flux
  - Normal operating procedure (discuss runtimes)
  - Chemical cleaning procedure
  - Method of chemical cleaning waste disposal
  - Backwash procedure
  - Integrity testing
  - Energy usage

3.4 Pilot-Scale Ozone Testing Protocol

This section presents a sample pilot-scale ozone testing protocol.

3.4.1 Objectives

The objectives of the ozone pilot test are as follows:

- Satisfy TCEQ testing requirements;
- Determine ozone residual decay curves for multiple ozone doses;
- Determine ozone generator capacity and ozone equipment sizing requirements;
- Quantify bromate and NDMA formation;
- Quantify treatment efficiencies for CECs and project-specific contaminants[10]; and
- Investigate diurnal and weekend variability.

3.4.2 Pilot Testing Site Description

The pilot unit may be housed in an indoor structure that is heated during the winter months or placed on a concrete pad outdoors if a self-contained trailer is provided. Feed and waste piping, as well as communication and electrical connections will be provided for Vendor use.

3.4.3 Equipment Requirements

Vendor equipment shall satisfy the following minimum requirements:

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[10] Additional parameters should be added as needed to satisfy project-specific goals.

3.4.3.1 General Equipment Requirements

- Provide a complete, automated, and fully functional pilot system capable of completing the testing requirements outlined in this protocol. The pilot system shall include all air feed equipment, ozone generation equipment, ozone reaction vessel equipment, ozone off-gas collection and destruct equipment, piping, valves, water tanks, instruments, PLCs, sample panels, and ancillary equipment required to perform ozone treatment testing during the pilot-study;
- Furnish materials compatible with a corrosive environment containing hydrogen sulfide gas; and
- Provide the capability for remote, real-time monitoring, downloading, and trending of pilot system data for use by the City, Engineer, and Vendor.

3.4.3.2 Specific Equipment Requirements

- Provide an ozone generator capable of achieving an ozone-in-gas concentration of *Ozone-in-Gas Concentration A*[11];
- Provide an ozone generator with a production capacity of *Capacity A*[11];

3.4.3.3 Instrumentation Requirements

Provide instrumentation to measure and record parameters in accordance with Table 4 (as applicable). Provide multiple, evenly spaced ozone residual analyzers such that ozone residual decay may be monitored through the reaction vessel(s). Instrumentation shall also be provided to measure and record ozone gas flow, ozone-in-gas feed concentration, ozone off-gas concentration, and ozone generator energy consumption. Specific details required for the City to complete pilot system installation, such as pilot system connection sizes and electrical specifications, shall be collected from the Vendor(s) selected for pilot testing. Analytical instruments shall transmit data to the pilot system PLC and be calibrated within 30 days prior to startup.

Table 4: Ozone Pilot Instrumentation Requirements

Parameter	Reaction Vessel Inlet	Reaction Vessel Outlet
Flow Meter (Liquid)	X	
Pressure Gauge	X	X
Pressure Transmitter	X	X

[11] Select ozone-in-gas and capacity requirements appropriate to the application and anticipated full-scale design. These parameters are typically established by the engineer in coordination with the utility and manufacturer(s).

Ozone Residual	X	X
Turbidity	X	
pH	X	
Temperature	X	

3.4.4 Division of Responsibilities

The City shall:

- Unload the pilot equipment and unpack or remove shipping crates (retain for return of equipment) at the test site;
- Provide shelter for the pilot equipment (as needed);
- Furnish and install piping and tank(s) to supply MF/UF filtrate to the pilot equipment (connections to pilot equipment to be completed by Vendor);
- Furnish and install waste piping for the pilot equipment (connections to pilot equipment to be completed by Vendor);
- Furnish and install electrical, and communication connections to the pilot system (connections to pilot equipment to be completed by Vendor);
- Operate the pilot systems as directed by and in conjunction with the Vendor(s) and Engineer;
- Collect and analyze, or make arrangements (inclusive of shipping) for a third party laboratory to analyze, water quality samples in accordance with the sampling plan;
- Calibrate pilot system turbidity and pH instrumentation per pilot protocol requirements and instrument manufacturer instructions;
- Participate in conference calls with Engineer and each Vendor(s) as needed to discuss the pilot study. Emergency calls will be required in the event of any equipment malfunction that stops testing; and
- Pack and load pilot system equipment onto a truck furnished by the Vendor.

The Vendors shall:

- Furnish and deliver a complete, automated ozone pilot system;
- Provide installation, equipment startup, and equipment maintenance services;
- Provide operator training on the operation of the pilot system;
- Provide timely consultation, equipment repair, and replacement services during the pilot study;

- Calibrate pilot system flow, pressure, and ozone residual instrumentation per the pilot protocol requirements and instrument manufacturer instructions;

- Furnish tracer study results indicating reactor hydraulics across the range of flows evaluated by this protocol;

- Participate in conference calls with City and Engineer (as needed) to discuss the pilot study. Emergency calls will be required in the event of any equipment malfunction that stops testing;

- Demobilize pilot equipment following completion of pilot testing; and

- Remove the pilot system from City property following completion of pilot testing.

The Engineer shall:

- Compile, analyze, and summarize water quality data and process data and provide to the City and Vendor(s) on a monthly basis;

- Provide monthly pilot testing progress reports to the City;

- Participate in conference calls with City and Vendor(s) as needed to discuss the pilot study. Emergency calls will be required in the event of any equipment malfunction that stops testing; and

- Provide a draft pilot study report to the City and a final report to the City and the TCEQ (if applicable).

3.4.5 Test Plan

The pilot-scale ozone study shall treat filtrate produced by the UF pilot (refer to Paragraph 3.3). Testing shall be conducted in three phases as described below.

Phase 1: Ozone Residual Decay

The objective of test Phase 1 is to identify the typical ozone doses necessary to obtain a CT value that is sufficient to achieve the pathogen log reduction target while complying with TCEQ disinfection rules. To achieve this objective:

1. Evaluate the test matrix presented in Figure 2;
2. Develop ozone residual decay curves for each testing scenario; and
3. Conduct water quality testing in accordance with Table 6.

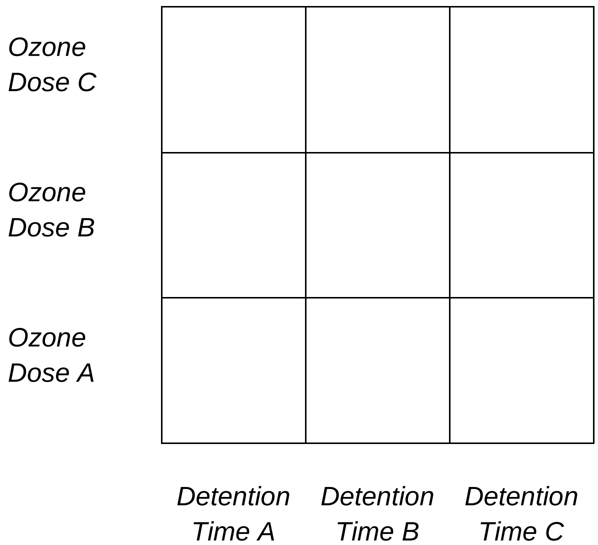

Figure 2: Preliminary Ozone Test Plan – Phase 1

(Adapted from Langlais et al., 1991)

Phase 2: Byproduct Formation and Contaminant Removal Efficiencies

The objective of test Phase 2 is to quantify bromate and NDMA formation as well as removal efficiencies for CECs and project-specific contaminants. To achieve this objective:

1. Operate the ozone pilot unit to achieve a realistic CT value; and
2. Conduct water quality testing in accordance with Table 6.

If bromate formation is determined to be a water quality concern during test Phase 2, additional testing should be performed to evaluate bromate formation control strategies.

Phase 3: Operation

The objective of test Phase 3 is to simulate full-scale operations such that the downstream BAC process may be evaluated (refer to 3.5). To achieve this objective, ozonated water shall be collected and used as a feed water source for the BAC column(s). The ozone pilot system shall operate to achieve an appropriate CT value for disinfection.

3.4.6 Test Schedule

Table 5 presents a preliminary test schedule for the pilot study. The schedule is subject to change at the discretion of the City and Engineer.

Table 5: Preliminary Ozone Pilot-Scale Testing Schedule

Event	Approximate Duration	Sequence Order
Installation, Startup, and Testing	2 weeks	1
Pilot Testing Phase 1 – Ozone Residual Decay	*Duration A*[12]	2
Pilot Testing Phase 2 – Operation	*Duration B*[12]	3
Pilot Testing Phase 3 – Irreversible Fouling	*Duration C*[12]	4
Disconnect, Pack, Ship Equipment from Site	1 week	5
Final Report Preparation and Review[13]	30 days	5
Final Report Submittal Deadline	2 weeks	6

3.4.7 Data Collection

A. Continuous Monitoring (Responsibility of Vendor) – At a minimum, the following data shall be continuously recorded electronically (at 5-minute intervals) and be remotely accessible.
   1. Date (Day, Month, Year) and Time (Hour, Minute, Second)
   2. Reaction vessel inlet flow, pressure, ozone residual concentration, turbidity, pH, and temperature
   3. Reaction vessel ozone residual concentration at intermediate sampling points
   4. Reaction vessel outlet pressure and ozone residual concentration

B. Water Quality Sampling (Responsibility of City) – Table 6[14] presents the sample plan for the pilot-scale ozone testing. For Phase 1, samples shall be collected at a minimum frequency of once per dose-detention time scenario. For Phase 2, a morning, evening, and weekend sample shall be collected for each parameter at a minimum frequency of *Frequency A*[15]. Feed water sampling for DOC, ammonia, bromide, bromate, NDMA, CECs, and project-specific contaminants may be coordinated with the pilot-scale UF testing. Sample collection procedures and volumes shall be conducted per the recommendations of the testing laboratory.

