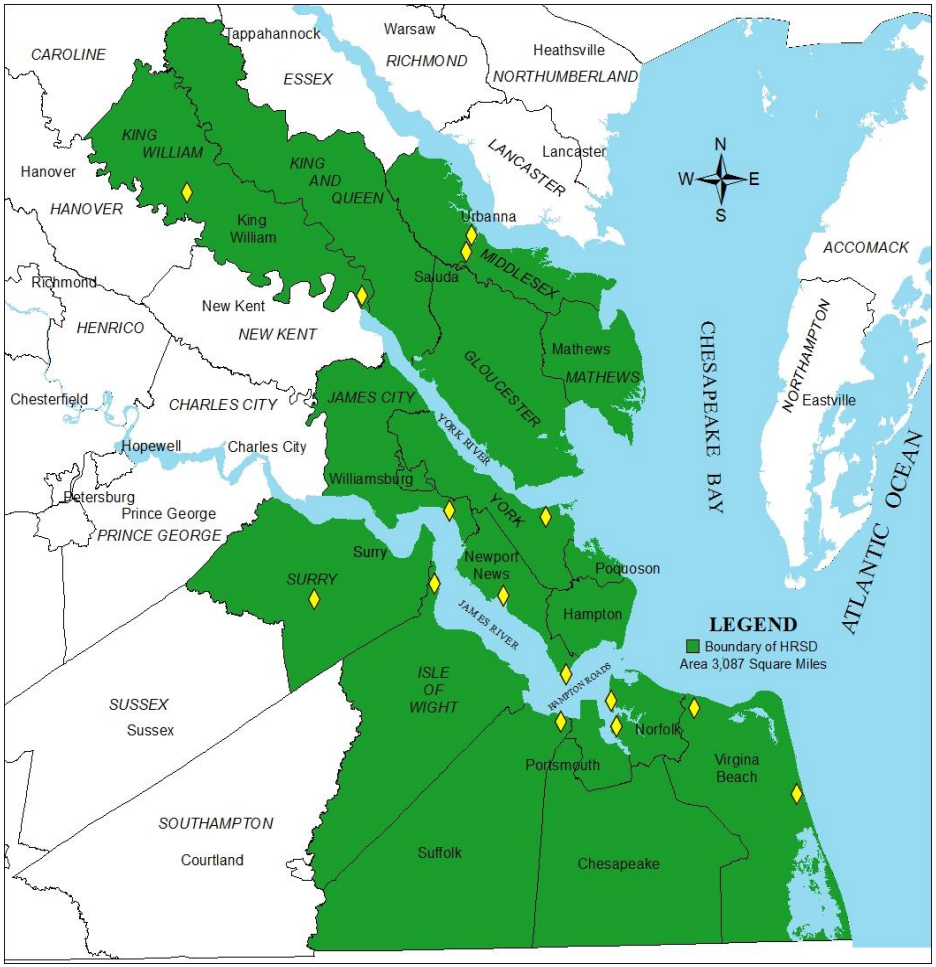
HRSD's Vision for Managed Aquifer Recharge in Eastern Virginia

Sustainable Water Initiative for Tomorrow

Charles B. Bott, PhD, PE, BCEE

Director of Water Technology and Research

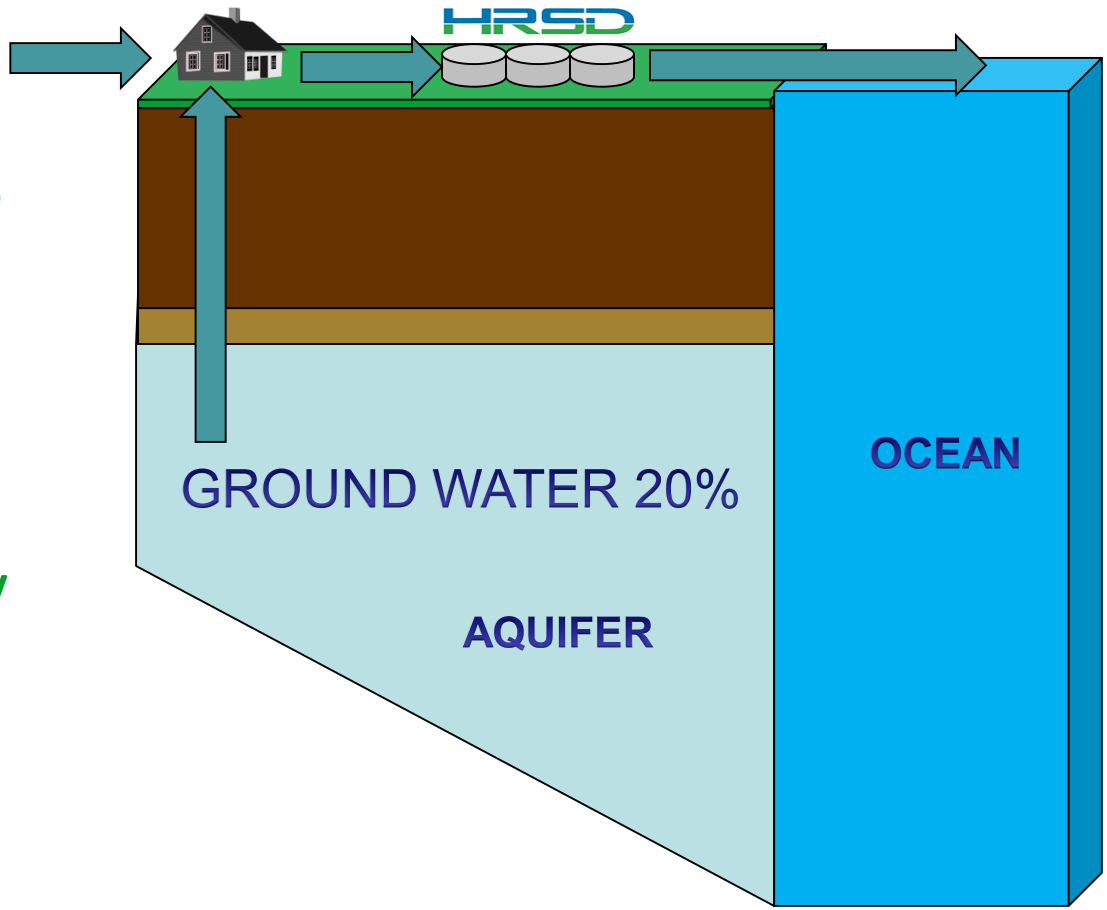
Who/What is HRSD?



- Provide wastewater treatment for 18 localities (250 mgd treatment capacity)
- Serve 1.7 million people (20% of all Virginians)
- Independent political subdivision with Governor appointed Commission

Current state of wastewater in Hampton Roads

SURFACE WATER 80%



HRSD costs are rising to treat water to higher standards.

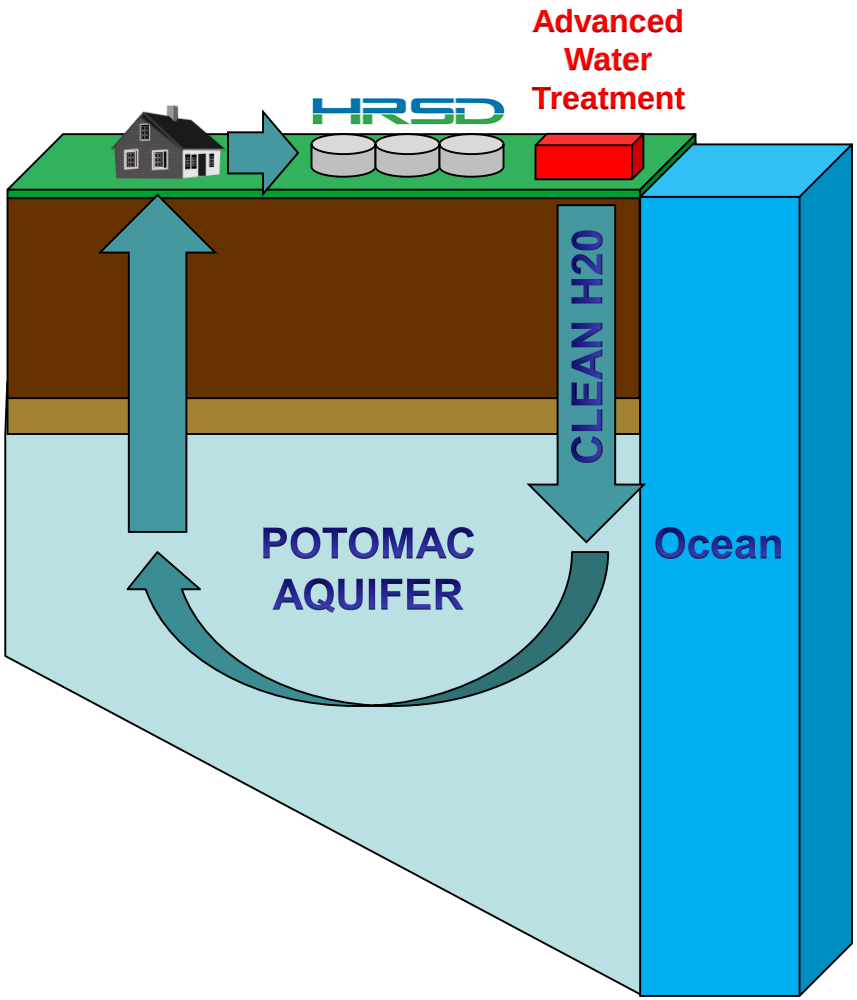
Treated water currently discharged to area waterways – no beneficial use.

The Challenges/Opportunities for HRSD

- ~$750M in Nutrient Removal Upgrades by 2021
- ~$2.2B in Consent Decreed Mandated Upgrades to Reduce Sanitary Sewer Overflows over 20 years
- Very large managed aquifer recharge effort pending
  - Indirect potable reuse?
  - ~120 MGD
  - ~$1B

SWIFT – Sustainable Water Initiative for Tomorrow

- Treat water to meet drinking water standards and replenish the aquifer with clean water to:
  - Provide regulatory stability for wastewater treatment
  - Reduce nutrient discharges to the Bay
  - Reduce the rate of land subsidence
  - Provide a sustainable supply of groundwater
  - Protect the groundwater from saltwater contamination



