Hampton Roads Sanitation District (HRSD)

Virginia Beach, VA

Sustainable Water Initiative for Tomorrow (SWIFT)

Managed Aquifer Recharge (MAR) Program

"MAR Well Design for a Challenging Environment"

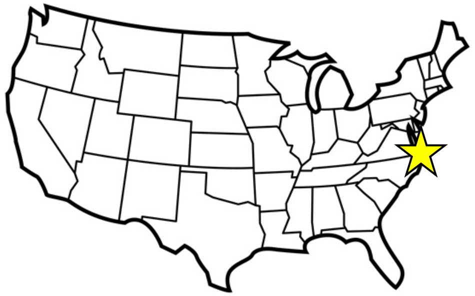
Presented to

GROUNDWATER PROTECTION COUNCIL

Annual Forum

Sept. 12-14, 2023

Tampa, FL



About Us

- Population served: 1.9 million
- 14^{th} Largest Wastewater Utility
- Political Subdivision created in 1940
- Serves 20 Cities and Counties
- Combined wastewater treatment capacity: 225 million gallons/day
- Operate 8 major and 6 smaller treatment plants and more than 100 pump stations
- Separate Sanitary System with > 500 miles of pipe

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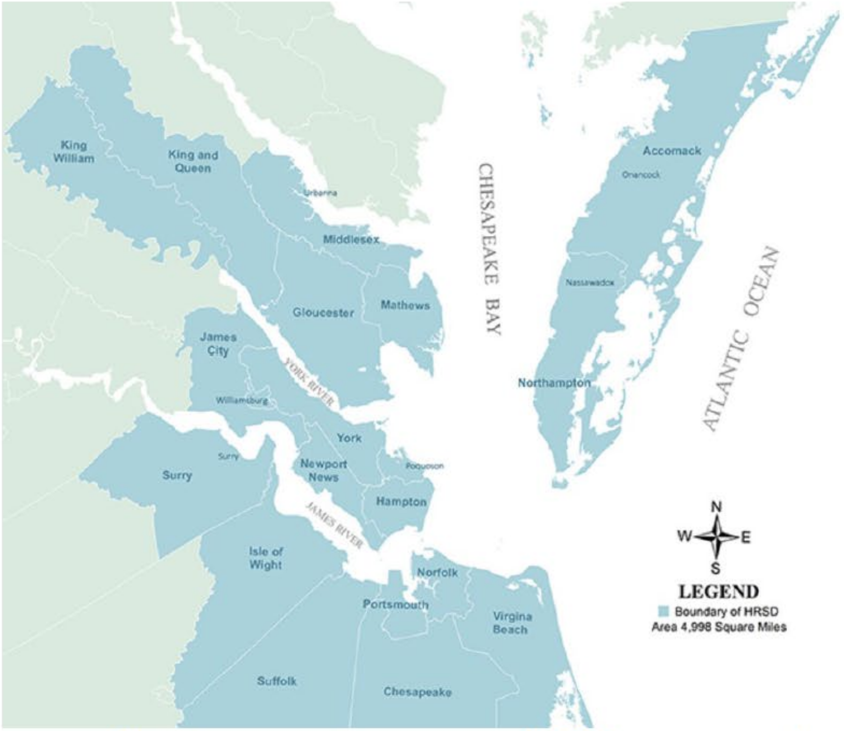


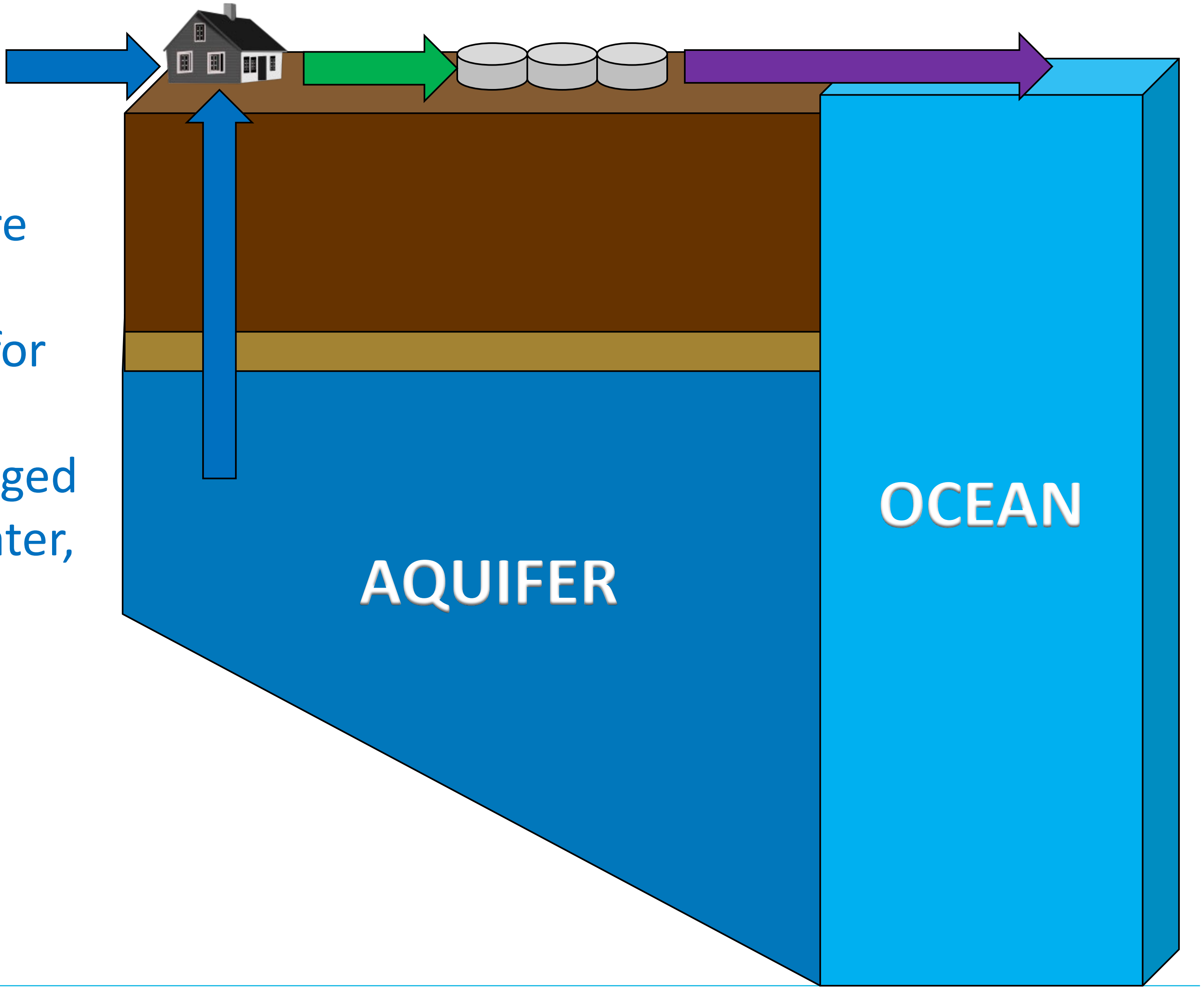
Service area is approx. 5,000 square miles