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[12] Select testing durations in accordance with testing requirements and goals. Testing durations are typically established by the engineer in coordination with the utility and manufacturer(s).

[13] May be conducted concurrently with demobilization.

[14] This sampling plan is primarily focused on process evaluation. Regulatory sampling and monitoring requirements may also apply. Please refer to Section H.5 of this Appendix for additional information.

[15] Define the sampling frequency for each parameter in accordance with project specific requirements.

Table 6: Preliminary Ozone Pilot-Scale Testing Sample Plan

Parameter	Phase 1		Phase 2	
	Feed	**Ozonated Water**	**Feed**	**Ozonated Water**
Alkalinity	X		X	
Ammonia	X	X	X	X
Bromate			X	X
Bromide			X	X
CECs			X	X
DOC	X		X	
NDMA			X	X
Nitrate	X	X	X	X
Nitrite	X	X	X	X
pH	X		X	
Temperature	X		X	
UV 254	X	X	X	X
Project-Specific Contaminant(s)	As needed	As needed	As needed	As needed

C. Weekly Quality Control Sampling (Responsibility of City) – The following water quality parameters shall be sampled, measured, and recorded weekly using handheld or laboratory instruments for the purpose of checking onboard pilot instrument readings:
   1. Reaction vessel inlet pH, temperature, and turbidity

D. Daily Log Sheet (Responsibility of City) – The following online instrument data shall be hand recorded daily on log sheets:
   1. Date (Day, Month, Year) and Time (Hour, Minute)
   2. Reaction vessel inlet flow rate, pressure, ozone residual concentration, turbidity, pH, and temperature
   3. Reaction vessel ozone residual concentration at intermediate sampling points
   4. Reaction vessel outlet pressure and ozone residual concentration

3.4.8 Quality Assurance/Quality Control

Quality assurance/quality control (QA/QC) measures shall be taken by the Vendor(s) and City during the pilot study. The City shall be responsible for regularly calibrating online turbidity, pH, and temperature instruments associated with the pilot system in accordance with the recommendations of the instrument manufacturer following initial calibration by the Vendor. The Vendor shall calibrate flow, pressure, and ozone residual instruments for the entire pilot study duration in accordance with the recommendations of the instrument manufacturer. The City shall incorporate QA/QC measures into the sampling and analysis of water quality data. Refer to the 22nd Edition of *Standard Methods for the Examination of Water and*

Wastewater (APHA, AWWA, WEF 2012) for QA/QC guidelines on water sample collection and water quality data analysis.

The following procedures shall be used for monitoring pilot equipment and verifying instrument readings:

- Daily visual inspection of pilot equipment to check for leaks or equipment malfunctions by City;
- Weekly turbidity, pH and temperature measurement verification with calibrated handheld or laboratory instruments by City;
- Weekly verification of pressure transmitter readings using pressure gauges mounted to each pilot system by City;
- Cleaning of equipment and instruments by City and Vendor (as needed); and
- Instrument maintenance and calibration per manufacturer recommendations (by City and Vendors).

The analytical methods applied during the pilot study shall conform to the following requirements.

- Analytical procedures, calibration procedures, frequency, and accuracy of measurement requirements shall comply with Title 30 Texas Administrative Code 290.46(s), 290.110(d), 290.111(d), and 290.119.

3.4.9 Report

A pilot study report will be prepared by the Engineer to report, summarize, and interpret the data and findings from the study. The pilot study report will undergo review by the City. The report shall consist of, but not be limited to, the content outlined below. If applicable, refer to TCEQ guidance for additional report requirements.

- Pilot System Description
  - Ozone system equipment
- Analytical Methods
  - Pilot system instrumentation and calibration procedures/records
  - Applicable water quality sampling and laboratory analysis procedures
- Results and Discussion
  - Ozone residual decay.
  - Bromate formation control strategies (if applicable).
  - Water quality testing results including pH, temperature, alkalinity, DOC, ozone residual, ammonia, bromide, bromate, NDMA, CECs, and project-specific contaminants.
- Recommendations
  - Ozone dose and generator capacity.
  - Bromate formation control strategy and chemical usage (if applicable).
  - Feasibility of ozone disinfection with respect to bromate and NDMA formation.

- o Removal efficiencies for CECs and project specific contaminants.

3.5 Pilot-Scale BAC Filter Testing Protocol

This section presents a sample pilot-scale BAC filter testing protocol.

3.5.1 Objectives

The objectives of the bench-scale study are as follows:

- Establish design HLR and EBCT;
- Quantify BDOC reduction efficiency;
- Quantify treatment efficiencies for project-specific contaminants[16]; and
- Investigate diurnal and weekend variability.

3.5.2 Pilot Testing Site Description

The pilot unit shall be housed in an indoor structure that is heated during the winter months.

3.5.3 Equipment Requirements

The BAC columns shall satisfy the following minimum requirements:

3.5.3.1 General Equipment Requirements

- Provide a complete and fully functional pilot system capable of completing the testing requirements outlined in this protocol. The pilot system shall include all pumps, pipes, valves, fittings, water tanks, instruments, PLCs, sample ports, and ancillary equipment required to perform BAC filter testing during the pilot study.
- Provide the capability for remote, real-time monitoring and downloading of pilot system data for use by the City and Engineer.

3.5.3.2 Specific Equipment Requirements

Provide a BAC pilot system that meets the design criteria provided in Table 7. Prior to testing, exhaust the adsorptive capacity of the GAC and allow sufficient time for a naturally occurring biological community to acclimate. If previously exhausted GAC is used to seed or fill the pilot columns, verify that the exhausted GAC is not contaminated in such a way as to influence testing results.

[16] Additional parameters should be added as needed to achieve project-specific goals and/or evaluate the effects of biological treatment on specific contaminants.

Table 7: BAC Pilot System Design Parameters

Parameter	Value
Column Dimensions	
Column Material	*Material A*[17]
Column Diameter	*Column Diameter A*[17]
Column Length	*Column Length A*[17]
Media Depth	*Media Depth A*[17]
GAC Physical Properties	
Type	*Type A*[17]
Size Distribution	*Size Distribution A*[17]
Moisture Content	*Moisture Content A*[17]
Apparent Density	*Apparent Density A*[17]
Effective Size	*Effective Size A*[17]
Uniformity Coefficient	*Uniformity Coefficient A*[17]
Abrasion Resistance Number	*Abrasion Resistance Number A*[17]
Water Soluble Ash Content	*Water Soluble Ash Content A*[17]
Total Ash Content	*Total Ash Content A*[17]
Non-wetted Materials	*Non-wetted Materials A*[17]
Adsorption Capacity	*Adsorption Capacity A*[17]
Process Flows	
Backwash Flow Rate	*Backwash Flow Rate A*[17]
Backwash Frequency	*Backwash Frequency A*[17]
Air Scour Flow Rate	*Air Scour Flow Rate A*[17]
Air Scour Frequency	*Air Scour Frequency A*[17]

3.5.3.3 Instrumentation Requirements

Provide instrumentation to measure and record parameters in accordance with Table 8. Analytical instruments shall transmit data to the pilot system PLC and be calibrated within 30 days prior to startup.

Table 8: BAC Pilot Instrumentation Requirements

Parameter	Reaction Vessel Inlet	Reaction Vessel Outlet
Flow Meter	X	
Pressure Gauge	X	X
Pressure Transmitter	X	X
Dissolved Oxygen	X	X

[17] Select design requirements appropriate to the application and anticipated full-scale design. These parameters are typically established by the engineer in coordination with the utility and manufacturer(s).

Parameter	Reaction Vessel Inlet	Reaction Vessel Outlet
Turbidity	X	X
pH	X	
Temperature	X	

3.5.4 Division of Responsibilities

The City shall:

- Furnish materials for and construct the BAC pilot-scale column(s) at the test site[18];
- Provide heated shelter for the pilot equipment;
- Furnish and install tank(s), pumps(s), piping, and ancillary equipment to supply water from the pilot-scale ozone reaction vessel(s) to the pilot equipment;
- Furnish and install tank(s), pump(s), and ancillary equipment for the backwash system;
- Furnish and install waste piping for the pilot equipment;
- Furnish and install the PLC and instrumentation as well as required electrical and communication connections to the pilot system;
- Provide timely equipment repair and replacement services during the pilot study;
- Operate the pilot systems as directed by and in conjunction with the Engineer;
- Collect and analyze, or make arrangements (inclusive of shipping) for a third party laboratory to analyze, water quality samples in accordance with the sampling plan;
- Calibrate pilot system instrumentation per pilot protocol requirements and instrument manufacturer instructions; and
- Participate in conference calls with Engineer as needed to discuss the pilot study. Emergency calls will be required in the event of any equipment malfunction that stops testing;

The Engineer shall:

- Provide installation and equipment startup services;
- Provide operator training on the operation of the pilot system;

[18] Alternatively, a pilot-scale unit could be rented from an equipment vendor.