Hydrogeologic Section: Coastal Plain of Virginia

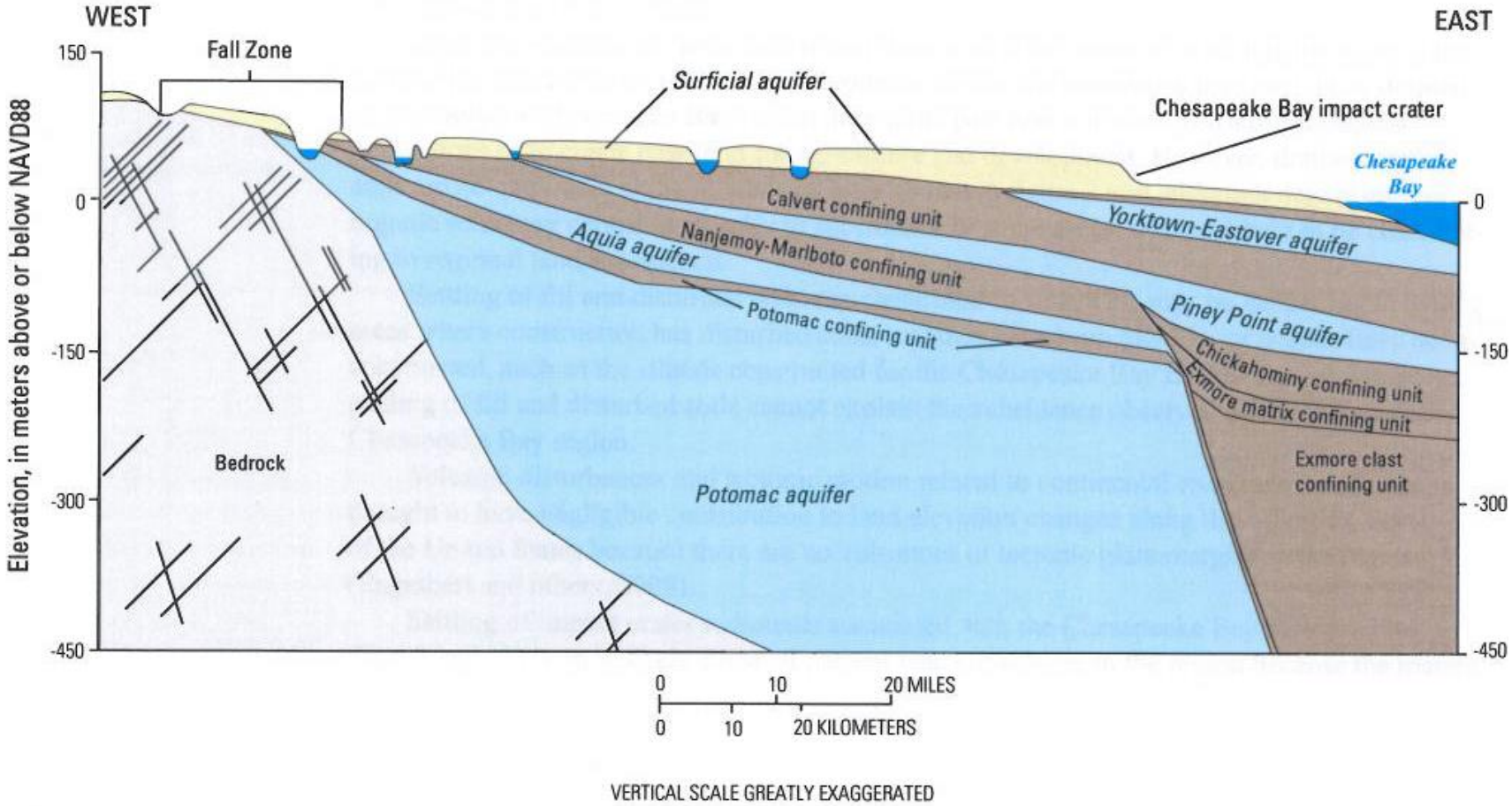
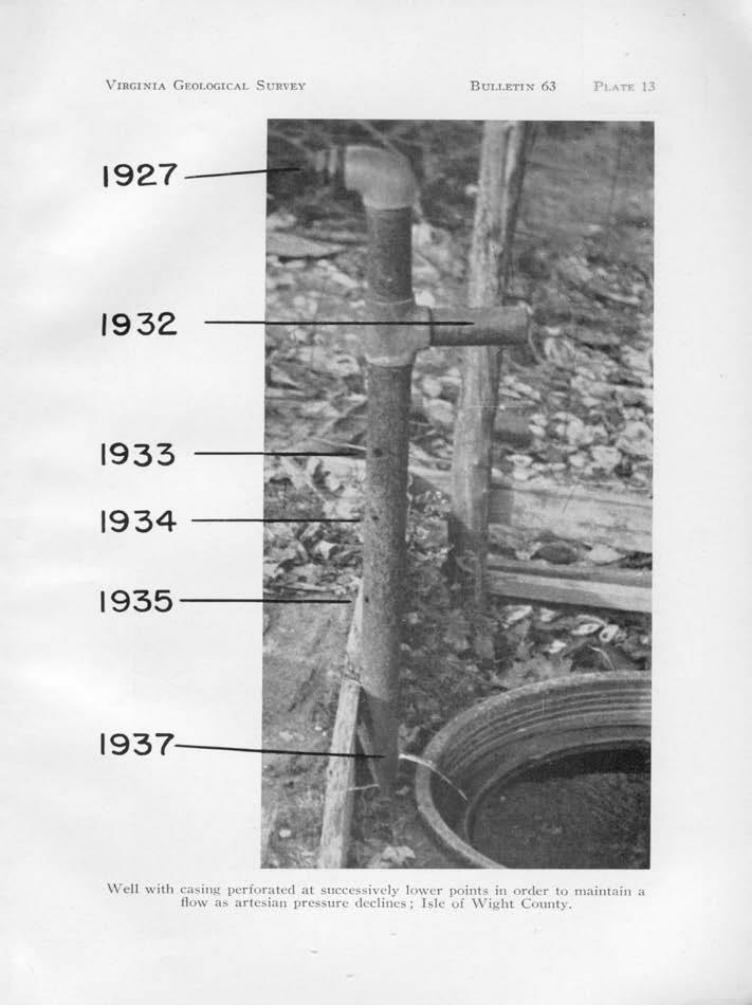


Figure 11. Section illustrating layering in the Virginia Coastal Plain aquifer system from west to east. Elevation relative to North American Vertical Datum of 1988 (NAVD88). Modified from McFarland and Bruce (2006).

Groundwater depletion has been rapid

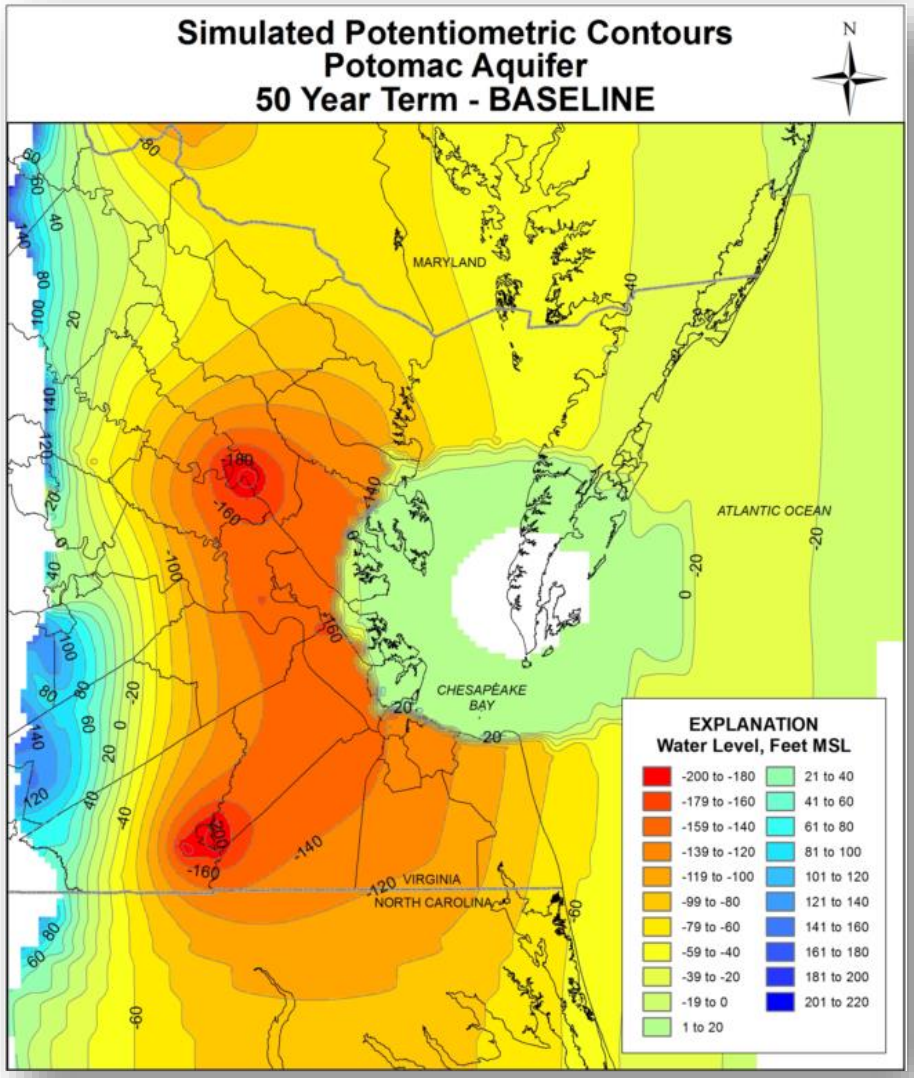
A, Overflow from artesian well in Isle of Wight County is wasted.

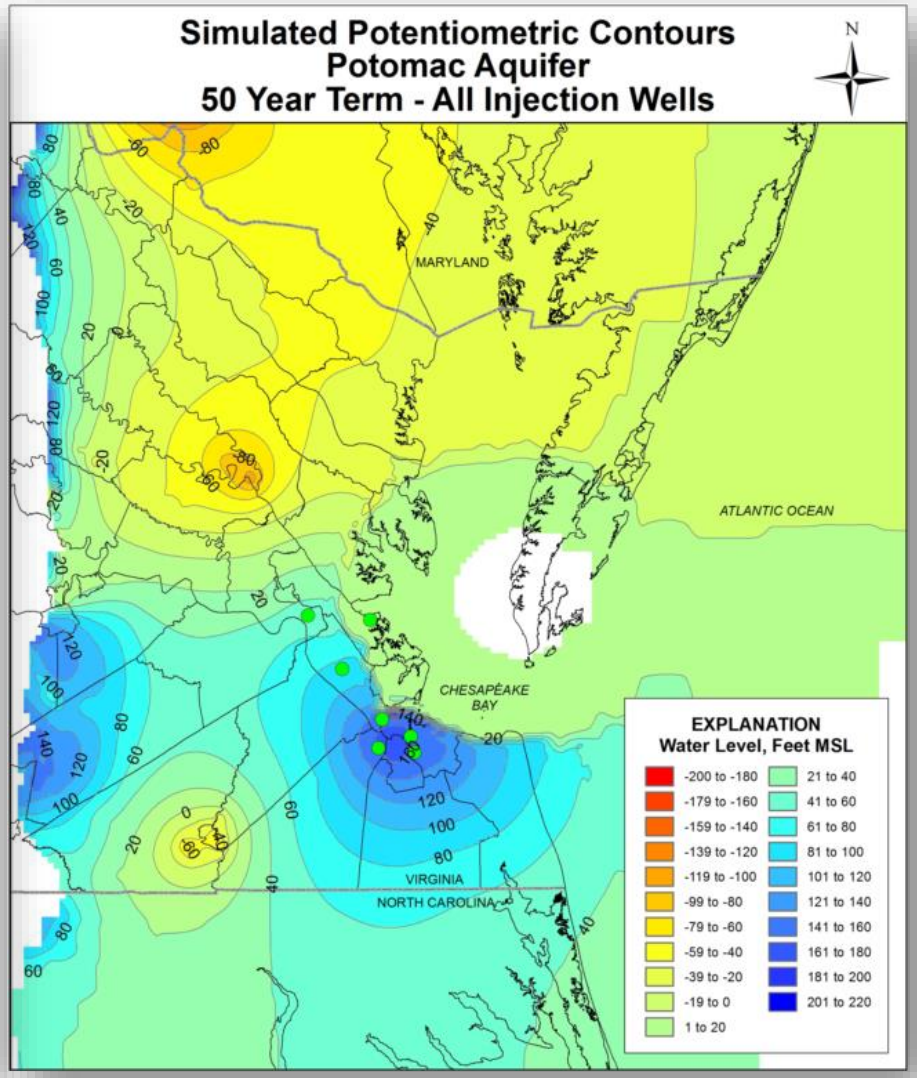


Well with casing perforated at successively lower points in order to maintain a flow as artesian pressure declines; Isle of Wight County.

- Artesian wells in early 1900s – groundwater wells required valves not pumps!
- In about 100 years have gone from water levels at 31 feet above sea level to 200± feet below.