Water challenges

- Restoration of the Chesapeake Bay
  - **Nutrient loading**
  - Harmful Algal Blooms
  - Localized bacteria impairments
  - Urban stormwater retrofits (cost and complexity)
- Adaptation to sea level rise
  - Recurrent flooding
  - **Land subsidence**
- **Depletion of groundwater resources**
  - **Including potential for saltwater contamination**
- Wet weather sewer overflows
  - Compliance with Federal enforcement action

Currently…

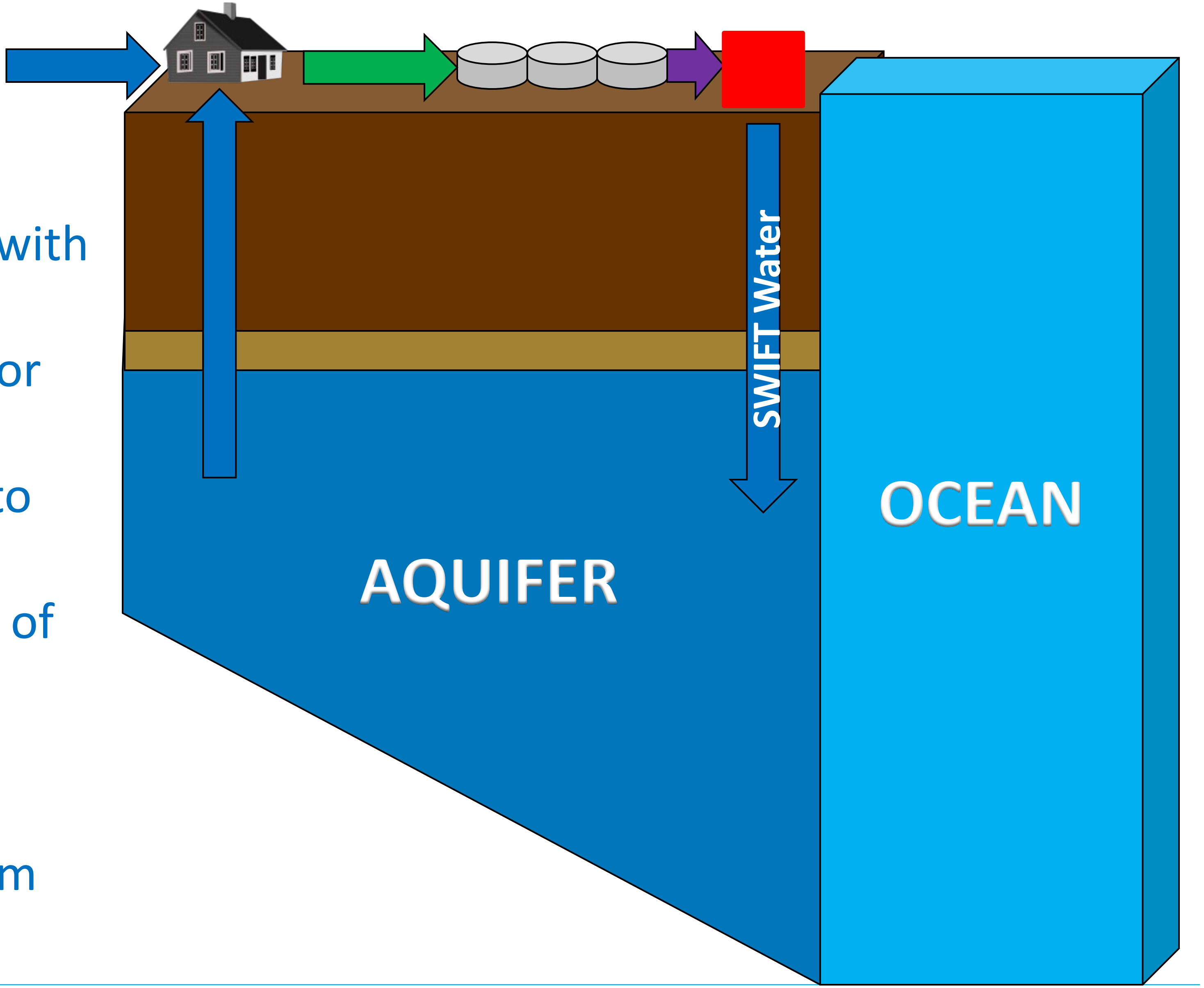
- Surface water and groundwater are consumed
- Wastewater is conveyed to HRSD for treatment
- Highly treated wastewater discharged to lower Chesapeake Bay – salt water, tidal with flow to Atlantic – no downstream users



The future…SWIFT

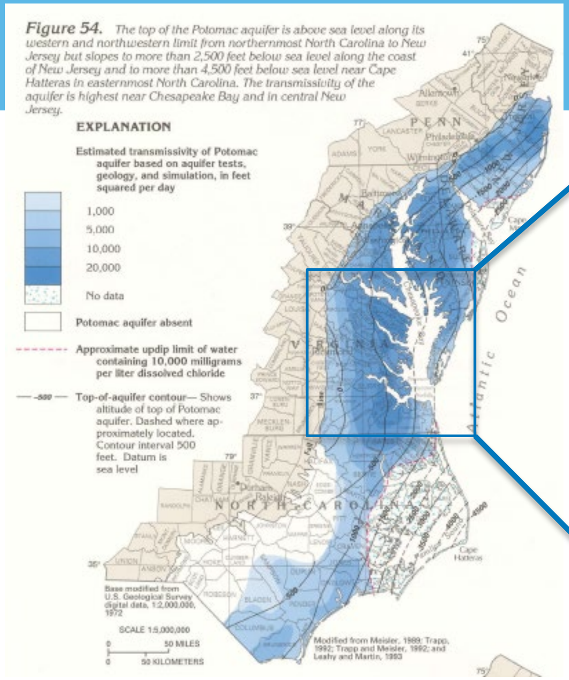
Treat water to meet drinking water standards and replenish the aquifer with clean water to:

