PAROC SWIFT Update
SWIFT Water Dissolved Oxygen and Arsenic

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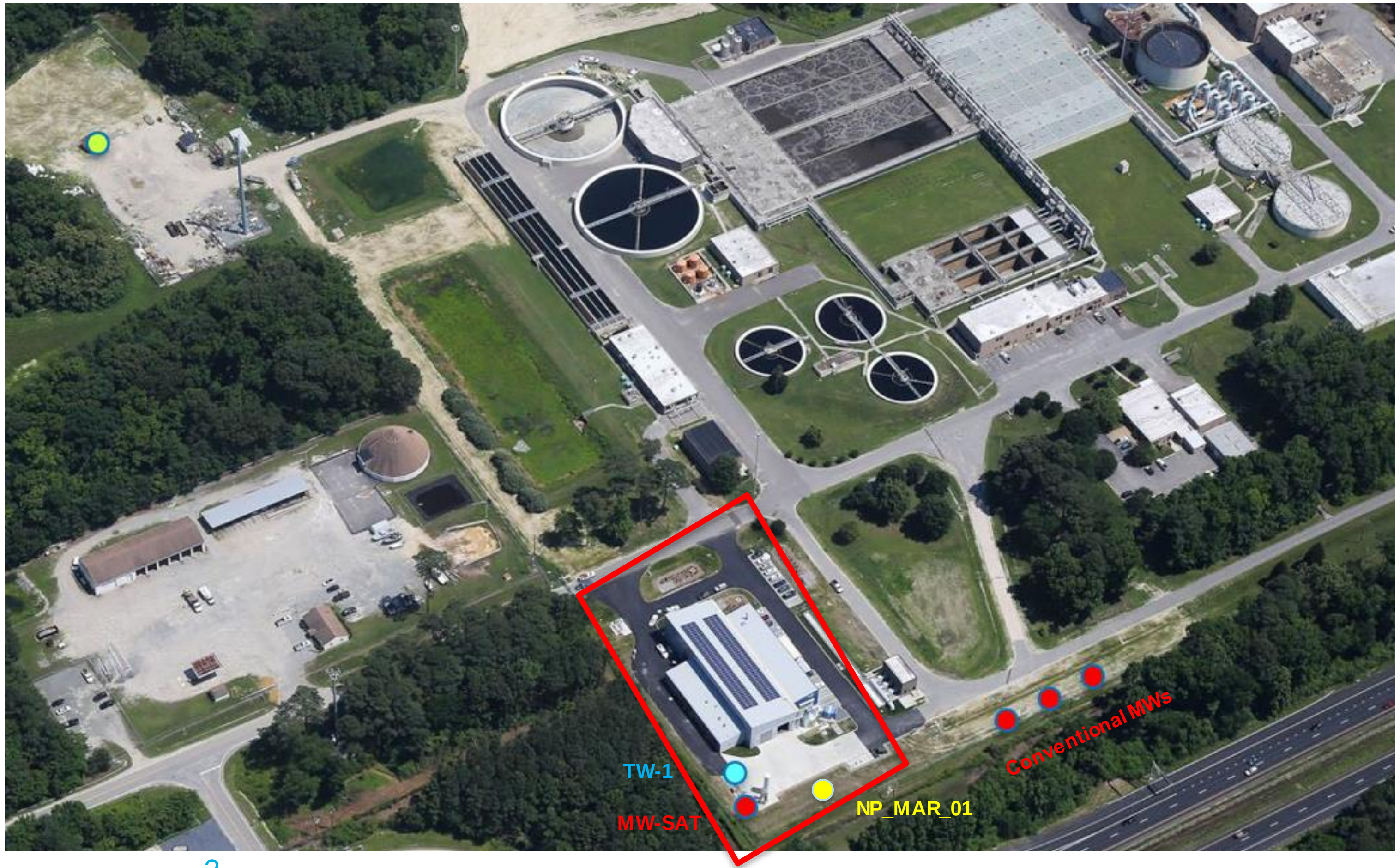
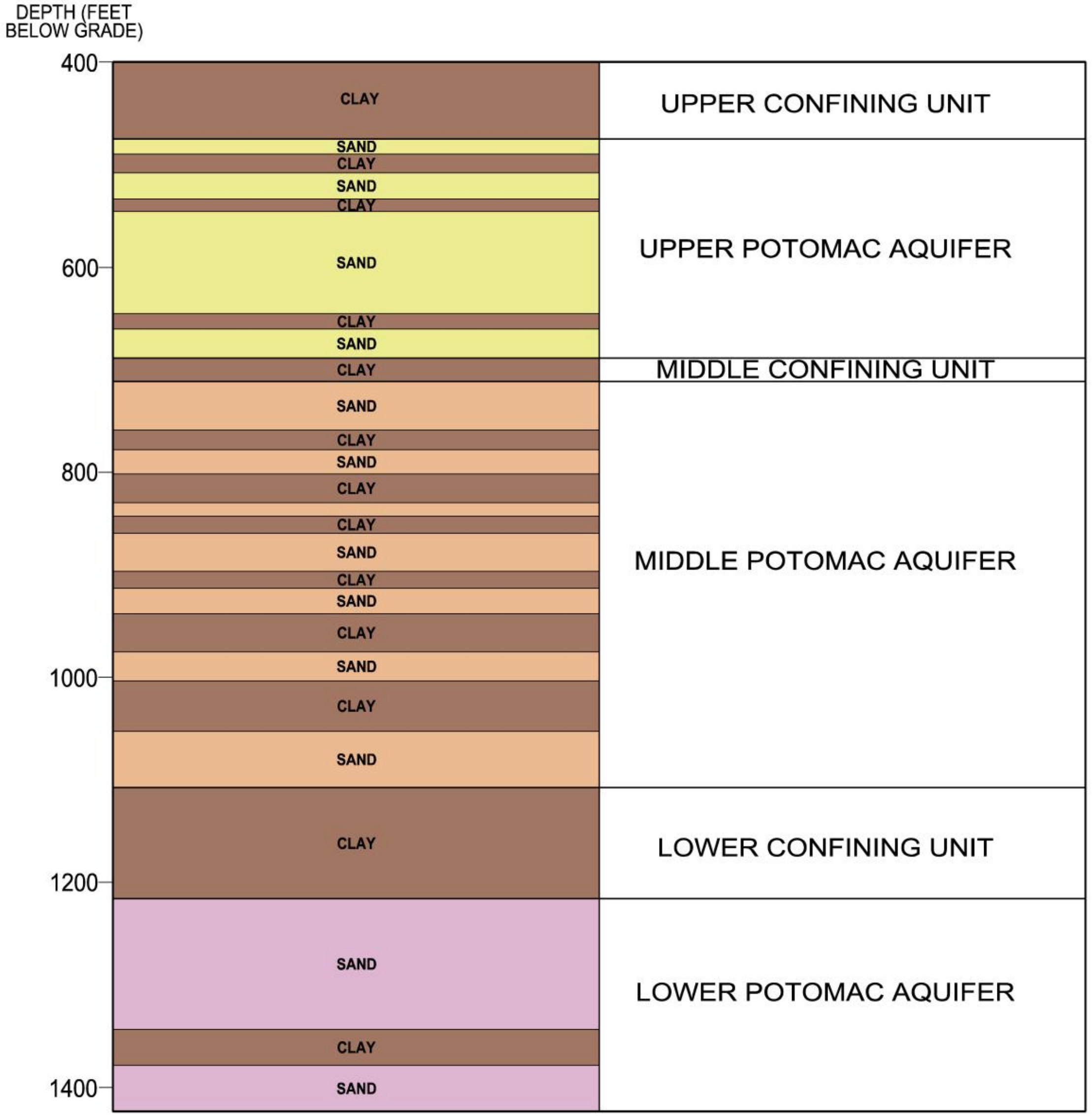
3/18/22