- Provide timely consultation and equipment troubleshooting services during the pilot study;
- Compile, analyze, and summarize water quality data and process data and provide to the City on a monthly basis;
- Provide monthly pilot testing progress reports to the City;
- Participate in conference calls with City as needed to discuss the pilot study. Emergency calls will be required in the event of any equipment malfunction that stops testing; and
- Provide a draft and final pilot study report to the City.

3.5.5 Test Plan

The pilot-scale BAC filter(s) shall treat water from the pilot-scale ozone reaction vessel(s) produced during Phase 3 of pilot-scale ozone system operation (refer to Section 3.4). The objectives of BAC filter testing are to establish appropriate EBCT values to reduce BDOC and other contaminant concentrations at warm and cold weather conditions and to assess contaminant treatment efficiencies under variable water quality conditions[19]. To accomplish these objectives:

1. Evaluate the test matrix presented in Figure 3; and
2. Conduct water quality testing in accordance with Table 10.

[19] Depending on project-specific conditions, it may be advantageous to assess additional design criteria such as GAC type. Add additional test phase(s) as needed.

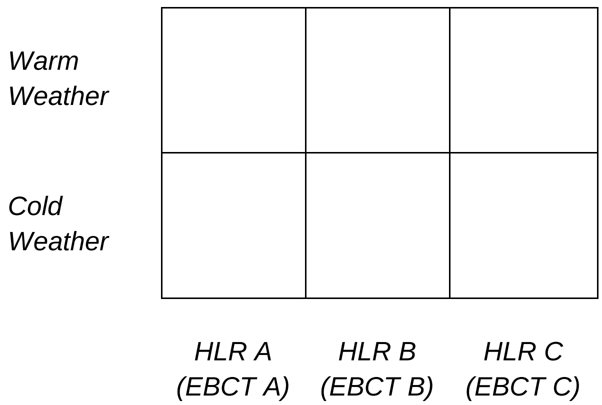

Figure 3: Preliminary Pilot-Scale BAC Filter Test Plan

3.5.6 Test Schedule

Table 9 presents a preliminary test schedule for the pilot study. The schedule is subject to change at the discretion of the City and Engineer.

Table 9: Preliminary BAC Filter Pilot-Scale Testing Schedule

Event	**Approximate Duration**	**Sequence Order**
Pilot System Construction	4 weeks	1
Installation, Startup, and Testing	2 weeks	2
Warm Weather Testing	*Duration A*[20]	3
Cold Weather Testing	*Duration B*[20]	4
Disconnect, Pack, Remove Equipment	1 week	5
Final Report Preparation and Review[21]	30 days	5
Final Report Submittal Deadline	2 weeks	6

[20] Select testing durations in accordance with testing requirements and goals. Testing durations are typically established by the engineer in coordination with the utility.

[21] May be conducted concurrently with demobilization.

3.5.7 Data Collection

A. Continuous Monitoring (Responsibility of City) – At a minimum, the following data shall be continuously recorded electronically (at 5-minute intervals) and be remotely accessible.
   1. Date (Day, Month, Year) and Time (Hour, Minute, Second)
   2. BAC pilot feed flow, pressure for loss of head (LOH) calculation, dissolved oxygen concentration, turbidity, pH, and temperature
   3. BAC pilot filtered water pressure for LOH calculation, dissolved oxygen concentration, and turbidity

B. Water Quality Sampling (Responsibility of City) – Table 10[22] presents the sample plan for the pilot-scale BAC filter testing. A morning, evening, and weekend sample shall be collected for each parameter at a minimum frequency of *Frequency A*[23]. Feed water sampling for ammonia, DOC, NDMA and project-specific contaminants may be coordinated with the pilot-scale ozone testing. Sample collection procedures and volumes shall be conducted per the recommendations of the testing laboratory.

C. Weekly Quality Control Sampling (Responsibility of City) – The following water quality parameters shall be sampled, measured, and recorded weekly using handheld or laboratory instruments for the purpose of checking onboard pilot instrument readings:
   1. BAC pilot feed dissolved oxygen concentration, pH, temperature, and turbidity
   2. BAC pilot filtered water dissolved oxygen concentration and turbidity

D. Daily Log Sheet (Responsibility of City) – The following online instrument data shall be hand recorded daily on log sheets:
   1. Date (Day, Month, Year) and Time (Hour, Minute)
   2. BAC pilot feed flow rate, pressure for LOH calculation, dissolved oxygen concentration, turbidity, pH, and temperature
   3. BAC pilot filtered water dissolved oxygen concentration, pressure for LOH calculation, and turbidity

---

[22] This sampling plan is primarily focused on process evaluation. Regulatory sampling and monitoring requirements may also apply. Please refer to Section H.5 of this Appendix for additional information.

[23] Define the sampling frequency for each parameter in accordance with project specific requirements.

Table 10: Preliminary Pilot-Scale BAC Filter Sampling Plan

Parameter	Feed	Filtered Water
Alkalinity	X	
Ammonia	X	X
Calcium	X	
Dissolved Oxygen	X	X
DOC	X	
Iron, Dissolved	X	X
Magnesium	X	
Manganese, Dissolved	X	X
Orthophosphate	X	X
Phosphorous, Total	X	X
NDMA	X	X
Nitrate	X	X
Nitrite	X	X
Oxidation Reduction Potential	X	X
pH	X	
Temperature	X	
Turbidity	X	X
UV 254	X	X
Project-Specific Contaminant(s)	As needed	As needed

3.5.8 Quality Assurance/Quality Control

Quality assurance/quality control (QA/QC) measures shall be taken by the City during the pilot study. The City shall be responsible for regularly calibrating online instruments associated with the pilot system in accordance with the recommendations of the instrument manufacturer. The City shall incorporate QA/QC measures into the sampling and analysis of water quality data. Refer to the 22nd Edition of *Standard Methods for the Examination of Water and Wastewater* (APHA, AWWA, WEF 2012) for QA/QC guidelines on water sample collection and water quality data analysis.

The following procedures shall be used by the City for monitoring pilot equipment and verifying instrument readings:

- Daily visual inspection of pilot equipment to check for leaks or equipment malfunctions;
- Weekly dissolved oxygen, turbidity, pH and temperature measurement verification with calibrated handheld or laboratory instruments;
- Weekly verification of pressure transmitter readings using pressure gauges mounted to each pilot system;
- Cleaning of equipment and instruments by City (as needed); and
- Instrument maintenance and calibration per manufacturer recommendations.

The analytical methods applied during the pilot study shall conform to the following requirements.

- Analytical procedures, calibration procedures, frequency, and accuracy of measurement requirements shall comply with Title 30 Texas Administrative Code 290.46(s), 290.110(d), 290.111(d), and 290.119.

3.5.9 Report

A pilot study report will be prepared by the Engineer to report, summarize, and interpret the data and findings from the study. The pilot study report will undergo review by the City. The report shall consist of, but not be limited to, the content outlined below. If applicable, refer to TCEQ guidance for additional report requirements.

- Pilot System Description
  - BAC filter column and media physical characteristics and operating limits
  - BAC filter system operating procedures
- Analytical Methods
  - Pilot system instrumentation and calibration procedures/records
  - Applicable water quality sampling and laboratory analysis procedures
- Results and Discussion
  - Process data including HLRs, EBCTs, filter runtimes, total throughputs, and head losses
  - Water quality testing results
- Recommendations
  - GAC media type
  - Warm weather EBCT
  - Cold weather EBCT
  - Treatment efficiencies for BDOC, NDMA, and project-specific contaminants at variable water quality conditions

3.6 Disinfection Bench-Scale Testing Protocol

Bench-scale disinfection testing shall be performed using standard titration equipment. This protocol presents the objectives, procedures and equipment, test plan, sample plan, QA/QC, and report requirements for the bench-scale testing.

3.6.1 Objectives

The objectives of the bench-scale study are as follows:

- Determine chlorine demand;
- Estimate disinfectant usage;
- Quantify TTHM and HAA_5 formation potential; and
- Investigate diurnal and weekend variability.

3.6.2 Equipment and Methods

The bench-scale chlorine disinfection study shall use BAC filter filtered water that is representative of the optimum EBCT and operating conditions determined during pilot-scale BAC filter testing (refer to Section 3.5). Experimental design for the bench-scale chlorine disinfection testing shall reference *Standard Practice for Estimation of Chlorine Demand of Water* (ASTM, 2011) and *5710 Formation of Trihalomethanes and Other Disinfection By-Products* (APHA, AWWA, WEF, 2012). The bench-scale chlorine disinfection study shall be performed using a realistic CT value that is sufficient to achieve the pathogen log reduction target while complying with TCEQ disinfection rules.

3.6.3 Test Plan

The bench-scale chlorine disinfection study shall be conducted in two phases and will evaluate BAC filter filtered water samples collected during three sampling events (one weekday morning sample, one weekday evening sample, and one weekend sample). Descriptions of each test phase are provided below. Testing should begin as soon as is practical to minimize the effects of holding time on water quality.

Phase 1: Chlorine Demand

The objective of test Phase 1 is to determine the chlorine demand of the BAC filter filtered water. To achieve this objective, titrate BAC filter filtered water samples with sodium hypochlorite in accordance with Table 11 and collect water quality data in accordance with the Table 12. In addition to water quality data, record titrant volumes and solution strength.