- Provide regulatory stability for wastewater treatment
- Reduce nutrient discharges to the Bay
- Provide a sustainable supply of groundwater
- Reduce the rate of land subsidence
- Protect the groundwater from saltwater contamination

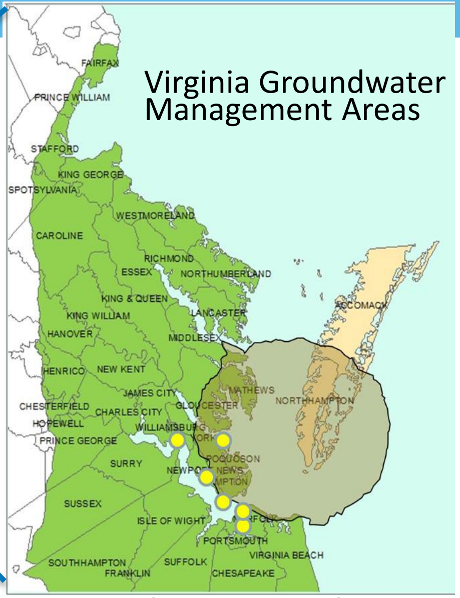


VA Coastal Plain Aquifer System Geometry

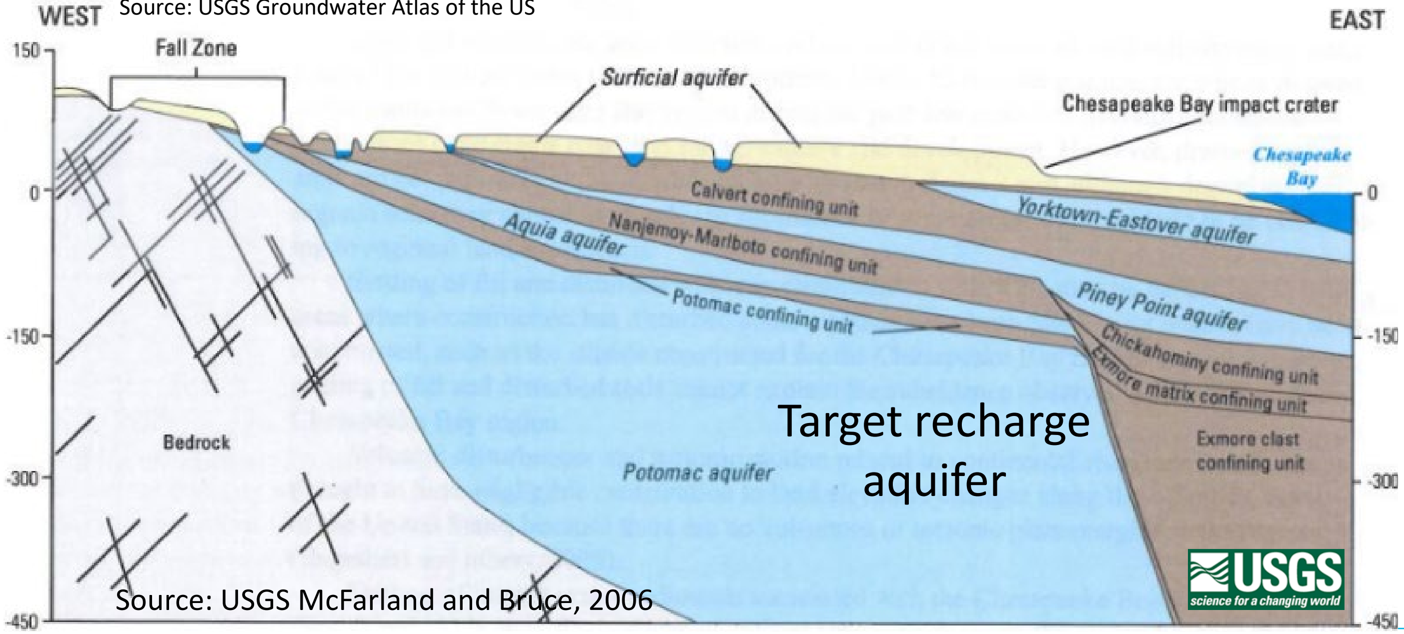
- Fall Zone to the Ocean
- Horizontally stacked aquifers = confined aquifers
- Wedge shaped that widens and dips toward the east
- 2,000 feet of unconsolidated sediments (gravels, sands, silts, clays, shells).
- Potomac aquifer, thick and highly interbedded



