CAPITAL IMPROVEMENT PLAN

MOUNTAIN WATER DISTRICT
PIKEVILLE, KENTUCKY

OCTOBER 2020

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MOUNTAIN WATER DISTRICT
PIKEVILLE, KENTUCKY

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PIKEVILLE, KENTUCKY
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I. EXECUTIVE SUMMARY

This report is in response to the Kentucky Public Service Commission (PSC) and Mountain Water District's (MWD) agreement to develop a comprehensive Capital Improvement Plan to reduce unaccounted-for water (UW) to 15%.

In 2019, MWD operated with an annual UW of 49.51%. UW has remained about the same since 2015 and can be partly attributed to a declining customer base, reduced household consumption, inaccurate metering, and physical problems in the system. This report will examine system components, historical trends, and current operating conditions. Current operating conditions will be used to develop a water balance. The findings will be used to draft a plan to reduce UW over a 15-year planning period.

The plan will list specific capital improvements focused on improving metering accuracy, establishing system monitoring capabilities, replacing failing infrastructure, and increasing the operational / loss reduction capacity of MWD. Major items of work will include: installing zone meters, establishing districted metering areas (DMAs), installing advanced metering infrastructure (AMI), replacing residential and commercial meters, developing institutional controls, booster pump station replacement and rehabilitation, water storage tank improvements, water treatment plant improvements, telemetry installation, and replacing problematic mains and service lines. An implementation strategy will also be presented with a list of measurable outcomes that can be used to evaluate the success of the plan.

The goal is to reduce UW to 15% by 2035. In doing so, MWD hopes to achieve regulatory compliance, develop a sustainable operation, and provide the citizens of Pike County with a reliable source of public water for decades to come.

II. INTRODUCTION

On December 19, 2019, the Public Service Commission (PSC) and Mountain Water District (MWD) informally met to discuss the steps involved to develop a Capital Improvements Plan to reduce water loss. Bell Engineering and Environmental Design Consultants were procured to assist MWD with preparation of the comprehensive Capital Improvement Plan.

For calendar year ending 2019, MWD reported 23.12% unaccounted-for water (UW) as shown on the attached Monthly Loss Report Annual Summary for 2019. However, based on the standard established by 807 KAR 5:066, system overflows and estimated line breaks should be included in the UW calculation. The revised UW for MWD for 2019, which considers water losses due to system overflows and line breaks as unaccounted-for losses has been calculated as

49.51%. The PSC has encouraged MWD to reduce its unaccounted-for water (UW) to 15% annually. The goal of this comprehensive Capital Improvement Plan is to reduce UW to 15% over the next 15-years.

This report will present information on the current condition of the MWD distribution system, analyze historic operating trends, propose capital improvements, outline a course for implementation, and establish measurable outcomes.

III. SYSTEM INFORMATION

MWD was established in 1986 and is located at 6332 Zebulon Highway, Pikeville, Kentucky 41502. MWD, Kentucky Division of Water (DOW) permit number KY0980575, provides potable water service to approximately 16,500 customers in Pike County. MWD is regulated by the PSC and DOW and is a member of the Kentucky Rural Water Association (KRWA) and the Big Sandy Area Development District (BSADD) Regional Water Management Council. MWD is a distribution and production system and purchases water for resale from the cities of Pikeville and Williamson, and operates and maintains a 3.0 million gallon per day (mgd) Water Treatment Plant. System data can be found on the Kentucky Water Resource and Information System (WRIS) website at www.wris.ky.gov. Copies of the WRIS system data report and asset inventory report are attached.

A complete list of MWD's infrastructure is included in the attached asset inventory report. The last major infrastructure project, the Johns Creek Railroad and Deskins/Kimper Pump Station Relocation Project, was completed in 2020. An existing system map is attached.

The following section discusses MWD's existing lines, storage facilities, pump stations, meters, telemetry, staff, institutional controls, equipment, rates, and wholesale supply. The objective is to provide an overview of the system and identify potential sources of UW in the system.

A. Lines

Summary- MWD is composed of approximately 5,348,191 linear feet (lf) of transmission, distribution, and service line. The District inherited lines from four other water districts when they merged to become MWD in 1986 that range in size from 3/4-inch diameter to 16-inch diameter. MWD has maps dating back to the early 70's, but project files from the other four systems no longer exist. The Marrowbone area has the oldest lines to MWD's knowledge. The types of line include polyethylene (PE), polyvinyl chloride (PVC), asbestos cement (AC), and ductile iron (DI). The majority of line is composed of 4-inch, 6-inch, and 8-inch PVC.

Potential Sources of UW- The PSC considers the useful life of water line to be 50 to 75 years. Improper installation, improper application, poor maintenance, and environmental influence can shorten a water line's useful life. For the purpose of identifying potential contributors to UW, only lines with a reported date of installation of 1960 or earlier are considered. MWD does not currently have any data or information which allows identification of waterline with an installation date prior to 1960.

MWD estimates 75% of their UW is through their service lines and connections and primarily comprised of 3/4-inch polyethylene pipe. This accounts for roughly $600,000 - $700,000 annually in losses, and was the basis of wanting to start this infrastructure repair when it was first presented in 2011. It is estimated by the Operations Manager that MWD has lost approximately $6,000,000 in water purchased and produced since that presentation. (Please refer to the PowerPoint presentation for BPS, Regulator, and Tanks.)

It should be noted that all known water line creek crossings with issues have been addressed. MWD should continue its annual inspection of valves and other system components as required by 807 KAR 5:006, Section 26(6)(b) and replace and/or repair as needed.

B. Storage Facilities

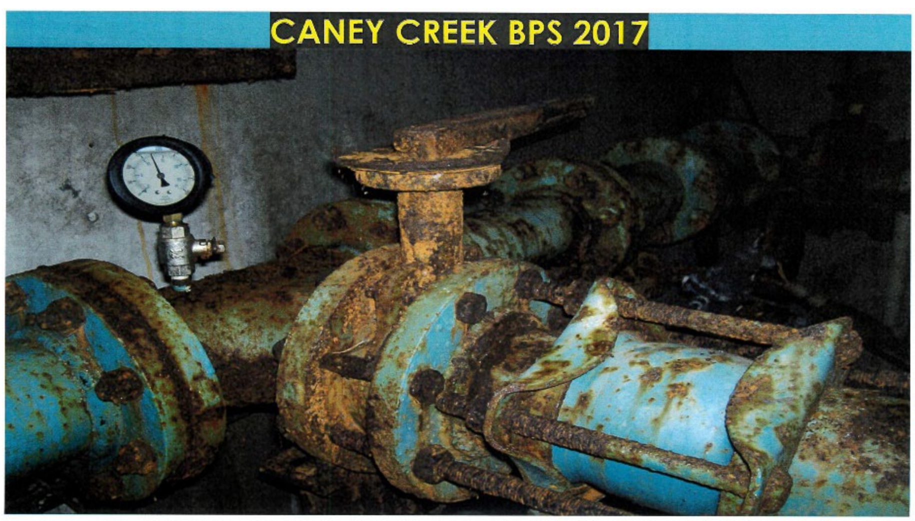
Summary- MWD has 108 above-ground storage facilities, including stand-pipes and elevated storage tanks. MWD's total combined storage capacity is approximately 8,662,000 gallons. These facilities were installed between 1971 and 2008.

Potential Sources of UW- The useful life of above-ground storage facilities is approximately 40 years. The only storage facility in the system that is older than 40 years is the Graveyard Hollow Tank. This 100,000-gallon tank was installed in 1971 and was last inspected by DOW in 2017. The Graveyard Hollow Tank represents approximately 1.15% of the system storage capacity. Two important aspects of steel tank construction are the interior and exterior coating systems. These coating systems often need to be replaced several times throughout the useful life of a tank. Typically, coating systems are good for approximately 12-15 years and need to be inspected on an annual or biennial basis. Of the 108 tanks in operation, six (6) tanks do not appear to have been inspected within the last 15 years. MWD has 39 water storage tanks in a maintenance contract until 2026 and, to-date, has invested over $500,000 into tank maintenance activities.

C. Pump Stations

Summary- MWD has 137 booster pump stations. These pump stations are located in the Grapevine, Marrowbone, Pond Creek, and Shelby Valley areas.

Potential Sources of UW- The images below are inside the Indian and Caney Creek Booster Pump Stations respectively. The Indian Creek Station is in an underground vault and showed signs of accelerated deterioration on exposed plumbing and electrical fixtures. Rehabilitation was complete in 2018 costing approximately $12,500. The Caney Creek Station is an above ground pump station and was also rehabilitated in 2018 including a new building costing approximately $50,000. Based on the condition of these stations, MWD has identified certain stations either for rehabilitation or replacement over the next 15 years.



D. Meters

Summary-The MWD system contains approximately 17,880 meters including residential meters, commercial meters, and master meters. The type of meter varies as do the dates of installation. The following is a breakdown of the meters in the system based on application.

Residential and Commercial Meters				
Meter Size	**Meter Type**	**Meter Count**	**Application**	**Date Installed**
¾-Inch	Badger	28	Residential/Commercial	2004-2006
¾-Inch	RG3	16,626	Residential/Commercial	2017-2020
¾-Inch	RG3	1,060	Inactive Residential/Commercial	Various
1 Inch	RG3	56	Residential/Commercial	Various
2 Inch	Badger	41	Commercial	Various
2 Inch	RG3	17	Commercial	Various
3 Inch	Badger	4	Commercial	Nov. 2011, Sept. 2012
3 Inch	Sensus	4	Commercial	March 2000, October 2004, January 2006, January 2015
3 Inch	RG3	3	Commercial	November 2016, May 2018, November 2019
4 Inch	RG3	2	Commercial	Oct 2017, July 2018
4 Inch	Badger	7	Commercial	July 2011
6 Inch	Badger	4	Commercial	May 2013, March 2017, Oct 2012

Master Meters				
MMS No.	Name/Location	Meter Size	Meter Type	Date Installed
M-01JC	TOWN MOUNTAIN	6 INCH	COMPOUND	1987
M-02JC	META	6 INCH	TURBO	1987
M-03BC	BIG CREEK	6 INCH	TURBO	1987
M-04CC	CHLOE CREEK	6 INCH	COMPOUND	1980
M-05SV	INDIAN HILLS	4 INCH	TURBO	1996
M-061C	ISLAND CREEK	4 INCH	TURBO	1992
M-071C	RACOON BRANCH	4 INCH	TURBO	1993
M-081C	HOOPWOOD HOLLOW	2 INCH	TURBO	1998
M-09SX	SOOKEY CREEK #1	4 INCH	TURBO	1992
M-10SV*	SOOKEY CREEK #2	6 INCH	TURBO	1993
M-11EC	ELKHORN CREEK	4 INCH	TURBO	1997
M-12CP	COWPEN	4 INCH	TURBO	1993
M-13HC	HURRICANE CREEK (OUT OF SERVICE)	4 INCH	TURBO	1992
M-15MC	MILLIARD	6 INCH	TURBO	1992
M-16PC	WILLIAMSON #1	10 INCH	TURBO	1984
M-17PC	WILLIAMSON #2	6 INCH	COMPOUND	1978
M-181C	MODERN MOBILE HOME PARK	2 INCH	COMPOUND	1979?
M-18MC	GREASY CREEK	6 INCH	TURBO	1992
M-19MC	FERRELLS CREEK	4 INCH	COMPOUND	2001
M-20JC	BRUSHY CREEK	4 INCH	COMPOUND	2003
M-21HC	CEDAR GAP/HURRICANE	4 INCH	COMPOUND	2005
M-22MC	ELKHORN CONNECTOR	6 INCH	COMPOUND	2005
M-23JC	LOWER JOHNS CREEK	6 INCH	COMPOUND	2006
M-24MC	RUSSELL FORK WTP	12 INCH	COMPOUND	2003
M-25JC	MILLER’S CREEK	4 INCH	COMPOUND	2006
M-26JC	LEFT JOE’S CREEK	2 INCH	TURBO	2006
M-27MC	MARROWBONE	6 INCH	COMPOUND	2009

Existing Zone Metering				
Meter Size	Meter Type	Meter Count	Location	Date Installed
NONE	NONE	0	N/A	N/A

Potential Sources of UW- MWD began a meter replacement project and reported replacing all meters at the time of this report. Meters have varied useful lives depending on size, type, application, and frequency of use. Manufacturers will promote lifetime meters; however, the PSC has taken a more realistic approach and requires the following meter testing frequency.

Required Meter Testing Frequency	
Meter Size	**Testing Frequency**
3/4-Inch to 1-Inch	Once every 10 years
1 1/4-Inch to 2-Inch	Once every 4 years
3-Inch	Once every 2 years
4-Inch and Larger	Annually

MWD currently utilizes RG3 radio read meters utilizing two (2) laptops with appropriate software for meter reading.

MWD should consider subdividing its system into districted metering areas (DMA). Typically, DMAs are divided by pressure zones and are capable of being isolated. DMAs utilize "zone" meters to monitor flow entering the area. The flow is then compared to metered sales to determine area loss. A compound meter is recommended for zone meter application. These meters can be equipped with pressure sensing equipment and integrated into an AMI network.

The installation of zone meters and establishment of DMAs will provide MWD with accurate, real-time flow information that can be used to pinpoint areas of loss, focus repair efforts, and prioritize future projects. MWD should considered installing zone meters and establishing DMAs as soon as funding permits.

E. Telemetry

Summary- MWD uses telemetry/SCADA devices supplied by MicroComm. Devices are installed at tank and pump station locations and provide data to MWD but currently do not connect to a single server located at MWD's office. MicroComm also provides the necessary software updates and services this equipment upon request. MWD is currently demoing four (4) cellular remote units manufactured by High Tide.

Potential Sources of UW- Without being able to monitor telemetry from a remote location, being able to respond in a timely manner to issues increases water loss in the system. MWD estimates if pump stations were connected to water level transducer sensors, 95% of overflows would be eliminated.

F. Staff

Summary- MWD employs (55) full-time staff and (5) temporary staff along with five commissioners. A list of current employees along with their respective job titles, qualifications and dates of hire appears below.

CURRENT EMPLOYEES- MWD			
TITLE	**NAME**	**DATE OF HIRE**	**QUALIFICATIONS**
Operations Manager	David M. Taylor	6/12/00	Drinking Water Distribution 3 / Drinking Water Treatment 4-A
Wastewater Manager	Jamey Keathley	9/10/91	Drinking Water Distribution 3 /Wastewater Treatment 1 /Wastewater Collection 2
Call Out Supervisor/WTP Opr.	Kris Dills	12/18/07	Drinking Water Treatment 3A
Water Plant Operator	Austin Overstreet	2/20/18	Drinking Water Treatment 2A
Field Supervisor	William D. Scalf	3/24/88	Drinking Water Distribution 3
Water Treatment Plant Opr.	Mitchell Taylor	10/31/14	Drinking Water Treatment 4A
Water Treatment Plant Opr.	Dakoda Smith	9/6/16	Drinking Water Treatment 3A
Field Supervisor	Timmy Lucas	4/1/95	Drinking water Distribution 3 / CDL
Leak Detection Supervisor	Jonathan Joyce	8/25/03	Drinking Water Distribution 3
Leak Detect/Equip. Opr.	Jason Sesco	11/7/05	Drinking Water Distribution 3
Field Supervisor	David W. Taylor	2/6/06	Drinking Water Distribution 3 /CDL
Water/Wastewater Tech.	Terry Wright	10/27/08	Wastewater Collection 1 / CDL
Wastewater Opr.	Chris Dempsey	9/20/10	Wastewater Treatment 2
Wastewater Opr. Trainee	Chris Biliter	10/20/08	Wastewater Collection 2
Wastewater Tech.	Jeffery K. Tackett	10/10/14	Wastewater Collection 2
Wastewater Tech.	Robbie Scarberry	4/4/16	Wastewater Collection 1
Waster Water Opr.	James Cory Mullins	9/6/16	Wastewater Treatment 2
Repair Maintenance Supervisor	David Wolford	8/18/02	CDL
Maintenance Tech.	Ronnie Belcher	6/12/17	CDL
Financial Admin.	Carrie Hatfield	5/13/99	Bachelor in Accounting
Office / Billing Manger	Kevin Low	5/10/99	Masters of Business Administration
Compliance / Off. Manger	Tammy Olson	6/30/03	Bachelor in Business Administration
Customer Service Manager	Melissa Wright	6/6/02	Business & Business Manager Associate
District Project Manager	Roy Sawyers	7/1/00	
HR Specialist/AP Asst.	Tammie Fields	8/1/16	
Administration Asst.	Flora Newsome	6/27/08	
Meter Service Supervisor	Brian Bentley	8/6/02	
Cashier	Michelle Huffman	2/14/13	
Meter Service Tech 3	Crit Justice	7/16/07	
Customer Service Clerk 2	Silena McCown	8/1/91	
Meter Service Tech 2	Jason H. Stanley	10/8/01	

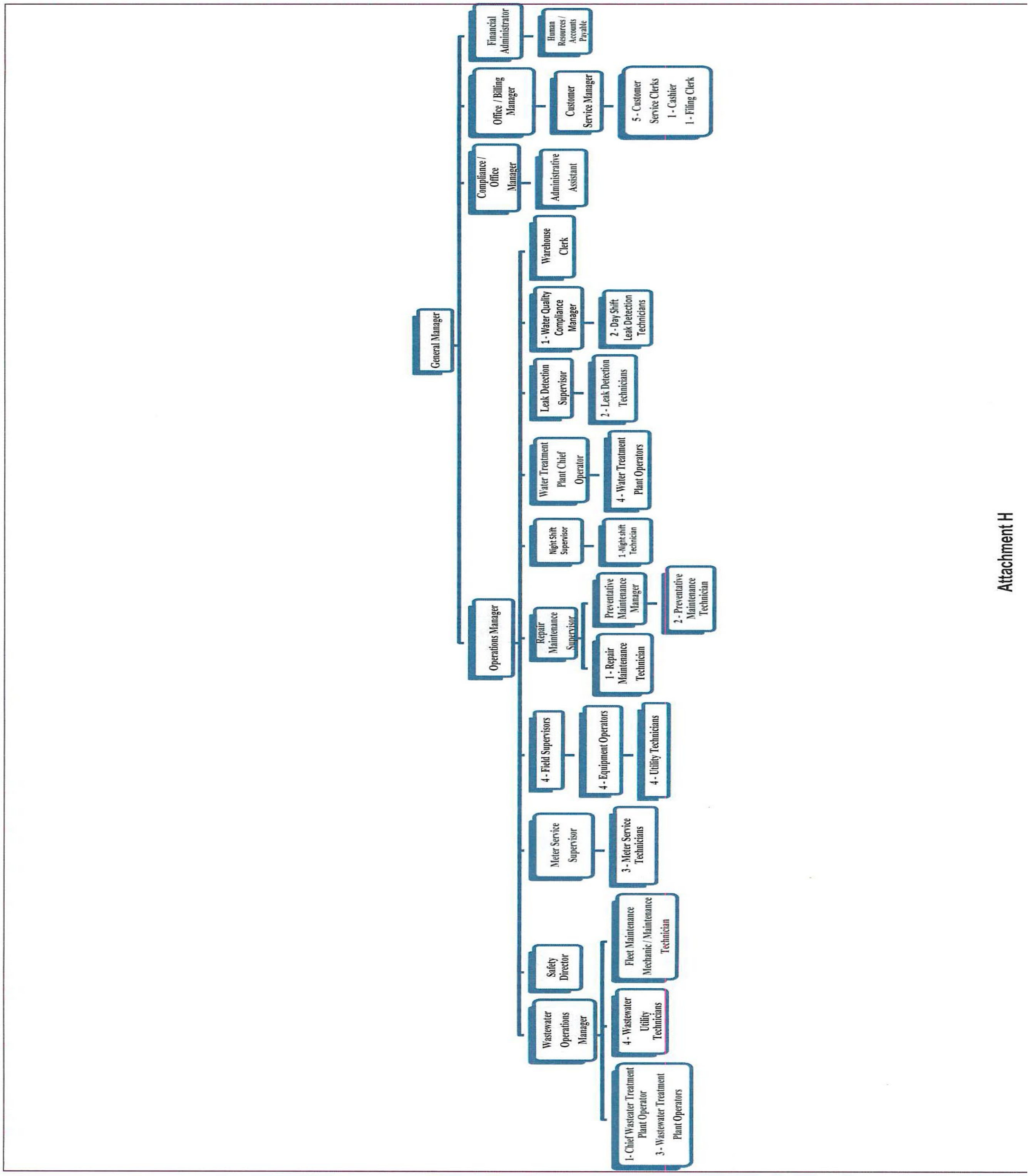
Attachment I

Customer Service Clerk 2	Melissa Watson	8/6/00	
Customer Service Clerk 2	Katrina Brooks	9/6/16	
Meter Service Tech 2	David Grubb	7/17/17	
Filing Clerk	Angela Smith	8/23/17	
Meter Service Tech 1	Donald Mullins	7/23/18	
Customer Service Clerk 1	Courtney Snodgrass	1/3/19	
Safety Director	Jamie Stacy	9/616	CPR Instructor
Water Treatment Plant Opr. Trainee 1	Matthew Adkins	9/4/18	
Prevent Maint. Tech. 1	Jacob Lockard	9/30/19	
Equip. Operator 3	Brandon Beckett	8/2/07	
Compliance Tech1	Gary Jason Blackburn	1/4/00	
Warehouse Clerk	Williams Burnette	10/17/94	
Fleet Garage Mechanic	Ed Dotson	7/10/06	Diesel Mechanics/Auto Mechanics/ASE Refrigerant Recovery & Recycling
Field Supervisor 2	Robbie Nichols	5/15/06	
Equipment Operator 2	Josh Blackburn	9/6/16	
Equipment Operator 1	Josh Stanley	12/23/13	
Call Out Utility Tech 1	Tyler Elswick	2/5/18	
Prevent Maint. Tech. 1	Brandon Sheppard	7/5/18	
Water Utility Tech. 1	Karson Newsome	8/27/18	
WTP Operator Trainee 1	Daniel Caudill	6/10/19	
Water Utility Tech. 1	Sam Newcomb	2/17/19	
Waste Water Collection	Cameron Price	1/29/19	
Leak Detection	Todd Sesco	12/14/15	
Prevent Maint. Supervisor	Brad Taylor	5/15/17	
Prevent Maint. Tech. 1	Chris Whitt	5/5/08	Workers Comp
Water Utility Tech. 1	Brady Woods	11/14/19	Contractor
Meter Service/Water Utility Tech. 1	Dustin Varney	6/17/20	Contractor
Wastewater Tech. Trainee	Austin Hatfield	6/15/20	Contractor
Wastewater Tech. Trainee	James Horn	6/8/20	Contractor

Potential Sources of UW- It appears that the MWD's office staff size is adequate, but field staff needs to be expanded. It is recommended MWD consider hiring eight to ten (8-10) additional field personnel. Potential problems associated with undersized field staff include but are not limited to:

1. Inability to provide proper roadside safety and traffic control during repairs along state and county rights-of-way.
2. Inability to perform routine maintenance.
3. Slower response times to emergency calls.
4. Increased work-related stress.
5. Territorialism.

The flow chart below depicts MWD's current organizational structure.



G. Institutional Controls

Summary- One of the proven practices of sustainable water utilities is the establishment and implementation of institutional controls in the form of written planning and procedure documents. These documents typically focus on providing fundamental services, optimizing daily operations, investing capital assets and preparing for future demands. Such documents may include: O&M Manuals, Policy and Procedures Manual, Loss Detection Plan, Comprehensive Loss Reduction Plan, Capital Improvements Plan, Water Audit, Flushing Plan and system wide hydraulic model. MWD currently has an O&M Manual, which is reviewed and checked by inspectors annually or semi-annually. MWD has an Employee Handbook, Water Loss Control Program, Emergency Response Plan, and a Preventative Maintenance Program for the Water and Sewer Divisions. MWD's flushing plan is also in development.

Potential Sources of UW- MWD should review existing institutional controls and address any deficiencies identified.

H. Equipment

Summary- MWD currently owns the following meter reading and leak detection equipment: RGS radio read meters, (4) Micronics Portaflow Ultrasonic Flowmeter, (2) Subsurface LD-12, (2) Subsurface LD-7, (1) Subsurface LD-18, (1) Subsurface/Flow Metrix DigiCoor Correlation Machine, and (2) Digital Leak Detector Listening Devices.

In addition to the metering and leak detection equipment, MWD also owns the following equipment that is used to sustain daily operations and perform routine maintenance:

MOUNTAIN WATER DISTRICT
VEHICLE LIST
UPDATED OCTOBER 2019

6/15/2020

Vehicles

	Vehicle Number	Driver	Dept.	Year	Gas/Diesel	Description	License Number	VIN Number	Gross Weight	Cost New	Current Mileage
1	113	Caudill, Daniel	CS	2008	GAS	Chevy Colorado	N3877	1GCCS149688102647	6000	$12,337.65	162,030
2	124	Conley, Randy	FC	2009	GAS	Chevy 2500 HD 4WD	495204	1GBHK44K19F149421	10000	$33,799.24	199,605
3	125	Spare	CO	2009	GAS	Chevy 2500 HD 4WD	495203	1GBHK44K59F166626	10000	$33,799.24	261,681
4	DT001	Lucas, Timmy	FC	2008	DIESEL	Kenworth Dump Truck	N3103	2NKMHN7X98M216503	10000	$70,750.00	65,407
5	PT	Wastewater	WW	2000	DIESEL	Sterling Pumper Truck	P0908	2FZHAJBA6YAG71514	10785	$26,000.00	
6	128	Spare	CS	2010	GAS	Chevy Colorado 2WD	P0907	1GCCSBD96A8141394	6000	$16,495.00	218,696
7	129	Mullins, Donald	CS	2010	GAS	Chevy Colorado 2WD	P0906	1GCCSBD98A8145589	6000	$16,495.00	206,198
8	130	Hurley, Zach	CS	2011	GAS	Chevy Colorado 2WD	P1991	1GCCSBF95B8105579	6000	$15,488.00	107,658
9	133	Whitt, Chris	FC	2011	GAS	Chevy Silverado 2500 4WD	KP2530	1GB0KVCG6BZ388340	9500	$30,040.20	141,869
10	134	Elswick, Tyler	FC	2011	GAS	Chevy Silverado 2500 4WD	KP3228	1GB0KVCG2BZ382986	9500	$30,040.20	189,357
11	135	Sesco, Jason	LD	2011	GAS	Nissan Frontier Ext Cab 4WD	P4736	1N6AD0CW9BC442184	5690	$24,399.72	193,753
12	137	Blackburn, Jason	FC	2012	GAS	Chevy Colorado 4WD	P5075	1GCJTBF98C8121913	10000	$22,163.52	161,991
13	138	Wright, Terry	FC	2012	DIESEL	Chevy Silverado	P6050	1GB0KVCL2CF176373	10000	$34,353.24	170,888
14	140	Wolford, David	FC	2012	GAS	Chevy Silverado	P6048	1GCOKVCGCZ184827	10000	$26,983.98	193,939
15	141	Stacy, Jamie	WW	2012	GAS	Ford F-250 4WD	6744126	1FDBF2B67CEC68860	10000	$27,308.04	226,640
16	142	Dills, Kris	CO	2013	GAS	Ford F150	P7974	1FTMF1EMODFC28732	6650	$19,767.00	154,210
17	143	Scarberry, Robbie	WW	2014	GAS	Ford F150	P9426	1FTMF1EM9EFC09534	6650	$20,500.00	169,756
18	144	Mullins, Cory	WW	2014	GAS	Ford F150	P9427	1FTMF1EM0EFC09535	6650	$20,500.00	180,145
19	145	Dotson, Eddie	FC	2014	GAS	Ford F150 4WD	P9425	1FTMF1EM2EFC09536	6650	$20,500.00	78,215
20	CT002	Crane Truck	FC	2016	GAS	Dodge Ram 5500	C6039	3C7WRMBJ1GG306999		$28,875.00	5,929
21	146	Beckett, Brandon	FC	2015	DIESEL	Chevy Silverado 4WD Reg Cab	C4164	1GB0KUE85FZ529324	9900		146,416
22	147	Tackett, Keith	WW	2016	GAS	Ford F250 - Utility Bed 4 X 4	C6877	1FDBF2B63GEB96897			74,141
23	148	Stanley, Josh	FC	2016	GAS	Ford F250 - Utility Bed 4 X 4	C6876	1FDBF2B61GEB96898			98,538
24	149	Nichols, Robbie	FC	2016	GAS	Ford F150 4WD	C7360	1FTMF1E88GKD92759	6100	$25,648.00	72,576
25	150	Jason Stanley	CS	2016	GAS	Ford F150 4WD	C7363	1FTMF1E88GFC12219	6100	$21,939.00	100,009
26	151	Dempsey, Chris	WW	2016	GAS	Ford F150 4WD	C7366	1FTMF1E88GFB97009	6100	$21,939.00	47,925
27	152	Billiter, Chris	WW	2017	GAS	Ford F150 4WD	C9529	1FTMF1E88HFB88098	6050	$22,849.00	70,167
28	153	Taylor, David W.	FC	2017	GAS	Ford F 150 4WD		1FTMF1E89HFC58465	6050	$22,814.00	53,776
29	154	Taylor, Brad	FC	2017	GAS	Ford F 250 4WD	D1053	1FDBF2B68HEE75212	10000		46,692
30	155	Justice, Crit	CS	2017	GAS	Ford F 150 4WD	D3066	1FTMF1EB9JKD15644			39,264
31	156	Bentley, Brian	CS	2018	GAS	Chevy Silverado 4WD		1GCNKNEH4JZ278182			45,794
32	157	Grubbs, David	CS	2018	GAS	GMC Sierra 1500 4WD		1GTN2LEH8JZ286354			37,169
33	158	Lucas, Timmy	FC	2018	GAS	Ford F 150 4WD		1FTMF1EB6JKE75173	6050	$26,460.94	38,706
34	159	Scalf, Doug	FC	2018	GAS	Ford F 150 4WD		1FTMF1EB4JFD94844	6050	$25,660.94	37,992
35	160	Blackburn, Josh	FC	2018	DIESEL	Chevy Silverado 3500 Utility Bed		1GB3KYCY9JH245664		$47,665.00	11,590
36	161	Mullins, Donald	CS	2019	GAS	Ford F150 4WD		1FTMF1EB3KKD11509		$24,017.00	19,277
37	162	Joyce, Jonathon	LD	2020	GAS	Ford F150 4WD		1FTEX1EB1LKD22799		$24,474.00	

ATTACHMENT J

AD - Administration
CO - Call Out Crew
CC - Construction Crew
FC - Field Maintenance Crew
MC - Meter Crew

MOUNTAIN WATER DISTRICT
VEHICLE LIST
UPDATED OCTOBER 2019

6/15/2020

Equipment

Backhoe Number	Operator		Year	Make	Area	Serial Number	Driven Home?	Radio?	Current Hours
013	Floats - Field Crews	MB	2005	Case	Marrowbone	N5C390957	N/A	Yes	3905.1
	Various			Ditch Witch 1320 Walk Behind Trencher	MWD Lot		N/A	No	
SL 1	Burnette, Randy			Gehl/Skid Steer Forklift	Warehouse		N/A	No	1850
EXC 1	Billiter, Chris	WW	2006	PC 27Komatsu Mini Excavator	Wasetewater		N/A	No	5810
EXC 2	Blackburn, Josh	GV	2018	Kobelco 35 Mini Excavator	Grapevine		N/A	No	50
EXC 3	Wright, Terry	SV	2018	Kobelco 35 Mini Excavator	Shelby Valley		N/A	No	
EXC 4	Beckett, Brandon	PC	2016	Caterpillar Mini Excavator	Pond Creek				122
EXC 5	Stanley, Josh	MB	2019	Kobelco 35 Mini Excavator	Marrowbone				
SL 2	Scarberry, Robbie	WW	2008	JCB 190T Skid Steer Loader	Freeburn WWTP	1400331	N/A	No	

Miscellaneous Equipment

Descr.	Make	Location	Model	Serial No.	
20 KW	Cohler Generator	Behind MWD Office			
25 KW	Atlas Copco Generator	MWD Lot			
20 KW	Cummins Power Generator	MWD Lot			
	Thermal ARC AC/DC Welding Generator	Electrican's Shop/Office	TA10/270		
5500 Watts	Troy Bilt Generator	Douglas WWTP			
150.4 KW	Olympia Generator	Phelps WWTP	D15OPI	Oly00000LNAT00650	
25-31 KW	Atlas Copco Generator	Phelps Intersection Lift Station	QAS30	HOP100028	
UP TO 107 KW	Generac Generator (2017)	MWD Lot	MMG	7FSPG1820HB996601	
	2" Trash Pump	MWD Lot			
	2" Trash Pump	MWD Lot			
	Atlas Copco XAS - 96 Air Compressor	Marrowbone Area	XAS-96		
	Sullivan Palatek Air Compressor	Pond Creek Area	D18506CABGAL	100620	
	Ingersoll Rand Air Compressor	Grapevine Area	P185-WIR		
	Amflo Tru Flate Air Compressor	Mechanics Garage	7.5 HP		
45-65 KW	Baldor TS80-T Trailer Type Generator	MWD Lot	TS80-T		
	Pioneer Diesel By-Pass Pump	WW - Shared by SV and Phelps Area	PP66S12L72-D914L04		
PC 4	Pond Creek Trailer	Pulled behind vehicle #146 (Gatormade)			
GV 2	Grapevine Trailer	Pulled behind vehicle #134 (Gatormade)			
SV 3	Shelby Valley Trailer	Pulled behind vehicle #138 (Gatormade)			
WW 1	Wastewater Department	RediHaul Trailer - Shared by SV and Phelps area			
WW 2	Wastewater Department	6.5 X 16 - Primarily Used in the Phelps Area			
WW 3	Wastewater Department	5 X 10 - Utility Trailer - Phelps Area			
MB 5	Marrowbone Trailer	Gatormade - Pullled behind #148			
MWD 6	Spare	Equipment Trailer - MWD Lot			
DT 7	Dump Truck Trailer	Pulled behind the Dump Truck 8X24			
SJ 8	Pull Behind Sewer Jetter	Stored at MWD Lot Shed	7040-SC	OBM-1621	1H9PS2123EM511621

AD - Administration
CO - Call Out Crew
CC - Construction Crew
FC - Field Maintenance Crew
MC - Meter Crew

Potential Sources of UW-Old, unserviceable equipment can impair daily operations, inflate maintenance cost, reduce leak detection capabilities, increase repair times, and create an unsafe workplace. Some of the equipment listed above appears to be beyond its useful life and may no longer be safely operated. The Kentucky Association of Counties (KaCo) will conduct safety audits for county agencies upon request. MWD should request such and implement its recommendations.

I. Existing Rates

Summary- The MWD has approximately 16,517 customers. Metered sales are checked and billed on a monthly basis. The total volume of metered sales for 2019 was approximately 790,602,230 gallons. Metered customers are categorized by meter size. The current rates were placed into effect on February 28, 2020. A copy of the current rate tariff has been included as an attachment. The following is a breakdown of the current rate schedule.

5/8-Inch Meters			
First	2,000 Gallons	$23.93	Minimum Bill
Next	8,000 Gallons	$8.47	per 1,000 Gallons
Over	10,000 Gallons	$7.54	per 1,000 Gallons
1-Inch Meter			
First	5,000 Gallons	$49.34	Minimum Bill
Next	5,000 Gallons	$8.47	per 1,000 Gallons
Over	10,000 Gallons	$7.54	per 1,000 Gallons
2-Inch Meter			
First	20,000 Gallons	$167.09	Minimum Bill
Over	20,000 Gallons	$7.54	per 1,000 Gallons
3-Inch Meter			
First	30,000 Gallons	$242.49	Minimum Bill
Over	30,000 Gallons	$7.54	per 1,000 Gallons
4-Inch Meter			
First	50,000 Gallons	$393.29	Minimum Bill
Over	50,000 Gallons	$7.54	per 1,000 Gallons
6-Inch Meter			
First	100,000 Gallons	$770.29	Minimum Bill
Over	100,000 Gallons	$7.54	per 1,000 Gallons
Martin County Water District		$3.09	per 1,000 Gallons
Mingo County Water District		$4.66	per 1,000 Gallons
Jenkins Utilities			
First 50,000 Gallons per Day		$3.09	per 1,000 Gallons
Over 50,000 Gallons per day		$3.50	per 1,000 Gallons

City of Elkhorn		
First 215,000 Gallons per day	$2.91	per 1,000 Gallons
Over 215,000 Gallons per day	$3.09	per 1,000 Gallons

Water Taps:

5/8" x ¾" Standard:	$825.00
1" and Above:	At Cost

Water withdrawn from a hydrant and water withdrawn for construction shall be charged at the lowest rate in the current rate schedule. $7.54 / 1,000 gallons

Average monthly usage per meter is approximately 3,873 gallons with a corresponding average monthly bill of approximately $39.49. MWD disconnects approximately 167 and reconnects approximately 112 meters per month.

Meters are read using radio read technology. There are 10 cycles ranging from four (4) to 25 routes per cycle in the system which takes approximately 2 to 4 days per cycle to cover. Meter reading typically starts around the 2nd of each month and finishes around the 29th. Disconnects/Reconnects typically occur around the 4th of each month and conclude around the 27th. It takes MWD staff approximately 3 days to complete each disconnect/reconnect cycle.

Potential Sources of UW- The initial concern is that the existing rate structure will not provide sufficient revenue to support the water loss reduction activities recommended in this plan. MWD should consider requesting PSC approval to assess a surcharge of which proceeds would be used solely to support the water loss reduction activities recommended in this plan.

MWD should adopt a policy that requires a rate study on a biennial basis to assess the adequacy of existing rates. Agencies such as the Kentucky Rural Community Action Partnership (RCAP) can assist with these rate studies. MWD should plan for 3.5% inflationary increases in operating cost per year.

MWD should apply for an adjustment in its rates using the PSC's purchased water adjustment process as soon as possible when its wholesale suppliers increase their rates for wholesale water service. Any delay in applying for such an adjustment will compound MWD's current revenue problems and will result in a reduction in net operating income.

It is recommended that MWD perform billing software audits on a periodic basis.

J. Wholesale Supply

Summary- MWD is a retail supplier and producer of potable water. Water is purchased at wholesale rates from the City of Pikeville at $1.97 per 1,000 gallons with a minimum 28,000,000 gallons per month not to exceed 40,000,000 gallons, and from Williamson, West Virginia at $1.83 per 1,000 gallons with a minimum 20,000,000 gallons per month.

MWD's water purchase agreements with these suppliers are on file with the PSC. MWD also produced 844,515,772 gallons in 2019 at an estimated average cost of $1.17 per 1,000 gallons. A breakdown of MWD's wholesale supply appears below.

Wholesale Water Distribution				
Supplier	**MWD Location**	**Number of MWD Customers Supplied**	**Percent of Customers Supplied**	**Annual Volume (gal)**
City of Pikeville	Island Creek	1,293	7.84 %	43,195,000
	Hurricane Creek	336	2.03 %	20,604,000
	Indian Hills	106	0.64%	114,590,000
	Town Mountain	2,196	13.32%	220,795,000
	Chloe	312	1.89%	21,494,000

	Cowpen	391	2.37%	33,823,000
	Coon Branch	26	0.15%	1,130,000
	Modern MHP	36	0.21%	2,116,000
	Hoopwood	23	0.13%	1,118,000
Total Pikeville		4,719	28.58%	458,865,000
City of Williamson, WV	Williamson #1- Front of Williamson WTP	2877	17.42%	237,328,407
	Williamson #2- Wilson Loop	359	2.17%	35,092,600
Total Williamson		3,236	19.59%	272,421,007
Combined Total		**7,955**	**48.17%**	**731,286,007**

MWD purchases water from the City of Pikeville at a rate of $1.97 per 1,000 gallons and $1.83 per 1,000 from Williamson, West Virginia.

Potential Sources of UW- There is always the potential for inaccuracy in master meter readings. Without redundancy in metering, MWD is forced to rely on results of annual meter calibration tests and/or variances in monthly bills to be made aware of metering errors. MWD should consider installing redundant metering devices at all master meter locations. These meters should be compound meters and should be integrated into an AMI network as zone meters.

Other water sources of supply may be available to MWD in an emergency. It is recommended that MWD explore emergency regional interconnect options with adjacent Water Districts.

IV. SITUATIONAL ASSESSMENT

The focus of this section of the report is a situational assessment of MWD as it relates to system loss. The first part of the assessment will analyze historical data provided by MWD and develop trends for customer base, average monthly usage, average annual sales, annual water purchases, and Non-Revenue Water (NRW). The second part of the assessment will identify the "as-is" condition of the MWD system by analyzing data reported for 2019, the last full year of operation. The final part of the assessment will predict future operating conditions for MWD by applying the historical trends to the data provided for the last full year of operation.

A key component of the "as-is" analysis is the development of a water balance. A water balance is a preliminary effort conducted in lieu of a water audit. The objective of a water balance is to quantify the components of NRW in the system and assign realistic volumes and monetary values to each component. In order to do this, several assumptions had to be made. Assumptions were based on sound engineering principles, estimates provided by MWD, system characteristics, and the results of the trend analysis. It is recommended that a water audit be completed once zone meters are installed and DMAs are established. Once a water audit is completed and more precise information is available, the water balance can be revised and updated.

A. Historical Trends (2009-2019)

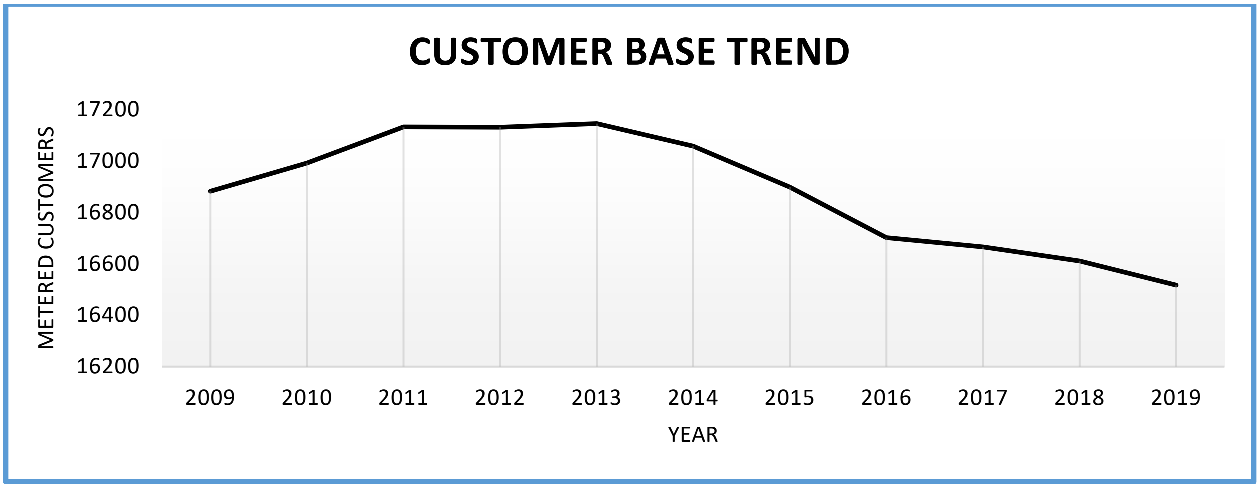
The following table summarizes historical information provided by MWD for the period beginning in 2009 and ending in 2019.

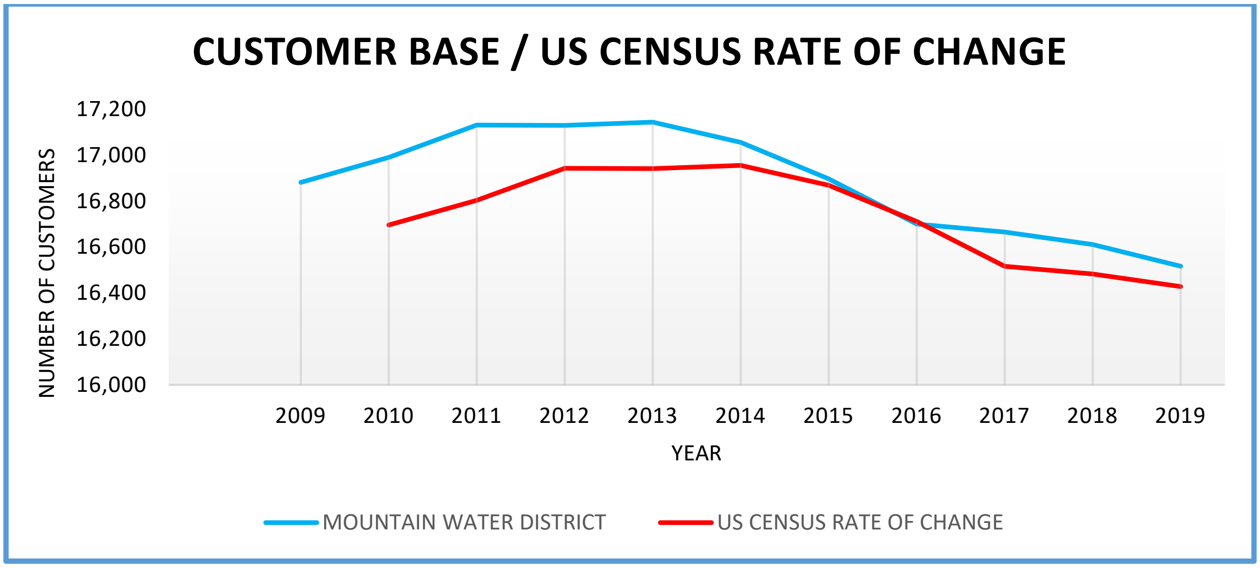
10-Year Historical Trends for the MWD					
Year	**Customer Base (meters)**	**Average Monthly Usage Per Customer (gallons)**	**Annual Metered Sales (gallons)**	**Annual Purchased Water (gallons)**	**Annual Produced Water (gallons)**
2009	16,882	4,703	952,700,780	698,363,000	877,881,000
2010	16,991	4,783	975,218,400	733,374,000	912,364,000
2011	17,132	4,626	951,002,270	734,798,000	918,640,000
2012	17,131	4,720	970,304,910	747,027,000	928,118,000
2013	17,145	4,566	939,414,430	735,778,000	893,344,000
2014	17,057	4,650	951,863,980	720,732,000	948,905,000
2015	16,898	4,453	903,053,190	795,253,000	921,461,000
2016	16,701	4,254	852,523,930	769,602,000	904,924,075
2017	16,666	4,158	831,618,490	696,426,000	869,357,090
2018	16,611	4,102	817,687,690	705,963,400	878,894,848
2019	16,517	3,989	790,602,230	731,556,097	844,514,772

1. Customer Base Trend

The reported customer base information for the period occurring from 2009 through 2019 is shown in the table below.

Customer Base Data											
Year	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Customer Base (Meters)	16,882	16,991	17,132	17,131	17,145	17,057	16,898	16,701	16,666	16,611	16,517
Change from Previous Year (Meters)		109	141	-1	14	-88	-159	-197	-35	-55	-94
% Change from Previous Year		0.65%	0.83%	-0.01%	0.08%	-0.51%	-0.93%	-1.17%	-0.21%	-0.33%	0.65%





The United States Census Bureau has estimated that Pike County, Kentucky, had a population rate of change of -11.0% from July 2010 to July 2019. A copy of the US Census Bureau Quick Facts sheet for Pike County has been included as an attachment. This trend is prevalent throughout eastern Kentucky and can be directly attributed to the decline in the coal mining industry.

Data Analysis

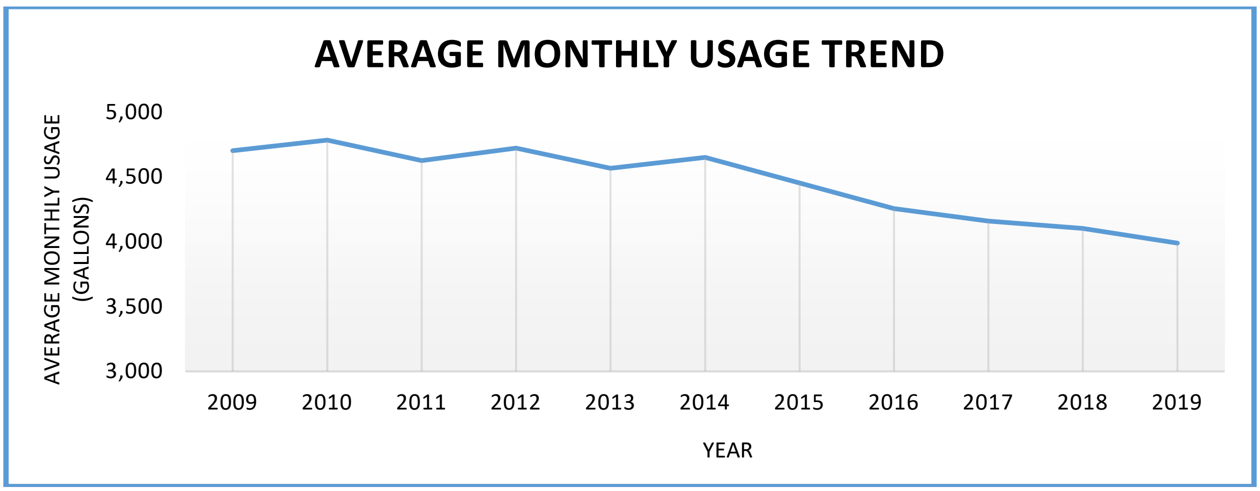
- The total change in customer base was -365 customers.
- The average annual change in customer base was -36.5 customers per year.
- The largest change occurred between 2015 and 2016, -197 customers.
- Years with positive growth were 2010, 2011, and 2013.
- Years with negative growth include 2012, 2014, 2015, 2016, 2017, 2018 and 2019.
- The average annual rate of change in customer base was approximately -0.22% per year.
- The change in population projected by the US Census Bureau for the same period was -11.0% per year.
- The decline in the MWD customer base trends in the same direction as the decline in local population.
- It can be assumed that this trend will continue and will mirror US Census Bureau population projections into the foreseeable future.

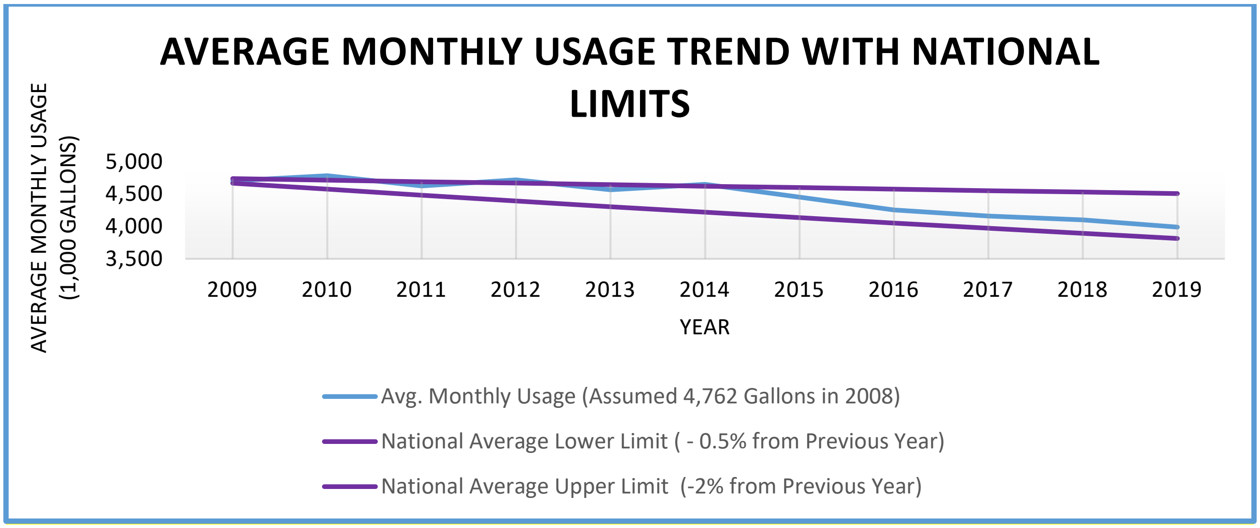
- When performing any rate analysis, the decline in customer base should be taken into consideration and included in revenue projections.

2. Average Monthly Usage Trend

The reported average monthly usage information for the period occurring from 2009 through 2019 is shown in the following table.

Average Monthly Usage Data											
Year	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Average Monthly Usage (Gallons)	4703	4783	4626	4720	4566	4650	4453	4254	4158	4102	3989
Change from Previous Year (Gallons)		80	-157	94	-154	84	-197	-199	-96	-56	-113
% Change from Previous Year		1.70%	-3.28%	2.03%	-3.26%	1.84%	-4.24%	-4.47%	-2.26%	-1.35%	-2.75%





According to research, the domestic consumption of treated water is decreasing nationally at a rate between 0.5% and 2.0% on an annual basis. Three (3) articles are included as an attachment that discuss this trend in further detail. Each state's primary factors influencing decreasing domestic consumption are declining household populations, increased use of water efficient appliances, and improved plumbing codes/ building practices.

Data Analysis

- The total change in average monthly usage was -714 gallons per customer.
- The average annual change in average monthly usage was -71.4 gallons per meter per year.
- The largest change occurred between 2015 and 2016, -199 gallons per customer or -4.47%.
- Years with positive growth include 2010, 2012, and 2014.
- Years with negative growth include 2011, 2013, 2015, 2016, 2017, 2018, and 2019.
- The average rate of change was approximately -1.6% per year.
- The national range is between -0.5% and -2.0% per year.
- By assuming a common starting point in 2008 and applying the -0.5% and -2.0% national rate of change on a yearly basis from 2009 through 2019, the graph above shows that MWD's average monthly usage decline is within the upper and lower limits of national averages.

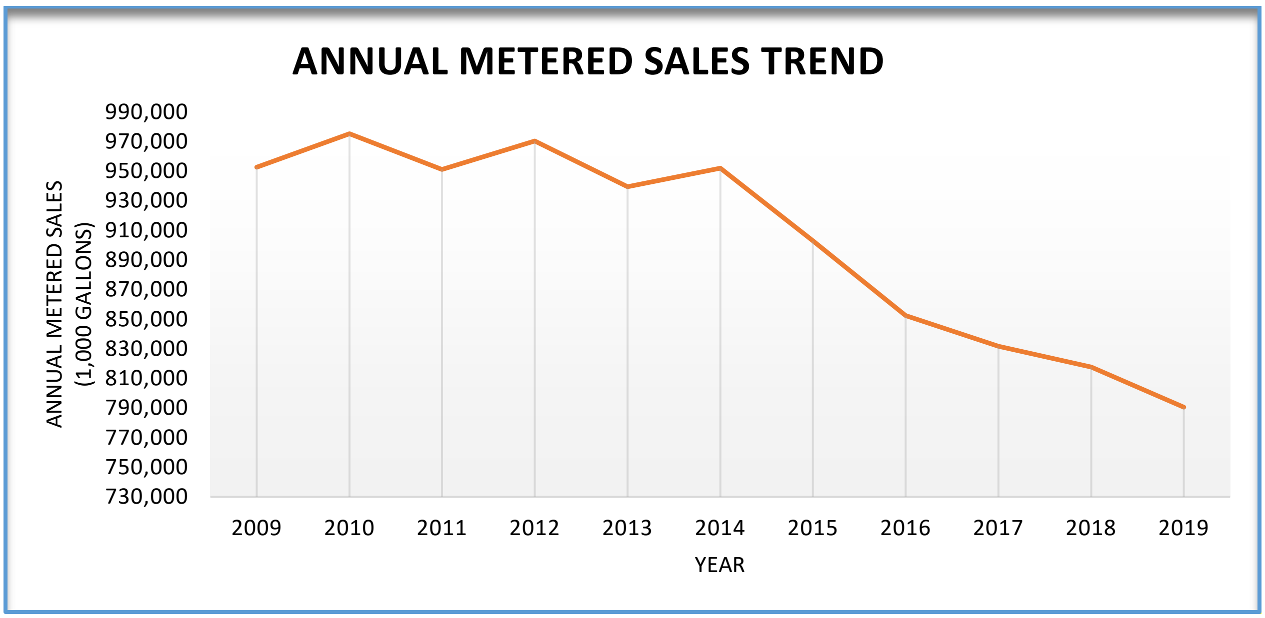
- It would be expected that MWD's rate would trend towards the lower end of the national range given that MWD is a rural distribution system that should not be as heavily influenced by the factors affecting the national trend as a municipal system.

- The fact that MWD's usage trend falls within the national range is useful in predicting future usage.

3. Annual Metered Sales Trend

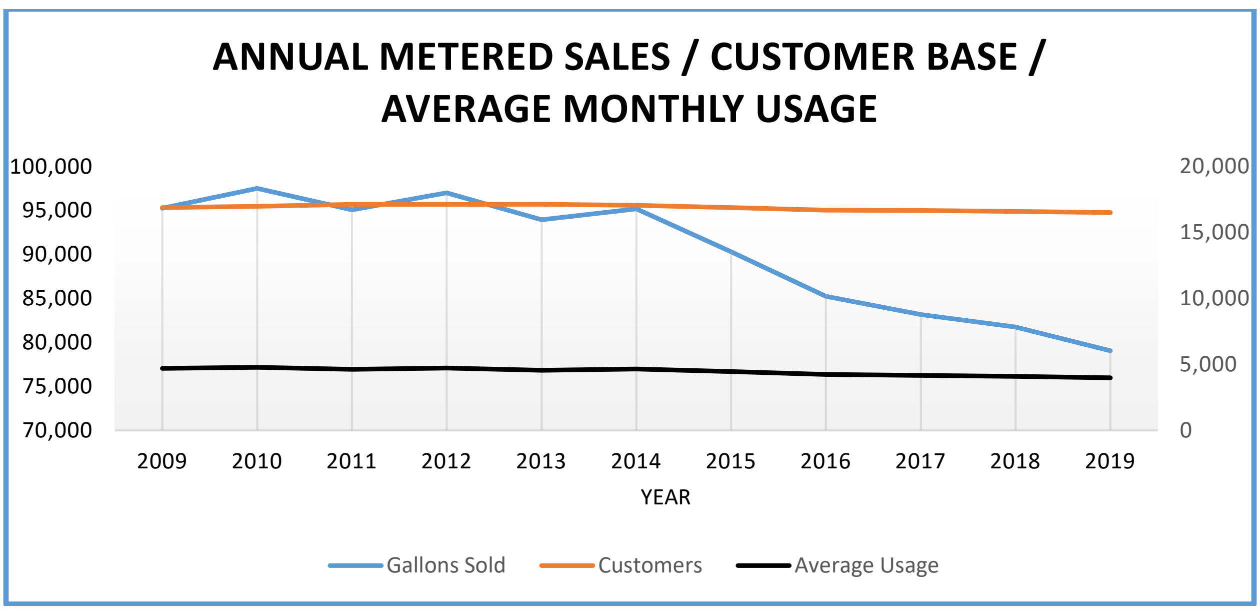
The reported annual metered information for the period occurring from 2009 through 2019 is shown in the following table.

Annual Metered Sales Data											
Year	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Annual Metered Sales (1000 Gallons)	952,701	975,218	951,002	970,305	939,414	951,864	903,053	852,524	831,618	817,688	790,602
Change from Previous Year (1000 Gallons)		22,518	-24,216	19,303	-30,890	12,450	-48,811	-50,529	-20,905	-13,931	-27,085
% Change from Previous Year		2.36%	-2.48%	2.03%	-3.18%	1.33%	-5.13%	-5.60%	-2.45%	-1.68%	-3.31%



Calculations were made using an Excel spreadsheet. The calculated results were used to compare changes in customer base and average monthly usage with the change in annual metered sales. The objective was to compare the reported difference in annual sales with the calculated difference in annual sales in order to determine the accuracy of reported data. An example of the calculations for calendar year 2010 follows. Similar calculations were conducted for each year.

for 2010	
2009 Metered Sales	952,700,780
2010 Metered Sales	975,218,400
Difference in Metered Sales (2009-2010)	22,517,620
2009 Customer Base	16,882
2010 Customer Base	16,991
Difference In Customer Base (2009-2010)	109
Average Monthly Usage in 2009	4,703
AverageMonthly Usage in 2009 x Diff. in Customer Base	512,599
12 Month Loss is Sales attributed to Difference in Customer Base	6,151,190
2009 Average Usage	4,703
2010 Average Usage	4,783
Difference	80
2010 Customer Base	16,991
Difference in Average Monthly Usage x Customer Base	1,363,869
12 Month Loss in Sales Attributed to Difference in Average Usage	16,366,430
Total Calculated Loss in Sales (12 Month Loss from Customer Base + 12 Moth Loss from Averag	22,517,620
Total Loss from Reported Sales	22,517,620
Difference	0
% Deviation from Difference in Calculated Loss from Reported Loss Compared to Reported Los	0.00%



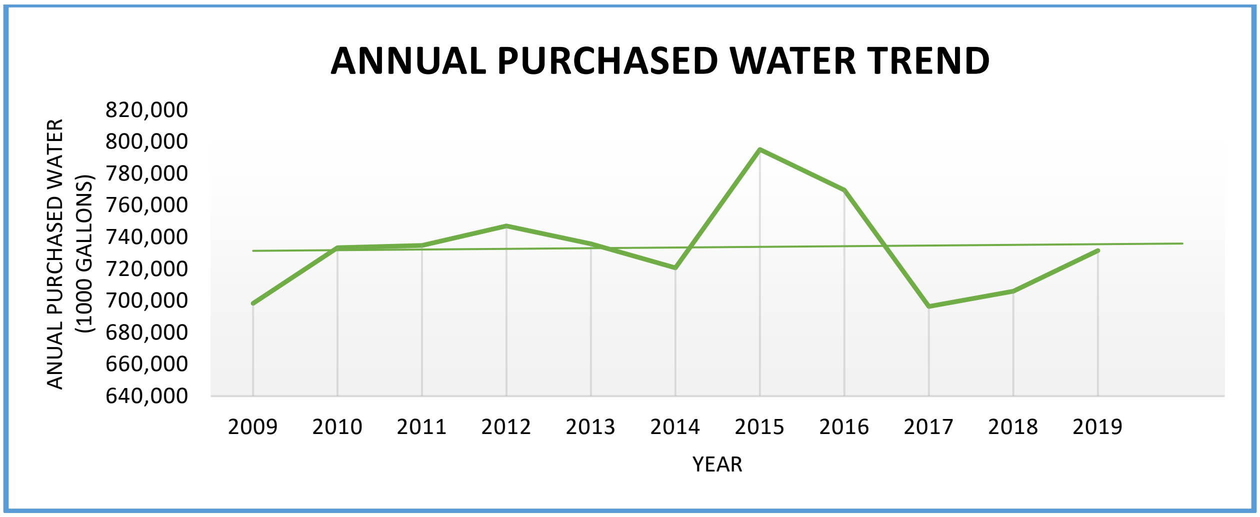
Data Analysis

- The total change in annual metered sales was -162,098,550 gallons.
- The average annual change in annual metered sales was -16,209,855 gallons per year.
- The largest change occurred between 2015 and 2016, -50,529,260 gallons.
- Years with positive growth include 2010, 2012 and 2014.
- Years with negative growth include 2011, 2013, 2015, 2016, 2017, 2018, and 2019.
- The average annual rate of change was approximately -1.81% per year.
- The annual change in metered sales was -1.81% which was greater than both the annual change in customer base, -0.22%, and the annual change in monthly usage, -1.6%.
- From the graph above it is apparent that sales are trending at a faster rate than monthly usage and the change in customer base.
- It has been previously established that both the declining customer base and declining monthly usage are typical for the region and nation as a whole.
- The greater rate of decline in metered sales relative to the rate of decline of the customer base and monthly usage may be an indicator of metering inaccuracies or inaccuracies in billings.
- All residential meters were replaced between 2018 and 2020. This should correct any inaccuracies in metered sales due to inaccurate meter readings.

4. Annual Purchased Water Trend

The annual purchased water information reported by MWD for the period occurring from 2009 through 2019 follows.

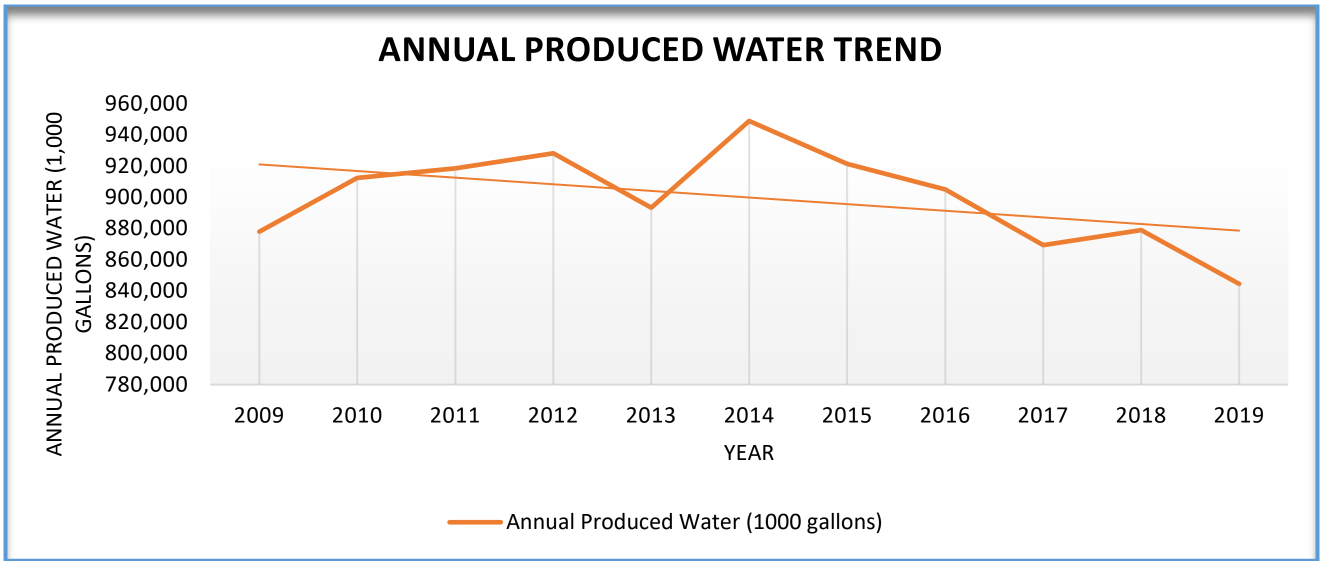
Annual Purchased Water Data											
Year	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Annual Purchased Water (1000 Gallons)	698,363	733,374	734,798	747,027	735,778	720,732	795,253	769,602	696,426	705,963	731,556
Change from Previous Year (1000 Gallons)		35,011	1,424	12,229	-11,249	-15,046	74,521	-25,651	-73,176	9,537	25,593
% Change from Previous Year		5.01%	0.19%	1.66%	-1.51%	-2.04%	10.34%	-3.23%	-9.51%	1.37%	3.63%

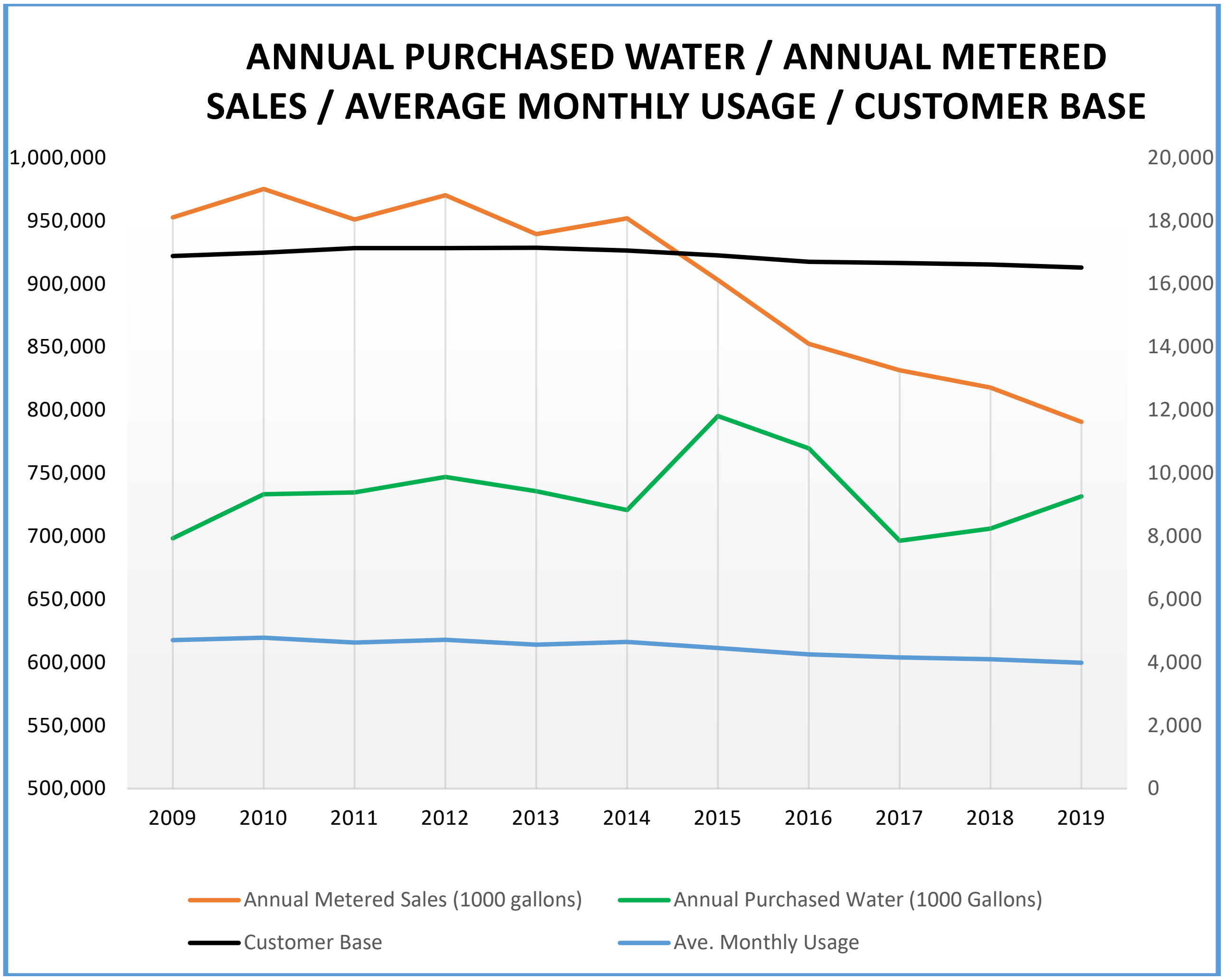


5. Annual Produced Water Trend

The annual produced water information reported by the MWD for the period occurring from 2009 through 2019 follows.

Annual Produced Water Data											
Year	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Annual Produced Water (1000 Gallons)	877,881	912,364	918,640	928,118	893,344	948,905	921,461	904,924	869,357	878,895	844,515
Change from Previous Year (1000 Gallons)		34,483	6,276	9,478	-34,774	55,561	-27,444	-16,537	-35,567	9,538	-34,380
% Change from Previous Year		3.93%	0.69%	1.03%	-3.75%	6.22%	-2.89%	-1.79%	-3.93%	1.10%	-3.91%





Data Analysis

- The total change in annual purchased water was 33,193,097 gallons.
- The average annual change was 3,319,310 gallons per year.
- The largest change occurred between 2014 and 2015, 74,521,000 gallons.
- Years with increased purchase include 2010, 2011, 2012, 2015, 2018, and 2019.
- The average annual rate of change was approximately 0.59%.
- Annual purchased water has changed by less than 1% from 2009 to 2019. The only substantial variance occurred in 2015 and 2017.

- The rate of change of purchased water when compared to the rate of change of the monthly usage and metered sales is significantly less, and is slightly higher than the customer base rate of change.

- Since 2012, it appears that the difference between the annual purchased water and meter sales is increasing. This can be directly attributed to the -0.59% rate of change of purchased compared to the -1.81% rate of change of metered sales.