SWIFT Research Center

- 1 MGD demonstration facility
  - Training facility
  - Education facility
  - Research facility
- May 2018 start-up
  - Recharge Well TW-1
  - Research Well MW-SAT
  - Conventional MWs
- New Recharge Well NP_MAR_01



Closer Look at Potomac Aquifer

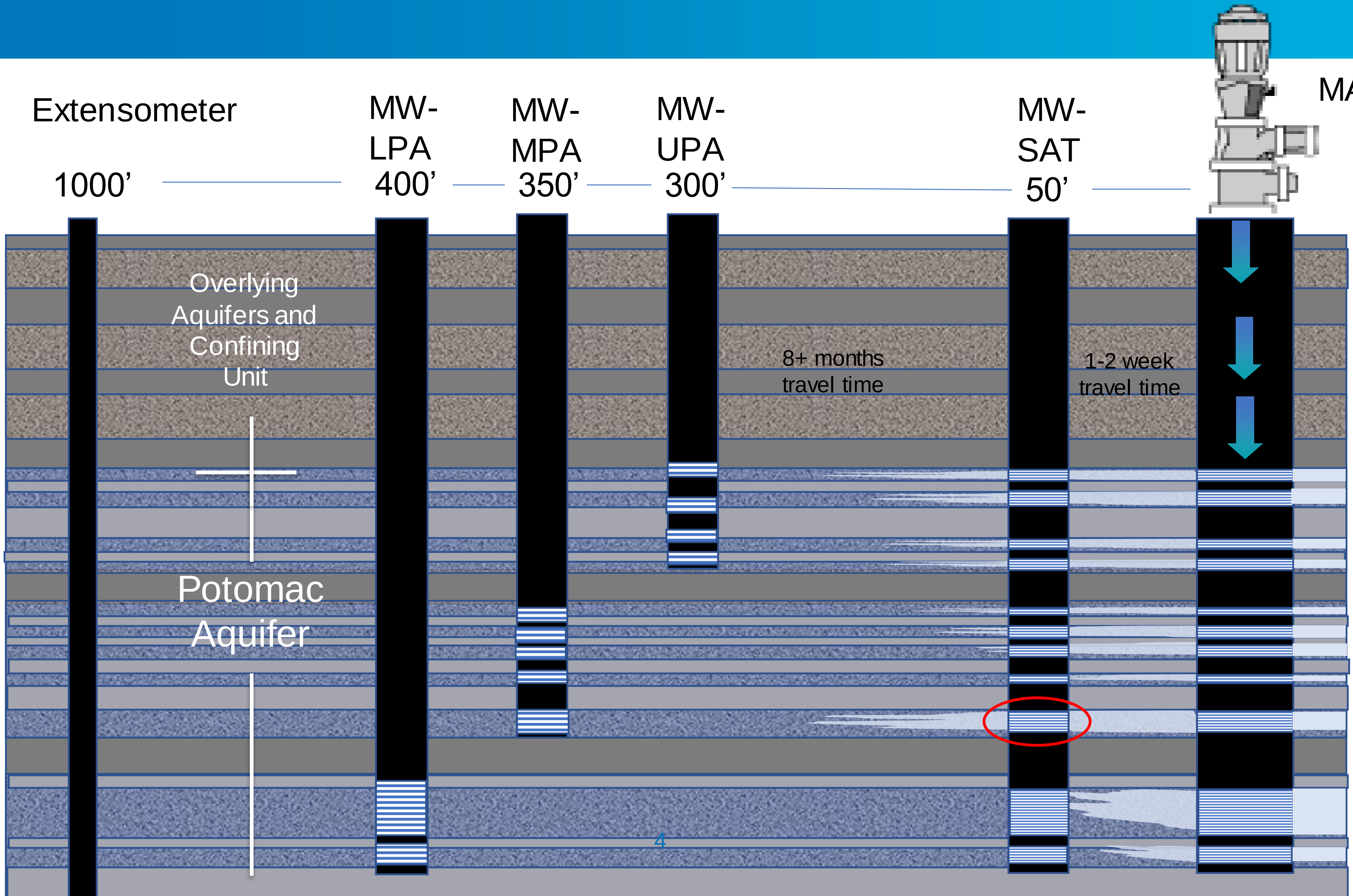


Penetrated Upper, Middle and portion of Lower Potomac zones