Table 11: Bench-Scale Chlorination Test Plan

Phase	BAC Filter Filtered Water Sample	Chlorine Dose	Contact Time
1	Weekday Morning	Variable	---
	Weekday Evening	Variable	---
	Weekend	Variable	---
2	Weekday Morning	Per CT Calculation	Per CT Calculation
	Weekday Evening	Per CT Calculation	Per CT Calculation
	Weekend	Per CT Calculation	Per CT Calculation

Phase 2: DBP Formation

The objective of test Phase 2 is to quantify TTHM and HAA_5 formation potential. To achieve this objective, dose BAC filter filtered water with sufficient sodium hypochlorite to achieve a realistic CT value in accordance with Table 11 and collect water quality data in accordance with Table 12. In addition to water quality data, record sodium hypochlorite dose, contact time, and free chlorine residual data.

3.6.4 Sample Plan

Table 12[24] presents the sample plan for the bench-scale disinfection testing. Sample frequency and volume shall be as defined in the applicable test method. Feed water sampling for DOC and NDMA may be coordinated with the pilot-scale BAC filter testing. Sample collection procedures and volumes will be conducted per the recommendations of the testing laboratory.

[24] This sampling plan is primarily focused on process evaluation. Regulatory sampling and monitoring requirements may also apply. Please refer to Section H.5 of this Appendix for additional information.

Table 12: Bench-Scale Chlorination Sample Plan

Parameter	**Phase 1**		**Phase 2**	
	BAC Filter Filtered Water	**Disinfected Water**	**BAC Filter Filtered Water**	**Disinfected Water**
Ammonia	X	X	X	X
DOC	X	X	X	X
Free Chlorine		X	X	X
HAA_5			X	X
NDMA			X	X
Nitrate	X	X	X	X
Nitrite	X	X	X	X
pH	X	X	X	X
Temperature	X	X	X	X
Total Chlorine		X		X
TTHM			X	X
Project Specific Contaminants			As needed	As needed

3.6.5 QA/QC

Quality assurance/quality control (QA/QC) measures shall be taken during the bench-scale study. Refer to the 22nd Edition of *Standard Methods for the Examination of Water and Wastewater* (APHA, AWWA, WEF, 2012) for QA/QC guidelines on water sample collection and water quality data analysis. Analytical procedures, calibration procedures, frequency, and accuracy of measurement requirements shall comply with Title 30 Texas Administrative Code 290.46(s), 290.110(d), 290.111(d), and 290.119.

3.6.6 Report

A bench-scale study report will be prepared to report, summarize, and interpret the data and findings from the study. The report shall consist of, but not be limited to, the content outlined below. If applicable, refer to TCEQ guidance for additional report requirements.

- Bench-Scale System Description
  - Titration apparatus
- Analytical Methods
  - ASTM 1291 (current version)
  - Standard Method 5710 (current version)
  - Applicable water quality sampling and laboratory analysis procedures
- Results and Discussion
  - Chlorine demand

  - Water quality testing results including pH, temperature, free chlorine residual, DOC, TTHM, and HAA_5
- Recommendations
  - Disinfectant usage
  - Feasibility of free chlorine disinfection with respect to DBP formation potential

3.7 References

APHA, AWWA, and WEF, 2012, Standard Methods for the Examination of Water and Wastewater, 22nd ed. American Public Health Association, Washington D.C.

ASTM Standard D1291-06, 2011, “Standard Practice for Estimation of Chlorine Demand of Water,” ASTM International, West Conshohocken, PA, 2011, DOI: 10.1520/D1291-06R11, www.astm.org.

Langlais, B., Reckhow, D.A., Brink, D.R., 1991, Ozone in Water Treatment Application and Engineering, American Water Works Association Research Foundation/Lewis Publishers, Denver, CO.

USEPA, 2005, Membrane Filtration Guidance Manual, EPA 815-R-06-009.

4 Example Scenario II Example Protocol[25]

4.1 Introduction

For this example scenario, a West Texas municipality (City) is assumed to be conducting a pilot-scale UF study and a pilot-scale RO study at the WWTP in conjunction with a bench-scale UV/AOP study performed by third party specialist(s). The purpose of the three studies is to satisfy TCEQ testing requirements, establish process design criteria, evaluate contaminant reduction efficiency, assist with procurement activities, and familiarize operators with new technologies and equipment. It is assumed that an engineering firm (Engineer) would be retained by the City to conduct the studies in coordination with vendors and/or original equipment manufacturers (OEMs). It is also assumed that a bench-scale stabilization study will not be performed. For the purpose of brevity, a UF protocol will not be presented in this section. Please refer to the UF pilot protocol in Section 3.3 for guidelines on UF pilot testing.

4.2 Background

This section contains background information concerning the existing facility, tertiary effluent water quality, and the DPR treatment scheme.

4.2.1 Existing Facility Description

The WWTP is a biological nutrient removal (BNR) facility that traditionally discharges a portion of the total effluent to a nearby stream. Existing full-scale treatment includes bar screens, grit chambers, primary clarifiers, anaerobic, anoxic, and aerobic zones, secondary clarifiers, cloth disk filters, post-aeration, chlorine gas disinfection, and dechlorination.

4.2.2 Tertiary Effluent Water Quality Data

The advanced treatment system will treat WWTP tertiary effluent downstream of the post-aeration basin. The following generic assumptions concerning tertiary effluent water quality are provided:

- The total dissolved solids concentration is greater than 1000 mg/L; and

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[25] For Example Scenario II, Treatment Scheme No. 2, which consists of UF, RO, UV/AOP, and stabilization processes in series upstream of a WTP, has been selected for the development of a sample DPR treatment protocol. The protocol is intended to provide a reference tool for use by practitioners during the development of project-specific testing protocols. Accordingly, the protocol contains general pilot- and bench-scale testing considerations and does not reference project-specific contaminants or treatment considerations. It is assumed that a robust sampling plan to identify contaminants (refer to Tasks 2 and 3 of this project) and risk assessment (refer to Task 8 of this project) have been performed and that the selected treatment scheme is applicable for treatment of the hypothetical West Texas source water. It is recommended that DPR treatment study protocols be developed on a case-by-case basis to address project-specific treatment goals and requirements.

- Industrial inputs into the waste collection system are minimal and an effective source control program has been implemented (refer to Task 5 of this project).

4.2.3 Treatment Scheme

Treatment Scheme No. 2 (Figure 4) was selected for Example Scenario II. The treatment scheme consists of MF/UF, RO, UV/AOP, and stabilization processes in series upstream of a WTP. Nanofiltration (NF) could be substituted for the RO process in Treatment Scheme No. 2 if suitable for site-specific feed water quality and project-specific goals and requirements. Please refer to Task 6 of this project for additional information on Treatment Scheme No. 2. It is assumed that an adsorption process is not needed to remove contaminants from the source water that would pass through this treatment scheme.

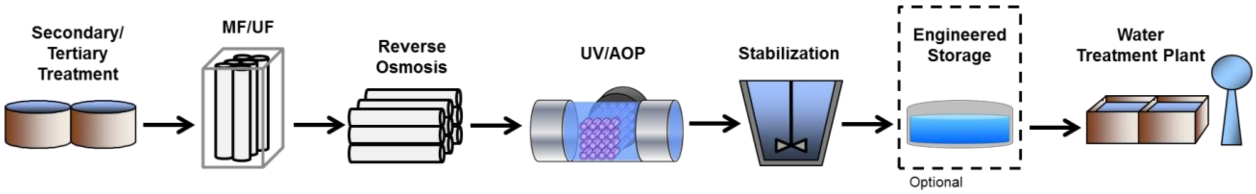

Figure 4: Example Scenario II – Treatment Scheme No. 2

4.3 RO Pilot-Scale Testing Protocol

This section contains the objectives, pilot testing site description, RO pretreatment, equipment requirements, division of responsibilities, performance criteria, test stages, membrane autopsy, test schedule, data collection, QA/QC, and report components of the RO pilot-scale testing protocol.

4.3.1 Objectives

The objectives of the RO pilot test are as follows:

- Determine flux, recovery, cartridge filter replacement frequency, chemical cleaning frequency, and chemical cleaning regime(s) for full-scale RO process design;
- Determine design criteria for sulfuric acid, antiscalant, sodium hypochlorite, and liquid ammonium sulfate feed systems (if applicable,; chemical clean-in-place (CIP) systems, and a concentrate disposal method;
- Collect water quality data and determine treatment efficiency;
- Satisfy TCEQ pilot testing requirements;
- Identify fouling issues and evaluate RO pretreatment strategies;
- Determine post-treatment requirements;
- Familiarize staff with the operation and maintenance of the RO process and ancillary equipment;
- Determine energy cost; and

- Evaluate OEM service, responsiveness, and assistance.

4.3.2 Pilot Testing Site Description

The pilot units will be housed in an indoor structure that is heated during the winter months. A rollup door will provide access to the testing site for equipment installation and removal. Feed and waste piping, as well as communication and electrical wiring/conduit connections, will be furnished and installed by the City. The RO permeate and concentrate streams will be recycled to the WWTP head works. Compressed air is not available at the test site. OEMs requiring compressed air shall furnish their own equipment suitable to their individual needs.

4.3.3 RO Pretreatment

Tertiary effluent will be filtered through the UF pilot system and collected in a storage tank to serve as the feed source for the RO pilot unit. The storage tank will be of a type that restricts the passage of light to limit algae growth and will be equipped with level switches and sensors to coordinate RO process operations with the water level in the tank. In addition to the UF process, RO pretreatment shall include the following (as needed):

- Chloramine formation for biological fouling control;
- Sulfuric acid addition for pH adjustment;
- Antiscalant addition for scaling control; and
- Cartridge filters.