Modeled Potomac Aquifer water levels with and without SWIFT

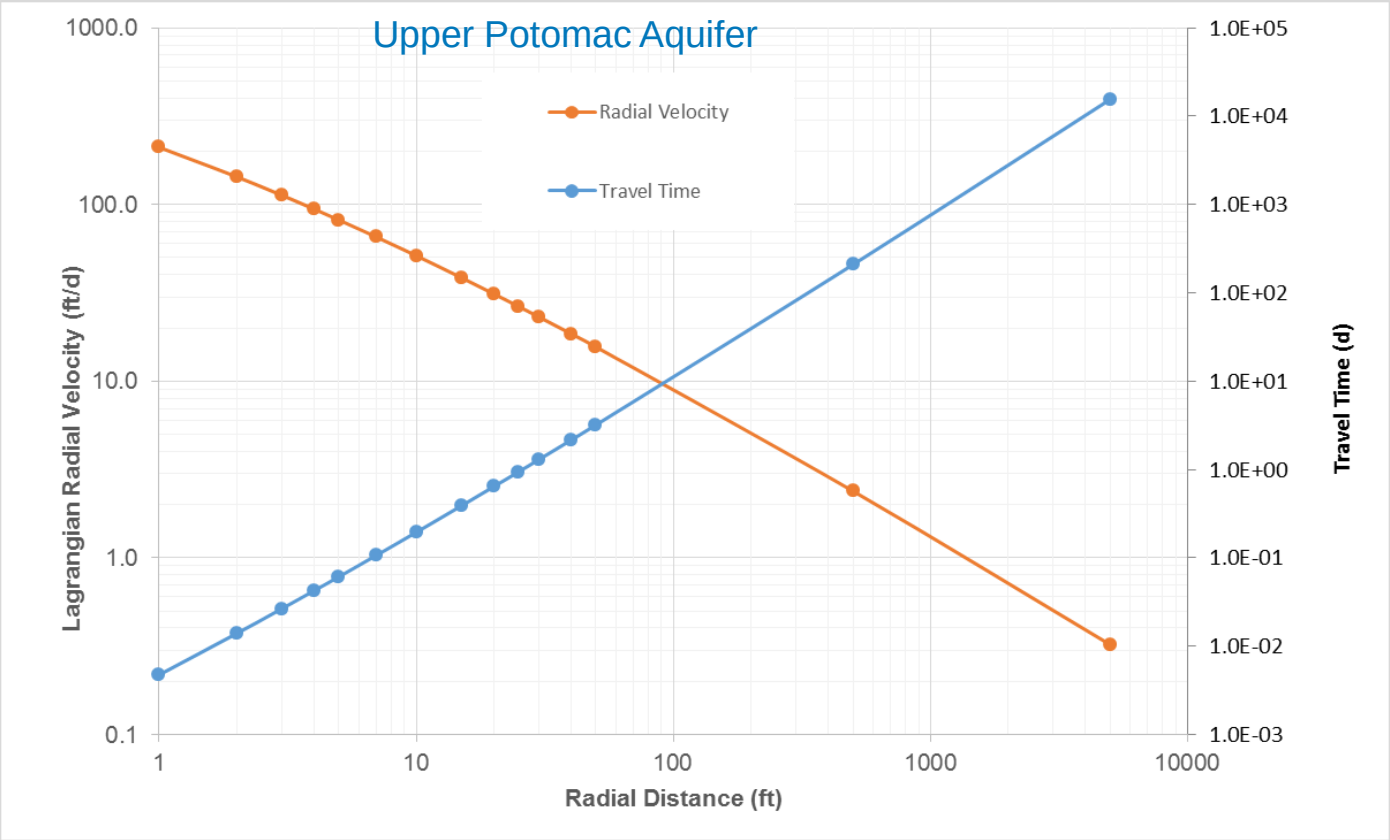




What is the travel time of the injected water?

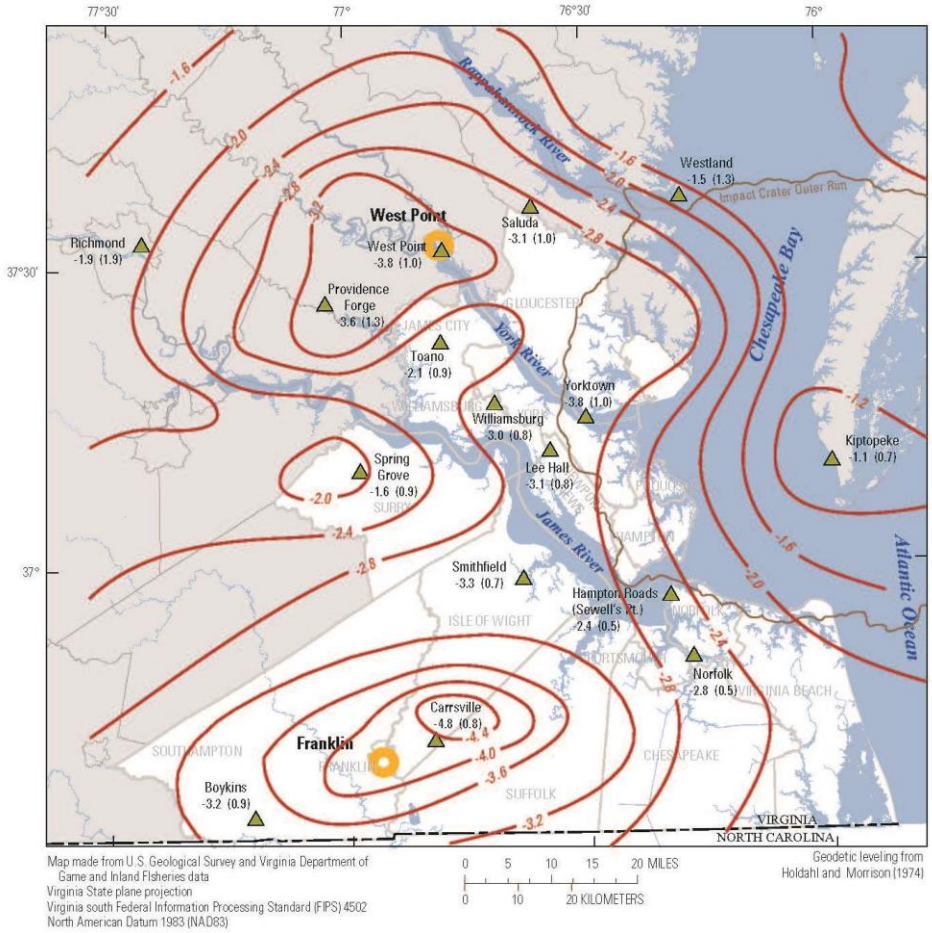
Approximately <u>180 years to travel one mile</u>

- Recharge water velocity decelerates rapidly as it moves from the injection site
- Model predictions range from 3 to 29 feet/year
- Data from the SWIFT Research Center ➔ refinement of recharge velocities and travel times



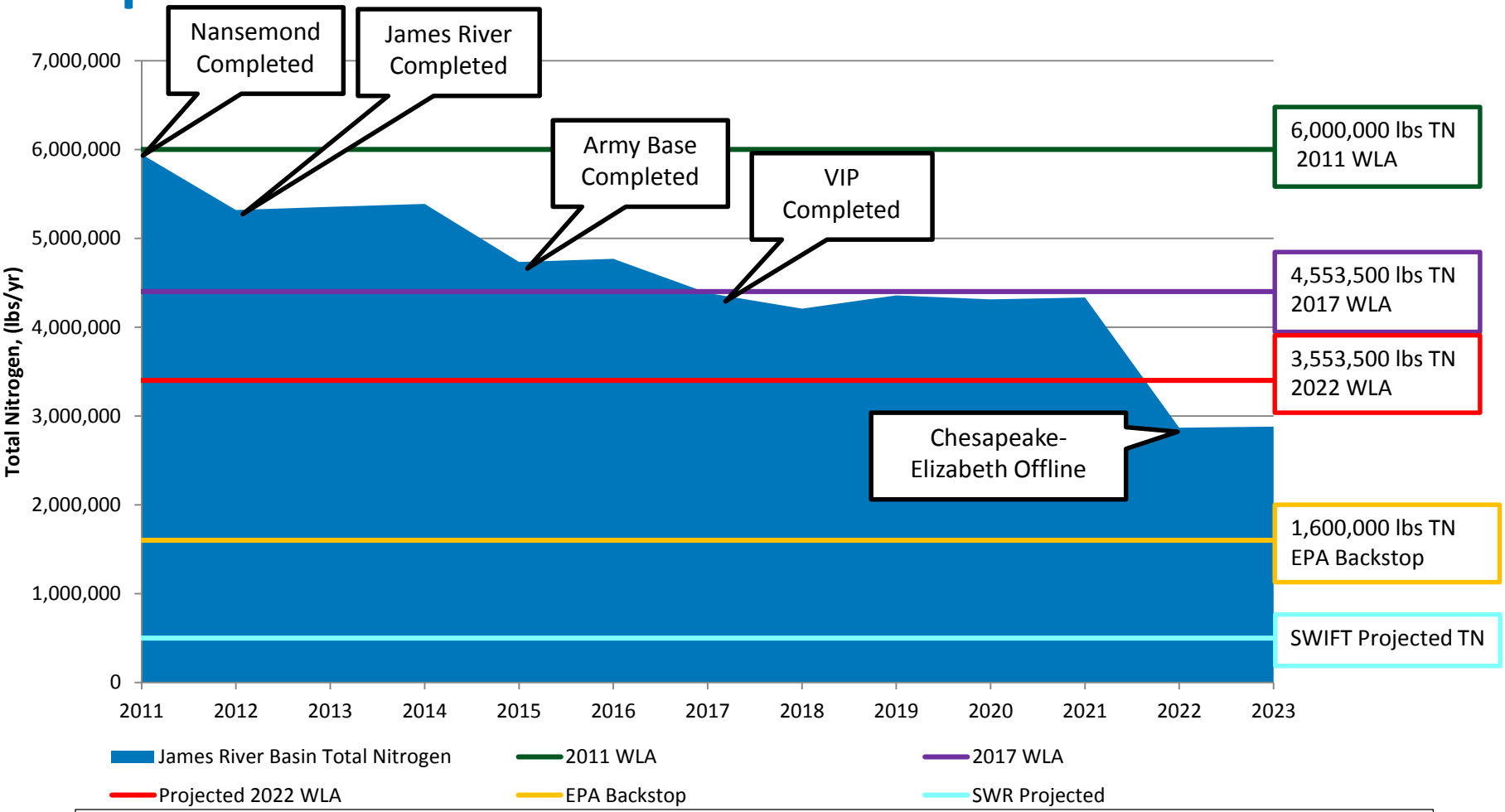
Land subsidence – *we are sinking*

- According to USGS
  - Up to 50% of relative sea-level rise may be due to land subsidence
  - **Up to 50% of land subsidence may be due to aquifer compaction**



HAMPTON ROADS IS THE #2 LARGEST POPULATION CENTER AT RISK

Impact on nutrient reductions



James River Basin – TN Similar results with TP and TSS and in other river basins.

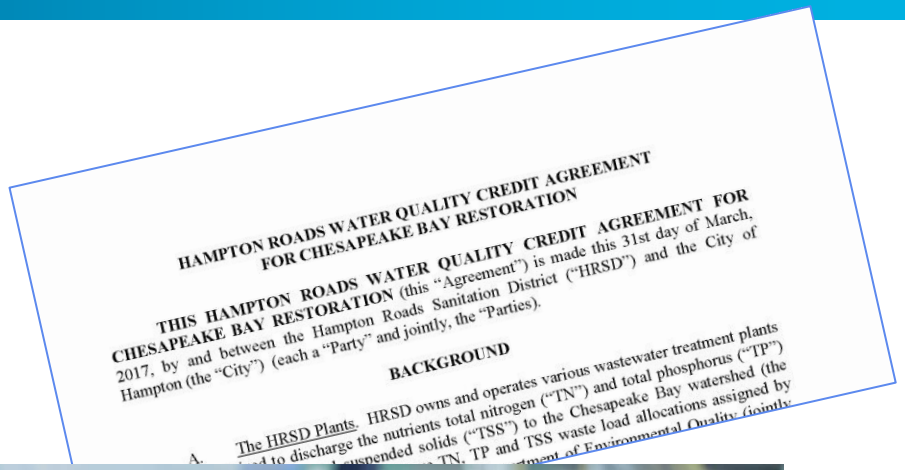
WLA – Nutrient Waste Load Allocation in lbs/yr

Potential to offset stormwater reductions

	Approximate total credits due to SWIFT	Regional Stormwater Reduction Needs*
Nitrogen		
James	2,900,000	63,039
York	250,000	19,114
Phosphorus		
James	250,000	13,088
York	16,000	3,887

* DEQ Regulated Stormwater w/o federal lands

Executed nutrient trading agreements with 11 localities



HAMPTON ROADS WATER QUALITY CREDIT AGREEMENT
FOR CHESAPEAKE BAY RESTORATION

THIS HAMPTON ROADS WATER QUALITY CREDIT AGREEMENT FOR CHESAPEAKE BAY RESTORATION (this "Agreement") is made this 31st day of March, 2017, by and between the Hampton Roads Sanitation District ("HRSD") and the City of Hampton (the "City") (each a "Party" and jointly, the "Parties).