Highly interbedded sands and clays

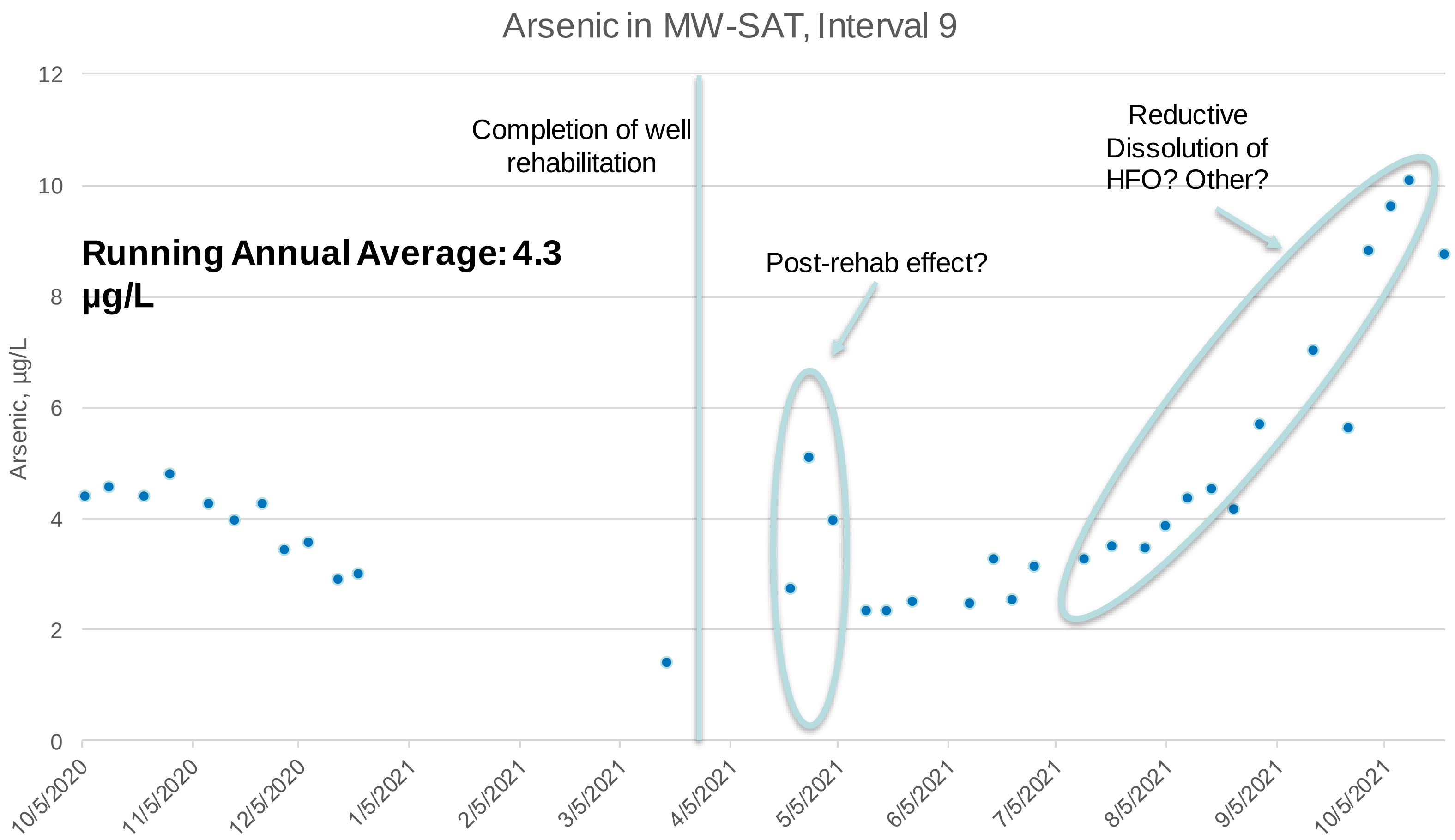
Wells have a lot of screen sections

SWIFT RC Monitoring wells



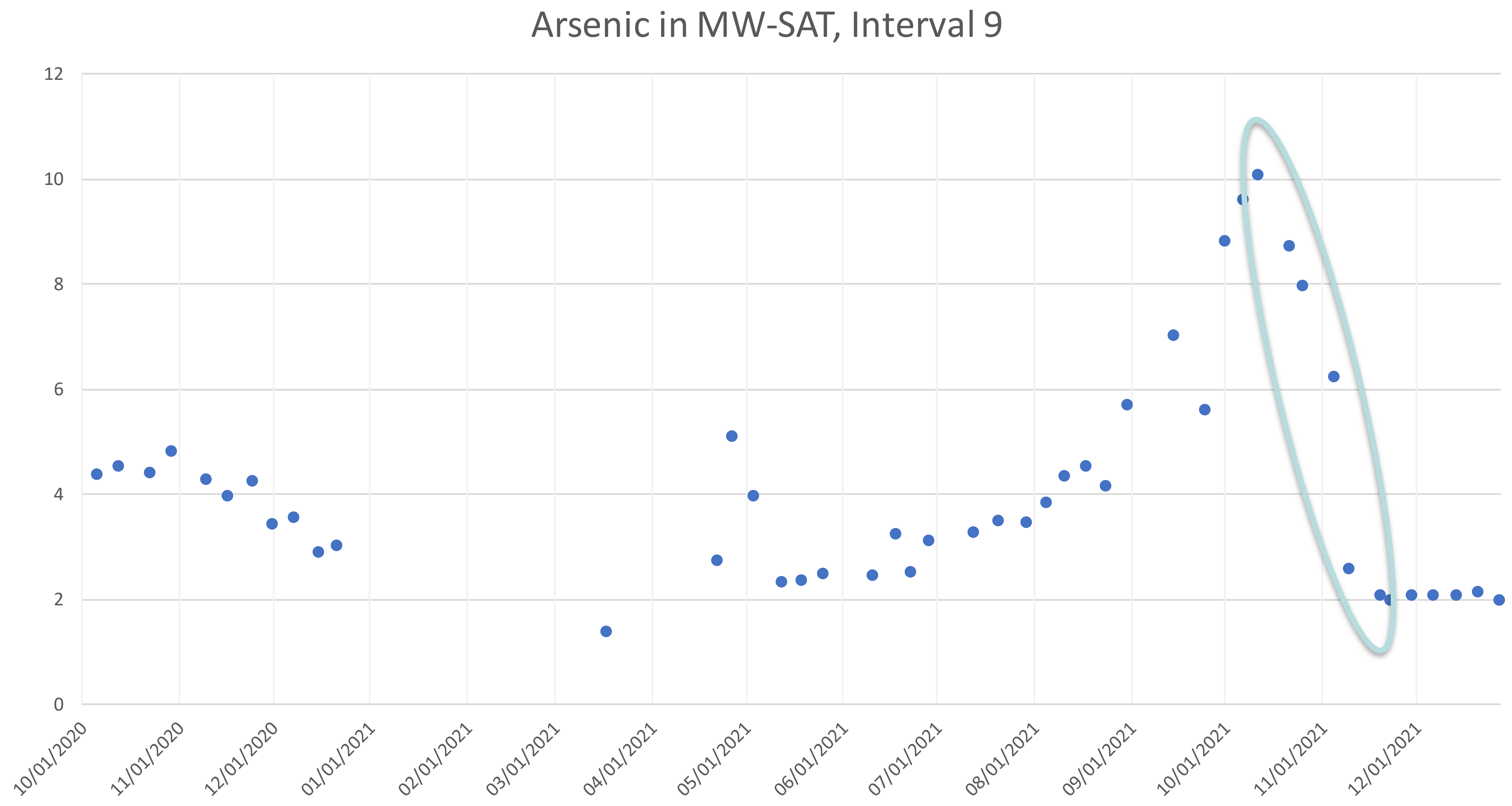
- MW SAT same screen zones as TW-1
- FLUTe sampling system allows sampling of each screen
- **Dedicated sampl port located at center of each screen zone**