4.3.4 Equipment Requirements

OEM equipment shall satisfy the following minimum requirements:

General Equipment Requirements:

- Provide a fully functional, automated 3 stage RO pilot system that includes the following equipment and capabilities:
  - Feed booster pump;
  - High pressure pump;
  - Cartridge filter housing with cartridge filters;
  - Interstage booster pump;
  - Automated process and water quality data recording;
  - Remote monitoring and data downloading capabilities;
  - Water quality sampling panel;
  - Sulfuric acid, antiscalant, sodium hypochlorite, and liquid ammonium sulfate (if applicable) feed pumps and control systems;
  - Day tanks for chemical storage; and
  - RO flush tank and CIP system.

Membrane Requirements:

- Provide RO membranes satisfying the following requirements:
  - Polyamide thin-film composite type;
  - Minimum salt rejection of 99.5-percent;
  - ANSI/NSF 61 certification;
  - 4 inch diameter elements that are hydraulically comparable to full-scale 8 inch elements for RO process stages 1 and 2; and
  - 2.5 inch diameter elements that are hydraulically comparable to full-scale 8 inch elements for RO process stage 3.

Instrumentation Requirements:

Provide instrumentation to measure and record parameters in accordance with Table 13 (as applicable). Instrumentation shall also be provided to measure and record RO system power consumption.

Table 13: RO Pilot Instrumentation Requirements

Parameter	Feed	Permeate (1st stage, 2nd stage, & 3rd stage)	Concentrate (1st stage, 2nd stage, 3rd stage)
Flow Meter	X	X	X
Pressure Gauge (Bourdon Type)	X	X	X
Pressure Transmitter	X	X	X
Turbidity Meter[26]	X		
pH Meter[27]	X	X	X
Temperature Meter	X		
Conductivity	X	X	X
Oxidation Reduction Potential (ORP)	X		

Specific details required for the City to complete pilot system installation, such as pilot system connection sizes and electrical specifications, shall be collected from the OEMs selected for pilot testing. All instruments shall transmit data to the pilot system PLC and be calibrated within 30 days prior to startup.

4.3.5 Division of Responsibilities

The City shall:

- Unload the pilot equipment and unpack or remove shipping crates (retain for return of equipment) at the test site and install the equipment with the assistance of the OEM.
- Provide shelter for the pilot equipment.
- Furnish and install feed, permeate, and waste piping and tanks, as well as electrical and communication connections to the pilot system.
- Operate the pilot units and perform routine maintenance on the pilot system as directed by and in conjunction with the OEMs.

[26] The UF pilot filtrate turbidity instrument may be used in place of a dedicated turbidity meter for the RO system.

[27] Measure pH in the combined permeate and combined concentrate.

- Furnish, handle, and distribute chemicals required for the pilot system per OEM specifications. All chemicals used during the pilot study shall conform to American National Standards Institute/National Sanitation Foundation (ANSI/NSF) Standard 60.
- Collect and analyze, or make arrangements (inclusive of shipping) for a third party laboratory to analyze, water quality samples in accordance with the sampling plan.
- Calibrate pilot system turbidity, conductivity, and pH instrumentation per pilot protocol requirements and instrument manufacturer instructions.
- Participate in conference calls with Engineer and each OEM every two weeks. Additional calls may be scheduled upon agreement between the City, Engineer, and OEM. Emergency calls will be required in the event of any equipment malfunction that stops testing.
- Remove, pack, ship and furnish services for the autopsies of one 1st stage RO element , one 2nd stage RO element, and one 3rd stage RO element used during the pilot study.
- Disconnect, pack, and load pilot system equipment onto a truck furnished by the OEM.

The OEM shall:

- Furnish and deliver a complete RO pilot system.
- Provide installation supervision, equipment startup services, and operator training on the operation and routine maintenance of the pilot system.
- Conduct the pilot test and select operating parameters and cleaning regimes in accordance with the test stages and test schedule (defined later in this protocol) to achieve optimum performance.
- Provide timely consultation, equipment repair and replacement services during the pilot study.
- Calibrate pilot system flow and pressure instrumentation per instrument manufacturer instructions.
- Compile, analyze, and summarize pilot data on a weekly basis and provide to the City and Engineer in Microsoft Excel file format.
- Participate in a conference call every two weeks to discuss the pilot study. Additional calls may be scheduled upon agreement between the City, Engineer, and OEM. Emergency calls will be required in the event of any equipment malfunction that stops testing.
- Furnish draft and final pilot testing reports.
- Provide one 1st stage RO element, one 2nd stage RO element, and one 3rd stage RO element used during the pilot study to the City for autopsy.
- Remove the pilot system from City property following completion of pilot testing.

The Engineer shall:

- Review weekly progress updates provided by OEMs.

- Compile, analyze, and summarize water quality data and process data and provide to the City and OEMs on a monthly basis.
- Provide monthly pilot testing progress reports to the City.
- Participate in conference calls with City and each OEM every two weeks. Additional calls may be scheduled upon agreement between the City, Engineer, and OEM. Emergency calls will be required in the event of any equipment malfunction that stops testing.
- Provide a draft pilot study report to the City and final reports to the City and the TCEQ.

4.3.6 Performance Criteria

The minimum performance requirements of the system are as follows:

- Achieve a minimum recovery equal to *Recovery A*[28];
- Achieve a minimum flux equal to *Flux A*[28];
- Achieve a minimum cleaning frequency of *Frequency A*[28];
- Achieve a salt passage of less than *Salt Passage A*[28].

4.3.7 Test Stages

The pilot study will consist of three stages with an optional fourth stage. The first three stages are intended to satisfy typical TCEQ pilot testing criteria for drinking water treatment[29], and the optional fourth stage is reserved for additional testing. A description of each stage is provided in the following sections. If an OEM is unable to start a test stage at the appointed start date, the OEM may be considered unsuccessful and disqualified from further testing at the discretion of the City and Engineer.

4.3.7.1 Stage 1 – Optimization

Stage 1 will be used to establish site-specific operating parameters for each membrane pilot unit. This stage is used to select a set of optimized operating conditions to be used in Stages 2 and 3. The operating parameters shall be documented and shall include, but are not limited to, the following:

- Pretreatment requirements
- Recovery

[28] Select recovery, flux, chemical cleaning, and salt passage requirements appropriate to the application and anticipated full-scale design. These parameters are typically established by the engineer in coordination with the utility and manufacturer(s).

[29] The TCEQ may require a different testing protocol as determined on a case-by-case basis.

- Flux
- Clean-in-Place (CIP) procedure

Stage 1 will last approximately 30 days. The pilot units will start up at conservative flux rates and recoveries, and then slowly increase the flux rates and recoveries to the OEM determined optimum values. OEM adjustments are permitted during Stage 1; however, all adjustments shall be documented and reported to the Engineer and City. If the feed pressure, differential pressure, or specific flux reaches unacceptable values per OEM guidelines, the pilot unit will undergo a CIP procedure and the flux rate or recovery will be reduced. Note that an account of each CIP (for all stages) should be documented in the Pilot Study Report. If Stage 1 testing reveals site-specific conditions that require modifications to the pilot study protocol, the pilot study protocol may be changed by the City and Engineer. OEMs will be notified of pilot study protocol changes in a timely manner.

4.3.7.2 Stage 2 – Operation

Stage 2 will include testing each membrane system under its optimum set of operating parameters, as determined from Stage 1 for a minimum of 30 days. During Stage 2, the pilot system shall operate under the selected membrane flux, recovery, pretreatment scheme, and CIP procedure without adjustment. Stage 2 is used to simulate acceptable periods between CIP procedures and to confirm conclusions reached from data collected in Stage 1. Stage 2 will conclude with a CIP.

The time taken to conduct cleaning procedures that result in time out-of-production shall be taken into account when calculating the TCEQ’s approved net capacity. For any unscheduled downtime greater than 24 hours, the OEM shall notify the City and Engineer prior to restarting the pilot system. If the feed pressure, differential pressure, or specific flux of a membrane pilot system reaches unacceptable levels before the end of the test period, the OEM may be eliminated from further consideration and testing at the discretion of the City and Engineer.

4.3.7.3 Stage 3 – Irreversible Fouling Assessment

Stage 3 of testing will be conducted to establish the percent loss of the original specific flux for each membrane system and to determine if irreversible fouling has occurred. Stage 3 involves operating the membrane system at the simulated full-scale operating conditions from Stage 2 for at least 10 days.

4.3.7.4 Stage 4 – Additional Testing (Optional)

The City and Engineer will determine whether or not to conduct the optional fourth stage[30]. Stage 4 testing, if conducted, will evaluate additional items such as alternative pretreatment schemes, operating parameter configurations, and/or water quality variability impacts to process performance. The Stage 4 scope will determine the required testing duration.

4.3.8 Membrane Autopsy

After the completion of the pilot study, one 1st stage RO element, one 2nd stage RO element, and one 3rd stage RO element will be removed for autopsy. The membrane autopsies will include the following tests:

- Visual examination of the exterior as-received;
- Sampling of artifacts on shell, feed, or concentrate ends;
- Measurement of telescoping and evaluation of feed channel spacer integrity;
- Performance of membrane flux and rejection testing;
- Dissection and examination of glue lines, permeate tube, and membrane surface;
- Collection and analysis of surface foulants;
- Analytical forensics;
- Cell testing;
- Cleaning tests; and
- Dye testing.