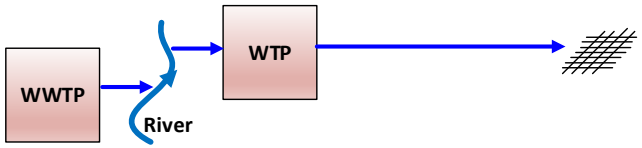
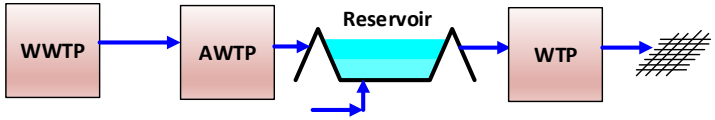
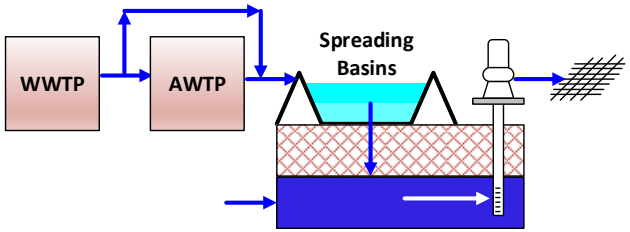
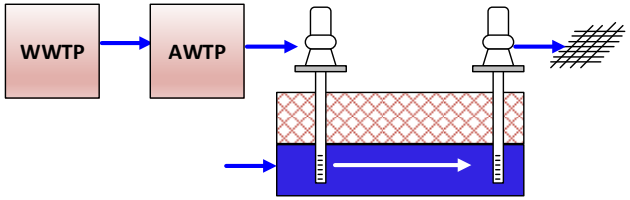
BACKGROUND

A. The HRSD Plants. HRSD owns and operates various wastewater treatment plants

The Challenges/Opportunities for HRSD

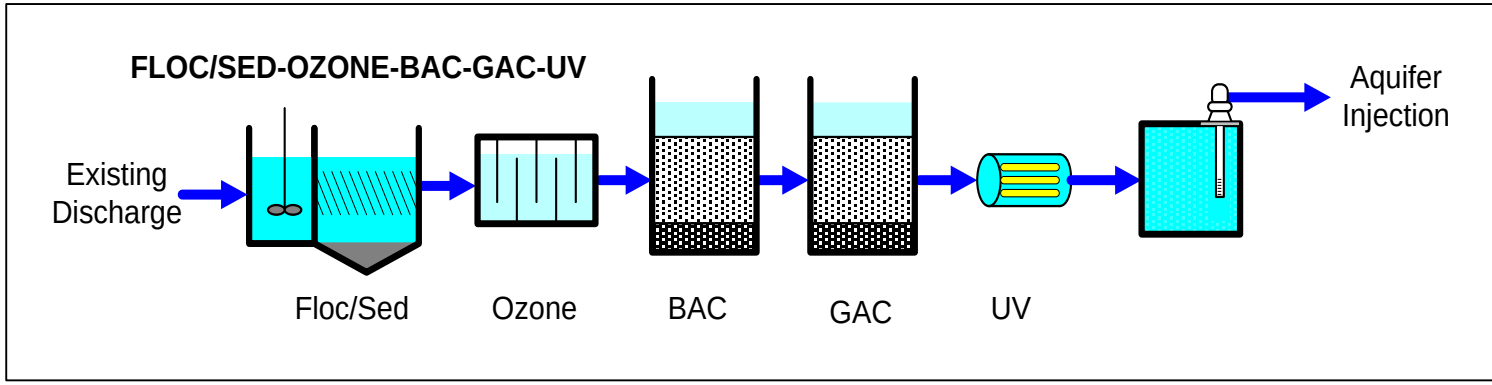
- ~$750M in Nutrient Removal Upgrades by 2021
- ~$2.2B in Consent Decreed Mandated Upgrades to Reduce Sanitary Sewer Overflow
  - **RWWMP in the form of an Integrated Plan, October 2017**
- Very large managed aquifer recharge effort pending
  - Indirect potable reuse?
  - ~120 MGD
  - ~$1B **(<u>over 10 years</u>)**

Water Supply Augmentation Approaches (Indirect Potable Reuse)

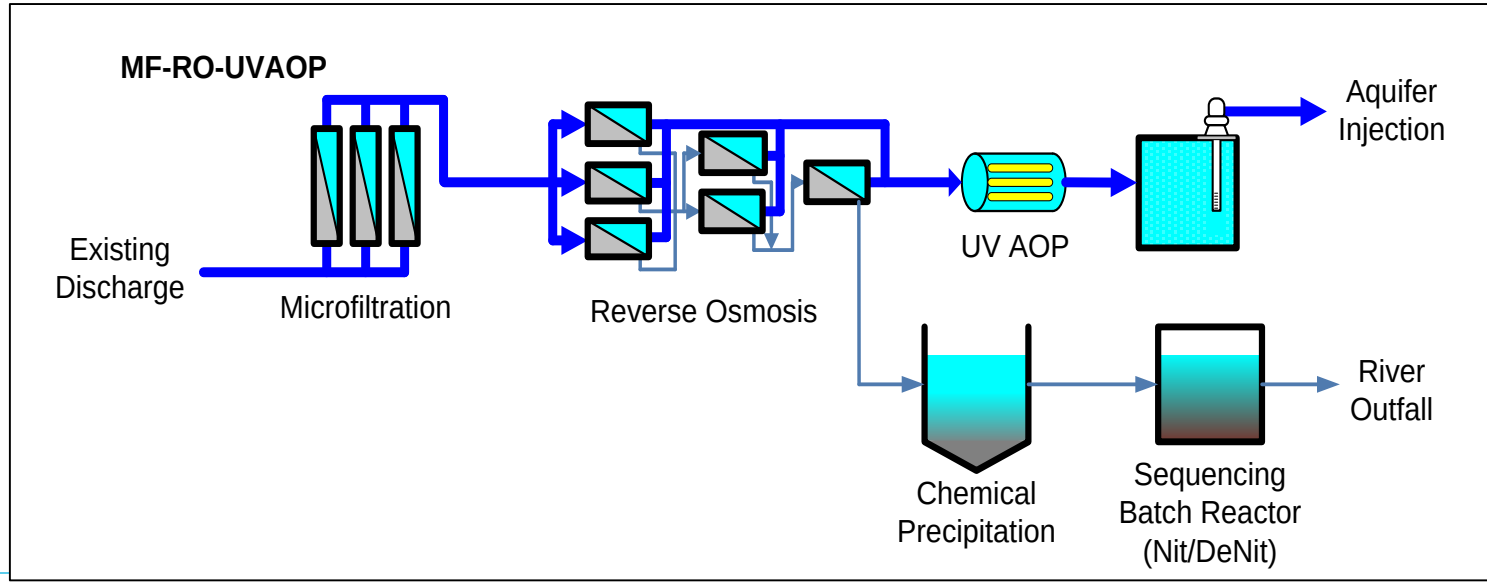
Indirect Potable Reuse Approaches	Examples
De Facto 	Common throughout the world (e.g., Mississippi River, Colorado River, etc…)
Surface Water Augmentation 	Upper Occoquan Service Authority (Northern Virginia); Gwinnett County (Georgia); Singapore NEWater
GW Recharge via Spreading Basins 	Montebello Forebay (Los Angeles, CA); El Paso (Texas); Chino Basin (Chico, CA)
GW Recharge via Direct Injection 	GWRS (Orange County, CA); West Basin (CA); Los Alamitos (Long Beach, CA); Scottsdale Water Campus (AZ)

Advanced water treatment alternatives

Carbon Based



Membrane Based



Typical Approach to Developing Finished Water Goals for Groundwater Recharge

- Meet all primary Maximum Contaminant Levels (MCLs) regulated by the USEPA in the SDWA
- Provide multiple barriers to pathogens and organics (including chemicals)
- Aquifer compatibility
- Hazard Analysis and Critical Control Points
  - Action level exceedance will prevent water from entering the recharge well

The SWIFT Pilot

VIRGINIA TECH

OLD DOMINION UNIVERSITY

Membrane-Based Pilot

Carbon-Based Pilot

Soil Columns to evaluate Soil Aquifer Treatment

SWIFT Pilot Testing Results

- Both trains meet drinking water quality standards
- All primary MCLs (regulated) are being met
- All secondary MCLs are being met, except in the Carbon-based AWT system:
  - TDS (salt) is slightly above 500 mg/L (50%/95% = 523/550 mg/L)
  - Sulfate and chloride are consistently less than 250 mg/L

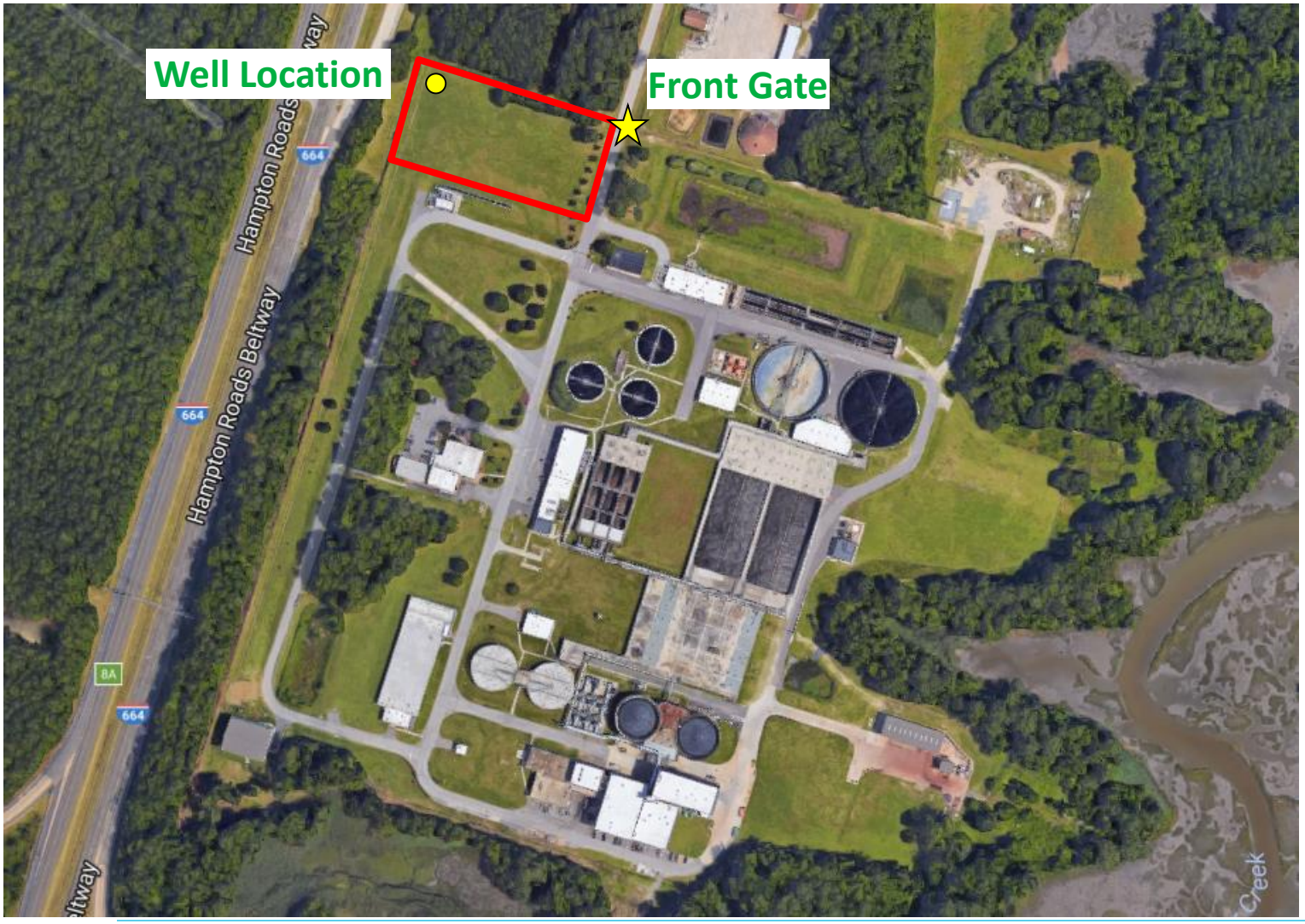
- Topics:
  - Pathogen removal
  - TOC
  - Emerging contaminants
  - Bromate, 1,4-dioxane, NDMA