Source: USGS Groundwater Atlas of the US



Source: VA DEQ



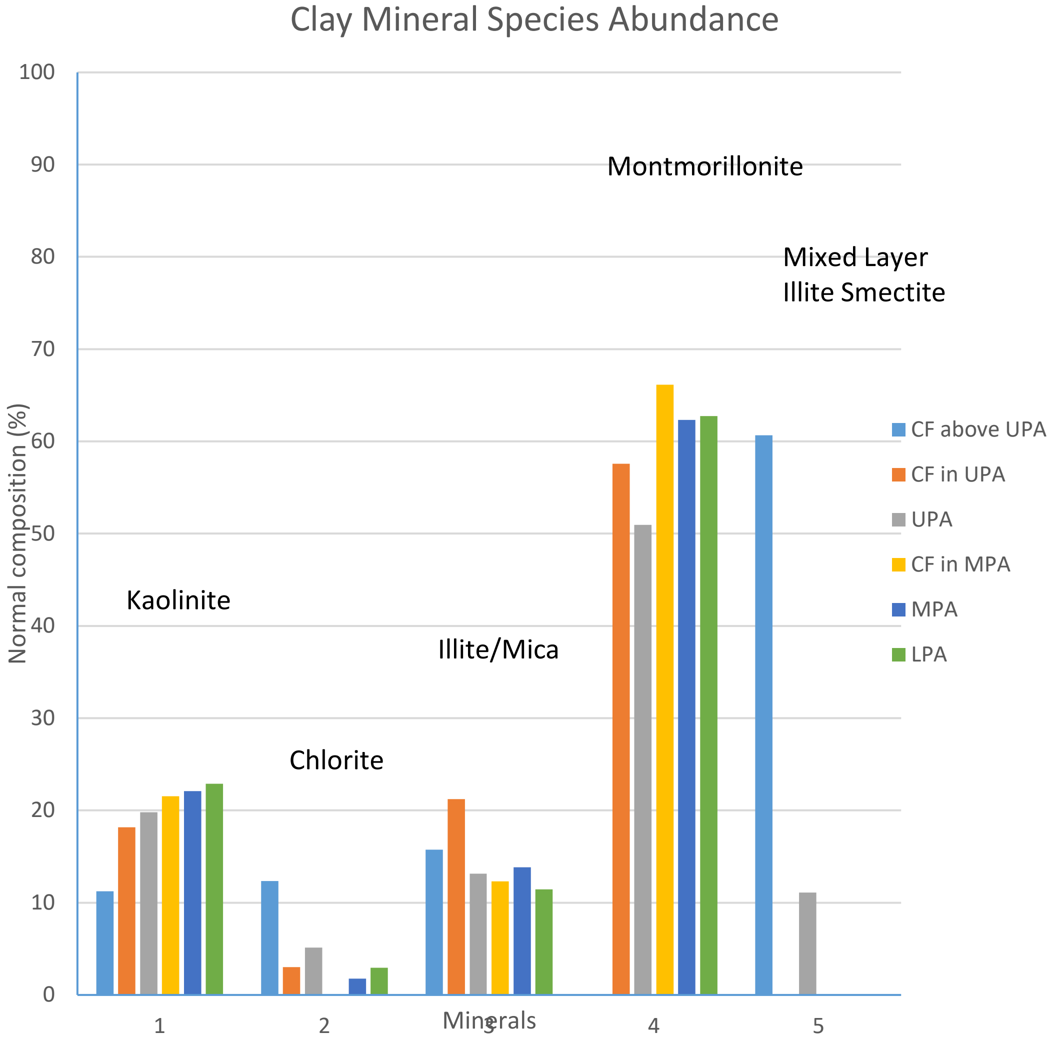
Source: USGS McFarland and Bruce, 2006

Well Design Drivers

- MAR Wells
  - design recharge and backflush rates and related well levels
  - anticipated casing and screen depths
  - filter pack stability and maintenance
  - recharge zone groundwater quality and static pressures
  - Native GW and SWIFT water quality
- Monitoring Wells
  - design purge rates and related well levels
  - anticipated casing and screen depths
  - recharge zone groundwater quality and static pressures
  - Native GW and SWIFT water quality

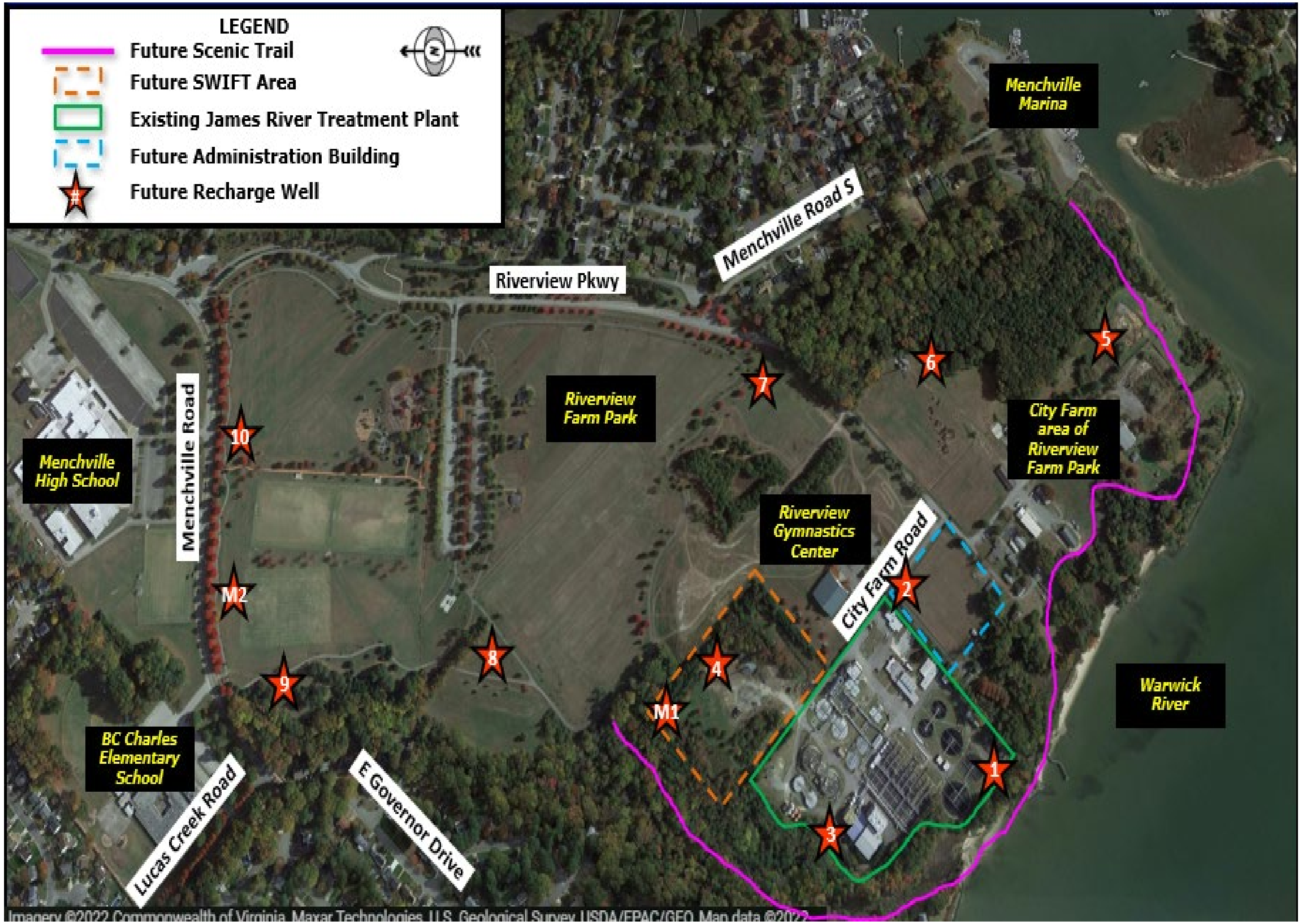
Well Design Drivers (Cont'd)

- Schedule constraints
  - JRTP MAR wells constructed in two phases
  - Phase 1 (on-site) 3 MAR wells
  - Phase 2 (off-site) 7 MAR wells
  - Based on availability of drilling locations and desire to minimize conflicts with design-build contractor
  - Phase 1 MAR wells (on-site) could sit idle up to 4 years
- Recharge zone plugging
  - SWIFT water significantly lower ionic strength than Native GW
  - clay minerals present in the matrix pores



James River Wastewater Treatment Plant (JRTP) is site of first MAR well construction project

- 2 Contracts
  - On-Site = 3 MAR wells
  - Off-Site = 7 MAR wells + 1 monitoring well nest