SWIFT Research Center Arsenic Monitoring, MW-SAT previous meeting

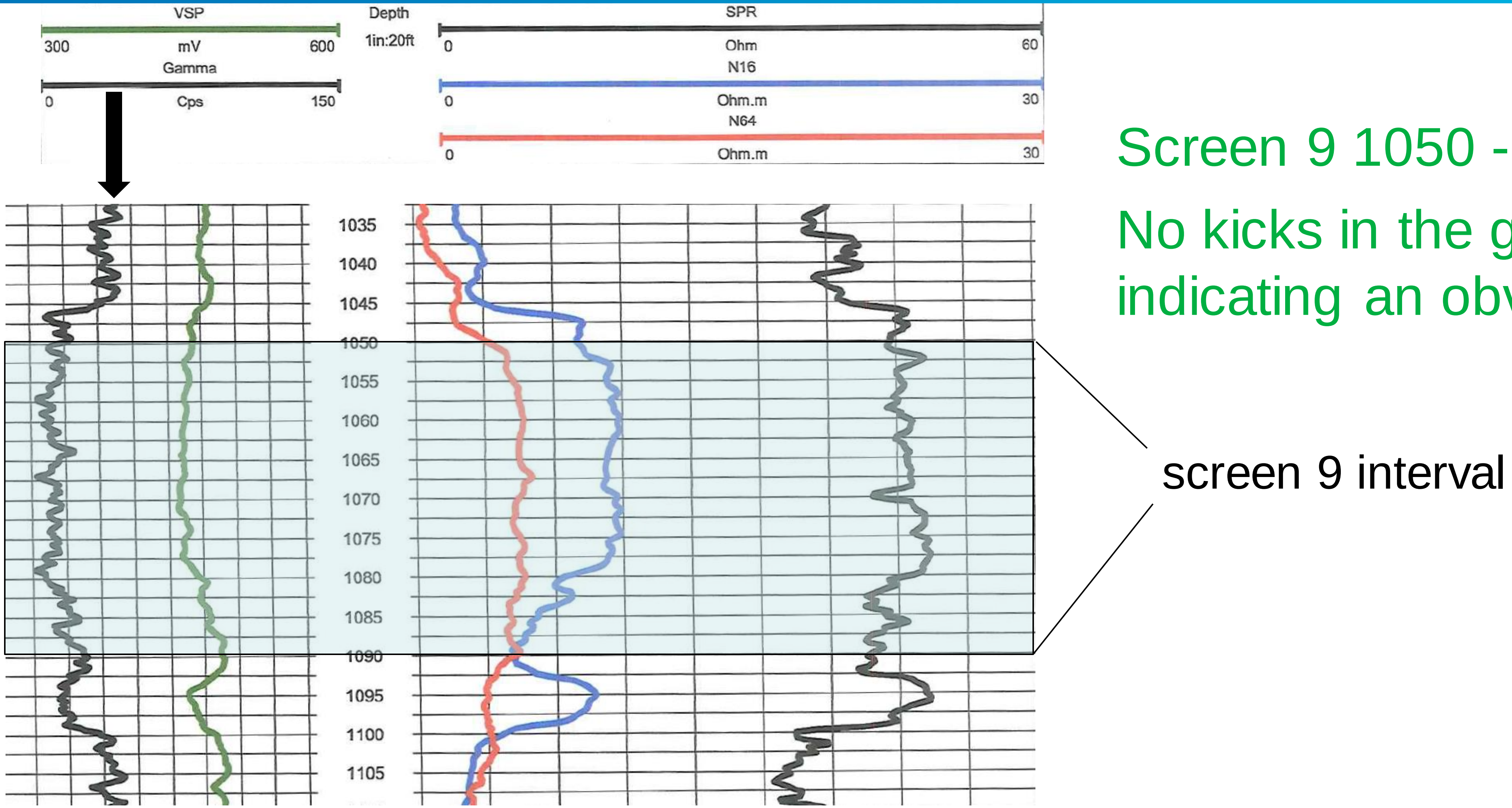


Arsenic in conventional MW-UPA and MW-MPA wells remains <1µg/L

SWIFT Research Center Arsenic Monitoring, MW-SAT updated



- SWIFT Water As consistently below <1µg/L
- No source was observed in the well cuttings or core from Test Well program
- Source must be in aquifer matrix
- DEQ suggestion to examine geophysical logs/geology logs for indications of known source



Screen 9 1050 - 1090

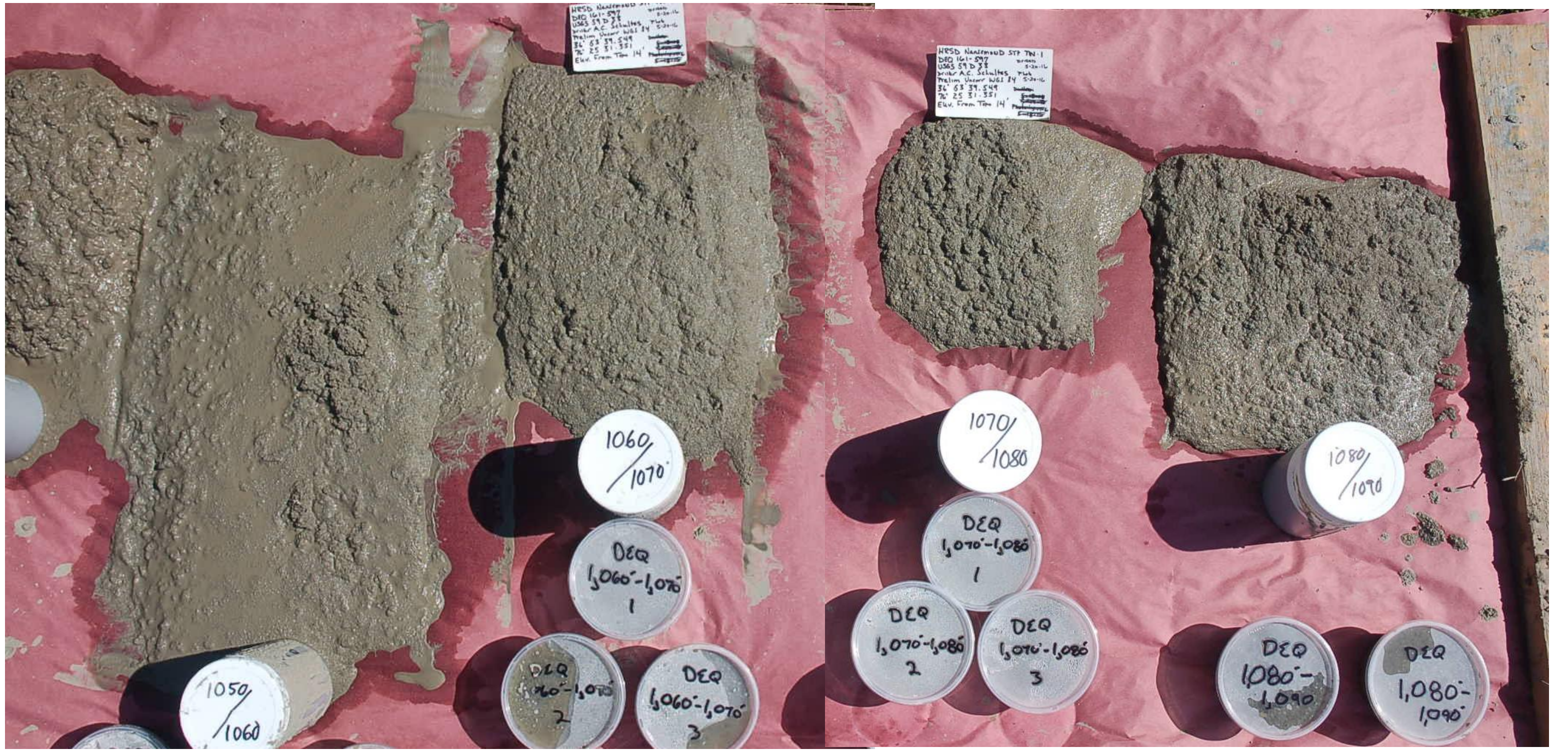
No kicks in the gamma log indicating an obvious source

FEET FROM GROUND SURFACE 0 TO	WELL LOG
865-885	Clay and sand mix, more clay than sand
885-896	Harder clay with sand streaks
896-921	Soft clay with sand layers
921-926	Med hard clay
926-934	Hard, red clay
934-947	Red and gray clay hard
947-958	Hard red and gray clay
958-968	Gray and red clay
968-973	Gray clay
973-989	Sand and gray clay
989-1020	Med hard clay
1020-1025	Med hard clay
1025-1050	Sand and sandy clay
1050-1077	Good sand
1077-1085	Sand with clay layers
1085-1097	Sand and clay layer 50/50 mix
1097-1113	Hard red and gray clay
1113-1122	Hard clay with sand layers
1122-1139	Good sand