Aquifer Compatibility: inject similar water quality to that in the aquifer:

- Ionic strength/TDS - Prevent swelling, repulsion, and migration of clay mineral fragments
  - Within ½-order of magnitude of aquifer (TDS ~ 1,400 – 4,800 mg/L)
  - Major ions should match to prevent clay ion exchange
    - Calcium (~30 mg/L) and sodium (~1,000 mg/L)
- EPA secondary MCL for TDS = 500 mg/L
- Pilot values for Carbon-based AWT:
  - 50th Percentile: 541 mg/L
  - 99th Percentile : 635 mg/L
- Recommendation:
  - Given high ionic strength of aquifer, aquifer compatibility should take precedence over finished water TDS limit
  - No specific TDS limit; targets will be created for compatibility

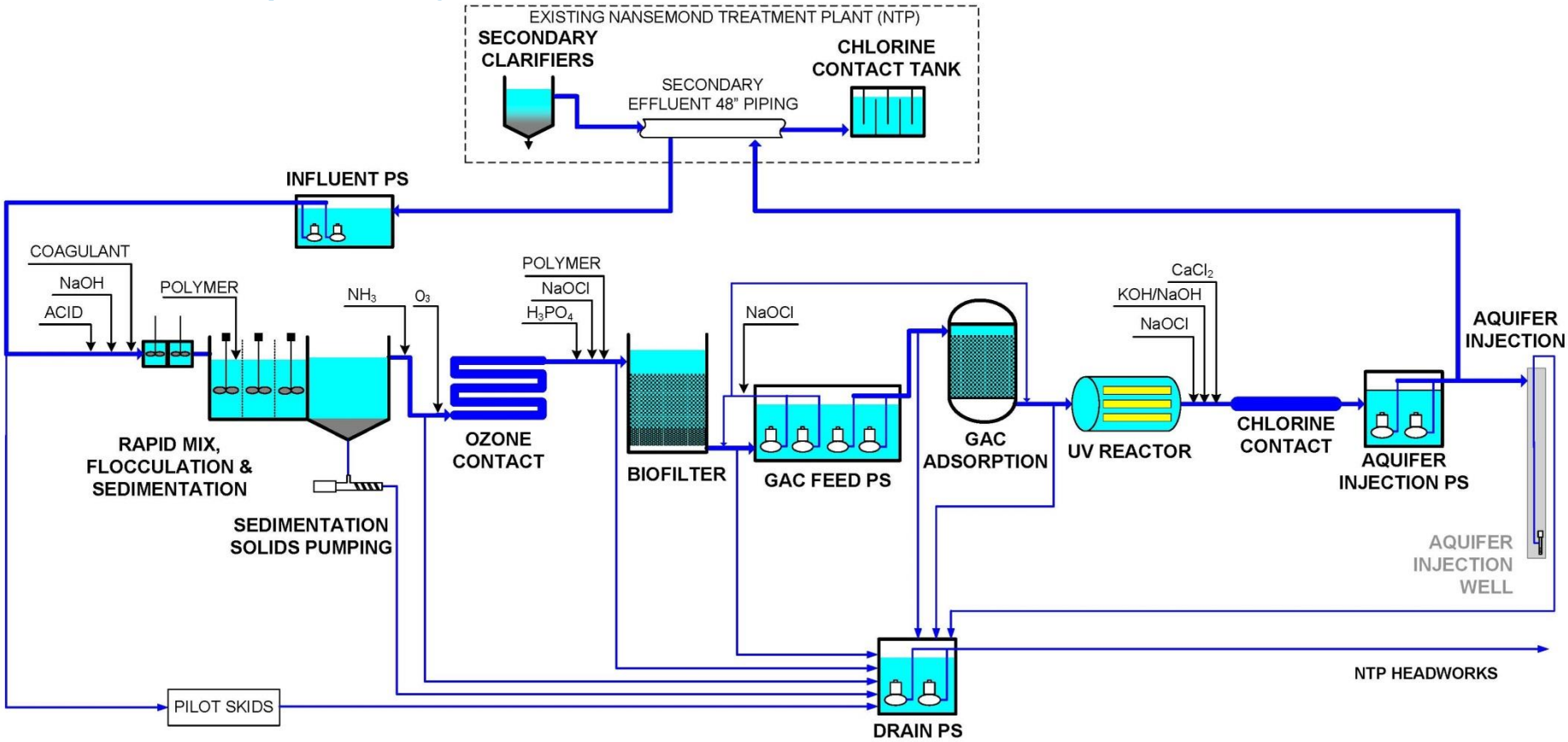
SWIFT Research Center
(1 MGD AWT + recharge well + monitoring wells)

Location of facility within Nansemond TP site



Process Flow Diagram for SWIFT Research Center

- Carbon treatment process selected to ensure aquifer compatibility



SWIFT Research Center
(1 MGD AWT + recharge well + monitoring wells)

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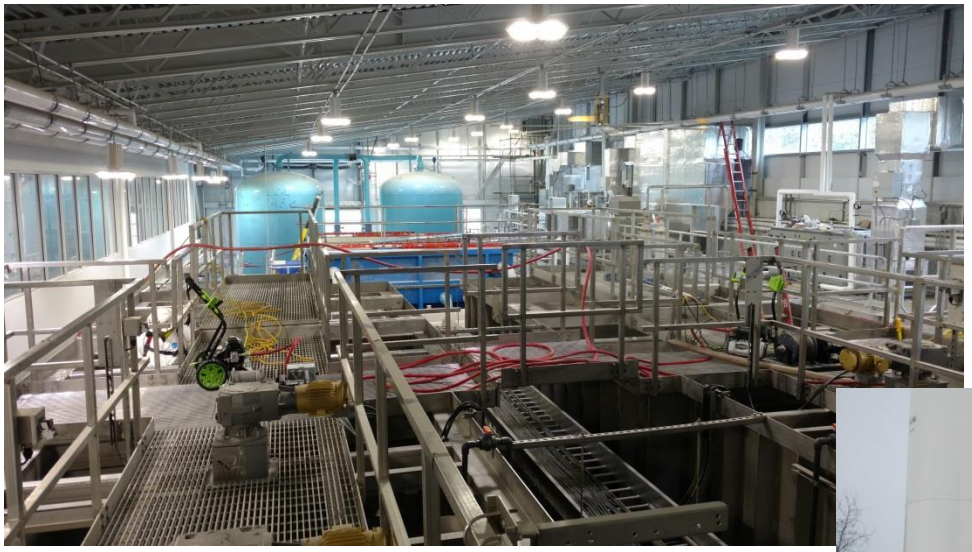
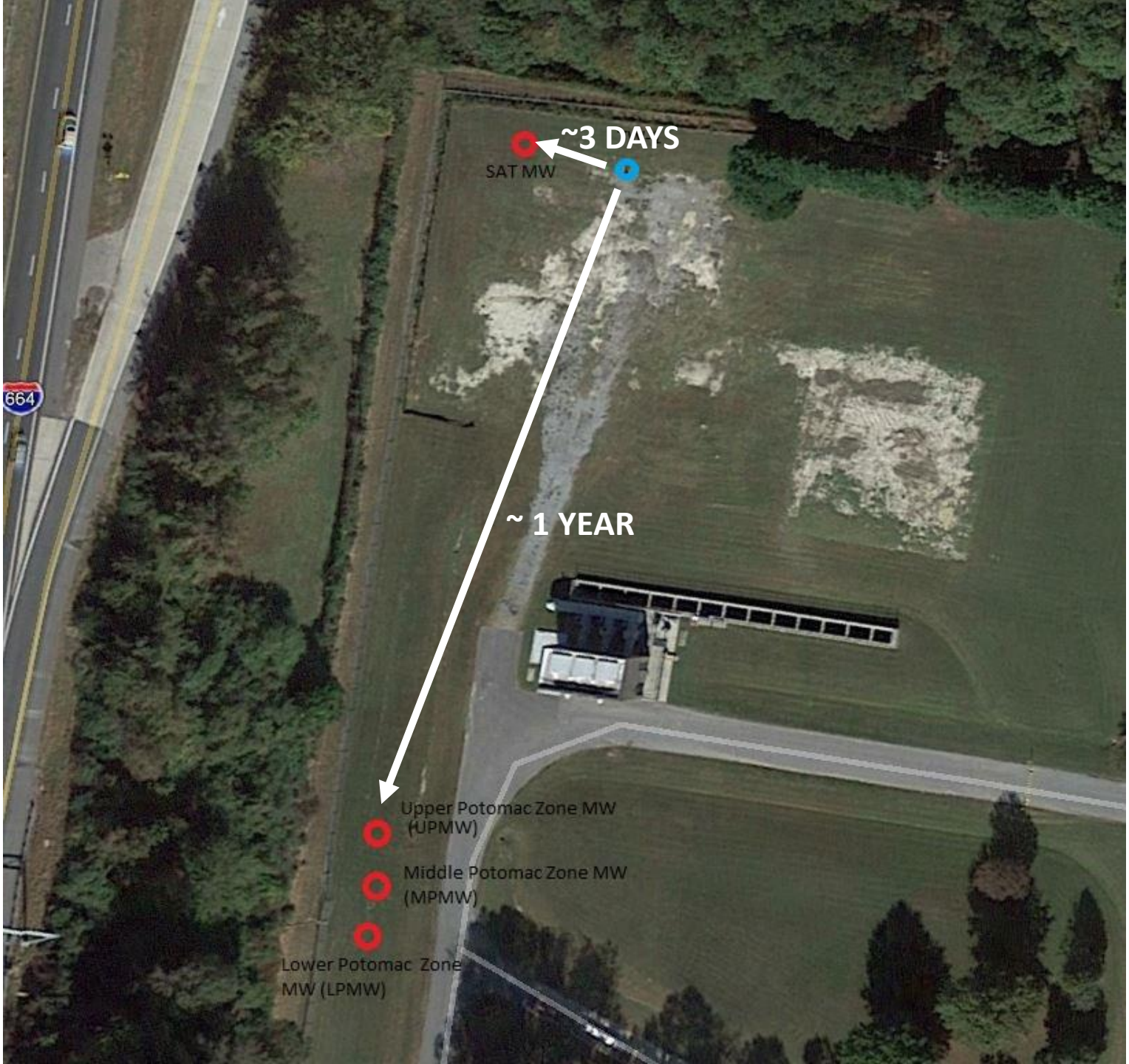
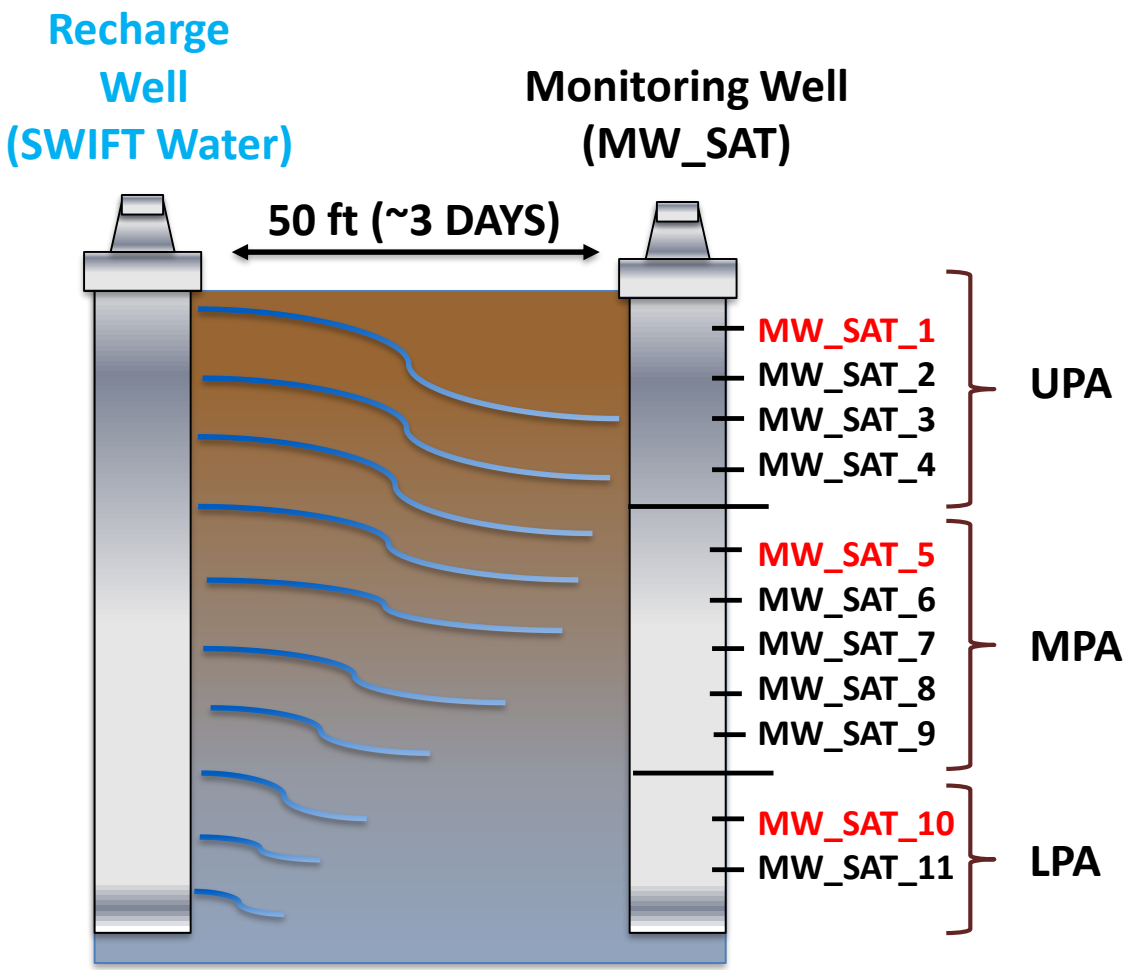
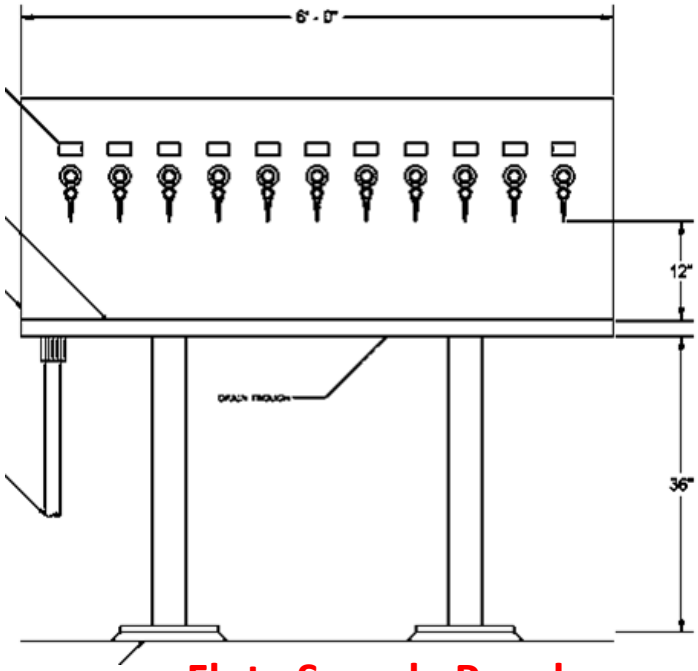