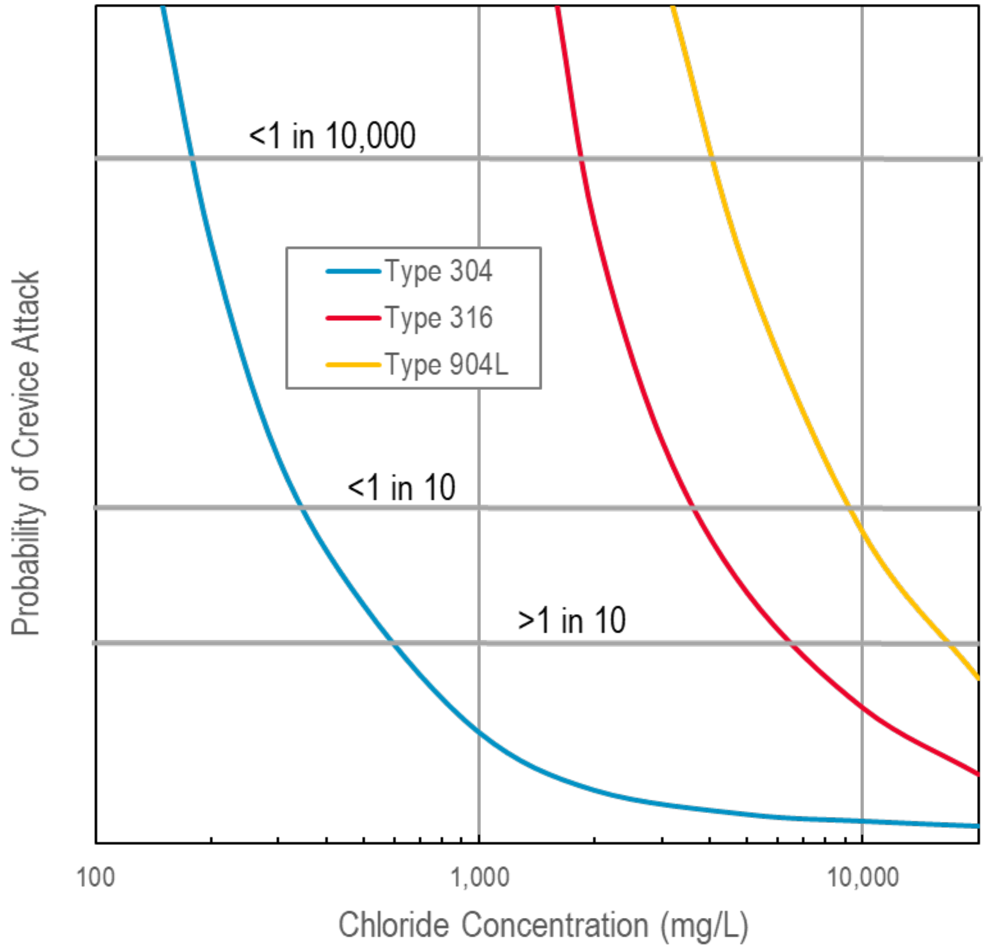


MAR Well Design Parameters and Features

- Recharge rate – 2 mgd
- Backflush rate – 3 mgd
- Accommodate 15-in diameter vertical turbine pump w/ 10-in diameter column pipe
- Backflush pump column length – 300 linear feet
- Outer casing depth – approx. 400 feet bgs
- In-line orifice to control recharge
- Separate external 2” SST monitoring pipe to accommodate instrumentation

Corrosive NGW and Extended Startup

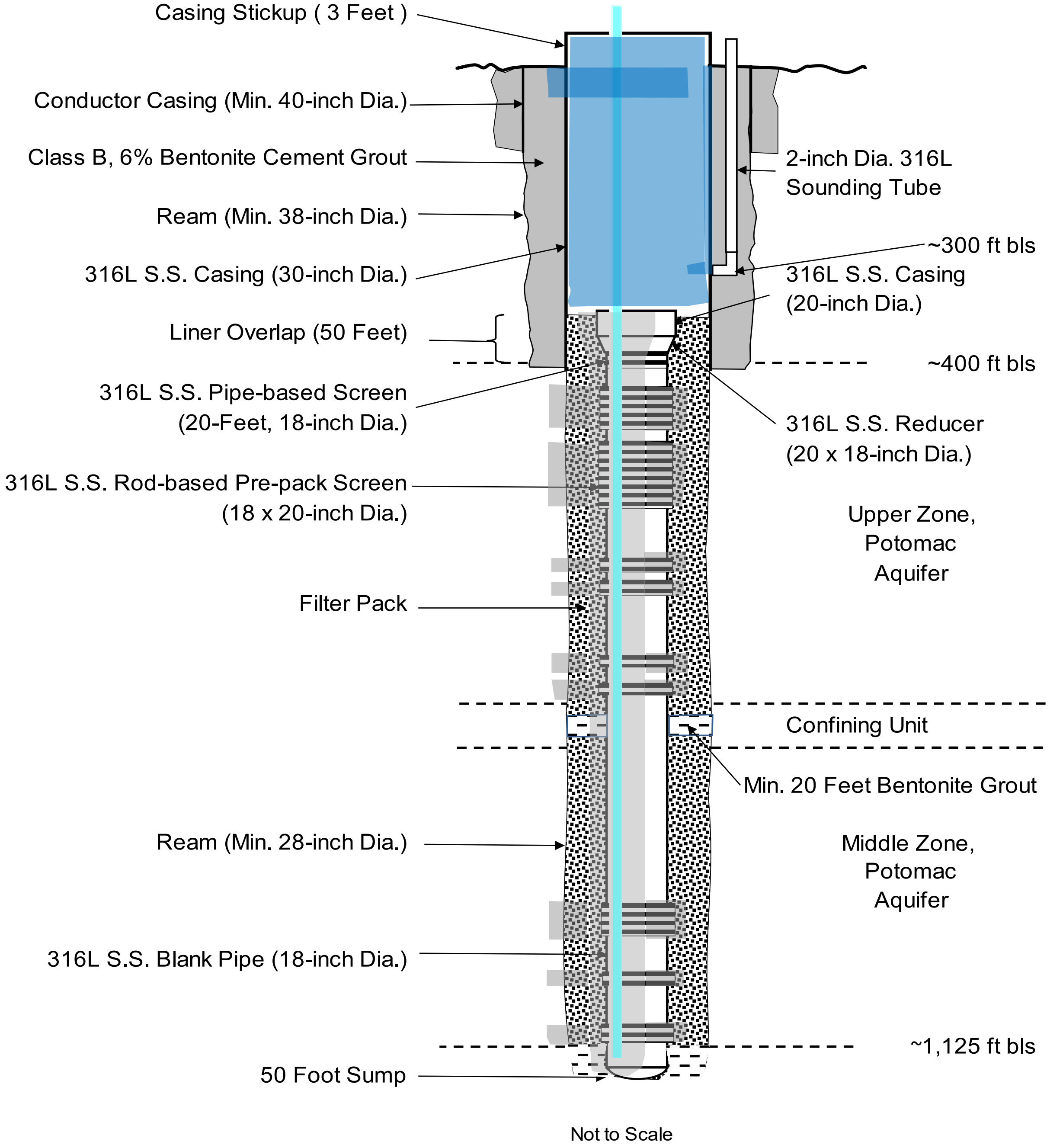
- Middle Potomac Aquifer chloride concentration up to 4,500 mg/L
- Potential for uphole migration into UPA
- Shut-in period could exceed 4 years for the on-site wells
- Type 316 SS suitable to 3,000 mg/L chloride