Screen 9 1050 - 1090

Indicates some clay layers in deeper portion of screen zone

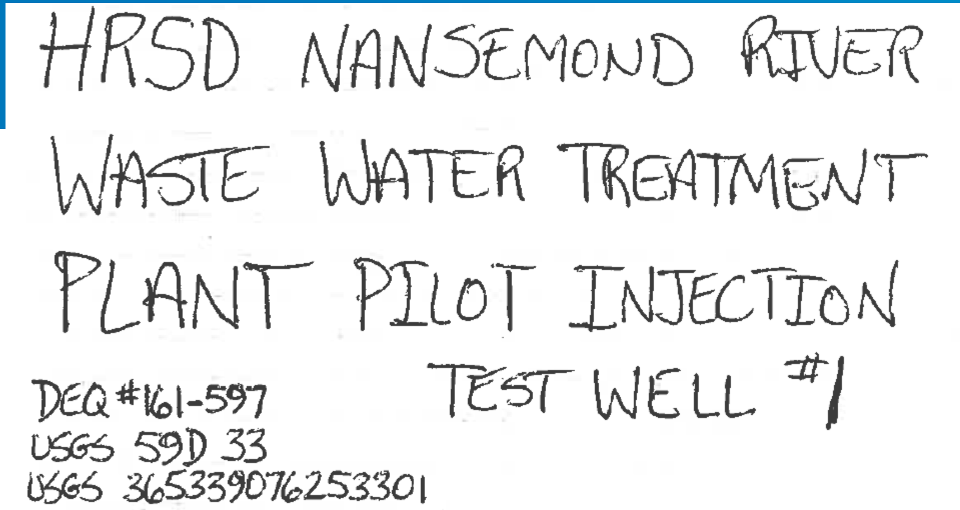
screen 9 interval



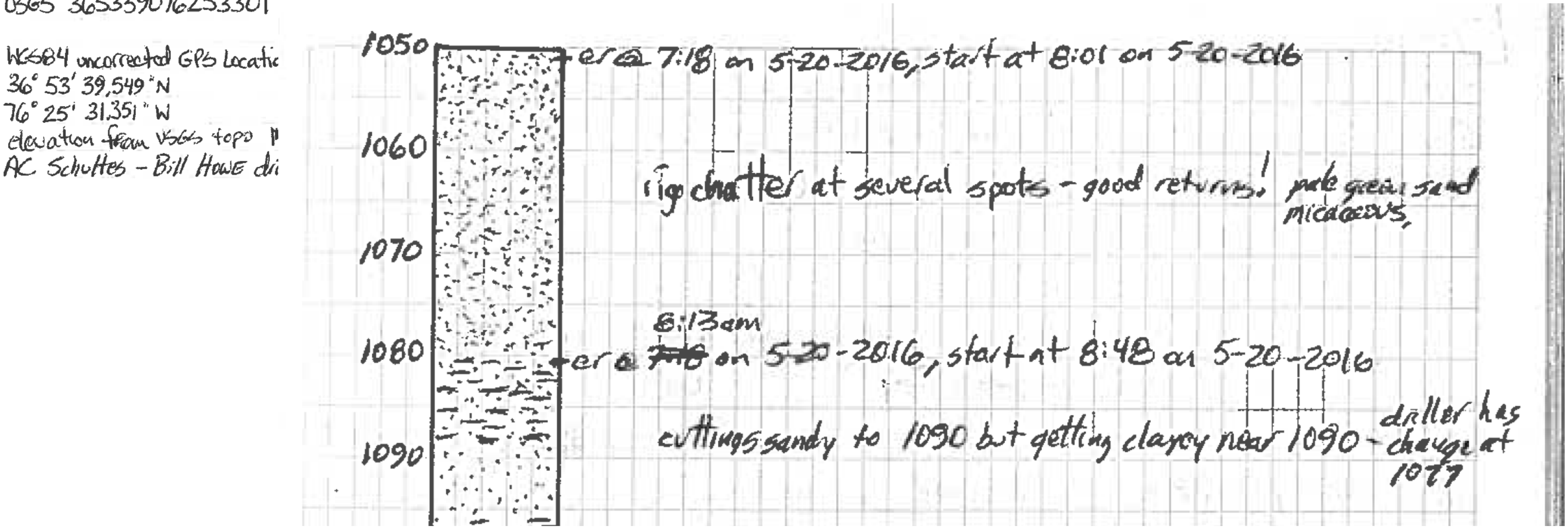
1050-1060 1060-1070 1070-1080 1080-1090

Screen 9 1050 - 1090

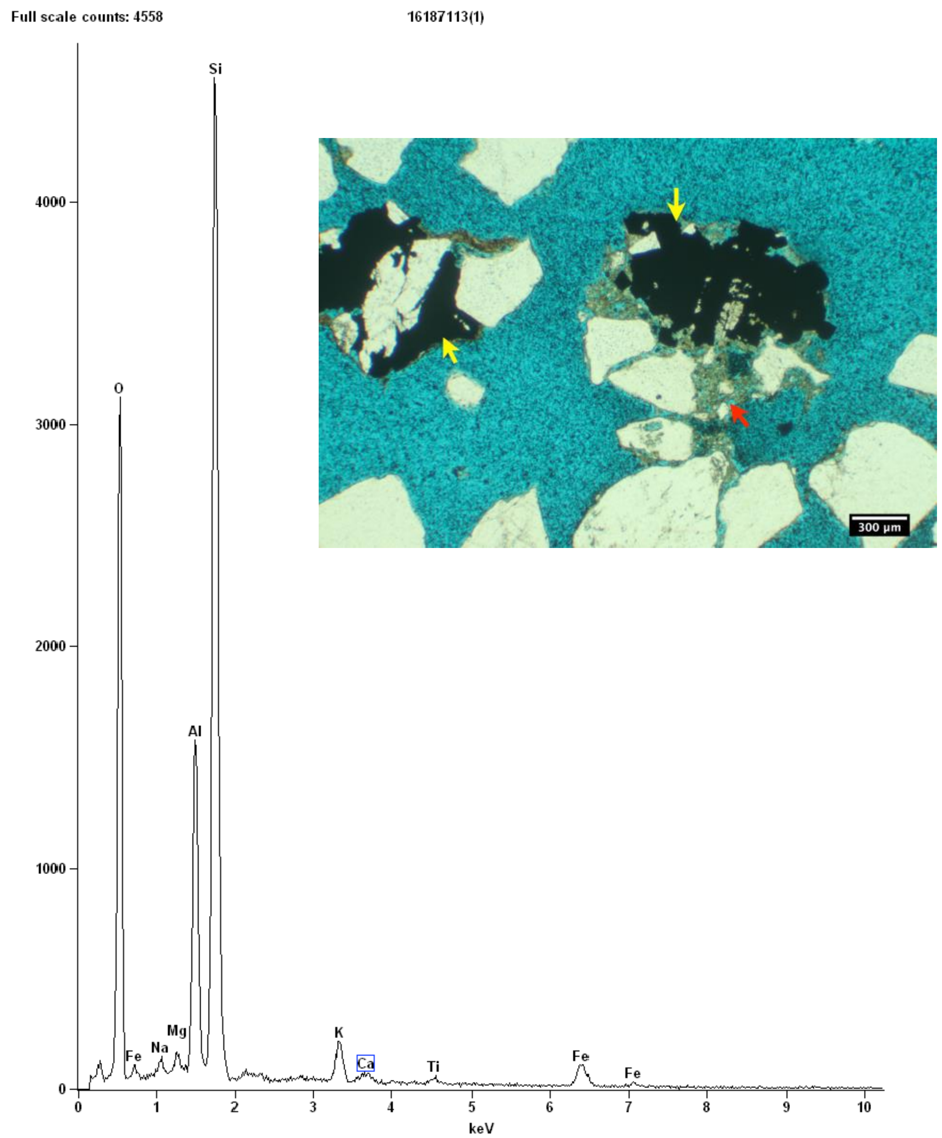
No indication of heavy clay or greasy layer known to be associated with pyrite/As.



Encounter some finer grained units approaching 1090'



- **XRF** – X-rays irradiate a sample and the elements present emit a fluorescent X-ray radiation that is characteristic for those elements.
- **XRD** – x-ray irradiate a sample and measuring intensities and diffraction angles
- **EDX** - energy dispersive x-ray – hit sample with electron beam and measure unique x-rays coming off
- **Petrographic** – quantitative thin section petrography
- *And later…***ICP-MS** - Inductively coupled plasma mass spectrometry, can detect at very low levels



SRC TW-1 Cuttings

- 10 cuttings samples
- XRD Pyrite:
  - <0.3% @ 700 to 710 fbg, UPA
  - < 0.3% @ 925 to 935 fbg MPA
  - 1% @ 1020 to 1030 fbg MPA
- XRD iron oxides FeOH3(a):
  - 0.5% @ 525 to 535 fbg
  - 0.5% @ 555 to 565 fbg
  - 0.5% @ 720 to 730 fbg
- XRF: As below MDLs
- Petrographic analysis: Pyrite & amorphous Fe(OH)3(a) not IDed during point counts.