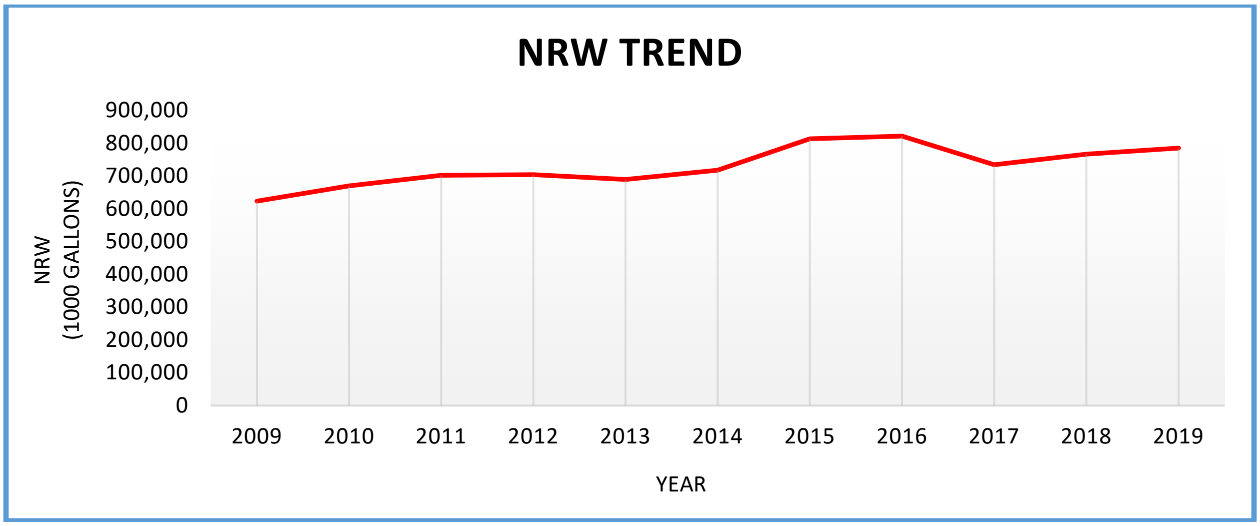
- As established, the difference between purchased water and metered sales is NRW.

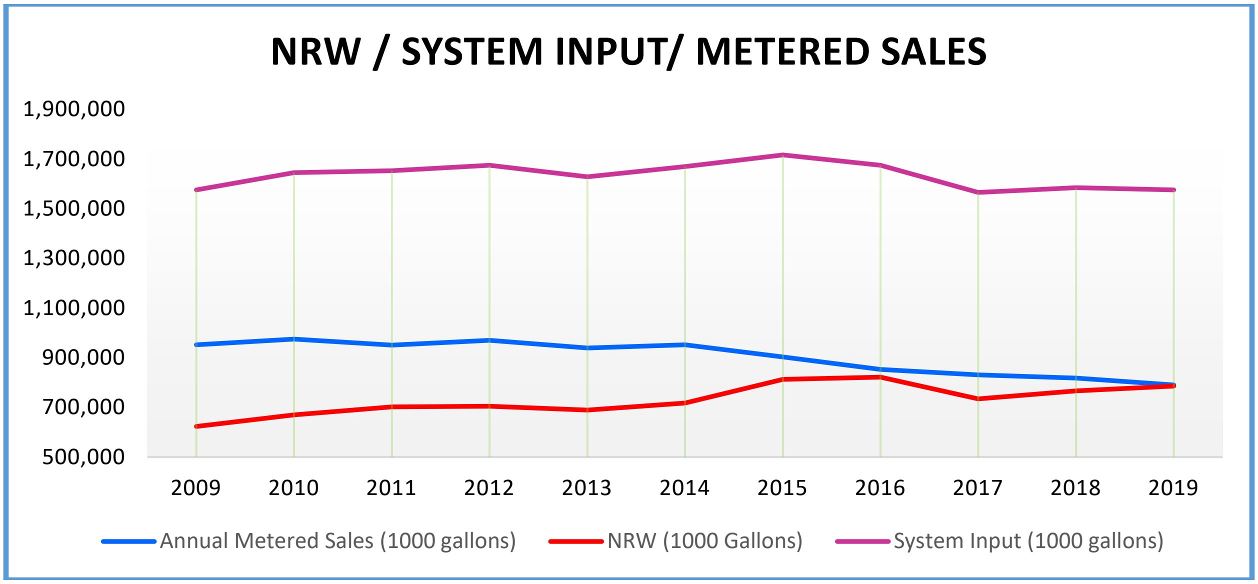
- The fact that the difference between the purchased water and meter sales depicts an increasing NRW trend.

6. Non-Revenue Water Trend

Non-Revenue Water (NRW) is the difference between the combined produced and purchased water and water used in metered sales. The calculated NRW for the 10-year period from 2009 through 2019 is shown below.

NRW Data											
Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NRW (1000 Gallons)	623,543	670,520	702,436	704,840	689,708	717,773	813,661	822,002	734,165	767,171	785,469
Change from Previous Year (1000 Gallons)		46,976	31,916	2,404	-15,133	28,065	95,888	8,341	-87,838	33,006	18,298
% Change from Previous Year		7.53%	4.76%	0.34%	-2.15%	4.07%	13.36%	1.03%	-10.69%	4.50%	2.39%





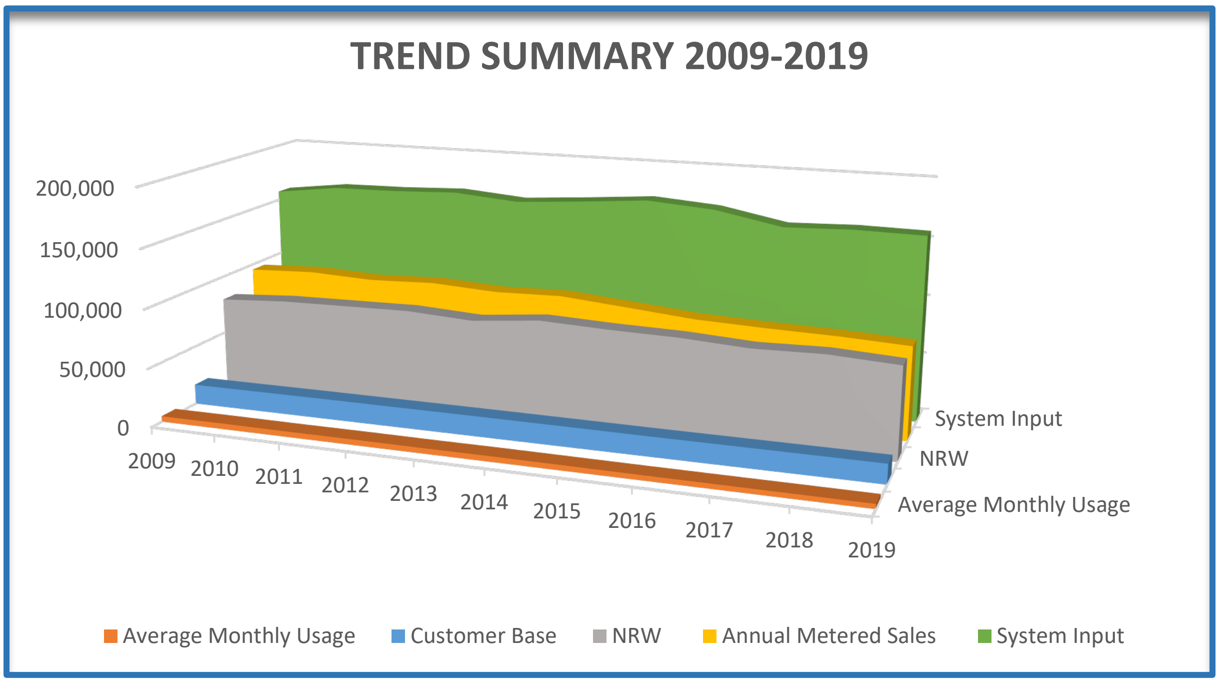
Data Analysis

- The total change in NRW was 161,925,419 gallons.
- The average annual change in NRW was 16,192,542 gallons per year.
- The largest change occurred between 2014 and 2015, 95,887,790 gallons.
- Years with increasing NRW include 2010, 2011, 2012, 2014, 2015, 2016, 2018, and 2019.
- The average annual rate of change was approximately 2.51% per year.
- The overall trend has steadily increased since 2009.
- The year-to-year increase in NRW is an indicator of the continued degradation of the existing infrastructure and the increase in metering/billing inaccuracies.

7. Trend Summary

The following summarizes the trends developed in the previous section.

Summary of Trend Data (2009-2019)		
Trend	**Change Over 10 Years**	**% Change per Year**
Customer Base	-365 customers	-0.22 %
Average Monthly Usage	-714 gallons per meter	-1.6 %
Annual Meter Sales	-162,098,550gallons	-1.81 %
Annual Water Purchased	33,193,097 gallons	0.59 %
Annual Water Produced	-33,366,228 gallons	-0.33 %
Annual System Input	- 173,131 gallons	0.05 %
NRW	161,925,419 gallons	2.51 %



Summary

- The customer base is decreasing at a rate of approximately 0.22% per year.
- Average monthly usage is decreasing at a rate of approximately 1.6% per year, which falls within the national range.
- Annual metered sales are decreasing at a rate of approximately 1.81%, which can be directly attributed to a declining customer base and declining usage.
- Purchased water has increased at a rate approximately 0.59% per year.

- Water produced has decreased at a rate approximately 0.33% per year.
- System Input has remained virtually unchanged
- The annual NRW rate is growing because of the decreasing annual metered sales and the increasing annual water purchased.

B. Existing Conditions (2019)

MWD's water trend report for 2019 is included as Attachment I.

C. Water Balance (2019)

A water audit has not been performed on the MWD system. In lieu of a water audit, a water balance has been developed for calendar year 2019. The objective is to help assign preliminary volumetric amounts to potential contributors of NRW and UW. Volumetric amounts will prioritize capital improvements. The volumetric amounts will be derived from MWD's reported percentages. Where information is unavailable, assumptions will be made based on system condition and trends. The water balance is not a substitute for a water audit, but simply provides a starting point from which decisions can be made. The water balance should be updated as more information becomes available. The components of the water balance are:

System Input Volume- System input volume is the annual volume of water produced combined with water purchased.

Billed Authorized Consumption- Billed authorized consumption is the annual volume of water billed by registered customers who are authorized to do so.

Non-Billed Authorized Consumption- Non-billed authorized consumption is the annual volume of water used by the local fire department or consumed to sustain operations.

Unaccounted for Water- Unaccounted for water is the annual volume of water calculated by the difference in system input volume and billed authorized consumption and non-billed authorized consumption.

Non-Revenue Water- NRW is the difference between the system input volume and the billed authorized consumption.
Apparent Loss- Apparent loss is that portion of NRW composed of unauthorized consumption and is typically associated with metering and/or billing inaccuracies and theft.

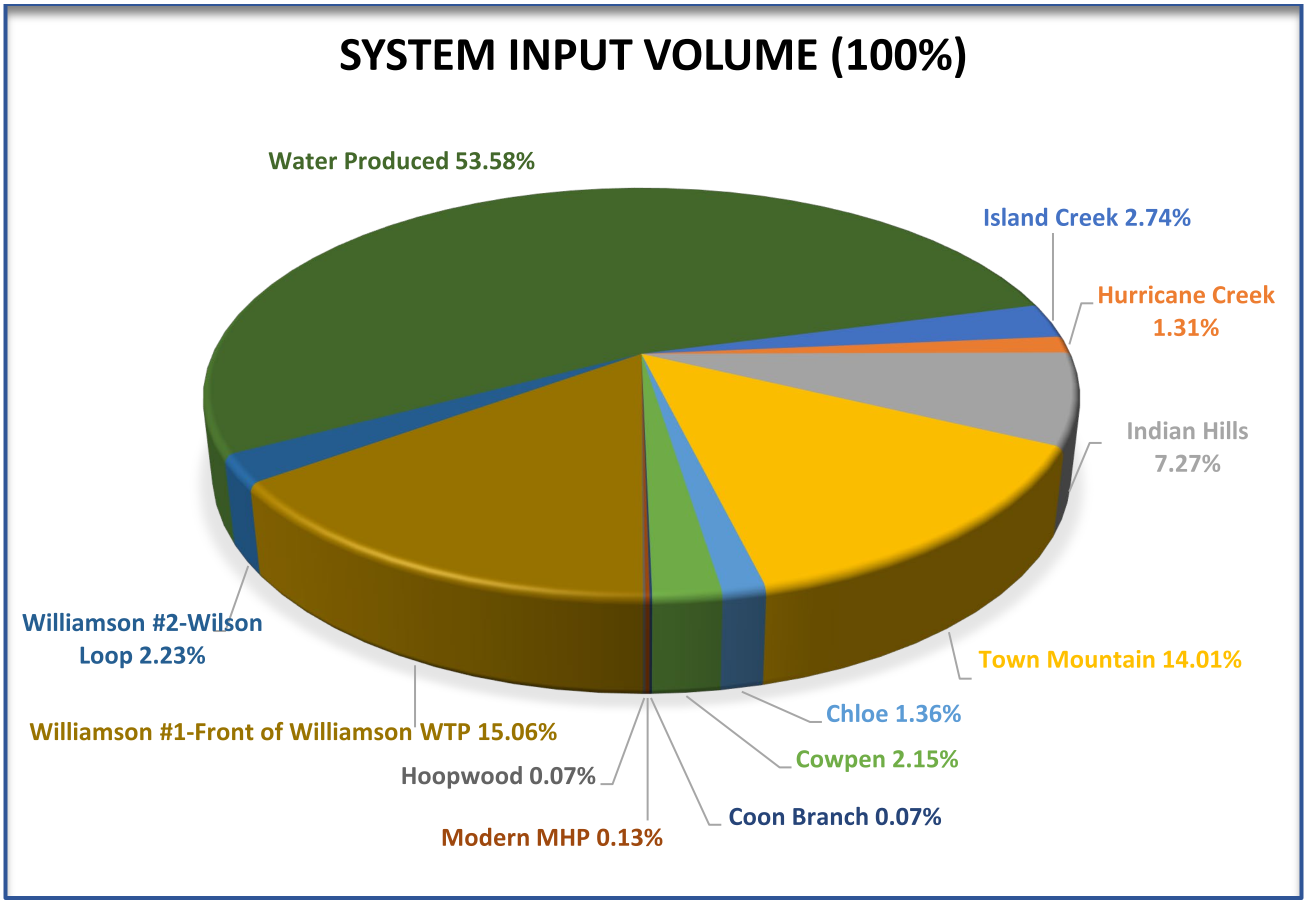
Real Loss- Real loss is that portion of NRW lost through line leaks including service line connections up to the point of metered sales.

1. System Input Volume

The system input volume for MWD for calendar year 2019 was reported to be 1,576,070,869 gallons. The water was purchased from 11 separate metering locations. The following table and graph summarize the purchases and 100% of the total system input volume for the water balance. The established purchase prices given by MWD were $1.97 per 1,000 gallons for City of Pikeville sales and $1.83 per 1,000 for City of Williamson, West Virginia sales. Water purchases as shown in Attachment M were used to calculate an average purchase price using total volume divided by the total purchase amount. These were $1.65/1,000 gallons for the City of Pikeville and $1.72/1,000 gallons for the City of Williamson and were applied to the reported volumes to determine cost. Water produced costs were reported to be $988,082.28 for 844,514,772 gallons which equates to a cost of $1.17/1,000 gallons as shown in Attachment N.

System Input Volume 2019						
Supplier	Description	Volume	Unit	Percent of System Input Volume	Percent of Water Balance	Cost $ USD
City of Pikeville	Island Creek	43,195,000	Gallons	2.74%	2.74%	$71,453.17
	Hurricane Creek	20,604,000	Gallons	1.31%	1.31%	$34,083.14
	Indian Hills	114,590,000	Gallons	7.27%	7.27%	$189,554.78
	Town Mountain	220,795,000	Gallons	14.01%	14.01%	$365,239.09
	Chloe	21,494,000	Gallons	1.36%	1.36%	$35,555.37
	Cowpen	33,823,000	Gallons	2.15%	2.15%	$55,950.01
	Coon Branch	1,130,000	Gallons	0.07%	0.07%	$1,869.25
	Modern MHP	2,116,000	Gallons	0.13%	0.13%	$3,500.29
	Hoopwood	1,118,000	Gallons	0.07%	0.07%	$1,849.40
Total Pikeville		458,865,000	Gallons	29.11%	29.11%	$759,054.48
City of Williamson, WV	Williamson #1- Front of Williamson WTP	237,328,407	Gallons	15.06%	15.06%	$408,204.86
	Williamson #2- Wilson Loop	35,092,600	Gallons	2.23%	2.23%	$60,359.27
Total Williamson		272,421,007	Gallons	17.28%	17.28%	$468,564.13
Total Purchased		731,286,007	Gallons	46.40%	46.40%	$1,227,618.62
MWD	Water Produced	844,514,772	Gallons	53.58%	53.58%	$988,082.28
TOTAL		**1,575,800,779**	**Gallons**	**99.98%**	**99.98%**	**$2,215,700.91**

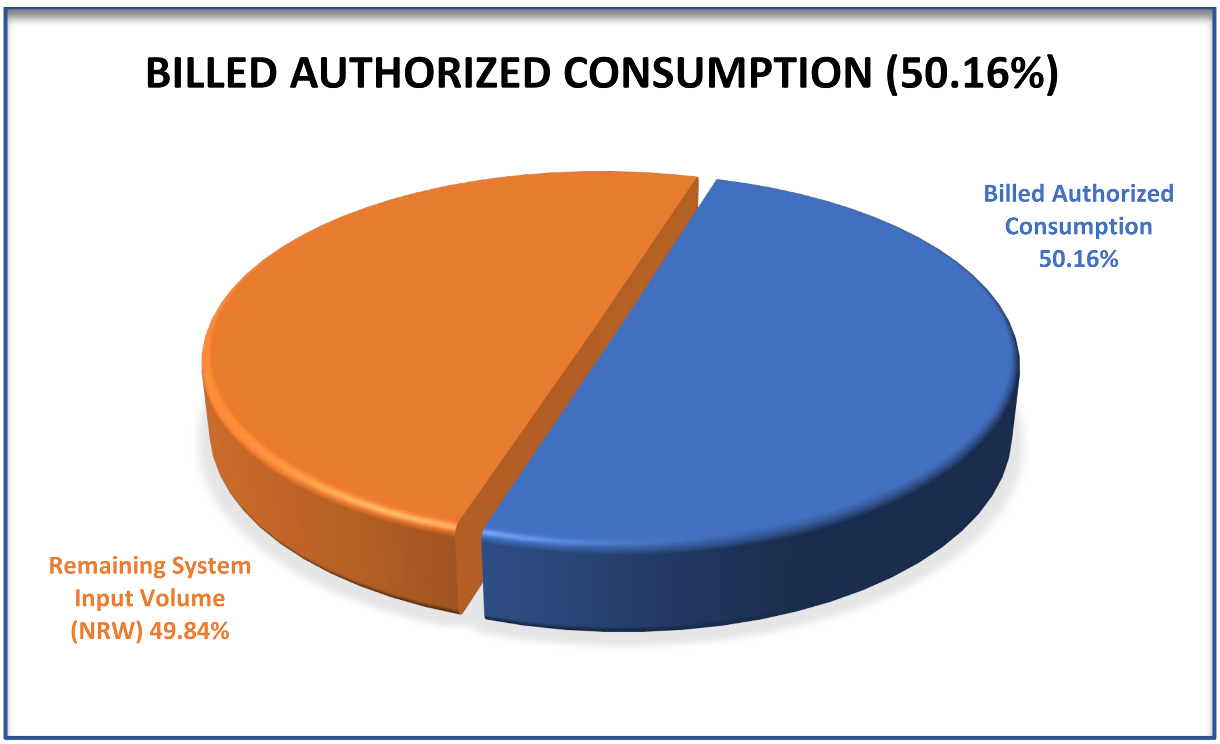
The calculated price per gallon of purchased water and produced water (system input) was calculated to be $0.0014 per gallon.


SYSTEM INPUT VOLUME (100%)
Water Produced 53.58%
Island Creek 2.74%
Hurricane Creek 1.31%
Indian Hills 7.27%
Town Mountain 14.01%
Chloe 1.36%
Cowpen 2.15%
Coon Branch 0.07%
Modern MHP 0.13%
Hoopwood 0.07%
Williamson #1-Front of Williamson WTP 15.06%
Williamson #2-Wilson Loop 2.23%

2. Billed Authorized Consumption

The billed authorized consumption for MWD for calendar year 2019 was reported to be 790,602,230 gallons. The billed authorized consumption is 50.16% of the system input volume and represents metered sales. The following table and graph summarize the billed authorized consumption.

Billed Authorized Consumption 2019					
Description	**Volume**	**Unit**	**Percent of Billed Authorized Consumption**	**Percent of System Input Volume**	**Cost**
Residential	659,199,134	Gallons	83.38%	41.83%	$6,704,803.91
Commercial	56,854,737	Gallons	7.19%	3.61%	$578,277.25
Industrial	5,442,899	Gallons	0.69%	0.35%	$55,360.46
Public Auth	39,592,528	Gallons	5.01%	2.51%	$402,700.98
Multi Family	29,512,932	Gallons	3.73%	1.87%	$300,180.04
TOTAL	**790,602,230**	**Gallons**	**100.00%**	**50.16%**	**$8,041,322.64**



The remaining system input volume is NRW, which is calculated as follows:

NRW = System Input Volume-Billed Authorized Consumption
Percent NRW = (NRW/System Input Volume) x 100

NRW (2019)		
Description	**Volume**	**Unit**
System Input Volume (Purchased Water)	731,556,097	Gallons
System Input Volume (Produced Water)	844,514,772	Gallons
Billed Authorized Consumption	790,602,230	Gallons
NRW	785,468,639	Gallons
Percent NRW	49.84	%

3. Non-Billed Authorized Consumption

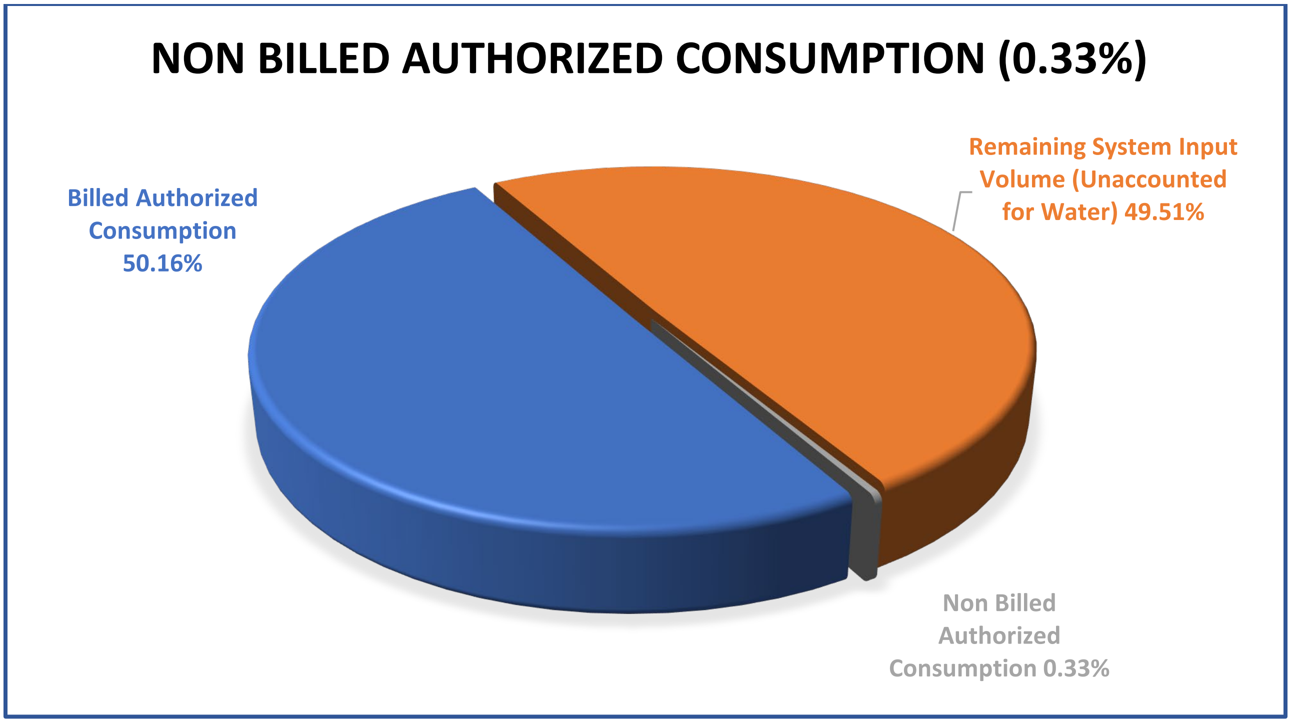
The non-billed authorized consumption for the MWD for calendar year 2019 as provided was 5,201,034 gallons. The non-billed authorized consumption is approximately 0.33% of the system input volume. The following table and graph summarize the non-billed authorized consumption.

Non-Billed Authorized Consumption 2019					
Description	**Volume**	**Unit**	**Percent of Non-Billed Authorized Consumption**	**Percent of System Input Volume**	**Approximate Cost**
Flushing	2,829,227	Gallons	54.40%	0.18%	$3,978.12
Fire Department Use	2,371,807	Gallons	45.60%	0.15%	$3,334.95
TOTAL	**5,201,034**	**Gallons**	**100.00%**	**0.33%**	**$7,313.07**

Fire Department use is calculated by applying a factor of 0.3% to MWD's total billed sales.

Estimating flushing volumes are calculated by use of a spreadsheet developed by KRWA that utilizes the formula $GPM = 29.83(cd^2)(\sqrt{p})$.

Estimated volumes associated with breaks and/or line repairs are calculated using a similar spreadsheet developed by KRWA. Volumes are determined based on duration, pipe size, operating pressure and type leak.



The remaining system input volume is unaccounted for water, which is calculated as follows:

Unaccounted for Water = System Input Volume-(Billed Authorized Consumption + Non Billed Authorized Consumption)
Percent Unaccounted for Water = (Unaccounted for Water / System Input Volume) x 100

Unaccounted for Water (2019)		
Description	**Volume**	**Unit**
System Input Volume (Purchased+Produced Water)	1,576,070,869	Gallons
Billed Authorized Consumption	790,602,230	Gallons
Non-Billed Authorized Consumption	5,201,034	Gallons
Unaccounted for Water	780,267,605	Gallons
Percentage of Unaccounted for Water	49.51	%

4. Real and Apparent Loss

Unaccounted for Water (UW) is composed of real and apparent loss. Real and apparent loss are the focal point of the water balance and have been calculated to be 780,267,605 gallons, collectively. Real loss includes water loss occurring from leaks in the distribution system; whereas, apparent loss includes water loss occurring from malfunctioning meters, billing errors and theft. The combined volume represents 49.51% of the system input volume.

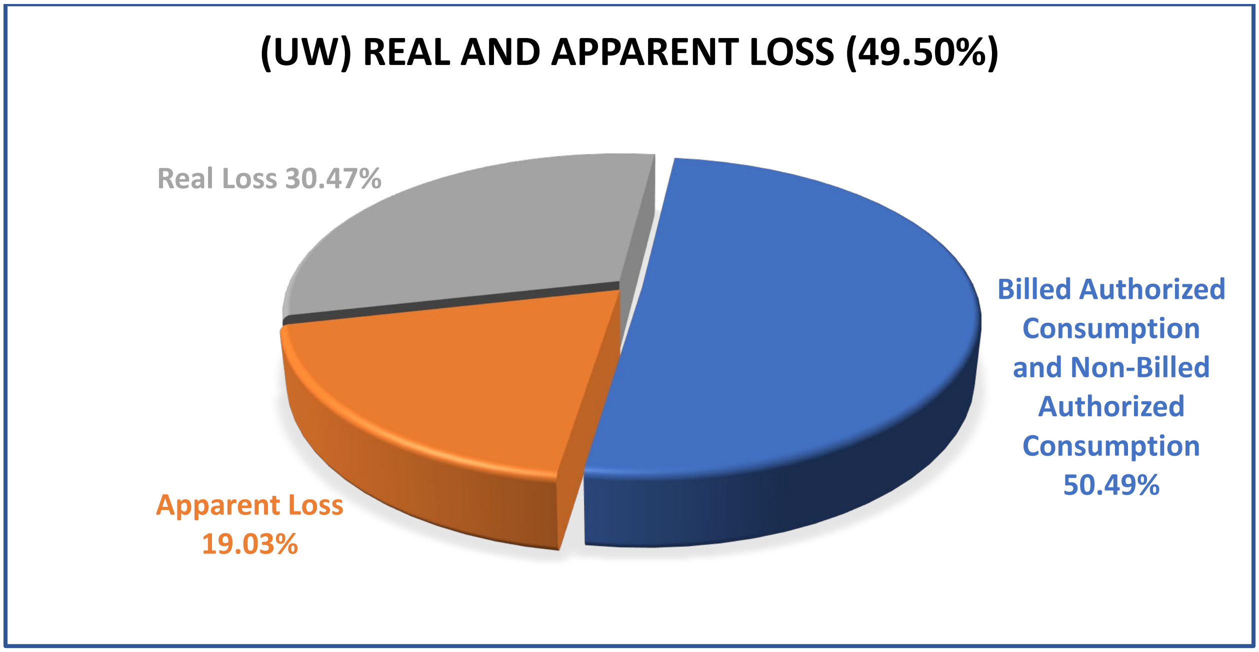
Up to this point, most data presented herein has been provided by MWD or derived from the data provided. Unfortunately, determining the actual volumes of the various components of real and apparent loss is difficult due to the lack of available information. Once zone meters are installed, DMAs are established, and a water audit is completed, the following estimated volumes can be replaced with more accurate information.

MWD believes metering inaccuracies are a significant contributor to UW. Metering inaccuracies are categorized as apparent loss. No data was provided by MWD but based on metering inaccuracies found in other water districts, an assumed 20% of UW, or 156,053,461 gallons per year, was used. Total metered sales for 2019 were 790,602,230 gallons. The estimated volume from metering inaccuracies represents approximately 19.7% of the total metered sales volume for 2019. Once a water audit is completed, this amount can be revised.

MWD estimated that loss from main and service line leaks, breaks, and system overflows account for approximately 23.11% of the UW or 180,284,350 gallons per year. Line leaks would be categorized as real loss. This estimate was derived from known breaks that were repaired. Based on the age of the system and the pressure issues in the MWD's areas, there may be additional sources of loss that remain undiscovered. Once a water audit is complete, this amount can be revised.

The remaining 76.89% of UW, or 599,983,255 gallons, will be equally divided among real loss and apparent loss. As a result, the total real loss is estimated at 480,275,978 gallons per year and the apparent loss is estimated at 299,991,628 gallons per year. The following table and chart summarize real and apparent loss.

UW or Real and Apparent Loss 2019					
Description	**Volume**	**Unit**	**Percent of Unaccounted for Water**	**Percent of System Input Volume**	**Approximate Cost**
Real Loss	480,275,978	Gallons	61.55%	30.47%	$675,306.12
Apparent Loss	299,991,628	Gallons	38.45%	19.03%	$421,812.03
TOTAL	**780,267,606**	**Gallons**	**100.00%**	**49.50%**	**$1,097,118.15**



5. Detailed Real Loss

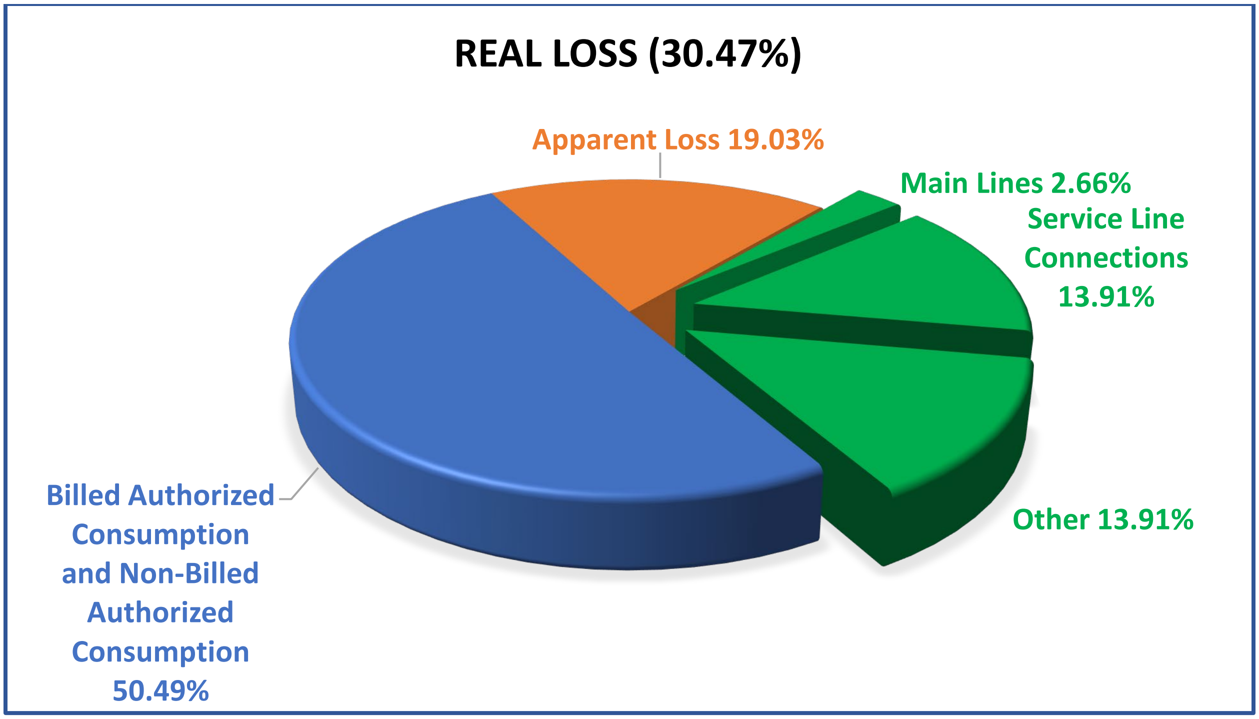
It has been reasoned that real loss makes up 61.55% of the UW, or 30.47% of the system input volume on an annual basis, and has a volume of approximately 480,275,978 gallons. It has also been reported by MWD that main line leaks and breaks account for approximately 41,944,260 gallons per year, or approximately 8.73%, of the real loss. The remaining 91.26% of real loss will be evenly divided between service line connections and "other." Other will include sources of real loss yet to be identified. Once the water audit is complete the detailed real loss can be adjusted.

The following table details the Marrowbone and Pond Creek areas as having the highest percentage real loss.

2019	SERVICE LINE LEAKS	GALLONS	SERVICE LINE BREAKS	GALLONS	MAIN LINE LEAKS	GALLONS	MAIN LINE BREAKS	GALLONS	GALLONS PER AREA
GRAPEVINE	29	3,040,000	1	1,500	14	3,422,100	6	536,000	6,999,600
MARROWBONE	117	41,723,189	6	382,000	27	19,186,200	4	544,600	61,835,989
POND CREEK	117	70,138,879	10	58,500	11	3,426,000	4	265,000	73,888,379
SHELBY VALLEY	76	22,986,022	1	10,000	39	14,244,360	3	320,000	37,560,382
ANNUAL TOTALS	463	104,344,249	20	370,500	123	43,139,660	18	1,535,100	149,389,509
TOTAL PERCENTAGE OF LEAK/BREAK LOSS		69.85%		0.25%		28.88%		1.02%	

The following table and chart summarize detailed real loss.

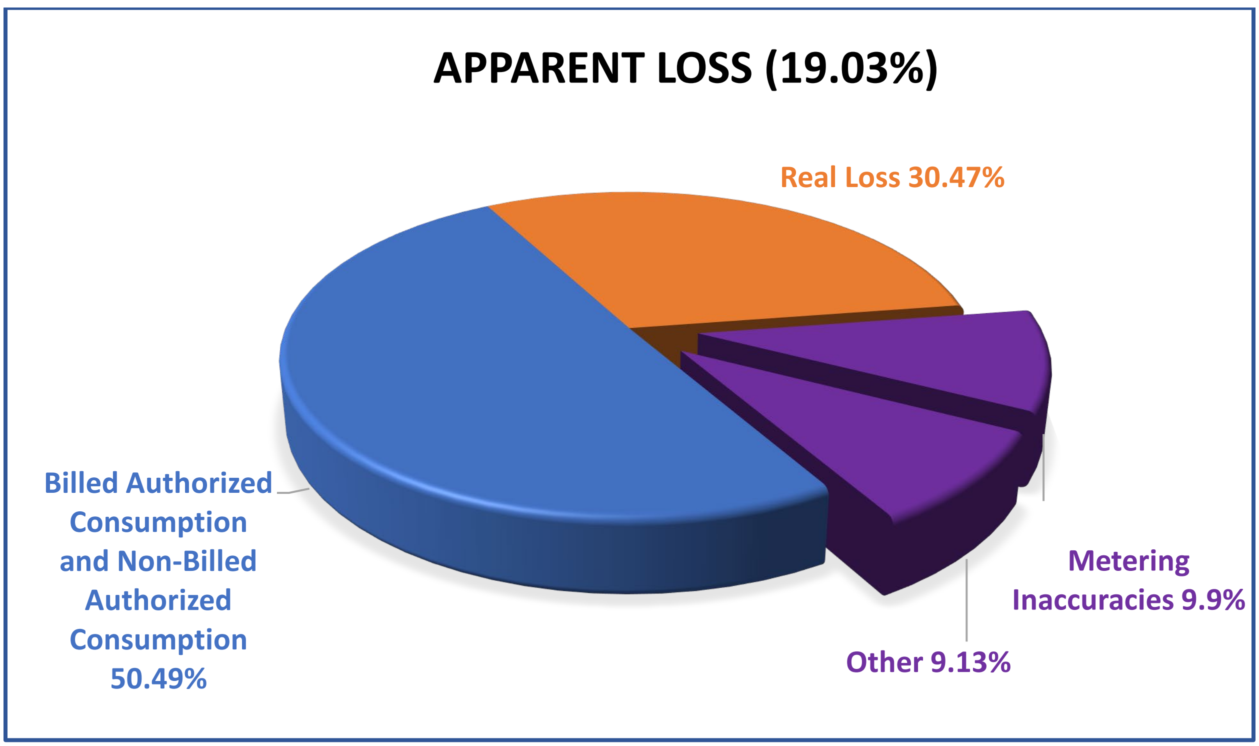
Detailed Real Loss (30.47%) 2019					
Description	**Volume**	**Unit**	**Percent of Real Loss**	**Percent of System Input Volume**	**Approximate Cost**
Main Line Leaks, Breaks	41,944,260	Gallons	8.73%	2.66%	$58,977
Service Line Connections	219,165,859	Gallons	45.63%	13.91%	$308,165
Other	219,165,859	Gallons	45.63%	13.91%	$308,165
TOTAL	**480,275,978**	**Gallons**	**100.00%**	**30.47%**	**$675,306**


REAL LOSS (30.47%)
Apparent Loss 19.03%
Main Lines 2.66%
Service Line Connections 13.91%
Other 13.91%
Billed Authorized Consumption and Non-Billed Authorized Consumption 50.49%

6. Detailed Apparent Loss

It has been assumed that apparent loss makes up 38.45% of the UW, or 19.03% of the system input volume, and has an annual volume of approximately 299,991,628 gallons. It has also been assumed that inaccurate meters account for approximately 156,053,521 gallons per year, or 52.02%, of the apparent loss. The remaining 47.98% of apparent loss will be attributed to "other." Other will include staffing limitations, deficiencies in institutional controls and sources, potential metering inaccuracies, and sources of apparent loss yet to be identified. Once the water audit is completed, detailed apparent loss can be adjusted. The following table and chart summarize detailed apparent loss

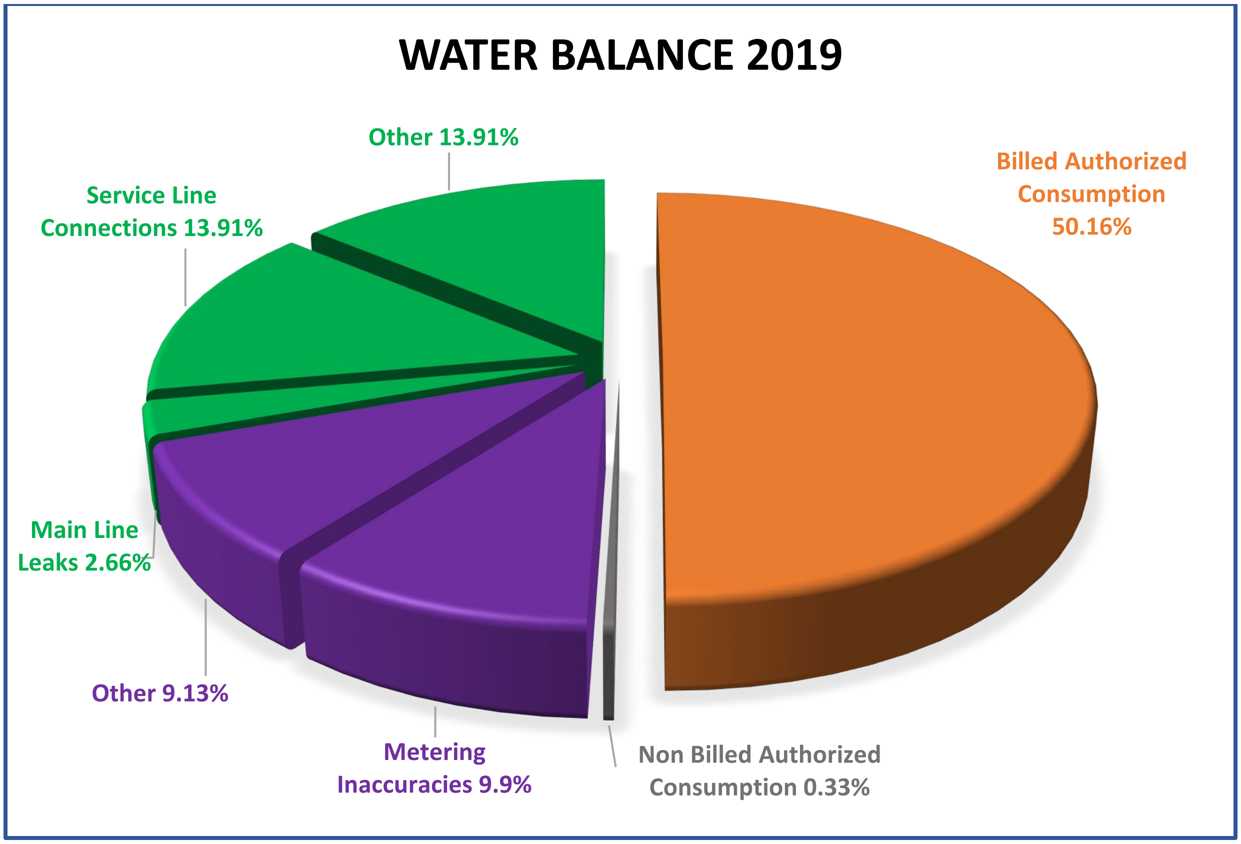
Detailed Apparent Loss (19.03%) 2019					
Description	**Volume**	**Unit**	**Percent of Apparent Loss**	**Percent of System Input Volume**	**Approximate Cost**
Metering Inaccuracy	156,053,521	Gallons	52.02%	9.90%	$219,424
Other	143,938,107	Gallons	47.98%	9.13%	$202,388
TOTAL	299,991,628	Gallons	100.00%	19.03%	$421,812

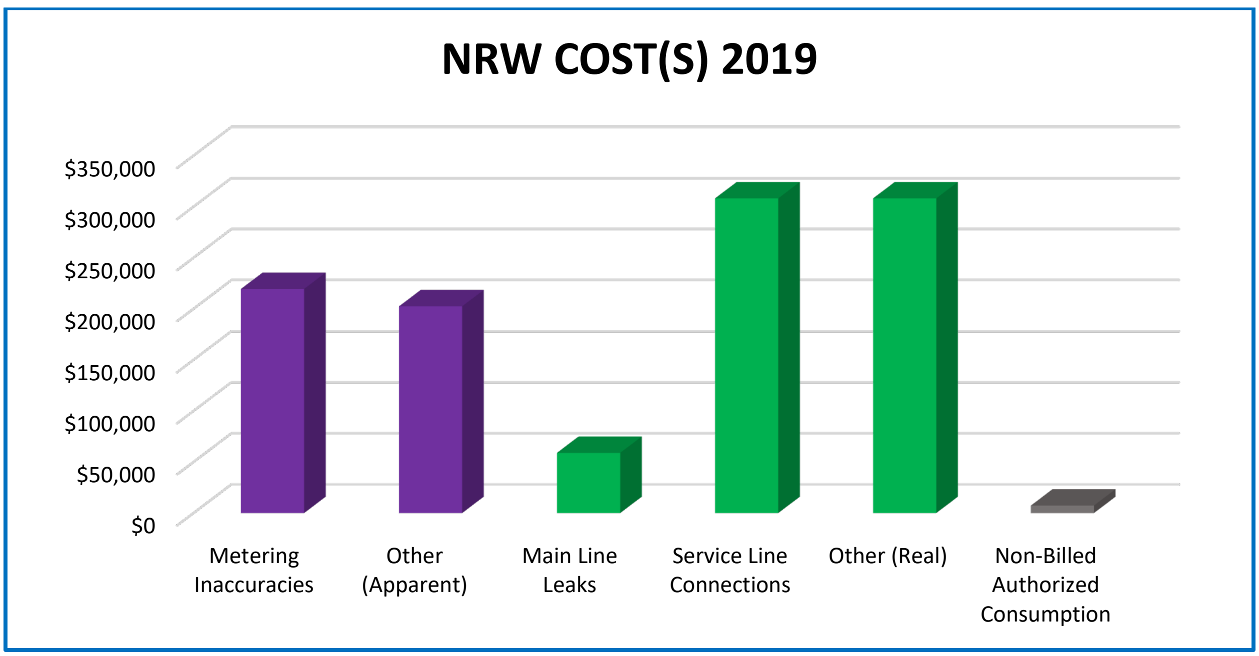


7. Water Loss Balance Summary (2019)

The following table and graph highlight the initial water balance developed herein.

2019 Water Balance Summary MWD				
Description	**Volume**	**Units**	**Percent of System Input Volume**	**Approximate Cost**
System Input Volume (100%)				
Purchased Water	731,556,097	Gallons	46.40%	$1,227,618.62
Produced Water	844,514,772	Gallons	53.60%	$988,082.28
Total System Input Volume	1,576,070,869	Gallons	100.00%	$2,215,700.90
Billed Authorized Consumption (50.16%)				
Residential	659,199,134	Gallons	41.83%	$6,704,803.91
Commercial	56,854,737	Gallons	3.61%	$578,277.25
Industrial	5,442,899	Gallons	0.35%	$55,360.46
Public Auth	39,592,528	Gallons	2.51%	$402,700.98
Multi Family	29,512,932	Gallons	1.87%	$300,180.04
Total Billed Authorized Consumption	790,602,230	Gallons	50.16%	$8,041,322.64
Non-Billed Authorized Consumption (0.33%)				
Flushing	2,829,227	Gallons	0.18%	$3,978.12
Fire Department Use	2,371,807	Gallons	0.15%	$3,334.95
Total Non-Billed Authorized Consumption	5,201,034	Gallons	0.33%	$7,313.07
Real Loss (30.47%)				
Main Line Leaks	41,944,260	Gallons	2.66%	$58,977
Service Line Connections	219,165,859	Gallons	13.91%	$308,165
Other	219,165,859	Gallons	13.91%	$308,165
Total Real Loss		Gallons	30.47%	$675,306
Apparent Loss (19.03%)				
Metering Inaccuracy	156,053,521	Gallons	9.90%	$219,424
Other	143,938,107	Gallons	9.13%	$202,388
Total Apparent Loss	299,991,628	Gallons		$421,812


WATER BALANCE 2019
Other 13.91%
Billed Authorized Consumption 50.16%
Service Line Connections 13.91%
Main Line Leaks 2.66%
Other 9.13%
Metering Inaccuracies 9.9%
Non Billed Authorized Consumption 0.33%

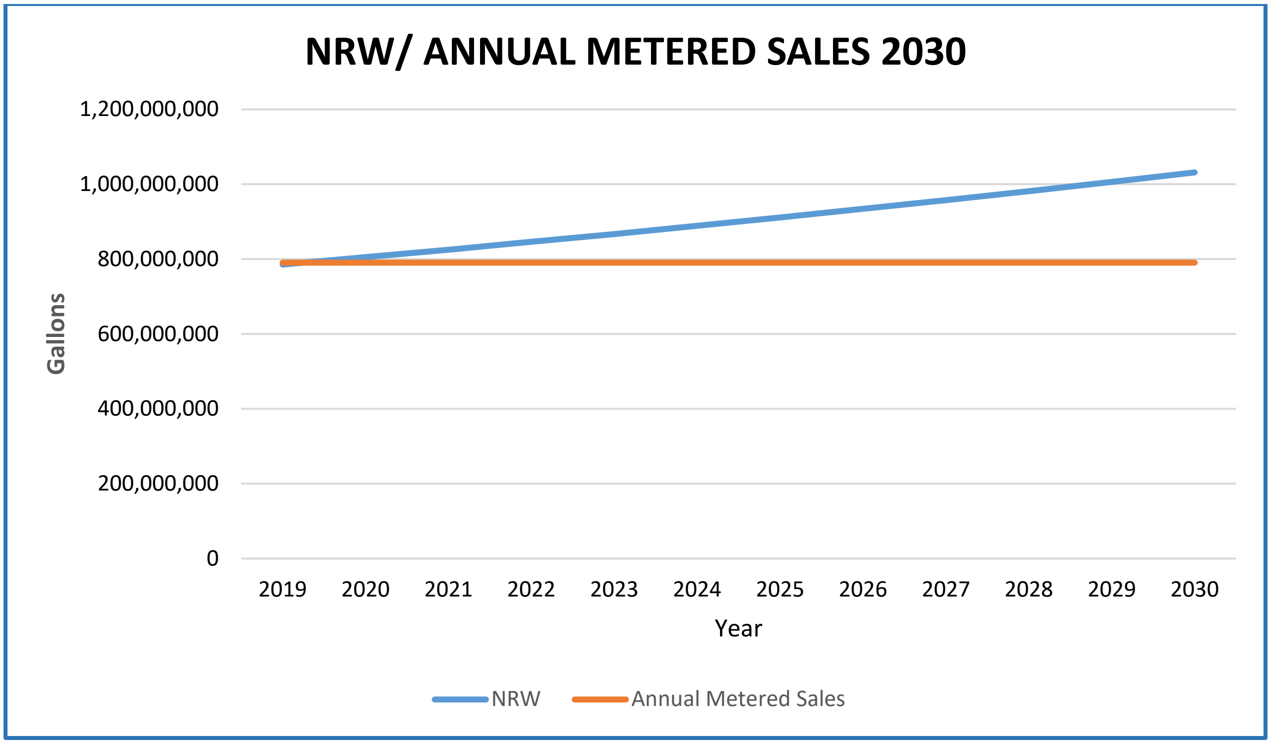

NRW COST(S) 2019
$350,000
$300,000
$250,000
$200,000
$150,000
$100,000
$50,000
$0
Metering Inaccuracies
Other (Apparent)
Main Line Leaks
Service Line Connections
Other (Real)
Non-Billed Authorized Consumption

D. Future Projections (2030)

It is important that MWD understand the future operating conditions it may face over the next 10 years and the importance of implementing a loss reduction plan. The following table and graph highlight the projections for NRW and annual metered sales through 2035. These projections assume that no action has been taken by MWD to reduce loss in the system.

Annual metered sales assumed to remain constant from 2020 through 2030. As discovered during the trend analysis, the annual metered sales rate is declining on average by 1.81% per year. A conservative approach was chosen and the annual meter sales were held constant. The NRW projection was calculated by applying the average annual increase to the 2020 amount through 2030. The table below summarizes these calculations.

NRW/Annual Metered Sales Projection through 2030												
	2019	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
NRW w/ 2.51% Annual Rate of Increase	785,468,639	805,183,902	825,394,018	846,111,408	867,348,804	889,119,259	911,436,152	934,313,200	957,764,461	981,804,349	1,006,447,638	1,031,709,474
Annual Metered Sales w/ No Annual Rate Increase	790,602,230	790,602,230	790,602,230	790,602,230	790,602,230	790,602,230	790,602,230	790,602,230	790,602,230	790,602,230	790,602,230	790,602,230



The graph above depicts the "no action" approach to loss reduction. The trend lines presented above are linear. The linear trend line represents a tangent to a non-linear equation. Should the current conditions persist, and no action is taken to reduce NRW in the system, NRW will exceed annual metered sales between 2020 and 2030. At this point, daily operations will no longer be feasible.

V. STRATEGIC PLANNING

Strategic planning is a management activity that enables organizations to focus resources and energy towards achieving a common goal. The common goal is the reduction of UW to 15% by 2035. In doing so, MWD hopes to achieve regulatory compliance, develop a sustainable operation, and provide the citizens of Pike County with a reliable source of public water for decades to come.

This section of the report provides a framework for reducing system loss by defining proposed capital improvements and developing an implementation strategy. Consideration is given to potential problems typically encountered and subsequent steps that can be taken to avoid these problems. Finally, a list of measurable outcomes that can be used to evaluate the plans overall success is provided.

A. Goals

The established goal is the reduction of UW to 15% by 2035.

B. Capital Improvements

MWD can take the following capital improvements to achieve the strategic goals previously outlined. Each task has been categorized according to anticipated date of completion.

0-3 Years

1. *Develop a Project Profile for the Replacement of Service Line Connections in the Marrowbone Area*- MWD should develop a project to replace existing service line connections in the Marrowbone area. Project development should include defining the scope, estimating project costs, establishing a project timeline, and identifying possible funding sources. The project profile should be submitted to BSADD for inclusion in the WRIS database. Professional services will be required.

2. *Develop a Project Profile for the Replacement of Water Main in the Burning Fork, Dorton Hill, and Cornette Road Area*- MWD should develop a project profile to replace existing water mains in the Burning Fork, Dorton Hill, and Cornette Road area. Project development should include defining the scope of work, estimated project costs, establishing a project timeline, and identifying possible funding sources. The project profile should be submitted to the BSADD water management council for inclusion in the WRIS database. Professional services will be required.

3. *Develop a Project Profile for Zone Meter Installation*- MWD should develop a project profile to include the installation of zone meters, establishment of DMA's, and the installation of advanced metering infrastructure (AMI). A map depicting the proposed DMA's and zone meter locations is being developed. Professional services will be required.

4. *Develop a Project Profile for the Replacement Booster Pump Stations at Pike Central, Graveyard, and Forest Hills, for the Rehabilitation of Booster Pump Stations at Hardy, Long Branch, and Cabin Knoll, for the Installation of a New Water Storage Tank at the Right Fork of Greasy and Kendrick*- MWD should develop a project profile to replace existing Booster Pump Stations at the Pike Central, Graveyard, and Forest Hills area. MWD should develop a project profile to rehabilitate the Booster Pump Stations at the Hardy, Long Branch, and Cabin Knoll. MWD should develop a project profile to install a new water storage tank at the Right Fork of Greasy and Kendrick areas. Project development should include defining the scope of work, estimated project costs, establishing a project timeline, and identifying possible funding sources. The project profile should be submitted to the BSADD water management council for inclusion in the WRIS database. Professional services will be required.

5. *Develop a Project Profile for Water Treatment Plant Improvements, Instrumentation Purchase, Telemetry Improvements, and Property Acquisition*- MWD should purchase and install the following equipment for the Water Treatment Plant: air compressor, coagulation day tank, and chemical pumps. Six (6) Mag Meters should be purchased and installed. Cellular telemetry should be purchased for 14 sites. Twelve (12) property sites should also be purchased for future expansion. Project development should include defining the scope of work, estimating project costs, establishing a project timeline, and identifying possible funding sources. The project profile should be submitted to the BSADD for inclusion in the WRIS database. Professional services will be required.

6. *Develop a Project Profile to Purchase General Equipment*- MWD should purchase the following general equipment: four (4) service trucks, two (2) excavators, and two (2) pull trailers. This project may be done with MWD general funds.

7. *Develop a Project Profile for Skid Tank Rehabilitation and to Purchase and Install Pressure Reducing Valves*- MWD should rehabilitate skid tanks at 10 site locations. MWD should also purchase and install Pressure Reducing Valves at the Blackberry No. 2, Lyntrough, and Pitstop areas. Project development should include defining the scope of work, estimating project costs, establishing a project timeline, and identifying possible funding sources. The project profile should be submitted to the BSADD for inclusion in the WRIS database. Professional services will be required.

8. *Request Authority from the PSC to Assess a Loss Reduction Surcharge*- MWD will require additional funds to perform the capital improvements recommended in this report. MWD should seek authority from the PSC to assess a surcharge of which proceeds would be used solely for water loss reduction efforts.

9. *Hire Dedicated Loss Reduction Staff and Purchase Additional Leak Detection Equipment*-When funds are available, MWD should hire additional staff for the sole purpose of loss reduction. In addition, MWD should purchase additional leak detection equipment as needed. Surcharge proceeds can be used as a potential source of financing for this activity.

10. *Secure Professional Services to Conduct a Condition Assessment of all Storage Facilities in the System*-When funds are available, MWD should secure professional services to conduct a condition assessment of all storage facilities in the system not currently under contract with Southern Corrosion. Surcharge proceeds can be used as a potential source of financing for this activity.

11. *Secure Professional Services to Conduct a Condition Assessment of all Pump Stations in the System*-When funds are available, MWD should secure professional services to conduct a condition assessment of all pump stations in the system. Surcharge proceeds can be used as a potential source of financing for this activity.

12. *Conduct an Audit of Telemetry Systems*-When funds are available, MWD should retain MicroComm to conduct an audit of all telemetry systems. Surcharge proceeds can be used as a potential source of financing for this activity.

13. *Secure Professional Services to Develop a Hydraulic Model for Parallel Lines and the Rocky Road Area*- When funds are available, MWD should secure professional services for the development of a comprehensive hydraulic model of the parallel lines in the system as well as the Rocky Road Area. The model can be initially developed from physical attributes and refined as more information becomes available from zone metering. Surcharge proceeds can be used as a potential source of financing for this activity.

14. *Upgrade and Develop Institutional Controls*- When funds are available, MWD should secure professional service or enlist the services of KACO, BSADD, KRWA or RCAP to upgrade or develop a Policy and Procedures Manual, a Comprehensive Loss Reduction Plan, a Leak Detection Plan, appropriate O&M Manuals, a Water Audit, and a Capital Improvements Plan. Surcharge proceeds can be used as a potential source of financing for this activity.

15. *Install Pressure Recording Devices in the Burning Fork, Dorton Hill, and Cornette Road Areas*- When funds are available, MWD should secure professional services to install pressure recording devices in these areas. Data gathered can be used to verify the need for main replacement. Surcharge proceeds can be used as a potential source of financing for this activity.

16. *Hire Leak Detection Services*- When funds are available, MWD should considered hiring leak detection services to pinpoint sources of loss in problematic areas in the system. Surcharge proceeds can be used as a potential source of financing for this activity.

17. *Rate Study/Rate Increase*- MWD should hire professional services or utilize public agencies to complete a rate study. The rate study should determine if existing rates are sufficient to sustain daily operations, pay debt service and fund loss reduction efforts.

18. *Billing Software Audit*- MWD should conduct periodic audits of billing software and billing procedures.

19. *Continued Education and Training*-The PSC and DOW require that key personnel receive the proper training and maintain the necessary licensure with regards to operating and/or managing a water distribution system. MWD should continue to provide ample opportunity for staff to receive continued education training and continue to maintain accurate training records.

4-6 Years

1. *Develop a Project Profile for the Replacement of Service Line Connections in the Pond Creek Area*-MWD should develop a project to replace existing service line connections in the Pond Creek area. Project development should include defining the scope, estimating project costs, establishing a project timeline, and identifying possible funding sources. The project profile should be submitted to BSADD for inclusion in the WRIS database. Professional services will be required.

2. *Develop a Project Profile for the Replacement of Water Main in the Yellow Hill, Blair Adkins, Greasy Creek, and Little Creek Area*- MWD should develop a project profile to replace existing water mains in the Yellow Hill, Blair Adkins, Greasy Creek, and Little Creek area. Project development should include defining the scope of work, estimated project costs, establishing a project timeline, and identifying possible funding sources. The project profile should be submitted to the BSADD water management council for inclusion in the WRIS database. Professional services will be required.

3. *Develop a Project Profile for the Replacement Booster Pump Stations at the Stone, McVeigh, and Toler Areas, for the Rehabilitation of Booster Pumps Stations at the Jerry Bottom, Turkeytoe, and Dials Branch Areas, for the Installation of a New Water Storage Tank at the Forest Hills Area*-MWD should develop a project profile to replace existing Booster Pump Stations at the Stone, McVeigh, and Toler areas. MWD should develop a project profile to rehabilitate the Booster Pumps Stations at the Jerry Bottom, Turkeytoe, and Dials Branch areas. MWD should develop a project profile to install a new water storage tank at Forest Hills area. Project development should include defining the scope of work, estimated project costs, establishing a project timeline, and identifying possible funding sources. The project profile should be submitted to the BSADD water management council for inclusion in the WRIS database. Professional services will be required.

4. *Develop a Project Profile for Water Treatment Plant Improvements, Instrumentation Purchase, General Equipment, Telemetry Improvements, and Property Acquisition*- MWD should purchase and install the following equipment for the Water Treatment Plant: vacuum pumps, turbidity/sand filters, and air valves. Six (6) Mag Meters should be purchased and

installed. The following general equipment should also be purchased: two (2) service trucks. Cellular telemetry should be purchased for 14 sites. Twelve (12) property sites should also be purchased for future expansion. Project development should include defining the scope of work, estimating project costs, establishing a project timeline, and identifying possible funding sources. The project profile should be submitted to the BSADD for inclusion in the WRIS database. Professional services will be required.

5. *Develop a Project Profile for Skid Tank Rehabilitation and to Purchase and Install Pressure Reducing Valves*- MWD should rehabilitate skid tanks at 15 site locations. MWD should also purchase and install Pressure Reducing Valves at the Widows, Phelps One and Two, and Rockhouse of Marrowbone areas. Project development should include defining the scope of work, estimating project costs, establishing a project timeline, and identifying possible funding sources. The project profile should be submitted to the BSADD for inclusion in the WRIS database. Professional services will be required.

6. *Hire Dedicated Loss Reduction Staff and Purchase Additional Leak Detection Equipment*- When funds are available, MWD should hire additional staff for the sole purpose of loss reduction. In addition, MWD should purchase additional leak detection equipment as needed. Surcharge proceeds can be used as a potential source of financing for this activity.

7. *Secure Professional Services to Develop a Hydraulic Model for Parallel Lines and the Robinson Creek and Marrowbone 460 Area*- When funds are available, MWD should secure professional services for the development of a comprehensive hydraulic model of the parallel lines in the system as well as the Robinson Creek and Marrowbone 460 areas. The model can be initially developed from physical attributes and refined as more information becomes available from zone metering. Surcharge proceeds can be used as a potential source of financing for this activity.

8. *Rate Study/Rate Increase*- MWD should hire professional services or utilize public agencies to complete a rate study. The rate study should determine if existing rates are sufficient to sustain daily operations, pay debt service and fund loss reduction efforts.

7-9 Years

1. *Develop a Project Profile for the Replacement of Service Line Connections in the Shelby Valley Area*- MWD should develop a project to replace existing service line connections in the Shelby Valley area. Project development should include defining the scope, estimating project costs, establishing a project timeline, and identifying possible funding sources. The project profile should be submitted to BSADD for inclusion in the WRIS database. Professional services will be required.

2. *Develop a Project Profile for the Replacement of Water Main in the Poorbottom to Graveyard, and Garden Village Areas*- MWD should develop a project profile to replace existing water mains in the Poorbottom to Graveyard, and Garden Village areas. Project development should include defining the scope of work, estimated project costs, establishing a project timeline, and identifying possible funding sources. The project profile should be submitted to the BSADD water management council for inclusion in the WRIS database. Professional services will be required.

3. *Develop a Project Profile for the Replacement Booster Pump Stations at the Smith Fork and Prichard Areas, for the Rehabilitation of Booster Pumps Stations at the Island Creek, Grassy Two, Pinson Fork, and Peter Fork Areas, for the Installation of a New Water Storage Tank at the Poor Bottom and Allegheny Areas*- MWD should develop a project profile to replace existing Booster Pump Stations at the Smith Fork and Prichard areas. MWD should develop a project profile to rehabilitate the Booster Pumps Stations at the Island Creek, Grassy Two, Pinson Fork, and Peter Fork areas. MWD should develop a project profile to install a new water storage tank at the Poor Bottom and Allegheny areas. Project development should include defining the scope of work, estimated project costs, establishing a project timeline, and identifying possible funding sources. The project profile should be submitted to the BSADD water management council for inclusion in the WRIS database. Professional services will be required.

4. *Develop a Project Profile for Water Treatment Plant Improvements, Instrumentation Purchase, Telemetry Improvements, and Property Acquisition*- MWD should purchase and install the following equipment for the Water Treatment Plant: filtration equipment, dehumidifier, and streaming current. Six (6) Mag Meters should be purchased and installed. Cellular telemetry should be purchased for 14 sites. Twelve (12) property sites should also be purchased for future expansion. Project development should include defining the scope of work, estimating project costs, establishing a project timeline, and identifying possible funding sources. The project profile should be submitted to the BSADD for inclusion in the WRIS database. Professional services will be required.

5. *Develop a Project Profile for Skid Tank Rehabilitation and to Purchase and Install Pressure Reducing Valves*- MWD should rehabilitate skid tanks at 15 site locations. MWD should also purchase and install Pressure Reducing Valves at the Sugar Camp, and Rockhouse of Brushy One and Two areas. Project development should include defining the scope of work, estimating project costs, establishing a project timeline, and identifying possible funding sources. The project profile should be submitted to the BSADD for inclusion in the WRIS database. Professional services will be required.

6. *Secure Professional Services to Develop a Hydraulic Model for the Homemade Hollow and Pike Central Areas*- When funds are available, MWD should secure professional services for the development of a comprehensive hydraulic model of the Homemade Hollow and Pike Central areas. The model can be initially developed from physical attributes and refined as more information becomes available from zone metering. Surcharge proceeds can be used as a potential source of financing for this activity.

7. *Rate Study/Rate Increase*- MWD should hire professional services or utilize public agencies to complete a rate study. The rate study should determine if existing rates are sufficient to sustain daily operations, pay debt service and fund loss reduction efforts.

10-12 Years

1. *Develop a Project Profile for the Replacement of Service Line Connections in the Grapevine Area*- MWD should develop a project to replace existing service line connections in the Grapevine area. Project development should include defining the scope, estimating project costs, establishing a project timeline, and identifying possible funding sources. The project profile should be submitted to BSADD for inclusion in the WRIS database. Professional services will be required.

2. *Develop a Project Profile for the Replacement of Water Main in the Wolfpit and the Twin Bridges to Poorbottom Areas*- MWD should develop a project profile to replace existing water mains in the Wolfpit and the Twin Bridges to Poorbottom areas. Project development should include defining the scope of work, estimated project costs, establishing a project timeline, and identifying possible funding sources. The project profile should be submitted to the BSADD water management council for inclusion in the WRIS database. Professional services will be required.

3. *Develop a Project Profile for the Replacement Booster Pump Stations at the Indian Creek, Long Fork, and Cowpen Areas, for the Rehabilitation of Booster Pumps Stations at the Wolfpit and Brushy Areas, and for the Installation of a New Water Storage Tank at the Mudlick and Narrows Areas*- MWD should develop a project profile to replace existing Booster Pump Stations at the Indian Creek, Long Fork, and Cowpen areas. MWD should develop a project profile to rehabilitate the Booster Pumps Stations at the Wolfpit and Brushy areas. MWD should develop a project profile to install a new water storage tank at the Poor Bottom and Allegheny areas. Project development should include defining the scope of work, estimated project costs, establishing a project timeline, and identifying possible funding sources. The project profile should be submitted to the BSADD water management council for inclusion in the WRIS database. Professional services will be required.

4. *Develop a Project Profile for Water Treatment Plant Improvements, Instrumentation Purchase, Telemetry Improvements, and Property Acquisition*- MWD should purchase and install the following equipment for the Water Treatment Plant: SCADA upgrades, chemical day tanks, electronics upgrades (i.e. computers, monitors). Six (6) Mag Meters should be purchased and installed. Cellular telemetry should be purchased for 14 sites. Twelve (12) property sites should also be purchased for future expansion. Project development should include defining the scope of work, estimating project costs, establishing a project timeline, and identifying possible funding sources. The project profile should be submitted to the BSADD for inclusion in the WRIS database. Professional services will be required.

5. *Develop a Project Profile to Purchase General Equipment*- MWD should purchase the following general equipment: two (2) service trucks, two (2) excavators, and two (2) pull trailers. This project may be done with MWD general funds.

6. *Develop a Project Profile for Skid Tank Rehabilitation and to Purchase and Install Pressure Reducing Valves*- MWD should rehabilitate skid tanks at 15 site locations. MWD should also purchase and install Pressure Reducing Valves at the Lower Pompey, Feds Creek, and Yellow Hill areas. Project development should include defining the scope of work, estimating project costs, establishing a project timeline, and identifying possible funding sources. The project profile should be submitted to the BSADD for inclusion in the WRIS database. Professional services will be required.

7. *Secure Professional Services to Develop a Hydraulic Model for the Justiceville and Jerry Bottom Areas*- When funds are available, MWD should secure professional services for the development of a comprehensive hydraulic model of the Justiceville and Jerry Bottom areas. The model can be initially developed from physical attributes and refined as more information becomes available from zone metering. Surcharge proceeds can be used as a potential source of financing for this activity.

13-15 Years

1. *Develop a Project Profile for the Replacement of Service Line Connections* -MWD should develop a project to replace existing service line connections in any remaining areas not already. Project development should include defining the scope, estimating project costs, establishing a project timeline, and identifying possible funding sources. The project profile should be submitted to BSADD for inclusion in the WRIS database. Professional services will be required.

2. *Develop a Project Profile for the Replacement of Water Main in the Red Creek to Peytons Area*- MWD should develop a project profile to replace

existing water mains in the Red Creek to Peytons area. Project development should include defining the scope of work, estimated project costs, establishing a project timeline, and identifying possible funding sources. The project profile should be submitted to the BSADD water management council for inclusion in the WRIS database. Professional services will be required.

3. *Develop a Project Profile for the Replacement Booster Pump Stations at the Bowling Fork and Allegheny Right Fork Areas, for the Rehabilitation of Booster Pumps Stations at the Wilson Loop and Anderson Branch Areas, and for the Installation of a New Water Storage Tank at the Slones Branch and Peytons Areas*- MWD should develop a project profile to replace existing Booster Pump Stations at the Bowling Fork, and Allegheny Right Fork areas. MWD should develop a project profile to rehabilitate the Booster Pumps Stations at the Wilson Loop and Anderson Branch areas. MWD should develop a project profile to install a new water storage tank at the Slones Branch and Peytons areas. Project development should include defining the scope of work, estimated project costs, establishing a project timeline, and identifying possible funding sources. The project profile should be submitted to the BSADD water management council for inclusion in the WRIS database. Professional services will be required.

4. *Develop a Project Profile for Water Treatment Plant Improvements, Instrumentation Purchase, Telemetry Improvements, and Property Acquisition*- MWD should purchase and install the following equipment for the Water Treatment Plant: Chemical Pumps and hardware. Six (6) Mag Meters should be purchased and installed. Cellular telemetry should be purchased for 14 sites. Twelve (12) property sites should also be purchased for future expansion. Project development should include defining the scope of work, estimating project costs, establishing a project timeline, and identifying possible funding sources. The project profile should be submitted to the BSADD for inclusion in the WRIS database. Professional services will be required.

5. *Develop a Project Profile for Skid Tank Rehabilitation and to Purchase and Install Pressure Reducing Valves*- MWD should rehabilitate skid tanks at 15 site locations. MWD should also purchase and install Pressure Reducing Valves at the Zebulon, Grapevine School, and Upper Camp areas. Project development should include defining the scope of work, estimating project costs, establishing a project timeline, and identifying possible funding sources. The project profile should be submitted to the BSADD for inclusion in the WRIS database. Professional services will be required.