Source: Nickel Development Institute, 1987. Nickel stainless steels for marine environments, natural waters and brines.

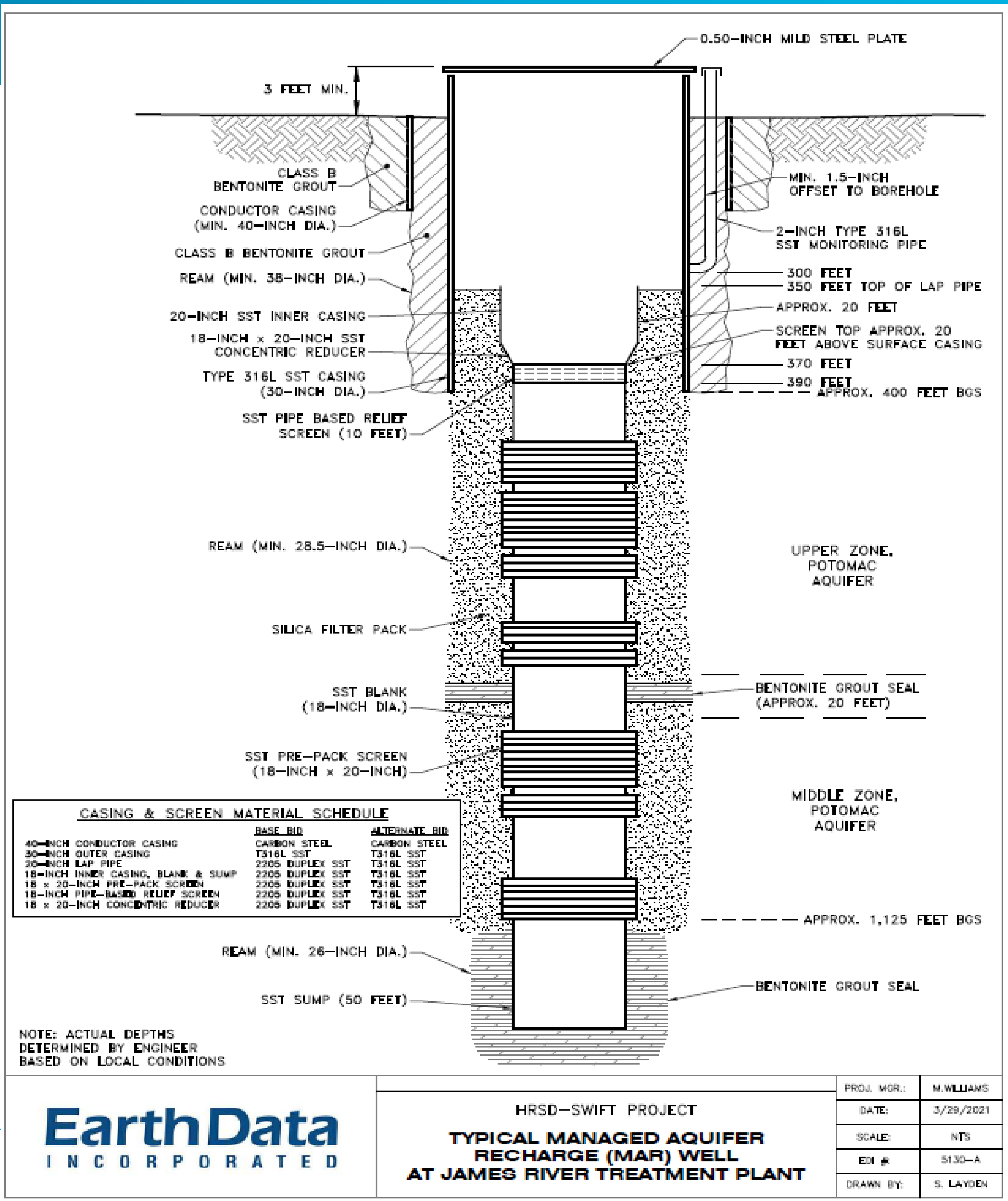
Solutions

- Use 2205 Duplex SS for recharge string (JRTP on-site wells only)
  - Cost ≈ 4 x 316L SS)
- Change the well environment
  - freshwater-based sodium bentonite suspension
  - placed from base of sump to top recharge string
  - freshwater placed from surface in upper casing and external monitoring pipe



JRTP MAR Well Design Details

- 2-piece construction allows for future filter pack augmentation
- 40” steel surface casing
- 30” SST outer casing
- 20” liner swedge to 18” to facilitate liner rehab
- 18” pipe-based relief screen
- 18” X 20” SST pre-pack recharge screen & 18 ” SST inner casing & sump based on pilot hole and geophysical logs
- 50’ sump for extended run times between potential well rehab events
- 20’ thick bentonite seal between UPA and MPA for zone isolation