- 9 Core samples
- XRD - No pyrite or amorphous Fe(OH)3(a) IDed
- XRF - As below MDLs
- Petrographic modal analysis - every sample examined contained around 0.3% Fe(OH)3(a), but no pyrite.

ICP-MS analysis

Represents the best analysis to look for arsenic as shown at VIP:

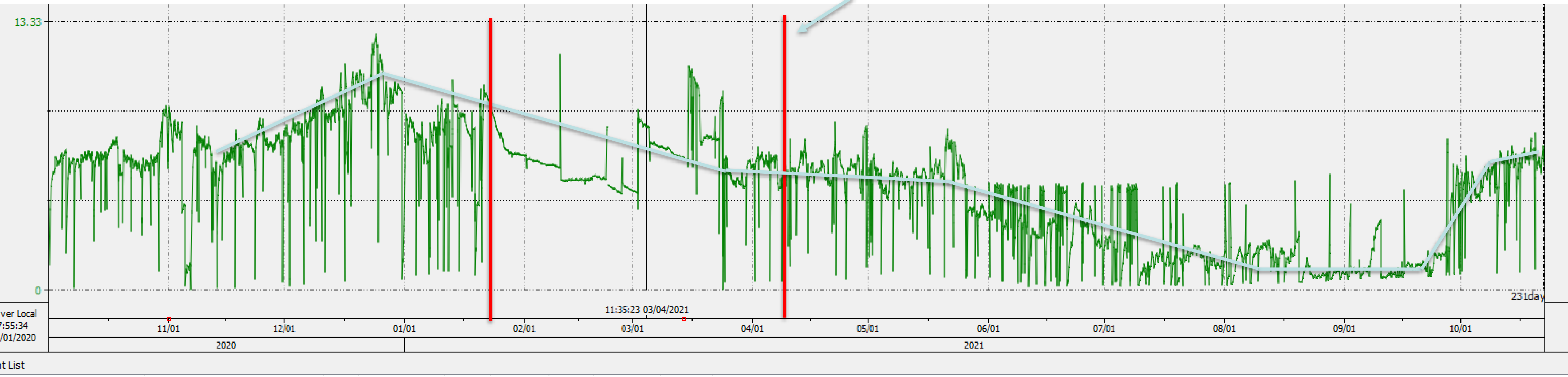
Summary of Cores Selected for ICP-MS Analysis							ICP-MS Analysis							
Depth Interval (ft below grade)		Screen	Aquifer	Main Component and Grain size	Sorting	Mineralogy	Constituents (mg/Kg)							
From	To	(#)					Arsenic	Manganese	Aluminum	Calcium	Iron	Magnesium	Potassium	Sodium
740	746	1	UPA	fine to coarse SAND	well	trace RTZ, and dark minerals	0.55	22.2	3190	742	2060	589	356	659
761	763.2	Between 1 & 2	UPA	fine to very coarse SAND	well	trace RTZ, k-spar, and black minerals	1.75	18.6	2050	563	2140	387	303	404
809	811.5	2	UPA	medium to coarse SAND,	well	trace RTZ and black minerals	0.85	14.9	806	484	1520	281	216	335
991	993.4	4	UPA	silty SAND	poorly		0.4	24	2080	561	1520	435	240	746
1196	1198.5	6	MPA	medium to coarse SAND, trace pebbles	poorly	some clay, little muscovite, trace undifferentiated black minerals	0.62	8.74	686	290	858	241	164	489
1310	1311.5	7	MPA	medium to fine SAND, little Silt, trace (+) Clay	poorly	trace opaques, RTZ, and EPI/CHL	0.94	11.5	12300	2140	6270	150	1000	3490
1377	1378.5	8	MPA	very fine to fine SAND,	moderately	trace orthoclase and undifferentiated opaque minerals	0.85	9.87	2750	447	1910	374	307	752
1541	1543	10	LPA	fine to coarse SAND, little fine gravel	poorly	laminated gray staining	2.47	14.6	1300	404	1880	392	256	846
1607.7	1609.5	11	LPA	medium to coarse clayey SAND, trace fine gravel and clay clasts			0.72	9.59	1360	428	1330	286	213	831
1776	1778	13	LPA	fine to coarse SAND, trace fine gravels	moderately		0.16	38.7	2370	344	1380	264	336	951
1860	1870	14	LPA	fine to medium SAND	moderately	trace black and pink minerals,	<0.3	15.2	6490	1580	3720	1140	527	2640

- Didn’t observe As, but have one borehole – **must assume it is present**
- Increase SWIFT Water pH above the solubility limit of iron,
- Buffers the dissolution of iron-bearing minerals, and
- Precipitating HFO on the surface of the minerals, which performs the following:
  - Inhibits the reactivity of reduced metal-bearing minerals (passivate)
  - Adsorbs arsenic migrating in the aquifer
  - Adsorbs potential competitive oxyanions
- The approach works well in aquifers rich in iron-bearing minerals and redox-transitional zones, like the Potomac aquifer in the Nansemond area

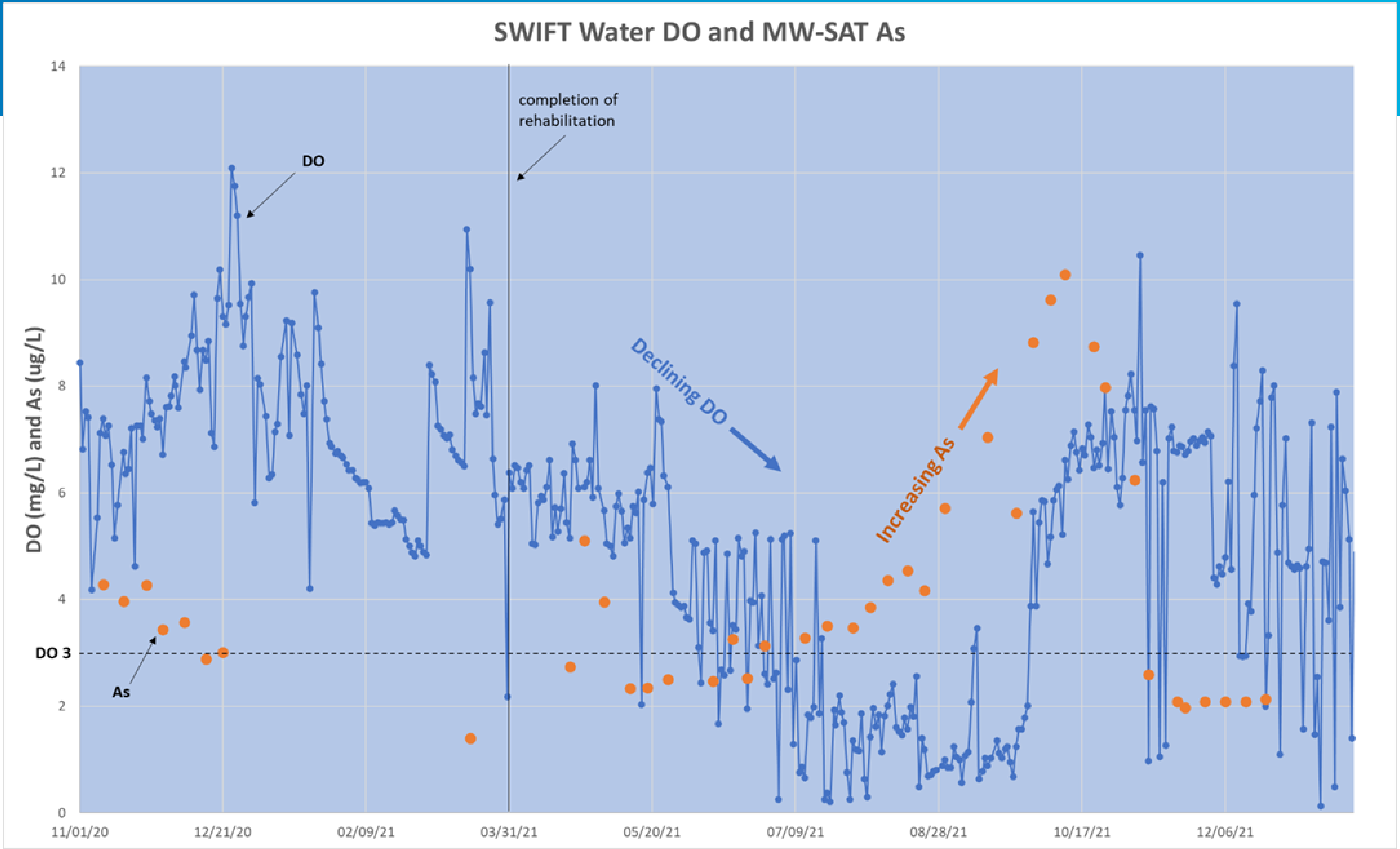
- Three general mechanisms for releasing Arsenic
  - Pyrite Oxidation, dissolution of arsenic-bearing pyrite and arsenopyrite (melting pyrite) – occurs at leading edge of bubble
  - Competitive desorption between phosphate and arsenic at higher pH (phosphate kicks off the arsenic) – occurs later in recharge operations
  - Reductive dissolution of arsenic-bearing iron oxides (melting HFO), **Declining DO**, or increasing reactive organic carbon, in the SWIFT Water could produce redox conditions reducing enough to dissolve HFO – increase in As V (has affinity for HFO)