6. *Secure Professional Services to Develop a Hydraulic Model for the Coburn Mountain Area*- When funds are available, MWD should secure

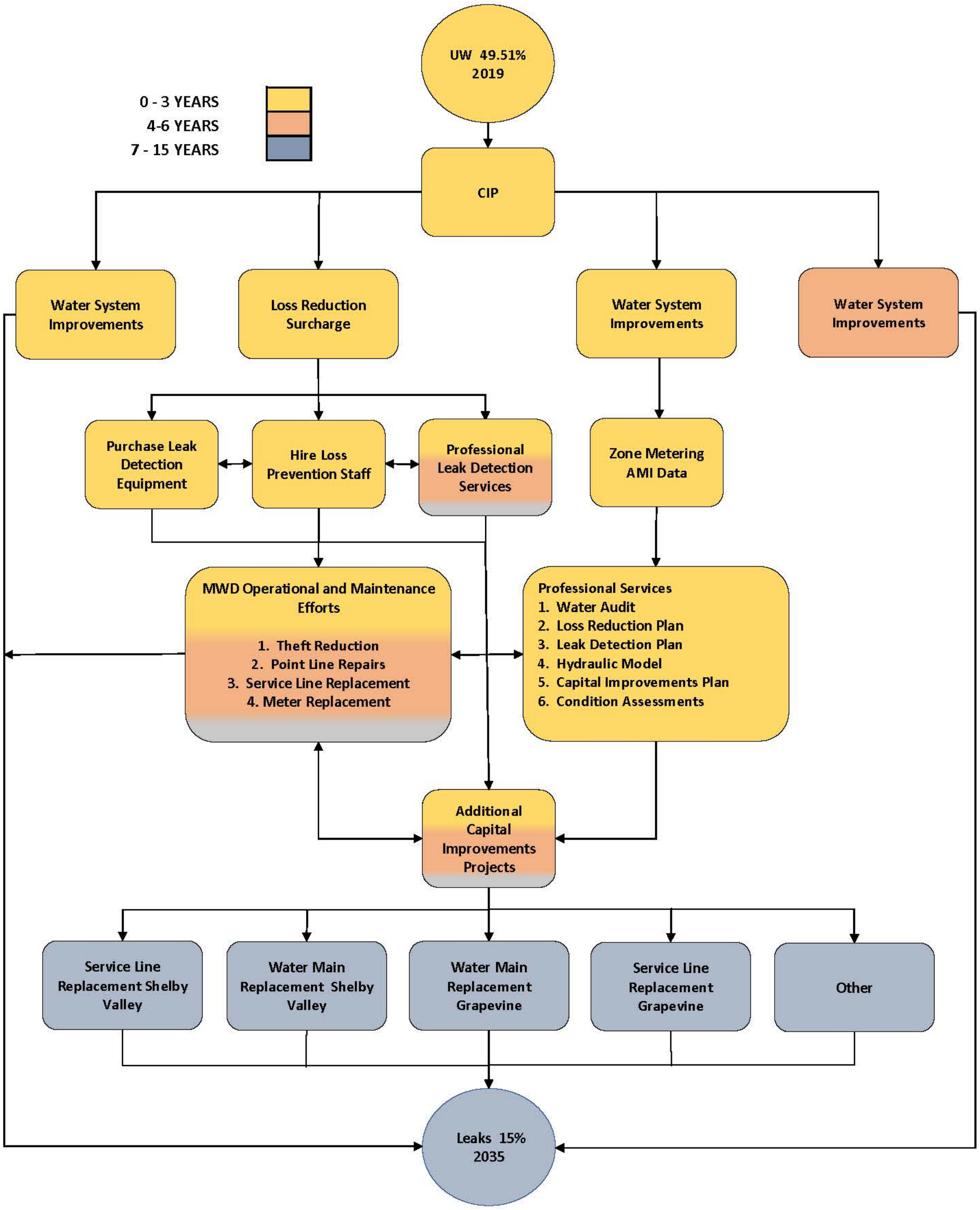
professional services for the development of a comprehensive hydraulic model for the Coburn Mountain area. The model can be initially developed from physical attributes and refined as more information becomes available from zone metering. Surcharge proceeds can be used as a potential source of financing for this activity.

C. Implementation

1. Plan Schematic

The following is a graphic representation of the Capital Improvement Plan for MWD. The flowchart should be examined using a top-down method. Each task or group of tasks is colored coded depending on the date of implementation. Tasks are linked with arrows indicating the sequence of implementation.

Corrective Action Implementation Flow-Chart



D. Priority of Work

The following is a list of priorities of work. The goal is to establish priorities of work that are reasonable, supportive of subsequent projects and provide the best return on investment.

1. *Improving the Operating Efficiency and Loss Reduction Capabilities of MWD*- This priority of work focuses on improving the operating efficiency and loss reduction capabilities of MWD. Capital improvements include: replacement of service and main line, booster pump station replacement and rehabilitation, new water tank installations; hiring additional staff for the sole purpose of loss reduction; upgrading and developing institutional controls; assessing system components through inspection and/or pressure monitoring; completing a water audit; developing a hydraulic model; maintaining sufficient rates; and purchasing additional leak detection equipment. Many of these tasks should be accomplished in the 0-2 year period; however, the goal is the progressive improvement of operational efficiency and loss reduction capabilities beyond the 15 year planning period.

2. *Installing Zone Meters, Establishing DMAs and Installing an AMI Network*- This priority of work focuses on installing zone meters, establishing DMAs, and installing an AMI network to provide MWD with sufficient system information to enable MWD to focus on loss reduction efforts. Zone metering will establish redundant metering at each wholesale purchase and distribution point. Capital improvements that are involved in this priority include the project profile development and funding acquisition.

3. *Develop and Prioritization Capital Improvement Projects*– The final priority of work focuses on developing and prioritizing capital improvement projects aimed at replacing infrastructure with significant loss contribution. In order to identify and prioritize capital projects, information from the zone meters and the AMI network will need to be analyzed. For this reason, this priority of work was ranked third overall. Capital improvements that are involved in this priority of work include: water treatment plant improvements, telemetry upgrades, skid tank rehabilitation, pressure reducing valves installation, and others.

E. Potential Problems

Before the implementation of any plan, it is important to mitigate risk. The following is a list of potential problems and mitigation efforts that should be taken to avoid these problems.

1. *Ineligible to Receive Funding Assistance Because of Payment History*- USDA RD and KIA are primary lending agencies that fund rural water infrastructure projects in Kentucky. Several of the capital improvements outlined above involve large scale capital improvements which will require use of USDA RD and/or KIA loan funds. To remain eligible, MWD is advised to keep existing loans current, make timely payment on all loans, and maintain required reserve accounts.

2. *Delays in Funding Assistance Because of Incomplete Financial Records*- Most funding agencies will require the submittal of financial records during the application process. Incomplete financial records can cause delays in processing funding applications. MWD is advised to continue to keep detailed financial records.

3. *Noncompliance with DOW*- DOW provides regulatory oversight, reviews plans and specifications, and assists in the administration of KIA funds. It is imperative that MWD maintain a good working relationship with the DOW. MWD should continue to comply with all monitoring and reporting requirements and ensure that all employees maintain the required licensure for their position. MWD is encouraged to use professional engineering services to assist with DOW compliance issues when needed.

4. *Noncompliance with the PSC*- The PSC provides regulatory oversight for water districts in Kentucky. MWD is advised to continue to comply with PSC orders and encouraged to continue to use legal counsel to assist with compliance efforts when needed.

5. *Funding Availability*- The availability of funds from different sources vary as do the application and qualification requirements. It is recommended that MWD develop strategic partnerships to assist with funding needs. The following is a list of partners that can provide assistance: KIA, USDA RD, BSADD, Department for Local Government (DLG), the Pike County Fiscal Court, DOW, RCAP and the Kentucky Economic Development Authority (EDA).

F. Measurable Outcomes

This section of the report will establish measurable outcomes associated with the capital improvements presented herein. The overall goal is to reduce UW to 15% by 2035. Since the Residential Meter Replacement Project has been completed at the time of this report, each proposed capital improvement is estimated to be 70% effective in apparent loss reduction, and 60% effective in real loss reduction.

0-3 Years

The following sources of loss should be addressed within the first three (3) years of implementing the capital improvements plan. At 60-70% effective, the anticipated result is a 14.06% reduction in UW by the end of the three (3) year period. This 14.06% reduction should correspond to a reduction in annual purchased and produced water of 221,595,564 gallons.

1. *Service Line Replacement*- It is assumed that service line connections are responsible for approximately 13.91% of the annual water purchased and produced and contribute approximately 219,165,859 gallons annually to UW. Between Year 0 and Year 3, it is assumed that MWD will use KIA or USDA RD funds to complete a project focused on replacing service line connections in the Marrowbone area. It is anticipated that replacing service line connections in Marrowbone will reduce the percent contribution of service line connections by 1.67% (20% complete x 60% effective x 13.91% of purchased and produced water). This should result in the reduction of annual purchased and produced water by 26,298,319 gallons.

2. *Main Line Leaks*- It has been assumed that main line leaks are responsible for approximately 2.66% of the annual water purchased and produced and contribute approximately 41,944,260 gallons annually to UW. Between Year 0 and Year 3, it is assumed that MWD will use KIA or USDA RD funds to complete projects aimed at replacing main lines in the Marrowbone area. It is anticipated that replacing main lines in these areas will reduce the percent contribution by 0.32% (60% effective x 20% complete 2.66% of purchased and produced water). This should result in the reduction of the annual purchased and produced water amount by 5,030,818 gallons.

3. *Other*- It has been assumed that other (real loss) is responsible for 13.91% of the annual water purchased and contributes approximately 219,165,859 gallons to UW annually. Between Year 0 and Year 3, it is assumed that MWD will use KIA or USDA RD funds to complete projects aimed at rehabilitating pump stations and tanks identified during the condition assessment. In addition, it is assumed that other unknown sources of loss will be identified and repaired. It is anticipated that rehabilitating pump stations and tanks along with repairs to unknown sources will reduce the percent contribution of other (real loss) 1.95% (70% effective x 20% completion of other real loss x 13.91% of purchased and produced water). This should result in the reduction of the purchased and produced water amount by 30,681,372 gallons.

4. *Other (Apparent Loss)*- It has been assumed that other (apparent loss) is responsible for approximately 9.13% of the annual water purchased and contributes approximately 143,938,107 gallons annually to UW. During the first three (3) years of implementation, it is assumed that MWD will hire additional personnel dedicated to loss reduction, purchase additional leak detection equipment, upgrade and develop institutional controls, and hire leak detection professionals. It is anticipated that these actions will reduce other (apparent loss) contribution to UW by 3.2% (70% effective x 50%

completion x 9.13% of purchased water). This should result in the reduction of annual purchased and produced water by 50,363,345 gallons.

5. *Metering Inaccuracies*- It has been assumed that metering inaccuracies are responsible for approximately 9.9% of the annual water purchased and contributes approximately 156,053,521gallons annually to UW. MWD replaced all residential meters between 2018 and 2020 during the RG3 Radio Read Meter Replacement Project. This will reduce the loss contribution associated with metering inaccuracies by inaccurate meters by 6.93% (70% effective x 9.9% of purchased and produced water). This should result in the reduction of annual purchased and produced water by 109,221,711 gallons.

The following table summarizes the calculations presented above.

	2020	Main Line Leaks	Service Line Connections	Other	Metering Inaccuracy	Other	2023	
Main Line Leaks	2.66%	-0.32%					2.34%	Main Line Leaks
Service Line Connections	13.91%		-1.67%				12.24%	Service Line Connections
Other	13.91%			-1.95%			11.96%	Other
Metering Inaccuracy	9.90%				-6.93%		2.97%	Metering Inaccuracy
Other	9.13%					-3.20%	5.93%	Other
Total	49.50%	-0.32%	-1.67%	-1.95%	-6.93%	-3.20%	35.44%	Total

4-6 Years

At 70% effective, the anticipated result by the end of Year 6 is an additional 5.79% reduction in UW. This 5.79% reduction should correspond to a reduction in annual purchased and produced water of 91,286,734 gallons. The real loss effective rate has been increased to 70% because of the potential availability of system information acquired from the DMAs and AMI network, pressure monitoring, and professional leak detection services.

1. *Service Line Replacement*- Between Year 4 and Year 6, it is assumed that MWD will use KIA or USDA RD funds to complete a project focused on replacing service line connections in the Pond Creek area. It is anticipated that replacing service line connections in Pond Creek will reduce the

percent contribution of service line connections by 1.71% (20% complete x 70% effective x 12.24% of purchased and produced water). This should result in the reduction of annual purchased and produced water by 26,999,607 gallons.

2. *Main Line Leaks*- Between Year 4 and Year 6, it is assumed that MWD will use KIA or USDA RD funds to complete projects aimed at replacing main lines in the Pond Creek area. It is anticipated that replacing main lines in these areas will reduce the percent contribution by 0.33% (70% effective x 20% complete x 2.34% of purchased and produced water). This should result in the reduction of the annual purchased and produced water amount by 5,164,973 gallons.

3. *Other (Real)*- Between Year 4 and Year 6, it is assumed that MWD will use KIA or USDA RD funds to continue to complete projects aimed at rehabilitating pump stations and tanks identified during the condition assessment. In addition, it is assumed that other unknown sources of loss will be identified repaired. It is anticipated that rehabilitating pump stations and tanks along with repairs to unknown sources will reduce the percent contribution of other (real loss) 1.67% (70% effective x 20% completion of other real loss x 11.96% of purchased and produced water). This should result in the reduction of the purchased and produced water amount by 26,385,980 gallons.

4. *Other (Apparent Loss)*- During the next three (3) years of implementation, it is assumed that MWD will continue to hire additional personnel dedicated to loss reduction, purchase additional leak detection equipment, upgrade and develop institutional controls, and hire leak detection professionals. It is anticipated that these actions will reduce other (apparent loss) contribution to UW by 2.08% (70% effective x 50% completion x 5.93% of purchased water). This should result in the reduction of annual purchased and produced water by -32,736,174 gallons.

The following table summarizes the calculations presented above.

	2020	2023	Main Line Leaks	Service Line Connections	Other	Metering Inaccuracy	Other	2026	
Main Line Leaks	2.66%	2.34%	-0.33%					2.01%	Main Line Leaks
Service Line Connections	13.91%	12.24%		-1.71%				10.52%	Service Line Connections
Other	13.91%	11.96%			-1.67%			10.28%	Other
Metering Inaccuracy	9.90%	2.97%						2.97%	Metering Inaccuracy
Other	9.13%	5.93%					-2.08%	3.86%	Other
Total	49.50%	35.44%	-0.33%	-1.71%	-1.67%	0.00%	-2.08%	29.65%	Total

7-9 Years

At 70% effective, the anticipated result by the end of Year 9 is an additional 3.19% reduction in UW. This 3.19% reduction should correspond to a reduction in annual purchased and produced water of 50,353,482 gallons. The effective rate has remained at 70% effective because of the continued potential availability of system information acquired from the DMAs and AMI network, pressure monitoring, and professional leak detection services.

1. *Service Line Replacement*- Between Year 7 and Year 9, it is assumed that MWD will use KIA or USDA RD funds to complete a project focused on replacing service line connections in the Pond Creek area. It is anticipated that replacing service line connections in Pond Creek will reduce the percent contribution of service line connections by 1.47% (20% complete x 70% effective x 10.52% of purchased and produced water). This should result in the reduction of annual purchased and produced water by 23,219,662 gallons.

2. *Main Line Leaks*- Between Year 7 and Year 9, it is assumed that MWD will use KIA or USDA RD funds to complete projects aimed at replacing main lines in the Pond Creek area. It is anticipated that replacing main lines in these areas will reduce the percent contribution by 0.28% (70% effective x 20% complete x 2.01% of purchased and produced water). This should result in the reduction of the annual purchased and produced water amount by 4,441,877 gallons.

3. *Other (Real)*- Between Year 7 and Year 9, it is assumed that MWD will use KIA or USDA RD funds to continue to complete projects aimed at rehabilitating pump stations and tanks identified during the condition assessment. In addition, it is assumed that other unknown sources of loss will be identified repaired. It is anticipated that rehabilitating pump stations and tanks along with repairs to unknown sources will reduce the percent contribution of other (real loss) 1.44% (70% effective x 20% completion of other real loss x 10.28% of purchased and produced water). This should result in the reduction of the purchased and produced water amount by 22,691,942 gallons.

The following table summarizes the calculations presented above.

	2020	2023	2026	Main Line Leaks	Service Line Connections	Other	Metering Inaccuracy	Other	2029	
Main Line Leaks	2.66%	2.34%	2.01%	-0.28%					1.73%	Main Line Leaks
Service Line Connections	13.91%	12.24%	10.52%		-1.47%				9.05%	Service Line Connections
Other	13.91%	11.96%	10.28%			-1.44%			8.84%	Other
Metering Inaccuracy	9.90%	2.97%	2.97%						2.97%	Metering Inaccuracy
Other	9.13%	5.93%	3.86%						3.86%	Other
Total	49.50%	35.44%	29.65%	-0.28%	-1.47%	-1.44%	0.00%	0.00%	26.45%	Total

9-12 Years

At 70% effective, the anticipated result by the end of Year 12 is an additional 2.75% reduction in UW. This 2.75% reduction should correspond to a reduction in annual purchased and produced water of 43,303,994 gallons. The effective rate has remained at 70% effective because of the continued potential availability of system information acquired from the DMAs and AMI network, pressure monitoring, and professional leak detection services.

1. *Service Line Replacement*- Between Year 9 and Year 12, it is assumed that MWD will use KIA or USDA RD funds to complete a project focused on replacing service line connections in the Pond Creek area. It is anticipated that replacing service line connections in Pond Creek will reduce the percent contribution of service line connections by 1.27% (20% complete x 70% effective x 9.05% of purchased and produced water). This should result in the reduction of annual purchased and produced water by 19,968,909 gallons.

2. *Main Line Leaks*- Between Year 9 and Year 12, it is assumed that MWD will use KIA or USDA RD funds to complete projects aimed at replacing main lines in the Pond Creek area. It is anticipated that replacing main lines in these areas will reduce the percent contribution by 0.24% (70% effective x 20% complete x 1.73% of purchased and produced water). This should result in the reduction of the annual purchased and produced water amount by 3,820,014 gallons.

3. *Other (Real)*- Between Year 9 and Year 12, it is assumed that MWD will use KIA or USDA RD funds to continue to complete projects aimed at rehabilitating pump stations and tanks identified during the condition assessment. In addition, it is assumed that other unknown sources of loss will be identified repaired. It is anticipated that rehabilitating pump stations and tanks along with repairs to unknown sources will reduce the percent contribution of other (real loss) 1.24% (70% effective x 20% completion of other real loss x 8.84% of purchased and produced water). This should result in the reduction of the purchased and produced water amount by 19,515,070 gallons.

The following table summarizes the calculations presented above.

	2020	2023	2026	2029	Main Line Leaks	Service Line Connections	Other	Metering Inaccuracy	Other	2032	
Main Line Leaks	2.66%	2.34%	2.01%	1.73%	-0.24%					1.49%	Main Line Leaks
Service Line Connections	13.91%	12.24%	10.52%	9.05%		-1.27%				7.78%	Service Line Connections
Other	13.91%	11.96%	10.28%	8.84%			-1.24%			7.61%	Other
Metering Inaccuracy	9.90%	2.97%	2.97%	2.97%						2.97%	Metering Inaccuracy
Other	9.13%	5.93%	3.86%	3.86%						3.86%	Other
Total	49.50%	35.44%	29.65%	26.45%	-0.24%	-1.27%	-1.24%	0.00%	0.00%	23.71%	Total

12-15 Years

At 70% effective, the anticipated result by the end of Year 15 is an additional 2.36% reduction in UW. This 2.36% reduction should correspond to a reduction in annual purchased and produced water of 37,241,435 gallons. The effective rate has remained at 70% because of the continued potential availability of system information acquired from the DMAs and AMI network, pressure monitoring, and professional leak detection services.

1. *Service Line Replacement*- Between Year 12 and Year 15, it is assumed that MWD will use KIA or USDA RD funds to complete a project focused on replacing service line connections. It is anticipated that replacing additional service line connections will reduce the percent contribution of service line connections by 1.09% (20% complete x 70% effective x 7.78% of purchased and produced water). This should result in the reduction of annual purchased and produced water by -17,173,262 gallons.

2. *Main Line Leaks*- Between Year 12 and Year 15, it is assumed that MWD will use KIA or USDA RD funds to complete projects aimed at replacing main lines in additional areas. It is anticipated that replacing main lines in these areas will reduce the percent contribution by 0.21% (70% effective x 20% complete x 1.49% of purchased and produced water). This should result in the reduction of the annual purchased and produced water amount by 3,285,212 gallons.

3. *Other (Real)*- Between Year 12 and Year 15, it is assumed that MWD will use KIA or USDA RD funds to continue to complete projects aimed at rehabilitating pump stations and tanks identified during the condition assessment. In addition, it is assumed that other unknown sources of loss will be identified repaired. It is anticipated that rehabilitating pump stations and tanks along with repairs to unknown sources will reduce the percent contribution of other (real loss) 1.06% (70% effective x 20% completion of other real loss x 7.61% of purchased and produced water). This should result in the reduction of the purchased and produced water amount by 16,782,961 gallons.

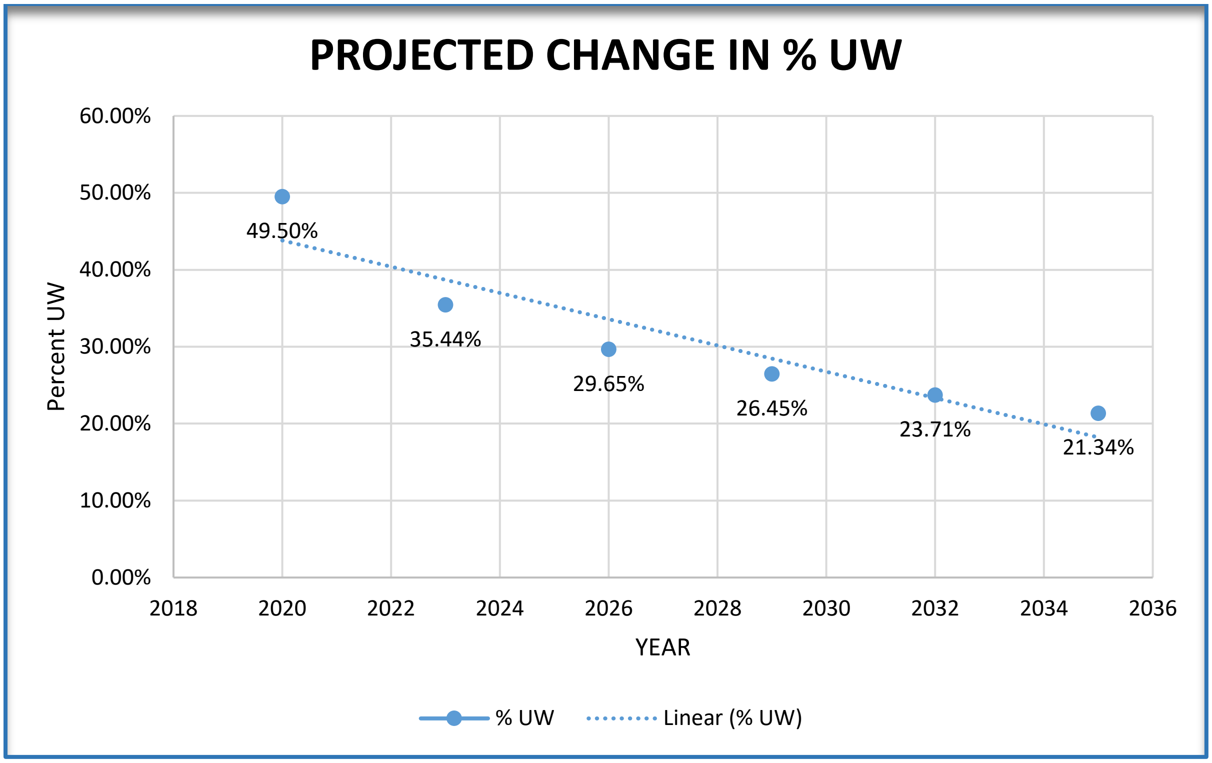
Note: The final UW water loss of 21.34% does not account for the PSC allowed less plant use of 172,790,584 from the 2018 Annual Report. Once this number is factored in, the final UW water loss is 10.84%.

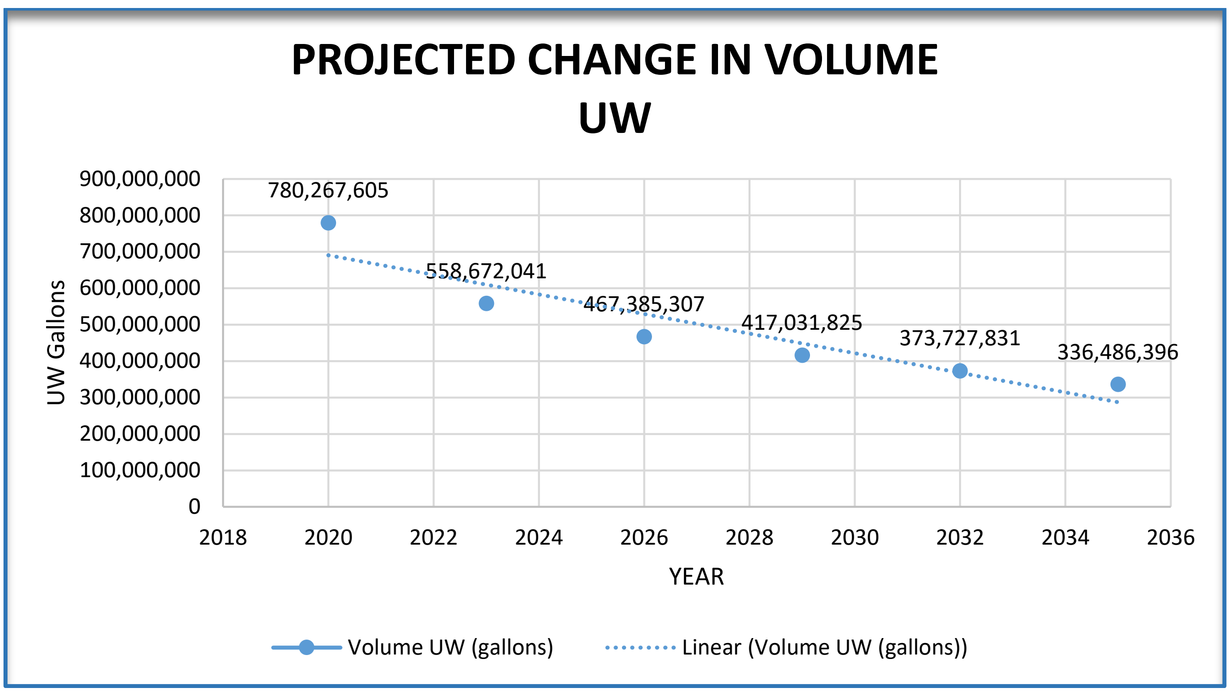
The following table summarizes the calculations presented above.

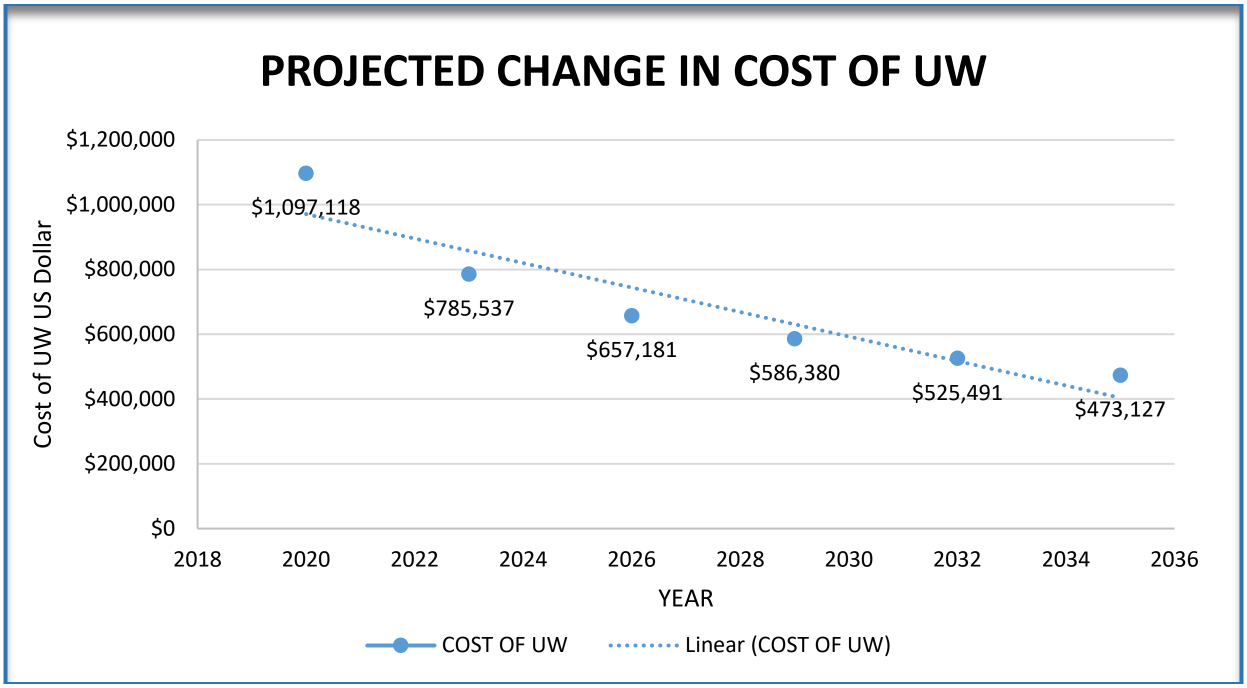
	2020	2023	2026	2029	2032	Main Line Leaks	Service Line Connections	Other	Metering Inaccuracy	Other	2035	
Main Line Leaks	2.66%	2.34%	2.01%	1.73%	1.49%	-0.21%					1.28%	Main Line Leaks
Service Line Connections	13.91%	12.24%	10.52%	9.05%	7.78%		-1.09%				6.69%	Service Line Connections
Other	13.91%	11.96%	10.28%	8.84%	7.61%			-1.06%			6.54%	Other
Metering Inaccuracy	9.90%	2.97%	2.97%	2.97%	2.97%						2.97%	Metering Inaccuracy
Other	9.13%	5.93%	3.86%	3.86%	3.86%						3.86%	Other
Total	49.50%	35.44%	29.65%	26.45%	23.71%	-0.21%	-1.09%	-1.06%	0.00%	0.00%	21.34%	Total

The following summarizes the measurable outcomes for the planning period. The table is intended for a quick reference and has been color coded to match the color coding on the implementation flow chart. The results presented herein are based on results of the water balance and assumes a 70% effective rate of the proposed capital improvements. These volumes should be refined as more accurate data is available from the DMAs and the AMI network.

Planning Period (Year Ending)	Capital Improvement(s)	Reduction in UW %	Reduction in UW Volume (gallons)	Reduction in UW Cost (dollars)
0-3 Years (2023)	1. Replacement of Service Line Connections in the Marrowbone Area 2. Replacement of Water Main in the Burning Fork, Dorton Hill, and Cornette Road Area 3. Establish DMAs and install Zone Meters 4. Booster Pump Station Replacement and Rehabilitation and New Water Storage Tank 5. Water Treatment Plant Improvements, Instrumentation Purchase, Telemetry Improvements, and Property Acquisition 6. Purchase General Equipment 7. Skid Tank Rehabilitation and Purchase and Install Pressure Reducing Valves 8. Request Authority from the PSC to Assess a Loss Reduction Surcharge 9. Hire Dedicated Loss Reduction Staff and Purchase Additional Leak Detection Equipment 10. Secure Professional Services to Conduct a Condition Assessment of all Storage Facilities in the System 11. Secure Professional Services to Conduct a Condition Assessment of all Pump Stations in the System 12. Conduct an Audit of Telemetry Systems 13. Secure Professional Services to Develop a Hydraulic Model for Parallel Lines and the Rocky Road Area 14. Upgrade and Develop Institutional Controls 15. Install Pressure Recording Devices in the Burning Fork, Dorton Hill, and Cornette Road Areas 16. Hire Leak Detection Services 17. Rate Study/Rate Increase 18. Billing Software Audit 19. Continued Education and Training	14.06%	221,595,564 gallons	$311,586
4-6 Years (2026)	1. Replacement of Service Line Connections in the Pond Creek Area 2. Replacement of Water Main in the Yellow Hill, Blair Adkins, Greasy Creek, and Little Creek Areas 3. Booster Pump Station Replacement and Rehabilitation and New Water Storage Tank 4. Water Treatment Plant Improvements, Instrumentation Purchase, Telemetry Improvements, and Property Acquisition 5. Skid Tank Rehabilitation and Purchase and Install Pressure Reducing Valves 6. Hire Dedicated Loss Reduction Staff and Purchase Additional Leak Detection Equipment 7. Secure Professional Services to Develop a Hydraulic Model for Parallel Lines and the Robinson Creek and Marrowbone 460 Area 8. Rate Study/Rate Increase	5.79%	91,286,734 gallons	$128,358
7-15 Years (2035)	1. Replacement of Service Line Connections in the Shelby Valley Area 2. Replacement of Water Main in the Poorbottom to Graveyard, and Garden Village Areas 3. Booster Pump Station Replacement and Rehabilitation and New Water Storage Tank 4. Water Treatment Plant Improvements, Instrumentation Purchase, Telemetry Improvements, and Property Acquisition 5. Skid Tank Rehabilitation and Purchase and Install Pressure Reducing Valves 6. Secure Professional Services to Develop a Hydraulic Model for Additional Areas 7. Rate Study/Rate Increase 8. Replacement of Service Line Connections in the Grapevine Area and Additional Areas as Necessary 9. Replacement of Water Main in the Wolfpit and the Twin Bridges to Poorbottom Areas and Additional Areas as Necessary 10. Purchase General Equipment	8.31%	130,898,911 gallons	$184,057


PROJECTED CHANGE IN % UW
Percent UW
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
49.50%
35.44%
29.65%
26.45%
23.71%
21.34%
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
YEAR
% UW
Linear (% UW)


PROJECTED CHANGE IN VOLUME UW
UW Gallons
900,000,000
800,000,000
700,000,000
600,000,000
500,000,000
400,000,000
300,000,000
200,000,000
100,000,000
0
780,267,605
558,672,041
467,385,307
417,031,825
373,727,831
336,486,396
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
YEAR
Volume UW (gallons)
Linear (Volume UW (gallons))


PROJECTED CHANGE IN COST OF UW
$1,200,000
$1,000,000
$800,000
$600,000
$400,000
$200,000
$0
Cost of UW US Dollar
$1,097,118
$785,537
$657,181
$586,380
$525,491
$473,127
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
YEAR
COST OF UW
Linear (COST OF UW)

VI. SOURCES OF POTENTIAL PROJECT FUNDING

Some communities and organizations may use their own resources, borrow the money by issuing utility revenue bonds, or solicit loans from federal and state agencies. Revenue bonds, while a common source for financing these types of improvements, places a heavy burden on utility customers. There are a variety of potential state and federal sources of funding for capital improvement projects that enable communities to receive potential sources of funding and are summarized below. Additional information concerning available funding sources including eligibility requirements, amount of available grant/loan, match limitations, and application process details are included in Table 6.1.

APPALACHIAN REGIONAL COMMISSION (ARC)

The Appalachian Regional Commission (ARC), under the Office of the Governor and administratively attached to the Department of Local Government (DLG), awards grants and contracts from funds appropriated annually by Congress. Grants are awarded to state and local agencies, governmental entities, local governing boards, and nonprofit organizations. Contracts are awarded for research on topics that directly impact economic development in the Appalachian Region.

ARC's community infrastructure work focuses primarily on the provision of water and wastewater services to support business and community development projects, and to alleviate public and environmental health hazards. Many Appalachian communities lack basic public services and do not have the financial capacity to fund water and wastewater improvements. More than 25% of the Region's population is not served by a community water system and must rely on private well water for their drinking water needs. Nearly 50% of all Appalachian households rely on on-site wastewater disposal. ARC's residential infrastructure program targets the Region's most economically distressed communities and utility systems that are struggling to resolve public health and environmental emergencies.

ARC also supports infrastructure investments that promote economic and employment opportunities. Water is critical to attracting new development and supporting the expansion and economic health of the Region's existing business sector. ARC uses grant funds to leverage other public dollars and private-sector investment to attract commercial and industrial development.

KENTUCKY INFRASTRUCTURE AUTHORITY (KIA)

The Kentucky Infrastructure Authority (KIA), also under DLG, provides financial aid by way of grant and loan assistance to communities for water and wastewater needs. The KIA program focuses on improving infrastructure and helps foster community development.

COMMUNITY DEVELOPMENT BLOCK GRANT (CDBG)

The U.S. Housing and Urban Development's (HUD) Community Development Block Grant (CDBG) program is allocated annually in Kentucky by the Department for Local Government (DLG). The CDBG program focuses on improving economic opportunities, specifically in disadvantaged areas, but can also be used to meet community development needs.

RURAL DEVELOPMENT (RD)

USDA's Rural Utilities Service (RUS) works to provide rural communities with loans, grants, or combination loan/grant funds for needed water and wastewater infrastructure projects. The goal of these investments is to support rural communities in their efforts to compete in a global economy.

ABANDONED MINE LANDS (AML)

The Kentucky Division of Abandoned Mine Lands (AML) program allocates money annually for the completion of projects in Kentucky coal producing counties. The AML program is 100% funded by the Federal government through the collection of a fee on every ton of coal produced by mining operations nationwide.

For years, AML has focused on extending water lines into areas where drinking water has been contaminated as a result of past mining activities. Additionally, AML now administers the Economic Development Pilot Program. Kentucky AML, in consultation with state and local economic development authorities, has developed a list of eligible projects in Appalachian counties that demonstrate a nexus with AML cleanup and community development. This AML Pilot Program provides an opportunity for local communities to return impacted areas to productive use, thus promoting the economic development goals identified for the community and/or region.

ECONOMIC DEVELOPMENT ADMINISTRATION (EDA)

The U.S. Economic Development Administration's (EDA's) mission is to lead the Federal economic development agenda by promoting innovation and competitiveness, preparing American regions for economic growth, and promoting success in the worldwide economy. EDA fulfills this mission through strategic investments and partnerships that create the regional economic ecosystems required to foster globally competitive regions throughout the United States.

EDA's programs provide economically distressed communities and regions with comprehensive and flexible resources to address a wide variety of economic needs. Projects funded by these programs will support the creation and retention of jobs, provide workforce development opportunities, and promote growing ecosystems that attract direct investment. Through these programs, EDA supports bottom-up strategies that build on regional assets to spur economic growth and resiliency. EDA specifically strives to advance economic prosperity in distressed communities.

VII. SURCHARGES

A. Surcharges

A surcharge is an additional cost added to utility customers' bills and is also referred to by other terms such as a rider, adjustment clause and recovery mechanism. The imposition of these surcharges is a departure from the traditional utility rate setting process. The Kentucky Public Service Commission (PSC) evaluates utility requests for additional surcharges on a case-by-case basis to determine whether there is a proper balance of meeting utility needs and assuring customer protections. In the past, surcharges were often only approved by regulators in rare circumstances to address substantial, volatile, and uncontrollable costs that, if not addressed outside of a base rate case, could threaten to harm a utility's financial health.

Examples of such surcharges include fuel and purchased power adjustment mechanisms for electric utilities and gas cost recovery mechanisms for natural gas distribution utilities. In recent years, however, requests for other types of surcharges and tracking mechanisms by utilities have significantly increased and have been looked upon favorably by PSC when applied to a specific goal such as water loss. Recent examples of surcharges approved by the PSC for utility's wishing to utilize the money for water loss include the Estill County Water District and the Cannonsburg Water District.

A surcharge allows the utility to separately charge customers for costs that would have otherwise been part of the utility's standard base rates. This means the utility recovers dollar-for-dollar the level of costs incurred or estimated to be incurred. A surcharge appears as an additional charge on a ratepayer's bill, above and beyond the base rates. Some surcharges are a flat rate while others fluctuate, either based on usage or changes in the surcharge rate. Approved PSC surcharges for water loss have typically been a flat rate.

These surcharges are needed so the utility can make investments in aging infrastructure and comply with Public Service Regulations without compromising its financial health. The surcharges often result in smaller and less frequent rate increases as well as reduce the frequency of their general rate cases, which can be time consuming and costly to process. In the case of water loss, a reduction in the amount of loss incurred can significantly strengthen the utility's balance sheet and result in lower long-term rates to customers.

Typically, a utility will present the mechanics for its proposed surcharge to PSC for approval. Consumer advocates and intervenors may participate in the proceeding and make recommendations to adjust or modify the utility's proposal. The PSC will weigh the information and make its decision. The time for approval is typically three to six months.

MWD will require additional funds to perform the corrective actions recommended in this report. Present rates for service do not generate sufficient funds to meet current operating expenses and debt service. MWD should seek authority from the PSC to assess a surcharge whose proceeds would be used solely for water loss reduction efforts.

B. Potential Surcharge Amounts

Recent PSC approved surcharge amounts for water loss reduction have been between $3.50 and $4.00 per customer/month. Table 8.1 represents the amount of revenue that can be generated on a monthly and yearly basis based on various surcharge amounts.

Typically, these surcharge collections must be placed in a specific account and may only be used for the approved purposes such as water loss reduction. The district will be required to provide the Public Service Commission information concerning how money in this account is spent.

Potential Revenue Generation by Differing Surcharge Amounts			
Surcharge Amount	Number of Customers	Surcharge Revenue Generated / Month	Surcharge Revenue Generated / Year
$3.00	16,500	$49,500	$594,000
$3.25	16,500	$53,625	$643,500
$3.50	16,500	$57,750	$693,000
$3.75	16,500	$61,825	$742,500
$4.00	16,500	$66,000	$792,000

Based on a customer count of 16,500, a surcharge of $3.79 per customer/month would generate approximately $750,000 each year for use in water loss reduction.

VIII. CURRENT AND FUTURE REGULATORY CONSIDERATIONS

Design considerations encompass all aspects of the water treatment, including owner preference, capital cost items, operating cost items, operations complexity, and current, future, and anticipated regulatory requirements. This portion of the Capital Improvements Plan focuses on regulatory requirements and their effect on design. The reference for the current regulations is the 2018 Edition of the Drinking Water Standards and Health Advisories from EPA (DWSHA), Attachment J. As appropriate, regulatory requirements that have changed due to Kentucky Division of Water interpretation will also be discussed.

1. Regulatory Requirements

1.1 Microbiological Contaminants

1.1.1 Filter Backwash Recycling Rule (FBRR)- The FBRR required that if filter backwash water, thickener supernatant, and dewatering processes were recycled, they must be returned to a location upstream of any treatment. The FBRR as described in the Study is still applicable, with the Division of Water adding the constraint that the recycle water flow is limited to <10% of the instantaneous flow. Recycled water must meet the requirements of the utilities' KPDES permit, and monitoring is required.

1.1.2 Total Coliform Rule (TCR)/Revised TCR- The TCR relates to the presence of total coliforms in drinking water, setting a maximum contaminant level goal (MCLG) of zero and a maximum contaminant level (MCL) of not more than 5% of samples with coliforms. The Revised TCR went into effect April 2016. It changes the monitoring requirements for total coliform and E. Coli in the distribution system.

1.1.3 Surface Water Treatment Rule (SWTR)- The SWTR required filtration and disinfection to meet prescribed reductions for viruses (99.99% or 4 log reduction), giardia lamblia (99.9% or 3 log reduction), and Legionella. There have been no changes since the Study related to this rule. However, it should be noted that in the federal rule, meeting the turbidity limit at the filter effluent gives the treatment plant credit for a 2.5 log (99.7%) removal of giardia, while Kentucky only allows 2.0 log (99%) removal credit for the same water quality. This means that more disinfection contact time (CT) is required to meet the Kentucky standard, since a total of 3.0 log (99.9%) removal is required.

1.1.4 Interim Enhanced SWTR (IESWTR)- This rule strengthened filter turbidity limits to address problems with the protozoa cryptosporidium

1.1.5 Long Term 2 Enhanced SWTR (LT2ESWTR)- This rule required source water monitoring for cryptosporidium, with systems being placed in “bins”, depending on the number of cryptosporidium found.

1.2 Disinfectants/ Disinfection Byproducts (D/DBP)

1.2.1 Stage 1 Disinfectants & Disinfection By-Products Rule (S1DBPR)- This rule lowered the MCL for total trihalomethanes and added MCLs for five haloacetic acids (HAA5). It established maximum residual disinfection level (MRDL) limits for chlorine, chloramines, and chlorine dioxide. It also established a treatment technique for DBP precursor reduction by reducing the amount of total organic carbon (TOC).

1.2.2 Stage 2 Disinfectants & Disinfection By-Products Rule (Stage 2 DBPR)- This rule included testing to determine representative sample sites. It did not lower the TTHM and HAA5 MCLs, but did require that the levels be maintained at every sample site, rather than averaging all results together. Compliance is determined by a locational running annual average (LRAA).

1.3 Inorganic Chemicals- This list consists of 17 inorganic chemicals, ranging from antimony to thallium. The entire list with MCLs is found in the Appendix. Also considered as inorganic chemicals are the radionuclides, also found in the Appendix.

1.4 Organic Chemicals- This list consists of 32 synthetic organic chemicals (SOCs) and 21 volatile organic chemicals (VOCs), listed in the Appendix. Ten (10) organic chemicals have been added to the DWSHA list, nine (9) of which are actually covered under the S1DBPR.

1.5 Secondary Standards- There are 15 secondary standards, ranging from aluminum to zinc, listed in the Appendix. These are non-enforceable guidelines under the federal regulations. However, 401 KAR 8:600 allows the appropriate Kentucky authorities to direct the supplier to modify the treatment procedure or to locate a more suitable source of water if the limits are exceeded or there are customer complaints.

1.6 Future Regulations (Reviewed/Proposed Prior to WTP Completion)- EPA periodically produces a drinking water contaminant candidate list (CCL), which is a list of contaminants that may require regulation in the future. It will be an extended period before any of the chosen contaminants will be actually regulated. There are other regulations whose promulgation is expected to be proposed including the following: strontium, perchlorate, long-term lead and copper rule revisions, hexavalent chromium, nitrosamines, and chlorate. Of more immediate concern are regulations related to harmful algal blooms (HAB), which can lead to unsafe levels of cyanotoxins in the raw water. These have caused numerous shutdowns of water plants in the last several years. Although HAB is normally associated with reservoirs, streams such as the Kentucky River, which essentially consists of a series of long narrow reservoirs, can also be affected. Health advisories have been issued, and regulations are expected to follow in the future.

IX. CONTAMINANTS OF EMERGING CONCERN (CECS)

Contaminants of Emerging Concern (CECs) is a term used by water quality professionals to describe pollutants that have been detected in water bodies, that may cause ecological or human health impacts, and typically are not regulated under current environmental laws. Sources of these pollutants include agriculture, urban runoff, ordinary household products (such as soaps and disinfectants) and pharmaceuticals that are disposed to sewage treatment plants and subsequently discharged to surface waters.

Contaminants of Emerging Concern		
Compound	**Where it is Found**	**Health Risks**
Trichloropropane (TCP)	CPs are denser than water so they sink to the bottom aquifers and contaminate them	Considered a likely carcinogen
Dioxane	Often at industrial sites, and they move rapidly from soil to groundwater	Rapid disruption of lung, liver, kidney, spleen, colon, and muscle tissue, may be toxic to developing fetuses and is a potential carcinogen
Trinitrotuluene	Major contaminant of groundwater and soils	Listed as cancer-causing by Office of Environmental Health
Dinitroluene	Found in surface water, groundwater, and soil at hazardous waste sites	Considered a hepatocarcinogen and may cause ischemic heart disease, hepatobiliary cancer, and urothelial and renal cell cancers
Hexahydro-trinitrotriazane	Exists as particulate matter in the atmosphere, easily leaches into groundwater and aquifers from soil	Kidney and liver damage, possible carcinoma, insomnia, nausea, and tremor
Nanomaterials	Released as consumer waste or spillage, may be airborne, found in food, or in many diverse industrial processes	May translocate into the circulatory system, exposing the body to an accumulation of compounds in the liver, spleen, kidney, and brain
N-nitroso-dimethylamine	Highly mobile when released into soil and will likely leach into groundwater	Probable carcinogen, evidence of liver, kidney and lung damage
Perchlorate	Highly soluble in water so it can greatly accumulate in groundwater	Eye, skin, and respiratory irritation and in high volumes
Perfluoro-octane-sulfonate & Perfluorooctanic acid	During manufacturing, the compounds were released into the surrounding air, ground, and water, is resistant to typical environmental degradation processes	possible carcinogen, may cause high cholesterol, increased liver enzymes, and adverse reproductive and developmental effects
Polybrominated biphenyls	Detected in the air, sediments, surface water, fish and other marine animals	Classified as likely carcinogenic, neurotoxic, and thyroid, liver, and kidney toxicity
Polybrominated diphenyl ethers	Enter the environment through emissions and has been detected in surface water	Shown to be an endocrine disruptor as well as carcinogenic
Tunsten	Tungsten is water-soluble and may be found in dangerous quantities in water sources	May cause respiratory complications and investigated as a potential carcinogen

These contaminants mainly deal with contaminants that may be in the raw water because of wastewater discharges upstream. Each contaminant is summarized below. The EPA fact sheets for each is included in Attachment K. Each fact sheet provides a brief summary of the contaminant, including physical and chemical properties, environmental and health impacts, existing federal and state guidelines, and detection and treatment methods. These fact sheets are intended for project managers and field personnel to use when addressing specific contaminants at cleanup sites and are updated annually to include timely information.

Examples of emerging contaminants are 1,4-Dioxane, food additives, pharmaceuticals, and natural and synthetic hormones. CECs have the ability to enter the water cycle after being discharged as waste through the process of runoff making its way into rivers, directly through effluent discharge, or by the process of seepage and infiltration into the water table, eventually entering the public water system. Emerging contaminants are known to cause endocrine disrupting activity and other toxic mechanisms, and some are recognized as known carcinogens by the United States Environmental Protection Agency (EPA).

X. CONCLUSION AND RECOMMENDATIONS

In 2019, MWD's UW was 49.50%. UW has been steadily increasing over the past 10 years. If no action is taken, UW will exceed meter sales within the next 2-3 years. PSC Case No. 2020-00068 requires that MWD develop a comprehensive Capital Improvement Plan focused on reducing UW to 15%. The excessive UW is a function of a declining customer base, a nation-wide trend of reduced domestic consumption, loss from leaks, inaccurate meters, and other issues. MWD intends to implement capital improvements over a 15-year period. Efforts focus on installing zone meters, establishing DMAs, constructing an AMI network, replacing residential and commercial meters, improving operational efficiency, expanding loss reduction capabilities, developing institutional controls, and completing capital improvement projects.

It is recommended that MWD proceed initially with the capital improvements presented herein. Once zone meters are installed, DMAs are established, and the AMI network is put into operation, MWD should revise the Capital Improvements Plan. It is recommended that MWD track progress by maintaining records of completed tasks.

ATTACHMENT A

PSC ORDER FOR

CASE NO. 2014-00342

CASE NO. 2020-0068

COMMONWEALTH OF KENTUCKY

BEFORE THE PUBLIC SERVICE COMMISSION

In the Matter of:

APPLICATION OF MOUNTAIN WATER DISTRICT FOR AN ADJUSTMENT OF WATER AND SEWER RATES	)))	CASE NO. 2014-00342

ORDER

On October 9, 2015, the Commission issued a final Order in this matter that, *inter alia*, set new rates for Mountain Water District ("Mountain Water"), required Mountain Water to conduct a water loss study and to issue a request for proposals ("RFP").

The Commission's Order specifically required Mountain Water, within 90 days of the Order's date, to identify sources of excessive water loss, quantify the amount of water loss from each identified source, prioritize the identified water loss projects, establish a schedule for eliminating each source of water loss, and within 120 days of the date of the Order, to provide a detailed plan to fund each identified water loss project and specifically identify a credible funding source.

The Commission's Order further required Mountain Water to obtain the services of an outside independent consultant to prepare and issue an RFP to solicit bids from firms interested in providing managerial and operational services to Mountain Water. We ordered Mountain Water to analyze the bids received, identify the top response, and document the analysis within 180 days of the Order. We required Mountain Water to submit a written report that discusses the results of the RFP solicitation within 240 days of the October 9, 2015 Order.

On October 28, 2015, Mountain Water filed an application for rehearing pursuant to KRS 278.400. It requested rehearing of the October 9, 2015 Order on the two issues pertaining to the water loss plan as set forth in ordering paragraphs 6 and 7, as well as the obligation to issue a RFP as set forth in ordering paragraphs 8 and 9.

Regarding the water loss plan, Mountain Water first argues that it is not possible to complete the water loss study within the time allotted by the Order. Mountain Water contends that due to the length of water mains in service and the mountainous terrain, the physical effort to monitor, test, and identify leaks necessitates a longer period of time. Moreover, it states that the potential for cold weather, ice, and snow during the study period may further impede the process. Mountain Water proposes new time requirements for the water loss requirements set forth in the Commission's Order. Mountain Water's proposed new time requirements are as follows:

(a) Identify water loss sources – six months;

(b) Quantify the water loss – seven months;

(c) Prioritize the identified water loss projects – eight months;

(d) Establish a schedule for eliminating water loss sources – ten months; and

(e) Provide an estimated cost for each project – ten months.

Mountain Water further proposes to file the detailed water plan to fund each water loss project within 12 months.

Regarding the RFP requirement, Mountain Water seeks to modify or clarify the October 9, 2015 Order as to whether Mountain Water must issue the RFP and prepare the written report should it elect to operate with district employees rather than contracted employees. Mountain Water requests the deletion of the requirement to issue an RFP and submit a written report on the analysis of the RFP or, alternatively, clarification that the RFP is not required if the district's board adopts a resolution prior to January 1, 2016, to terminate the management contract and resume management of the operations of the district with employees of the district. Mountain Water takes the position that a decision to end contractual services will render an RFP unnecessary.

Mountain Water states that if it has not notified the Utility Management Group ("UMG") of the termination of the current agreement by January 2, 2016, the time line for issuing the required RFP and the required actions on this point should commence on January 2, 2016.

Based on a review of the application for rehearing and being otherwise sufficiently advised, the Commission finds that Mountain Water has presented good cause to modify the time line for completing each step of the water loss plan as originally ordered by the Commission. The October 9, 2015 Order required Mountain Water to complete five discrete steps within 90 days, and to provide a detailed plan to fund each identified water-loss project within 120 days. Given the unique circumstances that exist in Mountain Water's territory, including the length of water mains, the terrain, the severity of the water loss problem and the imminent winter weather, the Commission finds that Mountain Water's request for additional time is reasonable and should be granted. The Commission further finds that the time line proposed by Mountain Water within which to perform each of the steps set forth in ordering paragraphs 6 and 7[1] to the October 9, 2015 Order is reasonable and should be adopted.

Second, Mountain Water requests that the Commission modify its Order to either (1) remove the RFP requirement or (2) permit Mountain Water the option of cancelling its contract with UMG and to conduct its operations in-house—or if it chooses not to operate with its own employees, to then issue an RFP. Mountain Water further proposes that if it does not cancel the UMG contract by January 2, 2016, the RFP requirement would then be triggered. Mountain Water contends that removing the RFP requirement would save expenditures that would potentially be wasted if it did not decide to contract with another management group to run the utility's operations.

Having considered Mountain Water's arguments, the Commission finds that Mountain Water's request to modify the RFP requirement should be denied. As noted in the Commission's October 9, 2015 Order, in the last ten years Mountain Water has not issued an RFP or "attempt[ed] to conduct a benefit analysis to show that the outsourcing of its operations to UMG is beneficial to its ratepayers."[2] The RFP is necessary to assess the potential costs of operating the district, particularly in consideration of the passage of a decade since the contract was last bid. While Mountain Water contends that the RFP would be unnecessary should it choose to

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[1] Ordering paragraph 6 required, within 90 days, Mountain to:

a. Identify the sources of the excessive water loss;
b. Quantify the amount of water loss from each identified source;
c. Prioritize the identified water loss projects;
d. Establish a time schedule for eliminating each source of water loss; and
e. Provide an estimated cost for each identified project.

Ordering paragraph 7 required Mountain to provide a funding plan for each water loss project within 120 days.

[2] October 9, 2015 Order at 33.

perform its operations internally, the RFP would clearly still provide useful information for Mountain Water in assessing the most reasonable and cost-effective means for operating the district.

Moreover, Mountain Water has not presented any evidence or made any showing that conducting an RFP would be especially onerous in regards to costs or resources. Conversely, the Commission finds that the RFP will provide value by enabling Mountain Water and its ratepayers to learn whether the UMG's continued operation of the utility is in the ratepayers' best interest. It will further provide valuable information for Mountain Water to utilize in ultimately assessing the efficacy of conducting its operations with its own employees. A utility board fully informed as to the range of methods and costs of operating its district will best serve its ratepayers in the most transparent and cost-effective manner. Accordingly, the Commission affirms the requirement that Mountain Water conduct an RFP as directed by our October 5, 2015 Order.

IT IS THEREFORE ORDERED that:

1. Mountain Water's application for rehearing is granted in part and denied in part.

2. Mountain Water's request to amend ordering paragraphs 6 and 7 of the Commission's October 9, 2015 Order is granted.

3. Ordering paragraph 6 of the October 9, 2015 Order is modified as follows:

Mountain Water District shall:
(a) Within six months, identify water loss sources;
(b) Within seven months, quantify the water loss;
(c) Within eight months, prioritize the identified water loss projects;

(d) Within ten months establish a schedule for eliminating water loss sources; and

(e) Within ten months, provide an estimated cost for each project.

4. Ordering paragraph 7 of the October 9, 2015 Order is modified as follows:

Within 12 months of the date of the October 9, 2015 Order, Mountain Water District shall provide a detailed plan to fund each identified water loss project that specifically identifies credible funding sources.

5. Mountain Water's request to amend paragraphs 8 and 9 to the Commission's October 9, 2015 Order is denied.

By the Commission

ENTERED

NOV 17 2015

KENTUCKY PUBLIC SERVICE COMMISSION

ATTEST:

Aaron D. Greenwell for

Executive Director

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ATTACHMENT B

WRIS SYSTEM DATA AND INVENTORY REPORT(S)

WRIS System Data Report
KY0980575 - Mountain Water District

DOW Permit ID: **KY0980575**

Link: DOW SDWIS Report

DOW Permit Type: **DRINKING WATER (PWSID)**
DOW Permit Name: **Mountain Water Dist**
WRIS System Name: **Mountain Water District**

System Type: **Community** | Water Source Type: **Surface Water** | ADD WMC Contact: **Brandon Montgomery**
ADD ID: **BSADD** | Primary County: **Pike** | Dow Field Office: **Hazard**
Permit Dates: Issued: **12.01.1986** | Expired: | Inactivated:

OPERATIONS AND MANAGEMENT INFORMATION

Primary Facility Information:

✓ This is a treatment facility.
◯ This is a maintenance facility.

Facility Name: **Russell Fork Water Treatment Plant**
Facility Contact: **David Taylor**
Facility Phone: **606-754-4218**
Facility Addr 1: **43 Harless Creek Road**
Facility Addr 2:
City, State Zip: **Regina, KY 41559**

Date Last Modified: **05.30.2014**

System Management Entity Information:

Entity Name: **Mountain Water District (Water)**
Office Phone: **606-631-9162** Fax: **606-631-3087**
Office Address 1: **PO Box 3157**
Office Address 2:
City, State Zip: **Pikeville, KY 41502**

System Management Contact Information:

Contact Type	Contact Name	Title	EMail
1 Operations Contact:	David Taylor	Operations Manger	dtaylor@mtwater.org
2 Business Contact:	Carrie Hatfield	Financial Administrator	chatfield@mtwater.org
Manager:	Roy Sawyers	District ~~Administrator~~ Manager	rsawyers@mtwater.org

1 Person responsible for physical infrastructure operations.
2 Person responsible for billing and financial operations.

Date Last Modified: **04.20.2018**

OWNER ENTITY INFORMATION

Entity Type: **Water District (KRS 74)** | PSC Group ID: **25605**
Entity Name: **Mountain Water District**
Web URL: **www.mountainwaterdistrictky.com**
Office EMail: **rsawyers@mtwater.org**
Office Phone: **606-631-9162** | Toll Free: | Fax: **606-631-3087**

Mail Address Line 1: **PO Box 3157** | Phys Address Line 1:
Mail Address Line 2: | Phys Address Line 2:
Mail City, State Zip: **Pikeville, KY 41502** | Phys City, State Zip:

Contact: **Roy Sawyers** | Financial Contact: | Auth Official: **Michael Blackburn**
Contact Title: **District Administrator** | Financial Contact Title: | Auth Official Title: **Chair Person**
Contact EMail: **rsawyers@mtwater.org** | Financial Contact EMail: | Auth Official EMail: ~~mblackburn@alphanr.com~~ eky7952@gmail.com
Contact Phone: **606-631-9162** | Financial Contact Phone: | Auth Official Phone: **606-353-0928**

Data Source: **Kentucky Infrastructure Authority**

Date Last Modified: **05.03.2017**

System Respondent ____________ ADD WMP ____________ Date ____________

ATTACHMENT E

WRIS System Data Report
KY0980575 - Mountain Water District

DOW Permit ID: **KY0980575** — Link: DOW SDWIS Report

DOW Permit Type: **DRINKING WATER (PWSID)**

DOW Permit Name: **Mountain Water Dist**

WRIS System Name: **Mountain Water District**

System Type: **Community** — Water Source Type: **Surface Water** — ADD WMC Contact: **Brandon Montgomery**

ADD ID: **BSADD** — Primary County: **Pike** — Dow Field Office: **Hazard**

Permit Dates: Issued: **12.01.1986** — Expired: — Inactivated:

DEMOGRAPHIC INFORMATION

Counties Directly Served: **4**

	Population	Households
Directly Serviceable:	39,999	18,563
Indirectly Serviceable:	16,237	7,064
Total Serviceable:	56,236	25,627

Note: Population counts are based on KIA census block overlay with WRIS mapped features.

County Served	Connection Count	Serviceable Population	Serviceable Households	Med. HH Income	MHI MOE
Mingo, WV	27				
Letcher		8	5	$27,245	$6,065
Martin	130	2	1	$33,631	$9,607
Pike	16,701	39,988	18,557	$34,530	$8,188
Totals:	**16,701**	**39,998**	**18,563**	**$34,528**	**$8,188**

MHI Source: American Community Survey 2014-2018 5Yr Estimates (Table B19013). MHI MOE = Med HH Income Margin of Error.

FISCAL ATTRIBUTES

Date Established: **07.01.1986** — Employees: **60**

Does this system:
- (a) Produce Water? **Yes**
- (b) Have wholesale customers? **Yes**
- (c) Purchase water? **Yes**

If this is a municipal system, what is the cost per 4,000 gallons of finished water for customers:
- (a) inside your municipality:
- (b) outside your municipality:

If this is a non-municipal system, what is the customer cost per 4,000 gallons of finished water? **$39.71**

Date of Last Rate Adjustment: **10-10-2017**

Comments: ~~Pikeville rates are being negotiated and will change this year. (2020) $1.97 proposed~~ completed @ $1.97/1,000

Date Last Modified: **06.07.2020**

Providers that sell water to this system:

Seller DOW Permit ID	Seller Name	Water Type	Ann. Vol. (MG)	Cost Raw	Cost Fin	Interconnects Perm	Interconnects Seas	Interconnects Emer
KY0980350	City of Pikeville	F	732.853		$1.68	9	0	0
	Totals and Averages		**732.853**		**$1.68**	**9**	**0**	**0**
WV3303009	City of Williamson, WV		272,421		$1.83	2	0	0

Providers that purchase water from this system:

Purchaser DOW Permit ID	Purchaser Name	Water Type	Ann. Vol. (MG)	Cost Raw	Cost Fin	Interconnects Perm	Interconnects Seas	Interconnects Emer	Serviceable Population	Serviceable Households
KY0980120	Elkhorn City Water Department	F	49.524		$2.25	1	0	0	1,445	725
KY0670213	Jenkins Water System					0	0	1	2,612	1,244
KY0800273	Martin County Water District	F			$2.40	0	0	1	12,180	5,095
	Totals and Averages		**49.524**		**$2.33**	**1**	**0**	**2**	**16,237**	**7,064**
WV3303031	Mingo Co PSD		2.376			1	0	0		27

- MG = Million Gallons
- Water Types: R = Raw Water, F = Finished Water, B = Both Raw and Finished Water
- Cost Categories: Raw = Raw Untreated Water, Fin = Finished Treated Water
- Raw and Finished costs are per 1,000 gallons.
- Interconnect Types: Perm = Permanent, Seas = Seasonal, Emer = Emergency

WRIS System Data Report
KY0980575 - Mountain Water District

DOW Permit ID: **KY0980575**

Link: DOW SDWIS Report

DOW Permit Type: **DRINKING WATER (PWSID)**

DOW Permit Name: **Mountain Water Dist**

WRIS System Name: **Mountain Water District**

System Type: **Community** | Water Source Type: **Surface Water** | ADD WMC Contact: **Brandon Montgomery**

ADD ID: **BSADD** | Primary County: **Pike** | Dow Field Office: **Hazard**

Permit Dates: Issued: **12.01.1986** | Expired: | Inactivated:

SYSTEM PLANNING

Water Treatment Plants:

Facility Name	Design Capacity (MGD)	Ave. Daily Prod. (MGD)	High. Daily Prod. (MGD)
RUSSELL FORK WTP	3.000	2.250	2.400
Totals	**3.000**	**2.250**	**2.400**

Operational Statistics:

	WRIS	SDWIS MOR	
Total Annual Vol. Produced (MG):	844.514	869.276	
Total Annual Vol. Purchased (MG):	732.853	7,456.193	745.619
Total Annual Vol. Provided (MG):	1,577.367	8,325.469	?832.546
Estimated Annual Water Loss:	42%	~~89%~~	

Wrong- ck SDWIS - not converted #'s!

			WRIS	SDWIS MOR
Wholesale Customers:	4	Wholesale Usage (MG):	49.524	55.405
Residential Customers:	15,519	Residential Usage (MG):	627.576	
Commercial Customers:	789	Commercial Usage (MG):	64.428	
Institutional Customers:		Institutional Usage (MG):		
Industrial Customers:	2	Industrial Usage (MG):	0.074	
Other Customers:		Other Cust. Usage (MG):	39.163	
Total Customers:	16,314			
		Flushing, Maintenance and Fire Protection Usage (MG):	140.630	
		Total Annual Water Usage (MG):	921.395	927.276

Water supply inadequacies during normal operating conditions:

Not provided.

Water supply inadequacies during drought operating conditions:

Not provided.

Comments: **None.**

Date Last Modified: **06.07.2020**

WMP Site Visit - Survey Information:

Site Visit / Survey Date: **03.12.2020**

Survey Administrator: **Brandon Montgomery**

Principal Respondent: **Roy Sawyer** S

Other Respondent(s):

Comments: **Jamie Pinson also updated GIS.**

Date Last Modified: **03.12.2020**

DOW Permit ID: **KY0980575** — **Link: DOW SDWIS Report**

DOW Permit Type: **DRINKING WATER (PWSID)**

DOW Permit Name: **Mountain Water Dist**

WRIS System Name: **Mountain Water District**

System Type: **Community** — Water Source Type: **Surface Water** — ADD WMC Contact: **Brandon Montgomery**

ADD ID: **BSADD** — Primary County: **Pike** — Dow Field Office: **Hazard**

Permit Dates: Issued: **12.01.1986** — Expired: — Inactivated:

SYSTEM MAINTENANCE

- ✓ The management of this system participates in an Area Water Management Planning Council (AWMPC).
- ✓ The management of this system participates in regular training activities.
- ✓ System operator(s) participate in regular training activities.
- ○ This system has an asset management plan.

  Date asset management plan last updated:
- ✓ This system as a capital improvement plan.

  Date capital improvement plan last updated: **12/01/2019**
- ○ This system has GIS capabilities.

  Date GIS data last submitted to the WRIS:

This system has a policy manual in place containing the following items:

- ✓ Personnel Policies
- ✓ Line Maintenance Program
- ✓ Routine Pressure Checks
- ✓ Emergency Operation Procedures
- ✓ A Water Shortage Plan
- ✓ Standard Operating Procedures
- ✓ Meter Testing Program
- ✓ Pump Station Maintenance Schedule
- ✓ Backup Sources
- ✓ A Water Conservation Plan

Date of last DOW Sanitary Survey: Month: **10**, Year: **2019**

- ○ This system has periodic service outages.

  Cause(s):
- ✓ This system has periodic pump failures.

  Cause(s): **Mechanical/Electrical**
- ✓ This system has periodic line breaks.

  The following components are associated with periodic line breaks:

  Typical line size: **6.00**

  Typical line location(s): **Marrowbone**

  Typical cause(s): **Substandard material/Aging infrastructure**

  Other cause(s):

  Est. Water Loss Percentage: **25.0 %**
- ✓ This system has localized problems.

  The following components are associated with localized problems:

  Problem location(s): **Marrowbone**

  Problem diameter(s): **6.00**

  Problem pressure(s); **120**

  Problem cause(s): **Class 160 pipe**

  Other problem characteristics:
- ✓ This system has as-built plans (record drawings).

  Est. degree of accuracy for as-built plans (%): **85%**
- ○ This system uses an on-staff inspector(s) for construction projects.