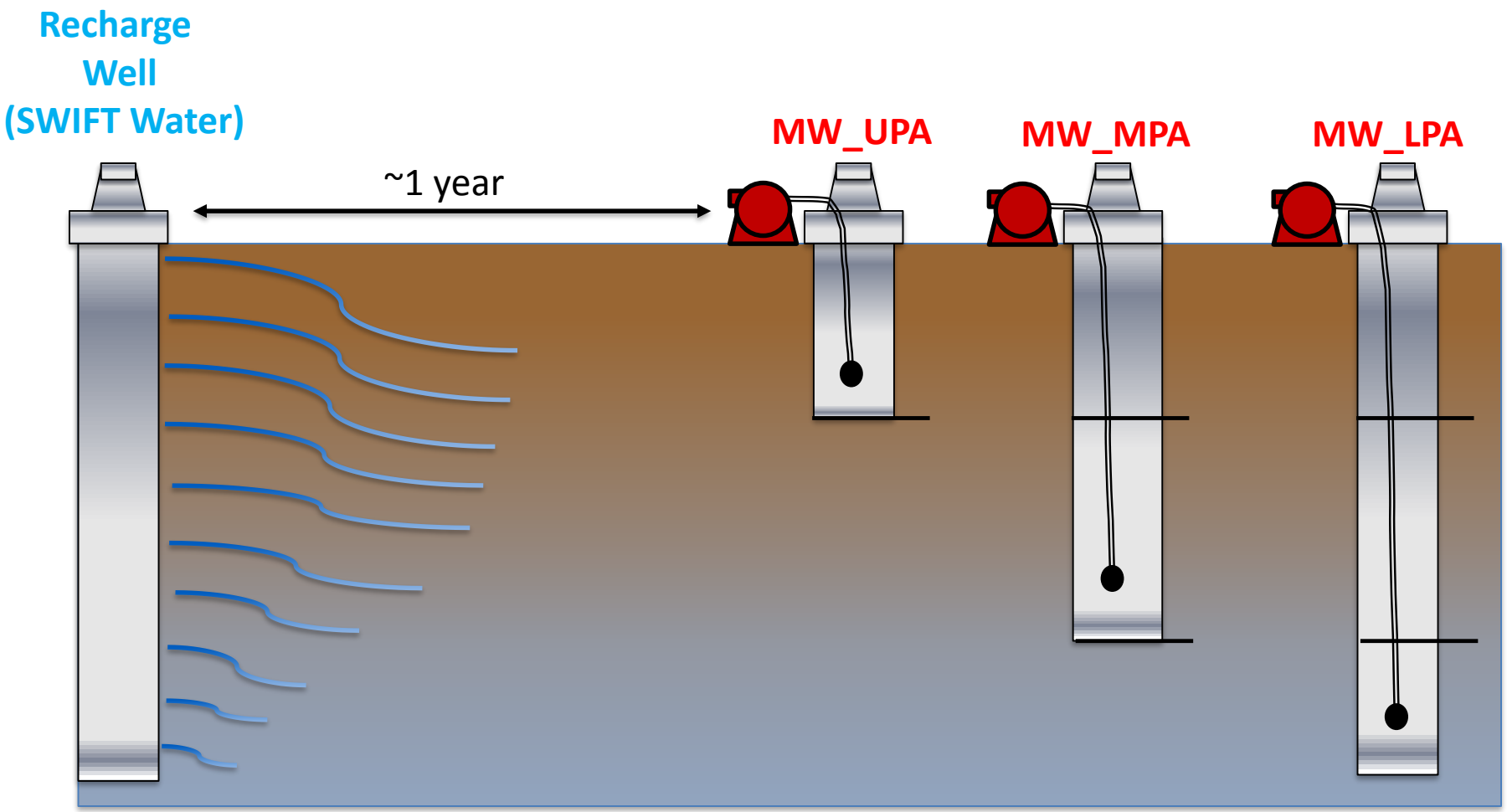

~3 DAYS
SAT MW
~ 1 YEAR
664
Upper Potomac Zone MW
(UPMW)
Middle Potomac Zone MW
(MPMW)
Lower Potomac Zone
MW (LPMW)





Flute Sample Panel


VENT
PRESSURE
1
2
3
4
5
6
7
8
UPPER POTOMAC
MIDDLE POTOMAC
LOWER POTOMAC


Recharge
Well
(SWIFT Water)
~1 year
MW_UPA
MW_MPA
MW_LPA

Finished Water Quality Preliminary Targets

Parameter	Proposed Regulatory Limit	Water Quality Goal (non-regulatory)
MCLs	Meet all primary MCLs	N/A
TN	5 mg/L monthly average; 8 mg/L max daily	Secondary Effluent CCP Action Limit for TIN = 6 mg/L
Turbidity	IFE <0.15 NTU 95% of time & never > 0.3 NTU in two consecutive measurements	CCP Action Limit at 0.10 NTU to initiate backwash or place filter in standby
TOC	4 mg/L monthly average 6 mg/L maximum	COP Action Limit at 4 mg/L, laboratory 10 day average
Total coliform	< 2 CFU / 100 mL; 95% of time; Not to exceed geometric mean of 3 CFU/100 mL, based on a running calculation of 20 days of daily samples for total coliforms.	CCPs to achieve 12 LRV for viruses and 10 LRV for Crypto & Giardia
E. Coli	Non-detect	
Unreg Chemicals	None	Monitor suite of chemicals and address as necessary
Total Dissolved Solids	None	Monitor PAS compatibility

Design to Achieve Expected Pathogen LRVs – 12/10/10 including SAT (NWRI Recommendation)

Operate to achieve using CCPs

Parameter	Log Reduction Credits								
	Coag/Sed (+BAC)	Ozone	BAC	GAC	UV (186 mJ/cm^2)	Cl_2	Total AWT	SAT	Total
Enteric Viruses	2	0-3 (TBD)	0	0	4	0-4	6-13	6	12-19
Cryptosporidium	4	0	0	0	6	0	10	6	16
Giardia	2.5	0-1.5 (TBD)	0	0	6	0	8.5-10	6	14.5-16

Unregulated Chemical Constituents that are of Public Health Interest *(Final Report of an NWRI Independent Advisory Panel: Recommended DPR General Guidelines and Operational Requirements for New Mexico, 2016)*

Chemical	Criterion	Carbon-based Train Conc.	Notes
1,4-Dioxane	1 µg/L	0.34-0.39 µg/L[1]	CCL3; CA Notification limit
17-B-estradiol	TBD (ng/L range)	<0.005 µg/L[2]	CCL3
DEET	200 µg/L	<0.010 µg/L[2]	Minnesota Health guidance value
Ethinyl Estradiol	TBD (ng/L range)	<0.005 µg/L[2]	CCL3
NDMA	10 ng/L	6.6 -14 ng/L[3]	CCL3; CA Notification limit
Perchlorate	6 µg/L	< 4 µg/L[4]	CA Notification limit
PFOA +PFOS	70 ng/L	< 60 ng/L[5]	USEPA Health Advisory
TCEP	5 µg/L	<0.010 µg/L[2]	Minnesota Health guidance value

1. Based on 3 samples in finished water
2. Based on 8 samples in finished water
3. Based on 9 samples in finished water
4. Based on 4 samples in pilot feed
5. Based on 1 sample in finished water

Unregulated chemical constituents that provide information on the effectiveness of treatment (*Final Report of an NWRI Independent Advisory Panel: Recommended DPR General Guidelines and Operational Requirements for New Mexico, 2016*)

Chemical	Criterion[1]	Carbon-based Train FW Conc.	Notes
Cotinine	1 µg/L	<0.010 µg/L[2]	Surrogate for low MW, partially charged cyclics
Primidone	10 µg/L	< 0.005 µg/L[2]	
Phenyltoin	2 µg/L	No data	
Meprobamate	200 µg/L	< 0.005 µg/L[2]	High occurrence in WWTP effluent
Atenolol	4 µg/L	< 0.005 µg/L[2]	
Carbamazepine	10 µg/L	< 0.005 µg/L[2]	Unique structure
Estrone	320 µg/L	< 0.005 µg/L[2]	Surrogate for steroids
Sucralose	150 mg/L	Range: <0.1 to 61 µg/L (GAC1) Range: <0.1 to 0.32 µg/L (GAC2)	Surrogate for water soluble, uncharged chemicals, moderate MW
Triclosan	2100 µg/L	<0.010 µg/L[2]	Chemical of interest

1. In most cases, criterion based on drinking water equivalent concentration for lowest therapeutic dose divided by 1,000 or 10,000 to provide a safety factor.
2. Based on 8 samples in finished water

Next Steps

- Establish Monitoring and Oversight Program
  - Legislation was introduced in January 2018
- Conduct outreach to private well owners in partnership with the Virginia Extension Service
- Obtain EPA Permit for Recharge Well at Research Center
- Commence operations at Research Center
  - Producing 1 million gallons per day of SWIFT Water and pumping into the thirsty Potomac Aquifer in northern Suffolk
- Begin extensive data gathering at Research Center