4.3.9 Test Schedule

Table 14 provides a tentative schedule for the pilot study based on the stages listed above. The schedule is subject to change at the discretion of the City and Engineer.

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[30] Stage 4 testing, along with any subsequent testing stages, may be used to collect additional data and should be customized to project-specific goals and requirements.

Table 14: Preliminary RO Pilot Testing Schedule

Event	Approximate Duration	Sequence Order
Installation, Startup, and Testing	2 weeks	1
Pilot Testing Stage 1	30 days	2
Pilot Testing Stage 2	30 days	3
Pilot Testing Stage 3	10 days	4
Optional Testing	TBD	5
Disconnect, Pack, Ship Equipment from Site	1 week	6
Membrane Autopsy[31]	30 days	6
OEM Final Report Preparation and Review[31]	30 days	6
OEM Final Report Submittal Deadline	2 weeks	7

4.3.10 Data Collection

The subsequent sections outline the frequency at which process and water quality data shall be recorded.

A. Continuous Monitoring (Responsibility of OEM) - At a minimum, the following data shall be continuously recorded electronically (at 5-minute intervals) by each OEM's equipment and be remotely accessible for real-time monitoring. Data for CIPs shall be recorded at least once per event.

1. Date (Day, Month, Year) and Time (Hour, Minute, Second)
2. Feed temperature, pH, conductivity, and ORP
3. Permeate pH (Total) and conductivity (1^{st}, 2^{nd}, and 3^{rd} stage)
4. Concentrate pH (Total) and conductivity (1^{st}, 2^{nd}, and 3^{rd} stage)
5. Feed pressure and flow rate
6. Permeate pressure and flow rate (1^{st}, 2^{nd}, and 3^{rd} stage)
7. Concentrate pressure and flow rate (1^{st}, 2^{nd}, and 3^{rd} stage)
8. Differential Pressure
9. Sulfuric acid, antiscalant, chlorine, and ammonia (if applicable) feed rates
10. Elapsed run time for permeate production
11. Totalized volume and corresponding run time for each flow monitoring device

[31] May be conducted concurrently with demobilization.

B. Water Quality Sampling (Responsibility of City) - The following water quality data shall be sampled, tested, and recorded at the specified frequency indicated in Table 15[32]. Samples shall be collected as grab samples. Daily tests shall be performed either by online instrumentation or plant operators. Weekly and monthly tests shall be performed by the plant operators or sent to an outside laboratory for analysis. RO feed water sampling and testing may be coordinated with UF filtrate sampling and testing. Sample collection procedures and volumes will be conducted per the recommendations of the testing laboratory.

Table 15: Pilot-Scale RO Sampling Plan

Water Quality Parameter	Feed	Total Permeate	Concentrate
Alkalinity	W	W	W
Aluminum	M	M	
Ammonia	M	M	
Barium	M	M	
Boron	M	M	
Bromide	M	M	
Calcium	M	M	
CECs	M	M	
Chloride	W	W	W
DOC[33]	W	W	
Fluoride	M	M	
Iron (Total and Dissolved)	M	M	
Magnesium	M	M	
Manganese	M	M	
Nitrate	D	D	
Potassium	M	M	
Selenium	M	M	
Silica	M	M	
Silt Density Index	D		
Sodium	W	W	W
Strontium	M	M	
Sulfate	W	W	W

[32] This sampling plan is primarily focused on process evaluation. Regulatory sampling and monitoring requirements may also apply. Please refer to Section H.5 of this Appendix for additional information.

Water Quality Parameter	Feed	Total Permeate	Concentrate
TDS[33]	W	W	W
TOC[33]	W	W	
Total Phosphate	W	M	
UV_{254} absorbance[33]	W	W	
Project-Specific Contaminant(s)	M	M	

D-Daily, M-Monthly, W- Weekly.

C. Weekly Quality Control Sampling (Responsibility of City) - The following water quality parameters shall be sampled, measured, and recorded weekly using handheld or laboratory instruments for the purpose of checking onboard pilot instrument readings and process performance:
1. Feed temperature, pH, conductivity, free chlorine, total chlorine, and ORP
2. Permeate pH (Total) and conductivity (1st, 2nd, and 3rd stage)
3. Concentrate pH (Total) and conductivity (1st, 2nd, and 3rd stage)

D. Daily Log Sheet (Responsibility of City) – The following online instrument data shall be hand recorded daily on log sheets:
1. Date (Day, Month, Year) and Time (Hour, Minute)
2. Feed temperature, pH, conductivity, ORP
3. Permeate pH (Total) and conductivity (1st, 2nd, and 3rd stage)
4. Concentrate pH (Total) and conductivity (1st, 2nd, and 3rd stage)
5. Feed pressure and flow rate
6. Permeate pressure and flow rate (1st, 2nd, and 3rd stage)
7. Concentrate pressure and flow rate (1st, 2nd, and 3rd stage)
8. Differential Pressure
9. Sulfuric acid, antiscalant, chlorine, and ammonia (if applicable) feed rates
10. Totalized permeate volume

E. CIP Water Quality Sampling and Data Recording (Responsibility of City) - The following water quality data shall be collected and recorded for each CIP
1. CIP solution pH, temperature, and concentration
2. CIP chemical, flow rate, volume, duration, pressure

[33] Test should also be performed when raw water quality changes are observed.

4.3.11 Quality Assurance/Quality Control

Quality assurance/quality control (QA/AC) measures should be followed by the OEMs and City during the pilot study. The City will be responsible for regularly calibrating online turbidity, pH, temperature, and ORP instruments associated with the pilot units in accordance with the recommendations of the instrument manufacturer (following initial calibration by the OEM). The OEM will calibrate flow and pressure instruments for the entire pilot study duration in accordance with the recommendations of the instrument manufacturer. The City will incorporate QA/QC measures into the sampling and analysis of water quality data. Refer to the 22nd Edition of *Standard Methods for the Examination of Water and Wastewater* (APHA, AWWA, WEF, 2012) for QA/QC guidelines on water sample collection and water quality data analysis.

The following procedures will be used for monitoring pilot equipment and verifying instrument readings:

1. Daily visual inspection of pilot equipment to check for leaks or equipment malfunctions
2. Weekly temperature, pH, conductivity, and ORP measurement verification with calibrated handheld or laboratory instruments
3. Daily verification of permeate flow rate (5 gallon bucket test)
4. Weekly verification of chemical feed pump flow rates (calibration column drawdown)
5. Weekly verification of pressure transmitter readings using Bourdon type pressure gauges mounted to each pilot unit
6. Weekly cleaning of equipment and instruments (if needed)
7. Monthly valve actuation
8. Instrument maintenance and calibration per manufacturer recommendations

The analytical methods applied during the pilot study will conform to the following requirements.

- Analytical procedures, calibration procedures, frequency, and accuracy of measurement requirements shall comply with Title 30 TAC 290.46(s), 290.110(d), 290.111(d), and 290.119.

4.3.12 Report

A pilot study report will be prepared by each OEM for their respective membrane unit to report, summarize, and interpret the data and findings from the pilot study. The pilot study report will undergo review by the City and Engineer. The TCEQ may request a meeting with the OEM during the review of the pilot study report. In the event the TCEQ makes this request, the OEM will be required to participate in the meeting in a timely manner and to coordinate with the Engineer in setting up the meeting. The pilot study report will consist of, but is not limited to, the content outlined below and should include the data recorded during the test stages. Refer to TCEQ guidance for additional report requirements. The OEM supplied report will be attached as an appendix to an independent pilot study report prepared by the engineer.

- Pilot System Description
  - Membrane model information, physical characteristics, and operating limits
  - Pilot system operating procedures
- Analytical Methods
  - Pilot system instrumentation and calibration procedures/records
  - Applicable water quality sampling and laboratory analysis procedures
- Results and Discussion
  - Performance graphs of feed pressure, normalized differential pressure, normalized permeate conductivity, specific flux, and salt passage as a function of pilot system runtime for each stage
  - CIP procedures
  - CIP results including a graph showing the percent recovery of specific flux following each CIP
  - Operating parameters and procedures for the test stages. Indicate operating parameter/protocol changes on performance graphs. Discuss the effects of process changes on system performance and membrane fouling
- Recommendations
  - Pretreatment
  - Operating recovery and flux demonstrated during Stage 2 testing
  - Cartridge filter replacement frequency
  - Chemical feed requirements
  - CIP frequency, procedure, and chemical consumption
  - Energy usage

4.4 Bench-Scale Ultraviolet Light/Advanced Oxidation Process Testing Protocol

Bench-scale UV/AOP testing will be performed in coordination with UV equipment suppliers such that test results may be used for full-scale UV reactor design. This protocol presents the objectives, procedures and equipment, test plan, sample plan, QA/QC, and report requirements for the bench-scale testing.

4.4.1 Objectives

The objectives of the bench-scale study are as follows:

- Determine optimum UV and peroxide doses; and
- Quantify treatment efficiencies for NDMA, CECs, and project-specific contaminants[34].

4.4.2 Equipment and Methods

The bench-scale UV/AOP study shall use RO permeate collected during pilot-scale RO testing (refer to Paragraph 4.3). The permeate samples used for the UV/AOP testing will be collected as composite samples from the RO pilot systems[35]. Experimental design for the bench-scale UV/AOP testing shall be prepared in cooperation with UV equipment suppliers. The bench-scale UV/AOP study shall be performed using a validated UV dose sufficient to achieve the pathogen log reduction target while complying with TCEQ disinfection rules.