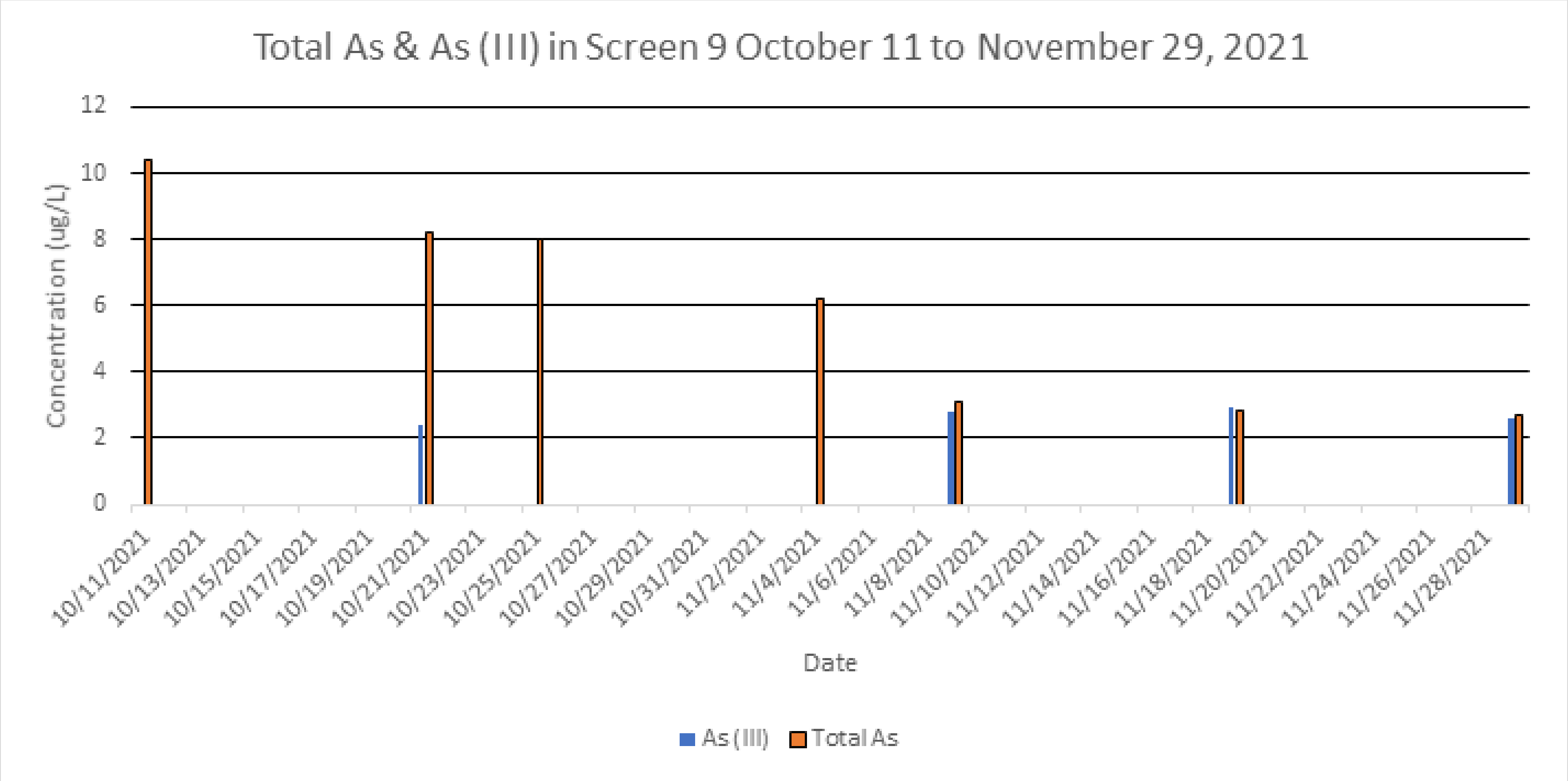
SWIFT Water DO trend

End of
rehabilitation



12/20 04/21 06/21 10/21


SWIFT Water DO and MW-SAT As
DO (mg/L) and As (ug/L)
14
12
10
8
6
4
DO 3
2
0
11/01/20
12/21/20
02/09/21
03/31/21
05/20/21
07/09/21
08/28/21
10/17/21
12/06/21
completion of rehabilitation
DO
As
Declining DO
Increasing As



- Arsenic III is very stable across the speciated samples, just above 2 Ug/L
- When As values are low, As (III) dominates
- When As concentration is elevated, As (III) stable, As (V) increases
- Points to reductive dissolution

- Elevated As due to drop in SWIFT Water DO below 3 mg/L resulting in reductive dissolution of HFO surfaces
- Ensure SWIFT Water quality that establishes and maintains HFO
  - Maintain SWIFT Water DO at 3 mg/L or higher
  - Maintain SWIFT Water pH at 6.8
- Continue to collect data that will help us understand and model geochemical relationships between arsenic, redox chemistry, organic carbon and pH
- Answer the following questions:
  - What caused SWIFT DO to drop?
  - How can that be mitigated?

- Extra slides

As sources at JR

- XRD: Pyrite 1% @ 491 to 493 fbg, UPA
- XRF: As 0.0056% @ 1120 to 1122 fbg, MPA.
- Petrographic Analysis: Pyrite 0.3% of 300-point count at 1178 to 1180 fbg MPA.
- Obtain ICP-MS on cutting samples from the first three wells at JR SWIFT.