Timeline

- 2016-2017
  - Pilot AWT system operating since June 2016
  - Soil column tests to evaluate soil aquifer treatment
  - Working with VA Dept of Health to identify existing private wells around recharge sites
  - Preparing for full-scale implementation
  - MS4 trade agreements with Hampton Roads localities
  - NWRI independent panel transition to SWIFT oversite and monitoring entity
- 2018
  - SWIFT Research Center with 1 MGD recharge well
- 2020
  - Permits issued for full scale facilities
- 2020 to 2030
  - Construction through phased implementation
- 2030 Fully operational
  - ~120 MGD of clean water recharging the aquifer

swift

Sustainable Water

SWIFTVA.COM

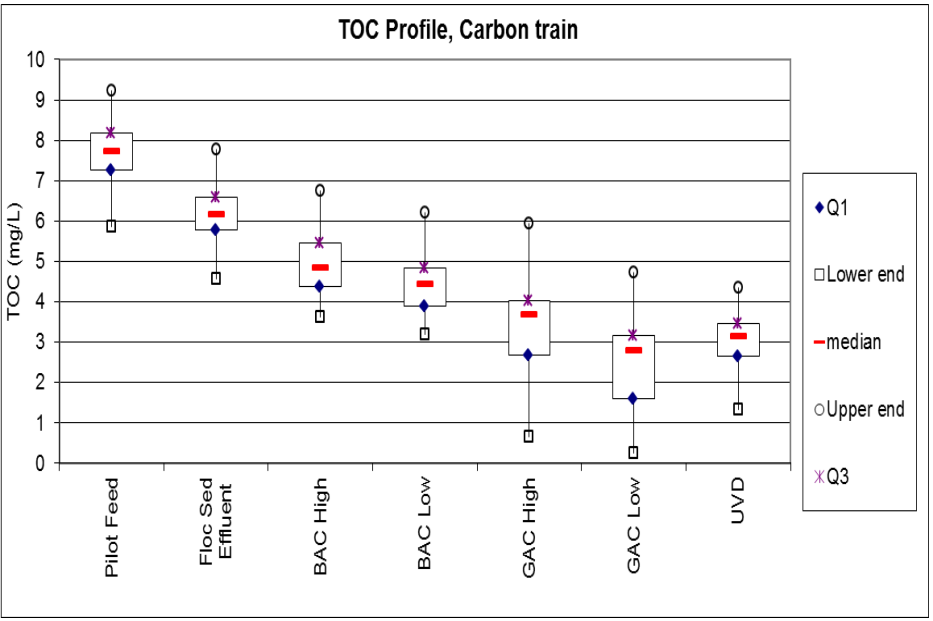
cbott@hrsd.com

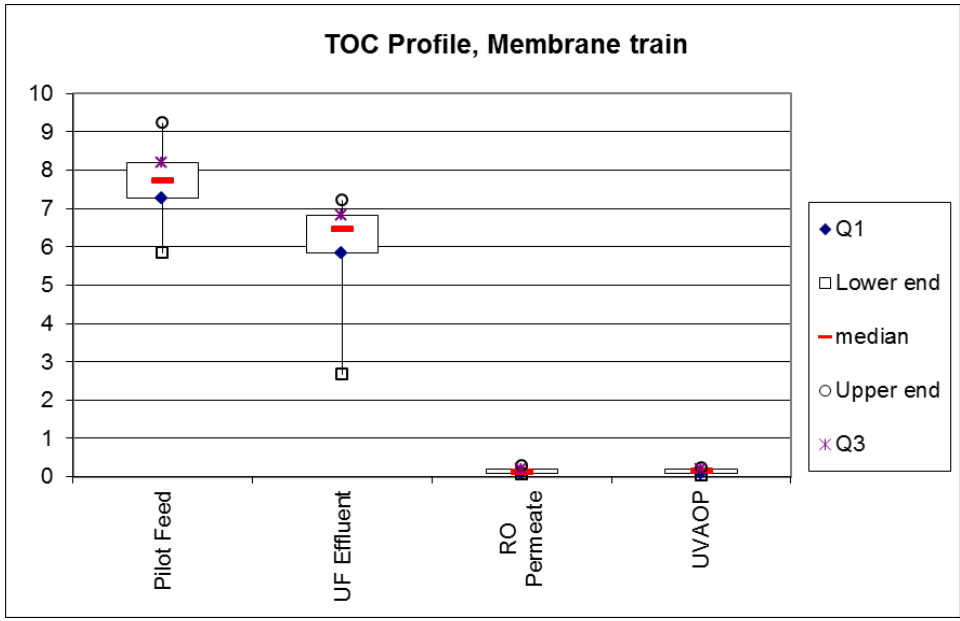
Pilot Evaluation: Carbon vs Membrane Pathogens

- Both trains provide similar quantifiable log removal credit for viruses, *Cryptosporidium*, and *Giardia*, and demonstrated complete removal of Male specific coliphage (virus) (>8 log removal) in challenge testing

Pathogen Indicators	Carbon Train Finished Water	Membrane Train Finished Water
Total coliform, 99th percentile	<1 MPN/100mL	1
E coli, 99th percentile	<1 MPN/100mL	<1 MPN/100mL
MS2 Challenge Test	> 8-log removal	> 8-log removal
Pepper Mild Mottle Virus	>5.9 log removal	>5.9 log removal

Average Total Organic Carbon (TOC) removal in both treatment processes during pilot operation





Pilot Evaluation: Carbon vs Membrane Contaminants of Emerging Concern

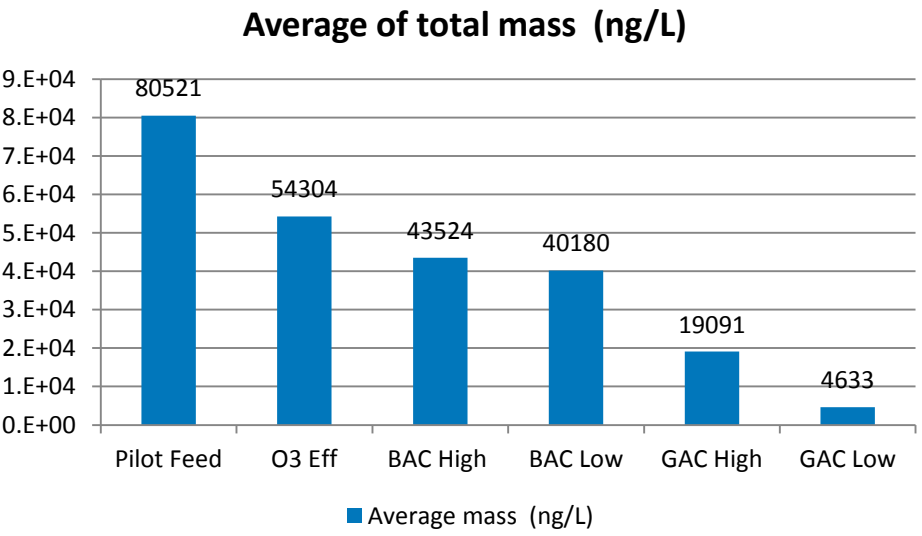
- A suite of 96 CECs analyzed in both treatment processes
- Treatment case study for 8/31/16
  - Only constituents detected by analysis are displayed in chart
- Multi-barrier approach is shown by decrease in concentration through the treatment process
- All values shown in ng/L (parts per trillion)

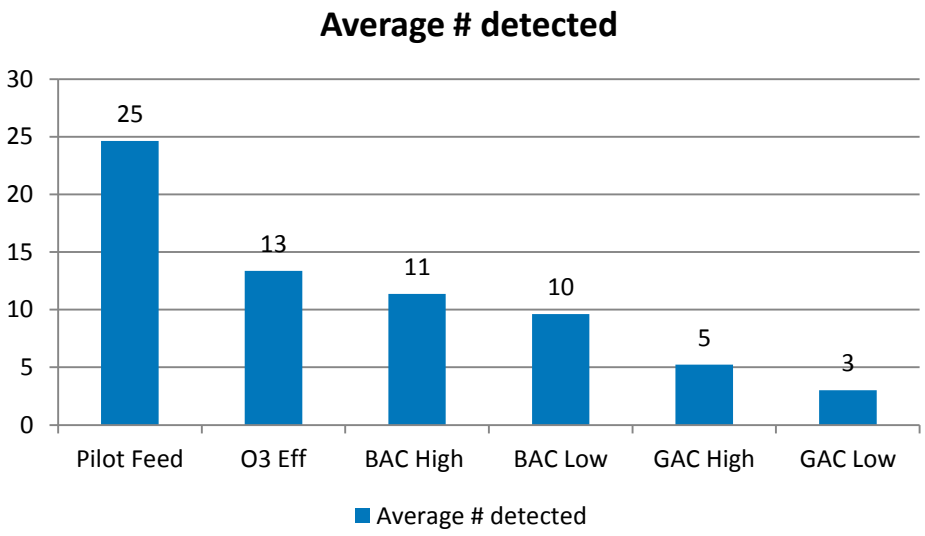
		Carbon Train			Membrane Train	
Contaminant	Pilot Feed	O3 Eff	BAC Low	GAC Low	RO Eff	UVAOP Eff
4-nonylphenol	1100	320	<100	<100	100	<100
Acesulfame-K	1100	360	290	<20	<20	<20
Iohexal	7500	4000	1400	<10	31	<10
Sucralose	43000	28000	12000	<100	140	130
Primidone	130	46	21	<5	<5	<5
TCEP	140	130	45	<10	<10	<10

Average number of CECs detected

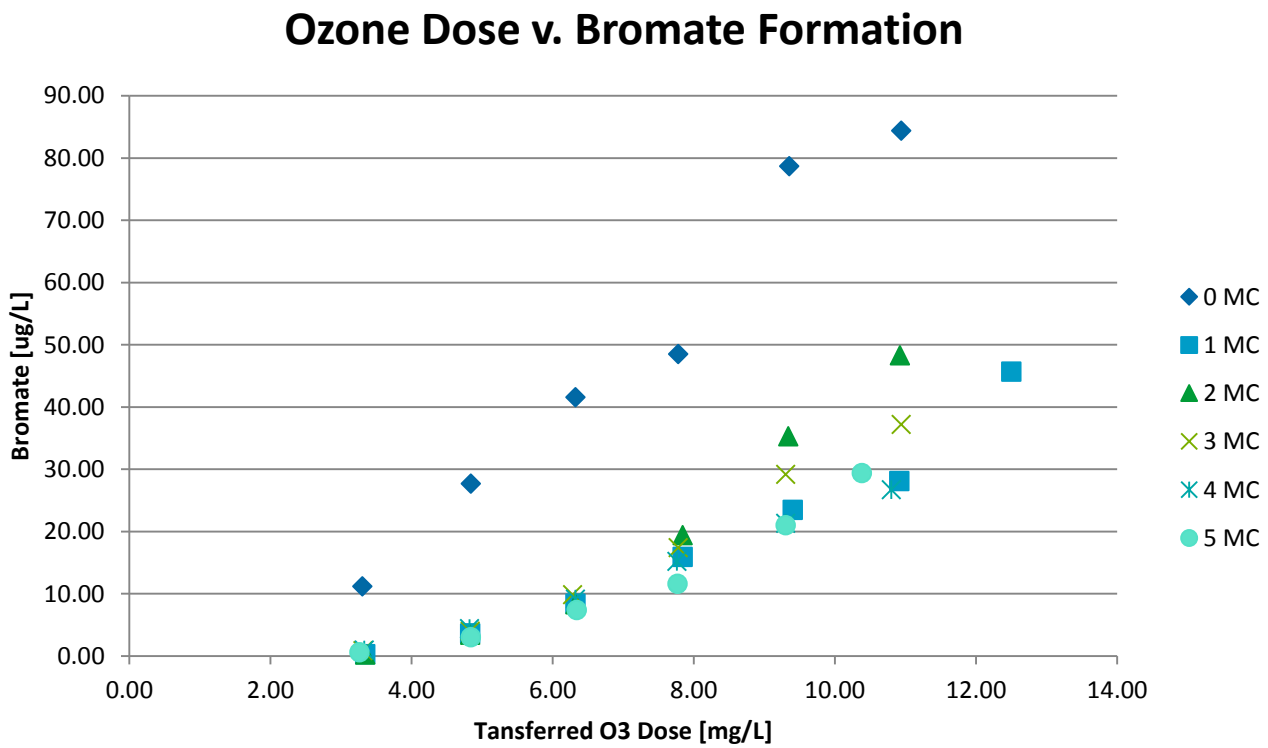
CECs (ng/L)	S1	S3	S4.1	S4.2	S5.1	S5.2	S8	S10
	Pilot Feed	O3 Eff	BAC1 Eff	BAC2 Eff	GAC1 Eff	GAC2 Eff	RO Eff	UVAOP Eff
n (sampling events)	15	5	5	5	13	13	3	9
Average # detected throughout operation	25	16	11	10	6	3	2	1