Maintenance notes for this system:

Date Last Modified: **03.12.2020**

DOW Permit ID: **KY0980575**

Link: DOW SDWIS Report

DOW Permit Type: **DRINKING WATER (PWSID)**

DOW Permit Name: **Mountain Water Dist**

WRIS System Name: **Mountain Water District**

System Type: **Community** | Water Source Type: **Surface Water** | ADD WMC Contact: **Brandon Montgomery**

ADD ID: **BSADD** | Primary County: **Pike** | Dow Field Office: **Hazard**

Permit Dates: Issued: **12.01.1986** | Expired: | Inactivated:

The following projects are associated with this system (included constructed projects):

PNUM	Applicant	Project Status	Funding Status	Schedule	Project Title	Agreed Order	Profile Modified	GIS Modified
WX21195017	Mountain Water District	Constructed	Partially Funded	0-2 Years	MWD-System Wide Tank Rehabilitation	N	05.03.2017	12.11.2013
WX21195018	Mountain Water District	Constructed	Fully Funded	0-2 Years	Johns Creek Rail Road and Deskins/Kimper Pump Station Relocation Project	N	03.12.2020	12.08.2015
WX21195021	Mountain Water District	Approved	Not Funded	0-2 Years	Greasy Creek Booster Pump Station	N	02.23.2015	04.05.2017
WX21195023	Mountain Water District	Constructed	Partially Funded	0-2 Years	MWD - Ridgeline Road Section 3 Upper Pompey	N	10.18.2018	02.04.2014
WX21195025	Mountain Water District	Constructed	Fully Funded	0-2 Years	2nd Magisterial District Water Line Extensions	N	06.08.2018	03.03.2014
WX21195027	Mountain Water District	Approved	Not Funded	0-2 Years	Water Loss Prevention Program Phase I – Contract #1	N	01.11.2019	04.05.2017
WX21195028	Mountain Water District	Approved	Not Funded	0-2 Years	Water Loss Prevention Program Phase I – Contract #2	N	03.02.2018	04.05.2017
WX21195029	Mountain Water District	Under Construction	Not Funded	0-2 Years	Radio Read Meter Replacement Project	N	03.12.2020	04.05.2017
WX21195031	Mountain Water District	Approved	Not Funded	0-2 Years	Phelps Pump Stations Relocation Project	N	02.08.2016	12.22.2015
WX21195037	City of Pikeville	Approved	Not Funded	0-2 Years	Pikeville Water Plant Filter Subsurface Wash System Improvements	Y	02.07.2018	
WX21195042	Pike County Fiscal Court	Approved	Not Funded	0-2 Years	Wolfpit Industrial Park Water Infrastructure	N	03.23.2020	02.27.2020
WX21195632	Mountain Water District	Constructed	Not Funded	11-20 Years	MWD-Dorton/Caney Area Waterline Extensions	N	03.20.2014	09.20.2010
WX21195638	Mountain Water District	Constructed	Over Funded	11-20 Years	MWD - Ridgeline Road Water Supply Project Section 2 Jonican	N	12.01.2014	12.04.2012
WX21195662	Mountain Water District	Constructed	Not Funded	11-20 Years	Mountain Water - Rockhouse (Dorton) Line Extension	N	03.20.2014	09.16.2010
WX21195672	Mountain Water District	Approved	Not Funded	11-20 Years	MWD - Lower Johns Creek Phase III	N	03.20.2014	09.16.2010
WX21195690	Mountain Water District	Constructed	Not Funded	6-10 Years	MWD-Hurricane Connector Project	N	03.20.2014	09.16.2010
WX21195699	Mountain Water District	Constructed	Partially Funded	0-2 Years	MWD-Lmi Service Connections	N	03.20.2014	
WX21195734	Mountain Water District	Constructed	Fully Funded	3-5 Years	MWD - Water Treatment Plant Intake Upgrades	N	03.20.2014	12.11.2013
WX21195735	Mountain Water District	Constructed	Not Funded	11-20 Years	MWD - Lmi Program	N	03.20.2014	09.20.2010
WX21195736	Mountain Water District	Constructed	Fully Funded	Constructed	MWD - Telemetry	N	03.12.2020	
WX21195738	Mountain Water District	Approved	Not Funded	6-10 Years	MWD - Scott Fork Phase 1	N	03.02.2018	12.11.2013

ATTACHMENT C
EXISTING SYSTEM MAP

BOOSTER PUMP STATIONS

BPS NO.	NAME	AREA	PUMP RATE	SUCTION PRESSURE		DISCHARGE PRESSURE		ELEVATION	CONST. DATE
				Static	Dynamic	Static	Dynamic		
03RC	GRASSY FORK #1	GV	25 GPM	70	60	195	175	885	1990
05JC*	CABIN KNOLL	GV	700 GPM	90	35	225	235	870	1988
07JC*	JOHNS CREEK RAILROAD	GV	500 GPM	115	80	120	160	732	1987
08JC*	DESKINS (KIMPER)	GV	350 GPM	80	60	175	190	834	1987
09JC	ELKHORN MOUNTAIN (INACTIVE)	GV	280 GPM	70	62	215	220	1056	1988
10GV	GRAPEVINE SCHOOL (INACTIVE)	GV	200 GPM	70	70	280	125	963	1988
11GV	UPPER CAMP BRANCH (INACTIVE)	GV	200 GPM	42	33	180	190	1176	1988
13JC	STRATTON FORK	BC	28 GPM	80	85	125	125	1065	1988
14JC	MEATHOUSE	BC	28 GPM	65	90	175	125	1059	1988
15JC*	COBURN MOUNTAIN #1 (JERRY BTM)	BC	350 GPM	110	90	121	128	1007	1989
17BC*	LONG FORK OF BIG CREEK	BC	100 GPM	65	60	194	190	792	1989
18PC	ROGERS PARK	BC	25 GPM	50	42	165	180	785	1985
19PC	KY 292 (WILSON LOOP)	PC	180 GPM	62	30	62	72	667	2000
22PC	FOREST HILLS	PC	50 GPM	25	20	190	198	914	1985
23PC*	US 119 - TOLER	PC	400 GPM	55	50	90	90	687	1993
24PC*	SHARONDALE (STONE)	PC	300 GPM	48	42	130	140	720	1985-1993
25PC	RUNYON SCHOOL	PC	100 GPM	64	58	150	155	900	1985
26PC*	HARDY	PC	180 GPM	80	40	175	190	680	1988
27PC*	TURKEY TOE	PC	168 GPM	70	50	140	140	988	1988
28BB*	DIALS BRANCH	PC	120 GPM	88	72	180	182	1088	1988
30BB	LFT FK OF BLACKBERRY (OLD HOUSE)	PC	35 GPM	146	141	150	153	1008	1988
31BB	SMITH FORK OF BLACKBERRY	PC	42 GPM	128	120	219	221	744	1988
32BB	PETER FORK	PC	36 GPM	30	26	120	120	962	1988
33BC	PINSON FORK OF ROCKHOUSE	BC	10 GPM	88	85	185	188	857	1990
35CC	KENDRICK FORK	MC	25 GPM	65	60	185	188	877	1987
36CC*	IVY FORK	MC	100 GPM	70	56	170	175	825	1987
38MC	POOR BOTTOM	MC	25 GPM	50	40	192	198	1172	2008
39MC	TWIN BRIDGES (INACTIVE)	MC	75 GPM	38	33	126	130	940	1981
40MC	GRAVEYARD HOLLOW	MC	50 GPM	66	51	105	109	1078	1981
41SV*	FORDS BRANCH (INDIAN HILLS)	MC	500 GPM	100	95	130	170	715	1996
42SV*	SOOKEYS CREEK BPS OR S.V.	SV	290 GPM	80	50	160	178	681	1991
43RC	GRASSY FORK #2	GV	25 GPM	105	102	190	184	1010	1990
44IC*	ISLAND CREEK	SV	400 GPM	75	245	65	248	752	1991
45SV*	CANEY CREEK	SV	250 GPM	58	50	230	233	960	1991
46DC	DORTON HILL	SV	20 GPM	28	26	143	145	1169	1991
47GC*	GREASY CREEK	MC	100 GPM	68	10	185	190	832	1992
48BC	BUCKLEY CREEK	GV	100 GPM	38	35	60	58	1098	1991
49GC	UPPER GREASY CREEK	MC	32 GPM	70	68	170	190	1077	1992
50GC	GILLESPI BRANCH	MC	29 GPM	40	35	126	130	788	1992
52JC*	PHELPS #1	GV	250 GPM	90	76	190	185	969	1993
53JC*	PHELPS #2	GV	250 GPM	60	58	190	210	1283	1993
54JC	LONG FORK OF KIMPER	GV	26 GPM	20	27	140	150	1304	1993
56CP*	COWPEN CREEK (COWPEN #1)	GV	200 GPM	80	37	160	170	692	1993
57CP*	ADKINS BRANCH (COWPEN #2)	GV	100 GPM	52	37	250	260	949	1993
58PC	NARROWS BRANCH	PC	35 GPM	35	24	130	135	712	1992
59PC	MUDLICK BRANCH	PC	30 GPM	64	50	110	115	1070	1992
60PC	PINSON FORK OF POND CREEK	PC	26 GPM	60	54	270	275	901	1992
61PC	COBURN MOUNTAIN #2 (WEST RD)	BC	200 GPM	135	125	245	260	737	1993
62PC	SCANT BRANCH (PECCO HOLLOW)	PC	30 GPM	43	45	140	135	758	1992
63PC	RUNYONS BRANCH	PC	22 GPM	30	25	150	155	1098	1992
64GV	SCOTT FORK (AQUAVAR)	GV	VD 1-15GPM	115	102	80	102	667	2009
65MC	ALLEGHANY	MC	23 GPM	40	36	150	154	1239	1993
66PC	BELFRY HILL	PC	32 GPM	62	56	108	108	750	1993
67SV*	INDIAN CREEK	SV	250 GPM	60	46	235	240	742	1993
68MC	PEYTON CREEK	MC	34 GPM	40	35	128	130	704	1993
69SV	LONG FORK OF ROBINSONSON CREEK	SV	100 GPM	52	40	230	230	968	1994
70LP	SLONES BRANCH	MC	25 GPM	25	20	155	160	625	1992
71PF	SMITH FORK OF PHELPS	GV	70 GPM	145	138	235	240	1150	1995
72HC	HURRICANE CREEK (INACTIVE)	SV	100 GPM	100	90	240	248	660	1995
73SV	ELKHORN CREEK	SV	300 GPM	75	46	210	219	1070	1995
74PC	SHARRON HEIGHTS	PC	10 GPM	38	38	165	165	680	1995
76JC	LAYNE BRANCH (AQUAVAR)	GV	10 GPM	40	45	133	130	781	1994
77PC	CANEY FORK OF ROGERS PARK (AQUAVA	PC	12 GPM	118	115	170	175	780	1995
78SV	PIGEON BRANCH (PNEUMATIC BPS)	SV	15 GPM	38	38	90	90	1470	1996
79HC	SPRING BRANCH	GV	25 GPM	40	38	120	128	686	1996
80MC	POWELL CREEK	MB	30 GPM	54	50	235	240	850	1998
81PF*	WIDOWS BRANCH	GV	150 GPM	100	80	290	300	960	1998
82PF*	BARRENSHEE HOLLOW	GV	70 GPM	55	46	255	258	889	1998
83IC	EDGEWOOD LANE (INACTIVE)	MC	10 GPM	30	25	95	120	*****	1998
84SV	LIZZIE FORK	SV	25 GPM	59	56	205	219	920	1999
85SV	LITTLE ROBINSON CREEK	SV	25 GPM	50	36	170	190	1000	1999
86EC	MILLS BRANCH	SV	25 GPM	66	54	188	191	1280	2000
87PF	BEECH CREEK	GV	25 GPM	50	45	190	200	980	2000
88MC	BIGGS BRANCH	MC	25 GPM	102	97	240	245	760	2000
89GV	PRITCHARD FORK	GV	25 GPM	60	65	190	185	1080	2000
90PC	BALL FORK	PC	25 GPM	74	70	190	200	833	2000
91PF	BONES BRANCH	GV	25 GPM	65	55	155	160	853	2000
92MC	BRUSHY FORK OF HELLIER	MC	35 GPM	60	58	295	280	1340	2001
93MC	CONTRARY HOLLOW	SV	20 GPM	70	67	165	170	1240	2001
94MC	SARAH BRANAHAM HOLLOW	SV	20 GPM	105	100	125	135	1200	2001
95PC	STRAIGHT HOLLOW	PC	25 GPM	70	65	170	175	1120	2001
96GV	TRACE FORK (PNEUMATIC BPS)	GV	10 GPM	28	20	100	125	1068	2000
96PF	UPPER PETER CREEK	GV	25 GPM	62	55	148	165	1000	2002
97MC	ROCKHOUSE, MARROWBONE	MC	118 GPM	55	50	290	298	830	2002
98BC	BRUSHY CREEK	BC	140 GPM	100	95	270	280	1080	2002
99PF	HURRICANE FORK OF KNOX CREEK	GV	25 GPM	55	40	125	130	1010	2002
100MC	WOLFPIT HOLLOW	MC	25 GPM	60	50	240	260	885	2002
101SV	KELLY MOUNTAIN ROAD	SV	30 GPM	35	30	187	195	1300	2002
102SV	SUGAR CAMP BRANCH	SV	25 GPM	38	36	158	160	1080	2002
103MC	BOWLING FORK ROAD	MC	40 GPM	64	48	157	160	970	2002
104PF	CAMP CREEK	PC	35 GPM	50	40	185	170	1105	2003
105FC*	HUNTS BRANCH	GV	300 GPM	25	38	225	170	1130	2003
106FC*	ANDERSON BRANCH	GV	300 GPM	70	64	260	275	940	2003
107MC	SUTTON	BC	500 GPM	130	40	172	172	713	2004
110FC*	FERRELLS CREEK	FC	500 GPM	81	51	220	245	1010	2002
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

SOLENOID VALVE STATIONS

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

WATER STORAGE TANKS

TANK NO.	NAME	GPP	CAPACITY	HEIGHT	OVERFLOW ELEVATION	CONSTRUCTION DATE
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
112FC	MOTLEY FORK	2000	20,000	10 FT	1545	2004
113SV	BEEFHIDE	3000	30,000	10 FT	1380	2005
114SV	BOOKER FORK	2000	20000	10 FT	1470	2005
115SV	ELSWICK FORK LICK BRANCH	2000	20000	10 FT	1290	2004
116SV	LITTLE CREEK	2000	20000	10 FT	1415	2006
117SV	LITTLE FORK	2000	20000	10 FT	1335	2005
118PC	STRINGTOWN BURNWELL	2500	25000	10 FT	980	2006
119GV	JOES CREEK	2000	20000	10 FT	1255	2006
120GV	DRY BRANCH JOHNS CREEK	2000	20000	10 FT	1202	2006
121SV	ELSWICK FORK JONANCY	2000	20000	10 FT	1230	2006
122MB	JIMMIES CREEK	630	5000	8 FT	1240	2007
123GV	RIVER HURRICANE	2000	20000	10 FT	1796	2011
124GV	UPPER POMPEY	2000	20000	10 FT	1710	2017
		TOTAL	8,592,000			

PRESSURE REDUCING STATIONS

PRV NO.	LOCATION	INLET PRESSURE	2ND REG	DISCHARGE PRESSURE	CONST. DATE
R-01JC	BURNING FORK	225	110	70	1987
R-02CV	GRAPEVINE #1	160	90	90	1987
R-03CV	GRAPEVINE #2	160	100	90	1987
R-04PT	PHELPS #1	180		45	1993
R-05PT	PHELPS #2	190		95	1993
R-06BC	BENT MOUNTAIN	BY PASSED			1990
R-07BC	SIDNEY	235		160	1990
R-08BC	ROCKHOUSE OF BIG CREEK	155		98	1990
R-09SV	BURGGETT BRANCH	125		70	1990
R-10BB	BLACKBERRY #1	135		50	1989
R-11BB	BLACKBERRY #2	150		110	1989
R-12SV	SOOKEY CREEK	BY PASSED			1991
R-13DC	DORTON	181		76	1991
R-14EC	EKHORN CREEK - JACKSON BRANCH	215		90	1997
R-15MC	HARRIS BOTTOM	144		118	1980
R-16MC	SUTTON BOTTOM	80		70	1980
R-17PT	WIDOWS BRANCH-TURKEY CREEK(SAME AS TURKE	165		120	1998
R-18PT	TURKEY CREEK - MAJESTIC (SAME AS WIDOWS BI	"		"	1998
R-19PT	MAJESTIC	192		85	1998
R-20PT	BOARD TREE	170		90	1998
R-21CC	CHLOE	190		130	1988
R-22SV	ROBINSON CREEK SCHOOL	NO GAUGE		GOOD SHAPE	1981
R-23OC	DOUGLAS PARK	NO GAUGE		GOOD SHAPE	1992
R-24MC	MILLARD	185		140	1996
R-25MC	MARROWBONE WTP	OUT OF	SERVICE		1975
R-26SV	DRY FORK OF SHELBY	175		60	1999
R-27MC	GREASY CREEK	OUT OF	SERVICE		1999
R-28CC	RACCOON CREEK				2000
R-29BR	BRUSHY CREEK #1	240		135	2002
R-30BR	BRUSHY CREEK #2	198		70	2002
R-31HC	CEDAR GAP	BY PASSED			2005
R-32 MC	ROCKHOUSE OF MARROWBONE	275	240	160	2006
R-33MC	YELLOW HILL	210		122	2006
R-34EC	JACKSON BRANCH	218		51	1995
R-35MC	LICK CREEK	255	105	80	2003
R-36MC	FEDS CREEK	NA	200	175	2004
R-37GV	KIMPER MTN.	OUT OF	SERVICE		
R-38MC	LOWER POMPEY	150		80	2003
R-39SV	SUGAR CAMP	140		140	2003
R-40PC	LYNN TROUGH	255		60	1998
R-41MC	MARROBONE BRIDGE (THREE-WAY)	185		135	2008
R-42MC	WATER PLANT	238		180	2007
R-43GV	HURRICANE CREEK	OUT OF	SERVICE		
R-44PC	TURKEY CREEK - AT OLD SCHOOL	NO GAUGE		115	1989
R-45GV	JOHNS CREEK (AT EXCEL MINING)	120		85	2006
R-46GV	HURRICANE OF RIDGELINE	240		50	2011
R-47GV	JONICAN	225		60	2013
R-48GV	RIDGELINE ROAD	190		40	2017
R-49GV	UPPER POMPEY	210		40	2017
R-50GV	LYNN LANE	295		150	2017

LEGEND

EXISTING WATER LINES

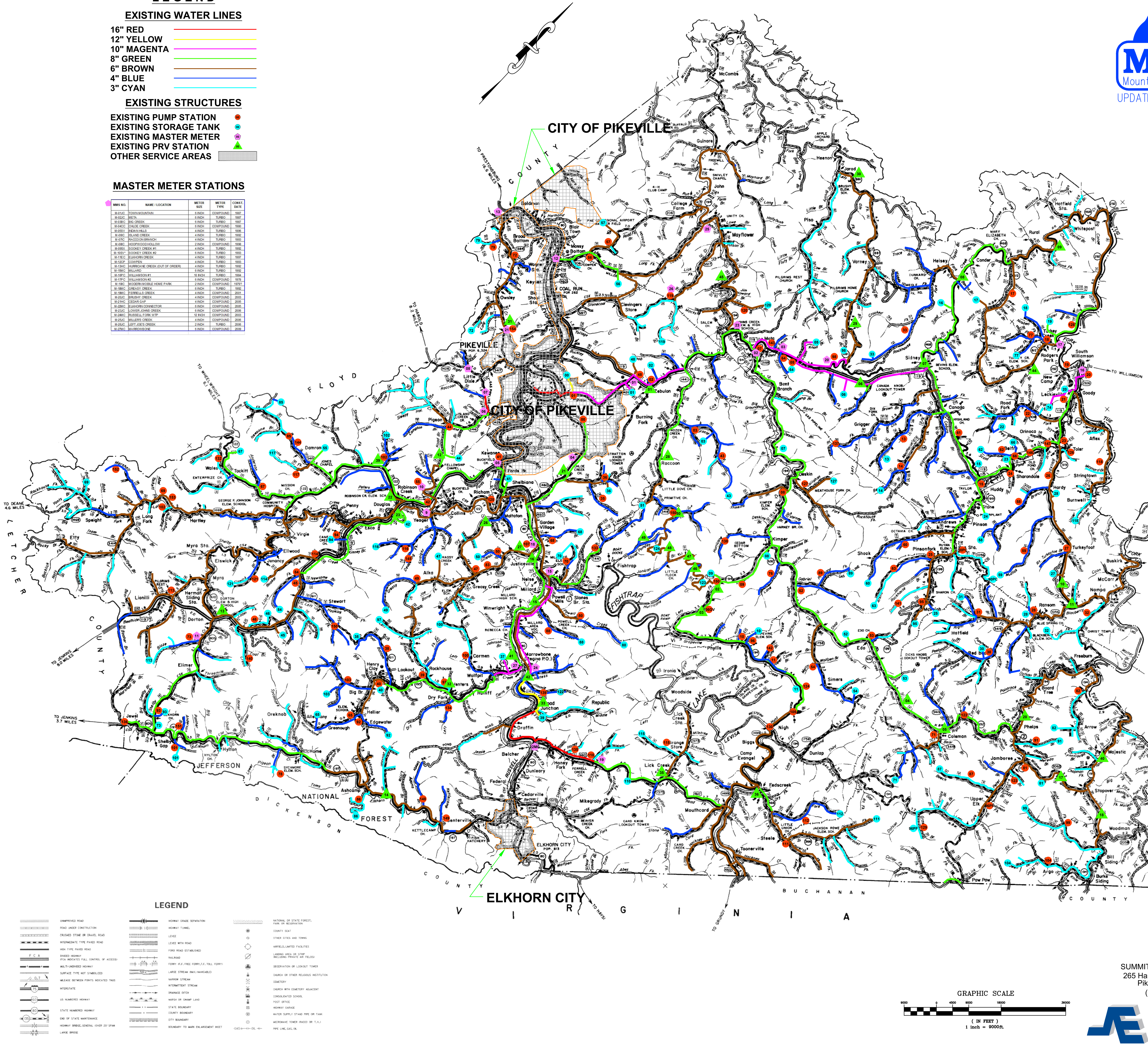
- 16" RED
- 12" YELLOW
- 10" MAGENTA
- 8" GREEN
- 6" BROWN
- 4" BLUE
- 3" CYAN

EXISTING STRUCTURES

- EXISTING PUMP STATION
- EXISTING STORAGE TANK
- EXISTING MASTER METER
- EXISTING PRV STATION
- OTHER SERVICE AREAS

MASTER METER STATIONS

MMS NO.	NAME / LOCATION	METER SIZE	METER TYPE	CONST. DATE
M-01JC	TOWN MOUNTAIN	6 INCH	COMPOUND	1987
M-02JC	META	6 INCH	TURBO	1987
M-03BC	BIG CREEK	6 INCH	TURBO	1987
M-04CC	CHLOE CREEK	6 INCH	COMPOUND	1980
M-05SV	INDIAN HILLS	4 INCH	TURBO	1996
M-06IC	ISLAND CREEK	4 INCH	TURBO	1992
M-07IC	RACCOON BRANCH	4 INCH	TURBO	1993
M-08IC	HOOPWOOD HOLLOW	2 INCH	COMPOUND	1998
M-09SX	SOOKEY CREEK #1	4 INCH	TURBO	1992
M-10SV*	SOOKEY CREEK #2	6 INCH	TURBO	1993
M-11EC	ELKHORN CREEK	4 INCH	TURBO	1997
M-12CP	COWPEN	4 INCH	TURBO	1993
M-13HC	HURRICANE CREEK (OUT OF ORDER)	4 INCH	TURBO	1992
M-15MC	MILLARD	6 INCH	TURBO	1992
M-16PC	WILLIAMSON #1	10 INCH	TURBO	1984
M-17PC	WILLIAMSON #2	6 INCH	COMPOUND	1978
M-18IC	MODERN MOBILE HOME PARK	2 INCH	COMPOUND	1979?
M-18MC	GREASY CREEK	6 INCH	TURBO	1992
M-19MC	FERRELLS CREEK	4 INCH	COMPOUND	2001
M-20JC	BRUSHY CREEK	4 INCH	COMPOUND	2003
M-21HC	CEDAR GAP	4 INCH	COMPOUND	2005
M-22MC	ELKHORN CONNECTOR	6 INCH	COMPOUND	2005
M-23JC	LOWER JOHNS CREEK	6 INCH	COMPOUND	2006
M-24MC	RUSSELL FORK WTP	12 INCH	COMPOUND	2003
M-25JC	MILLER'S CREEK	4 INCH	COMPOUND	2006
M-26JC	LEFT JOE'S CREEK	2 INCH	TURBO	2006
M-27MC	MARROWBONE	6 INCH	COMPOUND	2009



MWD
Mountain Water District
UPDATED OCTOBER, 2019

SUMMIT ENGINEERING, INC.
265 Hambley Blvd., Ste. 100
Pikeville, Ky. 41501
(606) 432-1447

SUMMIT ENGINEERING INC.

ATTACHMENT D

CURRENT RATE TARIFF

APPENDIX B

APPENDIX TO AN ORDER OF THE KENTUCKY PUBLIC SERVICE COMMISSION IN CASE NO. 2020-00068 DATED APR 02 2020

The following rates and charges are prescribed for the customers in the area served by Mountain Water District. All other rates and charges not specifically mentioned herein shall remain the same as those in effect under the authority of the Commission prior to the effective date of this Order.

Monthly Water Rates

5/8-Inch Meter

First	2,000	Gallons	$23.93	Minimum Bill
Next	8,000	Gallons	8.47	per 1,000 Gallons
Over	10,000	Gallons	7.54	per 1,000 Gallons

1-Inch Meter

First	5,000	Gallons	$49.34	Minimum Bill
Next	5,000	Gallons	8.47	per 1,000 Gallons
Over	10,000	Gallons	7.54	per 1,000 Gallons

2-Inch Meter

First	20,000	Gallons	$167.09	Minimum Bill
Next	20,000	Gallons	7.54	per 1,000 Gallons

3-Inch Meter

First	30,000	Gallons	$242.49	Minimum Bill
Next	30,000	Gallons	7.54	per 1,000 Gallons

4-Inch Meter

First	50,000	Gallons	$393.29	Minimum Bill
Next	50,000	Gallons	7.54	per 1,000 Gallons

6-Inch Meter

First	100,000	Gallons	$770.29	Minimum Bill
Over	100,000	Gallons	7.54	per 1,000 Gallons

Martin County Water DIstrict	3.09	per 1,000 Gallons
Mingo County Public Service District	4.66	per 1,000 Gallons

Jenkins Utilities

First 50,000 Gallons per day	$3.09	per 1,000 Gallons
Over 50,000 Gallons per day	3.50	per 1,000 Gallons

City of Elkhorn

First 215,000 Gallons per day	$2.91	per 1,000 Gallons
Over 215,000 Gallons per day	3.09	per 1,000 Gallons

ATTACHMENT E

U.S. CENSUS QUICK FACTS FOR PIKE COUNTY

QuickFacts
Pike County, Kentucky

QuickFacts provides statistics for all states and counties, and for cities and towns with a ***population of 5,000 or more***.

Table

All Topics	Pike County, Kentucky
Population estimates, July 1, 2019, (V2019)	**57,876**
PEOPLE	
Population	
Population estimates, July 1, 2019, (V2019)	**57,876**
Population estimates base, April 1, 2010, (V2019)	65,029
Population, percent change - April 1, 2010 (estimates base) to July 1, 2019, (V2019)	-11.0%
Population, Census, April 1, 2010	65,024
Age and Sex	
Persons under 5 years, percent	5.3%
Persons under 18 years, percent	20.7%
Persons 65 years and over, percent	19.4%
Female persons, percent	51.2%
Race and Hispanic Origin	
White alone, percent	97.7%
Black or African American alone, percent (a)	0.8%
American Indian and Alaska Native alone, percent (a)	0.1%
Asian alone, percent (a)	0.5%
Native Hawaiian and Other Pacific Islander alone, percent (a)	Z
Two or More Races, percent	0.8%
Hispanic or Latino, percent (b)	1.0%
White alone, not Hispanic or Latino, percent	96.8%
Population Characteristics	
Veterans, 2014-2018	2,700
Foreign born persons, percent, 2014-2018	0.8%
Housing	
Housing units, July 1, 2019, (V2019)	31,150
Owner-occupied housing unit rate, 2014-2018	72.6%
Median value of owner-occupied housing units, 2014-2018	$78,400
Median selected monthly owner costs -with a mortgage, 2014-2018	$1,042

Median selected monthly owner costs -without a mortgage, 2014-2018	$308
Median gross rent, 2014-2018	$666
Building permits, 2019	8
Families & Living Arrangements	
Households, 2014-2018	25,768
Persons per household, 2014-2018	2.30
Living in same house 1 year ago, percent of persons age 1 year+, 2014-2018	88.0%
Language other than English spoken at home, percent of persons age 5 years+, 2014-2018	1.2%
Computer and Internet Use	
Households with a computer, percent, 2014-2018	81.3%
Households with a broadband Internet subscription, percent, 2014-2018	71.6%
Education	
High school graduate or higher, percent of persons age 25 years+, 2014-2018	76.1%
Bachelor's degree or higher, percent of persons age 25 years+, 2014-2018	13.0%
Health	
With a disability, under age 65 years, percent, 2014-2018	22.1%
Persons without health insurance, under age 65 years, percent	7.6%
Economy	
In civilian labor force, total, percent of population age 16 years+, 2014-2018	45.6%
In civilian labor force, female, percent of population age 16 years+, 2014-2018	40.5%
Total accommodation and food services sales, 2012 ($1,000) (c)	91,769
Total health care and social assistance receipts/revenue, 2012 ($1,000) (c)	579,915
Total manufacturers shipments, 2012 ($1,000) (c)	219,022
Total merchant wholesaler sales, 2012 ($1,000) (c)	483,206
Total retail sales, 2012 ($1,000) (c)	936,224
Total retail sales per capita, 2012 (c)	$14,588
Transportation	
Mean travel time to work (minutes), workers age 16 years+, 2014-2018	24.5
Income & Poverty	
Median household income (in 2018 dollars), 2014-2018	$34,081
Per capita income in past 12 months (in 2018 dollars), 2014-2018	$21,646
Persons in poverty, percent	23.8%

BUSINESSES

Businesses	
Total employer establishments, 2018	1,174
Total employment, 2018	17,800
Total annual payroll, 2018 ($1,000)	747,920
Total employment, percent change, 2017-2018	-0.4%
Total nonemployer establishments, 2018	2,824

All firms, 2012	4,183
Men-owned firms, 2012	2,384
Women-owned firms, 2012	1,158
Minority-owned firms, 2012	56
Nonminority-owned firms, 2012	3,894
Veteran-owned firms, 2012	240
Nonveteran-owned firms, 2012	3,663

GEOGRAPHY

Geography	
Population per square mile, 2010	82.6
Land area in square miles, 2010	786.83
FIPS Code	21195

About datasets used in this table

Value Notes

Estimates are not comparable to other geographic levels due to methodology differences that may exist between different data sources.

Some estimates presented here come from sample data, and thus have sampling errors that may render some apparent differences between geographies statistically indistinguishable. Click the Quick Info icon to the left of each row in TABLE view to learn about sampling error.

The vintage year (e.g., V2019) refers to the final year of the series (2010 thru 2019). *Different vintage years of estimates are not comparable.*

Fact Notes

- **(a)** Includes persons reporting only one race
- **(b)** Hispanics may be of any race, so also are included in applicable race categories
- **(c)** Economic Census - Puerto Rico data are not comparable to U.S. Economic Census data

Value Flags

- **-** Either no or too few sample observations were available to compute an estimate, or a ratio of medians cannot be calculated because one or both of the median estimates falls in the lowest or upper interval of an open ended distribution.
- **D** Suppressed to avoid disclosure of confidential information
- **F** Fewer than 25 firms
- **FN** Footnote on this item in place of data
- **N** Data for this geographic area cannot be displayed because the number of sample cases is too small.
- **NA** Not available
- **S** Suppressed; does not meet publication standards
- **X** Not applicable
- **Z** Value greater than zero but less than half unit of measure shown

QuickFacts data are derived from: Population Estimates, American Community Survey, Census of Population and Housing, Current Population Survey, Small Area Health Insurance Estimates, Small Area Income and Poverty Estimates, State and County Housing Unit Estimates, County Business Patterns, Nonemployer Statistics, Economic Census, Survey of Business Owners, Building Permits.

ATTACHMENT F

ARTICLES ON DECLINE IN DOMESTIC CONSUMPTION OF TREATED WATER

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Declining Residential Water Usage

Introduction

In households across the U.S., water usage is declining slowly but steadily; a trend that is expected to continue for the next 15 years or even more. This is good news in light of the challenges some areas in the U.S. face when it comes to managing this essential resource. At the same time, it presents a challenge to water utilities, who must adapt their systems and rates to reduced consumption trends in order to cover fixed costs and maintain reliable service.

A 2010 study by the Water Research Foundation concluded that "a pervasive decline in household consumption has been determined at the national and regional levels."[1] As reported in Journal AWWA, the study, which tracked trends in household water use in North America over the past 30 years, found that "a household in the 2008 billing year used 11,678 gallons less water annually [an approximate 13 percent decline] than an identical household did in 1978."[2]

This finding is supported by American Water's experience, which serves approximately 15 million people in more than 30 states and parts of Canada. The company reported in its 2010 Annual Report a declining trend in residential water usage for all of its regulated states to be in the range of 0.5 to 2 percent annually over the last ten years. Monthly analyses of residential sales across

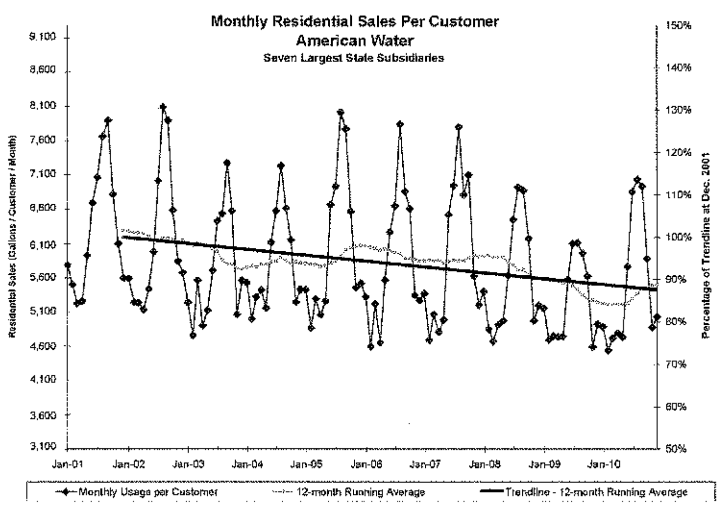


Figure 1

[1] Coomes et al. *North American Water Usage Trends Since 1992*, Water Research Foundation. 2010.
[2] Rockaway et al. "Residential Water Use Trends in North America," *Journal AWWA*. February 2011.

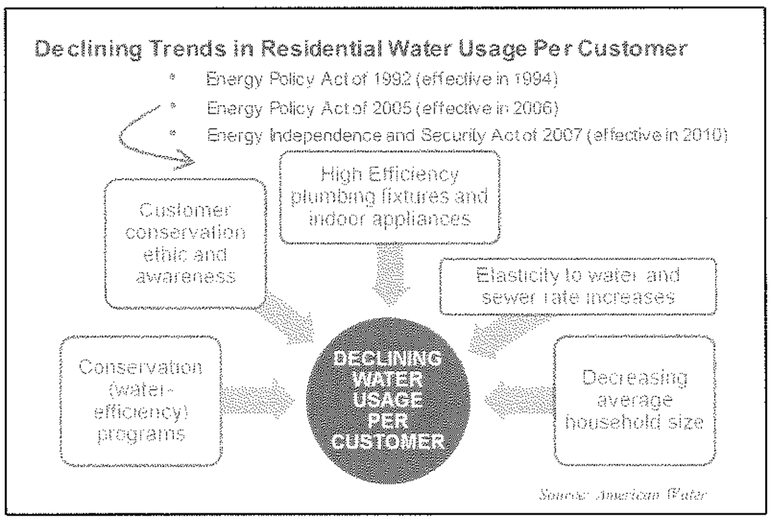
its largest state subsidiaries from 2001 to 2010 reveal an annual decrease of 1 to 2 percent (based on gallons/customer/month) (see figure 1). These subsidiaries provide service to a wide range of household demographics in climates that span from arid to water-rich, providing a broad base by which to assess water usage trends.

The results held true when American Water limited its analysis to winter-only consumption in service areas in the northern portions of the U.S. Because varying weather conditions in summer months can cause large fluctuations in outdoor water needs (lawn and garden watering, for instance, increases during hot, dry periods and is lower in cooler, wetter summers), it is particularly useful to study winter-only trends, when outdoor water usage is at a minimum.

The consistency of findings in both the Water Research Foundation study and American Water's own research indicates that several strong underlying factors are driving indoor residential usage patterns.

Driving the Decline

According to the Water Research Foundation, the primary forces behind this drop are the increased use of water-efficient appliances and a decrease in the number of occupants per household.[3] Others factors to consider are price elasticity, a growing conservation ethic among consumers, and conservation programs implemented by utilities and other entities.



A few highlights:

Water-efficient appliances: Technological advances continue to improve the water efficiency of household appliances, driven by government mandates such as The Energy Policy and Conservation Act of 1992, which required the manufacture of water-efficient toilets, showerheads and faucet fixtures, and the Energy Independence & Security Act of 2007, which established similar high-efficiency standards for dishwashers and clothes washers. As a result, toilets manufactured after 1994 use 1.6 gallons or less per flush, compared to 3.5 to 7 gallons per flush

[3] Coomes et al., 2010.

for older models, while dishwashers manufactured after 2009 and clothes washers after 2010 are held to water efficiency requirements that could reduce usage by 54 and 30 percent, respectively. What's more, fixtures and appliances that surpass these requirements are increasingly prevalent in the marketplace thanks to consumer demand. These improvements correspond to a 35% decrease in water usage by a typical residential household in a new home constructed in 2011 compared to the same household in a non-retrofitted home built prior to 1994.

Background – Flow rates from different appliances

Type of Use	Pre-Regulatory Flow*	New Regulatory Standards and Flows			WaterSense / ENERGY STAR Current Specification+
		New Standard (maximum)	Federal Standard	Year Effective	
Toilets	3.5 gpf	1.6 gpf	U.S. Energy Policy Act	1994	1.28 gpf
Clothes washers**	41 gpl (14.6 WF)	Estimated 26.6 gpl (9.5 WF)	Energy Independence & Security Act of 2007	2011	Estimated 22.4 gpl (8.0 WF)
Showers	2.75 gpm	2.5 gpm at 80 psi	U.S. Energy Policy Act	1994	No specification
Faucets***	2.75 gpm	2.5 gpm at 80 psi (1.5 gpm)	U.S. Energy Policy Act	1994	1.5 gpm at 60 psi
Dishwashers	14.0 gpc	6.5 gpc for standard; 4.5 gpc for compact	Energy Independence & Security Act of 2007	2010	5.8 gpc for standard; 4.0 gpc for compact

* Source: *Handbook of Water Use and Conservation*, Amy Vickers May 2001
** Average estimated gallons per load and water factor (see calculations)
*** Regulation maximum of 2.5 gpm at 80 psi, but lavatory faucets available at 1.5 gpm maximum (see calculations)
\+ Source: http://www.epa.gov/watersense/ and http://www.energystar.gov websites

ABBREVIATIONS USED:
gpf – gallons per flush, gpl – gallons per load, gpc – gallons per cycle, gpm – gallons per minute
WF – water factor or gallons per cycle per cubic feet capacity of the washer

Figure 3

Price elasticity: Non-essential outdoor water usage – from irrigation to car washing and swimming pools – is more responsive to water and sewer rate increases than is indoor water usage, which is primarily for consumption and hygiene. However, there is some price elasticity there as well, as households are more vigilant about fixing leaks under higher rates.[4] A recent industry study investigating the sensitivity of residential water demand to water price found that a 10% increase in price led to a 3.3% decline in customer demand.[5]

Water conservation practices: Whether as a cost-cutting measure or due to growing environmental awareness, American consumers are increasingly conscientious about conserving household water. Utilities, too, have been educating their customer bases about the importance of preserving the world's water supply. For its part, American Water became a promotional partner of the Environmental Protection Agency's WaterSense program in 2008, and all American Water subsidiaries have links on their websites to the EPA WaterSense site. The company has dedicated its 125th anniversary year (2011) to promoting the value of water and the need to protect it through a variety of national and regional educational programs reaching its customer base and the general public, including a series of public service announcements (PSAs) produced in conjunction with EPA WaterSense and the Student Conservation Association. American Water subsidiaries also offer conservation-related educational materials, and several subsidiaries have pilot or statewide conservation programs that include offering water-efficient fixtures by request or by rebates.

[4] Coomes et al., 2010.
[5] Olmstead et al. *Managing Water Demand: Price vs. Non-Price Conservation Programs*. July 2007.

Benefits of Reduced Usage

By 2013, it is estimated that 36 states will face serious water shortages.[6] Therefore, a decline in per-household water usage is crucial if the nation is to meet the water needs of a growing population.

The water industry, too, reaps certain benefits from this trend. Less water use means less need to divert water from supply sources, leaving more water for passing flows or drought reserve. It leads to reduced power consumption, chemical usage, and waste disposal, which not only lowers operating costs but also provide environmental benefits such as reduced carbon footprint and waste streams.

At times of declining customer usage, operators can seize the opportunity to optimize management of existing water supplies, treatment facilities, and pump stations. For systems that rely on multiple sources of supply, this may translate into operational cost savings by minimizing use of water from higher-cost sources.

Other opportunities include more efficient and effective pumping and treatment. More available storage means operators can schedule more pumping at off-peak times, thus reducing electricity demand charges. Less demand also means less strain on certain process equipment, allowing operators to stretch out scheduled maintenance.

Utility planners need to base capital projects on the most current information and consider downsizing or postponing supply development projects when customer demand projections reflect an anticipated decline in usage. At the same time, they must continue to factor in peak-day demand, which, driven by hot, dry weather spells and other short-term events, may or may not follow the same declining trend as average-day consumption. Because it is peak-day demand that determines capital infrastructure needs such as treatment and pumping capacity, it is essential that utilities understand their own peak usage patterns.

The Challenge

The downside for the water utility industry is that reduced usage creates a revenue decline while a number of fixed costs continue to rise. These range from water utility capital needs – infrastructure renewal, reliability, and regulatory projects, for instance – to operating costs such as plant maintenance, customer services needs, IT support, and security.

"Pricing that recovers the costs of building, operating and maintaining the systems is absolutely essential to achieving sustainability," reports the Water Research Foundation. "Drinking water and wastewater utilities must be able to price water to reflect the full costs of treatment and delivery."[7]

For water utilities that are regulated by public service commissions, the challenge, therefore, is to work with regulators to be progressive in establishing rates that allow appropriate investment in the pipes and plants that ensure reliable service.

[6] U.S. Government Accountability Office. *Natural Resources, Energy, and the Environment Challenges for the 21st Century.* February 2005.
[7] Coomes et al, 2010.

Solutions

Despite the financial challenges it presents, water utilities are wise to not just accept but embrace the declining usage trend, if simply because it's the right thing to do. As stewards of the nation's water supply, conservation of this vital resource must continue to be a key message and operational focus. Rather, utilities must meet the challenge of reduced demand by building that 1% to 2% decline into its long-term planning.

The value of water is another key message utilities must continue to underscore. It is essential that customers understand that, at about a penny or less a gallon, the clean, quality water delivered to their tap is a bargain, especially compared to other common household utilities.

Investor-owned water utilities also need to work with regulators for a more progressive rate structure so that revenues are not entirely dependent on fluctuations in sales. Revenue balancing, where rates provide for surcharges or refunds based on fluctuations in sales, is one tool to consider. Another would be to increase the fixed charge on the customers' utility bill to recover a greater portion of the utilities fixed costs, thereby reducing exposure to sales volatility. For utilities operating on a basis of decoupled revenue streams, water saved through conservation can be viewed as more cost effective than adding capacity via expansion of water delivery infrastructure.[8]

Conclusion

Based on the average life expectancy of appliances, it is estimated that the replacement of old fixtures with new, more efficient models will continue to affect water usage trends for another 10 to 15 years.[9] Other drivers are likely to continue into the foreseeable future. Looking forward, water utility managers and operators will need to adapt their business planning to accommodate the historic declining trend of 1 to 2% annually, while also watching for signs of its leveling off.

[8] Massachusetts Institute of Technology, Mission 2012: Clean Water: http://web.mit.edu/12.000/www/m2012/finalwebsite

[9] Naumick, Gary A., P.E., *Trends in Residential Water Usage and its Impact on Water Utility Financial Planning*, AWWA Utility Management Conference, February 10, 2011.

Fact Sheet

WATER EFFICIENCY

Water Use Estimates

How Water Sales and Research Studies Can Be Used to Predict Future Needs

Quick Facts

- Utility data are useful for analyzing water use trends, but have limitations
- Research studies on residential water use show an overall decline in consumption over time
- New methodologies, standardization of customer categories, and improved documentation will improve use estimates

Overview

Utilities need a comprehensive understanding of the many uses of potable water in order to meet current and future water supply demands. Water sales have been used to understand and predict demands and are based on periodic readings of the customer's meter. However, water meter data has limitations because utilities don't use uniform customer categories, lack detailed water use information, readings may not occur frequently enough to be useful, and not all customers have a meter. Research studies can provide more detailed water use measurements and averages. When combined with non-sales information, such data can help elucidate customer sales.

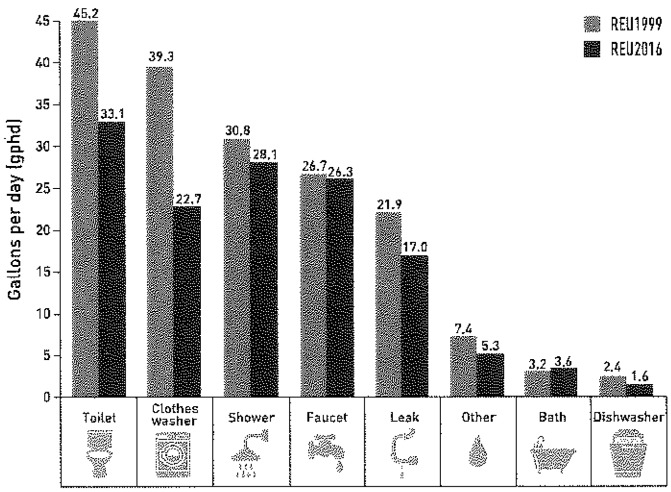
National Water Use Estimates

The national effort to collect water use information is conducted every five years by the U.S. Geological Survey (USGS). In the latest report, the USGS estimated that in 2010 the total water used in the United States was 355 billion gallons per day, a decrease of 13% from 2005. The largest uses of water were thermoelectric power (45%), irrigation (33%) and public supply—residential, commercial, and industrial freshwater uses (12%) (Maupin et al. 2014).

Utility Data On Water Use

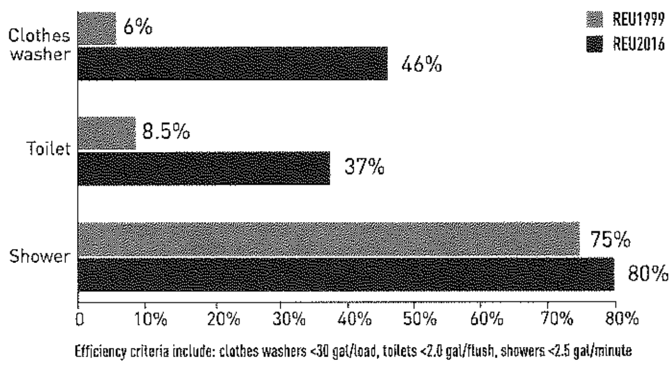
Utilities do not use uniform categories and sub-categories for customer sales, thus water use trends analysis is hampered by a lack of accurate and consistent data. The

Water Research Foundation (WRF) report, *Evaluation of Customer Information and Data Processing Needs for Water Demand Analysis, Planning and Management*, recommended the development of standardized customer classification. It also recommended that utilities geographically reference water customers with their unique locations and maintain at least a 10-year record of customer water use and billing information (Kiefer and Krentz 2016). Some advances in data aggregation of water use information is underway, in part spurred by advanced metering infrastructure and the recognition that data analytics could inform water use trends analysis. Using water sales data, American Water Works Association (AWWA) (2015) calculated "total per capita" consumption at 121.3 gal/person/day and "domestic per capita" consumption at 66.6 gal/person/day. Research studies can provide more detailed measurements of water use.



Source: DeOreo et al. 2016

Figure 1. Indoor per household water use



Source: DeOreo et al. 2016

Figure 2. Percent of homes meeting EPA's WaterSense efficiency criteria

Residential Customers: Single-Family, Detached Homes

Single-family detached homes typically are the largest category of customers, both by volume of water consumer and revenue generated. These homes have the most direct record of water sales since each is individually metered. In the WRF reports, *Residential End Uses of Water* (Mayer et al. 1999) and *Residential End Uses of Water, Version 2* (DeOreo et al. 2016), water use per household was calculated from billing data and detailed water use information was collected for two weeks, which allowed for identification of water use by specific fixtures, appliances or water using behavior (like irrigation). Comparing water use amongst utilities is difficult with billing data alone because it includes irrigation and varies widely based on local climate conditions. The studies focused on comparing residential "indoor" water use since this is more comparable. In the 2016 report, the average indoor water use was 138 gallons per household per day (Figure 1) and 58.6 gallons per capita per day.

Comparing Residential Water Use Over Time

North American Water Usage Trends analyzed 25 years of national sales data from 43 utilities, beginning in 1992. Residential water use per customer (house) declined 389 gallons per year. Reasons for water use declines in various study locations may differ because they are affected by the local economy, demographics, age of housing stock, and growth patterns (Coomes et al. 2010).

Comparing *Residential End Uses of Water* in 1999 and *Residential End Uses of Water,* *Version 2* in 2016, water use has declined 22% per household, from 177 to 138 gallons per household per day (gphd), or 15% per capita (from 69.3 to 58.6 gallons per capita per day [gpcd]).The decline in indoor water use resulted in part from the increased prevalence of more efficient toilets and clothes washers (Figure 2) (DeOreo et al. 2016).

The change in the occurrence of water-efficient appliances and fixtures is being studied in WRF's ongoing project, "Integrating Water Use From Efficient Technology and New Building Codes into Demand Forecasting" (Cooley and Heberger, forthcoming).

Multi-Family Residential Water Use

The multi-family housing sector, larger in urban areas, is a component of most utilities' sales and may be increasing. About 34% of housing units are some form of multi-family housing (U.S. Census Bureau 2013). Water use per unit is not well-documented because most units are not individually metered (Mayer et al. 2004).

It's a commonly held idea that indoor water use from single family homes might be a proxy for use in multi-family housing units, but that has not been proven. Estimates of multi-family housing water use from research studies is 121–217 gallons per day per housing unit (Mayer et al. 2004, DeOreo and Hayden 2008). "Water Use in the Multi-Family Housing Sector" will develop and recommend strategies for estimating multi-family water use (Kiefer, forthcoming).

Commercial, Industrial, And Institutional (CII) Water Use

The CII sector of customers makes up about one-third of utility sales. Understanding such sales is complicated because not all businesses are individually metered, and their diversity prevents creation of homogenous groups of customers.

In the WRF study, *Commercial and Institutional End Uses of Water*, usage was calculated for popular categories of non-residential customers (Table 1). While size or magnitude of operations was accounted for, the study did not take into account variables such as the number of customers or employees (Dziegielewski et al. 2000)

Two WRF projects further the study of water use estimates for non-residential customers. *Methodology for Determining Baseline Commercial, Institutional and Industrial End Uses of Water* developed analytical elements and developed data collection methods for differentiating among the CII groupings (Kiefer and Krentz 2015). The study suggested using 13 primary categories as a starting point: lodging, office building, school/college, health care facility, eating/drinking establishment, retail store, warehouse, auto/auto service, religious building, retirement/nursing home, manufacturing, other commercial/institutional, largest individual users, or dominant end uses. In the ongoing study, "Developing Water Use Metrics and Class Characteristics for Categories in the CII Sector," goals include setting benchmarks for select CII customer categories (Fedak, forthcoming).

Typical water sales data based on monthly or bi-monthly readings of meters and have limitations because of non-uniform customer categories, lack of detailed water use information, and the lack of 1:1 relationship between meter and customer account. Research studies provide more detailed studies of water use by customer type, but are limited snapshots in time. Advances in

Table 1. Water use for non-residential customers from billing data

	Average annual daily use*
Hotels and motels	7,113
Laundries / laundromats	3,290
Car washes	3,031
Urban irrigation	2,596
Schools and colleges	2,117
Hospitals / medical offices	1,236
Office buildings	1,204
Restaurants	906
Food stores	729
Auto shops	687
Membership organizations	629

*gallons per day per utility customer

Source: Dziegielewski et al. 2000

technology (like advanced metering infrastructure) and practices (such as using standardized customer categories and geocoding customer accounts) will help improve the industry's understanding of water use trends and drivers.

There is a need to improve the usefulness of customer data for analyzing water use trends.

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Last updated April 2017

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WaterNews

U.S. Household Water Use Continues to Decline

November 8, 2017 / in Water Management, Water News / by Brett Walton

Federal report tracks conservation pattern that began two decades ago.

A neighborhood in Weld County, Colorado, one of the few states where household water use is increasing. Photo © J. Carl Ganter / Circle of Blue

By Brett Walton, Circle of Blue

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Continuing a trend that began in the early 1990s with tighter federal plumbing standards, U.S. household water use dropped again in 2015.

When assessing national figures, there are two main ways to gauge water use at home: the amount used per person and total water use, which incorporates changes in population. By both measures, water use is declining [https://pubs.er.usgs.gov/publication/ofr20171131], according to the latest report from the U.S. Geological Survey, the agency that gathers national data every five years.

For people served by public and private utilities, water use for cooking, drinking, showering, lawn watering, car washing, and other household tasks dropped to an average of 83 gallons per person per day in 2015, down seven percent compared to 2010. Household use was 105 gallons per person per day in 1990.

Total household use declined as well, even as the number of people supplied by utilities increased by 14 million. Household water use in the country dropped by 381 million gallons per day, or two percent. Savings are evident across all utility operations. Total water withdrawals for public supply, a category that includes household use as well as water provided by utilities for commercial and industrial purposes, are the lowest since 1995.

Three factors explain the decline, according to Molly Maupin, a U.S. Geological Survey hydrologist who helped to collect the water-use data. A severe drought in California prompted Gov. Jerry Brown in 2015 to order urban water utilities to cut demand by 25 percent. Those utilities are also implementing a state water conservation law that was passed in 2009. California, not surprisingly, showed the largest decline in total household water use in the country between 2010 and 2015.

Second is that water utilities are paying more attention — by fixing leaks and installing meters. The Georgia Legislature, for instance, passed a law in 2010 that requires utilities to conduct an annual audit to check for leaks.

“People are continuing to use water more carefully,” Maupin told Circle of Blue.

Conservation yields financial benefits for residents, too. A study published earlier this year by the Alliance for Water Efficiency, a Chicago-based nonprofit, found that using less water in two Arizona cities [https://www.circleofblue.org/2017/water-management/saving-water-lowered-rates-two-arizona-cities/] led to cheaper rates than if new water supply projects were built in order to keep pace with higher demand.

The third factor is water-saving plumbing fixtures. The federal Energy Policy Act of 1992 dramatically strengthened the plumbing code, requiring toilets, showerheads, faucets, dishwashers, and clothes washers to cut down the flow of water. As a result of the act, toilets flush half as much water as before and showerheads spray 30 percent less.

Research bears this out. Nearly all the decline in residential indoor water use in the last two decades is due to more-efficient fixtures, according to a 2016 study [https://www.circleofblue.org/2016/water-management/infrastructure/study-efficient-fixtures-cut-u-s-indoor-water-use/] funded by the Water Research Foundation. That study examined in detail the behavior of households in nine large cities.

Some states have turned the screws even tighter. California ordered that toilets sold after January 1, 2014, flush 20 percent less water than the federal standard of 1.6 gallons. Texas, Georgia, and Colorado followed with similar laws.

Water use is not declining in every state, though. According to the USGS report, which uses data from state agencies and water utilities, per person water use increased in the states of Alaska, Colorado, Idaho, Louisiana, Utah, Virginia, Wisconsin, and Wyoming.

Most of these states are in the American West, and three are in the upper basin of the Colorado River, where there is strong debate about whether to increase water withdrawals from the shrinking river [https://www.circleofblue.org/2016/world/colorado-rivers-tale-two-basins/] .

Brett Walton [https://www.circleofblue.org/author/brett/]

Brett writes about agriculture, energy, infrastructure, and the politics and economics of water in the United States. He also writes the Federal Water Tap [https://www.circleofblue.org/water-tap/] , Circle of Blue's weekly digest of U.S. government water news. He is the winner of two Society of Environmental Journalists reporting awards, one of the top honors in American environmental journalism: first place for explanatory reporting for a series on septic system pollution in the United States [https://www.circleofblue.org/2016/world/brettwalton/] (2016) and third place for beat reporting in a small market (2014). Brett lives in Seattle, where he hikes the mountains and bakes pies. Contact Brett Walton [https://www.circleofblue.org/contactbrettwalton/]

[https://twitter.com/waltonwater]

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Water Use Across the United States Declines to Levels Not Seen Since 1970

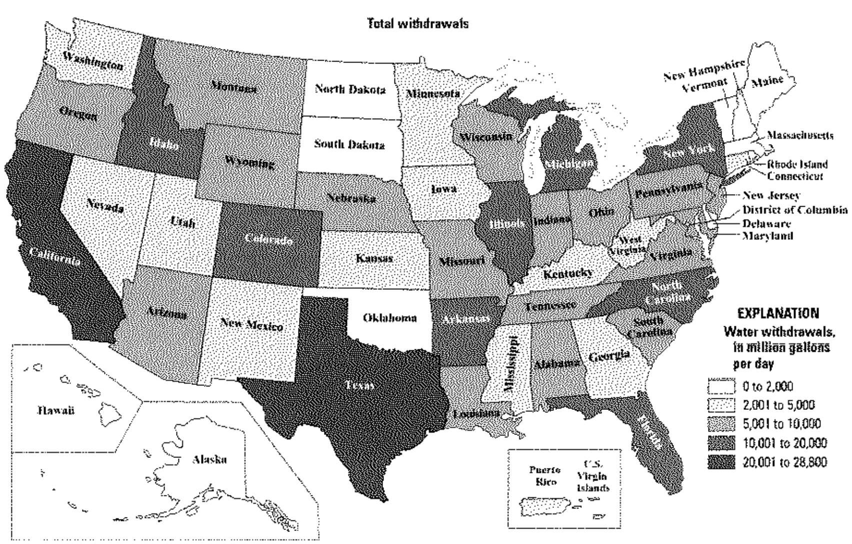
Release Date: JUNE 19, 2018

Reductions in water use first observed in 2010 continue, show ongoing effort towards "efficient use of critical water resources."

Water use across the country reached its lowest recorded level in 45 years. According to a new USGS report, 322 billion gallons of water per day (Bgal/d) were withdrawn for use in the United States during 2015.

This represents a 9 percent reduction of water use from 2010 when about 354 Bgal/d were withdrawn and the lowest level since before 1970 (370 Bgal/d).

"The downward trend in water use shows a continued effort towards efficient use of critical water resources, which is encouraging," said Tim Petty, assistant secretary for Water and Science at the Department of the Interior. "Water is the one resource we cannot live without, and when it is used wisely, it helps to ensure there will be enough to sustain human needs, as well as ecological and environmental needs."



Total water withdrawals by State, 2015 [1 Bgal/d = 1,000 million gallons per day].

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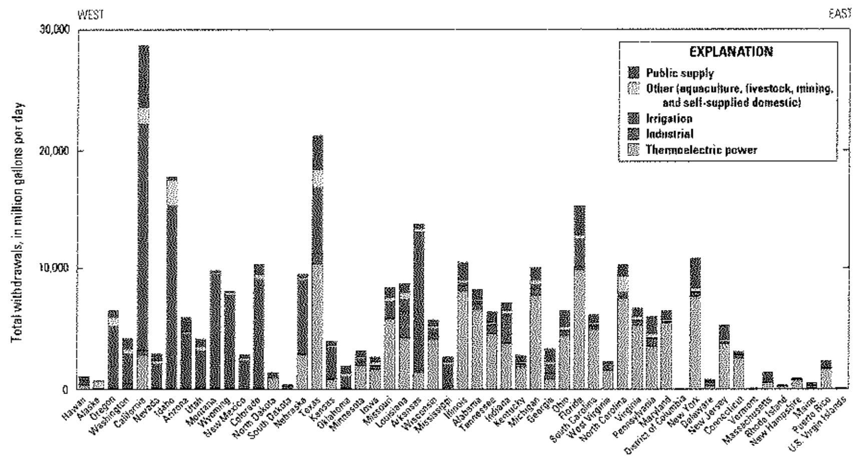
In 2015, more than 50 percent of the total withdrawals in the United States were accounted for by 12 states (in order of withdrawal amounts): California, Texas, Idaho, Florida, Arkansas, New York, Illinois, Colorado, North Carolina, Michigan, Montana, and Nebraska.



Total water withdrawals by category and by State from west to east, 2015 [1 Bgal/d = 1,000 million gallons per day].

California accounted for almost 9 percent of the total withdrawals for all categories and 9 percent of total freshwater withdrawals. Texas accounted for about 7 percent of total withdrawals for all categories, predominantly for thermoelectric power generation, irrigation, and public supply.

Florida had the largest share of saline withdrawals, accounting for 23 percent of the total in the country, mostly saline surface-water withdrawals for thermoelectric power generation. Texas and California accounted for 59 percent of the total saline groundwater withdrawals in the United States, mostly for mining.

"The USGS is committed to providing comprehensive reports of water use in the country to ensure that resource managers and decision makers have the information they need to manage it well," said USGS director Jim Reilly. "These data are vital for understanding water budgets in the different climatic settings across the country."

For the first time since 1995, the USGS estimated consumptive use for two categories — thermoelectric power generation and irrigation. Consumptive use is the fraction of total water withdrawals that is unavailable for immediate use because it is evaporated, transpired by plants, or incorporated into a product.

"Consumptive use is a key component of the water budget. It's important to not only know how much water is being withdrawn from a source, but how much water is no longer available for other immediate uses," said USGS hydrologist Cheryl Dieter.

The USGS estimated a consumptive use of 4.31 Bgal/d, or 3 percent of total water use for thermoelectric power generation in 2015. In comparison, consumptive use

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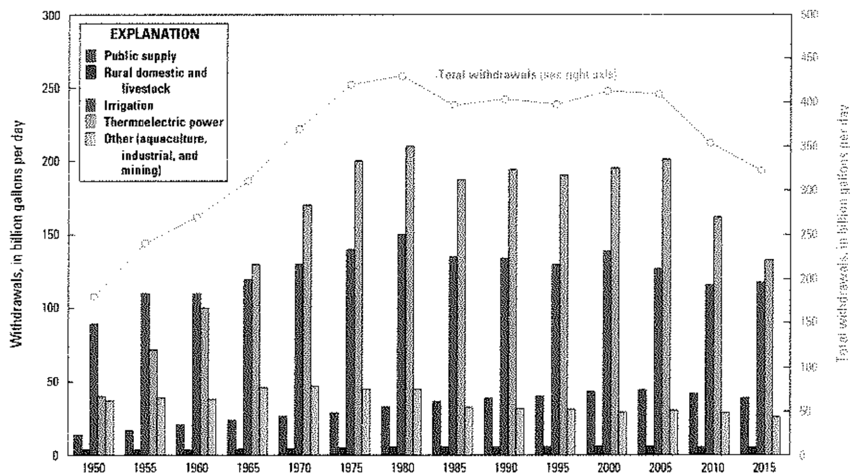
was 73.2 Bgal/d, or 62 percent of total water use for irrigation in 2015.

Water withdrawn for thermoelectric power generation was the largest use nationally at 133 Bgal/d, with the other leading uses being irrigation and public supply, respectively. Withdrawals declined for thermoelectric power generation and public supply, but increased for irrigation. Collectively, these three uses represented 90 percent of total withdrawals.

- Thermoelectric power decreased 18 percent from 2010, the largest percent decline of all categories.
- Irrigation withdrawals (all freshwater) increased 2 percent.
- Public-supply withdrawals decreased 7 percent.



Trends in total water withdrawals by water-use category, 1950-2015.

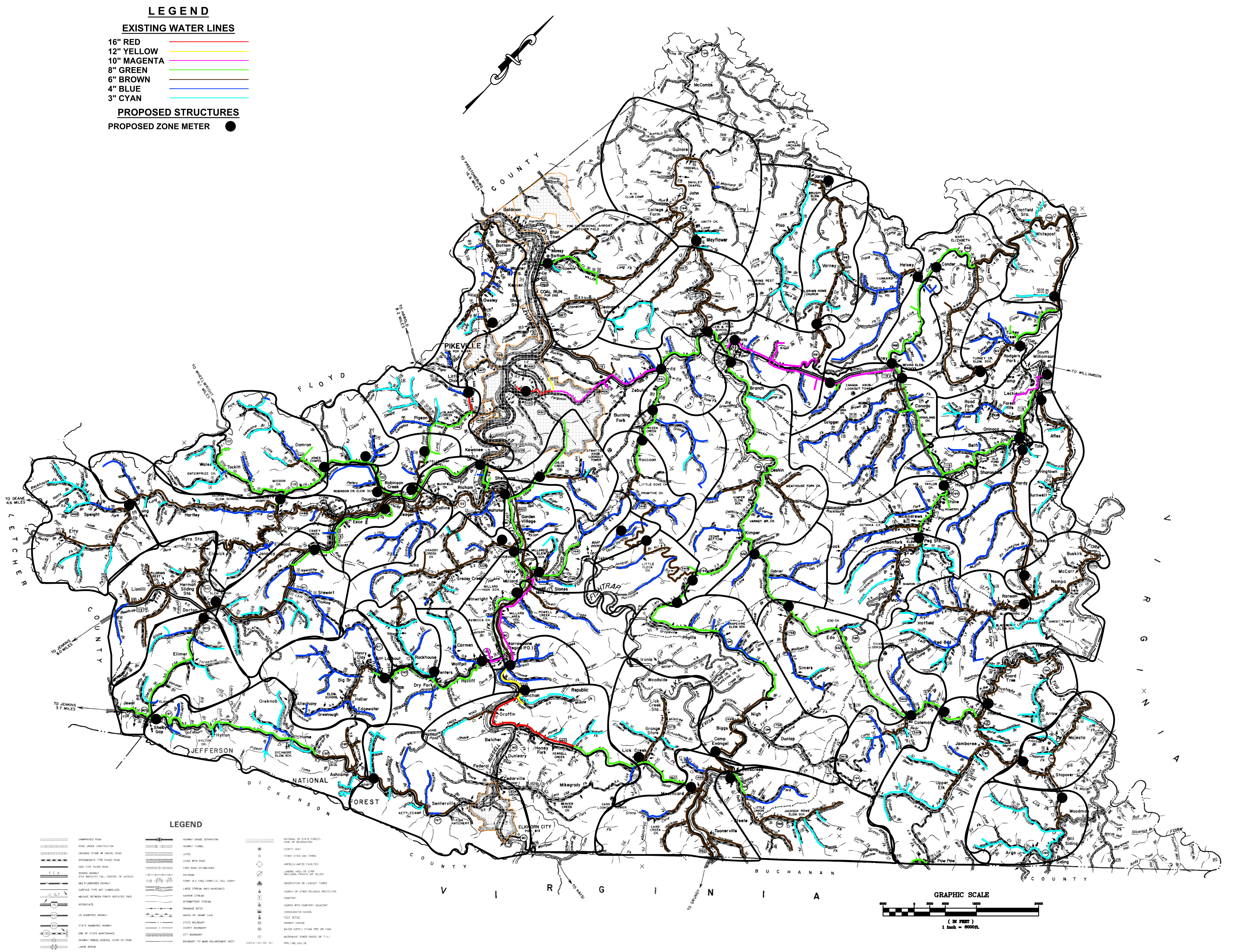
A number of factors can be attributed to the 18 percent decline in thermoelectric-power withdrawals, including a shift to power plants that use more efficient cooling-system technologies, declines in withdrawals to protect aquatic life, and power plant closures.

As it did in the period between 2005 and 2010, withdrawals for public supply declined between 2010 and 2015, despite a 4 percent increase in the nation's total population. The number of people served by public-supply systems continued to increase and the public-supply domestic per capita use declined to 82 gallons per day in 2015 from 88 gallons per day in 2010. Total domestic per capita use (public supply and self-supplied combined) decreased from 87 gallons per day in 2010 to 82 gallons per day in 2015.

The USGS is the world's largest provider of water data and the premier water research agency in the federal government.