4.4.3 Test Plan

The bench-scale UV/AOP study shall be conducted in one phase and will evaluate RO permeate samples. Testing should begin as soon as is practical to minimize the effects of holding time on water quality. The objectives of bench-scale testing are to identify appropriate UV and peroxide dose(s) and determine process treatment efficiency for CECs and project specific contaminants. To achieve these objectives:

1. Coordinate with and provide RO permeate samples to the selected UV equipment manufacturer(s) to determine the recommended UV and peroxide dose(s)[36]; and
2. Arrange for a third party laboratory to analyze the UV/AOP treated samples for CECs and other project specific contaminants in accordance Table 16.

4.4.4 Sample Plan

Table 16[37] presents the sample plan for the bench-scale UV/AOP testing. Feed water sampling for DOC, CECs, and project-specific contaminants may be coordinated with the pilot-scale RO testing. Sample collection procedures and volumes will be conducted per the recommendations of the equipment manufacturers and water quality testing laboratory.

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[34] Additional parameters should be added as needed to satisfy project-specific goals.

[35] Permeate samples from each individual RO pilot may be collected (if applicable) and tested if desired; however, this will increase water quality testing costs.

[36] Bench-scale collimated beam testing could also be considered to assess treatment efficiency; however, collimated beam testing results alone may not be acceptable to UV equipment manufacturers for the purposes of equipment design.

[37] This sampling plan is primarily focused on process evaluation. Regulatory sampling and monitoring requirements may also apply. Please refer to Section H.5 of this Appendix for additional information.

Table 16: Bench-Scale UV/AOP Sample Plan

Parameter	**Feed**	**Treated Water**
pH	X	X
BDOC	X	X
HAA_5	X	X
Nitrate	X	X
Nitrite	X	X
Temperature	X	X
TTHMs	X	X
Turbidity	X	X
DOC	X	X
UV Transmittance	X	
NDMA	X	X
CECs	X	X
Project-Specific Contaminant(s)	X	X

4.4.5 QA/QC

Quality assurance/quality control (QA/QC) measures shall be taken during the bench-scale study. Refer to the 22nd Edition of *Standard Methods for the Examination of Water and Wastewater* (APHA, AWWA, WEF, 2012) for QA/QC guidelines on water sample collection and water quality data analysis. Analytical procedures, calibration procedures, frequency, and accuracy of measurement requirements shall comply with Title 30 Texas Administrative Code 290.46(s), 290.110(d), 290.111(d), and 290.119.

4.4.6 Report

A bench-scale study report will be prepared to report, summarize, and interpret the data and findings from the study. The report shall consist of, but not be limited to, the content outlined below. If applicable, refer to TCEQ guidance for additional report requirements.

- Bench-Scale System Description
  - UV/AOP system equipment
- Analytical Methods
  - UV equipment supplier's standard procedures
  - Applicable water quality sampling and laboratory analysis procedures
- Results and Discussion
  - UV and peroxide doses
  - Water quality testing results including pH, temperature, turbidity, DOC, BDOC, UV transmittance, CECs, and project-specific contaminants

- Recommendations
  - Peroxide and UV doses
  - Treatment efficiencies for NDMA, CECs, and project specific contaminants

4.5 References

APHA, AWWA, and WEF, 2012. Standard Methods for the Examination of Water and Wastewater, 22nd ed. American Public Health Association, Washington D.C.

5 Regulatory Sampling - Possible TCEQ Sampling Requirements

The TCEQ will determine water quality sampling requirements on a case-by-case basis following a review of the source water quality and the proposed treatment scheme. Table 17 is intended to provide a reference for sampling that may be required by the TCEQ as part of a DPR treatment study. The listed water quality parameters and sampling frequencies may be required in addition to or in place of the example sample plans presented in the Appendix H example protocols.

Table 17: Regulatory Sampling - Possible TCEQ Sampling Requirements

Parameter	Sampling Frequency
Wastewater Treatment Plant Effluent	
1. pH	Every 5 minutes
2. Turbidity (NTU)	Every 5 minutes
3. Temperature (°C)	Every 5 minutes
4. *Escherichia coli (E. coli)* enumeration	Weekly before disinfection
5. *Giardia* (cysts/L) enumeration method 1623	Monthly before disinfection
6. *Cryptosporidium* (oocysts/L) enumeration method 1623	Monthly before disinfection
7. Total suspended solids (TSS, mg/L)	Monthly
8. Nitrate (mg/L) & Nitrite (mg/L)	Daily
9. Total dissolved solids (TDS, mg/L)	Monthly
10. Alkalinity (mg/L)	Weekly
11. Total organic carbon (TOC, mg/L)	Weekly
12. Dissolved organic carbon (DOC, mg/L)	Weekly
13. Reference the Wastewater treatment plant permit and assure that all sample results from the pilot study test period are submitted with the pilot report. Also these samples may inform other samples that are needed to show mitigation of wastewater treatment plant effluent issues. Some result examples include the "full metal scan" and CBOD5.	As required by the wastewater permit or 210 authorization
14. Chemicals listed in §290.106(b) Inorganic Chemicals	Start, Middle, End (total of 3 samples during the pilot)
15. Chemicals listed in §290.107(b) Organic Chemicals	Start, Middle, End
16. Chemicals listed in §290.108(b)(1) (radium 226, radium 228, uranium, gross alpha activity)	Start, Middle, End
17. Chemicals listed in §290.108(b)(2) & 40 CFR §141.66(d) (gross beta particle & photon radioactivity, tritium, strontium 90)	Start, Middle, End
18. Chemicals listed in §290.118(b) Secondary Chemicals	Weekly for sulfate, iron, and manganese; Start, Middle, End for the other secondary chemicals
19. Lead (µg/L)	Start, Middle, End

Parameter	**Sampling Frequency**
20. Total trihalomethanes (TTHM, report the species: chloroform, dichlorobromomethane, dibromochlor0methane, bromoform) (µg/L)	Start, Middle, End
21. Haloacetic acids (group of 5) (HAA5, report the species: monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid, dibromoacetic acid) (µg/L)	Start, Middle, End
22. Bromide (mg/L)	Start, Middle, End
23. Total culturable viruses (MPN/L)	Monthly
24. Free Chlorine Residual (if fed)	Daily or every 4 hours (if used for inactivation credit)
25. Total Hardness	Weekly
26. project specific contaminants	As needed
27. UV 254	Weekly
28. Heterotrophic Plate Count	Weekly
After Clarifier (flocculation & clarification) if used	
1. Effluent flow rate (gpm)	Every 15 minutes
2. Settled water turbidity level (NTU)	Every 4 hours
3. Effluent pH level	Every 4 hours
4. Effluent TOC (mg/L)	Weekly
5. Effluent DOC (mg/L)	Weekly
Selected MF Membrane Unit influent	
1. Inlet pressure for TMP(psi)	Every 5 minutes
Selected MF Membrane Unit Filtrate Quality	
1. Effluent turbidity (mNTU)	Every 5 minutes
2. Effluent flow rate (gpm)	Every 5 minutes
3. Outlet pressure (psi) for TMP	Every 5 minutes
4. Temperature (^{o}C)	Every 15 minutes if different from WWTP effluent temperature
5. pH level	Weekly
6. Alkalinity (mg/L)	Weekly
7. TOC (mg/L)	Weekly
8. DOC (mg/L)	Weekly
9. Total Hardness	Weekly
10. UV-254	Weekly
11. project specific contaminants	As needed
12. *Escherichia coli (E. coli)* enumeration	Weekly
13. *Giardia* (cysts/L) enumeration	Monthly
14. *Cryptosporidium* (oocysts/L)	Monthly
15. Total culturable viruses (MPN/L)	Monthly (optional)

Parameter	Sampling Frequency
16. Heterotrophic Plate Count	Weekly
Selected RO Membrane Unit Feed Water	
1. Influent flow rate (gpm)	Every 5 minutes
2. Inlet pressure (psi)	Every 5 minutes
3. Temperature (^{o} C)	Every 5 minutes
4. Nitrate (mg/L)	Monthly
5. TDS (mg/L)	Every 5 minutes
6. SDI	Daily
7. pH level	Every 5 minutes
8. Alkalinity (mg/L)	Weekly
9. TOC (mg/L)	Weekly
10. DOC (mg/L)	Weekly
11. pressure	Every 5 minutes
12. Aluminum, Barium, Boron, Bromide, Calcium, Chloride, Fluoride, Iron, Magnesium, Manganese, Potassium Selenium, Sodium, Strontium, Sulfate	Monthly
13. ORP	Every 5 minutes
14. CECs	Monthly
15. Silica (mg/L)	Monthly
16. UV254	Weekly
17. project specific contaminants	Monthly
Interstage RO Membranes - validate modeling	
1. Flow rate (gpm) at measured temperature	Daily
2. Conductivity (TDS)	Every 5 minutes
Selected RO Membrane Unit Reject Water Quality	
1. All items needed for wastewater or other permit	As required
Selected RO Membrane Unit Permeate Quality	
1. Flow rate per unit (gpm)	Every 5 minutes
2. TDS (mg/L)	Daily (minimum)
3. Effluent pressure (psi)	Every 5 minutes
4. pH level	Every 5 minutes
5. Nitrate (mg/L) - on- line	Every five minutes
6. Nitrite (mg/L) *if nitrite is detected in RO membrane feed water*	Daily
7. *Escherichia coli (E. coli)* enumeration	Weekly
8. *Giardia* (cysts/L)	Monthly
9. *Cryptosporidium* (oocysts/L)	Monthly
17. Total culturable viruses (MPN/L)	Monthly (optional)