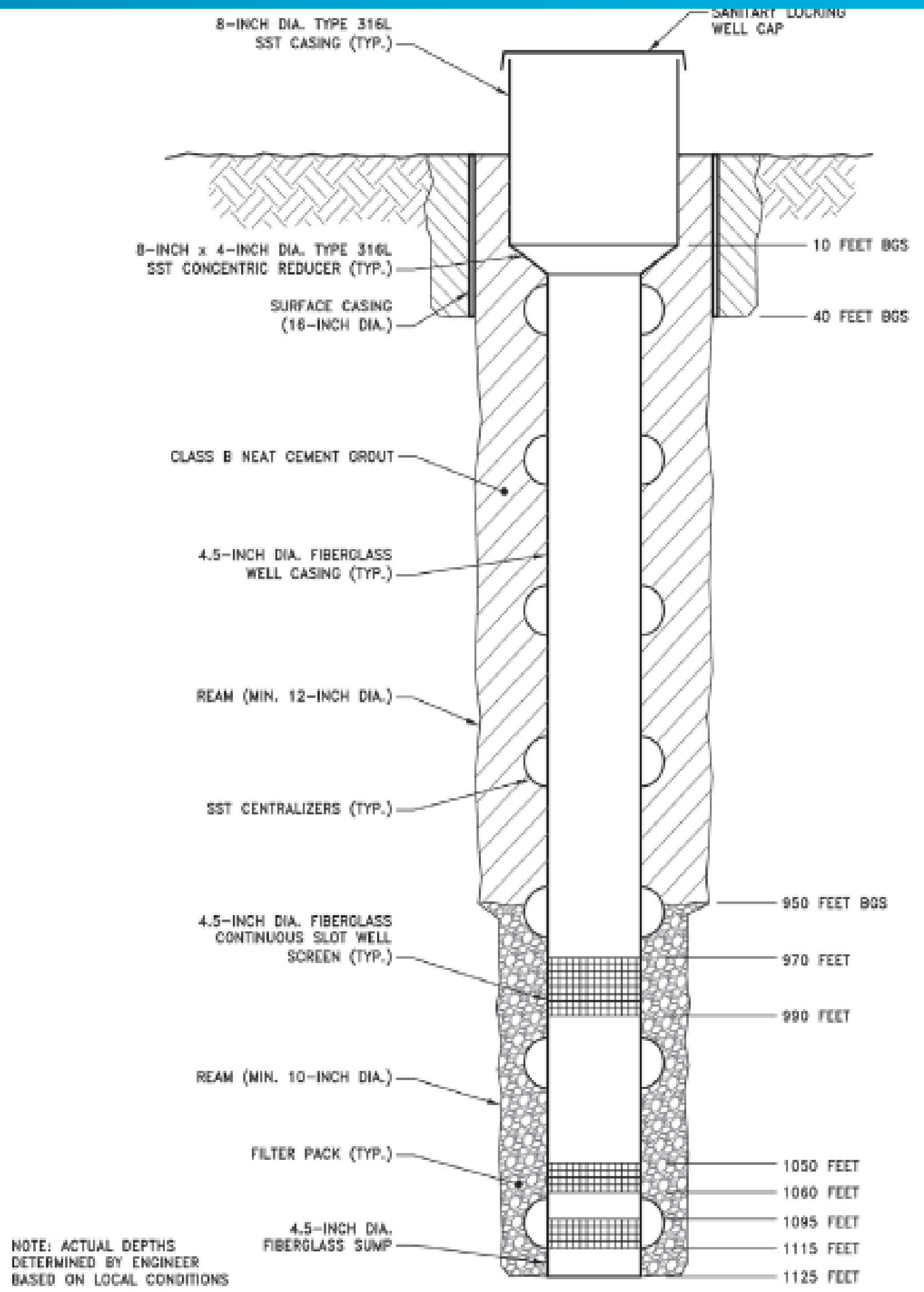


CASING & SCREEN MATERIAL SCHEDULE

	BASE BID	ALTERNATE BID
40-INCH CONDUCTOR CASING	CARBON STEEL	CARBON STEEL
30-INCH OUTER CASING	T316L SST	T316L SST
20-INCH LAP PIPE	2205 DUPLEX SST	T316L SST
18-INCH INNER CASING, BLANK & SUMP	2205 DUPLEX SST	T316L SST
18 x 20-INCH PRE-PACK SCREEN	2205 DUPLEX SST	T316L SST
18-INCH PIPE-BASED RELIEF SCREEN	2205 DUPLEX SST	T316L SST
18 x 20-INCH CONCENTRIC REDUCER	2205 DUPLEX SST	T316L SST

MW Design Parameters and Features

- Four MWs in close proximity to each other at four different depths
  - ➢ Approx. 500’, 700’, 800’ and 1,200’
  - ➢ Three MWs completed in the Upper Zone of the Potomac Aquifer and one in Middle Zone
- 8” SST upper casing & 4.5” FRP casing and continuous slot screen
- Baseline pumping test data & water quality sampling
- Permanent sampling pumps to be installed to facilitate regular compliance sampling by HRSD
- Level monitoring – single pressure transducer



JR_MN1_MA AND JR_MN2_MA MONITORING WELL DETAIL
MIDDLE ZONE OF THE POTOMAC AQUIFER
NOT TO SCALE

HRSD SWIFT - JAMES RIVER WWTP

JRMN2 CLUSTER MONITORING WELLS
PRELIMINARY ESTIMATED SCREEN PICKS
4/25/2023 - DRAFT UA & UB and Finalized JR_MN2_MA & UC

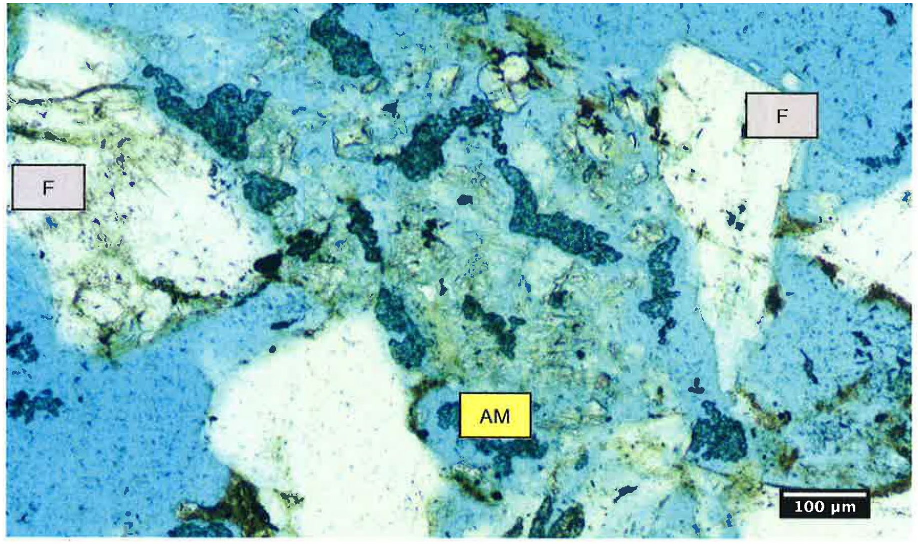
Based on JRMN2_MA Geophysical Log and Nearest JR_MAR Wells							
MN_ZONE	WELL ID	Screen #	Top Depth	Bottom Depth	LF	Total LF	Status
UzA of PA	JR_MN2_UA DEQ:216-00136	1	425	440	15	20	*DRAFT*
		2	488	493	5		
UzB of PA	JR_MN2_UB DEQ:216-00137	1	513	528	15	45	*DRAFT*
		2	548	553	5		
		3	590	600	10		
		4	630	635	5		
		5	682	692	10		
UzC of PA	JR_MN2_UC DEQ:216-00138	1	744	754	10	20	FINAL
		2	795	805	10		
MzA of PA	JR_MN2_MA DEQ:216-00135	1	938	953	15	60	FINAL DEQ Approved
		2	990	1010	20		
		3	1115	1130	15		
		4	1142	1147	5		
		5	1233	1238	5		