ATTACHMENT G

DMA/ZONE METERING MAP



ATTACHMENT G
CAPITAL IMPROVEMENT PLAN
PROPOSED ZONE METERING MAP
MOUNTAIN WATER DISTRICT
PIKEVILLE, KENTUCKY

Scale: 1" = 6,000 ft

Sheet: G

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Checked: SHC
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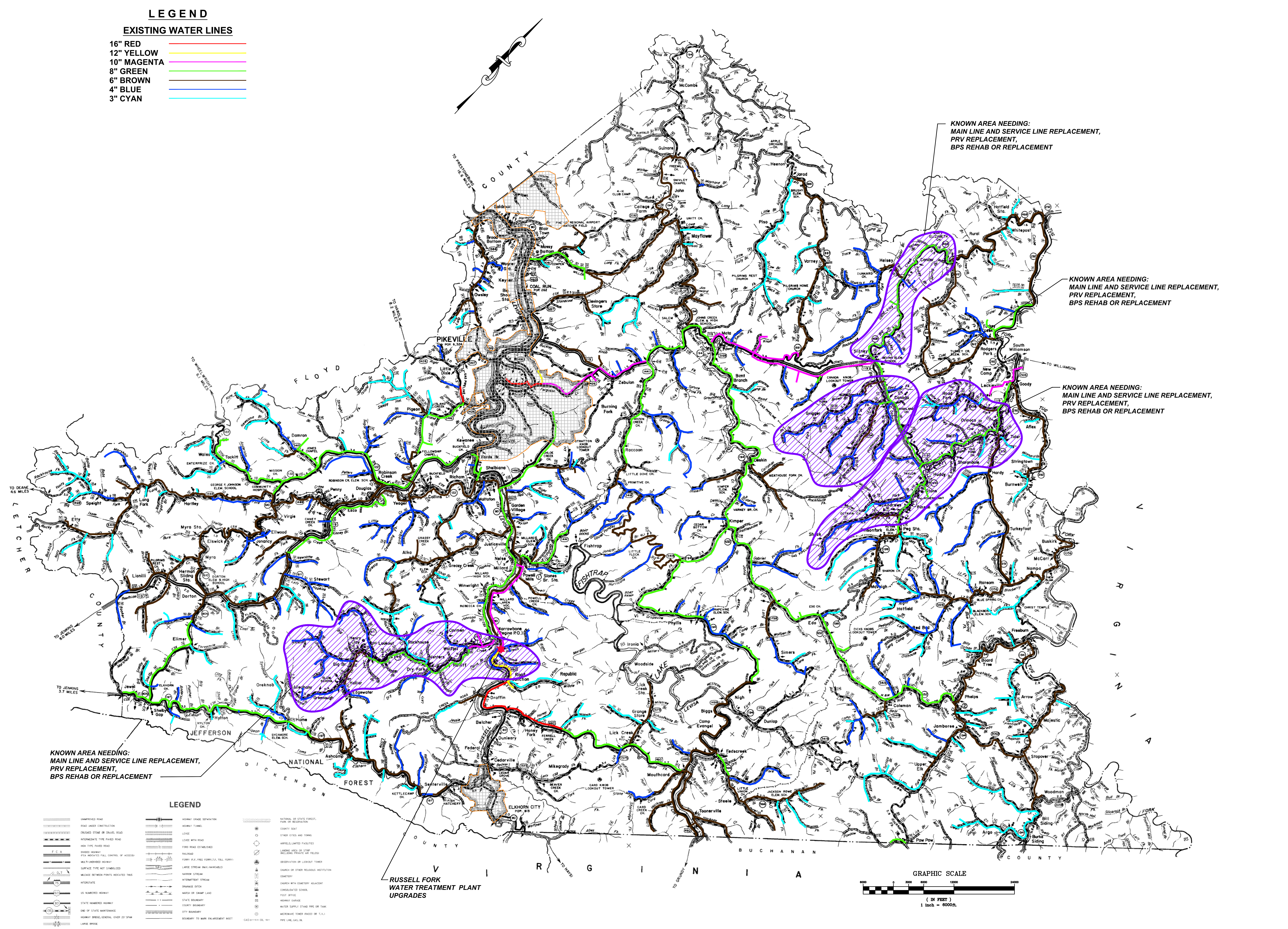
ATTACHMENT H

PROPOSED SYSTEM IMPROVEMENTS

MAP



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ATTACHMENT H
CAPITAL IMPROVEMENT PLAN
PROPOSED SYSTEM IMPROVEMENTS MAP
MOUNTAIN WATER DISTRICT
PIKEVILLE, KENTUCKY

Date:	10/26/2020
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ATTACHMENT I

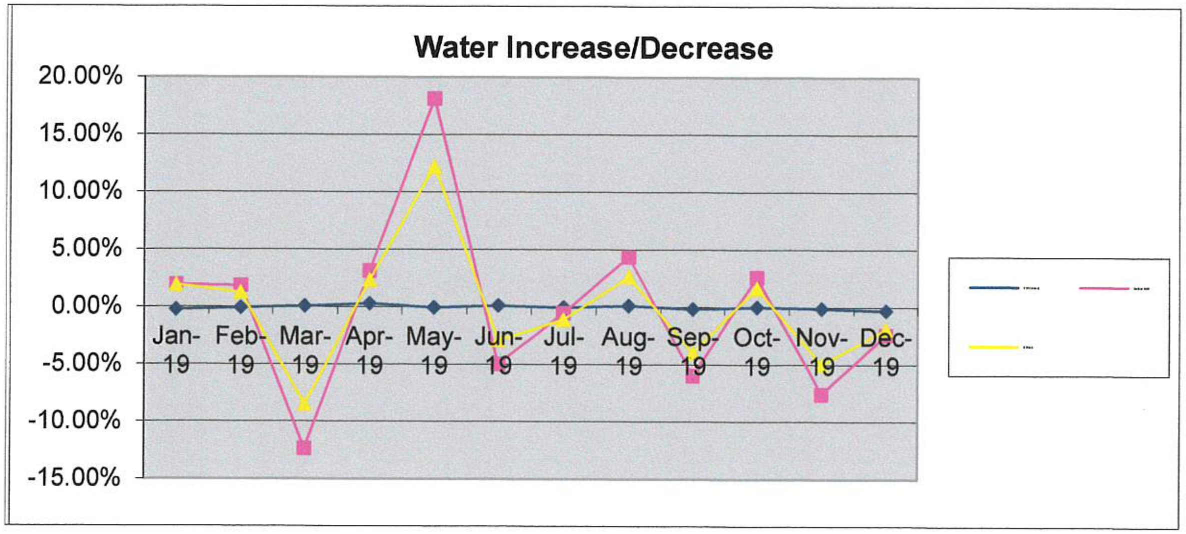
REPORTED MWD USAGE DATA

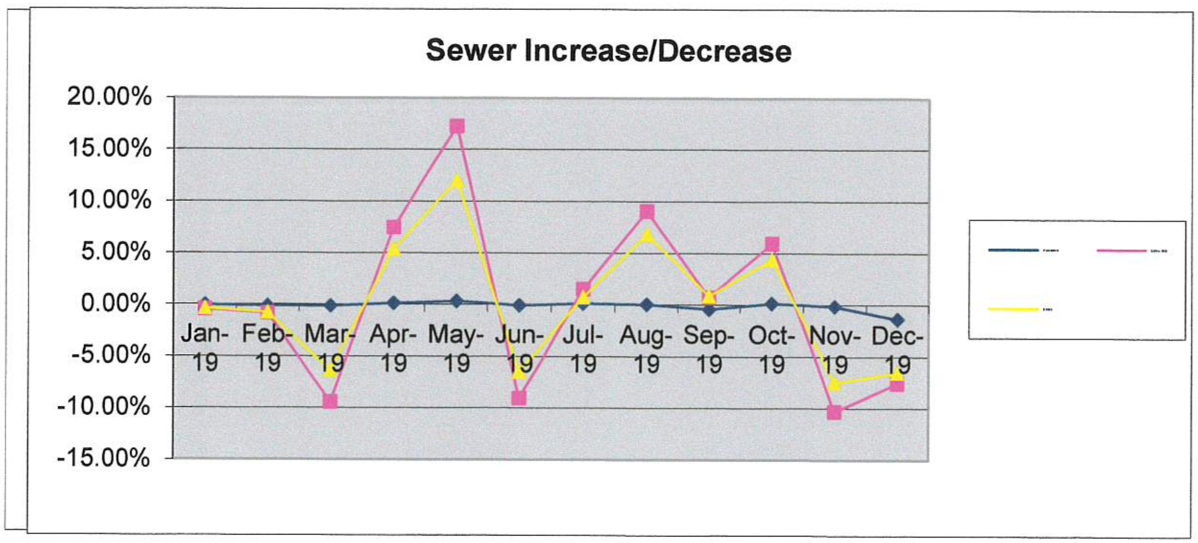
Water and Sewer Trends
2019

	Water			Sewer			Total		
	# Customers	Gallons Sold	$ Billed	# Customers	Gallons Sold	$ Billed	# Customers	Gallons Sold	$ Billed
Jan-19	16,568	65,975,490	$ 678,187.21	2,227	8,299,934	$ 172,223.70	18,795	74,275,424	$ 850,410.91
Feb-19	16,555	67,200,970	$ 686,838.64	2,224	8,229,984	$ 170,858.49	18,779	75,430,954	$ 857,697.13
Mar-19	16,561	58,891,370	$ 628,478.26	2,221	7,452,664	$ 159,905.13	18,782	66,344,034	$ 788,383.39
Apr-19	16,608	60,727,320	$ 643,129.64	2,223	8,008,774	$ 168,454.19	18,831	68,736,094	$ 811,583.83
May-19	16,598	71,732,000	$ 721,595.32	2,230	9,392,124	$ 188,678.23	18,828	81,124,124	$ 910,273.55
Jun-19	16,613	68,158,080	$ 700,594.42	2,228	8,541,474	$ 176,418.28	18,841	76,699,554	$ 877,012.70
Jul-19	16,603	67,792,860	$ 692,946.47	2,230	8,668,914	$ 177,662.86	18,833	76,461,774	$ 870,609.33
Aug-19	16,619	70,748,060	$ 711,252.47	2,230	9,453,364	$ 189,813.44	18,849	80,201,424	$ 901,065.91
Sep-19	16,589	66,524,160	$ 682,974.91	2,220	9,522,304	$ 191,470.01	18,809	76,046,464	$ 874,444.92
Oct-19	16,588	68,244,820	$ 694,230.84	2,223	10,088,264	$ 199,839.64	18,811	78,333,084	$ 894,070.48
Nov-19	16,567	63,069,100	$ 659,516.85	2,220	9,044,834	$ 184,822.92	18,787	72,113,934	$ 844,339.77
Dec-19	16,517	61,538,000	$ 646,857.20	2,189	8,358,484	$ 172,708.94	18,706	69,896,484	$ 819,566.14
Total		**790,602,230**	**$ 8,146,602.23**		**105,061,118**	**$ 2,152,855.83**		**895,663,348**	**$ 10,299,458.06**

	% Increase (Decrease) Water			% Increase (Decrease) Sewer			% Increase (Decrease) Total		
	# Customers	Gallons Sold	$ Billed	# Customers	Gallons Sold	$ Billed	# Customers	Gallons Sold	$ Billed
Jan-19	-0.26%	1.92%	1.92%	-0.05%	-0.45%	-0.39%	-0.23%	1.65%	1.44%
Feb-19	-0.08%	1.86%	1.28%	-0.13%	-0.84%	-0.79%	-0.09%	1.56%	0.86%
Mar-19	0.04%	-12.37%	-8.50%	-0.13%	-9.44%	-6.41%	0.02%	-12.05%	-8.08%
Apr-19	0.28%	3.12%	2.33%	0.09%	7.46%	5.35%	0.26%	3.61%	2.94%
May-19	-0.06%	18.12%	12.20%	0.31%	17.27%	12.01%	-0.02%	18.02%	12.16%
Jun-19	0.09%	-4.98%	-2.91%	-0.09%	-9.06%	-6.50%	0.07%	-5.45%	-3.65%
Jul-19	-0.06%	-0.54%	-1.09%	0.09%	1.49%	0.71%	-0.04%	-0.31%	-0.73%
Aug-19	0.10%	4.36%	2.64%	0.00%	9.05%	6.84%	0.08%	4.89%	3.50%
Sep-19	-0.18%	-5.97%	-3.98%	-0.45%	0.73%	0.87%	-0.21%	-5.18%	-2.95%
Oct-19	-0.01%	2.59%	1.65%	0.14%	5.94%	4.37%	0.01%	3.01%	2.24%
Nov-19	-0.13%	-7.58%	-5.00%	-0.13%	-10.34%	-7.51%	-0.13%	-7.94%	-5.56%
Dec-19	-0.30%	-2.43%	-1.92%	-1.40%	-7.59%	-6.55%	-0.43%	-3.07%	-2.93%
Average	**-0.05%**	**-0.16%**	**-0.11%**	**-0.15%**	**0.35%**	**0.17%**	**-0.06%**	**-0.11%**	**-0.06%**

Water and Sewer Trends
2019





METER DEPARTMENT
BILLING / USAGE REPORT
December 2018

CYCLE	DATE	NUMBER OF CUSTOMERS	TOTAL WATER SALES	USAGE	CONTRACT BILLING	SEWAGE FEES
1-SV	12/16/2019	3,859	$ 151,198.71	13,717,750		$ 51,092.30
2-M	12/20/2019	1924	$ 65,557.09	5,545,730		$ -
3-PC	12/27/2019	1,990	$ 84,783.24	7,983,240		$ 43,900.26
4-GV	1/2/2020	2,426	$ 86,782.54	7,494,720		$ 2,969.03
5-BC	1/9/2020	1,634	$ 77,370.09	10,435,290		$ 5,680.18
6-SV	12/16/2019	408	$ 19,014.96	1,890,610	$ 3,281.65	$ 3,535.15
7-M	12/20/2019	665	$ 23,175.55	1,978,600		$ -
8-M	12/20/2019	914	$ 33,416.44	2,944,860		$ 443.01
9-PC	12/27/2019	405	$ 14,953.53	1,431,040		$ 13,410.79
10-GV	1/6/2020	2292	$ 90,605.05	8,116,160		$ 51,678.22
TOTALS:		**16,517**	**$ 646,857.20**	**61,538,000**	**$ 3,281.65**	**$ 172,708.94**

TOTAL WATER CUSTOMERS: 16,517

TOTAL SEWER CUSTOMERS: 2189

Multi: 803

Customer Billing
December 2019

Description		12/16/2019 SV Cycle 1	12/20/2019 M Cycle 2	12/27/2019 PC Cycle 3	1/2/2020 GV Cycle 4	1/9/2020 BC Cycle 5	12/16/2019 SV Cycle 6	12/20/2019 M Cycle 7	12/20/2019 M Cycle 8	12/27/2019 PC Cycle 9	1/6/2020 GV Cycle 10	TOTALS
Residential Water	4611-00	128,218.83	61,733.20	65,911.68	77,368.85	57,267.25	13,039.77	21,592.87	28,985.05	13,661.92	73,612.68	541,392.10
Commercial Water	4612-00	13,396.62	2,158.97	9,128.37	5,300.29	1,517.45	5,275.36	369.99	2,611.47	84.94	5,725.61	45,569.07
Industrial Water	4613-00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4,817.58	4,817.58
Multi User Water	4615-00	7,373.64	829.67	3,092.91	840.50	5,237.32	164.43	1,165.99	1,025.75	261.89	3,082.79	23,074.89
Other Water (WHOLESALE)	4614-00	0.00	0.00	0.00	0.00	12,238.02	0.00	0.00	0.00	862.64	0.00	13,100.66
Public Authority Water	4614-00	2,209.62	835.25	6,650.28	3,272.90	1,110.05	535.40	46.70	794.17	82.14	3,366.39	18,902.90
School Tax	2423-00	4,532.21	1,956.01	2,539.18	2,598.05	1,947.08	570.40	694.48	1,002.20	423.82	2,714.75	18,978.18
Sales Tax	2423-00	1,433.95	163.26	1,535.39	347.59	357.43	323.29	64.64	188.14	62.41	894.15	5,370.25
Residential Sewer	5211-17	36,451.15	0.00	29,647.47	2,969.03	5,167.02	3,421.96	0.00	443.01	12,516.05	43,332.19	133,947.88
Commercial Sewer	5212-17	14,641.15	0.00	14,252.79	0.00	513.16	113.19	0.00	0.00	894.74	8,346.03	38,761.06
Fire Hydrant	4621-00	50.00	0.00	0.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
Mall Charge	2421-00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Invoice Billing	4718-00	0.00	0.00	0.00	0.00	0.00	3,281.65	0.00	0.00	0.00	0.00	3,281.65
Total Taxes and other Charges	1411-00	6,016.16	2,119.27	4,074.57	2,995.64	2,304.51	893.69	759.12	1,190.34	486.23	3,608.90	24,448.43
Water Total	1411-00	151,198.71	65,557.09	84,783.24	86,782.54	77,370.09	19,014.96	23,175.55	33,416.44	14,953.53	90,605.05	646,857.20
Sewer Total	1427-17	51,092.30	0.00	43,900.26	2,969.03	5,680.18	3,535.15	0.00	443.01	13,410.79	51,678.22	172,708.94
Total not including Invoice Billings		208,307.17	67,676.36	132,758.07	92,747.21	85,354.78	23,443.80	23,934.67	35,049.79	28,850.55	145,892.17	844,014.57
Invoice Totals	1418-00	0.00	0.00	0.00	0.00	0.00	3,281.65	0.00	0.00	0.00	0.00	3,281.65
Total Billing		208,307.17	67,676.36	132,758.07	92,747.21	85,354.78	26,725.45	23,934.67	35,049.79	28,850.55	145,892.17	847,296.22
Total Adjustments												
Total After Adj.												

Gallons Sold
December 2019

	SV Cycle 1	M Cycle 2	PC Cycle 3	GV Cycle 4	BC Cycle 5	SV Cycle 6	M Cycle 7	M Cycle 8	PC Cycle 9	GV Cycle 10	Total by Type
Residential	11,279,510	5,267,380	5,917,130	6,713,500	5,131,260	1,146,230	1,860,600	2,480,780	1,203,570	6,343,130	47,343,090
Commercial	1,469,430	140,660	927,870	353,060	109,390	649,220	17,730	224,290	5,890	594,990	4,492,530
Industrial	-	-	-	-		-	-	-	-	651,000	651,000
Multi User	758,290	74,750	232,410	67,920	493,820	12,470	99,880	80,660	18,500	318,630	2,157,330
Other (WHOLESALE)	-	-	-	-	4,663,000	-	-	-	197,400	-	4,860,400
Public Authority	210,520	62,940	905,830	360,240	37,820	82,690	390	159,130	5,680	208,410	2,033,650
Total by Cycle	13,717,750	5,545,730	7,983,240	7,494,720	10,435,290	1,890,610	1,978,600	2,944,860	1,431,040	8,116,160	61,538,000

Sewer	**Cycle 1**	**Cycle 2**	**Cycle 3**	**Cycle 4**	**Cycle 5**	**Cycle 6**	**Cycle 7**	**Cycle 8**	**Cycle 9**	**Cycle 10**	**Total**
Total by Cycle	2,407,737	-	2,397,959	140,267	203,460	156,110	-	24,320	723,500	2,305,131	8,358,484

Water Adjustments	
Water After Adj.	61,538,000

Customer Count
December
2019

	SV Cycle 1	M Cycle 2	PC Cycle 3	GV Cycle 4	BC Cycle 5	SV Cycle 6	M Cycle 7	M Cycle 8	PC Cycle 9	GV Cycle 10	Total
Water	3859	1924	1990	2426	1634	408	665	914	405	2292	**16,517**
Sewer	599	0	378	49	104	72	0	8	218	761	**2189**
Total	4458	1924	2368	2475	1738	480	665	922	623	3053	18706

Residential	3658	1842	1816	2283	1564	376	632	853	393	2166	**15583**
Commercial	125	58	122	109	29	25	14	42	3	63	**590**
Industrial	0	0	0	0	0	0	0	0	0	2	**2**
Multi User	30	8	15	4	18	2	10	6	4	12	**109**
Public Authority	29	11	24	22	10	4	2	7	4	34	**147**
Multi Comm.	17	5	13	8	13	1	7	6	1	15	**86**
Res. Sewer	557	0	310	49	98	69	0	8	199	730	**2020**
Comm. Sewer	42	0	68	0	6	3	0	0	19	31	**169**
											18706

ATTACHMENT J

2018 EDITION OF THE DRINKING WATER STANDARDS AND HEALTH ADVISORIES TABLES

United States
Environmental Protection
Agency

2018 Edition of the Drinking Water Standards and Health Advisories Tables

The 2012 Drinking Water Standards and Health Advisories (DWSHA) Tables were amended March 2018 to fix typographical errors and add health advisories published after 2012.

2018 Edition of the Drinking Water Standards and Health Advisories

EPA 822-F-18-001

Office of Water
U.S. Environmental Protection Agency
Washington, DC

March 2018

The Health Advisory (HA) Program, sponsored by the EPA's Office of Water (OW), publishes concentrations of drinking water contaminants at Drinking Water Specific Risk Level Concentration for cancer (10^{-4} Cancer Risk) and concentrations of drinking water contaminants at which noncancer adverse health effects are not anticipated to occur over specific exposure durations - One-day, Ten-day, and Lifetime - in the *Drinking Water Standards and Health Advisories* (DWSHA) tables. The One-day and Ten-day HAs are for a 10 kg child and the Lifetime HA is for a 70 kg adult. The daily drinking water consumption for the 10 kg child and 70 kg adult are assumed to be 1 L/day and 2 L/day, respectively. The Lifetime HA for the drinking water contaminant is calculated from its associated Drinking Water Equivalent Level (DWEL), obtained from its RfD, and incorporates a drinking water Relative Source Contribution (RSC) factor of contaminant-specific data or a default of 20% of total exposure from all sources. Maximum Contaminant Levels (MCLs) and Maximum Contaminant Level Goals (MCLGs) for some regulated drinking water contaminants are also published.

HAs serve as the informal technical guidance for unregulated drinking water contaminants to assist Federal, State and local officials, and managers of public or community water systems in protecting public health as needed. They are not to be construed as legally enforceable Federal standards. EPA's OW has provided MCLs, MCLGs, RfDs, One-Day HAs, Ten-day HAs, DWELs, Lifetime HAs, Drinking Water Specific Risk Level Concentration for cancer (10^{-4} Cancer Risk), and Cancer Descriptors in the DWSHA tables. HAs are intended to protect against noncancer effects. The 10^{-4} Cancer Risk level provides information concerning cancer effects. The MCL values for specific drinking water contaminants must be used for regulated contaminants in public drinking water systems.

The DWSHA tables are revised periodically by the OW so that the benchmark values are consistent with the most current Agency assessments. Reference dose (RfD) values are updated to reflect the values in the Integrated Risk Information System (IRIS) and the Office of Pesticide Programs (OPP) Reregistration Eligibility Decisions (REDs) documents. The associated DWEL is recalculated accordingly. The 2018 DWSHA tables **do not** reflect assessments from IRIS or OPP published from 2012 to 2018. The DWSHA tables are currently undergoing a modernization effort to move the relevant HA information into a web-based format. This posting of the 2018 DWSHA tables is an intermediate step to address typographical errors and include health advisories published since the 2012 tables were published.

A Lifetime noncancer benchmark is made available to risk assessment managers for comparison to the cancer risk level drinking water concentration (10^{-4} Cancer Risk) and to determine whether the noncancer Lifetime HA or the cancer risk level drinking water concentration provides a more meaningful scenario-specific risk reduction. In this regard, the Office of Water defines the Lifetime HA as the concentration in drinking water that is not expected to cause any adverse noncarcinogenic effects for a lifetime of exposure, whereas the 10^{-4} Cancer Risk is the concentration of the chemical contaminant in drinking water that is associated with a specific probability of cancer. The Office of Water also advises consideration of the more conservative cancer risk levels (10^{-5}, 10^{-6}), found in the IRIS or OPP RED source documents, if it is considered more appropriate for exposure-specific risk assessment.

Many of the values on the DWSHA tables have been revised since the original HAs were published. Revised RfDs, 10^{-4} Cancer Risk values, and cancer designations or descriptors obtained from Integrated Risk Information System (IRIS) are presented in **BOLD** type. Revised RfDs, 10^{-4} Cancer Risk values, and cancer designations or descriptors obtained from Office of Pesticide Program's Registration Eligibility Decision (OPP RED) are presented in ***BOLD ITALICS*** type.

The summaries of IRIS Toxicological Reviews from which the RfDs and cancer benchmarks, as well as the associated narratives and references can be accessed at: http://www.epa.gov/IRIS. Those from OPP REDs can be accessed at: http://www.epa.gov/pesticides/reregistration/status.htm.

In some cases, there is an HA value for a contaminant but there is no reference to an HA document. Such HA values can be found in the Drinking Water Criteria Document for the contaminant.

With a few exceptions, the RfDs, Health Advisories, and Cancer Risk values have been rounded to one significant figure following the convention adopted by IRIS.

For unregulated chemicals with current IRIS or OPP REDs RfDs, the Lifetime Health Advisories are calculated from the associated DWELs, using the RSC values published in the HA documents for the contaminants.

The DWSHA tables may be reached from the Water Science home page at: http://www.epa.gov/waterscience/. The DWSHA tables are accessed under the Drinking Water icon.

Copies of the Tables may be ordered free of charge from

SAFE DRINKING WATER HOTLINE
1-800-426-4791
Monday thru Friday, 9:00 AM to 5:30 PM EST

DEFINITIONS

The following definitions for terms used in the DWSHA tables are not all-encompassing, and should not be construed to be "official" definitions. They are intended to assist the user in understanding terms used in the DWSHA tables.

Action Level: The concentration of a contaminant which, if exceeded, triggers treatment or other requirements which a water system must follow. For example, it is the level of lead or copper which, if exceeded in over 10% of the homes tested, triggers treatment for corrosion control.

Cancer Classification: A descriptive weight-of-evidence judgment as to the likelihood that an agent is a human carcinogen and the conditions under which the carcinogenic effects may be expressed. Under the 2005 EPA *Guidelines for Carcinogen Risk Assessment*, Cancer Descriptors replace the earlier alpha numeric Cancer Group designations (US EPA 1986 guidelines). The Cancer Descriptors in the 2005 EPA *Guidelines for Carcinogen Risk Assessment* are as follows:

- "carcinogenic to humans" (**H**)
- "likely to be carcinogenic to humans" (**L**)
- "likely to be carcinogenic above a specified dose but not likely to be carcinogenic below that dose because a key event in tumor formation does not occur below that dose" (**L/N**)
- "suggestive evidence of carcinogenic potential" (**S**)
- "inadequate information to assess carcinogenic potential" (**I**)
- "not likely to be carcinogenic to humans" (**N**)

The letter abbreviations provided parenthetically above are now used in the DWSHA tables in place of the prior alpha numeric identifiers for chemicals that have been evaluated under the new guidelines (the 2005 guidelines or the 1996 and 1999 draft guidelines) or whose records in the DWSHA tables have been revised.

Cancer Group: A qualitative weight-of-evidence judgment as to the likelihood that a chemical may be a carcinogen for humans. Each chemical was placed into one of the following five categories (US EPA 1986 guidelines). The Cancer Group designations are given in the Tables for chemicals that have not yet been evaluated under the new guidelines or whose records in the DWSHA tables have been revised.

Group	**Category**
A	Human carcinogen
B	Probable human carcinogen:
	B1 indicates limited human evidence
	B2 indicates sufficient evidence in animals and inadequate or no evidence in humans
C	Possible human carcinogen
D	Not classifiable as to human carcinogenicity
E	Evidence of noncarcinogenicity for humans

10^{-4} Cancer Risk: The concentration of a chemical in drinking water corresponding to an excess estimated lifetime cancer risk of 1 in 10,000.

Drinking Water Advisory: A nonregulatory concentration of a contaminant in water that is likely to be without adverse effects on health and aesthetics for the period it is derived.

DWEL: Drinking Water Equivalent Level. A DWEL is a drinking water lifetime exposure level, assuming **100%** exposure from that medium, at which adverse, noncarcinogenic health effects would not be expected to occur.

HA: Health Advisory. An estimate of acceptable drinking water levels for a chemical substance based on health effects information; an HA is not a legally enforceable Federal standard, but serves as technical guidance to assist Federal, State, and local officials.

> **One-Day HA:** The concentration of a chemical in drinking water that is not expected to cause any adverse noncarcinogenic effects for up to one day of exposure. The One-Day HA is intended to protect a 10-kg child consuming 1 liter of water per day.
>
> **Ten-Day HA:** The concentration of a chemical in drinking water that is not expected to cause any adverse noncarcinogenic effects for up to ten days of exposure. The Ten-Day HA is also intended to protect a 10-kg child consuming 1 liter of water per day.
>
> **Lifetime HA:** The concentration of a chemical in drinking water that is not expected to cause any adverse **noncarcinogenic effects** for a lifetime of exposure, incorporating a drinking water RSC factor of contaminant-specific data or a default of 20% of total exposure from all sources. The Lifetime HA is based on exposure of a 70-kg adult consuming 2 liters of water per day. For Lifetime HAs developed for drinking water contaminants before the Lifetime HA policy change to develop Lifetime HAs for all drinking water contaminants regardless of carcinogenicity status in this DWSHA update, the Lifetime HA for Group C carcinogens, as indicated by the 1986 Cancer Guidelines, includes an uncertainty adjustment factor of 10 for possible carcinogenicity.

MCLG: Maximum Contaminant Level Goal. A non-enforceable health benchmark goal which is set at a level at which no known or anticipated adverse effect on the health of persons is expected to occur and which allows an adequate margin of safety.

MCL: Maximum Contaminant Level. The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to the MCLG as feasible using the best available analytical and treatment technologies and taking cost into consideration. MCLs are enforceable standards.

Oral cancer slope factor: The slope factor is the result of application of a low-dose extrapolation procedure and is presented as the risk per (mg/kg)/day.

RfD: Reference Dose. An estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime.

Risk Specific Level Concentration: The concentration of the chemical contaminant in drinking water or air providing cancer risks of 1 in 10,000, 1 in 100,000, or 1 in 1,000,000.

SDWR: Secondary Drinking Water Regulations. Non-enforceable Federal guidelines regarding cosmetic effects (such as tooth or skin discoloration) or aesthetic effects (such as taste, odor, or color) of drinking water.

TT: Treatment Technique. A required process intended to reduce the level of a contaminant in drinking water.

Unit Risk: The unit risk is the quantitative estimate in terms of either risk per µg/L drinking water or risk per $\mu g/m^3$ air breathed.

ABBREVIATIONS

D	Draft
DWEL	Drinking Water Equivalent Level
DWSHA	Drinking Water Standards and Health Advisories
F	Final
HA	Health Advisory
I	Interim
IRIS	Integrated Risk Information System
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
NA	Not Applicable
NOAEL	No-Observed-Adverse-Effect Level
OPP	Office of Pesticide Programs
OW	Office of Water
P	Proposed
Pv	Provisional
RED	Registration Eligibility Decision
Reg	Regulation
RfD	Reference Dose
TT	Treatment Technique

Drinking Water Standards and Health Advisories

		Standards				Health Advisories						
						10-kg Child						
Chemicals	**CASRN Number**	**Status Reg.**	**MCLG (mg/L)**	**MCL (mg/L)**	**Status HA Document**	**One-day (mg/L)**	**Ten-day (mg/L)**	**RfD (mg/kg/day)**	**DWEL (mg/L)**	**Life-time (mg/L)**	**mg/L at 10^{-4} Cancer Risk**	**Cancer Descriptor[1]**
						ORGANICS						
Acenaphthene	83-32-9	-	-	-	-	-	-	0.06	2	-	-	-
Acifluorfen (sodium)	62476-59-9		-	-	F ’88	2	2	0.01	0.4	-	0.1	***L/N***
Acrylamide	79-06-1	F	zero	TT[2]	F ‘87	1.5	0.3	**0.002**	0.07	-	-	**L**
Acrylonitrile	107-13-1		-	-	-	-	-	-	-	-	0.006	B1
Alachlor	15972-60-8	F	zero	0.002	F ‘88	0.1	0.1	0.01	0.4	-	***0.04***	***B2***
Aldicarb[3]	116-06-3	F[4]	0.001	0.003	F ‘95	0.01	0.01	0.001	0.035	0.007	-	D
Aldicarb sulfone[3]	1646-88-4	F[4]	0.001	0.002	F ‘95	0.01	0.01	0.001	0.035	0.007	-	D
Aldicarb sulfoxide[3]	1646-87-3	F[4]	0.001	0.004	F ‘95	0.01	0.01	0.001	0.035	0.007	-	D
Aldrin	309-00-2	-	-	-	F ‘92	0.0003	0.0003	0.00003	0.001	-	0.0002	B2
Ametryn	834-12-8	-	-	-	F ‘88	9	9	0.009	0.3	0.06	-	D
Ammonium sulfamate	7773-06-0	-	-	-	F ‘88	20	20	0.2	8	2	-	D
Anthracene (PAH)[5]	120-12-7	-	-	-	-	-	-	0.3	10	-	-	D
Atrazine	1912-24-9	F	0.003	0.003	F ‘88	-	-	***0.02***	0.7	-	-	***N***
Baygon	114-26-1	-	-	-	F ‘88	0.04	0.04	0.004	0.1	0.003	-	C
Bentazon	25057-89-0	-	-	-	F ‘99	0.3	0.3	0.03	1	0.2	-	E
Benz[a]anthracene (PAH)	56-55-3	-	-	-	-	-	-	-	-	-	-	B2
Benzene	71-43-2	F	zero	0.005	F ’87	0.2	0.2	**0.004**	0.1	**0.003**	**1 to 10**	**H**
Benzo[a]pyrene (PAH)	50-32-8	F	zero	0.0002	-	-	-	-	-	-	0.0005	B2
Benzo[b]fluoranthene (PAH)	205-99-2	-	-	-	-	-	-	-	-	-	-	B2
Benzo[g,h,i]perylene (PAH)	191-24-2	-	-	-	-	-	-	-	-	-	-	D
Benzo[k]fluoranthene (PAH)	207-08-9	-	-	-	-	-	-	-	-	-	-	B2
Bis(2-chloro-1-methylethyl) ether	108-60-1	-	-	-	F ‘89	4	4	**0.04**	1	0.3	-	**-**
Bromacil	314-40-9	-	-	-	F ‘88	5	5	***0.1***	3.5	0.07	-	C
Bromobenzene	108-86-1	-	-	-	D ‘86	4	4	**0.008**	0.3	**0.06**	-	**I**

[1] Chemicals evaluated under the 2005 Cancer Guidelines or the 1996 or 1999 drafts are demoted by an abbreviation for their weight-of-the-evidence descriptor (see page iii). If the agency has not completed a new assessment for the chemical, the 1986 Guidelines Group designation (see page iii) is given in the Cancer Descriptor column.

[2] When Acrylamide is used in drinking water systems, the combination (or product) of dose and monomer level shall not exceed that equivalent to a polyacrylamide polymer containing 0.05% monomer dosed at 1 mg/L.

[3] The MCL value for any combination of two or more of these three chemicals should not exceed 0.007 mg/L because of a similar mode of action.

[4] Administrative stay of the effective date.

[5] PAH = Polycyclic aromatic hydrocarbon.

Drinking Water Standards and Health Advisories

		Standards				**Health Advisories**						
						10-kg Child						
Chemicals	**CASRN Number**	**Status Reg.**	**MCLG (mg/L)**	**MCL (mg/L)**	**Status HA Document**	**One-day (mg/L)**	**Ten-day (mg/L)**	**RfD (mg/kg/day)**	**DWEL (mg/L)**	**Life-time (mg/L)**	**mg/L at 10^{-4} Cancer Risk**	**Cancer Descriptor**
Bromochloromethane	74-97-5	-	-	-	F '89	50	1	0.01	0.5	0.09	-	D
Bromodichloromethane (THM)	75-27-4	F	zero	0.08[1]	-	1	0.6	0.003	0.1	-	0.1	L
Bromoform (THM)	75-25-2	F	zero	0.08[1]	-	5	0.2	0.03	1	-	0.8	L
Bromomethane	74-83-9	-	-	-	D '89	0.1	0.1	0.001	0.05	0.01	-	D
Butyl benzyl phthalate	85-68-7	-	-	-	-	-	-	0.2	7	-	-	C
Butylate	2008-41-5	-	-	-	F '89	2	2	0.05	2	0.4	-	D
Carbaryl	63-25-2	-	-	-	F '88	1	1	***0.01***	0.4	-	4	***L***
Carbofuran	1563-66-2	F	0.04	0.04	F '87	-	-	***0.00006***	-	-	-	***N***
Carbon tetrachloride	56-23-5	F	zero	0.005	F '87	4	0.2	**0.004**	0.1	**0.03**	**0.05**	**L**
Carboxin	5234-68-4	-	-	-	F '88	1	1	0.1	3.5	0.7	-	D
Chloramben	133-90-4	-	-	-	F '88	3	3	0.015	0.5	0.1	-	D
Chlordane	12798-03-6	F	zero	0.002	F '87	0.06	0.06	**0.0005**	0.02	**0.004**	**0.01**	B2
Chloroform (THM)	67-66-3	F	0.07	0.08[1]	-	4	4	**0.01**	0.35	0.07	-	**L/N**
Chloromethane	74-87-3	-	-	-	F '89	9	0.4	-	-	-	-	**I**
Chlorophenol (2-)	95-57-8	-	-	-	D '94	0.5	0.5	0.005	0.2	0.04	-	D
Chlorothalonil	1897-45-6	-	-	-	F '88	0.2	0.2	0.015	0.5	-	0.15	B2
Chlorotoluene o-	95-49-8	-	-	-	F '89	2	2	0.02	0.7	0.1	-	D
Chlorotoluene p-	106-43-4	-	-	-	F '89	2	2	0.02	0.7	0.1	-	D
Chlorpyrifos	2921-88-2	-	-	-	F '92	0.03	0.03	***0.0003***	0.01	0.002	-	***D***
Chrysene (PAH)	218-01-9	-	-	-	-	-	-	-	-	-	-	B2
Cyanazine	21725-46-2	-	-	-	D '96	0.1	0.1	0.002	0.07	0.001	-	

[1] 1998 Final Rule for Disinfectants and Disinfection By-products: The total for trihalomethanes (THM) is 0.08 mg/L.

Drinking Water Standards and Health Advisories

Chemicals	CASRN Number	Standards			Status HA Document	Health Advisories						Cancer Descriptor
						10-kg Child						
		Status Reg.	MCLG (mg/L)	MCL (mg/L)		One-day (mg/L)	Ten-day (mg/L)	RfD (mg/kg/day)	DWEL (mg/L)	Life-time (mg/L)	mg/L at 10^{-4} Cancer Risk	
Cyanogen chloride[1]	506-77-4	-	-	-	-	0.05	0.05	0.05	2	-	-	D
2,4-D (2,4-dichlorophenoxyacetic acid)	94-75-7	F	0.07	0.07	F '87	1	0.3	***0.005***	0.2	-	-	***D***
DCPA (Dacthal)	1861-32-1	-	-	-	F '08	2	2	***0.01***	0.35	0.07	-	***C***
Dalapon (sodium salt)	75-99-0	F	0.2	0.2	F '89	3	3	0.03	0.9	0.2	-	D
Di(2-ethylhexyl)adipate	103-23-1	F	0.4	0.4	-	20	20	0.6	20	0.4	3	C
Di(2-ethylhexyl)phthalate	117-81-7	F	zero	0.006	-	-	-	0.02	0.7	-	0.3	B2
Diazinon	333-41-5	-	-	-	F '88	0.02	0.02	***0.0002***	0.007	0.001	-	***E***
Dibromochloromethane (THM)	124-48-1	F	0.06	0.08[2]	-	0.6	0.6	0.02	0.7	0.06	0.08	S
Dibromochloropropane (DBCP)	96-12-8	F	zero	0.0002	F '87	0.2	0.05	-	-	-	0.003	B2
Dibutyl phthalate	84-74-2	-	-	-	-	-	-	**0.1**	4	-	-	D
Dicamba	1918-00-9	-	-	-	F '88	-	-	***0.5***	18	4	-	*N*
Dichloroacetic acid	76-43-6	F	zero	0.06[3]	-	**3**	**3**	**0.004**	0.1	**0.03**	**0.07**	**L**
Dichlorobenzene o-	95-50-1	F	0.6	0.6	F '87	9	9	0.09	3	0.6	-	D
Dichlorobenzene — [4]	541-73-1	-	-	-	F '87	9	9	0.09	3	0.6	-	D
Dichlorobenzene p-	106-46-7	F	0.075	0.075	F '87	11	11	0.1	4	0.075	-	C
Dichlorodifluoromethane	75-71-8	-	-	-	F '89	40	40	0.2	5	1	-	D
Dichloroethane (1,2-)	107-06-2	F	zero	0.005	F '87	0.7	0.7	-	-	-	0.04	B2
Dichloroethylene (1,1-)	75-35-4	F	0.007	0.007	F '87	2	1	**0.05**	2	**0.4**	**0.006**	**S**
Dichloroethylene (cis-1,2-)	156-59-2	F	0.07	0.07	F '90	4	**3**	**0.002**	0.07	**0.01**	-	**I**
Dichloroethylene (trans-1,2-)	156-60-5	F	0.1	0.1	F '87	20	**2**	**0.02**	0.7	0.1	-	**I**
Dichloromethane	75-09-2	F	zero	0.005	D '93	10	2	0.06	2	**0.2**	0.5	**L**
Dichlorophenol (2,4-)	120-83-2	-	-	-	D '94	0.03	0.03	0.003	0.1	0.02	-	E
Dichloropropane (1,2-)	78-87-5	F	zero	0.005	F '87	-	0.09	-	-	-	0.06	B2
Dichloropropene (1,3-)	542-75-6	-	-	-	F '88	0.03	0.03	**0.03**	1	-	**0.04**	**L**
Dieldrin	60-57-1	-	-	-	F '88	0.0005	0.0005	0.00005	0.002	-	0.0002	B2
Diethyl phthalate	84-66-2	-	-	-	-	-	-	0.8	30	-	-	D

[1] Under review.
[2] 1998 Final Rule for Disinfectants and Disinfection By-products: The total for trihalomethanes is 0.08 mg/L.
[3] 1998 Final Rule for Disinfectants and Disinfection By-products: The total for five haloacetic acids is 0.06 mg/L.
[4] The values for m-dichlorobenzene are based on data for o-dichlorobenzene.

		Standards				Health Advisories						
						10-kg Child						
Chemicals	**CASRN Number**	**Status Reg.**	**MCLG (mg/L)**	**MCL (mg/L)**	**Status HA Document**	**One-day (mg/L)**	**Ten-day (mg/L)**	**RfD (mg/kg/day)**	**DWEL (mg/L)**	**Life-time (mg/L)**	**mg/L at 10^{-4} Cancer Risk**	**Cancer Descriptor**
Diisopropylmethylphosphonate	1445-75-6	-	-	-	F '89	8	8	0.08	3	0.6	-	D
Dimethrin	70-38-2	-	-	-	F '88	10	10	0.3	10	2	-	D
Dimethyl methylphosphonate	756-79-6	-	-	-	F '92	2	2	0.2	7	0.1	0.7	C
Dimethyl phthalate	131-11-3	-	-	-	-	-	-	-	-	-	-	D
Dinitrobenzene (1,3-)	99-65-0	-	-	-	F '91	0.04	0.04	0.0001	0.005	0.001	-	D
Dinitrotoluene (2,4-)	121-14-2	-	-	-	F '08	1	1	0.002	0.1	-	0.005	L
Dinitrotoluene (2,6-)	606-20-2	-	-	-	F '08	0.4	0.04	0.001	0.04	-	0.005	L
Dinitrotoluene (2,6 & 2,4)[1]		-	-	-	F '92	-	-	-	-	-	0.005	B2
Dinoseb	88-85-7	F	0.007	0.007	F '88	0.3	0.3	0.001	0.035	0.007	-	D
Dioxane p-	123-91-1	-	-	-	F '87	4	0.4	**0.03**	1	0.2	**0.035**	**L**
Diphenamid	957-51-7	-	-	-	F '88	0.3	0.3	0.03	1	0.2	-	D
Diquat	85-00-7	F	0.02	0.02	-	-	-	***0.005***	0.02	-	-	***E***
Disulfoton	298-04-4	-	-	-	F '88	0.01	0.01	***0.0001***	0.0035	0.0007	-	***E***
Dithiane (1,4-)	505-29-3	-	-	-	F '92	0.4	0.4	0.01	0.4	0.08	-	D
Diuron	330-54-1	-	-	-	F '88	1	1	***0.003***	0.1	-	***0.2***	***L***
Endothall	145-73-3	F	0.1	0.1	F '88	0.8	0.8	***0.007***	0.25	0.05	-	***N***
Endrin	72-20-8	F	0.002	0.002	F '87	0.02	0.005	**0.0003**	0.01	0.002	-	I
Epichlorohydrin	106-89-8	F	zero	TT[2]	F '87	0.1	0.1	0.002	0.07	-	**0.3**	B2
Ethylbenzene	100-41-4	F	0.7	0.7	F '87	30	3	0.1	3	0.7	-	D
Ethylene dibromide (EDB)[3]	106-93-4	F	zero	0.00005	F '87	0.008	0.008	**0.009**	0.3	-	**0.002**	**L**
Ethylene glycol	107-21-1	-	-	-	F '87	20	6	**2**	70	14	-	D
Ethylene Thiourea (ETU)	96-45-7	-	-	-	F '88	0.3	0.3	***0.0002***	0.007	-	***0.06***	B2
Fenamiphos	22224-92-6	-	-	-	F '88	0.009	0.009	***0.0001***	0.0035	0.0007	-	***E***

[1] Technical grade.

[2] When epichlorohydrin is used in drinking water systems, the combination (or product) of dose and monomer level shall not exceed that equivalent to an epichlorohydrin-based polymer containing 0.01% monomer dosed at 20 mg/L.

[3] 1,2-dibromoethane.

Chemicals	CAS Number	Standards			Status HA Standards	Health Advisories						Cancer Descriptor
						10-kg Child						
		Status Reg.	MCLG (mg/L)	MCL (mg/L)		One-day (mg/L)	Ten-day (mg/L)	RfD (mg/kg/day)	DWEL (mg/L)	Life-time (mg/L)	mg/L at 10^{-4} Cancer Risk	
Fluometuron	2164-17-2	-	-	-	F '88	2	2	0.01	0.5	0.09		D
Fluorene (PAH)	86-73-7	-	-	-	-	-	-	0.04	1	-	-	D
Fonofos	944-22-9	-	-	-	F '88	0.02	0.02	0.002	0.07	0.01	-	D
Formaldehyde	50-00-0	-	-	-	D '93	10	5	**0.2**	7	1	-	B1[1]
Glyphosate	1071-83-6	F	0.7	0.7	F '88	20	20	***2***	70	-	-	D
Heptachlor	76-44-8	F	zero	0.0004	F '87	0.01	0.01	0.0005	0.02	-	0.0008	B2
Heptachlor epoxide	1024-57-3	F	zero	0.0002	F '87	0.01	-	0.00001	0.0004	-	0.0004	B2
Hexachlorobenzene	118-74-1	F	zero	0.001	F '87	0.05	0.05	0.0008	0.03	-	0.002	B2
Hexachlorobutadiene[2]	87-68-3	-	-	-	-	0.3	0.3	0.0003	0.01	-	0.09	L
Hexachlorocyclopentadiene	77-47-4	F	0.05	0.05	-	-	-	**0.006**	0.2	-	-	**N**
Hexachloroethane	67-72-1	-	-	-	F '91	5	5	0.001	0.04	0.001	**0.3**	C
Hexane (n-)	110-54-3	-	-	-	F '87	10	4	-	-	-	-	**I**
Hexazinone	51235-04-2	-	-	-	F '96	3	2	***0.05***	2	0.4	-	D
HMX[3]	2691-41-0	-	-	-	F '88	5	5	0.05	2	0.4	-	D
Indeno[1,2,3,-c,d]pyrene (PAH)	193-39-5	-	-	-	-	-	-	-	-	-	-	B2
Isophorone	78-59-1	-	-	-	F '92	15	15	0.2	7	0.1	4	C
Isopropyl methylphosphonate	1832-54-8	-	-	-	F '92	30	30	0.1	3.5	0.7	-	D
Isopropylbenzene (cumene)	98-82-8	-	-	-	D '87	11	11	0.1	4	-	-	D
Lindane[4]	58-89-9	F	0.0002	0.0002	F '87	1	1	***0.005***	0.2	-	-	***S***
Malathion	121-75-5	-	-	-	F '92	0.2	0.2	***0.07***	2	0.5	-	***S***
Maleic hydrazide	123-33-1	-	-	-	F '88	10	10	0.5	20	4	-	D
MCPA[5]	94-74-6	-	-	-	F '88	0.1	0.1	***0.004***	0.14	0.03	-	***N***
Methomyl	16752-77-5	-	-	-	F '88	0.3	0.3	0.025	0.9	0.2	-	E
Methoxychlor	72-43-5	F	0.04	0.04	F '87	0.05	0.05	**0.005**	0.2	0.04	-	D
Methyl ethyl ketone	78-93-3	-	-	-	F '87	75	7.5	**0.6**	20	4	-	D
Methyl parathion	298-00-0	-	-	-	F '88	0.3	0.3	***0.0002***	0.007	0.001	-	***N***

[1] Carcinogenicity based on inhalation exposure.
[2] Regulatory Determination Health Effects Support Document for Hexachlorobutadiene (http://www.epa.gov/safewater/ccl/pdfs/reg_determine1/support_cc1_hexachlorobutadiene_healtheffects.pdf).
[3] HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
[4] Lindane = γ – hexachlorocyclohexane.
[5] MCPA = 4 (chloro-2-methoxyphenoxy) acetic acid.

Drinking Water Standards and Health Advisories

Chemicals	CASRN Number	Standards			Status HA Document	Health Advisories						Cancer Descriptor
						10-kg Child						
		Status Reg.	MCLG (mg/L)	MCL (mg/L)		One-day (mg/L)	Ten-day (mg/L)	RfD (mg/kg/day)	DWEL (mg/L)	Life-time (mg/L)	mg/L at 10^{-4} Cancer Risk	
Metolachlor	51218-45-2	-	-	-	F '88	2	2	***0.1***	3.5	0.7	-	***C***
Metribuzin	21087-64-9	-	-	-	F '88	5	5	***0.01***	0.35	0.07	-	***D***
Monochloroacetic acid	79-11-8	F	0.07	0.06[1]	-	0.2	0.2	0.01	0.35	0.07	-	I
Monochlorobenzene	108-90-7	F	0.1	0.1	F '87	4	4	**0.02**	0.7	0.1	-	D
Naphthalene	91-20-3	-	-	-	F '90	0.5	0.5	**0.02**	0.7	0.1	-	**I**
Nitrocellulose[2]	9004-70-0	-	-	-	F '88	-	-	-	-	-	-	-
Nitroguanidine	556-88-7	-	-	-	F '90	10	10	0.1	3.5	0.7	-	D
Nitrophenol p-	100-02-7	-	-	-	F '92	0.8	0.8	0.008	0.3	0.06	-	D
N-nitrosodimethylamine		-	-	-	-	-	-	-	-	**-**	**0.00007**	**B2**
Oxamyl (Vydate)	23135-22-0	F	0.2	0.2	F '05	0.01	0.01	0.001	0.035		-	N
Paraquat	1910-42-5	-	-	-	F '88	0.1	0.1	***0.0045***	0.2	0.03	-	***E***
Pentachlorophenol	87-86-5	F	zero	0.001	F '87	1	0.3	**0.005**	0.2	0.04	**0.009**	**L**
PFOA	335-67-1	-	-	-	F '16	-	-	2×10^{-5}	3.7×10^{-4}	7×10^{-5}	5×10^{-2}	S
PFOS	1763-23-1	-	-	-	F '16	-	-	2×10^{-5}	3.7×10^{-4}	7×10^{-5}	-	S
Phenanthrene (PAH)	85-01-8	-	-	-	-	-	-	-	-	-	-	D
Phenol	108-95-2	-	-	-	D '92	6	6	**0.3**	11	2	-	D
Picloram	1918-02-1	F	0.5	0.5	F '88	20	20	***0.02***	0.7	-	-	D
Polychlorinated biphenyls (PCBs)	1336-36-3	F	zero	0.0005	D '93	-	-	-	-	-	0.01	B2
Prometon	1610-18-0	-	-	-	F '88	0.2	0.2	***0.05***	2	0.4	-	***N***
Pronamide	23950-58-5	-	-	-	F '88	0.8	0.8	***0.08***	3	-	***0.1***	***B2***
Propachlor	1918-16-7	-	-	-	F '88	0.5	0.5	***0.05***	2	-	0.1	***L***
Propazine	139-40-2	-	-	-	F '88	-	-	***0.02***	0.7	0.01	-	***N***
Propham	122-42-9	-	-	-	F '88	5	5	0.02	0.6	0.1	-	D
Pyrene (PAH)	129-00-0	-	-	-	-	-	-	0.03	-	-	-	D
RDX[3]	121-82-4	-	-	-	F '88	0.1	0.1	0.003	0.1	0.002	0.03	C
Simazine	122-34-9	F	0.004	0.004	F '88	-	-	***0.02***	0.7	-	-	***N***
Styrene	100-42-5	F	0.1	0.1	F '87	20	2	0.2	7	0.1	-	C
2,4,5-T (Trichlorophenoxy-acetic acid)	93-76-5	-	-	-	F '88	0.8	0.8	0.01	0.35	0.07	-	D

[1] 1998 Final Rule for Disinfectants and Disinfection By-products: the total for five haloacetic acids is 0.06 mg/L.
[2] The Health Advisory Document for nitrocellulose does not include HA values and describes this compound as relatively nontoxic.
[3] RDX = hexahydro -1,3,5-trinitro-1,3,5-triazine.

Drinking Water Standards and Health Advisories

Chemicals	CASRN Number	Standards			Status HA Document	Health Advisories						Cancer Descriptor
						10-kg Child						
		Status Reg.	MCLG (mg/L)	MCL (mg/L)		One-day (mg/L)	Ten-day (mg/L)	RfD (mg/kg/day)	DWEL (mg/L)	Life-time (mg/L)	mg/L at 10^{-4} Cancer Risk	
2,3,7,8-TCDD (Dioxin)	1746-01-6	F	zero	3E-08	F '87	1E-06	1E-07	1E-09	4E-08	-	2E-08	B2
Tebuthiuron	34014-18-1	-	-	-	F '88	3	3	0.07	2	0.5	-	D
Terbacil	5902-51-2	-	-	-	F '88	0.3	0.3	0.01	0.4	0.09	-	E
Terbufos	13071-79-9	-	-	-	F '88	0.005	0.005	***0.00005***	0.002	0.0004	-	D
Tetrachloroethane (1,1,1,2-)	630-20-6	-	-	-	F '89	2	2	0.03	1	0.07	0.1	C
Tetrachloroethane (1,1,2,2-)	79-34-5	-	-	-	F '08	3	3	0.01	0.4	-	0.04	L
Tetrachloroethylene[1]	127-18-4	F	zero	0.005	F '87	2	2	0.01	0.5	0.01	-	-
Tetrachloroterephthalic acid	236-79-0	-	-	-	F '08	100	100	-	-	-	-	I
Trichlorofluoromethane	75-69-4	-	-	-	F '89	7	7	0.3	10	2	-	D
Toluene	108-88-3	F	1	1	D '93	20	2	**0.08**	3	-	-	**I**
Toxaphene	8001-35-2	F	zero	0.003	F '96	0.004	0.004	0.0004	0.01	-	0.003	B2
2,4,5-TP (Silvex)	93-72-1	F	0.05	0.05	F '88	0.2	0.2	0.008	0.3	0.05	-	D
Trichloroacetic acid	76-03-9	F	0.02	0.06[2]	-	3	3	0.03	1	0.02	-	S
Trichlorobenzene (1,2,4-)	120-82-1	F	0.07	0.07	F '89	0.1	0.1	**0.01**	0.35	0.07	-	D
Trichlorobenzene (1,3,5-)	108-70-3	-	-	-	F '89	0.6	0.6	0.006	0.2	0.04	-	D
Trichloroethane (1,1,1-)	71-55-6	F	0.2	0.2	F '87	100	40	**2**	70	-	-	**I**
Trichloroethane (1,1,2-)	79-00-5	F	0.003	0.005	F '89	0.6	0.4	0.004	0.1	0.003	0.06	C
Trichloroethylene [1]	79-01-6	F	zero	0.005	F '87	-	-	0.007	0.2	-	0.3	B2
Trichlorophenol (2,4,6-)	88-06-2	-	-	-	D '94	0.03	0.03	0.0003	0.01	-	0.3	B2
Trichloropropane (1,2,3-)	96-18-4	-	-	-	F '89	0.6	0.6	**0.004**	0.1	-	-	**L**
Trifluralin	1582-09-8	-	-	-	F '90	0.08	0.08	***0.02***	0.7	0.01	0.4	***C***
Trimethylbenzene (1,2,4-)	95-63-6	-	-	-	D '87	-	-	-	-	-	-	D
Trimethylbenzene (1,3,5-)	108-67-8	-	-	-	D '87	10	-	-	-	-	-	D
Trinitroglycerol	55-63-0	-	-	-	F '87	0.005	0.005	-	-	0.005	0.2	-
Trinitrotoluene (2,4,6-)	118-96-7	-	-	-	F '89	0.02	0.02	0.0005	0.02	0.002	0.1	C
Vinyl chloride	75-01-4	F	zero	0.002	F '87	3	3	**0.003**	0.1	-	**0.002**	**H**
Xylenes	1330-20-7	F	10	10	D '93	40	40	**0.2**	7	-	-	**I**

[1] Under review.
[2] 1998 Final Rule for Disinfectants and Disinfection By-products: The total for five haloacetic acids is 0.06 mg/L.

Drinking Water Standards and Health Advisories

Chemicals	CASRN Number	Standards			Status HA Document	Health Advisories						Cancer Descriptor
						10-kg Child						
		Status Reg.	MCLG (mg/L)	MCL (mg/L)		One-day (mg/L)	Ten-day (mg/L)	RfD (mg/kg/day)	DWEL (mg/L)	Life-time (mg/L)	mg/L at 10^{-4} Cancer Risk	
INORGANICS												
Ammonia	7664-41-7	-	-	-	D ‘92	-	-	-	-	30	-	D
Antimony	7440-36-0	F	0.006	0.006	F ‘92	0.01	0.01	0.0004	0.01	0.006	-	D
Arsenic	7440-38-2	F	zero	0.01	-	-	-	**0.0003**	0.01	-	**0.002**	A
Asbestos (fibers/l >10Fm length)	1332-21-4	F	7 MFL[1]	7 MFL	-	-	-	-	-	-	700-MFL	A[2]
Barium	7440-39-3	F	2	2	D ‘93	0.7	0.7	**0.2**	7	-	-	**N**
Beryllium	7440-41-7	F	0.004	0.004	F ‘92	30	30	**0.002**	0.07	-	-	-
Boron	7440-42-8	-	-	-	F ‘08	3	3	**0.2**	7	6	-	**I**
Bromate	7789-38-0	F	zero	0.01	D ‘98	0.2	-	**0.004**	0.14	-	0.005	B2
Cadmium	7440-43-9	F	0.005	0.005	F ’87	0.04	0.04	0.0005	0.02	0.005	-	D
Chloramine[3]	10599-90-3	F	4[4]	4[4]	D ‘95	-	-	0.1	3.5	3.0	-	-
Chlorine	7782-50-5	F	4[4]	4[4]	D ‘95	3	3	0.1	5	4	-	D
Chlorine dioxide	10049-04-4	F	0.8[4]	0.8[4]	D ‘98	0.8	0.8	0.03	1	0.8	-	D
Chlorite	7758-19-2	F	0.8	1	D ‘98	0.8	0.8	0.03	1	0.8	-	D
Chromium (total)	7440-47-3	F	0.1	0.1	F ‘87	1	1	**0.003**[5]	0.1	-	-	D
Copper (at tap)	7440-50-8	F	1.3	TT[6]	D ‘98	-	-	-	-	-	-	D
Cyanide	143-33-9	F	0.2	0.2	F ‘87	0.2	0.2	**0.0006**[7]	-	-	-	**I**
Fluoride	7681-49-4	F	4	4	-	-[8]	-	**0.06**[9]	-	-	-	-
Lead (at tap)	7439-92-1	F	zero	TT[6]	-	-	-	-	-	-	-	B2
Manganese	7439-96-5	-	-	-	F”04	1	1	0.14[10]	1.6	0.3	-	D
Mercury (inorganic)	7487-94-7	F	0.002	0.002	F ‘87	0.002	0.002	**0.0003**	0.01	0.002	-	D
Molybdenum	7439-98-7	-	-	-	D ‘93	0.08	0.08	0.005	0.2	0.04	-	D
Nickel	7440-02-0	F	-	-	F ‘95	1	1	0.02	0.7	0.1	-	-

[1] MFL = million fibers per liter.
[2] Carcinogenicity based on inhalation exposure.
[3] Monochloramine; measured as free chlorine.
[4] 1998 Final Rule for Disinfectants and Disinfection By-products: MRDLG=Maximum Residual Disinfection Level Goal; and MRDL=Maximum Residual Disinfection Level.
[5] IRIS value for chromium VI.
[6] Copper action level 1.3 mg/L; lead action level 0.015 mg/L.
[7] This RfD is for hydrogen cyanide.
[8] In case of overfeed of the fluoridation chemical see CDC Guidelines in Engineering and Administrative Recommendations on Water Fluoridation www.cdc.gov/mmwr/preview/mmwrhtml/00039178.htm. Elevated F levels ≥ 10mg/L require action by the water system operator.
[9] Based on dental fluorosis in children, a cosmetic effect. MCLG based on skeletal fluorosis.
[10] Dietary manganese. The lifetime health advisory includes a 3 fold modifying factor to account for increased bioavailability from drinking water.

		Standards				Health Advisories						
						10-kg Child						
Chemicals	**CASRN Number**	**Status Reg.**	**MCLG (mg/L)**	**MCL (mg/L)**	**Status HA Document**	**One-day (mg/L)**	**Ten-day (mg/L)**	**RfD (mg/kg/day)**	**DWEL (mg/L)**	**Life- time (mg/L)**	**mg/L at 10^{-4} Cancer Risk**	**Cancer Descriptor**
Nitrate (as N)	14797-55-8	F	10	10	D '93	10[1]	10[1]	1.6	-	-	-	-
Nitrite (as N)	14797-65-0	F	1	1	D '93	1[1]	1[1]	0.16	-	-	-	-
Nitrate + Nitrite (both as N)		F	10	10	D '93	-	-	-	-	-	-	-
Perchlorate[2]	14797-73-0	-	-	-	I '08	-	-	0.007	0.025	0.015	-	L/N
Selenium	7782-49-2	F	0.05	0.05	-	-	-	0.005	0.2	0.05	-	D
Silver	7440-22-4	-	-	-	F '92	0.2	0.2	0.005[3]	0.2	0.1[3]	-	D
Strontium	7440-24-6	-	-	-	D '93	25	25	**0.6**	20	4	-	D
Thallium	7440-28-0	F	0.0005	0.002	F '92	0.007	0.007	-	-	-	-	**I**
White phosphorous	7723-14-0	-	-	-	F '90	-	-	0.00002	0.0005	0.0001		D
Zinc	7440-66-6	-	-	-	D '93	6	6	0.3	10	2	-	**I**
RADIONUCLIDES												
Beta particle and photon activity (formerly man-made radionuclides)		F	zero	4 mrem/yr	-	-	-	-	-		4 mrem/yr	A
Gross alpha particle activity		F	zero	15 pCi/L	-	-	-	-	-	-	15 pCi/L	A
Combined Radium 226 & 228	7440-14-4	F	zero	5 pCi/L	-	-	-	-	-	-	-	A
Radon	10043-92-2	P	zero	300 pCi/L AMCL[4] 4000 pCi/L	-	-	-	-	-	-	150 pCi/L	A
Uranium	7440-61-1	F	zero	0.03	-	-	-	0.0006[5]	0.02	-	-	A

[1] These values are calculated for a 4-kg infant and are protective for all age groups.
[2] Subchronic value for pregnant women.
[3] Based on a cosmetic effect.
[4] AMCL = Alternative Maximum Contaminant Level.
[5] Soluble uranium salts. Radionuclide Rule.

Secondary Drinking Water Regulations

Chemicals	CAS Number	Status	SDWR
Aluminum	7429-90-5	F	0.05 to 0.2 mg/L
Chloride	7647-14-5	F	250 mg/L
Color	NA	F	15 color units
Copper	7440-50-8	F	1.0 mg/L
Corrosivity	NA	F	non-corrosive
Fluoride	7681-49-4	F	2.0 mg/L
Foaming agents	NA	F	0.5 mg/L
Iron	7439-89-6	F	0.3 mg/L
Manganese	7439-96-5	F	0.05 mg/L
Odor	NA	F	3 threshold odor numbers
pH	NA	F	6.5 – 8.5
Silver	7440-22-4	F	0.1 mg/L
Sulfate	7757-82-6	F	250 mg/L
Total dissolved solids (TDS)	NA	F	500 mg/L
Zinc	7440-66-6	F	5 mg/L

Microbiology

	Status Reg.	Status HA Document	MCLG	MCL	Treatment Technique
Cryptosporidium	F	F 01	zero	TT	Systems that filter must remove 99% of *Cryptosporidium*
Cylindrospermosin	-	F 15	-	-	-
Cyanobacterial Microcystin Toxins	-	F 15	-	-	-
Giardia lamblia	F	F 98	zero	TT	99.9% killed/inactivated
Legionella	F[1]	F 01	zero	TT	No limit; EPA believes that if *Giardia* and viruses are inactivated, *Legionella* will also be controlled
Heterotrophic Plate Count (HPC)	F[1]	-	NA	TT	No more than 500 bacterial colonies per milliliter.
Mycobacteria	-	F 99	-	-	-
Total Coliforms	F	-	zero	5%	No more than 5.0% samples total coliform-positive in a month. Every sample that has total coliforms must be analyzed for fecal coliforms; no fecal coliforms are allowed.
Turbidity	F	-	NA	TT	At no time can turbidity go above 5 NTU (nephelometric turbidity units)
Viruses	F[1]	-	zero	TT	99.99% killed/inactivated

[1] Regulated under the surface water treatment rule.

Drinking Water Advisory Table

Chemicals	Status	Health-based Value	Taste Threshold	Odor Threshold
Ammonia	D '92	Not Available	30 mg/L	
Methyl tertiary butyl ether (MtBE)	F '98	Not Available	40 μg/L	20 μg/L
Sodium	F '03	20 mg/L (for individuals on a 500 mg/day restricted sodium diet).	30-60 mg/L	
Sulfate	F '03	500 mg/L	250 mg/L	

Taste Threshold: Concentration at which the majority of consumers do not notice an adverse taste in drinking water; it is recognized that some sensitive individuals may detect a chemical at levels below this threshold.

Odor Threshold: Concentration at which the majority of consumers do not notice an adverse odor in drinking water; it is recognized that some sensitive individuals may detect a chemical at levels below this threshold.

ATTACHMENT K

EPA FACT SHEETS

United States Environmental Protection Agency

Technical Fact Sheet – 1,4-Dioxane

November 2017

TECHNICAL FACT SHEET – 1,4-DIOXANE

At a Glance

- Flammable liquid and a fire hazard. Potentially explosive if exposed to light or air.
- Found at many federal facilities because of its widespread use as a stabilizer in certain chlorinated solvents, paint strippers, greases and waxes.
- Short-lived in the atmosphere, may leach readily from soil to groundwater, migrates rapidly in groundwater and is relatively resistant to biodegradation in the subsurface.
- Classified by EPA as "likely to be carcinogenic to humans" by all routes of exposure.
- Short-term exposure may cause eye, nose and throat irritation; long-term exposure may cause kidney and liver damage.
- Federal screening levels, state health-based drinking water guidance values and federal occupational exposure limits have been established.
- Modifications to existing sample preparation procedures may be required to achieve the increased sensitivity needed for detection of 1,4-dioxane.
- Common treatment technologies include advanced oxidation processes and bioremediation.
- No federal maximum contaminant level (MCL) has been established for 1,4-dioxane in drinking water.

Introduction

This fact sheet, developed by the U.S. Environmental Protection Agency (EPA) Federal Facilities Restoration and Reuse Office (FFRRO), provides a summary of the emerging contaminant 1,4-dioxane, including physical and chemical properties; environmental and health impacts; existing federal and state guidelines; detection and treatment methods; and additional sources of information. This fact sheet is intended for use by site managers who may address 1,4-dioxane at cleanup sites or in drinking water supplies and for those in a position to consider whether 1,4-dioxane should be added to the analytical suite for site investigations.

1,4-Dioxane is a likely human carcinogen and has been found in groundwater at sites throughout the United States. The physical and chemical properties and behavior of 1,4-dioxane create challenges for its characterization and treatment. It is highly mobile and does not readily biodegrade in the environment.

What is 1,4-dioxane?

- 1,4-Dioxane is a synthetic industrial chemical that is completely miscible in water (EPA 2006; ATSDR 2012).
- Synonyms include dioxane, dioxan, p-dioxane, diethylene dioxide, diethylene oxide, diethylene ether and glycol ethylene ether (EPA 2006; ATSDR 2012; Mohr 2001).
- 1,4-Dioxane is unstable at elevated temperatures and pressures and may form explosive mixtures with prolonged exposure to light or air (EPA 2006; HSDB 2011).
- 1,4-Dioxane is a likely contaminant at many sites contaminated with certain chlorinated solvents (particularly 1,1,1-trichloroethane [TCA]) because of its widespread use as a stabilizer for chlorinated solvents (EPA 2013a; Mohr 2001). Historically, the main use (90 percent) of 1,4-dioxane was as a stabilizer of chlorinated solvents such as TCA (ATSDR 2012). Use of TCA was phased out under the 1995 Montreal Protocol and the use of 1,4-dioxane as a solvent stabilizer was terminated (ECJRC 2002; NTP 2016). Lack of recent reports for other previously reported uses suggest that many other industrial, commercial and consumer uses were also stopped.

- It is a by-product present in many goods, including paint strippers, dyes, greases, antifreeze and aircraft deicing fluids, and in some consumer products (deodorants, shampoos and cosmetics) (ATSDR 2012; Mohr 2001).
- 1,4-Dioxane is used as a purifying agent in the manufacture of pharmaceuticals and is a by-product in the manufacture of polyethylene terephthalate (PET) plastic (Mohr 2001).
- Traces of 1,4-dioxane may be present in some food supplements, food containing residues from packaging adhesives or on food crops treated with pesticides that contain 1,4-dioxane (ATSDR 2012; DHHS 2011).

Exhibit 1: Physical and Chemical Properties of 1,4-Dioxane (ATSDR 2012)

Property	1,4-Dioxane
Chemical Abstracts Service (CAS) number	123-91-1
Physical description (physical state at room temperature)	Clear, flammable liquid with a faint, pleasant odor
Molecular weight (g/mol)	88.11
Water solubility	Miscible
Melting point (^{o}C)	11.8
Boiling point (^{o}C) at 760 mm Hg	101.1
Vapor pressure at 25^{o}C (mm Hg)	38.1
Specific gravity	1.033
Octanol-water partition coefficient (log K_{ow})	-0.27
Organic carbon partition coefficient (log K_{oc})	1.23
Henry's law constant at 25 ^{o}C (atm-m^3/mol)	4.80 X 10^{-6}

Abbreviations: g/mol – grams per mole; ^{o}C – degrees Celsius; mm Hg – millimeters of mercury; atm-m^3/mol – atmosphere-cubic meters per mole

Existence of 1,4-dioxane in the environment

- 1,4-Dioxane is typically found at some solvent release sites and PET manufacturing facilities (ATSDR 2012; Mohr 2001).
- It is short-lived in the atmosphere, with an estimated 1- to 3-day half-life due to photooxidation (ATSDR 2012; DHHS 2011).
- Migration to groundwater is weakly retarded by sorption of 1,4-dioxane to soil particles; it is expected to move rapidly from soil to groundwater (EPA 2006; ATSDR 2012).
- It is relatively resistant to biodegradation in water and soil, although recent studies have identified degrading bacteria (Inoue 2016; Pugazhendi 2015; Sales 2013).
- It does not bioaccumulate, biomagnify, or bioconcentrate in the food chain (ATSDR 2012; Mohr 2001).
- 1,4-Dioxane is frequently present at sites with TCA contamination (Mohr 2001; Adamson 2014).
- It may migrate rapidly in groundwater, ahead of other contaminants (DHHS 2011; EPA 2006).
- Where delineated, 1,4-dioxane is frequently found within previously delineated chlorinated solvent plumes and existing monitoring networks (Adamson 2014).
- As of 2016, 1,4-dioxane had been identified at more than 34 sites on the EPA National Priorities List (NPL); it may be present (but samples were not analyzed for it) at many other sites (EPA 2016b).

What are the routes of exposure and the potential health effects of 1,4-dioxane?

- Exposure may occur through ingestion of contaminated food and water, or dermal contact. Worker exposures may include inhalation of vapors (ATSDR 2012; DHHS 2011; EU 2002).
- Potential exposure could occur during production and use of 1,4-dioxane as a stabilizer or solvent (DHHS 2011; EU 2002).
- Short-term exposure to high levels of 1,4-dioxane may result in nausea, drowsiness, headache, and irritation of the eyes, nose and throat (ATSDR 2012; EPA 2013b; NIOSH 2010; EU 2002). 1,4-Dioxane is readily absorbed through the lungs and gastrointestinal tract. Some 1,4-dioxane may also pass through the skin, but studies indicate that much of it will evaporate before it is absorbed. Distribution is rapid and uniform in the lung, liver, kidney, spleen, colon and skeletal muscle tissue (ATSDR 2012).
- 1,4-Dioxane is weakly genotoxic and reproductive effects in humans are unknown; however, a developmental study on rats indicated that 1,4-dioxane may be slightly toxic to the developing fetus (ATSDR 2012; Giavini and others 1985).
- Animal studies showed increased incidences of nasal cavity, liver and gall bladder tumors after exposure to 1,4-dioxane (ATSDR 2012; DHHS 2011; EPA IRIS 2013).
- EPA has classified 1,4-dioxane as “likely to be carcinogenic to humans” by all routes of exposure (EPA IRIS 2013).
- The U.S. Department of Health and Human Services states that “1,4-dioxane is reasonably anticipated to be a human carcinogen based on sufficient evidence of carcinogenicity from studies in experimental animals” (DHHS 2011).
- The National Institute for Occupational Safety and Health (NIOSH) considers 1,4-dioxane a potential occupational carcinogen (NIOSH 2010).
- The European Union has classified 1,4-dioxane as having limited evidence of carcinogenic effect (EU 2002).

Are there any federal and state guidelines and health standards for 1,4-dioxane?

- EPA’s Integrated Risk Information System (IRIS) database includes a chronic oral reference dose (RfD) of 0.03 milligrams per kilogram per day (mg/kg/day) based on liver and kidney toxicity in animals and a chronic inhalation reference concentration (RfC) of 0.03 milligrams per cubic meter (mg/m^3) based on atrophy and respiratory metaplasia inside the nasal cavity of animals (EPA IRIS 2013).
- The cancer risk assessment for 1,4-dioxane is based on an oral slope factor of 0.1 mg/kg/day and the drinking water unit risk is 2.9 x 10^{-6} micrograms per liter (µg/L) (EPA IRIS 2013).
- EPA risk assessments indicate that the drinking water concentration representing a 1 x 10^{-6} cancer risk level for 1,4-dioxane is 0.35 µg/L (EPA IRIS 2013).
- No federal maximum contaminant level (MCL) for drinking water has been established (EPA 2012).
- 1,4-Dioxane is included on the fourth drinking water contaminant candidate list and is included in the Third Unregulated Contaminant Monitoring Rule (EPA 2009; EPA 2016a).
- EPA’s drinking water equivalent level is 1 mg/L (EPA 2012). EPA has calculated a screening level of 0.46 µg/L for tap water, based on a 1 in 10^{-6} lifetime excess cancer risk (EPA 2017b).
- EPA established a 1-day health advisory of 4.0 milligrams per liter (mg/L) and a 10-day health advisory of 0.4 mg/L in drinking water for a 10-kilogram child and a lifetime health advisory of 0.2 mg/L in drinking water (EPA 2012).
- EPA has calculated a residential soil screening level (SSL) of 5.3 milligrams per kilogram (mg/kg) and an industrial SSL of 24 mg/kg. The soil-to-groundwater risk-based SSL is 9.4 x 10^{-5} mg/kg (EPA 2017b).
- EPA has calculated a residential air screening level of 0.56 micrograms per cubic meter (µg/m^3) and an industrial air screening level of 2.5 µg/m^3 (EPA 2017b).
- A reportable quantity of 100 pounds has been established under the Comprehensive Environmental Response, Compensation, and Liability Act (EPA 2011).
- The Occupational Safety and Health Administration (OSHA) established a permissible

exposure limit (PEL) for 1,4-dioxane of 100 parts per million (ppm) or 360 mg/m^3 as an 8-hour time weighted average (TWA). While OSHA has established a PEL for 1,4-dioxane, OSHA has recognized that many of its PELs are outdated and inadequate for ensuring the protection of worker health. OSHA recommends that employers follow the California OSHA limit of 0.28 ppm, the NIOSH recommended exposure limit of 1 ppm as a 30-minute ceiling, or the American Conference of Governmental Industrial Hygienists threshold limit value of 20 ppm (OSHA 2017).

- Various states have established drinking water and groundwater guidelines, including the following:

State	Guideline (µg/L)	Source
Alaska	77	AL DEC 2016
California	1.0	Cal/EPA 2011
Colorado	0.35	CDPHE 2017
Connecticut	3.0	CTDPH 2013
Delaware	6.0	DE DNR 1999
Florida	3.2	FDEP 2005
Indiana	7.8	IDEM 2015
Maine	4.0	MEDEP 2016
Massachusetts	0.3	MADEP 2004
Mississippi	6.09	MS DEQ 2002
New Hampshire	0.25	NH DES 2011
New Jersey	0.4	NJDEP 2015
North Carolina	3.0	NCDENR 2015
Pennsylvania	6.4	PADEP 2011
Texas	9.1	TCEQ 2016
Vermont	3.0	VTDEP 2016
Washington	0.438	WA ECY 2015
West Virginia	6.1	WV DEP 2009

What detection and site characterization methods are available for 1,4-dioxane?

- As a result of the limitations in the analytical methods to detect 1,4-dioxane, it has been difficult to identify its occurrence in the environment. The miscibility of 1,4-dioxane in water causes poor purging efficiency and results in high detection limits (ATSDR 2012; EPA 2006; Mohr 2001).
- The Contract Laboratory Program SOW SOM02.3 includes a CRQL of 2.0 µg/L in water, 67 µg/kg in low soil and 2,000 µg/kg in medium soil (EPA 2013c).
- Conventional analytical methods can detect 1,4-dioxane only at concentrations 100 times greater than the concentrations of volatile organic compounds. Modifications of existing analytical methods and their sample preparation procedures may be needed to achieve lower detection limits for 1,4-dioxane (EPA 2006; Mohr 2001).
- High-temperature sample preparation techniques improve the recovery of 1,4-dioxane. These techniques include purging at elevated temperature (EPA SW-846 Method 5030); equilibrium headspace analysis (EPA SW-846 Method 5021); vacuum distillation (EPA SW-846 Method 8261); and azeotropic distillation (EPA SW-846 Method 5031) (EPA 2006).
- NIOSH Method 1602 uses gas chromatography – flame ionization detection (GC-FID) to determine the concentration of 1,4-dioxane in air (ATSDR 2012; NIOSH 2010).
- EPA SW-846 Method 8015D uses gas chromatography (GC) to determine the concentration of 1,4-dioxane in environmental samples. Samples may be introduced into the GC column by a variety of techniques including the injection of the concentrate from azeotropic distillation (EPA SW-846 Method 5031). The lower quantitation limits for 1,4-dioxane in aqueous matrices by azeotropic microdistillation are 12 µg/L (reagent water), 15 µg/L (groundwater) and 16 µg/L (leachate) (EPA 2003).
- EPA SW-846 Method 8260B detects 1,4-dioxane in a variety of solid waste matrices using GC and mass spectrometry (MS). The detection limit

depends on the instrument and choice of sample preparation method (ATSDR 2012).