Emerging contaminants – Carbon based



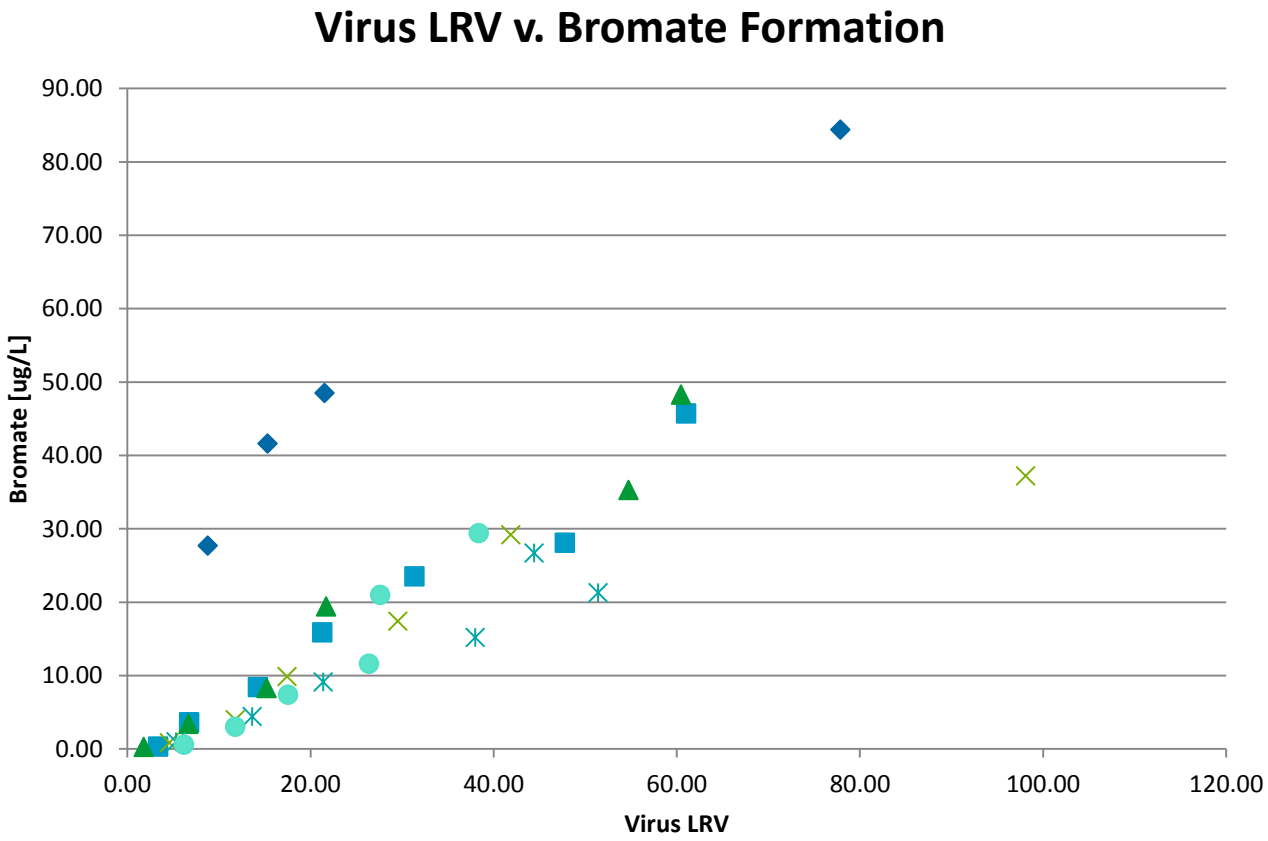


Bromate can be controlled by addition of preformed monochloramine

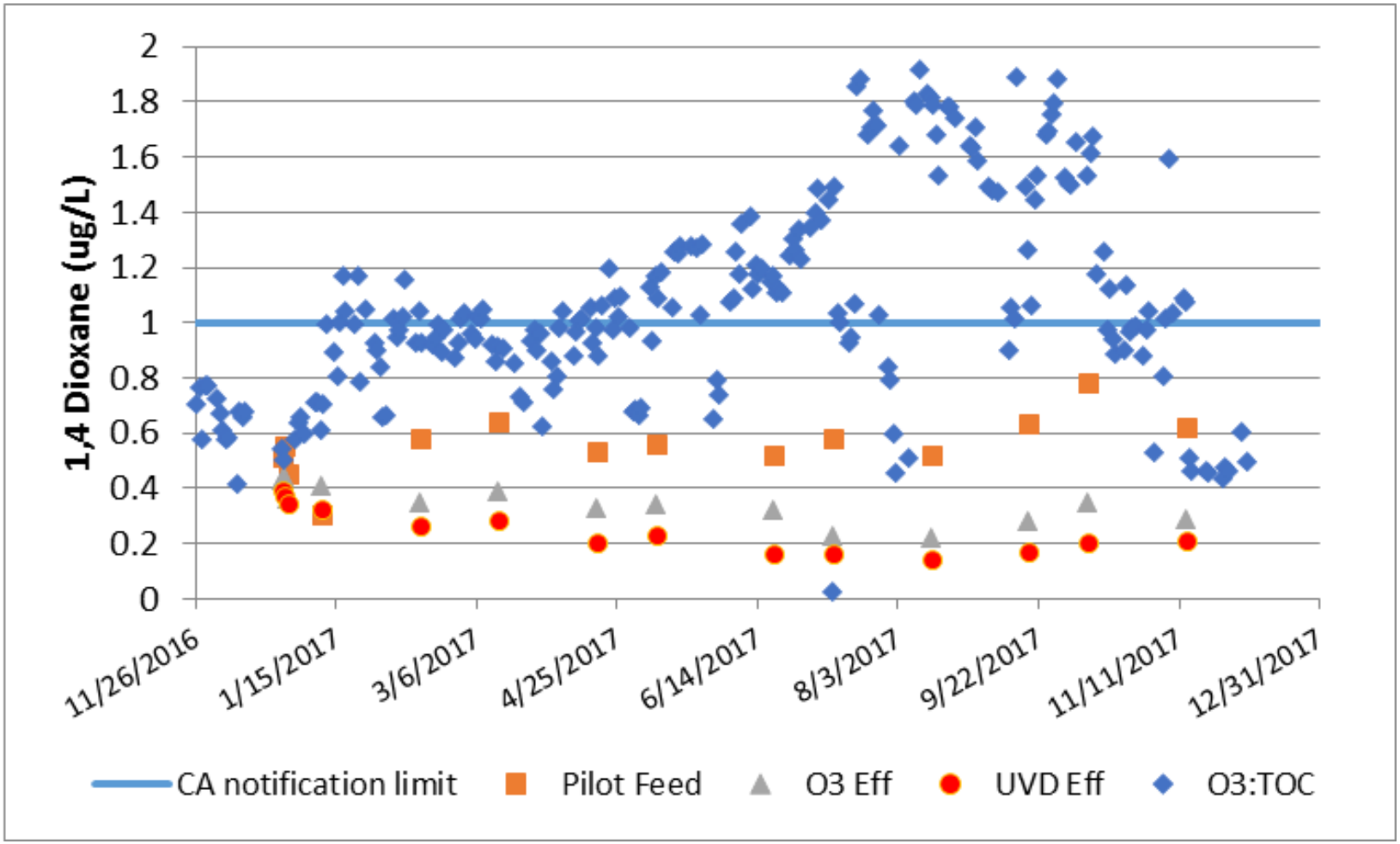


Bromide: 390-430 µg/L TOC: ~5.9mg/L Temperature: 15-17

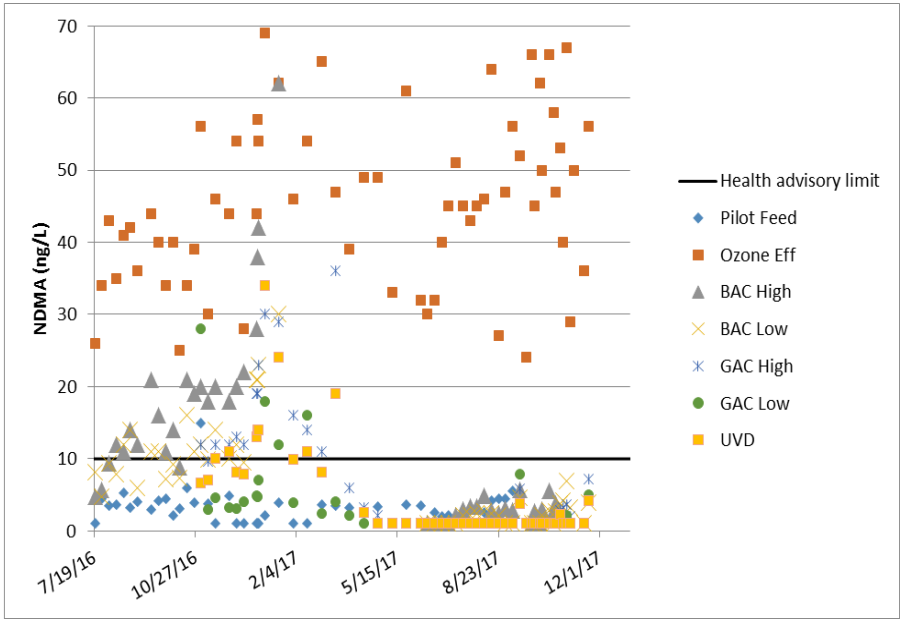
Now plotting Vs Virus LRV (approx.)

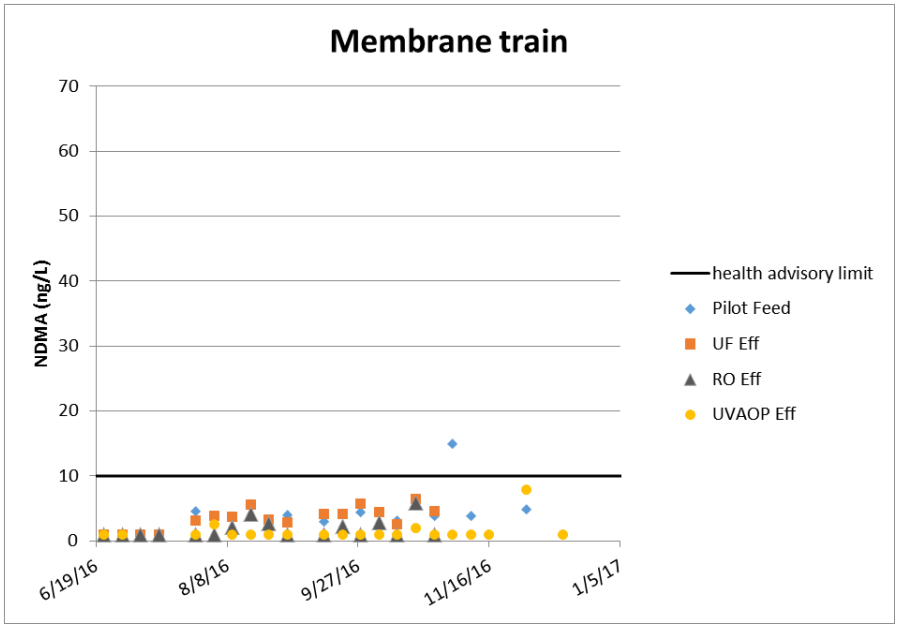


1,4 Dioxane removal in Carbon-based AWT



N-Nitrosodimethylamine (NDMA) removal in carbon and membrane processes emphasizing importance of BAC and GAC EBCT





N-Nitrosodimethylamine (NDMA) removal in carbon and membrane processes emphasizing importance of BAC and GAC EBCT