TOTAL SCREEN LENGTH (FT.)	145

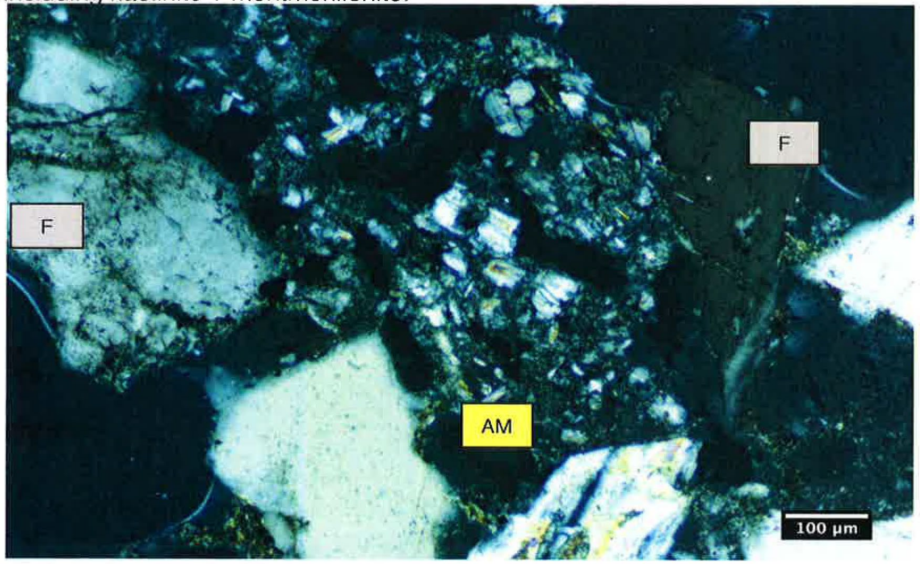
UzA PA = Upper zone of Potamac aquifer - subzone A: JR_MN2_UA
UzB PA = Upper zone of Potamac aquifer - subzone B: JR_MN2_UB
UzC PA = Upper zone of Potamac aquifer - subzone C: JR_MN2_UC
MzA PA = Middle zone of Potamac aquifer - undifferentiated: JR_MN2_MA

Clay Stability

- Iron oxides, clay minerals, and quartz overgrowths in pores
- Montmorillonite primary clay mineral w/ minor kaolinite and illite/mica in recharge zones
- JR SWIFT ionic strength (IS) =1.1e-02
- UPA IS = 7.5e-02
- MPA IS = 1.1e-01
- Potential for clay fragmentation



5E. Corroded feldspar (F) partially replaced with authigenic clay matrix (AM) - including kaolinite + montmorillonite.



Recharge Zone Conditioning

- Procedure developed during previous pilot testing at SWIFT sites
- NSF 60 Aluminum chlorohydrate (ACH) solution batched onsite (0.05 molar solution)
- Applied using straddle packers (up to 3 screen intervals) going from bottom to top screen
- 14-day minimum contact period
- Evacuate treated zones through packers
- Post-conditioning pumping tests compared to baseline well hydraulics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HRSD SWIFT - JAMES RIVER WWTP
PROPOSED ACH TREATEMENT AT 0.05 Molar Concentration
WELL JR_MAR_04 (DEQ 216-00124)

Summary of Treatment Zones at James River
Treatment Volumes ACH 14 feet into aquifer

Volume of 18-inch casing 12.14 gal/ft (17.25 I.D.)
Volume of 6-inch T&C pipe 1.50 gal/ft (6.065 I.D.)

Aquifer	Packed Zone	Screen Top	Screen Bottom	Screen Interval Length	Total Length of screen	Packer Zone Top	Packer Zone Bottom	Total Length of Zone	Treatment Radius	Volume treatment	Volume of water to evacuate	Volume ACH	
	Number	(fbg)	(fbg)	(ft)	(ft)	(fbg)	(fbg)	(feet)	(ft)	fluid (gallons)	(gallons)	(gallons)	(totes)
Upper	1	408	440	32		398	-						
Zone of the		448	458	10	42	-	459	61	14	36,748	1,413	524	2.2
Potomac	2	476	546	70		474	-						
		556	592	36	106	-	596	122	14	92,744	2,315	1323	5.5
	3	620	650	30	30	615	676	61	14	26,248	1,671	374	1.6
	4	734	754	20		698	-						
		772	800	28	48	-	820	122	14	41,997	2,639	599	2.5
Middle	5	962	1022	60	60	925	1047	122	14	52,497	2,924	749	3.1
Zone of the	6	1064	1074	10		1054	-						
Potomac		1112	1138	26		-	-						
		1154	1164	10	46	-	1176	122	14	40,247	3,212	574	2.4
Aluminum Chlorohydrate (ACH)			0.05 M			29 gallons per 1,000 gallons H_2O				290,481	14,173	4,142	17

Porosity (fraction) 0.19

Draft Calculation: 8/29/2023

290481 Total Treatment fluid (gallons)
4203 MINUS ACH volume (gallons)
286277 Treatment fluid minus ACH (gallons)
4142 ACH volume needed (gallons)
17 Totes
240 gallon/tote
14.5 gallons of ACH per 1,000 gallon solution

Comparison of Pre-and Post-ACH Specific Capacity and Turbidity in JR_MAR_01 and JR_MAR_03 (Preliminary Data)

	JR_MAR_01	JR_MAR_03
Pre-ACH pumping test rate (gpm)	1795	1500
Pre-ACH 60-minute specific capacity (gpm/ft)	78.10	66.80
Pre-ACH turbidity (NTU)	1.91	3.41
Post-ACH pumping test rate (gpm)	1795	1500
Post-ACH 60-minute specific capacity (gpm/ft)	73.90	44.60
Post-ACH turbidity (NTU)	1.84	1.96
Specific capacity change	-4.2	-22.2
Specific capacity % change	-5.4%	-33.2%

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