- ❖ A laboratory study is underway to develop a passive flux meter (PFM) approach to enhance the capture of 1,4-dioxane in the PFM sorbent to improve accuracy. Results to date show that the PFM is capable of quantifying low absorbing compounds such as 1,4-dioxane (DoD SERDP 2013b).
- ❖ EPA Method 1624 uses isotopic dilution gas chromatography – mass spectrometry (GC-MS) to detect 1,4-dioxane in water, soil and municipal discharges. The detection limit for this method is 10 µg/L (ATSDR 2012; EPA 2001b).
- ❖ EPA SW-846 Method 8270 uses liquid-liquid extraction and isotope dilution by capillary column GC-MS. This method is often modified for the detection of low levels of 1,4-dioxane in water (EPA 2007).
- ❖ EPA Method 522 uses solid phase extraction and GC-MS with selected ion monitoring for the detection of 1,4-dioxane in drinking water with detection limits as low as 0.02 µg/L (EPA 2008).
- ❖ GC-MS detection methods using solid phase extraction followed by desorption with an organic solvent have been developed to remove 1,4-dioxane from the aqueous phase. Detection limits as low as 0.03 µg/L have been achieved by passing the aqueous sample through an activated carbon column, following by elution with acetone-dichloromethane (ATSDR 2012; Kadokami and others 1990).
- ❖ Lab studies indicate effective methods for monitoring growth of dioxane-degrading bacteria in culture (Gedalanga 2014).
- ❖ Studies are underway to develop and assess methods for performing compound-specific isotope analysis (CSIA) on low levels of 1,4-dioxane in groundwater (DoD SERDP 2016).

What technologies are being used to treat 1,4-dioxane?

- ❖ Pump-and-treat remediation can treat dissolved 1,4-dioxane in groundwater and control groundwater plume migration, but requires ex-situ treatment tailored for the unique properties of 1,4-dioxane (e.g., its low octanol-water partition coefficient makes 1,4-dioxane hydrophilic) (EPA 2006; Kiker and others 2010).
- ❖ Commercially available advanced oxidation processes using hydrogen peroxide with ultraviolet light or ozone can be used to treat 1,4-dioxane in wastewater (Asano and others 2012; EPA 2006).
- ❖ Peroxone and iron activated persulfate oxidation of 1,4-dioxane might aid in the cleanup of VOC-contaminated sites (Eberle 2015; Zhong 2015; Li 2016; SERDP 2013d).
- ❖ In-situ chemical oxidation can be successfully combined with bioaugmentation for managing dioxane contamination (DoD SERDP 2013d; Adamson 2015).
- ❖ Ex-situ bioremediation using a fixed-film, moving-bed biological treatment system is also used to treat 1,4-dioxane in groundwater (EPA 2006).
- ❖ Electrical resistance heating may be an effective treatment method (Oberle 2015).
- ❖ Phytoremediation is being explored as a means to remove the compound from shallow groundwater. Pilot-scale studies have demonstrated the ability of hybrid poplars to take up and effectively degrade or deactivate 1,4-dioxane (EPA 2001a, 2013a; Ferro and others 2013).
- ❖ Microbial degradation in engineered bioreactors has been documented under enhanced conditions or where selected strains of bacteria capable of degrading 1,4-dioxane are cultured, but the impact of the presence of chlorinated solvent co-contaminants on biodegradation of 1,4-dioxane needs to be further investigated (EPA 2006, 2013a; Mahendra and others 2013).
- ❖ Results from a 2012 laboratory study found 1,4-dioxane-transforming activity to be relatively common among monooxygenase-expressing bacteria; however, both TCA and 1,1-dichloroethene inhibited 1,4-dioxane degradation by bacterial isolates (DoD SERDP 2012).
- ❖ Isobutane-metabolizing bacteria can consistently degrade low (<100 ppb) concentrations of 1,4-dioxane, often to concentrations <1 ppb. These organisms also can degrade many chlorinated co-contaminants such as TCA and 1,1-dichoroethene (1,1-DCE) (DoD SERDP 2013c).
- ❖ Ethane effectively serves as a cometabolite for facilitating the biodegradation of 1,4-dioxane at relevant field concentrations (DoD SERDP 2013f).
- ❖ Biodegradation rates are subject to interactions among transition metals and natural organic ligands in the environment. (Pornwongthong 2014; DoD SERDP 2013e).

- Photocatalysis has been shown to remove 1,4-dioxane in aqueous solutions. Laboratory studies documented that the surface plasmon resonance of gold nanoparticles on titanium dioxide (Au – TiO2) promotes the photocatalytic degradation of 1,4-dioxane (Min and others 2009; Vescovi and others 2010).
- Other in-well combined treatment technologies being assessed include air sparging; soil vapor extraction (SVE); enhanced bioremediation-oxidation; and dynamic subsurface groundwater circulation (Odah and others 2005).
- 1,4-Dioxane was reduced by greater than 90 percent in the treatment zone with no apparent downward migration of 1,4-dioxane using enhanced or extreme SVE, which uses a combination of increased air flow, sweeping with drier air, increased temperature, decreased infiltration and more focused vapor extraction to enhance 1,4-dioxane remediation in soils (DoD SERDP 2013a).

Where can I find more information about 1,4-dioxane?

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United States
Environmental Protection
Agency

Technical Fact Sheet – Dinitrotoluene (DNT)

November 2017

At a Glance

- Nitroaromatic explosive that exists as six isomers: 2,4- and 2,6-DNT are the most common forms.
- Not naturally found in the environment.
- Used as an intermediate in the production of ammunition, polyurethane polymers, dyes, plasticizers and automobile airbags.
- Found in waste streams of DNT manufacturing or processing facilities.
- Expected to remain in water for long periods of time because of its relatively low volatility and moderate water solubility.
- Adverse effects identified in the blood, nervous system, liver and kidney in animals after exposure.
- Classified as a Class B2 (probable human) carcinogen.
- Health-based goals, exposure limits, screening levels and state drinking water guidelines have been developed.
- Standard detection methods include gas chromatography (GC) and high-performance liquid chromatography (HPLC).
- Common treatment technologies include adsorption, chlorination, ozonation, ultraviolet radiation, alkaline hydrolysis and bioremediation.

Introduction

This fact sheet, developed by the U.S. Environmental Protection Agency (EPA) Federal Facilities Restoration and Reuse Office (FFRRO), provides a summary of dinitrotoluene (DNT), including physical and chemical properties; environmental and health impacts; existing federal and state guidelines; detection and treatment methods; and additional sources of information. This fact sheet is intended for use by site managers and field personnel who may address DNT contamination at cleanup sites or in drinking water supplies.

The widespread use of DNT in manufacturing munitions, polyurethane foams, and other chemical products has contributed to extensive soil and groundwater contamination. DNT can be transported in surface water or groundwater because of its moderate solubility and relatively low volatility, unless degraded by light, oxygen or biota. As a result, releases to water are important sources of human exposure and remain a significant environmental concern. DNT is considered toxic to most organisms, and chronic exposure may result in organ damage. EPA currently classifies DNT as a priority pollutant.

What is DNT?

- DNT is a nitroaromatic explosive that exists as six isomers: 2,4- and 2,6-DNT are the two major forms; 2,3-DNT, 2,5-DNT, 3,4-DNT and 3,5-DNT are minor isomers (ATSDR 2016; Lent and others 2012a).
- Technical grade DNT (Tg-DNT) is about 76.5% 2,4-DNT, 18.8% 2,6-DNT, and 4.7% minor isomers (2.43% 3,4-DNT, 1.54% 2,3-DNT, 0.69% 2,5-DNT, and 0.04% 3,5-DNT (ATSDR 2016; Lent and others 2012a).
- DNT is not found naturally in the environment. It is usually produced by mixing toluene with nitric and sulfuric acids and is an intermediate in 2,4,6-trinitrotoluene (TNT) manufacturing (ATSDR 2016; EPA 2008).
- A mixture of DNTs is sold as an explosive and is a starting material for the production of 2,4,6-TNT. The mixture is also used as a modifier for smokeless powders in the munitions industry, in airbags of automobiles, as a chemical intermediate for the production of toluene diisocyanate (TDI), dyes and urethane foams (ATSDR 2016; EPA 2008).
- There are currently a small number of DNT manufacturing facilities in the United States (EPA 2008).

Exhibit 1: Physical and Chemical Properties of 2,4- and 2,6-DNT
(ATSDR 2016; EPA 2008)

Property	2,4-DNT	2,6-DNT
Chemical Abstracts Service (CAS) number	121-14-2	606-20-2
Physical description (physical state at room temperature and atmospheric pressure)	Yellow solid	Yellow to red solid
Molecular weight (g/mol)	182.14	182.14
Water solubility (mg/L)	270 at 22 °C	180 at 20 °C
Melting point (°C)	71	66
Boiling point (°C)	300	285
Vapor pressure at 20 °C (mm Hg)	1.4×10^{-4}	5.67×10^{-4}
Specific gravity/Density	1.32 at 71 °C	1.28 at 111 °C
Octanol-water partition coefficient (log K_{ow})	1.98	2.10
Organic-carbon partition coefficient (log K_{oc})	1.65	1.96
Henry's law constant (atm-m^3/mol)	5.4×10^{-8}	7.47×10^{-7}

Abbreviations: g/mol – grams per mole; mg/L – milligrams per liter; °C – degree Celsius; mm Hg – millimeters of mercury; atm-m^3/mol – atmosphere-cubic meters per mole.

Existence of DNT in the environment

- DNT is commonly found in surface water, groundwater and soil at hazardous waste sites that contain buried ammunitions waste or waste from facilities that manufacture or process DNT (EPA 2008; Darko-Kagya and others 2010; Lent and others 2012a).
- As of 2016, DNT has been identified at 56 sites on the EPA National Priorities List (NPL) (EPA 2016).
- Because of their low vapor pressures and low Henry's Law constants, 2,4- and 2,6-DNT do not usually volatize from water or soil. The isomers are usually released to air in the form of dusts or aerosols from manufacturing plants or adsorbed to other suspended particles (EPA 2008).
- 2,4- and 2,6-DNT have only a slight tendency to sorb to sediments, suspended solids or biota based on their relatively low organic-carbon partition coefficients (EPA 2008).
- The retention of DNT in soil depends on the chemistry and content of the soil organic matter (Clausen and others 2011; Singh and others 2010).
- Unless broken down by light, oxygen or biota, DNT is expected to remain in water for long periods of time because of its relatively low volatility and moderate water solubility. As a result, DNT has the potential to be transported by groundwater or surface water (ATSDR 2016; EPA 2008).
- Vapor-phase 2,4- and 2,6-DNT have an estimated half-life of 75 days in the atmosphere and are broken down by photodegradation (EPA 2008; HSDB 2013).
- Photolysis is the primary means for DNT degradation in oxygenated water. The photodegradation of 2,6-DNT was assessed under simulated solar radiation in a seawater solution. Within 24 hours, 2,6-DNT had been reduced by 89 percent and after 72 hours had been fully degraded (EPA 2008; NAVFAC 2003).
- Biodegradation of 2,4- and 2,6-DNT in water can occur under both aerobic and anaerobic conditions (EPA 2008).
- Microorganisms indigenous to surface soil and aquifer materials collected at a munitions-contaminated site were able to transform 2,4- and 2,6-DNT to amino-nitro intermediates within 70 days (Bradley and others 1994).
- 2,4- and 2,6-DNT have relatively low octanol-water partition coefficients and, as a result, are not expected to bioaccumulate significantly in animal tissue (ATSDR 2016).
- As a result of its moderate solubility, DNT can be transferred to plants via root uptake from soil and is expected to accumulate readily in plant materials (EPA 2008).
- DNT's bioavailability and toxicity to plants are greatly altered by soil properties. Studies have found that the toxicity of 2,4- and 2,6-DNT for various plant species is significantly and inversely correlated with soil organic matter content (Rocheleau and others 2010).

What are the routes of exposure and the potential health effects of DNT?

- Potential exposure pathways include inhalation, dermal contact and incidental ingestion, usually in occupational settings (ATSDR 2016; EPA 2008).
- Adverse health effects posed by chronic DNT exposure have been identified in the central nervous system, heart and circulatory system of humans. Exposure to 2,4- and 2,6-DNT can lead to increased incidences of mortality from ischemic heart disease, hepatobiliary cancer, and urothelial and renal cell cancers (EPA 2008).
- Identified symptoms from prolonged exposure to DNT include nausea, headache, methemoglobinemia, jaundice, anemia and cyanosis (EPA 2008; Darko-Kagya and others 2010; OSHA 2013).
- 2,4- and 2,6-DNT have both shown adverse impacts to neurological, hematological, reproductive, hepatic and renal functions in animal studies of rats, mice and dogs (EPA 2008).
- Both isomers are moderately to highly toxic to rats and mice (EPA 2008; Hartley and others 1994).
- Symptoms such as cyanosis, anemia, increased splenic mass and hepatocellular lesions were observed in rats exposed to 2,4- and 2,6-DNT for 14 days (Lent and others 2012b).
- Animal studies have also shown that both 2,6- and Tg-DNT are hepatocarcinogens and can cause liver cancer in rats. Studies indicate that the hepatocarcinogenity of Tg-DNT could be attributed to the 2,6-DNT isomer (Lent and others 2012a).
- EPA classified the mixture of 2,4- and 2,6-DNT as a Class B2 (probable human) carcinogen based on multiple benign and malignant tumor types at multiple sites in rats and malignant renal tumors in male mice (EPA IRIS 1990).
- The American Conference of Governmental Industrial Hygienists (ACGIH) has classified DNT as a Group A3 carcinogen – confirmed animal carcinogen with unknown relevance to humans (HSDB 2013).

Are there any federal and state guidelines and health standards for DNT?

- EPA's Integrated Risk Information System (IRIS) database includes a chronic oral reference dose (RfD) of 2 x 10^{-3} milligrams per kilogram per day (mg/kg/day) for 2,4-DNT based on neurotoxicity and the presence of Heinz bodies and biliary tract hyperplasia in animals (EPA IRIS 1992).
- Based on a provisional peer-reviewed toxicity value (PPRTV) assessment conducted by the EPA for both 2,6-DNT and Tg-DNT, EPA established a provisional chronic RfD screening value of 3 x 10^{-4} mg/kg/day for 2,6-DNT and 9 x 10^{-4} mg/kg/day for Tg-DNT. The PPRTV assessments are developed for use in the EPA Superfund program and provide toxicity values and information about adverse effects of the chemical (EPA 2013a, b).
- The Agency for Toxic Substances and Disease Registry (ATSDR) has established a minimal risk level (MRL) of 0.05 mg/kg/day for acute-duration oral exposure (14 days or less), 0.007 mg/kg/day for intermediate-duration oral exposure (15 to 364 days) and 0.001 mg/kg/day for chronic-duration oral exposure (365 days or more) to 2,4-DNT (ATSDR 2013, 2016).
- For 2,6-DNT, an MRL of 0.09 mg/kg/day has been derived for acute-duration oral exposure and 0.004 mg/kg/day was derived for intermediate-duration oral exposure (ATSDR 2013, 2016).
- The cancer risk assessment for the 2,4- and 2,6-DNT mixture is based on an oral slope factor of 6.8 x 10^{-1} mg/kg/day and a drinking water unit risk of 1.90 x 10^{-5} micrograms per liter (µg/L) (EPA 2008; EPA IRIS 1990).
- EPA risk assessments indicate that the drinking water concentration representing a 1 x 10^{-6} cancer risk level for 2,4- and 2,6-DNT mixture is 0.05 µg/L (EPA IRIS 1990).
- The EPA has established drinking water health advisories for DNT, which are drinking water-specific risk level concentrations for cancer (10^{-4} cancer risk) and concentrations of drinking water contaminants at which noncancer adverse health effects are not anticipated to occur over specific exposure durations (EPA 2012).
  - EPA established a 1-day and 10-day health advisory of 1.0 mg/L for 2,4-DNT in drinking water for a 10-kilogram (kg) child.
  - For 2,6-DNT, EPA established a 1-day health advisory of 0.4 milligrams per liter (mg/L) and a 10-day health advisory of 0.04 mg/L in drinking water for a 10-kg child.
  - The drinking water equivalent levels for 2,4- and 2,6-DNT are 0.1 mg/L and 0.04 mg/L.
- For 2,6-DNT, EPA has calculated a residential soil screening level (SSL) of 3.6 x 10^{-1} mg/kg and an industrial SSL of 1.5 mg/kg. The soil-to-groundwater risk-based SSL is 6.7 x 10^{-5} mg/kg (EPA 2017).

- For the mixture of 2,4- and 2,6-DNT, EPA has also calculated a residential SSL of 8.0 x 10^{-1} mg/kg and an industrial SSL of 3.4 mg/kg. The soil-to-groundwater risk-based SSL is 1.5 x 10^{-4} mg/kg (EPA 2017).
- For 2,4-DNT, EPA has calculated a residential air screening level of 3.2 x 10^{-2} micrograms per cubic meter (µg/m^3) and an industrial air screening level of 1.4 x 10^{-1} µg/m^3. EPA has not established an ambient air screening level for 2,6-DNT or the mixture of 2,4- and 2,6-DNT (EPA 2017).
- For tap water, EPA has calculated screening levels of 2.4 x 10^{-1} µg/L for 2,4-DNT, 4.9 x 10^{-2} µg/L for 2,6-DNT, and 1.1 x 10^{-1} µg/L for 2,4- and 2,6-DNT mixture (EPA 2017).
- In 2008, the EPA made a determination not to regulate either isomer with a national primary drinking water regulation based on the infrequent occurrence of the isomers at levels of concern in public water supply systems (EPA OGWDW 2008).
- 2,4- and 2,6-DNT are designated as hazardous substances under Section 311(b)(2)(A) of the Federal Water Pollution Control Act and further regulated by the Clean Water Act. Any discharge of 2,4-DNT over a threshold level of 10 pounds and 2,6-DNT over 100 pounds into navigable waters is subject to reporting requirements (EPA 2011).
- 2,4-DNT is a listed substance under the Resource Conservation and Recovery Act (RCRA) Toxicity Characteristic Leaching Procedure (TCLP) organics list. If soils or wastes containing 2,4-DNT produce leachate with concentrations equal to or greater than the TCLP threshold (0.13 mg/L) for 2,4-DNT, they are classified as RCRA characteristic hazard waste and would require treatment (EPA 2006).
- Multiple states have adopted screening values or cleanup goals for 2,4-DNT, 2,6-DNT and/or the mixture of 2,4- and 2,6-DNT in soil ranging from 0.03 to 156 mg/kg for residential areas and 1.5 to 2,040 mg/kg for industrial areas.
- Various states have established drinking water or groundwater standards for 2,4-DNT, 2,6-DNT and/or the mixture of 2,4- and 2,6-DNT, including the following:

State	Guideline (µg/L)			Source
	2,4-DNT	2,6-DNT	Mixture	
Colorado	0.11	--	--	CDPHE 2016
Indiana	2.4	0.49	1.1	IDEM 2016
Maine	1	0.5	--	MDEP 2016
Maryland	7.3	3.7	--	MDE 2008
Michigan	7.7	--	--	Michigan DEQ 2013
Mississippi	73	36.5	0.0985	MDEQ 2002
Missouri	0.04	--	--	Missouri DNR 2014
Nebraska	0.22	9.1	0.099	NDEQ 2012
New Hampshire	10	--	--	NHDES 2015
New Mexico	2.17	36.5	0.988	NMED 2012
New York	5	5	--	NYDEC 2016
Ohio	2	0.42	0.92	Ohio EPA 2016
Oregon	--	0.049	--	Oregon DEQ 2015
Pennsylvania	2.4	0.49	--	PADEP 2016
Texas	0.0013	0.0013	--	TCEQ 2016
Virginia	2.4	0.48	--	VDEQ 2014
West Virginia	0.22	16	0.099	WVDEP 2014
Wyoming	66.7	33.3	--	WDEQ 2016

What detection and site characterization methods are available for DNT?

- Common analytical methods for DNT isomers rely on gas chromatography (GC) and high-performance liquid chromatography (HPLC) (ATSDR 2016; EPA 2008).
- GC is usually used in combination with various detectors including flame ionization detector, electron capture detector (ECD), Hall electrolytic conductivity detector, thermionic specific detector, fourier transform infrared, thermal energy analyzer or mass spectrometry (MS) (ATSDR 2016).
- Capillary GC columns with ECD have been developed to detect 2,4-DNT in both air and surface particulate samples (ATSDR 2016).
- Surface-enhanced raman spectroscopy was shown to detect 2,4-DNT vapor at a concentration level of 5 parts per billion (ppb) or less in air (ATSDR 2016; Sylvia and others 2000).
- Cross-reactive optical microsensors can detect 2,4-DNT in water vapor at a level of 23 ppb in clean, dry air (ATSDR 2016; Albert and Walt 2000).
- A continuous countercurrent liquid-liquid extraction method is capable of extracting 2,4- and 2,6-DNT from surface water samples (ATSDR 2016; Deroux and others 1996).
- Reversed-phase, HPLC enables the direct analysis of aqueous samples to identify DNT in wastewater. The estimated detection limit for 2,4-DNT is 10 µg/L (Jenkins and others 1986).

- Negative-ion chemical ionization is a sensitive and selective technique that has been used to identify trace amounts of nitroaromatic compounds in complex aqueous mixtures (ATSDR 2016; Feltes and others 1990).
- Pressurized fluid extraction and gas and liquid chromatography-MS can also be used to detect 2,4-DNT in soil (ATSDR 2016; Campbell and others 2003).
- In soils, a sonic extraction-liquid chromatographic method has been used to detect 2,4-DNT (ATSDR 2016; Griest and others 1993).
- EPA SW-846 Method 8330A, HPLC using a dual wavelength ultraviolet (UV) detector, has been used for the detection of ppb levels of certain explosive and propellant residues, such as 2,4- and 2,6-DNT, in water, soil or sediment (EPA 2007b).
- EPA SW-846 Method 8095 uses capillary-column GC with an ECD to analyze for explosives, such as 2,4- and 2,6-DNT, in water and soil (EPA 2007a).
- EPA Method 529 uses solid phase extraction and capillary column GC and MS for the detection of 2,4- and 2,6-DNT in drinking water (EPA 2002).
- There are currently no EPA-approved analytical methods for the other four DNT isomers (2,3-DNT, 2,5-DNT, 3,4-DNT, and 3,5-DNT).

What technologies are being used to treat DNT?

- Treatment technologies include adsorption, chlorination, ozonation, and ultraviolet radiation (EPA 2008).
- Remediation technologies for DNT-contaminated soil and groundwater sites typically involve the use of separation processes, advanced oxidation processes, chemical reduction, bioremediation and phytoremediation (Rodgers and Bunce 2001).
- Adsorption on a solid phase, such as granular adsorbent, is the basic method to collect DNT from the atmosphere. This treatment is followed by removal with solvents such as chloroform (ATSDR 2016).
- Munitions wastewater containing DNT is commonly treated by activated carbon adsorption followed by incineration of the spent carbon (Chen and others 2011).
- As a result of its high efficiency and ease of operation, electrochemical oxidation has been applied successfully to treat DNT-contaminated wastewater (Chen and others 2011).
- Nanotechnology has emerged as a potential technology for the reductive chemical degradation of DNT in soil and groundwater. Studies have shown that lactate-modification of nanoscale iron particles (NIPs) can enhance the transport of NIPs and chemical degradation of 2,4-DNT in soil (Darko-Kagya and others 2010; Reddy and others 2011).
- Batch experiments demonstrated that in situ chemical oxidation using iron sulfide activated persulfate was able to degrade 2,4-DNT completely in water (Oh and others 2011).
- 2,4-DNT is more easily degraded than 2,6-DNT by bioremediation in soil and groundwater and sequential treatment systems may be needed to treat soil or water containing both isomers (Nishino and Spain 2001).
- Recent studies have achieved a 2,4-DNT removal efficiency above 99 percent in wastewater using a sequential anaerobic/aerobic biodegradation treatment method (Kuşçu and Sponza 2011; Wang and others 2011).
- Study results suggested that bioremediation and natural attenuation of DNT-contaminated groundwater may be an effective treatment option (Han and others 2011).
- Conventional methods to treat DNT in soils are incineration or landfilling, immobilization, thermal removal, bioremediation and solvent extraction (Darko-Kagya and others 2010).
- A protocol document for the application of alkaline hydrolysis to treat DNT and other explosives in soil (“Management of Munitions Constituents in Soil using Alkaline Hydrolysis”) has been developed by the U.S. Army Corps of Engineers, Engineer Research and Development Center (ERDC) in Vicksburg, Mississippi (USACE 2011).

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United States
Environmental Protection
Agency

Technical Fact Sheet – Nanomaterials

November 2017

At a Glance

- ❖ Diverse class of substances that have structural components smaller than 100 nanometers (nm) in at least one dimension (Klaine and others 2008). Nanomaterials (NMs) include nanoparticles (NPs), which are particles with at least two dimensions between approximately 1 and 100 nm.
- ❖ Have high surface area to volume ratio and the number of surface atoms and their arrangement determines the size and properties of the NM.
- ❖ Can be categorized into three types: natural UFPs, incidental NMs and engineered NMs.
- ❖ Engineered NMs are used in a wide variety of applications, including environmental remediation, pollution sensors, photovoltaics, medical imaging and drug delivery.
- ❖ The mobility of NMs depends on factors such as surface chemistry and particle size, and on biological and abiotic processes in the media.
- ❖ May stay in suspension as individual particles, aggregate, dissolve or react with other materials.
- ❖ Characterization and detection technologies include differential mobility analyzers, mass spectrometry and scanning electron microscopy.

Introduction

This fact sheet, developed by the U.S. Environmental Protection Agency (EPA) Federal Facilities Restoration and Reuse Office (FFRRO), provides a summary of nanomaterials (NMs), including their physical and chemical properties; potential environmental and health impacts; existing federal and state guidelines; detection and treatment methods; and additional sources of information. This fact sheet is intended for use by site managers and other field personnel who may need to address or use NMs at cleanup sites or in drinking water supplies.

NMs are increasingly being used in a wide range of household, cosmetic and personal use, scientific, environmental, industrial and medicinal applications. NMs may possess unique chemical, biological and physical properties compared with larger particles of the same material (Exhibit 1). NM research is a rapidly growing area; current research is focused on carbon-based, metal and metal oxides, quantum dots and nanosilver. Due to the diverse nature of NMs, this fact sheet presents a high-level summary for NMs in general with specific focus on the NMs of current research interest.

What are nanomaterials?

- ❖ For purposes of this document, NMs are a diverse class of substances that have structural components smaller than 100 nanometers (nm) in at least one dimension. NMs include nanoparticles (NPs), which are particles with at least two dimensions between approximately 1 and 100 nm (Klaine and others 2008). EPA refers to nano-sized particles that are natural or aerosol as ultrafine particles (UFPs).
- ❖ NMs have high surface area to volume ratio and the number of surface atoms and their arrangement determines the size and properties of the NM (Sarma and others 2015).
- ❖ As of 2014, more than 1,800 consumer products containing NMs are on the market (Vance and others 2015).

- NMs and UFPs can be categorized into three types according to their source:
  - Natural UFPs include combustion products, viruses and sea spray.
  - Incidental NMs are generated by anthropogenic processes and include diesel exhaust, welding fumes and industrial effluents.
  - Engineered NMs are designed with very specific properties and are made through chemical and/or physical processes (Exhibit 1).

Exhibit 1: Properties and Common Uses of NMs and UFPs

(EPA 2007, 2008a; Klaine and others 2008; Watlington 2005; Gil and Parak 2008; Luoma 2008; Cota-Sanchez and Merlo-Sosa 2015)

Types of NMs and UFPs (Occurrence)	Physical/Chemical Properties	Uses	Examples
Carbon-based (Natural or Engineered)	Stable, limited reactivity, excellent thermal and electrical conductivity.	Biomedical applications, battery and fuel cell electrodes, super-capacitors, adhesives and composites, sensors and components in electronics, aircraft, aerospace and automotive industries.	Fullerenes, multi-walled and single-walled carbon nanotubes (CNTs) and graphene materials.
Metal-based Materials (Natural or Engineered)	High reactivity, varied properties based on type, some have photolytic properties and ultraviolet blocking ability. Capping agents are used in some cases.	Solar cells, paints and coatings, cosmetics, ultraviolet blockers in sunscreen, environmental remediation.	Nanogold, nanosilver, metal oxides such as titanium dioxide (TiO_2), zinc oxide (ZnO), cerium dioxide (CeO_2) and nanoscale zero-valent iron (nZVI).
Quantum Dots (Engineered)	Reactive core composed of metals or semiconductors controls the material's optical properties. Cores are surrounded by an organic shell that protects from oxidation.	Medical Bioimaging, targeted therapeutics, solar cells, photonics and telecommunication.	Quantum dots made from cadmium selenide (CdSe), cadmium telluride (CdTe), indium phosphide (InP) and zinc selenide (ZnSe).
Dendrimers (Engineered)	Three-dimensional nanostructures engineered to carry molecules encapsulated in their interior void spaces or attached to the surface.	Drug delivery systems, polymer materials, chemical sensors and modified electrodes.	Hyperbranched polymers, dendrigraft polymers and dendrons.
Composite NMs (Engineered)	Composite NMs consist of multifunctional components and have novel electrical, catalytic, magnetic, mechanical, thermal or imaging features.	Potential applications in drug delivery and cancer detection. Also used in auto parts and packaging materials to enhance mechanical and flame-retardant properties.	Produced using two different NMs or NMs combined with larger, bulk-type materials. They can also be made with NMs combined with synthetic polymers or resins.

Existence of nanomaterials in the environment

- Engineered NMs may be released into the environment primarily through industrial and environmental applications, improper handling or consumer waste (EPA 2007).
- NPs fate and transport in the environment are largely dependent on material properties such as surface chemistry, particle size and biological and abiotic processes in environmental media. Depending on these properties, NPs may stay in suspension as individual particles, aggregate, dissolve or react with other materials (EPA 2009; Luoma 2008).
- NZVI particles are one of the most widely used nanoparticles for environmental remediation because of their ability to degrade a wide range of contaminants. Such an increasingly widespread application of nZVI will lead to its release into the environment. The environmental fate and transport of nZVI is not yet fully understood making it difficult to determine the environmental risk of nZVI injected into the subsurface (Jang and others 2014).
- Many NMs containing inherently non-biodegradable inorganic chemicals such as ceramics, metals and metal oxides are not expected to biodegrade (EPA 2007).
- Under conditions of low or no UV exposure, TiO_2 NPs have been shown to cause mortality, reduced growth and negative impacts on cells and DNA of aquatic organisms. Many of these studies, however, neglect environmentally relevant interactions with acute exposure times and high concentrations (greater than 10 milligrams per liter) and thus are difficult to extrapolate to natural ecosystems (Haynes and others 2017).
- Toxic effects of nanosilver on fish have been observed and nanosilver may induce a stress response in fish; however, the results of a 28-day study on rainbow trout indicated that although nanosilver did engage a stress response in fish, it did not affect growth or condition at environmentally relevant concentrations (0.28 micograms per liter) and higher concentrations (average 47.6 micrograms per liter) (Murray and others 2017).
- ZnO NPs affected the growth rate of the algae and suggested that the ZnO NPs were more toxic to the marine algae than bulk ZnO (Manzo and others 2013).
- Recent studies have shown the following:
  - Carbon fullerenes are insoluble and colloidal aggregates in aqueous solutions are stable for months to years, allowing for chronic exposure to biological and environmental systems (Hegde and others 2015).
  - Single-walled CNTs are not readily degraded by fungal cultures or microbial communities (Parks and others 2015).
  - Coatings on iron oxide NPs caused different toxic effects, which were linked to decreasing colloidal stability, the release of ions from the core material or the ability to form reactive oxygen species in daphnids (Baumann and others 2014).
  - The degradation of a surface coating of nano-TiO_2 resulted in increased phototoxicity to a benthic organism (Wallis and others 2014).

What are the routes of exposure to nanomaterials?

- The growing production and use of NMs in diverse industrial processes, construction, and medical and consumer products is resulting in increasing exposure of humans and the environment. Humans encounter NMs from many sources and exposure routes, including ingestion of food, direct dermal contact through consumer products and by inhalation of airborne NMs (Laux and other 2017).
- The small size, solubility and large surface area of NMs may enable them to translocate from their deposition site (typically in the lungs, if inhaled) and interact with biological systems. Circulation time increases drastically when the NMs are water-soluble (DHHS 2009; SCENIHR 2009). Translocation of NMs was shown to be dependent on material and aggregate size This was demonstrated by translocation of NMs to secondary organs such as the liver, heart, spleen, or kidney, subsequent to pulmonary uptake (Laux and others 2017).
- Animal studies indicate that nano-TiO_2 may accumulate in the liver, spleen, kidney and brain after it enters the bloodstream through various exposure routes (Chang and others 2013).
- In humans, although most inhaled NMs remain in the lung, less than 1 percent of the inhaled dose may reach the circulatory system (SCENIHR 2009).
- Use of sunscreen products on damaged skin may lead to dermal exposure to NMs (TiO_2 and ZnO), (EPA 2010; Mortensen and others 2008; Nel and others 2006).
- Ingestion exposure may occur from consuming

NMs contained in drinking water or food (for example, fish) or from unintentional hand to mouth transfer of NMs (DHHS 2009; Wiesner and others 2006).

What are the potential health effects of nanomaterials?

- Potential health effects of NMs vary across different types of NMs.
- Clinical and experimental animal studies indicate that NMs can induce different levels of cell injury and oxidative stress, depending on their charge, particle size and exposure dose. In addition, particle coatings, size, charge, surface treatments and surface excitation by ultraviolet (UV) radiation can modify surface properties and thus the aggregation and potential biological effects of NMs (Chang and others 2013; Nel and others 2006).
- Metallic NPs have been linked to chromosomal aberrations and oxidative damage to DNA due to the generation of reactive oxygen species. An in vivo study showed that exposure to silver, titanium, iron or copper NPs leads to genotoxicity (Dayem and others 2017).
- CNTs possess attributes similar to asbestos fibers and have been shown to cause inflammation and lesions as well as allergic immune responses in mice and rats. Several studies also report cellular DNA damage after exposure to single-walled CNTs (Hegde and others 2015).
- Several toxicological studies suggest fullerenes induce oxidative stress in living organisms (Hegde and others 2015).
- Biomarker responses were characterized following multi-walled CNT exposure to human liver cells (Henderson and others 2016).
- Toxicity of TiO_2 NPs have been studied extensively in recent years due to their use in sunscreen and cosmetics. Studies have shown exposure resulted in micoglia activation, reactive oxygen species production, activation of signaling pathways that result in cell death, both in vitro and in vivo (Czajka and others 2015).
- The aging of nano-TiO2 in swimming pool water redistributed the coating and reduced its protective properties, thereby increasing reactivity and potential phototoxicity (Al-Abed and others 2016).
- A recent study showed that titanium was distributed to and accumulated in the heart, brain, spleen, lung, and kidney of mice after nano-TiO_2 exposure, in a dose-dependent manner. High doses of nano-TiO_2 significantly damaged the functions of liver and kidney and glucose and lipid metabolism, as showed in the blood biochemistry tests. Nano-TiO_2 caused damages in mitochondria and apoptosis of hepatocytes, generation of reactive oxygen species, and expression disorders of protective genes in the liver of mice (Jia and others 2017).
- Metal-containing NMs, such as quantum dots and nanometals, may cause toxicity to cells by releasing harmful components such as heavy metals or ions (Klaine and others 2008; Luoma 2008; Powell and Kanarek 2006).
- Research has shown that NMs may stimulate or suppress immune responses (or both) by binding to proteins in the blood (Dobrovolskaia and McNeil 2007).
- Study results suggest that certain NMs may pose a respiratory hazard after inhalation exposure. For example, rodent studies indicate that single-walled CNTs may cause pulmonary inflammation and fibrosis. Exposures to TiO_2 NPs have also resulted in persistent pulmonary inflammation in rats and mice (EPA 2007; NIOSH 2011, 2013).
- Based on the results of available animal inhalation and epidemiologic studies, the National Institute for Occupational Safety and Health (NIOSH) has concluded that TiO_2 NPs may have a higher mass- based potency than larger particles and should be considered as a potential occupational carcinogen (NIOSH 2011).

Are there any federal and state guidelines or health standards for nanomaterials?

- Federal standards and guidelines:
  - The U.S. Food and Drug Administration (FDA) has finalized guidelines on the evaluation and use of NMs in FDA-regulated products. These guidelines focus on assessing safety, effectiveness and quality of products containing NMs, although the FDA does not make a categorical judgment on the safety or hazard of NMs (FDA 2014a, 2014b, 2014c and 2015a).
  - Many NMs are regarded as “chemical substances" under the Toxic Substances Control Act (TSCA) and therefore are subject to the requirements of the Act. EPA has already determined that CNTs are subject to

reporting under Section 5 of TSCA. Under TSCA Section 8(a), EPA issued a one-time reporting rule for NMs that are existing chemicals (EPA 2008b and 2016; FDA 2015b).

- If NMs enter drinking water or are injected into a well, they may be regulated under the Safe Drinking Water Act (EPA 2007). However, currently no maximum contaminant level goals (MCLGs) or maximum contaminant levels (MCLs) have been established for NMs.
- NMs that are used as pesticides are subject to the requirements of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA section 2(u) and 3(a)). If their use as a pesticide will result in residues in food or animal feed, a tolerance (maximum residue level) must be established under the Federal Food, Drug and Cosmetic Act (FFDCA).
- NMs may be regulated under various programs such as Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Resource Conservation and Recovery Act (RCRA), Clean Water Act (CWA) and Clean Air Act on a site-specific basis or if their use results in emissions of pollutants that are or could be hazardous (EPA 2007).

❖ State and local standards and guidelines:
  - In 2006, Berkeley, California, adopted the first local regulation specifically for NMs, requiring all facilities manufacturing or using manufactured NMs to disclose current toxicology information, as available (Berkeley 2006).
  - In 2010 and 2011, the California Department of Toxic Substances Control (CA DTSC) issued formal request letters to the manufacturers of certain CNTs, nanometal oxides, nanometals and quantum dots requesting information related to chemical and physical properties, including analytical test methods and other relevant information (CA DTSC 2013).

What detection and characterization methods are available for nanomaterials?

❖ The analysis of NMs in environmental samples often requires the use of multiple technologies in tandem. Characterization methods include spectroscopy, microscopy, chromatography centrifugation, filtration and others (Gmiza and others 2015).

❖ Single-particle mass spectrometry provides chemical analysis of NMs suspended in gases and liquids (SCENIHR 2009).

❖ Aerosol fractionation technologies (differential mobility analyzers and scanning mobility particle sizers) use the mobility properties of charged NMs in an electrical field to obtain size fractions for subsequent analysis. Multi-stage impactor samplers separate NM fractions based on the aerodynamic mobility properties of the NMs (EPA 2007).

❖ Expansion condensation particle counters measure aerosol particle number densities for size diameters as low as 3 nm. (Saghafifar and others 2009).

❖ Size-exclusion chromatography, ultrafiltration and field flow fractionation can be used for size fractionation and collection of NM fractions in liquid media (EPA 2007).

❖ NM fractions in liquid may be further analyzed using dynamic light scattering for size analysis and mass spectrometry for chemical characterization (EPA 2007).

❖ One of the main methods of analyzing single NM characteristics is electron microscopy. Scanning electron microscopy and transmission electron microscopy can be used to determine the size, shape and aggregation state of NMs below 10 nm (EPA 2007; SCENIHR 2006; Sanchis and others 2015).

❖ Atomic force microscopy can provide single particle size and morphological information at the nm level in air and liquid media (EPA 2007).

❖ Dynamic light scattering is used to characterize manufactured silver NMs and provides information on the hydrodynamic diameter of NMs in suspensions. It is capable of measuring NPs from a few nm in size, but is not suitable for environmental samples (EPA 2010).

❖ Other analytical techniques include X-ray diffraction to measure the crystalline phase and X-ray photoelectron spectroscopy to determine the surface oxidation states and chemical composition of NMs (EPA 2010).

❖ A recent laboratory study employed absorption-edge synchrotron X-ray computed microtomography to extract silver NM concentrations within individual pores in static and transport systems (Molnar and others 2014).

What technologies are being used to control nanomaterials?

- Coagulation is regarded as a critical process for the effective removal of NPs during water and wastewater treatment (Popowich and others 2015).
- Air filters and respirators are used to filter and remove NMs from air. A study found that membrane-coated fabric filters could provide an NM collection efficiency above 95 percent (Tsai and others 2012; Wiesner and others 2006).
- NMs in groundwater, surface water and drinking water may be removed using flocculation, sedimentation and sand or membrane filtration (Wiesner and others 2006), but a recent laboratory study using TiO2 NPs found that these typical treatment methods may be inadequate for particles smaller than 450 nm (Kinsinger and others 2015).
- A recent study stabilized silver NPs using different capping agents to control the transport of the NPs in porous media (Badawy and others 2013).

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Technical Fact Sheet – N-Nitroso-dimethylamine (NDMA)

November 2017

At a Glance

- Formerly used in the production of rocket fuel, antioxidants and softeners for copolymers. Currently used only for research purposes.
- Unintended byproduct of chlorination of wastewater at wastewater treatment plants that use chloramines for disinfection, raising significant concern as a drinking water contaminant.
- Highly mobile in soil, with potential to leach into groundwater.
- Oral route is the primary human exposure pathway.
- Classified as a B2 (probable human) carcinogen.
- Listed as a priority pollutant by the EPA, but no federal standard has been established for drinking water.
- Detection methods include solid phase extraction, gas chromatography and liquid chromatography.
- Most common NDMA water cleanup method is via photolysis by ultraviolet radiation. Potential for aerobic and anaerobic NDMA biodegradation also exists.

Introduction

This fact sheet, developed by the U.S. Environmental Protection Agency (EPA) Federal Facilities Restoration and Reuse Office (FFRRO), provides a summary of the contaminant N-Nitrosodimethylamine (NDMA), including physical and chemical properties; environmental and health impacts; existing federal and state guidelines; detection and treatment methods; and additional sources of information. This fact sheet is intended for use by site managers and other field personnel who may address NDMA contamination at cleanup sites or in drinking water supplies.

NDMA is a drinking water contaminant of concern because of its miscibility with water, as well as its carcinogenicity and toxicity.

What is NDMA?

- NDMA is a semivolatile organic chemical that forms in both industrial and natural processes (Cal/EPA 2006; Mitch and others 2003b).
- NDMA is not currently produced in pure form or commercially used in the United States, except for research purposes. It was formerly used in production of liquid rocket fuel, antioxidants, additives for lubricants and softeners for copolymers (ATSDR 1989; HSDB 2013).
- NDMA can be unintentionally produced in and released from industrial sources through chemical reactions, such as those that involve alkylamines. Potential industrial sources include amine manufacturing plants, tanneries, pesticide manufacturing plants, rubber and tire manufacturers, fish processing facilities, foundries, dye manufacturers and surfactant industries (ATSDR 1989).
- NDMA is also an unintended byproduct of the chlorination of wastewater and drinking water at treatment plants that use chloramines for disinfection (Bradley and others 2005; Mitch and others 2003).

Exhibit 1: Physical and Chemical Properties of NDMA
(ATSDR 1989; Cal/EPA 2006; HSDB 2013; NIOSH 2016)

Property	Value/Description
Chemical Abstract Systems (CAS) number	62-75-9
Physical description (physical state at room temperature)	Yellow liquid with faint or no odor
Molecular weight (g/mol)	74.08
Water solubility at 25°C	Miscible
Melting point (°C)	-25 (estimated)
Boiling point (°C)	152 to 154
Specific gravity/Density at 20°F/4°C (g/mL)	1.005 to 1.006
Vapor pressure at 20°C (mm Hg)	2.7
Organic carbon partition coefficient (log K_{oc})	1.07 (estimated)
Octanol-water partition coefficient (log K_{ow})	-0.57
Henry's law constant at 20°C (atm-m^3/mol)	2.63×10^{-7} (ATSDR 1989) 1.08×10^{-6} (HSDB 2013)

Abbreviations: g/mol – grams per mole; °C – degrees Celsius; g/mL – grams per milliliter; mm Hg – millimeters of mercury; atm-m^3/mol – atmosphere-cubic meters per mole.

Existence of NDMA in the environment

- NDMA contamination may be found in air, soil and water (ATSDR 1999).
- When released to the air, NDMA is expected to exist solely as vapor in the ambient atmosphere and is broken down quickly by sunlight within minutes (HSDB 2013).
- When released to soil, NDMA can be highly mobile and will either volatilize or leach into groundwater (ATSDR 1999; HSDB 2013).
- In water, NDMA is completely miscible and is not expected to sorb onto solid particles or sediment. NDMA may break down in water as a result of exposure to sunlight or by natural biological processes. The potential for bioconcentration in aquatic organisms is low based on an estimated bioconcentration factor of 3 (ATSDR 1999; HSDB 2013; WHO 2008).
- At rocket engine testing facilities in California, NDMA has been found at high concentrations in groundwater on site (up to 400,000 nanograms per liter [ng/L]) and also in downgradient drinking water wells (up to 20,000 ng/L) (Mitch and others 2003b).
- In a 2002 survey conducted by the California Department of Health Services (CDHS), elevated concentrations of NDMA were detected in locations where wastewater treatment plant effluent was used for aquifer recharge and near facilities that use unsymmetrical dimethylhydrazine (UDMH)-based rocket fuel (CDHS 2002; Mitch and others 2003b).
- As of March 2011, NDMA was the predominant nitrosamine detected in samples obtained from public water systems, which were monitored as part of the unregulated contaminant monitoring rule (UCMR). The EPA uses the UCMR to monitor contaminants that are suspected to be present in drinking water but that do not currently have health-based standards under the Safe Drinking Water Act (EPA 2011a; EPA 2014).
- The second UCMR was analyzed for NDMA occurrence and trends across the U.S. NDMA occurrence was strongly associated with chloramine use. Elevated NDMA was more common in surface water systems than groundwater systems. Smaller utilities were found to have the most extreme NDMA levels (Woods and Dickenson 2015)

What are the routes of exposure and potential health effects of NDMA?

- NDMA exposure may occur through (1) ingesting food that contains nitrosamines, such as smoked or cured meats and fish; (2) ingesting food that contains alkylamines, which can cause NDMA to form in the stomach; (3) drinking contaminated water; (4) drinking malt beverages (such as beer and whiskey) that may contain low levels of nitrosamines formed during processing; (5) using toiletry and cosmetic products such as shampoos and cleansers that contain NDMA; and (6) breathing or inhaling cigarette smoke. Workplace exposure can occur at tanneries, pesticide manufacturing plants and rubber and tire plants (ATSDR 1989, 1999).
- The oral route, including consumption of contaminated food and water, is the primary human exposure pathway for NDMA (ATSDR 1989; Cal/EPA 2006).
- Exposure to high levels of NDMA may cause liver damage in humans (ATSDR 1999; HSDB 2013).
- Potential symptoms of overexposure include headache; fever; nausea; jaundice; vomiting; abdominal cramps; enlarged liver; reduced function of liver, kidneys and lungs; and dizziness (HSDB 2013; OSHA 2005).
- EPA has classified NDMA as a B2 (probable human) carcinogen based on the induction of tumors at multiple sites in different mammal species exposed to NDMA by various routes (EPA IRIS 2002).
- The U.S. Department of Health and Human Services (DHHS) states that NDMA is reasonably anticipated to be a human carcinogen (NTP 2014).
- DHHS states that NDMA caused tumors in numerous species of experimental animals, at several different tissue sites, and by several different routes of exposure. Tumors occurred primarily of the liver, respiratory tract, kidney and blood vessels (NTP 2014; IARC 1998).
- The American Conference of Governmental Industrial Hygienists (ACGIH) has classified NDMA as a Group A3 confirmed animal carcinogen with unknown relevance to humans (HSDB 2013).

Are there any federal and state guidelines and health standards for NDMA?

- EPA has not derived a chronic oral reference dose (RfD) or a chronic inhalation reference concentration (RfC) for evaluating NDMA's noncancer effects in the EPA's Integrated Risk Information System database (EPA IRIS 2002).
- EPA has derived a RfD of 8.0 x 10^{-6} mg/kg-day and an RfC of 4.0 x 10^{-5} mg/m^3 as Provisional Peer-Reviewed Toxicity Values (PPRTVs) for evaluating noncancer effects (EPA 2007).
- EPA has assigned an oral slope factor for carcinogenic risk of 51 milligrams per kilogram per day (mg/kg-day)$^{-1}$, a drinking water unit risk of 1.4 x 10^{-3} per microgram per liter (µg/L)$^{-1}$ and an inhalation unit risk of 1.4 x 10^{-2} µg per cubic meter (m^3) (EPA IRIS 2002).
- For tap water, EPA calculated a screening level of 0.11 ng/L for NDMA, based on a 10^{-6} lifetime excess cancer risk (EPA 2017).
- EPA's screening levels for soil are 2.0 x 10^{-3} milligrams per kilogram (mg/kg) for residential and 3.4 x 10^{-2} mg/kg for industrial (based on 10^{-6} cancer risk). The soil screening level for protection of groundwater is 2.7 x 10^{-8} mg/kg (EPA 2017).
- EPA's screening levels for air are 7.2 x 10^{-5} micrograms per cubic meter (µg/m^3) for residential and 8.8 x 10^{-4} µg/m^3 for industrial (based on 10^{-6} cancer risk) (EPA 2017).
- Various states have established drinking water and groundwater guidelines, including the following:

State	Guideline (µg/L)	Source
Alabama	0.0013	ADEM 2008
Alaska	0.017	AL DEC 2008
California	0.003	Cal/EPA 2006
Colorado	0.00069	CDPHE 2013
Delaware	0.001	DE DNR 1999
Florida	0.0007	FDEP 2005
Indiana	0.0049	IDEM 2015
Massachusetts	0.01	MADEP 2004
Mississippi	0.00131	MS DEQ 2002
New Jersey	0.0007	NJDEP 2015
North Carolina	0.0007	NCDENR 2015
Pennsylvania	0.0014	PADEP 2011
Texas	0.018	TCEQ 2016
Washington	0.000858	WA DEP 2015
West Virginia	0.0013	WV DEP 2009

- EPA included NDMA on the fourth Contaminant Candidate List (CCL4), which is a list of unregulated contaminants that are known to or anticipated to occur in public water systems and may require regulation under the Safe Drinking Water Act (EPA 2016b).
- In addition, EPA added NDMA to its UCMR 2, requiring many large water utilities to monitor for NDMA (EPA 2015).

What detection and site characterization methods are available for NDMA?

- For drinking water, EPA Method 521 uses solid phase extraction (SPE) and capillary column gas chromatography (GC) with large-volume injection and chemical ionization tandem mass spectroscopy (MS) (EPA 2004).
- For wastewater, EPA Method 607 uses methylene chloride extraction, GC and a nitrogen-phosphorus detector (NPD) (EPA 2007; EPA 2016a).
- For wastewater, EPA Method 1625 uses isotope dilution, GC and MS (EPA 2007; EPA 2016a).
- For groundwater, wastewater, soil, sediment and sludges, EPA SW-846 Method 8070 uses methylene chloride extraction, GC and a NPD (EPA 1996).
- For solid waste matrices, soil, air sampling media and water samples, EPA SW-846 Method 8270 uses GC and MS (EPA 1998).
- An analytical method has also been developed specifically to quantify NDMA precursors such as alkylamines in waste or wastewater (Mitch, and others 2003).
- A method using liquid chromatography tandem MS (LC/MS/MS) detects both thermally stable and unstable nitrosamines in drinking water (Zhao and others 2006).
- A study developed a method that is a combination of SPE and LC/MS/MS for determination of NDMA in surface water, groundwater and wastewater samples. The quantification limit identified was 2 ng/L (Topuz and others 2012).
- Modifications to GC-MS and GC-NPD methods including sample evapoconcentration and low concentration instrument calibration can be used to detect NDMA in soil to levels below 1 microgram per kilogram (µg/kg) (USACE 2009).

What technologies are being used to treat NDMA?

- The most common method to treat NDMA in drinking water systems is photolysis by ultraviolet radiation in the wavelength range of 225 to 250 nanometers (nm) (Mitch and others 2003b).
- Biological treatment, microfiltration and reverse osmosis treatment may be used to remove NDMA precursors from wastewater before chlorination (Mitch and others 2003b).
- Activated sludge, biological activated carbon and ultraviolet photolysis were found to be effective for NDMA mitigation in a study investigating 11 sites using ozone-based wastewater treatment trains (Gerrity and others 2015).
- The Department of Defense's Strategic Environmental Research and Development Program (SERDP) is investigating abiotic, biotic and coupled abiotic/biotic processes to accelerate NDMA degradation in the subsurface (DoD SERDP 2008, 2009, 2012).
- A recent study of NDMA precursors found that photolysis and biodegradation were effective removal mechanisms for precursors in the water column (Woods and Dickenson 2016).
- Laboratory-scale studies have shown that aerobic and anaerobic biodegradation of NDMA to low ng/L concentrations in water and soil may be possible (Bradley and others 2005; DoD SERDP 2008).
- A laboratory-scale study demonstrated the potential for in-situ aerobic cometabolism of NDMA in the presence of methane- and benzene-amended groundwater highlighting possible attenuation mechanisms and rates for NDMA biotransformation in aerobic aquifers undergoing active remediation, natural attenuation or managed aquifer recharge with treated wastewater (Weidhaas and Dupont 2013).
- An Environmental Security Technology Certification Program demonstration project evaluated the technical effectiveness and cost of using a fluidized bed bioreactor (FBR) for treating NDMA in groundwater at a test facility. The FBR was found to be an effective means to treat NDMA, decreasing concentrations from 1 µg/L to 4.2 ng/L. The cost of the full-scale FBR was determined to be significantly less than the comparable ultraviolet system over a 30-year remedial timeframe (ESTCP 2014).
- Laboratory-scale study results suggest that in-situ coupled abiotic/biotic processes may efficiently degrade NDMA in groundwater (DoD SERDP 2009).

- Membrane bioreactor (MBR) treatment was found to be effective in removing NDMA through biodegradation due to the presence of strong electron donating functional groups in their structure (Wijekoon and others 2013).
- An SERDP project was conducted to identify the organisms, enzymes and biochemical pathways involved in the aerobic biodegradation of NDMA. Laboratory-scale study results highlighted the importance of monooxygenases in the degradation of NDMA (DoD SERDP 2012).
- A SERDP field study was recently completed utilizing propane biosparging for in situ remediation of NDMA in groundwater. The field test results support that propane biosparging can be an effective approach to reduce the concentrations of NDMA in a groundwater aquifer by 3 to 4 orders of magnitude, and that concentrations in the low nanograms per liter (ng/L) range can be achieved with continuous treatment (DoD SERDP 2016).
- A laboratory-scale study observed the decomposition of NDMA in water using nanoscale zero-valent iron in the presence of aluminum and iron salts. The highest removal was found at a pH of 5. Improved removal was associated with a higher reaction temperature (Lin Lin and others 2013).

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Contact Information

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EPA United States Environmental Protection Agency

Technical Fact Sheet – Polybrominated Biphenyls (PBBs)

November 2017

At a Glance

- Class of brominated hydrocarbons that serve as flame retardants for electrical equipment, electronic devices, furniture, textiles and other household products.
- Structurally similar and exhibit low to moderate volatility.
- Exposure in rats and mice caused neuro-developmental toxicity and other symptoms.
- The U.S. Department of Health and Human Services states that PBBs are reasonably anticipated to be human carcinogens.
- EPA has calculated screening levels for PBBs in air, soil and tap water.
- Detection methods include gas chromatography, mass spectrometry and liquid chromatography.

Introduction

This fact sheet, developed by the U.S. Environmental Protection Agency (EPA) Federal Facilities Restoration and Reuse Office (FFRRO), provides a summary of the contaminant group polybrominated biphenyls (PBBs), including physical and chemical properties; environmental and health impacts; existing federal and state guidelines; detection and treatment methods; and additional sources of information. This fact sheet provides basic information on PBBs to site managers and other field personnel who may encounter these contaminants at cleanup sites.

The manufacture of PBBs was banned in the United States in 1976 after an agricultural contamination incident in 1973 when PBB was accidentally mixed into animal feed, exposing millions of Michigan residents to contaminated dairy products, eggs and meat (ATSDR 2004; NTP 2014).

What are PBBs?

- PBBs are a class of brominated hydrocarbons. They contain a central biphenyl structure surrounded by up to 10 bromine atoms (ATSDR 2004).
- PBBs were formerly used as additive flame retardants in synthetic fibers and molded plastics. They are no longer used in the United States (ATSDR 2004; NTP 2014).
- Three types of commercial PBB mixtures were: hexabromobiphenyl (hexaBB), octabromobiphenyl (octaBB) and decabromobiphenyl (decaBB) (ATSDR 2004).
- There are no known natural sources of PBBs (ATSDR 2004).
- PBBs are structurally similar to polychlorinated biphenyls (PCBs).
- PBBs are fat-soluble and hydrophobic (NTP 2014).

Exhibit 1: Physical and Chemical Properties of PBBs (ATSDR 2004)

Property	PBBs		
	HexaBB	OctaBB	DecaBB
Chemical Abstracts Service (CAS) number	36355-01-8	27858-07-7	13654-09-6
Physical description (physical state at room temperature)	White solid	White solid	White solid
Molecular weight (g/mol)	627.4	785.2	943.1
Water solubility at 25°C (µg/L)	11	20 to 30	Insoluble
Boiling point (°C)	Not available	Not available	Not available
Melting point (°C)	72	200 to 250	380 to 386
Vapor pressure (mm Hg)	5.2×10^{-8} (at 25°C)	7×10^{-11} (at 28°C)	Not available
Octanol-water partition coefficient (log K_{ow})	6.39	5.53	8.58
Soil organic carbon-water coefficient (log K_{oc})	3.33 to 3.87 [a]	Not available	Not available
Henry's law constant at 25°C (atm-m^3/mol)	3.9×10^{-6}	Not available	Not available

Abbreviations: g/mol – gram per mole; µg/L – micrograms per liter; °C – degrees Celsius; mm Hg – millimeters of mercury; atm-m^3/mol – atmosphere-cubic meters per mole.
[a] – Estimated value

Existence of PBBs in the environment

- PBBs have been detected in air, sediments, surface water, fish and other marine animals (ATSDR 2004).
- PBBs do not dissolve easily in water and bind strongly to soil or sediment particles. This reduces their mobility in soil, sediment, surface and groundwater, but increases their mobility in the atmosphere, where they are attached to airborne particulate matter (ATSDR 2004).
- Volatilization from soil surfaces is expected to be low to moderate, depending on the number of bromine atoms. More brominated congeners (higher numbers of bromine atoms) tend to exhibit lower volatilities (NTP 2014).
- Even though PBBs are stable, they are susceptible to photolytic debromination when they are exposed to ultraviolet light (ATSDR 2004).
- As of 2016, PBBs had been identified at few sites on the EPA National Priorities List (NPL); however, the number of sites evaluated for PBBs is not well documented (EPA 2016a).

What are the routes of exposure and the potential health effects of PBBs?

- Routes of potential human exposure to PBBs are ingestion, inhalation or dermal contact (NTP 2014).
- Since PBBs are not produced or used in the United States, the general population can only be exposed from historical releases or products (ATSDR 2004).
- The U.S. Department of Health and Human Services (DHHS) states that PBBs are reasonably anticipated to be human carcinogens based on sufficient evidence of carcinogenicity from experimental animal studies (NTP 2014).
- The International Agency for Research on Cancer (IARC) classified PBBs as “probably carcinogenic to humans” (IARC 2016).
- Studies on mice and rats, and evidence from cows exposed via feed show that PBBs cause neurotoxicity, weight loss, skin disorders, liver toxicity, kidney toxicity, thyroid toxicity immunotoxicity and cancer (ATSDR 2004; Birnbaum and Staskal 2004).
- Studies on animals and humans show that some PBBs can act as endocrine system disruptors, have been found in human breast milk, and tend to deposit in human adipose tissue (ATSDR 2004; Birnbaum and Staskal 2004; NTP 2014).

Are there any existing federal and state guidelines and health standards for PBBs?

- EPA has not derived chronic oral reference doses (RfDs) for PBBs.
- EPA has calculated the following screening levels for residential soil, industrial soil and tap water (EPA 2017b):

Chemical	Residential Soil (mg/kg)	Industrial Soil (mg/kg)	Tap Water (µg/L)
PBBs	0.018	0.077	0.0026

- For PBBs, EPA has also calculated a residential air screening level of 3.3×10^{-4} micrograms per cubic meter (µg/m^3) and an industrial air screening level of 1.4×10^{-3} µg/m^3 (EPA 2017b).
- The Agency for Toxic Substances and Disease Registry (ATSDR) has established a minimal risk level (MRL) of 0.01 mg/kg/day for acute-duration (14 days or less) oral exposure to PBBs (ATSDR 2016).
- Various states have adopted screening values or cleanup goals for PBBs in drinking water or groundwater, ranging from 0.0001 to 5 µg/L:

State	Guideline (µg/L)	Source
Indiana	0.026	IDEM 2016
Michigan	0.03	MDEQ 2015
Mississippi	0.00752	MS DEQ 2002
Nebraska	0.0022	NE DEQ 2012
New York	5	NYDEC 2016
Texas	0.0001	TCEQ 2016
West Virginia	0.0022	WV DEP 2009

- Some states have established soil standards or guidelines for PBBs, including Michigan, Mississippi, Nebraska, North Carolina, Texas, West Virginia and Wisconsin. The California Environmental Protection Agency (Cal/EPA) has established a No Significant Risk Level of 0.02 µg per day for PBBs (Cal/EPA 2017).

What detection and site characterization methods are available for PBBs?

- Analytical methods for PBB detection include gas chromatography-electron capture detector (GC-ECD) for commercial samples, soil, plant tissue, water, sediment, fish, dairy and animal feed; high resolution GC (HRGC)/high resolution mass spectrometry (HRMS) for fish samples; GC-flame ionization detector (FID)/ECD for soil; and liquid chromatography (LC)-GC-MS/FID for sediment (ATSDR 2004).

What technologies are being used to treat PBBs?

- Research is being conducted at the laboratory scale on potential treatment methods for media contaminated with PBBs.

Where can I find more information about PBBs?

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Technical Fact Sheet – Polybrominated Diphenyl Ethers (PBDEs)

November 2017

TECHNICAL FACT SHEET – PBDEs

At a Glance

- Classes of brominated hydrocarbons that serve as flame retardants for electrical equipment, electronic devices, furniture, textiles and other household products.
- Structurally similar and exhibit low to moderate volatility. Lower brominated congeners of PBDE tend to bioaccumulate more than higher brominated congeners.
- Exposure in rats and mice caused thyroid hormone bioactivity, neuro-developmental toxicity and other symptoms.
- According to EPA, evidence of carcinogenic potential is suggested for decaBDE.
- Detection methods include gas chromatography, mass spectrometry and liquid chromatography.
- Potential treatment methods being evaluated at the laboratory scale include debromination using zero-valent iron (ZVI) and nanoscale ZVI, activated carbon treatment and enhanced biodegradation.

Introduction

This fact sheet, developed by the U.S. Environmental Protection Agency (EPA) Federal Facilities Restoration and Reuse Office (FFRRO), provides a summary of the contaminant groups polybrominated diphenyl ethers (PBDEs), including physical and chemical properties; environmental and health impacts; existing federal and state guidelines; detection and treatment methods; and additional sources of information. This fact sheet provides basic information on PBDEs to site managers and other field personnel who may encounter these contaminants at cleanup sites.

PBDEs have been used widely in the United States since the 1970s; however, there is growing concern about their persistence in the environment and their tendency to bioaccumulate (ATSDR 2015; EPA 2009).

What are PBDEs?

- PBDEs are brominated hydrocarbons in which 2-10 bromine atoms are attached to the molecular structure (ATSDR 2015).
- PBDEs are used as flame retardants in a wide variety of products, including plastics, furniture, upholstery, electrical equipment, electronic devices, textiles and other household products (ATSDR 2015; EPA 2009).
- At high temperatures, PBDEs release bromine radicals that reduce both the rate of combustion and dispersion of fire (Hooper and McDonald 2000).
- PBDEs exist as mixtures of distinct chemicals called congeners with unique molecular structures (ATSDR 2015; EPA 2009).
- There are three types of commercial PBDE mixtures, including pentabromodiphenyl ether (pentaBDE), octabromodiphenyl ether (octaBDE) and decabromodiphenyl ether (decaBDE). DecaBDE is the most widely used PBDE globally (ATSDR 2015; EPA 2009).
- The production of octaBDE and pentaBDE in the United States ceased at the end of 2004 after the voluntary phase-out of these chemicals by the only U.S. manufacturer. In 2009, the two U.S. producers and the main U.S. importer of decaBDE announced plans to phase out the compound by the end of 2013 (EPA 2013).

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- In 2014, EPA identified 29 potentially functional, viable alternatives to decaBDE for use in select polyolefins, styrenics, engineering thermoplastics, thermosets, elastomers, or waterborne emulsions and coatings (EPA 2014).
- There are no known natural sources of PBDEs, except for a few marine organisms that produce forms of PBDEs that contain higher levels of oxygen (ATSDR 2015).
- PBDEs are structurally similar to polychlorinated biphenyls (PCBs). PBDEs are fat-soluble and hydrophobic (Hooper and McDonald 2000; NTP 2014).

Exhibit 1: Physical and Chemical Properties of PBDEs
(ATSDR 2015)

Property	PBDEs		
	PentaBDE	OctaBDE	DecaBDE
Chemical Abstracts System (CAS) number	32534-81-9	32536-52-0	1163-19-5
Physical description (physical state at room temperature)	Clear, amber to pale yellow liquid	Off-white powder	Off-white powder
Molecular weight (g/mol)	Mixture	Mixture	959.22
Water solubility at 25°C (µg/L)	13.3 (commercial)	Less than 1 (commercial)	Less than 1
Boiling point (°C)	Over 300	Over 330 (decomposes)	Over 320 (decomposes)
Melting point (°C)	-7 to -3 (commercial)	85 to 89 (commercial)	290 to 306
Vapor pressure at 25°C (mm Hg)	2.2×10^{-7} to 5.5×10^{-7}	9.0×10^{-10} to 1.7×10^{-9}	3.2×10^{-8}
Octanol-water partition coefficient (log K_{ow})	6.64 to 6.97	6.29 (commercial)	6.265
Soil organic carbon-water coefficient (log K_{oc})	4.89 to 5.10 [a]	5.92 to 6.22 [a]	6.80 [a]
Henry's law constant at 25°C (atm-m^3/mol)	1.2×10^{-5} [a]	7.5×10^{-8} [a]	1.62×10^{-6} [a]

Abbreviations: g/mol – gram per mole; µg/L – micrograms per liter; °C – degrees Celsius; mm Hg – millimeters of mercury; atm-m^3/mol – atmosphere-cubic meters per mole.
[a] – Estimated value

Existence of PBDEs in the environment

- PBDEs may enter the environment through emissions from manufacturing processes, volatilization from various products that contain PBDEs, recycling wastes and leachate from waste disposal sites (ATSDR 2015; EU 2001).
- PBDEs have been detected in air, sediments, surface water, fish and other marine animals (ATSDR 2015; EPA 2009).
- Based on a very limited number of studies, biodegradation does not appear to be significant for PBDEs (ATSDR 2015).
- Higher brominated congeners of PBDE tend to bind to sediment or soil particles more than lower brominated congeners (ATSDR 2015).
- PBDEs do not dissolve easily in water and bind strongly to soil or sediment particles. This reduces their mobility in soil, sediment, surface and groundwater, but increases their mobility in the atmosphere, where they are attached to airborne particulate matter (ATSDR 2015).
- Volatilization from soil surfaces is expected to be low to moderate, depending on the number of bromine atoms. More brominated congeners (higher numbers of bromine atoms) tend to exhibit lower volatilities (EPA 2009; NTP 2014).
- Even though PBDEs are stable, they are susceptible to photolytic debromination when they are exposed to ultraviolet light (ATSDR 2015).
- As of 2016, PBDEs were not identified at any of the current or former hazardous waste sites on the EPA National Priorities List (NPL); however, the number of sites evaluated for PBDEs is not well documented (EPA 2016).

What are the routes of exposure and the potential health effects of PBDEs?

- Routes of potential human exposure to PBDEs are ingestion, inhalation or dermal contact (NTP 2014).
- Traces of PBDEs have been detected in samples of human tissue, human blood and breast milk (EPA 2009; He and others 2006)
- According to EPA, evidence of carcinogenic potential is suggested for decaBDE (EPA 2009; EPA IRIS 2008).
- Neither the U.S. Department of Health and Human Services (DHHS) nor the International Agency for Research on Cancer (IARC) has classified the carcinogenicity of any PBDEs (IARC 2016; NTP 2014). However, the National Toxicology Program (NTP) evaluated a pentabromodiphenyl ether mixture in a rodent bioassay and concluded there was clear evidence of carcinogenicity in each species/sex tested (NTP 2014).
- Studies in rats and mice show that PBDEs cause neurotoxicity, developmental neurotoxicity, reproductive toxicity, thyroid toxicity, immunotoxicity, liver toxicity, pancreas effects (diabetes) and cancer (penta and decabromodiphenyl ether). There may be differences in the severity of effects depending on bromination level (ATSDR 2015; Birnbaum and Staskal 2004; EPA 2009).
- Studies on animals and humans show that some PBDEs can act as endocrine system disruptors and tend to deposit in human adipose tissue (ATSDR 2015; Birnbaum and Staskal 2004; He and others 2006; NTP 2014).
- Studies indicate that octaBDE is a teratogen (a prenatal developmental toxin) (Darnerud and others 2001; He and others 2006).

Are there any existing federal and state guidelines and health standards for PBDEs?

- EPA has established the following chronic oral reference doses (RfDs) for PBDEs (EPA 2017):

PBDE Congener	Milligrams per kilogram per day (mg/kg/day)
2,2',3,3',4,4',5,5',6,6' decaBDE-209 congener	7×10^{-3}
octaBDE congener	3×10^{-3}
pentaBDE congener	2×10^{-3}
2,2',4,4' - tetrabromodiphenyl ether (tetraBDE-47) congener	1×10^{-4}
2,2',4,4',5,5' - hexabromodiphenyl ether (hexaBDE-153) congener	2×10^{-4}
2,2',4,4',5 - pentaBDE-99 congener	1×10^{-4}

- For decaBDE-209, EPA has assigned an oral slope factor for carcinogenic risk of 7×10^{-4} (mg/kg/day)$^{-1}$ and a drinking water unit risk of 2.0×10^{-8} micrograms per liter (µg/L) (EPA IRIS 2008).
- EPA risk assessments indicate that the drinking water concentration representing a 1×10^{-6} cancer risk level for decaBDE-209 is 50 µg/L (EPA IRIS 2008).
- EPA has calculated the following screening levels for residential soil, industrial soil and tap water (EPA 2017):

Chemical	Residential Soil (mg/kg)	Industrial Soil (mg/kg)	Tap Water (µg/L)
decaBDE-209	440	3,300	110
octaBDE	190	2,500	61
pentaBDE	160	2,300	40
tetraBDE-47	6.3	82	2.0
hexaBDE-153	13	160	4.0
pentaBDE-99	6.3	82	2.0

- For lower brominated PBDEs, the Agency for Toxic Substances and Disease Registry (ATSDR) has established a minimal risk level (MRL) of 0.006 milligrams per cubic meter for intermediate-duration inhalation exposure. In addition, ATSDR established an MRL of 6×10^{-5} mg/kg/day for acute-duration oral exposure and 3×10^{-6} mg/kg/day for intermediate-duration oral exposure (ATSDR 2016).
- Some states, including California, Hawaii, Illinois, Maine, Maryland, Michigan, Minnesota, New York, Oregon, Rhode Island and Washington, have banned pentaBDE and octaBDE. States such as Maine, Maryland, Oregon and Washington have also introduced legislation that bans the sale of certain products containing decaBDE (EPA 2009).

- EPA issued a Significant New Use Rule (SNUR) in 2006 to phase out pentaBDE and octaBDE. According to this rule, no new manufacture or import of these two congeners is allowed after January 1, 2005, without a 90-day notification to EPA for evaluation (EPA 2013).
- In December 2009, the two U.S. producers and the main U.S. importer of decaBDE committed to end production, import and sales of the chemical for all consumer, transportation and military uses by the end of 2013 (EPA 2014). However, based on 2012 industry comments to EPA, there may be ongoing uses for decaBDE.