Parameter	**Sampling Frequency**
18. Heterotrophic Plate Count	Weekly
10. Alkalinity (mg/L)	Weekly
11. TOC (mg/L)	Weekly
12. DOC (mg/L)	Weekly
13. TTHM (µg/L)	Weekly
14. HAA5 (µg/L)	Weekly
15. Bromide (mg/L)	Monthly
16. Chemicals listed in §290.106(b) Inorganic Chemicals	Monthly for barium and selenium; Start, Middle, End for other listed inorganic chemicals
17. Chemicals listed in §290.107(b) Organic Chemicals	Start, Middle, End
18. Chemicals listed in §290.108(b)(1) and §290.108(b)(2) & 40 CFR §141.66(d)	Start, Middle, End
19. Chemicals listed in §290.118(b) Secondary Chemicals	Monthly for aluminum; fluoride, iron, and manganese; Weekly for chloride; Start, Middle, End for other listed secondary chemicals
20. Ammonia, Boron, Calcium, Magnesium, Potassium, Silica, Strontium	Monthly
21. CEC	Monthly
22. Sodium	Weekly
23. Sulfate	Weekly
24. Total Phosphate	Monthly
25. UV254 absorbance	Weekly
26. project specific contaminants	Monthly
Entry Point to distribution (if additional units are piloted after RO)	
1. Flow rate (gpm)	Every 4 hours
2. Nitrate (mg/L)	Either every 5 minutes at entry point or at RO. If measured every 5 minutes at RO effluent, then measure every day at entry point.
3. *E. coli* enumeration	Weekly
4. *Giardia* (cysts/L)	Monthly
5. *Cryptosporidium* (oocysts/L)	Monthly
19. Total culturable viruses (MPN/L)	Monthly
20. Heterotrophic Plate Count	Weekly

Parameter	**Sampling Frequency**
6. Alkalinity (mg/L)	Monthly
7. Hardness as calcium carbonate (mg/L)	Monthly
8. Stability study or calculations	Weekly
9. Chemicals listed in §290.106(b) Inorganic Chemicals [3]	Start, Middle, End
10. Chemicals listed in §290.107(b) Organic Chemicals [3]	Start, Middle, End
11. Chemicals listed in §290.108(b)(1) (radium 226, radium 228, uranium, gross alpha activity)	Start, Middle, End
12. Chemicals listed in §290.108(b)(2) & 40 CFR §141.66(d) (gross beta particle and photon radioactivity, tritium, strontium 90)	Start, Middle, End
13. Chemicals listed in §290.118(b) Secondary Chemicals	Start, Middle, End
14. TTHM (μg/L)	Weekly
15. HAA5 (μg/L)	Weekly
16. Lead (mg/L)	Start, Middle, End
17. Bromate (mg/L)	Start, Middle, End

* Table provided courtesy of the Texas Commission on Environmental Quality

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H Appendix:

TWDB Comments on Draft Report

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Direct Potable Reuse Resource Document

TWDB Contract #1248321508

TWDB Comments

APAI Responses are shown in italics

General Comments

- Great job on the resource document!
- Please consider including the contract number on the title page of the report. *Done.*
- Please consider not using abbreviations in figure and table captions. *Corrected*.
  - Figure 2-2, 5-7, 7-1, and 7-2
  - Table 2-8 and 2-9
- Please consider not using acronyms in the blue boxes. When using acronyms identify within the box (e.g. page 2-1)
  - Page 2-19
  - Page 5-1 and 5-3
  - Page 9-7
  - Others

  Most acronyms were eliminated. However, common acronyms such as DPR, TCEQ and EPA and common units were left as is in some cases. APAI believes that readers of this document will know these and writing them all out is more cumbersome for the reader than leaving them as abbreviations. The list of abbreviations is provided so that the reader can reference these as needed.
- Please consider not using abbreviations in the tables and figures. When abbreviations are used in the tables please add a note at the bottom and identify the acronym.
  - Table 2-2
  - Table 2-6
  - Others

  Most acronyms were eliminated. However, common acronyms such as DPR, TCEQ and EPA and common units were left as is in some cases. APAI believes that readers of this document will know these and writing them all out is more cumbersome for the reader than leaving them as abbreviations. Also, for some tables and boxes it was not practical to spell out all abbreviations due to formatting issues (e.g. maintaining a table on a single page). The list of abbreviations is provided so that the reader can reference these as needed.
- Please consider using fewer acronyms within a sentence when possible. For example, in chapter 6, on several occasions, within a sentence 3-4 acronyms were used.
  - Page 6-7, second paragraph. *Reduced number of acronyms in this paragraph.*

Specific Comments

- Page 1-1, Figure 1-1: Please consider removing "(TWDB, 2012)" from the caption and adding "Source: TWDB, 2012" under the figure. Please add "2012" before "State" in the caption to indicate the year of state water plan. *Change made.*

- Page 1-1, 2nd paragraph, 1st sentence: Please consider using same verbiage and replacing "Water for Texas 2012" with "2012 State Water Plan" or vice-versa. Please consider placing the citation at the end of the sentence. *Change made.*
- Page 1-2, 1st paragraph, last sentence: Please consider removing the sentence. *Change made.*
- Page 1-3, Figure 1-2: Please include the year for the source. *Change made.*
- Page 1-4, 1st paragraph, 1st sentence: Please consider replacing the beginning of the sentence with the following, "The TWDB allocated priority research funding…". *Change made.*
- Page 1-4, last paragraph: Please consider not abbreviating Technical Memorandum (TM) and spelling out. *Change made.*
- Page 2-3, 1st paragraph, 2nd sentence: Please consider adding a comma after listing the second set of information. *Change made.*
- Page 2-8, 1st paragraph, 1st sentence: Please consider using data from the 2011 regional water plans instead of 2006 data. *This information was not developed in the 2011 plans. It was a special requirement of the 2006 plans. A sentence was added to the footnote explaining this.*
- Page 2-8, footnote 7, 2nd sentence: Please consider replacing "Planning groups" with "Regional water planning groups". *Change made.*
- Figure 2-3: In the upper left box, please consider replacing "Individual planning regions" to "regional water planning areas". Please consider removing the background color for the regional water planning areas. *Change made.*
- Page 2-13, blue box: Please consider adding the graph inside the blue box. *Change made.*
- Page 2-21, 1st paragraph: Please consider defining a chemical mimic. *Change made.*
- Page 2-23, blue box: Please consider removing the extra space in the beginning of the second bullet. *Change made.*
- Page 4-7, blue box, bullet 8: Please consider adding the acronym for ERP on page VII. *Change made.*
- Page 5-3, 1st paragraph, 1st sentence: Please consider removing the double period. *Change made.*
- Page 5-5, Table 5-1, 5th row: Please consider specifying why concentrate disposal of nanofiltration is less problematic. *Change made.*
- Page 5-6, Table 5-1, 2nd row: Please consider adding that chlorine is not tolerated by reverse osmosis membranes. *Change made.*
- Page 5-14, 3rd paragraph, 1st sentence. Please consider removing the double period. *Change made.*
- Page 5-19, Table 5-4: Please considering adding a note to refer the reader to the page where the six different schemes are detailed. *Change made.*
- Page 5-20: Please consider removing the graphic on the page. *Change made.*
- Page 6-1, 1st paragraph, 3rd sentence: Please consider removing the extra space. *Change made.*
- Page 6-1, image: Please consider adding a year to the source. The words in the image are hard to read, please consider reproducing or enlarging image. *Change made.*
- Page 6-2 and 6-3: Please consider not using acronyms in the case study captions. *Change not made. We feel that writing out these acronyms makes the captions more difficult to*

read.

- Page 6-3: Please consider removing the colon after “Case Study 2”. *Change made.*
- Page 7-3, 1st paragraph, 1st sentence: Please consider replacing “include” with “including” if appropriate. *Change made.*
- Page 7-5, Figure 7-2: Please consider changing the color of the arrows or enlarging the arrowhead to make the path easier to follow. *Figure was deleted at the request of the TCEQ.*
- Page 8-5, last paragraph, 2nd sentence: Please consider removing “that” and adding period at the end of the sentence. *Some of this sentence was inadvertently deleted in the draft. The complete sentence is now included.*
- Page 8-7, second paragraph, 2nd sentence: please consider explaining how the team selected a 2-3 year timeframe. Please consider removing graphic. *Graphic removed. APAI does not feel that an explanation of how the timeframe was selected is appropriate. This is based on our experience and input from the TCEQ.*
- Page 9-6, blue box, last bullet: Please consider replacing “taking” with “tasting” and spelling out DPR. *Change made.*
- Page Gloss-1: Please consider clarifying the “Beneficial Use of Reclaimed Water” definition and including examples of beneficial uses. Does beneficial then mean it has to be economical and supplement existing source. *Change made.*
- Page Gloss-1: Please consider spelling out BMPs in the Best Management Practice definition. *Change made.*
- Page Gloss-5: Please consider replacing “Bioractor” with “Bioreactor”. *Change made.*
- Page Gloss-5: Please consider removing “Membrane Treatment” and listing only “Microfiltration” *Change made.*
- Page Gloss-8: Please consider adding that reject flow is also known as concentrate or brine in the reverse osmosis definition. Or define reject flow in the glossary. *Change made.*

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