What detection and site characterization methods are available for PBDEs?

- Analytical methods used for PBDE detection include gas chromatography (GC)-mass spectrometry (MS) for air, sewage, fish and animal tissues; capillary column GC/electron capture detector (ECD) for water and sediment samples; GC/high resolution MS (HRMS) for fish tissue; and liquid chromatography (LC)-GC-MS/flame ionization detector (FID) for sediments (ATSDR 2015).
- EPA Method 1614 uses isotope dilution and internal standard high resolution GC (HRGC)/HRMS to detect PBDEs in water, soil, sediment and tissue (EPA 2007).

What technologies are being used to treat PBDEs?

- Research is being conducted at the laboratory scale on potential treatment methods for media contaminated with PBDEs.
- Anaerobic bacteria may be utilized to partially degrade higher brominated PBDE, but may lead to the formation of less-brominated, more toxic congeners (He and others 2006; Lee and He 2010).

  Secondary treatment using cationic surfactants may be required to increase the availability of PBDE molecules for reactions with zero valent iron (ZVI) (Keum and Li 2005).
- Laboratory studies are also evaluating the use of bimetallic nanoparticles (BNPs) and nanoscale ZVI (nZVI) for the treatment of PBDEs. Sequential treatment with nZVI and aerobic biodegradation and treatment with iron silver BNPs coupled with microwave energy were both shown to effectively degrade PBDEs (Kim and others 2012, 2014; Luo and others 2012).
- A 2016 laboratory study indicates a tourmaline catalyzed Fenton-like reaction can remove PBDEs from soil (Li and others 2016).
- Bench-scale experiments indicate that electrokinetic remediation may be effective for the treatment of PBDEs in soil (Chun and others 2012).
- The use of activated carbon has also been investigated in a laboratory study for the treatment of PBDE in sediment (Choi and others 2003).

Where can I find more information about PBDEs?

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Where can I find more information about PBDEs? (continued)

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EPA United States Environmental Protection Agency

Technical Fact Sheet – Perchlorate

November 2017

At a Glance

- Both naturally occurring and man-made anion.
- Contamination has been found at sites involved in the manufacture, maintenance, use and disposal of ammunition and rocket fuel.
- Highly soluble in water; migrates quickly from soil to groundwater.
- Primary pathways for human exposure include ingestion of contaminated food and drinking water.
- Affects thyroid gland by interfering with iodide uptake.
- EPA issued Interim Drinking Water Health Advisory.
- Various states have screening values or cleanup goals for perchlorate in drinking water or groundwater.
- Various detection methods available.
- Common treatment technologies include ion exchange, bioremediation and membrane technologies.

Introduction

This fact sheet, developed by the U.S. Environmental Protection Agency (EPA) Federal Facilities Restoration and Reuse Office (FFRRO), provides a summary of the contaminant perchlorate, including physical and chemical properties; environmental and health impacts; existing federal and state guidelines; detection and treatment methods; and additional sources of information. This fact sheet provides basic information on perchlorate to site managers and other field personnel who are addressing perchlorate contamination at cleanup sites or in drinking water supplies.

What is perchlorate?

- Perchlorate is a naturally occurring and man-made anion that consists of one chlorine atom bonded to four oxygen atoms (ClO_4^-). Manufactured forms of perchlorate include perchloric acid and salts such as ammonium perchlorate, sodium perchlorate and potassium perchlorate (EPA FFRRO 2005; ITRC 2005).
- Perchlorate is commonly used in solid rocket propellants, munitions, fireworks, airbag initiators for vehicles, matches and signal flares (EPA FFRRO 2005; ITRC 2005). It is also used in some electroplating operations (ATSDR 2008; ITRC 2005).
- Of the domestically produced perchlorate, 90 percent is manufactured for use in the defense and aerospace industries, primarily in the form of ammonium perchlorate (GAO 2005; ITRC 2005).
- Perchlorate may occur naturally, particularly in arid regions such as the southwestern United States (Rao and others 2007).
- Perchlorate is found as a natural impurity in nitrate salts from Chile, which are imported and used to produce nitrate fertilizers, explosives and other products (EPA FFRRO 2005; ITRC 2005).

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Exhibit 1: Physical and Chemical Properties of Perchlorate Compounds
(ATSDR 2008; EPA FFRRO 2005; ITRC 2005; NIOSH 2014)

Property	Ammonium Perchlorate	Sodium Perchlorate	Potassium Perchlorate	Perchloric Acid
Chemical Abstracts Service (CAS) numbers	7790-98-9	7601-89-0	7778-74-7	7601-90-3
Physical description (physical state at room temperature)	White orthorhombic crystal	White orthorhombic deliquescent crystal	Colorless orthorhombic crystal or white crystalline powder	Colorless, oily liquid
Molecular weight (g/mol)	117.49	122.44	138.55	100.47
Water solubility (g/L at 25°C)	200	2,100	15	Miscible in cold water
Melting / Boiling point* (°C)	Melting point: 130	Melting point: 471 to 482	Melting point: 400 to 525	Melting point: -112 Boiling point: 19
Vapor pressure at 25°C (mm Hg)	Very low	Very low	Very low	N/A
Specific gravity (g/cm^3)	1.95	2	2.52	1.77
Octanol-water partition coefficient (log K_{ow})	-5.84	-7.18	-7.18	-4.63

*Different melting point temperatures are identified in literature.
Abbreviations: g/mol – grams per mole; g/L – grams per liter; °C – degrees Celsius; mm Hg – millimeters of mercury; g/cm^3 – grams per cubic centimeter.

Existence of perchlorate in the environment

- Perchlorate is highly soluble in water, and relatively stable and mobile in surface and subsurface aqueous systems. As a result, perchlorate plumes in groundwater can be extensive (ITRC 2005). For example, the perchlorate plume at a former safety flare manufacturing site (the Olin Flare Facility) in Morgan Hill, California, extends 10 miles (Cal/EPA 2016b).
- Because of their low vapor pressure, perchlorate compounds and the perchlorate anion do not volatilize from water or soil surfaces to air (ATSDR 2008; ITRC 2005).
- Perchlorate released directly to the atmosphere is expected to readily settle through wet or dry deposition (ATSDR 2008).
- High concentrations of perchlorate have been detected at current and Formerly Used Defense Sites historically involved in the manufacture, testing and disposal of ammunition and rocket fuel or at industrial sites where perchlorate is manufactured or used as a reagent during operations (ATSDR 2008; ITRC 2005).
- Types of military and defense-related facilities with known releases include missile ranges and missile and rocket manufacturing facilities. However, since site-specific documentation may not be available and based on historical uncertainties, it is generally difficult to identify specific military sites with known perchlorate releases (ITRC 2005).
- From 1997 to 2009, the Department of Defense reported perchlorate detections at 284 (almost 70 percent) of its installations sampled (GAO 2010).
- In addition, the past disposal of munitions in either burial pits or by open burning and open detonation may have resulted in releases to the environment. The amount of perchlorate released can vary depending on the length of time the disposal area was used and the types of munitions disposed of in the area (ITRC 2005).
- Nitrate is commonly found as a co-contaminant in water with perchlorate because ammonium nitrate is a main component in rocket fuel and explosives (DoD ESTCP 2013).
- Studies have shown perchlorate accumulates in some food crop leaves, tobacco plants and in broad-leaf plants (ATSDR 2008).
- Surveys conducted by the U.S. Food and Drug Administration have detected perchlorate in food crops and milk (Murray and others 2008).

- As of October 2009, perchlorate had been detected at varying levels in drinking water, groundwater, surface water, soil or sediment at private and federal facilities in 45 states, three U.S. territories and Washington D.C. The maximum concentrations reported in any media ranged from less than 4 parts per billion (ppb) to 2.6 million ppb (GAO 2010).
- EPA reported perchlorate detections at 40 hazardous waste sites on the EPA National Priorities List as of June 2010 (GAO 2010).

What are the routes of exposure and the potential health effects of perchlorate?

- Primary pathways for human exposure to perchlorate are ingestion of contaminated food and drinking water (ATSDR 2008; EPA FFRRO 2005).
- After perchlorate is ingested, it quickly passes through the stomach and intestines and enters the bloodstream (ATSDR 2008).
- The thyroid gland is the primary target of perchlorate toxicity in humans. Thyroid hormones play an important role in regulating metabolism and are critical for normal growth and development in fetuses, infants and young children. Perchlorate can interfere with iodide uptake into the thyroid gland at high enough exposures, disrupting the functions of the thyroid and potentially leading to a reduction in the production of thyroid hormones (ATSDR 2008; Cal/EPA 2015; National Research Council 2005).
- Potassium perchlorate was historically used to treat hyperthyroidism because of its ability to inhibit thyroid iodide uptake (ATSDR 2008; National Research Council 2005).
- Studies conducted on rodents showed that perchlorate concentrations below that required to alter thyroid hormone equilibrium are unlikely to cause thyroid cancer in human beings (ATSDR 2008; EPA IRIS 2005).
- Short-term exposure to high doses of ammonium, sodium or potassium perchlorate may cause eye, skin and respiratory tract irritation, coughing, nausea, vomiting and diarrhea. Perchloric acid is corrosive to the eyes, skin and respiratory tract, and short-term exposure to high doses may cause sore throat, coughing, labored breathing, deep burns, loss of vision, abdominal pain, vomiting or diarrhea (NIOSH 2014).

Are there any federal and state guidelines and health standards for perchlorate?

- EPA assigned perchlorate a chronic oral reference dose (RfD) of 0.0007 milligrams per kilogram per day (mg/kg/day). The RfD is an estimate of a daily exposure level that is likely to be without non-cancer health effects over a lifetime (EPA IRIS 2005).
- The Agency for Toxic Substances and Disease Registry (ATSDR) has established a minimal risk level (MRL) of 0.0007 mg/kg/day for chronic-duration oral exposure (365 days or more) to perchlorate. An MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse non-cancer health effects over a specified duration of exposure (ATSDR 2008, 2016).
- In 2011, EPA determined that perchlorate meets the Safe Drinking Water Act criteria for regulation as a contaminant. EPA then worked with the FDA to develop a dose-response model to analyze the effects of perchlorate on thyroid hormone production. In 2017, EPA completed a peer review to evaluate EPA's draft dose-response model. A future peer review will evaluate EPA's draft approach for deriving a Maximum Contaminant Level Goal (MCLG) for perchlorate in drinking water (EPA 2017a).
- In 2008, EPA established an Interim Drinking Water Health Advisory of 15 micrograms per liter (µg/L) for perchlorate. Exposure to this level for more than 30 days, but less than a year, is not expected to cause any adverse non-cancer effects. Health Advisories serve as informal guidance to assist managers of water systems; they are not legally enforceable standards (EPA 2008, 2012).
- EPA has calculated a tapwater screening level of 14 µg/L for perchlorate and perchlorate salts (EPA 2017b).
- EPA's Office of Land and Emergency Management recommends a preliminary remedial goal (PRG) of 15 µg/L at Superfund sites where there is an actual or potential drinking water exposure pathway, and where no applicable or relevant and appropriate requirements exist under federal or state laws (EPA 2009).
- California (6 µg/L) and Massachusetts (2 µg/L) have established enforceable standards for

perchlorate in drinking water (Cal/EPA 2016c; Massachusetts DEP 2016).

- Various states have adopted screening values or cleanup goals for perchlorate in drinking water or groundwater, ranging from 0.8 to 71 µg/L:

State	Guideline (µg/L)	Source
Alabama	24.5	ADEM 2008
California	1 (public health goal)	Cal/EPA 2016a
Colorado	4.9	CDPHE 2016
Florida	4	FDEP 2005
Illinois	4.9	IL EPA 2016
Indiana	15	IDEM 2016
Kansas	11 (residential) 71 (non-residential)	KDHE 2015
Maine	0.8	MDEP 2016
Maryland	2.6	MDE 2008
Nebraska	6.4	NDEQ 2012
Nevada	18	NDEP 2015
New Mexico	25.6	NMED 2012
Pennsylvania	15	PADEP 2011
Texas	17	TCEQ 2016
Utah	14	UDEQ 2012
Vermont	2 (interim preventive action level); 4 (interim enforcement standard)	VTDEC 2015
Virginia	15	VDEQ 2014
West Virginia	11	WVDEP 2014
Wyoming	23.3	WDEQ 2016

- EPA has calculated soil screening levels of 55 milligrams per kilogram (mg/kg) for residential areas and 820 mg/kg for industrial areas for perchlorate and perchlorate salts (ammonium, potassium, sodium and lithium) (EPA 2016b).
- Various states have adopted screening values or cleanup goals for perchlorate in soil, ranging from 0.1 to 150 mg/kg for residential areas, and from 5 to 2,000 mg/kg for industrial areas.

What detection and site characterization methods are available for perchlorate?

- Drinking water, groundwater and surface water:
  - EPA Method 314.0 - Ion Chromatography (EPA 2016a)
  - EPA Method 314.1 Rev 1.0 - Inline Column Concentration/Matrix Elimination Ion Chromatography with Suppressed Conductivity Detection (EPA 2016a)
  - EPA Method 314.2 - Two-Dimensional Ion Chromatography with Suppressed Conductivity Detection (EPA 2016a)
  - EPA Method 331.0 Rev. 1.0 - Liquid Chromatography/Electrospray Ionization/Mass Spectrometry (EPA 2016a)
- Drinking water: EPA Method 332.0 - Ion Chromatography with Suppressed Conductivity and Electrospray Ionization Mass Spectrometry (EPA 2016a)
- Surface water, groundwater, wastewater, salt water and soil: EPA SW-846 Method 6850 - High Performance Liquid Chromatography/Electrospray Ionization/Mass Spectrometry (EPA 2016c)
- Surface water, groundwater, salt water and soil: EPA SW-846 Method 6860 - Ion Chromatography/ Electrospray Ionization/Mass Spectrometry (EPA 2016c)
- The presence of high amounts of other anions, such as chloride, sulfate or carbonate, may interfere with the analysis of perchlorate (EPA 1999).
- Researchers have developed methods to distinguish man-made and natural sources of perchlorate in water samples using chlorine and oxygen stable isotope ratio analysis (Bŏhlke and others 2005; ITRC 2005; Sturchio and others 2014).

What technologies are being used to treat perchlorate?

- **Ex Situ Treatment**
  - Ion exchange using perchlorate-selective or nitrate-specific resins is a proven method for removal of perchlorate from drinking water, groundwater, and surface water (ITRC 2008).
  - Ex situ bioremediation is being used to treat a large perchlorate plume in southern Nevada (NDEP 2017).
  - Membrane technologies including electrodialysis and reverse osmosis have been used to remove perchlorate from groundwater, surface water and wastewater; however, these all require subsequent disposal of the perchlorate removed (EPA FFRRO 2005; ITRC 2008).
  - Although standard granular activated carbon (GAC) does not efficiently remove perchlorate, the adsorptive capacity of GAC may be increased through the addition of a surface-active coating to produce a modified or tailored GAC. Tailored GAC has proven to be effective for treating perchlorate in water; however, it

produces a waste stream requiring management (Hou and others 2013; ITRC 2008).

- Laboratory-study results indicate that an electrically switched ion exchange system using a conductive carbon nanotube nanocomposite material could be used for the large-scale treatment of wastewater and drinking water. This approach would produce less secondary waste than conventional ion exchange processes (DoD SERDP 2011).
- A recent field study demonstrated the effective treatment of perchlorate-contaminated groundwater to below detection limits using a large-scale weak base anion resin ion exchange system. This system allows efficient and economical regeneration of the spent resin (DoD ESTCP 2012b).
- A fluidized bed biological reactor treatment train successfully treated low concentrations of perchlorate in groundwater to meet the California drinking water standards (6 µg/L) in a field study. The microbial process completely destroyed the perchlorate molecules, so no subsequent treatment or waste disposal was needed (DoD ESTCP 2009b).
- Laboratory study results indicate that ultraviolet laser reduction can be used to decompose low levels of perchlorate (below 100 µg/L) in water. This technology is currently undergoing laboratory testing and has not yet been commercialized or used in full-scale systems (ITRC 2008). One laboratory study found that ultraviolet light and sulfite are able to degrade perchlorate when used together, but not when used alone (Vellanki and others 2013).

❖ **In Situ Treatment**

- Enhanced in situ bioremediation using ubiquitous perchlorate-reducing microbes can be an effective method for degrading perchlorate in groundwater and soil, at a lower cost than ex situ methods (DoD SERDP 2002; ITRC 2008; Stroo and Ward 2008).
- A laboratory study found that adding acetate or hydrogen as electron donors can increase perchlorate removal efficiency in groundwater (Wang and others 2013).
- Field study demonstration results indicate that a horizontal flow treatment well system can effectively deliver electron donor and promote the in situ biological reduction of perchlorate in groundwater (DoD ESTCP 2009c).
- A field study evaluated the use of gaseous electron donor injection technology for the anaerobic biodegradation of perchlorate in vadose zone soil. Results showed an average perchlorate destruction of more than 90 percent within the targeted 10-foot radius of influence within five months (DoD ESTCP 2009d).
- A field study evaluated the use of an emulsified oil biobarrier to enhance the in situ anaerobic biodegradation of perchlorate and chlorinated solvents in groundwater. Within 5 days of injection, perchlorate was degraded from an initial concentration range of 3,100 to 20,000 µg/L to below detection limits (less than 4 µg/L) in the injection and nearby monitoring wells (DoD SERDP 2008).
- A field study demonstrated that enhanced in situ bioremediation of perchlorate-impacted groundwater is effective using either an active or semi-passive approach. The active approach used on-going groundwater recirculation and delivery of an electron donor; perchlorate concentrations as high as 4,300 µg/L were reduced to less than 4 µg/L within 50 feet of the electron donor delivery/recharge well. The semi-passive approach involved periodic delivery of electron donor; perchlorate concentrations were reduced from levels over 800 µg/L to an average concentration of 3.4 µg/L (DoD ESTCP 2009a, 2012a).
- Laboratory and field studies have demonstrated the potential for using monitored natural attenuation to treat perchlorate in groundwater (DoD ESTCP 2010).
- Several bench-scale tests have demonstrated the potential effectiveness of phytoremediation and constructed wetlands to treat perchlorate-contaminated media; limited field study demonstrations have been implemented (ITRC 2008). Recent laboratory study results indicate that the wetland plant, *Eichhornia crassipes*, may be an effective plant for constructing a wetland to remediate high levels of perchlorate in water based on its high tolerance and accumulation ability (He and others 2013).

❖ DoD's environmental research programs have funded many projects to research the remediation of perchlorate. For more information, see www.serdp-estcp.org/Featured-Initiatives/Cleanup-Initiatives/Perchlorate and www.serdp-estcp.org/Tools-and-Training/Environmental-Restoration/Perchlorate.

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Additional information on perchlorate can be found at EPA's www.cluin.org/perchlorate.

Contact Information

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Technical Fact Sheet – Perfluorooctane Sulfonate (PFOS) and Perfluorooctanoic Acid (PFOA)

November 2017

At a Glance

- Manmade chemicals not naturally found in the environment.
- Fluorinated compounds that repel oil and water.
- Used in a variety of industrial and consumer products, such as carpet and clothing treatments and firefighting foams.
- Extremely persistent in the environment.
- Known to bioaccumulate in humans and wildlife.
- Readily absorbed after oral exposure. Accumulate primarily in the blood serum, kidney and liver.
- Toxicological studies on animals indicate potential developmental, reproductive and systemic effects.
- Health-based advisories or screening levels have been developed by EPA and state agencies.
- EPA has not issued a Maximum Contaminant Level (MCL) for drinking water.
- Standard analytical methods use high-performance liquid chromatography coupled with tandem mass spectrometry.
- Resistant to most chemical and microbial conventional treatment technologies. Most common groundwater treatment method is extraction and filtration through granular activated carbon filters.

Introduction

This fact sheet, developed by the U.S. Environmental Protection Agency (EPA) Federal Facilities Restoration and Reuse Office (FFRRO), provides a summary of two contaminants of emerging concern, perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA), including physical and chemical properties; environmental and health impacts; existing federal and state guidelines; detection and treatment methods; and additional sources of information. This fact sheet is intended for use by site managers who may address these chemicals at cleanup sites or in drinking water supplies and for those in a position to consider whether these chemicals should be added to the analytical suite for site investigations.

PFOS and PFOA are part of a larger group of chemicals called per- and polyfluoroalkyl substances (PFASs). PFASs, which are highly fluorinated aliphatic molecules, have been released to the environment through industrial manufacturing and through use and disposal of PFAS-containing products (Liu and Mejia Avendano 2013). PFOS and PFOA are the most widely studied of the PFAS chemicals. PFOS and PFOA are persistent in the environment and resistant to typical environmental degradation processes. As a result, they are widely distributed across all trophic levels and are found in soil, air and groundwater at sites across the United States. The toxicity, mobility and bioaccumulation potential of PFOS and PFOA result in potential adverse effects on the environment and human health.

What are PFOS and PFOA?

- They are human-made compounds that do not occur naturally in the environment (ATSDR 2015; EPA 2009b).
- PFOS and PFOA are fully fluorinated, organic compounds. They are the two PFASs that have been produced in the largest amounts within the United States (ATSDR 2015; EFSA 2008).
- PFOS and PFOA are part of a subset of PFASs known as perfluorinated alkyl acids (PFAAs).

PFAS Chemistry

- The PFAS group is made up of two subgroups: perfluoroalkyl substances and polyfluoroalkyl substances.
- PFOS and PFOA are **perfluoroalkyl substances** (compounds for which all hydrogens on all carbons (except for carbons associated with functional groups) have been replaced by fluorines).
- **Polyfluoroalkyl substances** are compounds for which some hydrogens (but not all) on the carbon atoms have been replaced by fluorines.
- PFASs are extremely persistent in the environment primarily because the chemical bond between the carbon and fluorine atoms is extremely strong and stable.

Source: Buck and others 2011

- PFOS and PFOA can also be formed by environmental degradation or by metabolism in larger organisms from a large group of related PFASs or precursor compounds (ATSDR 2015; UNEP 2006).
- PFOS and PFOA are stable chemicals that are comprised of chains of eight carbons. Because of their unique ability to repel oil and water, these chemicals have been used in: surface protection products such as carpet and clothing treatments; coatings for paper, cardboard packaging and leather products; industrial surfactants, emulsifiers, wetting agents, additives and coatings; processing aids in the manufacture of fluoropolymers such as nonstick coatings on cookware; membranes for clothing that are both waterproof and breathable; electrical wire casing; fire and chemical resistant tubing; and plumbing thread seal tape (ATSDR 2015).
- Through 2001, PFOS and other PFAS chemicals were used in the manufacture of aqueous film forming foam (AFFF), which is used to extinguish liquid hydrocarbon fires (ASTSWMO 2015; EPA 2016f; DoD SERDP 2014; Place and Field 2012). Manufacturers of AFFF in the United States now use PFASs other than PFOS; however, existing stocks of PFOS-based AFFF remain in use.
- By 2002, the primary U.S. manufacturer of PFOS voluntarily phased out production of PFOS. In 2006, eight major companies in the PFASs industry voluntarily agreed to phase out production of PFOA and PFOA-related chemicals by 2015. EPA is concerned about a limited number of ongoing uses of PFOA-related chemicals, which are still available in existing stocks and from companies not participating in the PFOA Stewardship Program. In addition, exposure could occur via goods imported from countries where PFOS and PFOA are still used (EPA 2016b, 2016c, 2016f).

Exhibit 1: Physical and Chemical Properties of PFOS and PFOA (ATSDR 2015; EFSA 2008; EPA 2016b, 2016c)

Property	PFOS (Free Acid)	PFOA (Free Acid)
Chemical Abstracts Service (CAS) number	1763-23-1	335-67-1
Physical description (physical state at room temperature and atmospheric pressure)	White powder (potassium salt)	White powder/ waxy white solid
Molecular weight (g/mol)	500	414
Water solubility at 25°C (mg/L)	680	9.5×10^3
Melting point (°C)	No data	54
Boiling point (°C)	258–260	192
Vapor pressure at 25°C (mm Hg)	0.002	0.525
Organic carbon partition coefficient (K_{oc})	2.57	2.06
Henry's law constant (atm-m^3/mol)	Not measurable	Not measurable

Abbreviations: g/mol – grams per mole; mg/L – milligrams per liter; °C – degree Celsius; mm Hg – millimeters of mercury; atm-m^3/mol – atmosphere-cubic meters per mole

Existence of PFOS and PFOA in the environment

- During manufacturing processes, PFASs were released to the air, water and soil in and around manufacturing facilities (ATSDR 2015). Recently, PFOS and PFOA contamination has also been observed in facilities using PFAS products to manufacture other products (secondary manufacturing facilities).
- PFOS has been detected in surface water and sediment downstream of production facilities and in wastewater treatment plant effluent, sewage sludge and landfill leachate at a number of cities in the United States (OECD 2002; Oliaei and others 2013).
- The environmental release of PFOS-based AFFF may also occur from tank and supply line leaks, use of aircraft hangar fire suppression systems, firefighting training activities, and use at airplane crash sites (DoD SERDP 2014).
- PFOS and PFOA products often contain residuals from manufacturing and formulation that are PFASs. PFOS- and PFOA-based products often contain impurities and residuals which may be precursors to PFOS and PFOA. Biological and abiotic environmental processes have been shown to transform these precursors into PFOS and PFOA (Liu and Mejia Avendano 2013; Buck and others 2011; Conder and others 2010).
- In general, PFOS and PFOA are stable in the environment and resist typical environmental degradation processes. As a result, these chemicals are persistent in the environment (OECD 2002; ATSDR 2015).
- PFOS and PFOA are detected in environmental media and biota in many parts of the world, including oceans and the Arctic, indicating that long-range transport is possible (ATSDR 2015).
- The wide distribution of perfluoroalkyl substances, such as PFOS, in higher trophic level organisms is strongly suggestive of the potential for bioaccumulation and/or bioconcentration (EPA 2015; UNEP 2006).
- PFOS has been shown to accumulate to levels of concern in fish. The estimated bioconcentration factor in fish ranges from 1,000 to 4,000 (EFSA 2008; MDH 2017a). PFOA has been shown to bioaccumulate in air breathing species, including humans, but not in fish (Vierke and others 2012).

What are the routes of exposure and the potential health effects of PFOS and PFOA?

- Studies have found PFOS and PFOA in the blood samples of the general human population and wildlife, indicating that exposure to the chemicals is widespread (ATSDR 2015; EPA 2015).
- Reported data indicate that blood serum concentrations of PFOS and PFOA are higher in workers and individuals living near facilities that use or produce PFASs than for the general population (ATSDR 2015; EPA 2009b).
- Potential exposure pathways include ingestion of food and water, use of consumer products or inhalation of PFAS-containing particulate matter (e.g., soils and dust) or vapor phase precursors (ATSDR 2015; EPA 2009b).
- PFOA and PFOS have been found in drinking water supplies, typically associated with manufacturing locations, industrial use or disposal.
- Human epidemiological studies found associations between PFOA exposure and high cholesterol, increased liver enzymes, decreased vaccination response, thyroid disorders, pregnancy-induced hypertension and preeclampsia, and cancer (testicular and kidney) (EPA 2016e).
- Human epidemiological studies found associations between PFOS exposure and high cholesterol and adverse reproductive and developmental effects (EPA 2016d).
- PFOS and PFOA are toxic to laboratory animals, producing reproductive, developmental and systemic effects in laboratory tests (Austin and others 2003; EPA 2016d, 2016e; Post and others 2012).
- EPA found that there is suggestive evidence that PFOS and PFOA may cause cancer (EPA 2016d, 2016e).
- The American Conference of Governmental Industrial Hygienists (ACGIH) has classified PFOA as a Group A3 carcinogen – confirmed animal carcinogen with unknown relevance to humans (ATSDR 2015).
- The World Health Organization’s International Agency for Research on Cancer has found that PFOA is possibly carcinogenic to humans (Group 2B) (IARC 2016).
- In 2009, the Stockholm Convention on Persistent Organic Pollutants added PFOS to Annex B, restricting its production and use. PFOA was proposed for listing in 2015 (Stockholm Convention 2016).

Are there any federal and state guidelines and health standards for PFOS and PFOA?

- EPA derived oral non-cancer reference doses (RfDs) of 0.00002 mg/kg/day for both PFOS and PFOA (EPA 2016d, 2016e). The RfD is an estimate of the daily exposure level that is likely to be without harmful effects over a lifetime.
- In May 2016, EPA established drinking water health advisories of 70 parts per trillion (0.07 micrograms per liter (µg/L)) for the combined concentrations of PFOS and PFOA. Above these levels, EPA recommends that drinking water systems take steps to assess contamination, inform consumers and limit exposure. The health advisory levels are based on the RfDs (EPA 2016b, 2016c).
- EPA found that there are insufficient data to derive inhalation non-cancer reference concentrations (RfCs) for PFOS and PFOA (EPA 2016d, 2016e).
- For PFOA, EPA estimated a cancer slope factor of 0.07 $(mg/kg/day)^{-1}$. Based on this slope factor, EPA calculated that a PFOA drinking water concentration of 0.5 µg/L would correspond to a one-in-a-million increased risk of cancer (EPA 2016c, 2016e).
- EPA has not issued a Maximum Contaminant Level (MCL) for drinking water.
- Various states have established drinking water and groundwater guidelines, including the following:

State	Guideline (µg/L)		Source
	PFOA	PFOS	
Delaware	0.4	0.2	DNREC 2016
Maine	0.13	0.56	MDEP 2016
Michigan	0.42	0.011	MDEQ 2015
Minnesota	0.035	0.027	MDH 2017b
New Jersey	0.04	NA	NJDEP 2016
North Carolina	2	NA	NCDEQ 2013
Texas	0.3	0.6	TCEQ 2016
Vermont	0.02	NA	VTDEC 2016

- Some states have fish consumption advisories for certain water bodies where PFOS has been detected in fish (MDH 2017c; MDHHS 2016).
- PFOS and PFOA are included on the fourth drinking water contaminant candidate list, which is a list of unregulated contaminants that are known to, or anticipated to, occur in public water systems and may require regulation under the Safe Drinking Water Act (EPA 2016a).

What detection and site characterization methods are available for PFOS and PFOA?

- Detection methods for PFOS and PFOA are primarily based on high-performance liquid chromatography (HPLC) coupled with tandem mass spectrometry (MS/MS) (ATSDR 2015).
- EPA Method 537, Version 1.1, is a liquid chromatography/tandem mass spectrometry (LC-MS/MS) method used to analyze PFOS, PFOA and other PFAAs in finished drinking water. While most sampling protocols for organic compounds require sample collection in glass, this method requires plastic sample bottles because PFASs are known to adhere to glass (ATSDR 2015; EPA 2009a). In addition, the method notes that analytes are found in common lab supplies and equipment such as PTFE (polytetrafluoroethylene) products, LC solvent lines, solid phase extraction sample transfer lines, methanol and aluminum foil (EPA 2009a).
- Currently, there are no standard EPA methods for analyzing PFASs in groundwater, surface water, wastewater or solids. EPA is developing analytical methods for these media. EPA expects to have draft methods for water and solids by fall 2017. EPA will also develop standard operating procedures for field sampling (EPA 2017).
- ASTM has published standards for analyzing PFAAs in soil (D7968-14) and in water, sludge, influent, effluent and wastewater (D7979-15). Both standards use LC-MS/MS (ASTM 2014, 2015). These methods have not been multi-lab validated.
- The available detection methods report sensitivities of low picograms per cubic meter (pg/m^3) levels in air, high picograms per liter (pg/L) to low ng/L levels in water, and high picograms per gram to low ng/g levels in soil (ATSDR 2015).
- Experimental techniques are available to measure PFASs in air samples. Some studies have used gas chromatography mass spectrometry (GC/MS) to measured PFASs in air samples (ATSDR 2015). In addition, some precursor chemicals and transformation products are measured by GC/MS/MS or LC/MS/MS (Liu and Mejia Avendano 2013). An oxidative technique has been proposed to estimate precursor levels by LC/MS/MS (Houtz and Sedlak 2012).

- Researchers are developing a new analytical method that uses particle induced gamma emission (PIGE) to quickly and non-destructively detect the presence of PFASs in consumer products and other solid materials (National Science Foundation 2015).

What technologies are being used to treat PFOS and PFOA?

- Chapter 10 of the PFOS and PFOA health advisories discuss the performance of common drinking water technologies to treat these chemicals (EPA 2016b, 2016c). In general, PFOS and PFOA resist most conventional chemical and microbial treatment technologies. Technologies with demonstrated effectiveness include granular activated carbon sorption and ion exchange resins (EPA 2016b, 2016c).
- PFAAs can be formed when precursor chemicals are transformed in the environment or in the body (EPA 2016b, 2016c). Therefore, if precursors are not addressed during remediation, over time they may be transformed to PFAAs, such as PFOS and PFOA. The presence of other contaminants, including PFAS precursors, can also impact design and performance of remedial technologies.
- The most common groundwater treatment is extraction and filtration through granular activated carbon. However, because PFOA and PFOS have moderate adsorbability, the design specifics are very important in obtaining acceptable treatment (EPA 2016b, 2016c). Other potential adsorbents include: ion exchange resins, organo-clays, clay minerals and carbon nanotubes (EPA 2016b, 2016c; Espana and others 2015). Evaluation of these sorbents needs to consider regeneration, as the cost and effort required may be substantial (EPA 2016b, 2016c).
- Other ex situ treatments including nanofiltration and reverse osmosis units have been shown to remove PFASs from water (EPA 2016b, 2016c). Incineration of the concentrated waste would be needed for the complete destruction of PFASs (MDH 2008; Vecitis and others 2009).
- Research into other treatment approaches for PFOS and PFOA in groundwater is ongoing (DoD SERDP 2016).
- One soil management approach is excavation and off-site disposal. Capping may also be an option.
- High-temperature incineration can also be used to destroy PFOS and PFOA (ASTSWMO 2015).
- Stabilization methods for PFAS-contaminated soil may be effective (Kupryianchyk and others 2016).

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Technical Fact Sheet – Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)

November 2017

TECHNICAL FACT SHEET – RDX

At a Glance

- Highly explosive, white crystalline solid.
- Synthetic product that does not occur naturally in the environment.
- Used extensively in the manufacture of munitions and accounts for a large part of the explosives contamination at active and former U.S. military installations.
- Not significantly retained by most soils and biodegrades very slowly under aerobic conditions. As a result, it can easily migrate to groundwater.
- Not expected to persist for a long period of time in surface waters because of transformation processes.
- Classified as a Group C (possible human) carcinogen.
- Can damage the nervous system if inhaled or ingested.
- Basic types of field screening methods include colorimetric and immunoassay.
- Primary laboratory analytical methods include liquid and gas chromatography.
- Potential treatment technologies include in situ bioremediation, granular activated carbon treatment, composting, phytoremediation and incineration.

Introduction

This fact sheet, developed by the U.S. Environmental Protection Agency (EPA) Federal Facilities Restoration and Reuse Office (FFRRO), provides a summary of hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), including its physical and chemical properties; environmental and health impacts; existing federal and state guidelines; detection and treatment methods; and additional sources of information. This fact sheet is intended for use by site managers and field personnel who may address RDX contamination at cleanup sites or in drinking water supplies.

RDX is a synthetic chemical used primarily as a military explosive. Major manufacturing of RDX began in the United States in 1943 during World War II with the rise in demand for improved explosives (U.S. Army 1984). RDX was combined with oils, waxes and other explosives, including 2,4-6-trinitrotoluene (TNT), to form usable compositions for military munitions (U.S Army 1984; EPA 2005).

With its manufacturing impurities and environmental transformation products, RDX accounts for a large part of the explosives contamination at active and former U.S. military installations (EPA 1999).

What is RDX?

- RDX, also known as Royal Demolition Explosive, Research Department Explosive, cyclonite, hexogen and T4, is a synthetic product that does not occur naturally in the environment and belongs to a class of compounds known as explosive nitramines (U.S. Army 1984; USACE CRREL 2006; ATSDR 2012).
- RDX is a white crystalline solid that can be used alone as a base charge for detonators or mixed with other explosives such as TNT to form cyclotols, which produce a bursting charge for aerial bombs, mines and torpedoes (U.S. Army 1984; ATSDR 2012; DoD 2016).
- RDX is one of the most powerful high explosives available and was widely used during World War II. It is present in more than 4,000 military items, from large bombs to very small igniters (DoD 2016).

- RDX is commonly found at hand grenade ranges, antitank rocket ranges, bombing ranges, artillery ranges, munitions testing sites, explosives washout lagoons, demolition areas and open burn/open detonation sites (USACE CRREL 2006; EPA 2005, 2012c).
- Production of RDX in the United States has been limited to Army ammunition plants (ATSDR 2012; HSDB 2016). The Holston Army Ammunition Plant in Kingsport, Tennessee is the only active manufacturing facility in the United States (ATSDR 2012; EPA 2012a).
- RDX is not produced commercially in the United States; however, some U.S. companies import RDX from outside the United States for use in commercial applications (ATSDR 2012; EPA 2012a).

Exhibit 1: Physical and Chemical Properties of RDX
(USACE CRREL 2006; ATSDR 2012; HSDB 2016; NIOSH 2016)

Property	Value
Chemical Abstracts Service (CAS) number	121-82-4
Physical description (physical state at room temperature)	White crystalline solid
Molecular weight (g/mol)	222.26
Water solubility at 25°C (mg/L)	59.7
Octanol-water partition coefficient (Log K_{ow})	0.87
Soil organic carbon-water coefficient (Log K_{oc})	1.80
Boiling point (°C)	Decomposes
Melting point (°C)	204 to 206
Vapor pressure at 20°C (mm Hg)	1.0×10^{-9} (ATSDR 2012); 4.0×10^{-9} (HSDB 2016)
Specific gravity at 20°C	1.82
Henry's law constant at 25°C (atm-m^3/mol)	2.0×10^{-11}

Abbreviations: g/mol – grams per mole; mg/L – milligrams per liter; °C – degrees Celsius; mm Hg – millimeters of mercury; atm-m^3/mol – atmosphere - cubic meters per mole.

Existence of RDX in the environment

- RDX can be released to the environment through spills, firing of munitions, disposal of ordnance, open incineration and detonation of ordnance, leaching from inadequately sealed impoundments and demilitarization of munitions. RDX can also be released from manufacturing and munitions processing facilities (ATSDR 2012).
- As of 2016, RDX had been identified at 32 sites on the EPA National Priorities List (NPL) (EPA 2016b).
- In the atmosphere, RDX is expected to exist in the particulate phase and settles by wet or dry deposition (ATSDR 2012; HSDB 2016).
- Low soil sorption coefficient (K_{OC}) values indicate that RDX is not significantly retained by most soils and can leach to groundwater from soil. However, the rate of migration depends on the composition of the soil (ATSDR 2012; EPA 2005).
- RDX can migrate through the vadose zone and contaminate underlying groundwater aquifers, especially at source areas that have permeable soils, a shallow groundwater table and abundant rainfall (USACE CRREL 2006; EPA 2012c).
- RDX has a slow rate of dissolution from the solid phase and does not evaporate from water readily as a result of its low vapor pressure (USACE CRREL 2006; EPA 2005).
- Based on its low octanol-water partition coefficient (K_{OW}) and low experimental bioconcentration factor, RDX has a low bioconcentration potential in aquatic organisms (HSDB 2016; ATSDR 2012; EPA 2005).
- Phototransformation of RDX in soil is not significant; however, it is the primary physical mechanism that degrades RDX in aqueous solutions. Consequently, RDX is not expected to persist for a long period of time in sunlit surface waters (ATSDR 2012; USACE CRREL 2006; HSDB 2016).
- Results from a study indicate that RDX may bioaccumulate in plants and could be a potential exposure route to herbivorous wildlife (USACE CRREL 2006; EPA 2005).
- RDX may biodegrade in water and soil under anaerobic conditions. Its biodegradation products include hexahydro-1-nitroso-3,5-dinitro-1,3,5-

triazine (MNX); 1,3-dinitroso-5-nitro-1,3,5-triazacyclohexane (DNX); hexahydro-1,3,5-trinitroso-1,3,5-triazine (TNX); hydrazine; 1,1-dimethyl-hydrazine; 1,2-dimethyl-hydrazine; formaldehyde and methanol (ATSDR 2012; USACE CRREL 2006).

What are the routes of exposure and the potential health effects of RDX?

- ❖ Potential exposure to RDX could occur by dermal contact or inhalation exposure; however, the most likely route of exposure at or near hazardous waste sites is ingestion of contaminated drinking water or agricultural crops irrigated with contaminated water (ATSDR 2012).
- ❖ EPA has assigned RDX a weight-of-evidence carcinogenic classification of C (possible human carcinogen) based on the presence of hepatocellular adenomas and carcinomas in female mice that were exposed to RDX (EPA IRIS 1993).
- ❖ RDX targets the nervous system and can cause seizures in humans and animals when large amounts are inhaled or ingested. Human studies also revealed nausea and vomiting after inhalation or oral exposure to unknown levels of RDX (ATSDR 2012; EPA 2005; HSDB 2016).
- ❖ Potential symptoms of overexposure include eye and skin irritation, headache, irritability, fatigue, tremor, nausea, dizziness, vomiting, insomnia and convulsions (HSDB 2016; NIOSH 2016).
- ❖ Animal studies found that the ingestion of RDX for 3 months or longer resulted in decreased body weight and slight liver and kidney damage in rats and mice (ATSDR 2012).
- ❖ Limited information is available regarding the effects of long-term, low-level exposure to RDX (ATSDR 2012).

Are there any federal and state guidelines and health standards for RDX?

- ❖ EPA assigned RDX a chronic oral reference dose (RfD) of 3 x 10^{-3} milligrams per kilogram per day (mg/kg/day) (EPA IRIS 1993).
- ❖ EPA has assigned an oral slope factor (OSF) for carcinogenic risk of 0.11 mg/kg/day, and the drinking water unit risk is 3.1 x 10^{-6} micrograms per liter (µg/L) (EPA IRIS 1993).
- ❖ The Agency for Toxic Substances and Disease Registry (ATSDR) has established a minimal risk level (MRL) of 0.2 mg/kg/day for acute-duration oral exposure (14 days or less), 0.1 mg/kg/day for intermediate-duration oral exposure (15 to 364 days) and 0.1 mg/kg/day for chronic-duration oral exposure (365 days or more) to RDX (ATSDR 2012).
- ❖ EPA risk assessments indicate that the drinking water concentration representing a 1 x 10^{-6} cancer risk level for RDX is 0.3 µg/L (EPA IRIS 1993). EPA has established drinking water health advisories for RDX, which are drinking water-specific risk level concentrations for cancer (10^{-4} cancer risk) and concentrations of drinking water contaminants at which noncancer adverse health effects are not anticipated to occur over specific exposure durations (EPA 2012b).
  - ▪ EPA has established a lifetime health advisory guidance level of 2 µg/L for RDX in drinking water. The health advisory for a cancer risk of 10^{-4} is 30 µg/L.
  - ▪ EPA also established a 1-day and 10-day health advisory of 100 µg/L for RDX in drinking water for a 10-kilogram child.
- ❖ For RDX in tap water, EPA has calculated a screening level of 0.7 µg/L (EPA 2017).
- ❖ EPA has calculated a residential soil screening level (SSL) of 6.1 milligrams per kilogram (mg/kg) and an industrial SSL of 28 mg/kg. The soil-to-groundwater risk-based SSL is 2.7 x 10^{-4} mg/kg (EPA 2017).
- ❖ EPA has not established an ambient air level standard or screening level for RDX (EPA 2017).
- ❖ EPA included RDX on the fourth Contaminant Candidate List (CCL). The CCL is a list of unregulated contaminants that are known to or may occur in drinking water and may require regulation under the Safe Drinking Water Act (EPA 2016a).
- ❖ The EPA Region III Biological Technical Assistance Group (BTAG) has established a freshwater screening benchmark of 360 µg/L and a freshwater sediment screening benchmark of 0.013 mg/kg (EPA 2006).
- ❖ Some states have established soil guidelines and standards for RDX. Residential soil guidelines range from 1 mg/kg (Massachusetts) to 160 mg/kg (Pennsylvania) (MADEP 2014 and PADEP 2011). Industrial soil guidelines range from 28 mg/kg (North Carolina) to 3,664 mg/kg (New Mexico) (NCDENR 2016 and NMED 2017).

- Few states have established surface water guidelines and water quality standards for RDX. Surface water guidelines and standards range from 5.8 µg/L (protective of human health, Michigan) to 2,591.5 µg/L (acute exposure, protective of fish and wildlife propagation, Oklahoma) (Michigan DEQ 2006 and OWRB 2014).
- Various states have established groundwater or drinking water standards and guidelines for RDX including the following:

State	Standard or Guideline (µg/L)	Source
California	0.3/30[a]	CalSWRCB 2005
Indiana	7	IDEM 2016
Maine	3	MEDEP 2016
Massachusetts	1	MADEP 2014
Mississippi	0.609	MDEQ 2002
Nebraska	0.61	NDEQ 2012
New Jersey	0.5	NJDEP 2011
New Mexico	7.02	NMED 2017
Pennsylvania	2	PADEP 2011
West Virginia	0.61	WVDEP 2014

a) The first value is the California State Water Resources Control Board, Division of Drinking Water notification level; the second value is the response level.

What detection and site characterization methods are available for RDX?

- EPA SW-846 Method 8330 is the most widely used analytical approach for detecting RDX in water, soil and sediment. The method specifies using high-performance liquid chromatography (HPLC) with an ultraviolet (UV) detector. It has been used to detect RDX and some of its breakdown products at levels in the low parts per billion (ppb) range in water, soil and sediment (EPA 2005, 2007b, 2012c).
- RDX is commonly deposited in the environment as discrete particles with strongly heterogeneous spatial distributions. As described in SW-846 Method 8330B, proper sample collection (using an incremental field sampling approach), sample processing (which includes grinding) and incremental subsampling are required to obtain reliable soil data (EPA 2006).
- Another method commonly used is EPA SW-846 Method 8095, which employs the same sample processing steps as EPA SW-846 Method 8330, but uses capillary column gas chromatography with an electron capture detector (GC/ECD) for detection of explosives in water and soil (EPA 2005, 2007a, 2012c.)
- EPA SW-846 Method 8321, which uses HPLC-mass spectrometry (MS), may be modified for the determination of RDX in soil. Since RDX is not a target analyte for this method and the sample processing steps are not appropriate for use with energetic compounds, this method is commonly modified for RDX to employ different sample processing steps, such as those identified in Method 8330 (EPA 2012c).
- EPA Method 529 used solid phase extraction and capillary column GC and MS for the detection of RDX in drinking water (EPA 2002, U.S. Army 2009).
- Specific field screening methods for RDX include EPA SW-846 Method 4051 to detect RDX in soil by immunoassay and EPA SW-846 Method 8510 to detect RDX and octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX) using a colorimetric screening procedure (U.S. Army 2009; EPA 2007c; USACE 2005). Other screening techniques may be used for identification purposes (USACE CRREL 2007).
- Prototype biosensor methods for RDX have been field-tested and are emerging methods for explosives analysis in water (EPA 1999).
- Fluorescence spot (fluo-spot) detection is an emerging method for in situ RDX detection (Wang et al 2016).

What technologies are being used to treat RDX?

- Ex situ methods for treating waters contaminated with RDX include granular activated carbon and UV irradiation (ATSDR 2012; USACE ERDC 2013).

- In situ bioremediation utilizing various substrates can be used to treat groundwater contaminated with explosives, including RDX (EPA 2005; DoD ESTCP 2012; ATSDR 2012).
- Bioaugmentation with aerobic explosive degrading bacteria may be a viable treatment technology for remediating RDX-contaminated groundwater (DoD SERDP 2012; Fuller and others 2015).
- In situ chemical remediation can also be used to treat RDX. Fenton oxidation and treatment with iron metal (Fe0) has been used to remediate RDX-contaminated soil and water but has not been used as a stand-alone, full-scale treatment technology (EPA 2005; EPA NCER 2013).
- Bioreactors, bioslurry treatments and passive subsurface biobarriers have proven successful in reducing RDX concentrations in soil (USACE CRREL 2006; EPA 2005; DoD ESTCP 2008 and 2010).
- Composting has been successful in achieving cleanup goals for RDX in soil at field demonstrations (EPA 2005).
- Incineration is a proven and widely-available method to treat RDX-contaminated soil and debris; however, resulting incinerator stack emissions may require treatment (EPA 2005).
- Phytoremediation of RDX-contaminated water and soil is being evaluated as a potential treatment technology (Lamichhane and others 2012; Panz and Miksch 2012; USACE CRREL 2013; Srivastava 2015).

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United States Environmental Protection Agency

Technical Fact Sheet – 2,4,6-Trinitrotoluene (TNT)

November 2017

At a Glance

- Synthetic product that does not occur naturally in the environment.
- Used extensively in the manufacture of munitions and accounts for a large part of the explosives contamination at active and former U.S. military installations.
- Sorbed by most soils, limiting its migration to water.
- Not expected to persist for a long period in surface waters because of transformation processes.
- 1,3,5-Trinitrobenzene (1,3,5-TNB) is one of the primary photodegradation products of TNT in environmental systems.
- Classified as a Group C (possible human) carcinogen.
- Primarily damages the liver and blood systems if inhaled or ingested.
- The primary laboratory methods for analysis include liquid and gas chromatography.
- Potential treatment technologies include in situ bioremediation, granular activated carbon treatment, composting and incineration.

Introduction

This fact sheet, developed by the U.S. Environmental Protection Agency (EPA) Federal Facilities Restoration and Reuse Office (FFRRO), provides a summary of 2,4,6-trinitrotoluene (TNT), including its physical and chemical properties; environmental and health impacts; existing federal and state guidelines; detection and treatment methods; and additional sources of information. This fact sheet is intended for use by site managers and field personnel who may address TNT contamination at cleanup sites or in drinking water supplies.

Major manufacturing of TNT began in the United States in 1916 at the beginning of World War I. Production increased between World War I and World War II. TNT was produced and used in enormous quantities during World War II (EPA 2005). In demilitarization operations conducted up to the 1970s, explosives were removed from munitions with jets of hot water. The effluent flowed into settling basins and the remaining water was disposed of in unlined lagoons or pits. The effluent from TNT manufacturing and demilitarization acted as a major source of munitions contamination in soils and groundwater at munition plants (EPA 2005).

TNT is still widely used in U.S. military munitions and accounts for a large portion of the explosives-related contamination at active and former U.S. military installations. With its manufacturing impurities and environmental transformation products, TNT presents various health and environmental concerns.

What is TNT?

- TNT is a yellow, odorless solid that does not occur naturally in the environment. It is made by combining toluene with a mixture of nitric and sulfuric acids (ATSDR 1995).
- It is a single-ring nitroaromatic compound that is a crystalline solid at room temperature (CRREL 2006).
- TNT is one of the most widely used military explosives, partly because of its insensitivity to shock and friction. It has been used extensively in the manufacture of explosives since the beginning of the 20th century and is used in military shells, bombs and grenades (ATSDR 1995; Cal/EPA 2010).

- It has been used either as a pure explosive or in binary mixtures. The most common binary mixtures of TNT are cyclotols (mixtures with RDX) and octols (mixtures with octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine [HMX]) (ATSDR 1995).
- In addition to military use, small amounts of TNT are used for industrial explosive applications, such as deep well and underwater blasting. Other industrial uses include chemical manufacturing as an intermediate in the production of dyestuffs and photographic chemicals (HSDB 2012).
- TNT is commonly found at hand grenade ranges, antitank rocket ranges, artillery ranges, bombing ranges, munitions testing sites and open burn/open detonation (OB/OD) sites (CRREL 2006, 2007b; EPA 2012c).
- Production of TNT in the United States is currently limited to military arsenals; however, it may be imported into the United States for industrial applications (Cal/EPA 2010; HSDB 2012).
- Effluent from TNT manufacturing is a major source of munitions constituent contamination in soils and groundwater at military ammunition plants (EPA 2005).

Exhibit 1: Physical and Chemical Properties of TNT
(ATSDR 1995; HSDB 2012; Ware 1999)

Property	Value
Chemical Abstracts Service (CAS) number	118-96-7
Physical description (physical state at room temperature)	Yellow, odorless solid
Molecular weight (g/mol)	227.13
Water solubility at 20°C (mg/L)	130
Octanol-water partition coefficient (Log K_{ow})	1.6 (measured)
Soil organic carbon-water coefficient (K_{oc})	300 (estimated)
Boiling point (°C)	240 (explodes)
Melting point (°C)	80.1
Vapor pressure at 20°C (mm Hg)	1.99×10^{-4}
Specific gravity at 20°C	1.654
Henry's law constant (atm-m^3/mol at 20°C)	4.57×10^{-7}

Abbreviations: g/mol – grams per mole; mg/L – milligrams per liter; °C – degrees Celsius; mm Hg – millimeters of mercury; atm-m^3/mol – atmosphere -cubic meters per mole.

Existence of TNT in the environment

- TNT can be released to the environment through spills, disposal of ordnance, OB/OD of ordnance, leaching from inadequately sealed impoundments and demilitarization of munitions. The compound can also be released from manufacturing and munitions processing facilities (ATSDR 1995).
- As of 2016, TNT had been identified at 30 sites on the EPA National Priorities List (NPL) (EPA 2016).
- Based on the partition coefficients identified by most investigators, soils have a high capacity for rapid sorption of TNT. Under anaerobic conditions, TNT that is not sorbed by the soil is usually transformed rapidly into its degradation by-products (Price and others 1997; USACE 1997).
- Most TNT may be degraded in the surface soil at impact areas; however, small quantities can reach shallow groundwater (CRREL 2006).
- Once released to surface water, TNT undergoes rapid photolysis to a number of degradation products. 1,3,5-Trinitrobenzene (1,3,5-TNB) is one of the primary photodegradation products of TNT in environmental systems (ATSDR 1995; EPA 2012c).
- Generally, TNT is broken down by biodegradation in water but at rates much slower than photolysis. In surface waters, TNT is degraded by photolysis and has a half-life of 0.5 to many hours. The biological half-life of TNT is much longer, ranging from several weeks to 6 months (CRREL 2006; EPA 1999).
- Biological degradation products of TNT in water, soil, or sediments include 2-amino-4,6-dinitrotoluene, 2,6-diamino-4-nitrotoluene, 4-amino-2,6-dinitrotoluene and 2,4-diamino-6-nitrotoluene (EPA 1999).
- TNT does not seem to bioaccumulate in animals, but may be taken up and metabolized by plants, including garden, aquatic and wetland plants, and some tree species (CRREL 2006, EPA 2005).
- Soils contaminated with TNT and TNT primary degradation products have been found to be toxic to certain soil invertebrates, such as earthworms (HSDB 2012).

- Based on its low octanol-water partition coefficient (K_{OW}) and low experimental bioconcentration factor, TNT is not expected to bioconcentrate to high levels in the tissues of exposed aquatic organisms and plants (ATSDR 1995; HSDB 2012).

What are the routes of exposure and the potential health effects of TNT?

- The toxicity of TNT to humans was well documented in the 20th century, with more than 17,000 cases of TNT poisoning resulting in more than 475 fatalities from manufacturing operations during World War I (ATSDR 1995).
- The primary routes of exposure in manufacturing environments are inhalation of dust and ingestion and dermal sorption of TNT particulates; significant health effects can include liver atrophy and aplastic anemia (ATSDR 1995; HSDB 2012).
- There is limited evidence regarding the carcinogenicity of TNT to humans; however, urinary bladder papilloma and carcinoma were observed in female rats. EPA has assigned TNT a weight-of-evidence carcinogenic classification of C (possible human carcinogen) (EPA IRIS 2002).
- The California Office of Environmental Health Hazard Assessment lists TNT as a chemical known to cause cancer for purposes of the Safe Drinking Water and Toxic Enforcement Act of 1986 (Cal/EPA 2016).
- Animal study results indicate male test animals treated with high doses of TNT developed serious reproductive system effects (EPA 2005; HSDB 2012).
- When TNT reaches the liver, it breaks down into several different substances. Not all of these substances have been identified. Most of these substances travel in the blood to the kidneys and leave the body in urine within 24 hours (ATSDR 1995).
- At high levels in air, workers involved in the production of TNT experienced anemia and liver function abnormalities. After long-term exposure to skin and eyes, some people experienced skin irritation and developed cataracts (ATSDR 1995).

Are there any federal and state guidelines and health standards for TNT?

- EPA assigned TNT an oral reference dose (RfD) of 5 x10^{-4} milligrams per kilogram per day (mg/kg/day) (EPA IRIS 2002).
- EPA assigned an oral slope factor for carcinogenic risk of 3 x 10^{-2} mg/kg/day, and the drinking water unit risk is 9.0 x 10^{-7} micrograms per liter (µg/L) (EPA IRIS 2002).
- EPA risk assessments indicate that the drinking water concentration representing a 1 x 10^{-6} cancer risk level for TNT is 1.0 µg/L (EPA IRIS 2002).
- EPA has established drinking water health advisories for TNT, which are drinking water-specific risk level concentrations for cancer (10^{-4} cancer risk) and concentrations of drinking water contaminants at which noncancer adverse health effects are not anticipated to occur over specific exposure durations (EPA 2012a).
  - EPA established a lifetime health advisory guidance level of 0.002 milligrams per liter (mg/L) for TNT in drinking water. The health advisory for a cancer risk of 10^{-4} is 0.1 mg/L.
  - EPA also established a 1-day and 10-day health advisory of 0.02 mg/L for TNT in drinking water for a 10-kilogram child.
- For TNT in tap water, EPA has calculated a risk-based carcinogenic screening level of 2.5 µg/L (EPA 2017).
- EPA has calculated a residential soil screening level (SSL) of 21 milligrams per kilogram (mg/kg) and an industrial SSL of 96 mg/kg. The soil-to-groundwater risk-based SSL is 1.5 x 10^{-2} mg/kg (EPA 2017).
- EPA has not established an ambient air level standard or screening level for TNT (EPA 2017).
- Since TNT is explosive, flammable and toxic, EPA has designated it as a hazardous waste once it becomes a solid waste, and EPA regulations for disposal must be followed (EPA 2012b).
- Various states have established groundwater standards including the following:

State	Guideline (µg/L)	Source
Indiana	9.8	IDEM 2016
Mississippi	2.23	MDEQ 2002
Missouri	2	MDNR 2014
Nebraska	2.2	NDEQ 2012
New Mexico	18.3	NMED 2012
Pennsylvania	2	PDEP 2011
Texas	0.012	TCEQ 2016
West Virginia	2.2	WVDEP 2014

- Some states have established soil guidelines. Residential soil standards range from 7.2 mg/kg

(North Carolina) to 110 mg/kg (Pennsylvania) (NCDENR 2016 and PDEP 2011). Industrial soil standards range from 96 mg/kg (North Carolina) to 1,400 mg/kg (Pennsylvania) (NCDENR 2016 and PDEP 2011).

What detection and site characterization methods are available for TNT?

- TNT is commonly deposited in the environment as discrete particles with strongly heterogeneous spatial distributions. Unless precautions are taken, this distribution causes highly variable soil data, which can lead to confusing or contradictory conclusions about the location and degree of contamination. As described in SW-846 Method 8330B, proper sample collection (using an incremental field sampling approach), sample processing (which includes grinding) and multi-incremental subsampling are required to obtain reliable soil data (EPA 2006).
- High performance liquid chromatography (HPLC) and high-resolution gas chromatography (HRGC) have been paired with several types of detectors, including mass spectrometry (MS), electrochemical detection (ED), electron capture detectors (ECD) and ultraviolet (UV) detectors to detect TNT in water (ATSDR 1995).
- EPA SW-846 Method 8330 is the most widely used analytical approach for detecting TNT in soil. The method specifies using HPLC with a UV detector. It has been used to detect TNT and some of its breakdown products at levels in the low parts per billion (ppb) range in water, soil and sediment (EPA 2006, 2012c).
- Another method commonly used is EPA SW-846 Method 8095, which employs the same sample-processing steps as Method 8330 but uses capillary-column gas chromatography (GC) with an ECD to analyze for explosives in water and soil (EPA 2007, 2012c).
- Specific field screening methods for TNT include EPA SW-846 Method 8515 to detect TNT in soil by a colorimetric screening method and EPA SW-846 Method 4050 to detect TNT in soil by immunoassay (USACE 2005).
- Colorimetric methods generally detect broad classes of compounds such as nitroaromatics or nitramines. As a result, these methods are able to detect the presence of the target analytes and also respond to many other similar compounds. Immunoassay methods are more compound specific (EPA 2005).
- The EXPRAY is a simple colorimetric screening kit that can support qualitative tests for TNT in soils. It is also useful for screening surfaces. The tool's detection limit is about 20 nanograms (EPA 2005).
- Tested field-screening instruments for TNT include GC-IONSCAN, which uses ion mobility spectrometry, for the detection of TNT in water and soil, and the Spreeta Sensor, which uses surface plasma resonance (SPR) for the detection of TNT in soil (EPA 2000; EPA 2001).
- Recent experiments have reported rapid and ultrasensitive TNT detection in the field using gold nanoparticles and spectroscopy in all environmental samples (Lin and others 2012; Yang and others 2014; and Jamil and others 2015).

What technologies are being used to treat TNT?

- In situ bioremediation is an emerging technology for treatment of groundwater contaminated with explosives, including TNT (EPA 2005; DoD ESTCP 2012).
- Biological treatment methods such as bioreactors, bioslurry treatment and passive subsurface biobarriers have proven successful in reducing TNT concentrations (EPA 2005; DoD ESTCP 2010).
- Composting has proven successful in achieving cleanup goals for TNT in soil at field demonstrations (EPA 2005; FRTR 2007).
- Incineration can be used on soil containing low concentrations of TNT (EPA 2005; FRTR 2007). Granular activated carbon (GAC) is a common ex situ method to treat explosives-contaminated groundwater (FRTR 2007).
- In situ chemical oxidation can also be used to treat TNT. Fenton oxidation and treatment with iron metal (FeO) has been used to remediate TNT-contaminated soil and water (EPA 2005, EPA NCER 2016).
- Pine bark has been used as a substitute for GAC treatment in experimental batches (Chusova and others 2014).
- Phytoremediation of TNT-contaminated water and soil is being evaluated as a potential treatment technology. Studies indicate phytoremediation has the potential to be a suitable remediation strategy for TNT contaminated sites (DoD SERDP 2009; HSDB 2012; Zhu and others 2012).
- In a laboratory scale study, TNT biodegraded under anaerobic reduction with whey as a substrate (Innemanova and others 2015).

- In a 28-day laboratory experiment, a combination of bioaugmentation-biostimulation coupled with phytoremediation revealed significant decreases in TNT concentrations (Nolvak and others 2013).

Where can I find more information about TNT?

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United States Environmental Protection Agency

Technical Fact Sheet – 1,2,3-Trichloropropane (TCP)

November 2017

TECHNICAL FACT SHEET – 1,2,3-TCP

At a Glance

- Produced as a chemical intermediate.
- Formerly used as a paint and varnish remover, solvent and degreasing agent.
- Evaporates readily from surface soil and surface water and travels quickly from subsurface soil to groundwater.
- In the pure form, likely to exist as a dense nonaqueous phase liquid.
- Primary human exposure routes are inhalation of ambient air and ingestion of drinking water.
- EPA has classified TCP as “likely to be carcinogenic to humans.”
- Short-term exposure may cause eye and throat irritation; long-term exposure has led to liver and kidney damage and reduced body weight in animal studies.
- A federal maximum contaminant level (MCL) has not been established for TCP in drinking water; federal and state health-based screening levels have been established.
- Remediation technologies available to treat TCP contamination in groundwater and soil include granular activated carbon (GAC), dechlorination by hydrogen release compound (HRC®), reductive dechlorination by zero valent zinc and others.

Introduction

This fact sheet, developed by the U.S. Environmental Protection Agency (EPA) Federal Facilities Restoration and Reuse Office (FFRRO), provides a summary of the contaminant 1,2,3-trichloropropane (TCP), including physical and chemical properties; environmental and health impacts; existing federal and state guidelines; detection and treatment methods; and sources of additional information. This fact sheet is intended for use by site managers and other field personnel in addressing TCP contamination at cleanup sites or in drinking water supplies and for those in a position to consider whether TCP should be added to the analytical suite for site investigations.

TCP is a contaminant of interest to the government, private sector and other parties. It is a persistent pollutant in groundwater and has been classified as “likely to be carcinogenic to humans” by EPA (EPA 2009).

What is TCP?

- TCP is exclusively a man-made chlorinated hydrocarbon, typically found at industrial or hazardous waste sites (Dombeck and Borg 2005; ATSDR 1992). TCP is often present at sites contaminated by other chlorinated solvents (Dombeck and Borg 2005).
- TCP has been used as an industrial solvent and as a cleaning and degreasing agent; it has been found as an impurity resulting from the production of soil fumigants (NTP 2016; HSDB 2009).
- TCP is used as a chemical intermediate in the production of other chemicals such as liquid polymers (NTP 2016; HSDB 2009).

Exhibit 1: Physical and Chemical Properties of TCP
(EPA 2017b; NTP 2016; Dombeck and Borg 2005; HSDB 2009)

Property	Value
Chemical Abstracts Service (CAS) number	96-18-4
Physical description (at room temperature)	Colorless to straw-colored liquid
Molecular weight (g/mol)	147.43
Water solubility at 25°C (mg/L)	1,750 (slightly soluble)
Melting point (°C)	-14.7
Boiling point (°C)	156.8
Vapor pressure at 25°C (mm Hg)	3.1 to 3.69 (high)
Specific gravity at 20°C (g/cm^3)	1.3889
Octanol-water partition coefficient (log K_{ow})	1.98 to 2.27 (temperature dependent)
Soil organic carbon-water partition coefficient (log K_{oc})	1.70 to 1.99 (temperature dependent)
Henry's law constant at 25°C (atm-m^3/mol)	3.43 x 10^{-4} (HSDB 2009; Dombeck and Borg 2005)

Abbreviations: g/mol – gram per mole; mg/L – milligrams per liter; °C – degrees Celsius; g/cm^3 – grams per cubic centimeter; mm Hg – millimeters of mercury; atm-m^3/mol – atmosphere-cubic meters per mole.

Existence of TCP in the environment

- TCP is not likely to sorb to soil based on its low soil organic carbon-water partition coefficient; therefore, it is likely to either leach from soil into groundwater or evaporate from soil surfaces (ATSDR 1992; HSDB 2009).
- As a result of low abiotic and biotic degradation rates, TCP may remain in groundwater for long periods of time (ATSDR 1992; Samin and Janssen 2012).
- TCP in pure form is likely to exist as dense nonaqueous phase liquid and thus, will sink to the bottom of a groundwater aquifer because its density is greater than that of water (Cal/EPA 2016a).
- TCP is expected to exist solely as a vapor in the ambient atmosphere and is subject to photodegradation by reaction with hydroxyl radicals, with an estimated half-life ranging from 15 to 46 days (NTP 2016; HSDB 2009; Samin and Janssen 2012).
- TCP is unlikely to become concentrated in plants, fish or other aquatic organisms because it has a low estimated bioconcentration factor (BCF) range of 5.3 to 13 (ATSDR 1992; HSDB 2009).

What are the routes of exposure and the potential health effects of TCP?

- Exposure to the general population primarily occurs through vapor inhalation or ingestion of contaminated water (ATSDR 1995; NTP 2016).
- Exposure is most likely to occur near hazardous waste sites where TCP was improperly stored or disposed of, or at locations that manufacture or use the chemical (ATSDR 1992; NTP 2016).
- EPA has classified TCP as "likely to be carcinogenic to humans" based on the formation of multiple tumors in animals (EPA 2009).
- The U.S. Department of Health and Human Services states that TCP is reasonably anticipated to be a human carcinogen based on sufficient evidence of carcinogenicity from studies in experimental animals (NTP 2016).
- The American Conference of Governmental Industrial Hygienists classified TCP as a Group A3 carcinogen: a confirmed animal carcinogen with unknown relevance to humans (HSDB 2009).
- The National Institute for Occupational Safety and Health considers TCP a potential occupational carcinogen (NIOSH 2010).
- TCP is recognized by the State of California as a human carcinogen (Cal/EPA 2016b).
- Animal studies have shown that long-term exposure to TCP may cause liver and kidney damage, reduced body weight and increased incidences of tumors in numerous organs (ATSDR 1992; NTP 2016; EPA 2009).
- Short-term inhalation exposure to high levels of TCP may cause irritation of eyes, skin and the respiratory tract, and depression of the central nervous system (HSDB 2009; NIOSH 2010). In addition, it may affect concentration, memory and muscle coordination (Cal/EPA 2016a).

Are there any federal and state guidelines and health standards for TCP?

- The EPA Integrated Risk Information System (IRIS) lists a chronic oral reference dose (RfD) of 4 x 10^{-3} milligrams per kilogram per day (mg/kg/day) and a chronic inhalation reference concentration (RfC) of 3 x 10^{-4} milligrams per cubic meter (mg/m^3) (EPA 2009).
- The cancer risk assessment for TCP is based on an oral slope factor of 30 mg/kg/day (EPA 2009).
- The Agency for Toxic Substances and Disease Registry (ATSDR) has established a minimal risk level (MRL) of 0.0003 ppm for acute-duration (14 days or less) inhalation exposure to TCP and an MRL of 0.06 mg/kg/day for intermediate-duration (>14 days to 364 days) oral exposure to TCP (ATSDR 2017).
- EPA has established drinking water health advisories for TCP, concentrations of drinking water contaminants at which noncancer adverse health effects are not anticipated to occur over specific exposure durations. EPA established a 1-day and a 10-day noncancer health advisory of 0.6 milligrams per liter (mg/L) for TCP in drinking water for a 10-kilogram (kg) child (EPA 2012).
- EPA's drinking water equivalent level (DWEL) for TCP is 0.1 mg/L based on lifetime exposure and noncancer effects (EPA 2012).
- EPA has calculated a residential soil screening level (SSL) of 5.1 x 10^{-3} milligrams per kilogram (mg/kg) and an industrial SSL of 0.11 mg/kg. The soil-to-groundwater risk-based SSL is 3.2 x 10^{-7} mg/kg (EPA 2017b).
- EPA has also calculated a residential air screening level of 3.1 x 10^{-1} micrograms per cubic meter ($\mu g/m^3$) and an industrial air screening level of 1.3 $\mu g/m^3$ (EPA 2017b).
- For tap water, EPA has calculated a screening level of 7.5 x 10^{-4} micrograms per liter (µg/L) (EPA 2017b).
- No federal maximum contaminant level (MCL) has been set for TCP in drinking water (EPA 2017a).
- EPA included TCP on the fourth Contaminant Candidate List (CCL4), which is a list of unregulated contaminants that are known to, or anticipated to, occur in public water systems and may require regulation under the Safe Drinking Water Act (SDWA) (EPA 2016b).
- In addition, EPA added TCP to its Unregulated Contaminant Monitoring Rule (UCMR) 3, requiring many large water utilities to monitor for TCP with a minimum reporting level of 0.03 µg/L. EPA uses the UCMR to monitor contaminants suspected to be present in drinking water that do not currently have health-based standards under the SDWA (EPA 2016a).
- California has established a state MCL of 0.005 µg/L (Cal/EPA 2017). Hawaii has established a state MCL of 0.6 µg/L (HDH 2014).
- Various other states have established health-based levels in drinking water ranging from 3 x 10^{-5} µg/L in Texas (TCEQ 2017) to 40 µg/L in New York (NYDEC 2016).
- Several states (Nebraska, North Carolina and West Virginia) (Nebraska 2012; North Carolina 2016; West Virginia 2014) have established residential SSLs similar to EPA's regional screening levels (RSLs). Some states developed levels much higher, ranging from 0.05 mg/kg in New Mexico (2017) to 1,300 mg/kg in Michigan (2013).

What detection and site characterization methods are available for TCP?

- EPA SW-846 Method 8260B uses gas chromatography (GC)/mass spectrometry (MS) for the detection of TCP in solid waste matrices (EPA 1996).
- EPA Method 551.1 uses liquid-liquid extraction and GC with electron-capture detection, for the detection of TCP in drinking water, drinking water during intermediate stages of treatment and raw source water (ATSDR 2011; EPA ORD 1990).
- EPA Method 504.1 uses microextraction and GC, for the detection of TCP in groundwater and drinking water (ATSDR 2011; EPA ORD 1995).
- EPA Method 524.3 uses capillary column GC/MS, for the detection of TCP in treated drinking water (EPA OGWDW 2009).
- CDPH uses liquid-liquid extraction and GC/MS and purge and trap GC/MS, for trace-level detection of TCP in drinking water (CDPH 2002a, b).

What technologies are being used to treat TCP?

- Treatment technologies for TCP in groundwater include traditional methods such as pump and treat, permeable reactive barriers, in situ chemical oxidation and bioremediation (reductive dechlorination) (Cal/EPA 2016a).
- TCP in water can be removed using granular activated carbon (GAC); however, TCP has only a low to moderate adsorption capacity for GAC and may require a larger GAC treatment system, increasing treatment costs (Dombeck and Borg 2005; Cal/EPA 2016a; Tratnyek and others 2008).
- In a full-scale study, hydrogen release compound (HRC®) successfully reduced TCP to non-detect levels through the promotion of anaerobic reductive dechlorination of TCP in groundwater (Tratnyek and others 2008).
- Treatment for TCP in water using ultraviolet radiation and chemical oxidation with potassium permanganate has achieved some success for low-flow systems (Dombeck and Borg 2005; Cal/EPA 2016a).
- Bench-scale tests have also investigated chemical oxidation with Fenton's reagent for the treatment of TCP in groundwater. A study found that Fe(2+) was the most effective type of iron at reducing TCP (Khan and others 2009; Samin and Janssen 2012).
- Bench-scale tests have shown evidence of TCP degradation in water to levels as low as 0.005 µg/l using advanced oxidation processes involving ozone and hydrogen peroxide (Cal/EPA 2016a; Dombeck and Borg 2005).
- Bench-scale tests using zero-valent iron have shown limited degradation of TCP in saturated soil and groundwater (Sarathy and others 2010; Tratnyek and others 2008, 2010).
- Bench- and field-scale studies have identified granular zero valent zinc as an effective reductant for remediation of TCP in groundwater, with more rapid degradation compared with granular zero-valent iron and limited accumulation of intermediate products (ATSDR 2011; Sarathy and others 2010; Salter-Blanc and others 2012; Tratnyek and others 2010).
- Recent studies are investigating the use of genetically engineered strains of *Rhodococcus* for the complete biodegradation of TCP under aerobic conditions (Samin and Janssen 2012).

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United States Environmental Protection Agency

Technical Fact Sheet – Tungsten

November 2017

At a Glance

- ❖ Tungsten is a naturally occurring element that exists in the form of minerals, but typically not as a pure metal.
- ❖ Typically used in welding, oil-drilling, electrical and aerospace industries.
- ❖ Introduced in the mid-1990s as a replacement for lead ammunitions.
- ❖ Under certain conditions, tungsten dissolves in water and is mobile in the environment, but little is known about its fate and transport in the environment.
- ❖ In 2002, elevated tungsten concentrations were found in drinking water and investigated for carcinogenic effects. No direct link was found, but tungsten was nominated for study under the National Toxicity Program.
- ❖ No federal drinking water standard established.
- ❖ 2017 EPA regional screening levels include soil and tapwater screening values for tungsten.
- ❖ Treatment methods for tungsten in environmental media are currently under development. Methods under investigation include electrokinetic soil remediation and phytoremediation.

Introduction

This fact sheet, developed by the U. S. Environmental Protection Agency (EPA) Federal Facilities Restoration and Reuse Office (FFRRO), provides a summary for tungsten, including physical and chemical properties; environmental and health impacts; existing federal and state guidelines; detection and treatment methods; and additional sources of information. This fact sheet provides basic information on tungsten to site managers and other field personnel who may address tungsten contamination at cleanup sites.

Historically, tungsten was thought to be insoluble and have little or no mobility in the environment. However, the presence of tungsten in groundwater near background sources and anthropogenic sources suggests that under certain conditions, tungsten dissolves in water and is mobile in the environment. Currently, limited information is available about the fate and transport of tungsten in the environment and its effects on human health. Research about tungsten is ongoing and includes health effects and risks, degradation processes and an inventory of its historic use in the defense industry as a substitute for lead-based munitions.

What is tungsten?

- ❖ Tungsten is a naturally occurring element that exists in the form of minerals, but typically not as a pure metal (ATSDR 2005).
- ❖ The color of tungsten may range from white for the pure metal to steel-gray for the metal with impurities (NIOSH 2016).
- ❖ There are more than 20 known tungsten-bearing minerals (ATSDR 2005). Wolframite ([FeMn]WO4) and Scheelite (CaWO4) are two common, commercially-mined minerals that contain tungsten (ATSDR 2005; Koutsospyros and others 2006).
- ❖ Natural tungsten is composed of five stable isotopes. There are 28 artificial radioactive isotopes, which have short half-lives ranging from less than a second to 121 days (ATSDR 2005; Audi and others 2003).
- ❖ The most common formal oxidation state of tungsten is +6, but it exhibits all oxidation states from -2 to +6 (Lemus and Venezia 2015).
- ❖ The melting point of tungsten is the highest among metals. It is resistant to corrosion, is a good conductor of electricity and acts as a catalyst in chemical reactions (ATSDR 2005; Gbaruko and Igwe 2007).

- Tungsten in the form of finely divided powder is highly flammable and may ignite spontaneously on contact with air. Powdered tungsten may also cause fire or explosion on contact with oxidants (HSDB 2009; NIOSH 2016).

Exhibit 1: Physical and Chemical Properties of Elemental Tungsten
(ATSDR 2005; NIEHS 2003; NIOSH 2016)

Property	Value
Chemical Abstracts Service (CAS) number	7440-33-7
Physical description (physical state at room temperature)	Hard, steel-gray to tin-white solid
Molecular weight (g/mol)	183.85
Water solubility	Insoluble
Boiling point (°C at 760 mm Hg)	5,900
Melting point (°C)	3,410
Vapor pressure at 2,327°C (mm Hg)	1.97×10^{-7}
Specific gravity/Density at 20°F /4°C	18.7 to 19.3

Abbreviations: g/mol – grams per mole; °C – degrees Celsius; mm Hg – millimeters of mercury.

Existence of tungsten in the environment

- Tungsten-based products have been used in a wide range of applications ranging from common household products to highly specialized components of science and technology (Koutsospyros and others 2006).
- Tungsten/nylon "green" bullets were introduced as a replacement to lead bullets and other ammunition in the United States in the 1990s. In early 2003, the production of tungsten/nylon bullets was discontinued based on flight instability issues (USACE 2007).
- Recent reports of tungsten contamination in groundwater and soil at military sites have raised concerns about tungsten's stability in the environment and resulted in the suspension of tungsten/nylon bullets in some military applications (Kennedy and others 2012; USACE 2007).
- Tungsten may be present in the environment as a result of mining, weathering of rocks, burning of coal and municipal solid waste, land application of fertilizers or industrial applications (ATSDR 2005).
- In the ambient atmosphere, tungsten compounds exist in the particulate phase because of their low vapor pressures. These particles may settle on soil, water or other surfaces and can be mobilized through rain or other forms of precipitation (ATSDR 2005; NIEHS 2003).
- Principal transport and transformation mechanisms include deposition (wet and dry), advective transport, colloidal transport, chemical precipitation, oxidation/reduction, dissolution, complexation, adsorption and anion exchange (Koutsospyros and others 2006).
- Studies indicate that an elevated pH in soil may increase the solubility of tungsten and cause it to leach more readily into the groundwater table (ASTSWMO 2011).
- Laboratory studies found that the dissolution of tungsten into tungstate ions was accompanied by significant reductions in pH and dissolved oxygen concentrations (ASTSWMO 2011).
- Studies found large amounts of dissolved tungsten when tungsten powder or alloy pieces were exposed to aqueous solutions. Additionally, tungsten appears to undergo strong uptake by clay minerals and organic soils (Dermatas and others 2004).
- Increased acidification and oxygen depletion of soils from dissolution of tungsten powder have been shown to trigger changes in the soil microbial community, causing an increase in fungal biomass and a decrease in the bacterial component (Dermatas and others 2004; Strigul and others 2005).
- Water soluble tungsten substances include sodium tungstate, ammonium metatungstate, sodium metatungstate and ammonium paratungstate. Insoluble tungsten substances include tungsten metal, tungsten carbide, ditungsten carbide, tungsten trioxide, tungsten oxides and tungsten disulfide (Lemus and Venezia 2015).
- Studies suggest that the tungsten powder used in the Army's tungsten/nylon bullets forms oxide coatings that dissolve in water and may be mobile under some environmental conditions. (Kennedy and others 2012; USACE 2007).
- Plants are known to take up and accumulate tungsten in substantial amounts and plant toxicity has been reported in the literature (Koutsospyros

and others 2006; Kennedy and others 2012; Adamakis and others 2008).

- Tungsten anions polymerize in environmental systems and under physiological conditions in living organisms. These reactions result in the development of several types of polyoxoanions that differ from monotungstates in certain chemical properties (Strigul 2010).
- Recent studies indicate that tungsten speciation may be important to ecotoxicology. Polytungstates develop and persist in environmental systems and are much more toxic than monotungstates. For example, sodium metatungstate, a polytungstate, is significantly more toxic to fish than sodium tungstate, a monotungstate (Strigul 2010).
- As of 2016, tungsten has been identified at one site on the EPA National Priorities List (NPL) (EPA 2016a).

What are the routes of exposure and the potential health effects of tungsten?

- Tungsten bioaccumulates in the liver of mammals (Kennedy and others 2012).
- Recent studies found evidence for bioaccumulation of tungsten in plants from soil, implying the potential for trophic transfer into the terrestrial food web (Kennedy and others 2012).
- Results from a bioaccumulation study conducted using cabbage and snails showed tungsten compartmentalized first in the hepatopancreas, following by the body and foot. The results also suggested snails consuming contaminated cabbage accumulated higher tungsten concentrations relative to the concentrations directly bioaccumulated from dermal exposure to soil (Kennedy and others 2012).
- A study conducted using male mice exposure to sodium tungstate in tapwater reported dose-dependent increases in tungsten concentration in bone and bone marrow (ATSDR 2015).
- Studies on mice have shown that exposure to sodium tungstate resulted in effects on the immune system and tungsten-related immune suppression (ATSDR 2015).
- Studies on female rats have shown that exposure to tungsten caused post-implantation deaths and developmental abnormalities in the musculoskeletal system (NIEHS 2003); pre and postnatal exposure to sodium tungstate may produce subtle neurobehavioral effects related to motor activity and emotionality in offspring (McInturf and others 2011); and tungsten primarily accumulated in bones and in the spleen after oral exposure (NIEHS 2003).
- Exposure to tungsten in large amounts may cause breathing problems and changes in behavior (ATSDR 2005, 2015; Lemus and Venezia 2015).
- Symptoms of tungsten exposure can include irritation of the eyes, skin and respiratory system, diffuse pulmonary fibrosis, loss of appetite, nausea, cough and blood changes (NIOSH 2016).
- The EPA's Toxic Substances Control Act (TSCA) Interagency Testing Committee has included tungsten compounds in the Priority Testing List, which is a list of chemicals regulated by TSCA for which there are suspicions of toxicity or exposure and for which there are few, if any, ecological effects, environmental fate or health effects testing data (EPA 2006).
- The occurrence of a cluster of childhood leukemia cases in Fallon, Nevada prompted a wide investigation that included several local, state and federal agencies led by the Centers for Disease Control and Prevention (CDC). Groundwater was a source of drinking water and was found to have naturally elevated tungsten concentrations. Although no direct link was found, in 2002, tungsten was nominated for study under the National Toxicology Program (NIEHS 2003). In 2011 it was nominated for human health risk assessment under the EPA's Integrated Risk Information System (IRIS) agenda (EPA 2016b).
- In 2005, the ATDSR issued its toxicological profile for tungsten, identifying several data gaps in toxicity and exposure pathways. In 2015, ATSDR published an addendum to the toxicological profile for tungsten (ATSDR 2015). Additional laboratory studies were described for tungsten and its related substances in the addendum, but the conclusion did not change from 2005 to 2015. Available data are insufficient for derivation of a Minimum Risk Level (ATSDR 2015).

Are there any federal and state guidelines and health standards for tungsten?

- A federal drinking water standard has not been established for tungsten. In addition, EPA has not derived a chronic inhalation reference concentration (RfC) or a chronic oral reference dose (RfD) for tungsten or tungsten compounds (EPA 2016c, d).
- EPA's regional screening levels include soil and tapwater screening values for tungsten due to Provisional Peer Reviewed Toxicity Values for Superfund (EPA 2017).
- Three states have standards for tungsten. Indiana is the only state that has soil and groundwater screening levels (IDEM 2016). North Carolina has preliminary soil remediation goals for tungsten (NCDEQ 2016). Texas has soil and groundwater protective concentration levels for sodium tungstate dihydride (TCEQ 2016).

What detection and site characterization methods are available for tungsten?

- Tungsten analysis is still in the development and optimization stage. For screening purposes, x-ray fluorescence seems to be the most common type of equipment used (ASTSWMO 2011).
- NIOSH Method 7074 is the preferred method for analysis (ASTSWMO 2011). It uses flame atomic absorption to detect tungsten in air. It has a detection limit of 0.25 mg (milligrams) for insoluble forms of tungsten and 0.1 mg for soluble forms of tungsten (NIOSH 1994).
- Other NIOSH methods for the detection of tungsten in air are Methods 7300 and 7301, involving inductively coupled argon plasma-atomic emission spectroscopy. The working range for these methods is 0.005 to 2.0 mg/m^3 for each element in a 500-liter air sample. Special sample treatment may be required for some tungsten compounds (NIOSH 2003a, b).
- OSHA Method ID-213 is also used for the detection of tungsten in air. The method uses inductively coupled plasma (ICP)-atomic emission spectroscopy (AES) and has a quantitative detection limit of 0.34 mg/m^3 (OSHA 1994).
- Tungsten in soil and water can be measured using the ICP-AES, ICP-mass spectrometry (ICP-MS), neutron activation analysis (NAA), ultraviolet/visible spectroscopy (UV/VIS) methods (ATSDR 2005). EPA SW-846 Methods 6010 and 6020 may be modified for the detection of tungsten in soil and water (ASTSWMO 2011).
- The microwave-assisted acid digestion SW-846 Method 3051A can be modified to enhance tungsten recovery from soils (Griggs and others 2009).
- Tungstate can be measured and mapped in waters, soils and sediments using the low-disturbance diffusive gradient in thin-films passive sampling technique (Guan and others 2016).

What technologies are being used to treat tungsten?

- Preliminary studies indicate that phytoremediation may be a potential treatment method for tungsten-contaminated sites based on the reported accumulation of tungsten in plant tissue (Strigul and others 2005; Tuna and others 2012; Erdemir and others 2016).
- Electrokinetic soil remediation is an emerging in situ technology for removal of tungsten from low-permeability soils in the presence of heavy metals such as copper and lead. A direct current is applied to contaminated soils using electrodes inserted into the ground (Braida and others 2007).
- Studies have reported the efficient removal (98 to 99 percent) of tungsten from industrial wastewater by precipitation, coagulation and flocculation processes using ferric chloride under acidic conditions (pH below 6) (Plattes and others 2007).
- A recent study reported 98 percent removal of tungsten from industrial wastewater using acid- and heat-treated sepiolite (Wang and others 2015).
- A recent study demonstrated the efficient recovery of tungsten (over 90 percent) in aqueous solutions using a water-soluble polymer (polyquaternium-6) for complexing anion forms of tungsten prior to ultrafiltration (Zeng and others 2012).

Where can I find more information about tungsten?

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ATTACHMENT L

ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST

CONTRACT 295-20-XX
WATER SYSTEM IMPROVEMENTS
MOUNTAIN WATER DISTRICT
PIKEVILLE, KENTUCKY

BELL ENGINEERING

0-3 Years **INFRASTRUCTURE CONTRACTOR**

Item No.	Description	Quantity	Unit	Engineer's Opinion of Probable Construction Costs Unit Price	Total
DIVISION "A"					
1.	Replace existing Booster Pump Stations at the Pike Central, Graveyard, and Forest Hills areas, complete, including excavation, regrade, security fence and gate, gate valves, piping, site work, concrete work, crushed stone, access road, including all electrical work, and all other items of work necessary for a complete and functional facility	3	Each	$250,000.00	$750,000.00
2.	Rehabilitate the Booster Pump Stations at the Hardy, Long Branch, and Cabin Knoll	3	Each	$40,000.00	$120,000.00
3.	Install a New Water Storage Tank w/ Telemetry, Complete, In-Service at the Right Fork of Greasy Creek (100,000 Gallon)	1	Each	$300,000.00	$300,000.00
4.	Install a New Water Storage Tank w/ Telemetry, Complete, In-Service at the Kendrick Fork Area (25,000 Gallon)	1	Each	$100,000.00	$100,000.00
5.	Purchase and install the following equipment for the Water Treatment Plant: air compressor, coagulation day tank, and chemical pumps	1	LS	$20,000.00	$20,000.00
6.	Rehabilitate skid tanks at (10) site locations.	10	Each	$20,000.00	$200,000.00
7.	Install Pressure Reducing Valves at the Blackberry No. 2, Lyntrough, and Pitstop areas.	3	Each	$15,000.00	$45,000.00
	SUBTOTAL DIVISION "A"				$1,535,000.00
	Project Contingency 20%	1	LS	$307,000.00	$307,000.00
	TOTAL BID, CONTRACT 295-20-01				**$1,842,000.00**

CONTRACT 295-20-XX
WATER SYSTEM IMPROVEMENTS
MOUNTAIN WATER DISTRICT
PIKEVILLE, KENTUCKY

BELL ENGINEERING

0-3 Years **INFRASTRUCTURE IN-HOUSE**

Item No.	Description	Quantity	Unit	Engineer's Opinion of Probable Construction Costs: Unit Price	Total
DIVISION "A"					
1.	Replace existing Booster Pump Stations at the Pike Central, Graveyard, and Forest Hills areas, complete, including excavation, regrade, security fence and gate, gate valves, piping, site work, concrete work, crushed stone, access road, including all electrical work, and all other items of work necessary for a complete and functional facility	3	Each	$50,000.00	$150,000.00
2.	Rehabilitate the Booster Pump Stations at the Hardy, Long Branch, and Cabin Knoll	3	Each	$13,334.00	$40,002.00
3.	Install a New Water Storage Tank w/ Telemetry, Complete, In-Service at the Right Fork of Greasy Creek (100,000 Gallon)	1	Each	$60,000.00	$60,000.00
4.	Install a New Water Storage Tank w/ Telemetry, Complete, In-Service at the Kendrick Fork (25,000 Gallon)	1	Each	$20,000.00	$20,000.00
5.	Purchase and install the following equipment for the Water Treatment Plant: air compressor, coagulation day tank, and chemical pumps	1	LS	$12,000.00	$12,000.00
6.	Rehabilitate skid tanks at (10) site locations.	10	Each	$15,000.00	$150,000.00
7.	Install Pressure Reducing Valves at the Blackberry No. 2, Lyntrough, and Pitstop areas.	3	Each	$13,334.00	$40,002.00
	SUBTOTAL DIVISION "A"				$472,004.00
	Project Contingency 20%	1	LS	$94,400.80	$94,400.80
	TOTAL BID, CONTRACT 295-20-01				**$566,404.80**

CONTRACT 295-20-XX
WATER SYSTEM IMPROVEMENTS
MOUNTAIN WATER DISTRICT
PIKEVILLE, KENTUCKY

BELL ENGINEERING

4-6 Years **INFRASTRUCTURE CONTRACTOR**

Item No.	Description	Quantity	Unit	Engineer's Opinion of Probable Construction Costs Unit Price	Total
DIVISION "A"					
1.	Replace existing Booster Pump Stations at the Stone, McVeigh, and Toler areas, complete, including excavation, regrade, security fence and gate, gate valves, piping, site work, concrete work, crushed stone, access road, including all electrical work, and all other items of work necessary for a complete and functional facility	3	Each	$250,000.00	$750,000.00
2.	Rehabilitate the Booster Pump Stations at the Jerry Bottom, Turkeytoe, and Dials Branch Areas	3	Each	$40,000.00	$120,000.00
4.	Install a New Water Storage Tank w/ Telemetry, Complete, In-Service at the Forrest Hills Area (20,000 Gallon)	1	Each	$100,000.00	$100,000.00
5.	Purchase and install the following equipment for the Water Treatment Plant:vacuum pumps, turbidity/sand filters, and air valves	1	LS	$100,000.00	$100,000.00
6.	Rehabilitate skid tanks at (10) site locations.	15	Each	$20,000.00	$300,000.00
7.	Install Pressure Reducing Valves at the Widows, Phelps One and Two, and Rockhouse of Marrowbone areas	3	Each	$15,000.00	$45,000.00
	SUBTOTAL DIVISION "A"				$1,415,000.00
	Project Contingency 20%	1	LS	$283,000.00	$283,000.00
	TOTAL BID, CONTRACT 295-20-01				**$1,698,000.00**

CONTRACT 295-20-XX
WATER SYSTEM IMPROVEMENTS
MOUNTAIN WATER DISTRICT
PIKEVILLE, KENTUCKY

BELL ENGINEERING

4-6 Years **INFRASTRUCTURE IN-HOUSE**

Item No.	Description	Quantity	Unit	Engineer's Opinion of Probable Construction Costs Unit Price	Total
DIVISION "A"					
1.	Replace existing Booster Pump Stations at the Stone, McVeigh, and Toler areas, complete, including excavation, regrade, security fence and gate, gate valves, piping, site work, concrete work, crushed stone, access road, including all electrical work, and all other items of work necessary for a complete and functional facility	3	Each	$70,000.00	$210,000.00
2.	Rehabilitate the Booster Pump Stations at the Jerry Bottom, Turkeytoe, and Dials Branch Areas	3	Each	$13,334.00	$40,002.00
4.	Install a New Water Storage Tank w/ Telemetry, Complete, In-Service at the Forrest Hills Area (20,000 Gallon)	1	Each	$80,000.00	$80,000.00
5.	Purchase and install the following equipment for the Water Treatment Plant:vacuum pumps, turbidity/sand filters, and air valves	1	LS	$70,000.00	$70,000.00
6.	Rehabilitate skid tanks at (10) site locations.	15	Each	$15,000.00	$225,000.00
7.	Install Pressure Reducing Valves at the Widows, Phelps One and Two, and Rockhouse of Marrowbone areas	3	Each	$10,000.00	$30,000.00
	SUBTOTAL DIVISION "A"				$655,002.00
	Project Contingency 20%	1	LS	$131,000.40	$131,000.40
	TOTAL BID, CONTRACT 295-20-01				**$786,002.40**

0-3 Years **MARROWBONE CONTRACTOR**
Main Line, Service Line, Zone Metering, Telemetry

Item No.	Description	Quantity	Unit	Engineer's Opinion of Probable Construction Costs Unit Price	Total
DIVISION "A"					
1.	3-Inch Pressure Class 350 Ductile Iron, Restrained Joint Pipe, Furnishing, Trenching, Bedding, Laying and Backfilling, Including Compact Ductile Iron, Mechanical Joint Fittings, Detectable Tape, Unclassified Excavation, Complete	9,958	L.F.	$20.00	$199,160.00
2.	4-Inch Pressure Class 350 Ductile Iron, Restrained Joint Pipe, Furnishing, Trenching, Bedding, Laying and Backfilling, Including Compact Ductile Iron, Mechanical Joint Fittings, Detectable Tape, Unclassified Excavation, Complete	81,745	L.F.	$30.00	$2,452,350.00
3.	6-Inch Pressure Class 350 Ductile Iron, Restrained Joint Pipe, Furnishing, Trenching, Bedding, Laying and Backfilling, Including Compact Ductile Iron, Mechanical Joint Fittings, Detectable Tape, Unclassified Excavation, Complete	10,468	L.F.	$32.00	$334,976.00
4.	8-Inch Pressure Class 350 Ductile Iron, Restrained Joint Pipe, Furnishing, Trenching, Bedding, Laying and Backfilling, Including Compact Ductile Iron, Mechanical Joint Fittings, Detectable Tape, Unclassified Excavation, Complete	25,593	L.F.	$40.00	$1,023,720.00
5.	10-Inch Pressure Class 350 Ductile Iron, Restrained Joint Pipe, Furnishing, Trenching, Bedding, Laying and Backfilling, Including Compact Ductile Iron, Mechanical Joint Fittings, Detectable Tape, Unclassified Excavation, Complete	9,700	L.F.	$42.00	$407,400.00
6.	12-Inch Pressure Class 350 Ductile Iron, Restrained Joint Pipe, Furnishing, Trenching, Bedding, Laying and Backfilling, Including Compact Ductile Iron, Mechanical Joint Fittings, Detectable Tape, Unclassified Excavation, Complete	9,779	LF	$52.00	$508,508.00
7.	Cellular Telemetry	14	Each	$7,500.00	$105,000.00
8.	4-Inch Zone Meter Setting on Existing 6-Inch Water Line Line Including but Not Limited to Sensus Omni AMR Meter w/ Strainer, Clow Resilient Seat Gate Valves, Valve Boxes and Collars, DIMJ Fittings, Foster Adaptors, Alpha Romac Couplings, ABS Meter Vault w/ lid, PVC SDR-21 Pipe, DI CL 350 Flanged to Plain End Pipe, as Well as Unclassified Excavation, Assembly, Testing, Transport, Disinfection, Bedding, Installation, and Backfill; in Order to Make the Zone Meter Setting Operational, Complete	4	Each	$17,500.00	$70,000.00
9.	4-Inch Zone Meter Setting on Existing 8-Inch Water Line Line Including but Not Limited to Sensus Omni AMR Meter w/ Strainer, Clow Resilient Seat Gate Valves, Valve Boxes and Collars, DIMJ Fittings, Foster Adaptors, Alpha Romac Couplings, ABS Meter Vault w/ lid, PVC SDR-21 Pipe, DI CL 350 Flanged to Plain End Pipe, as Well as Unclassified Excavation, Assembly, Testing, Transport, Disinfection, Bedding, Installation, and Backfill; in Order to Make the Zone Meter Setting Operational, Complete	6	Each	$19,500.00	$117,000.00
10.	3-Inch Zone Meter Setting on Existing 8-Inch Water Line Line Including but Not Limited to Sensus Omni AMR Meter w/ Strainer, Clow Resilient Seat Gate Valves, Valve Boxes and Collars, DIMJ Fittings, Foster Adaptors, Alpha Romac Couplings, ABS Meter Vault w/ lid, PVC SDR-21 Pipe, DI CL 350 Flanged to Plain End Pipe, as Well as Unclassified Excavation, Assembly, Testing, Transport, Disinfection, Bedding, Installation, and Backfill; in Order to Make the Zone Meter Setting Operational, Complete	1	Each	$18,000.00	$18,000.00
11.	8-Inch Zone Meter Setting on Existing 10-Inch Water Line Line Including but Not Limited to Sensus Omni AMR Meter w/ Strainer, Clow Resilient Seat Gate Valves, Valve Boxes and Collars, DIMJ Fittings, Foster Adaptors, Alpha Romac Couplings, ABS Meter Vault w/ lid, PVC SDR-21 Pipe, DI CL 350 Flanged to Plain End Pipe, as Well as Unclassified Excavation, Assembly, Testing, Transport, Disinfection, Bedding, Installation, and Backfill; in Order to Make the Zone Meter Setting Operational, Complete	1	Each	$17,500.00	$17,500.00

Telemetry

Item No.	Description	Quantity	Unit	Engineer's Opinion of Probable Construction Costs: Unit Price	Total
12.	4-Inch Zone Meter Setting on Existing 12-Inch Water Line Line Including but Not Limited to Sensus Omni AMR Meter w/ Strainer, Clow Resilient Seat Gate Valves, Valve Boxes and Collars, DIMJ Fittings, Foster Adaptors, Alpha Romac Couplings, ABS Meter Vault w/ lid, PVC SDR-21 Pipe, DI CL 350 Flanged to Plain End Pipe, as Well as Unclassified Excavation, Assembly, Testing, Transport, Disinfection, Bedding, Installation, and Backfill; in Order to Make the Zone Meter Setting Operational, Complete	1	Each	$25,000.00	$25,000.00
13.	3/4-Inch Polyethylene Service Pipe, with PVC or Polyethylene Cover Pipe, Detectable Wire, Furnishing, Trenching, Bedding, Laying and Backfilling, or by Jacking, Unclassified Excavation, Complete	49,500	L.F.	$22.00	$1,089,000.00
	SUBTOTAL DIVISION "A"				$6,367,614.00
	Project Contingency 20%	1	LS	$1,273,522.80	$1,273,522.80
	TOTAL BID, CONTRACT 295-20-01				**$7,641,136.80**

CONTRACT 295-20-XX
WATER SYSTEM IMPROVEMENTS
MOUNTAIN WATER DISTRICT
PIKEVILLE, KENTUCKY

BELL ENGINEERING

0-3 Years **MARROWBONE IN-HOUSE**
Main Line, Service Line, Zone Metering, Telemetry

Item No.	Description	Quantity	Unit	Engineer's Opinion of Probable Construction Costs: Unit Price	Total
DIVISION "A"					
1.	3-Inch Pressure Class 350 Ductile Iron, Restrained Joint Pipe, Furnishing, Trenching, Bedding, Laying and Backfilling, Including Compact Ductile Iron, Mechanical Joint Fittings, Detectable Tape, Unclassified Excavation, Complete	9,958	L.F.	$16.00	$159,328.00
2.	4-Inch Pressure Class 350 Ductile Iron, Restrained Joint Pipe, Furnishing, Trenching, Bedding, Laying and Backfilling, Including Compact Ductile Iron, Mechanical Joint Fittings, Detectable Tape, Unclassified Excavation, Complete	81,745	L.F.	$24.00	$1,961,880.00
3.	6-Inch Pressure Class 350 Ductile Iron, Restrained Joint Pipe, Furnishing, Trenching, Bedding, Laying and Backfilling, Including Compact Ductile Iron, Mechanical Joint Fittings, Detectable Tape, Unclassified Excavation, Complete	10,468	L.F.	$25.60	$267,980.80
4.	8-Inch Pressure Class 350 Ductile Iron, Restrained Joint Pipe, Furnishing, Trenching, Bedding, Laying and Backfilling, Including Compact Ductile Iron, Mechanical Joint Fittings, Detectable Tape, Unclassified Excavation, Complete	25,593	L.F.	$32.00	$818,976.00
5.	10-Inch Pressure Class 350 Ductile Iron, Restrained Joint Pipe, Furnishing, Trenching, Bedding, Laying and Backfilling, Including Compact Ductile Iron, Mechanical Joint Fittings, Detectable Tape, Unclassified Excavation, Complete	9,700	L.F.	$33.60	$325,920.00
6.	12-Inch Pressure Class 350 Ductile Iron, Restrained Joint Pipe, Furnishing, Trenching, Bedding, Laying and Backfilling, Including Compact Ductile Iron, Mechanical Joint Fittings, Detectable Tape, Unclassified Excavation, Complete	9,779	LF	$41.60	$406,806.40
7.	Cellular Telemetry	14	Each	$6,000.00	$84,000.00
8.	4-Inch Zone Meter Setting on Existing 6-Inch Water Line Line Including but Not Limited to Sensus Omni AMR Meter w/ Strainer, Clow Resilient Seat Gate Valves, Valve Boxes and Collars, DIMJ Fittings, Foster Adaptors, Alpha Romac Couplings, ABS Meter Vault w/ lid, PVC SDR-21 Pipe, DI CL 350 Flanged to Plain End Pipe, as Well as Unclassified Excavation, Assembly, Testing, Transport, Disinfection, Bedding, Installation, and Backfill; in Order to Make the Zone Meter Setting Operational, Complete	2	Each	$13,125.00	$26,250.00
9.	4-Inch Zone Meter Setting on Existing 8-Inch Water Line Line Including but Not Limited to Sensus Omni AMR Meter w/ Strainer, Clow Resilient Seat Gate Valves, Valve Boxes and Collars, DIMJ Fittings, Foster Adaptors, Alpha Romac Couplings, ABS Meter Vault w/ lid, PVC SDR-21 Pipe, DI CL 350 Flanged to Plain End Pipe, as Well as Unclassified Excavation, Assembly, Testing, Transport, Disinfection, Bedding, Installation, and Backfill; in Order to Make the Zone Meter Setting Operational, Complete	3	Each	$14,625.00	$43,875.00
10.	3-Inch Zone Meter Setting on Existing 8-Inch Water Line Line Including but Not Limited to Sensus Omni AMR Meter w/ Strainer, Clow Resilient Seat Gate Valves, Valve Boxes and Collars, DIMJ Fittings, Foster Adaptors, Alpha Romac Couplings, ABS Meter Vault w/ lid, PVC SDR-21 Pipe, DI CL 350 Flanged to Plain End Pipe, as Well as Unclassified Excavation, Assembly, Testing, Transport, Disinfection, Bedding, Installation, and Backfill; in Order to Make the Zone Meter Setting Operational, Complete	1	Each	$13,500.00	$13,500.00
11.	8-Inch Zone Meter Setting on Existing 10-Inch Water Line Line Including but Not Limited to Sensus Omni AMR Meter w/ Strainer, Clow Resilient Seat Gate Valves, Valve Boxes and Collars, DIMJ Fittings, Foster Adaptors, Alpha Romac Couplings, ABS Meter Vault w/ lid, PVC SDR-21 Pipe, DI CL 350 Flanged to Plain End Pipe, as Well as Unclassified Excavation, Assembly, Testing, Transport, Disinfection, Bedding, Installation, and Backfill; in Order to Make the Zone Meter Setting Operational, Complete	1	Each	$13,125.00	$13,125.00

Telemetry

Item No.	Description	Quantity	Unit	Unit Price	Total
				Engineer's Opinion of Probable Construction Costs	
12.	4-Inch Zone Meter Setting on Existing 12-Inch Water Line Line Including but Not Limited to Sensus Omni AMR Meter w/ Strainer, Clow Resilient Seat Gate Valves, Valve Boxes and Collars, DIMJ Fittings, Foster Adaptors, Alpha Romac Couplings, ABS Meter Vault w/ lid, PVC SDR-21 Pipe, DI CL 350 Flanged to Plain End Pipe, as Well as Unclassified Excavation, Assembly, Testing, Transport, Disinfection, Bedding, Installation, and Backfill; in Order to Make the Zone Meter Setting Operational, Complete	1	Each	$18,750.00	$18,750.00
13.	3/4-Inch Polyethylene Service Pipe, with PVC or Polyethylene Cover Pipe, Detectable Wire, Furnishing, Trenching, Bedding, Laying and Backfilling, or by Jacking, Unclassified Excavation, Complete	49,500	L.F.	$16.50	$816,750.00
	SUBTOTAL DIVISION "A"				$4,957,141.20
	Project Contingency 20%	1	LS	$991,428.24	$991,428.24
	TOTAL BID, CONTRACT 295-20-01				**$5,948,569.44**

CONTRACT 295-20-XX
WATER SYSTEM IMPROVEMENTS
MOUNTAIN WATER DISTRICT
PIKEVILLE, KENTUCKY

BELL ENGINEERING

4-6 Years **POND CREEK CONTRACTOR**
Main Line, Service Line, Zone Metering, Telemetry

Item No.	Description	Quantity	Unit	Engineer's Opinion of Probable Construction Costs — Unit Price	Total
DIVISION "A"					
1.	4-Inch Pressure Class 350 Ductile Iron, Restrained Joint Pipe, Furnishing, Trenching, Bedding, Laying and Backfilling, Including Compact Ductile Iron, Mechanical Joint Fittings, Detectable Tape, Unclassified Excavation, Complete	76,140	L.F.	$30.00	$2,284,200.00
2.	6-Inch Pressure Class 350 Ductile Iron, Restrained Joint Pipe, Furnishing, Trenching, Bedding, Laying and Backfilling, Including Compact Ductile Iron, Mechanical Joint Fittings, Detectable Tape, Unclassified Excavation, Complete	17,531	L.F.	$32.00	$560,992.00
3.	8-Inch Pressure Class 350 Ductile Iron, Restrained Joint Pipe, Furnishing, Trenching, Bedding, Laying and Backfilling, Including Compact Ductile Iron, Mechanical Joint Fittings, Detectable Tape, Unclassified Excavation, Complete	51,121	L.F.	$40.00	$2,044,840.00
4.	Cellular Telemetry	14	Each	$7,500.00	$105,000.00
5.	4-Inch Zone Meter Setting on Existing 6-Inch Water Line Line Including but Not Limited to Sensus Omni AMR Meter w/ Strainer, Clow Resilient Seat Gate Valves, Valve Boxes and Collars, DIMJ Fittings, Foster Adaptors, Alpha Romac Couplings, ABS Meter Vault w/ lid, PVC SDR-21 Pipe, DI CL 350 Flanged to Plain End Pipe, as Well as Unclassified Excavation, Assembly, Testing, Transport, Disinfection, Bedding, Installation, and Backfill; in Order to Make the Zone Meter Setting Operational, Complete	6	Each	$17,500.00	$105,000.00
6.	4-Inch Zone Meter Setting on Existing 8-Inch Water Line Line Including but Not Limited to Sensus Omni AMR Meter w/ Strainer, Clow Resilient Seat Gate Valves, Valve Boxes and Collars, DIMJ Fittings, Foster Adaptors, Alpha Romac Couplings, ABS Meter Vault w/ lid, PVC SDR-21 Pipe, DI CL 350 Flanged to Plain End Pipe, as Well as Unclassified Excavation, Assembly, Testing, Transport, Disinfection, Bedding, Installation, and Backfill; in Order to Make the Zone Meter Setting Operational, Complete	4	Each	$19,500.00	$78,000.00
7.	6-Inch Zone Meter Setting on Existing 8-Inch Water Line Line Including but Not Limited to Sensus Omni AMR Meter w/ Strainer, Clow Resilient Seat Gate Valves, Valve Boxes and Collars, DIMJ Fittings, Foster Adaptors, Alpha Romac Couplings, ABS Meter Vault w/ lid, PVC SDR-21 Pipe, DI CL 350 Flanged to Plain End Pipe, as Well as Unclassified Excavation, Assembly, Testing, Transport, Disinfection, Bedding, Installation, and Backfill; in Order to Make the Zone Meter Setting Operational, Complete	3	Each	$22,500.00	$67,500.00
8.	8-Inch Zone Meter Setting on Existing 8-Inch Water Line Line Including but Not Limited to Sensus Omni AMR Meter w/ Strainer, Clow Resilient Seat Gate Valves, Valve Boxes and Collars, DIMJ Fittings, Foster Adaptors, Alpha Romac Couplings, ABS Meter Vault w/ lid, PVC SDR-21 Pipe, DI CL 350 Flanged to Plain End Pipe, as Well as Unclassified Excavation, Assembly, Testing, Transport, Disinfection, Bedding, Installation, and Backfill; in Order to Make the Zone Meter Setting Operational, Complete	1	Each	$25,000.00	$25,000.00
9.	3/4-Inch Polyethylene Service Pipe, with PVC or Polyethylene Cover Pipe, Detectable Wire, Furnishing, Trenching, Bedding, Laying and Backfilling, or by Jacking, Unclassified Excavation, Complete	30,900	L.F.	$22.00	$679,800.00
	SUBTOTAL DIVISION "A"				$5,950,332.00
	Project Contingency 20%	1	LS	$1,190,066.40	$1,190,066.40
	TOTAL BID, CONTRACT 295-20-01				**$7,140,398.40**

CONTRACT 295-20-XX
WATER SYSTEM IMPROVEMENTS
MOUNTAIN WATER DISTRICT
PIKEVILLE, KENTUCKY

BELL ENGINEERING

4-6 Years **POND CREEK IN-HOUSE**
Main Line, Service Line, Zone Metering, Telemetry

Item No.	Description	Quantity	Unit	Engineer's Opinion of Probable Construction Costs — Unit Price	Total
DIVISION "A"					
1.	4-Inch Pressure Class 350 Ductile Iron, Restrained Joint Pipe, Furnishing, Trenching, Bedding, Laying and Backfilling, Including Compact Ductile Iron, Mechanical Joint Fittings, Detectable Tape, Unclassified Excavation, Complete	76,140	L.F.	$24.00	$1,827,360.00
2.	6-Inch Pressure Class 350 Ductile Iron, Restrained Joint Pipe, Furnishing, Trenching, Bedding, Laying and Backfilling, Including Compact Ductile Iron, Mechanical Joint Fittings, Detectable Tape, Unclassified Excavation, Complete	17,531	L.F.	$25.60	$448,793.60
3.	8-Inch Pressure Class 350 Ductile Iron, Restrained Joint Pipe, Furnishing, Trenching, Bedding, Laying and Backfilling, Including Compact Ductile Iron, Mechanical Joint Fittings, Detectable Tape, Unclassified Excavation, Complete	51,121	L.F.	$32.00	$1,635,872.00
4.	Cellular Telemetry	14	Each	$6,000.00	$84,000.00
5.	4-Inch Zone Meter Setting on Existing 6-Inch Water Line Line Including but Not Limited to Sensus Omni AMR Meter w/ Strainer, Clow Resilient Seat Gate Valves, Valve Boxes and Collars, DIMJ Fittings, Foster Adaptors, Alpha Romac Couplings, ABS Meter Vault w/ lid, PVC SDR-21 Pipe, DI CL 350 Flanged to Plain End Pipe, as Well as Unclassified Excavation, Assembly, Testing, Transport, Disinfection, Bedding, Installation, and Backfill; in Order to Make the Zone Meter Setting Operational, Complete	6	Each	$13,125.00	$78,750.00
6.	4-Inch Zone Meter Setting on Existing 8-Inch Water Line Line Including but Not Limited to Sensus Omni AMR Meter w/ Strainer, Clow Resilient Seat Gate Valves, Valve Boxes and Collars, DIMJ Fittings, Foster Adaptors, Alpha Romac Couplings, ABS Meter Vault w/ lid, PVC SDR-21 Pipe, DI CL 350 Flanged to Plain End Pipe, as Well as Unclassified Excavation, Assembly, Testing, Transport, Disinfection, Bedding, Installation, and Backfill; in Order to Make the Zone Meter Setting Operational, Complete	4	Each	$14,625.00	$58,500.00
7.	6-Inch Zone Meter Setting on Existing 8-Inch Water Line Line Including but Not Limited to Sensus Omni AMR Meter w/ Strainer, Clow Resilient Seat Gate Valves, Valve Boxes and Collars, DIMJ Fittings, Foster Adaptors, Alpha Romac Couplings, ABS Meter Vault w/ lid, PVC SDR-21 Pipe, DI CL 350 Flanged to Plain End Pipe, as Well as Unclassified Excavation, Assembly, Testing, Transport, Disinfection, Bedding, Installation, and Backfill; in Order to Make the Zone Meter Setting Operational, Complete	3	Each	$16,875.00	$50,625.00
8.	8-Inch Zone Meter Setting on Existing 8-Inch Water Line Line Including but Not Limited to Sensus Omni AMR Meter w/ Strainer, Clow Resilient Seat Gate Valves, Valve Boxes and Collars, DIMJ Fittings, Foster Adaptors, Alpha Romac Couplings, ABS Meter Vault w/ lid, PVC SDR-21 Pipe, DI CL 350 Flanged to Plain End Pipe, as Well as Unclassified Excavation, Assembly, Testing, Transport, Disinfection, Bedding, Installation, and Backfill; in Order to Make the Zone Meter Setting Operational, Complete	1	Each	$18,750.00	$18,750.00
9.	3/4-Inch Polyethylene Service Pipe, with PVC or Polyethylene Cover Pipe, Detectable Wire, Furnishing, Trenching, Bedding, Laying and Backfilling, or by Jacking, Unclassified Excavation, Complete	30,900	L.F.	$16.50	$509,850.00
	SUBTOTAL DIVISION "A"				$4,712,500.60
	Project Contingency 20%	1	LS	$942,500.12	$942,500.12
	TOTAL BID, CONTRACT 295-20-01				**$5,655,000.72**

ATTACHMENT M

STATEMENT OF NET POSITION

MOUNTAIN WATER DISTRICT
Statement of Net Position
As of December 31, 2019 and 2018

ASSETS

	2019	2018
Current Assets		
Cash In Bank	$ 656,539.01	$ 829,914.24
Accounts Receivable	1,102,892.79	1,155,733.46
Clearing Accounts	90,446.30	0.00
Inventory	270,662.90	270,662.90
Other Current Assets	46,110.57	35,223.30
Total Current Assets	2,166,651.57	2,291,533.90
Non Current Assets		
Restricted Cash		
Cash in Bank - Restricted	3,118,384.73	3,129,963.50
Total Restricted Cash	3,118,384.73	3,129,963.50
Capital Assets		
Water Supply Plant	4,682,574.42	4,682,574.42
Water Treatment Plant	9,785,509.64	9,784,555.98
Transmission & Distribution Plant	93,694,768.70	93,803,094.17
Water General Plant	4,464,482.02	4,327,294.36
Sewer General Plant	32,697,682.89	32,446,263.46
Construction In Progress	10,084,503.46	5,247,389.68
Total Plant In Service	155,409,521.13	150,291,172.07
Less Accumulated Depreciation	(66,172,223.87)	(62,293,943.63)
Net Capital Assets	89,237,297.26	87,997,228.44
Other Assets		
Bond Refinancing Cost	92,316.17	92,316.17
Less Accumulated Amortization	(21,516.29)	(21,516.29)
Total Other Assets	70,799.88	70,799.88
Total Non Current Assets	92,426,481.87	91,197,991.82
Total Net Assets	$ 94,593,133.44	$ 93,489,525.72
Deferred Outflow of Resources		
Deferred Pension Contributions	$ 3,168,103.06	$ 3,168,103.06

ATTACHMENT D

No assurance is provided on these financial statements. Management has elected to omit substantially all disclosures required by accounting principles generally accepted in the United States of America.

MOUNTAIN WATER DISTRICT
Statement of Net Position
As of December 31, 2019 and 2018

Liabilities and Net Assets

	2019	2018
Current Liabilities		
Accounts Payable	$ 282,953.57	$ 228,716.49
Current Portion Due - Notes Payable	1,014,257.00	1,014,257.00
Customer Deposits	399,494.94	367,569.96
Accrued Payroll and Related Expenses	148,285.10	78,130.31
Accrued Interest - Long Term Debt	346,421.26	144,516.00
Total Current Liabilities	2,191,411.87	1,833,189.76
Long-Term Liabilities		
Net Pension Liability	6,427,919.00	6,427,919.00
Notes Payable	4,271,604.52	4,915,945.95
Notes Payable - Ky Infrastructure Authority	4,837,394.01	2,232,155.61
Notes Payable - Rural Development	3,500,500.00	3,576,500.00
Less: Current Portion Due	(1,014,257.00)	(1,014,257.00)
Total Long-Term Liabilities	18,023,160.53	16,138,263.56
Total Liabilities	20,214,572.40	17,971,453.32
Deferred Inflows of Resources		
Deferred Pension Investment Earnings	639,324.00	639,324.00
Net Position		
Current Year Net Income (Loss)	(2,030,476.36)	(3,289,762.12)
Advances for Construction	5,885,690.32	5,148,216.11
Contributions in aid of Construction	65,757,383.36	69,022,088.48
Tap-On-Fees	7,294,742.78	7,141,251.99
Total Net Position	76,907,340.10	78,021,794.46

No assurance is provided on these financial statements. Management has elected to omit substantially all disclosures required by accounting principles generally accepted in the United States of America.

MOUNTAIN WATER DISTRICT
Statement of Revenues, Expenses and Changes in Net Position

	1 Month Ended December 31, 2019	12 Months Ended December 31, 2019
Operating Revenue		
	$ 833,714.53	$ 10,532,609.64
Total Operating Revenue	833,714.53	10,532,609.64
Operating Expenses		
Water Supply Expense	5,410.70	127,225.01
Water Purchases	121,386.63	1,226,429.23
Electricity Expense	117,767.89	1,329,805.15
Repairs & Maintenance - Sewer	12,208.95	97,918.54
Repairs & Maintenance - Water	42,963.16	539,942.02
Transmission & Distribution Expense	95,103.74	1,281,677.04
Customer Service Expense	46,089.61	564,114.64
Administrator Expense	254.45	2,222.74
Sewer Expense	44,254.39	574,814.70
General & Administrative	268,706.48	2,459,273.71
Total Operating Expenses	754,146.00	8,203,422.78
Depreciation Expense	323,628.00	3,883,536.00
General Tax Expense	0.00	21,048.25
Utility Operating Expense	1,077,774.00	12,108,007.03
Utility Operating Income (Loss)	(244,059.47)	(1,575,397.39)
Non Operating Revenue		
Interest Income	2,252.97	16,918.87
Interest Expense	(39,028.19)	(471,997.84)
Total Non Operating Revenue	(36,775.22)	(455,078.97)
Income (Loss) before Capital Contributions	$ (280,834.69)	$ (2,030,476.36)
Capital Contributions and Other Changes in Net Position		
Capital contibutions from:		
Advances for Construction	1,048,177.32	737,474.21
Customers through Tap-on Fees	11,550.00	153,490.79
Total Capital Contributions and Other Changes in Net Position	1,059,727.32	890,965.00
Change in Net Position	778,892.63	(1,139,511.36)
Net Position, beginning of period	76,128,447.47	78,046,851.46
Net Position, end of period	$ 76,907,340.10	$ 76,907,340.10

O+M

O+M

No assurance is provided on these financial statements. Management has elected to omit substantially all disclosures required by accounting principles generally accepted in the United States of America.

MOUNTAIN WATER DISTRICT
Statement of Cash Flows
For the 1 Month and 12 Months Ended December 31, 2019

		1 Month Ended December 31, 2019		12 Months Ended December 31, 2019
Cash Flows from Operating Activities				
Net Income (Loss)	$	(280,834.69)	$	(2,030,476.36)
Adjustments to reconcile net income (loss) to net cash provided by (used in) operating activities:				
Depreciation and Amortization		323,628.00		3,883,536.00
Losses (Gains) on Sales of Fixed Assets		0.00		0.00
Decrease (Increase) in Operating Assets:				
Accounts Receivable		69,631.92		52,840.67
Other Current Assets		0.00		(10,887.27)
Increase (Decrease) in Operating Liabilities:				
Accounts Payable		40,392.06		54,237.08
Accrued Interest		(3,151.37)		201,905.26
Advances for Construction		1,048,177.32		737,474.21
Accrued Liabilities		12,313.29		70,154.79
Tap on Fees		11,550.00		153,490.79
Customer Deposits		18,762.74		31,924.98
Clearing Accounts		(67,987.31)		(90,446.30)
Total Adjustments		1,453,316.65		5,084,230.21
Net Cash Provided By (Used In) Operating Activities		1,172,481.96		3,053,753.85
Cash Flows from Investing Activities				
Capital Expenditures		(16,794.17)		(1,102,178.28)
Construction in Progress		(1,078,715.62)		(4,837,113.78)
Net Cash Provided By (Used In) Investing Activities		(1,095,509.79)		(5,939,292.06)
Cash Flows from Financing Activities				
Notes Payable Borrowings		2,274.33		3,685,150.05
Notes Payable Repayments		(689,311.03)		(1,800,253.08)
Net Cash Provided By (Used In) Financing Activities		(687,036.70)		1,884,896.97
Net Increase (Decrease) In Cash and Cash Equivalents and Restricted Cash		(610,064.53)		(1,000,641.24)
Beginning Cash and Cash Equivalents and Restricted Cash		4,384,988.27		3,959,877.74
Ending Cash and Cash Equivalents and Restricted Cash	$	3,774,923.74	$	3,774,923.74

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MOUNTAIN WATER DISTRICT
Statement of Net Assets - Supporting Schedule Assets
As of December 31, 2019 and 2018

ASSETS:

	2019	2018
Operating Cash:		
BIG CREEK SEWER-COAL SETTLEMENT	$ 5,401.24	$ 5,401.24
CTB - Dist Wide WW Tap Fees	36,370.88	25,544.93
CTB - DIST. WIDE TAP FEES	48,742.06	42,419.39
CTB - Operating Account	530,668.28	667,633.43
CTB - R & M REIMBURSEMENT ACCT.	11,474.30	40,507.50
CTB.-M.W.D. Rehab Project	5,160.40	5,160.40
CTB-MWD Payroll Account	16,727.13	41,252.62
MWD INSURANCE SWEEP ACCOUNT	1,674.54	1,674.55
Petty Cash	320.18	320.18
Total Operating Cash	656,539.01	829,914.24
Cash Reserves - Restricted:		
Regions Bank Escrow	271,493.81	271,493.81
BB & T - DEPRECIATION RESERVE	0.00	851,513.31
BB & T - Sinking Fund	279,826.33	399,490.01
CTB - JOHNS CREEK WATER PROJ.	3,332.84	3,341.53
BB&T - Special Projects	374.29	557.00
CTB - CUSTOMER DEPOSIT ESCROW	372,930.05	379,459.27
CTB - FEMA Receivables	3,733.20	260.23
CTB-SEWER CUSTOMER DEPOSIT ACCT.	29,693.48	27,258.50
CTB - O & M RESERVES	258,191.93	178,777.07
Community Trust Bank - Misc Line Extension	1,436.71	1,407.78
CTB - PHELPS SEWER PROJECT	5,371.93	5,371.93
CTB - R & M RESERVE	869,003.03	868,134.58
CTB - Shelby Sewer Project	(29.99)	(29.99)
CTB - Cowpen Sewer Project	1,860.10	1,860.10
CTB - Phelps/Buskirk WW RD	8.52	8.52
WATER TEATMENT PLANT UPGRADE	0.50	0.50
CTB. Water Treatment Raw Water Intake Project	25.00	25.00
CTB-LMI Service Connection 08-09	656.08	656.08
CTB-Various Short Line Ext.	90.96	90.96
CTB-Various Water Line Ext.	100.00	100.00
CTB.M.W.D. Telemetry Project	98.80	98.80
CTB-M.W.D. Watson Hill Waterline Ext. Proj. Acct.	85.00	85.00
CTB.Long Fork Of Virgie Sewer Project Acct.	90.03	90.03
M.W.D. Belfry Pond Sewer	18,351.90	121.75
MWD PHELPS UPGRADE ACCT.	3,516.98	0.00
CTB- Recycling Revenue Acct.	26,235.71	5,710.86
CTB-Smith Fork WW Phase II	100.00	100.00
MWD DEPRECIATION RESERVE ACCOUNT	857,680.90	0.00
CTB. PCFC Projects	114,126.64	133,980.87
Total Cash Reserves - Restricted	3,118,384.73	3,129,963.50
Accounts Receivable:		
RECEIVABLE - WATER SALES	904,189.65	954,324.26
RECEIVABLE - RETURNED CHECKS	26,211.02	1,678.90
RECEIVABLE - OTHER FEES, ETC..	(106,067.76)	2,492.79
RECEIVABLE - SEWER REVENUE	224,033.58	238,237.51
PROVISION FOR UNCOLLECTIBLES	54,526.30	(41,000.00)
Total Accounts Receivable:	1,102,892.79	1,155,733.46

Clearing Accounts:

No assurance is provided on these financial statements. Management has elected to omit substantially all disclosures required by accounting principles generally accepted in the United States of America.

MOUNTAIN WATER DISTRICT
Statement of Net Assets - Supporting Schedule Assets
As of December 31, 2019 and 2018

MWD INTERCOMPANY TRANSFERS	90,446.30	0.00
Total Clearing Accounts:	90,446.30	0.00
Prepaid Expenses:		
Receivable - UMG R & M:		
FEMA Receivable - 2010 Flood:		
Other Current Assets:		
Prepaid Expense-WC	45,485.57	34,598.30
OTHER DEFERRED DEBTS	625.00	625.00
Total Other Current Assets	46,110.57	35,223.30

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MOUNTAIN WATER DISTRICT
Statement of Net Assets - Supporting Schedule - Liabilities
As of December 31, 2019 and 2018

LIABILITIES:

	2019	2018
Employee Related Payables:		
FICA TAXES WITHHELD	12,822.31	0.00
FEDERAL INCOME TAX WITHHELD	6,643.76	0.00
KY INCOME TAX WITHHELD	(10.22)	(20.28)
ACCRUED FUTA	2,767.28	0.00
Accrued CERS	92,185.85	47,241.63
Accrued County Withheld	5,429.71	5,442.63
MIS.TAX EXPENSE	(99.58)	0.00
ACCRUED GARNISHMENT WTH	1,390.10	1,073.60
TAXES COLLECTED ON CUST. BILLS	27,155.89	24,392.73
Total Employee Related Payables	148,285.10	78,130.31
Other Current Liabilities:		
Notes Payable:		
Note Payable Ky. Rural Water	3,772,981.18	4,300,000.00
US Bank Big Creek Water Loan	100,481.62	139,333.48
US Bank #153	0.00	15,131.53
#154 fORD f250 2017	23,260.76	23,787.70
# 155 CTB	8,226.78	18,178.00
CTB V# 156	14,834.57	20,565.41
CTB V # 157 2018 GMC Sierra	15,451.80	21,420.95
CTB LOC - COAL SEV 2005	(939.39)	0.00
CTB 158 & 159	36,069.32	50,208.87
WELLS FARGO MINI EXCAVATOR	30,309.57	85,037.63
CTB # 161	19,904.70	0.00
CTB- 162	44,995.08	0.00
N/P - CTB LOC N	0.40	0.00
N/P - CTB VEH. #146	0.00	3,253.10
COMMUNITY TRUST V#148	1,945.51	9,629.64
US Bank V#149	3,557.65	10,462.49
N/P - CTB VEH. #147	2,024.50	9,960.81
CTB-V# 150 FORD F-150	4,416.22	10,110.92
CTB. V# 151 FORD F-150	4,416.78	10,109.75
CTB-Boom Truck # CTO-02	9,927.84	16,788.39
CTB AEP Line of credit	142,453.45	157,287.74
V #152- US Bank	977.77	14,679.54
Kobelco mini excavator	36,308.41	0.00
Total Notes Payable	4,271,604.52	4,915,945.95
Notes Payable - Ky Infrastructure Authority:		
KIA LOAN B291-07 MULTI AREA	971,387.56	1,197,251.73
KIA LOAN B291-01 INDIAN CREEK	64,206.07	79,097.77
KIA LOAN F01-07 WATER PLANT	307,901.48	373,017.22
KIA LOAN A03-06 SO WMSN III	49,683.38	59,326.15
KIA Shelby III Phase II	228,987.47	237,993.17
KIA-A16-079 Grinder St	271,435.59	285,469.57
KIA-Douglas WWTP	2,943,792.46	0.00

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MOUNTAIN WATER DISTRICT
Statement of Net Assets - Supporting Schedule - Liabilities
As of December 31, 2019 and 2018

Total Notes Payable - Ky Infrastructure Authority	4,837,394.01	2,232,155.61
Notes Payable - Rural Development:		
RD Loan -91-40 WTP	575,000.00	585,000.00
RD Bond 91-33	1,384,000.00	1,412,000.00
RD Bond - Shelby Sewer Project	608,000.00	621,000.00
RD Bond - 91-01 Phelps Sewer	341,500.00	349,500.00
RD BOND 91-24 RUSSELL FK WTP	592,000.00	609,000.00
Total Notes Payable - Rural Development	3,500,500.00	3,576,500.00
Contributions in Aid of Construction:		
CONTRIBUTIONS - GOVT GRANTS	73,596,717.38	73,596,717.38
CONTRIBUTIONS IN AID - SEWER	26,992,605.38	26,992,605.38
CONTRIBUTIONS - OTHER AID	9,421,688.88	9,421,688.88
CONTRIBUTION IN AID - SEWER	1,883,509.26	1,883,509.26
INTERFUND TRANSFER (AUDIT)	58,131.56	58,131.56
INTERFUND TRANSFER (AUDIT)	(58,131.56)	(58,131.56)
Total Contributions in Aid of Construction	111,894,520.90	111,894,520.90

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MOUNTAIN WATER DISTRICT
Supporting Schedule - Plant in Service
As of December 31, 2019 and 2018

	2019	2018
Water Supply Plant in Service:		
LAND AND LAND RIGHTS	$ 37,942.57	$ 37,942.57
STRUCTURES AND IMPROVEMENTS	225,154.40	225,154.40
COLLECTING\IMPOUND RESERVOIRS	59,137.31	59,137.31
PUMPING EQUIPMENT	4,360,340.14	4,360,340.14
Total Cost of Water Supply Plant	4,682,574.42	4,682,574.42
Less: Accumulated Depreciation	(2,526,130.67)	(2,455,549.56)
Net Cost of Water Supply Plant	**$ 2,156,443.75**	**$ 2,227,024.86**
Water Treatment Plant in Service:		
LAND AND LAND RIGHTS	$ 2,400.00	$ 2,400.00
STRUCTURES AND IMPROVEMENTS	117,950.34	116,996.68
WATER TREATMENT PLANT	9,665,159.30	9,665,159.30
Total Cost of Water Treatment Plant	9,785,509.64	9,784,555.98
Less: Accumulated Depreciation	(3,172,445.52)	(2,912,412.60)
Net Cost of Water Treatment Plant	**$ 6,613,064.12**	**$ 6,872,143.38**
Water Transmission & Distribution Plant in Service:		
LAND AND LAND RIGHTS	$ 381,193.87	$ 381,193.87
DISTRIBUTION RESERVOIRS/STANDS	9,349,281.20	9,349,281.20
TRANSMISSION/DISTIBUTION MAINS	71,445,827.94	71,445,827.94
WATER SERVICES	6,742,859.65	6,682,796.26
WATER METERS & INSTALLATIONS	4,533,938.38	4,702,327.24
HYDRANTS	1,241,667.66	1,241,667.66
Total Cost of Water Transmission & Distribution Plant	93,694,768.70	93,803,094.17
Less: Accumulated Depreciation	(44,694,254.93)	(42,472,398.72)
Net Cost of Water Trans. & Dist. Plant	**$ 49,000,513.77**	**$ 51,330,695.45**
Water General Plant in Service:		
LAND AND LAND RIGHTS	$ 145,618.68	$ 145,618.68
STRUCTURES AND IMPROVEMENTS	351,050.19	351,050.19
OFFICE FURNITURE & EQUIPMENT	199,651.86	186,917.16
TRANSPORTATION EQUIPMENT	1,278,760.29	1,202,378.29
TOOLS, SHOP & GARAGE EQUIPMENT	302,122.28	298,611.32
LABORATORY EQUIPMENT	1,485.57	1,485.57
POWER OPERATED EQUIPMENT	311,598.37	267,038.37
COMMUNICATION EQUIPMENT	1,874,194.78	1,874,194.78
Total Cost of Water General Plant	4,464,482.02	4,327,294.36
Less: Accumulated Depreciation	(3,333,809.44)	(3,126,092.48)
Net Cost of Water General Plant	**$ 1,130,672.58**	**$ 1,201,201.88**
Sewer Plant in Service:		
STRUCTURES AND IMPROVEMENTS	$ 1,495.00	$ 1,495.00
COLLECTION SEWERS	25,584,226.70	25,584,226.70
PUMPING EQUIPMENT	26,000.00	26,000.00
TREATMENT AND DISPOSAL EQUIP.	6,105,075.48	6,105,075.48
SEWER SERVICES	378,975.48	362,570.85
SEWER METERS & INSTALLATIONS	411,811.67	177,666.87
OFFICE FURNITURE & EQUIPMENT	54,506.70	54,506.70
TRANSPORTATION EQUIPMENT	13,449.54	12,579.54
TOOLS & MISC. EQUIPMENT	122,142.32	122,142.32
Total Cost of Sewer Plant	32,697,682.89	32,446,263.46
Less: Accumulated Depreciation	(12,273,561.82)	(11,155,468.78)
Net Cost of Sewer Plant	**$ 20,424,121.07**	**$ 21,290,794.68**

No assurance is provided on these financial statements. Management has elected to omit substantially all disclosures required by accounting principles generally accepted in the United States of America.

MOUNTAIN WATER DISTRICT
Supporting Schedule - Plant in Service
As of December 31, 2019 and 2018

Construction in Progress:		
CONSTRUCTION IN PROGRESS	$ 2,732,001.64	$ 128,728.59
CIP-MATERIALS & SUPPLIES	441,377.61	0.00
RATE CASE EXPENSE IN PROGRESS	172,021.49	172,021.49
CONSTRUCTION IN PROGRESS	6,739,102.72	4,946,639.60
Total Construction in Progress	10,084,503.46	5,247,389.68
Less: Accumulated Depreciation	(172,021.49)	(172,021.49)
Net Construction in Progress	**$ 9,912,481.97**	**$ 5,075,368.19**
Total Plant in Service	**$ 89,237,297.26**	**$ 87,997,228.44**

No assurance is provided on these financial statements. Management has elected to omit substantially all disclosures required by accounting principles generally accepted in the United States of America.

MOUNTAIN WATER DISTRICT
Schedule of Operating Expenses

	1 Month Ended December 31, 2019	12 Months Ended December 31, 2019
Water Supply Expense:		
WATER TREATMENT LABOR - OPERATIONS	4,746.81	92,403.75
HEALTH INSURANCE - PUMPING OPERATIONS	0.00	19,692.76
HEALTH INSURANCE - WTP OPERATIONS	498.76	12,839.58
DENTAL INSURANCE - WTP OPERATIONS	79.04	1,050.91
VISION INSURANCE - PUMPING OPER.	0.00	12.40
VISION INSURANCE - WTP OPER.	(5.72)	19.41
LIFE INSURANCE - WTP OPER.	73.26	756.34
SHORT TERM DISAB. - WTP OPER.	18.55	84.81
UNIFORM EXPENSE (PLANT)	0.00	365.05
Total Water Supply Expenses	5,410.70	127,225.01
Water Purchases:		
Water Purchased -Williamson	38,522.23	467,376.91
WATER PURCHASED -PIKEVILLE	82,864.40	759,052.32
Total Water Purchases Expenses	121,386.63	1,226,429.23
Electricity Expense:		
Electrical Expense	117,767.89	1,329,805.15
Total Electricity Expenses	117,767.89	1,329,805.15
Repairs & Maintenance - Sewer Expense:		
Major Equipment R & M Sewer	26.97	388.02
Hnad Tools R & M Sewer	0.00	1,362.17
PS/LS R & M Sewer	11,706.64	81,795.91
Vehicle R & M Sewer	0.00	167.38
General R & M Sewer	475.34	14,205.06
Total Repairs & Maint. - Sewer Expenses	12,208.95	97,918.54
Repairs & Maintenance - Water Expense:		
Major Equipment R & M	366.74	24,304.88
Hand Tools R & M	1,333.01	21,947.82
PS/LS R & M	1,693.91	96,013.29
Vehicle R & M	2,761.20	60,823.43
General R & M	36,808.30	311,731.34
General R & M -Telemetry	0.00	25,121.26
Total Repairs & Maint. - Water Expenses	42,963.16	539,942.02
Transmission & Distribution Expense:		
T & D LABOR - OPERATIONS	72,249.49	950,745.93
T & D LABOR - MAINTENANCE	7,022.25	133,059.46
HEALTH INSURANCE - T & D OPERATIONS	13,487.62	169,909.26
HEALTH INSURANCE - T & D MAINTENANCE	0.00	51.49
DENTAL INSURANCE - T & D OPERATIONS	496.60	5,808.71
VISION INSURANCE - T & D OPER.	(153.60)	320.73
VISION INSURANCE - T & D MAINT.	0.00	(5.59)
LIFE INSURANCE - T & D OPER.	(140.56)	(1,330.71)

No assurance is provided on these financial statements. Management has elected to omit substantially all disclosures required by accounting principles generally accepted in the United States of America.

ATTACHMENT N
PRODUCTION COST

COST TO PRODUCE
844,514,772 GALLONS OF WATER
IN 2019

844,514,772 GAL

÷ 1,000 GAL

844,514.772 GAL

X 1.17 (AVG COST TO PRODUCE 1,000 GALS IN 2019)

$988,082.28

WATER PRODUCTION/WHOLESALE PURCHASE REPORT
2019

WATER PROD & PURCHASED	***JAN***	***FEB***	***MAR***	***APR***	***MAY***	***JUN***	***JUL***	***AUG***	***SEP***	***OCT***	***NOV***	***DEC***	***YTD TOTALS***
WATER PLANT PRODUCTION	78,859,000	59,462,000	74,683,000	71,336,000	75,119,000	67,172,000	70,927,000	73,485,000	72,735,000	76,428,000	76,521,000	72,549,000	869,276,000
BACKWASH (GALLONS)	356,595	356,595	1,737,404	1,737,404	2,732,007	2,430,304	2,424,968	2,221,864	2,496,736	2,582,544	2,729,248	3,293,920	25,099,589
AVERAGE DAILY PRODUCTION	2,543,839	1,918,129	2,409,129	2,301,161	2,423,194	2,166,839	2,287,968	2,370,484	2,346,290	2,465,419	2,550,700	2,418,300	2,350,121
MINIMUM DAILY PRODUCTION	2,187,000	360,000	2,115,000	1,735,000	1,600,000	0,000	874,000	1,935,000	2,169,000	1,635,000	2,359,000	831,000	1,483,333
MAXIMUM DAILY PRODUCTION	2,738,000	2,808,000	2,579,000	2,610,000	2,785,000	2,683,000	2,626,000	2,598,000	2,599,000	2,592,000	2,806,000	2,711,000	2,677,917
TOTAL PRODUCTION	78,502,405	59,105,405	72,945,596	69,598,596	72,386,993	64,741,696	68,502,032	71,263,136	70,238,264	73,845,456	73,791,752	69,255,080	844,176,411
TOTAL PURCHASED	64,647,997	68,378,200	55,370,000	55,157,300	62,991,100	54,192,500	65,085,900	65,588,000	64,251,000	61,616,000	57,078,400	64,079,700	738,436,097
TOTAL PURCHASED & PRODUCED	143,150,402	127,483,605	128,315,596	124,755,896	135,378,093	118,934,196	133,587,932	136,851,136	134,489,264	135,461,456	130,870,152	133,334,780	1,582,612,508
COST OF PURCHASED WATER/1,000 GAL.	$ 1.68	$ 1.68	$ 1.68	$ 1.68	$ 1.68	$ 1.68	$ 1.68	$ 1.68	$ 2.30	$ 2.30	$ 2.30	$ 2.30	
COST OF PRODUCED WATER/1,000 GAL.	$ 0.88	$ 1.41	$ 1.08	$ 1.90	$ 1.14	$ 1.40	$ 1.15	$ 1.36	$ 0.96	$ 0.97	$ 0.88	$ 0.94	$ 1.17

MARROWBONE WATER PLANT:

TURBIDITY (NTU):	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	***YTD AVERAGES***
AVERAGE DAILY TURBIDITY	0.10	0.11	0.12	0.10	0.10	0.16	0.17	0.14	0.13	0.13	0.13	0.13	0.13
MINIMUM DAILY TURBIDITY	0.05	0.00	0.06	0.00	0.06	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.03
MAXIMUM DAILY TURBIDITY	0.42	0.29	0.23	0.32	0.24	0.58	0.35	0.23	0.19	0.28	0.24	0.30	0.31
CHLORINE: **(FREE RESIDUAL IN MG/L)**													
AVERAGE DAILY RESIDUAL	1.8	2.0	1.7	1.6	2.0	1.8	1.9	1.9	1.9	1.8	1.9	1.8	1.9
MINIMUM DAILY RESIDUAL	1.6	1.6	1.5	1.2	1.6	1.5	1.6	1.6	1.6	1.4	1.7	1.2	1.5
MAXIMUM DAILY RESIDUAL	2.5	2.8	2.1	2.4	2.5	2.3	2.8	2.2	2.1	2.4	2.3	2.4	2.4
FLUORIDE (MG/L):													
AVERAGE DAILY RESIDUAL	0.9	1.0	0.3	0.3	0.4	0.4	0.7	0.7	0.7	0.5	0.5	0.5	0.6
MINIMUM DAILY RESIDUAL	0.8	0.8	0.2	0.2	0.3	0.3	0.6	0.5	0.5	0.4	0.3	0.4	0.4
MAXIMUM DAILY RESIDUAL	1.1	1.1	0.5	0.5	0.6	0.7	0.9	1.0	1.1	0.5	0.5	0.8	0.8
PH (ACIDITY):													
AVERAGE PH	7.0	7.7	7.9	8.0	7.9	7.5	8.0	8.1	8.1	8.2	8.3	8.0	7.9
MINIMUM PH	7.5	7.5	7.7	7.5	7.5	7.8	7.7	7.5	8.0	8.0	8.0	7.7	7.7
MAXIMUM PH	7.9	7.9	8.1	8.1	8.1	8.3	8.1	8.3	8.3	8.4	8.4	8.3	8.2
BACTERIOLOGICAL SAMPLES TESTED	52	52	52	52	52	52	52	52	52	52	52	52	624
EXCURSION OF PARAMETERS	NONE FOR THE PERIOD	NONE FOR THE PERIOD	NONE FOR THE PERIOD	NONE FOR THE PERIOD	NONE FOR THE PERIOD	NONE FOR THE PERIOD	NONE FOR THE PERIOD	NONE FOR THE PERIOD	NONE FOR THE PERIOD	NONE FOR THE PERIOD	NONE FOR THE PERIOD	NONE FOR THE PERIOD	

* UPDATED COST OF ELECTRICITY - MAY 2016