Nansemond SWIFT Full Scale Well: NP_MAR_01

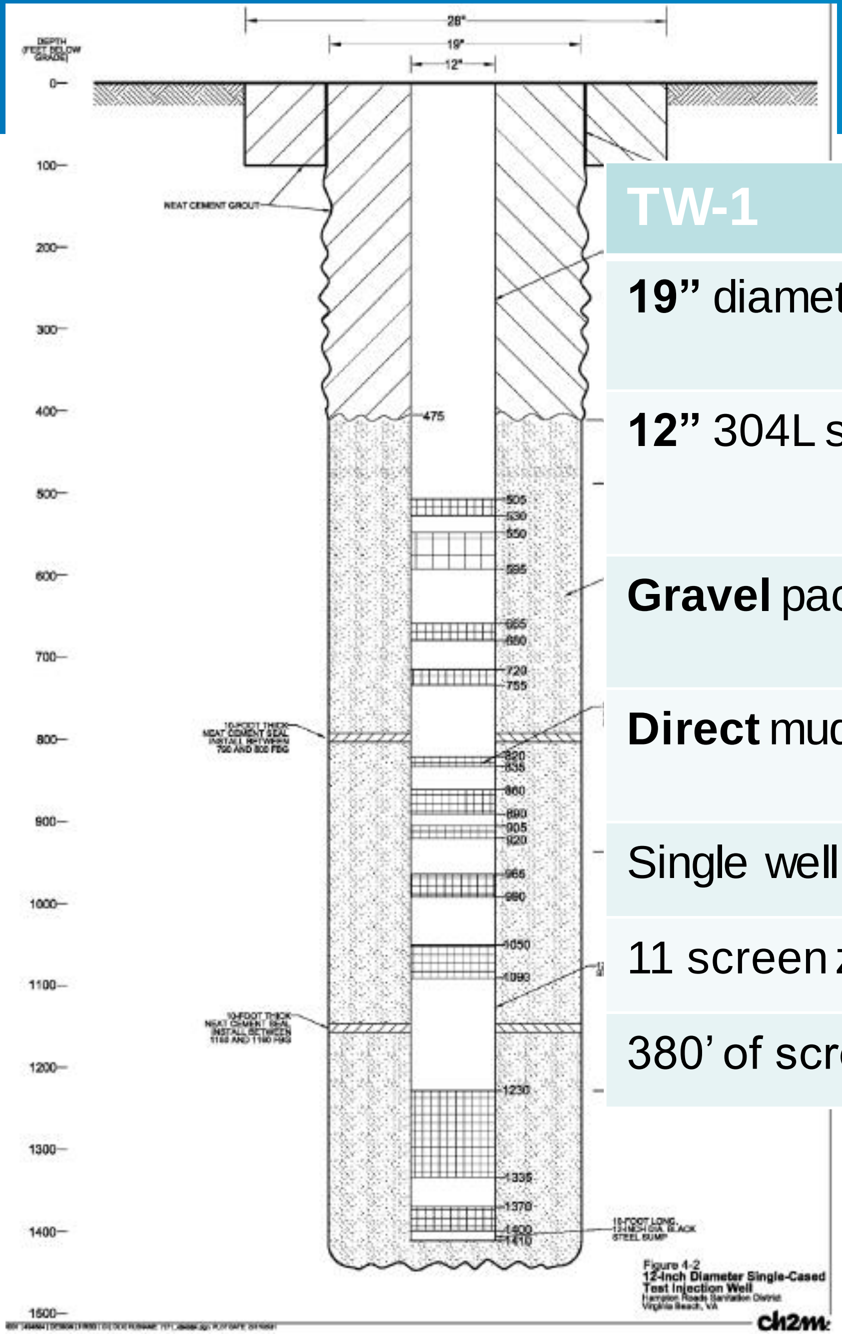
- Completed installation and testing of the first SWIFT Full Scale Managed Aquifer Recharge well
- Located at Nansemond SRC
- Very good hydraulic response
- 2,800 gpm (4 MGD!) with test pump wide open

NP_MAR_01 pumping 2,800 gpm during testing

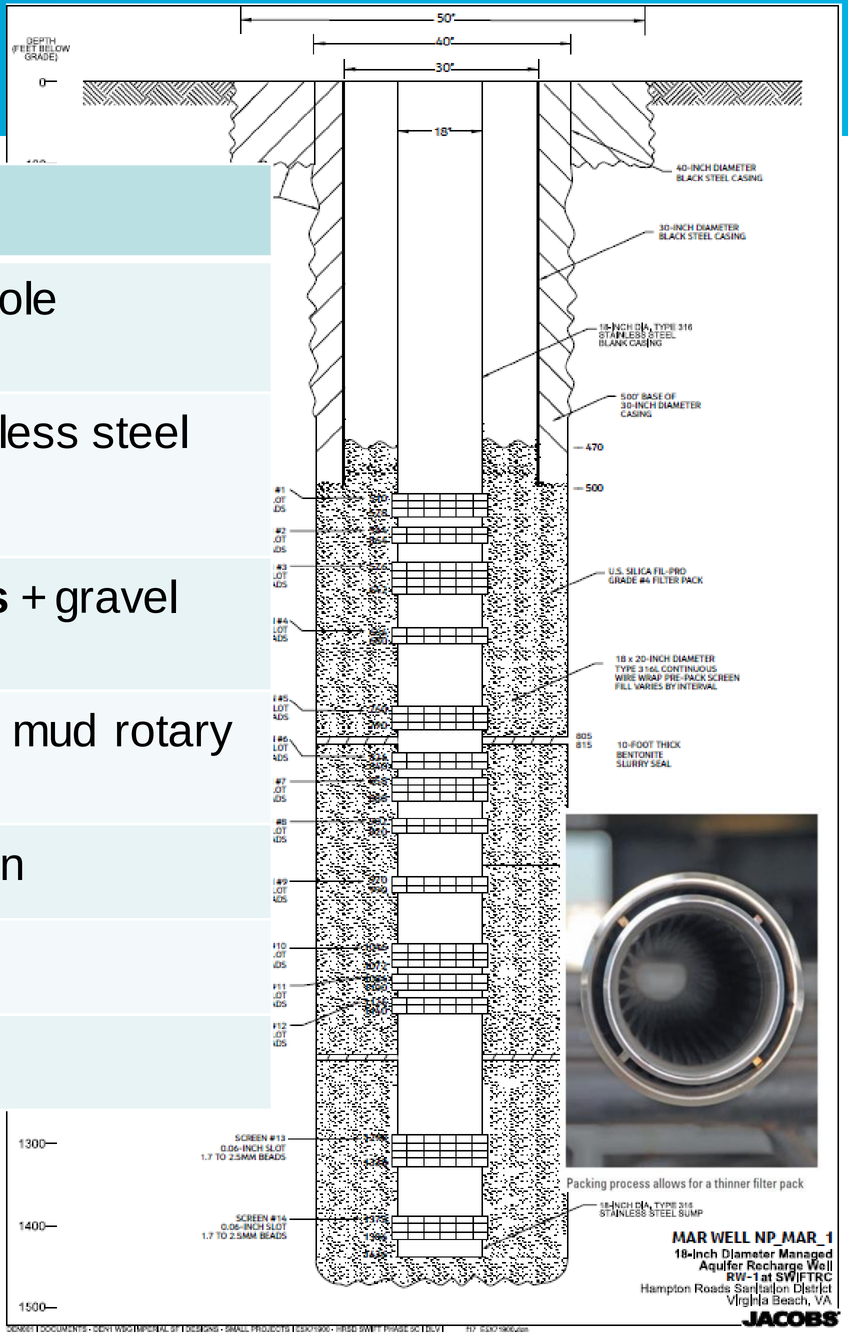
NP_MAR_01 going down the borehole

HRSD swift

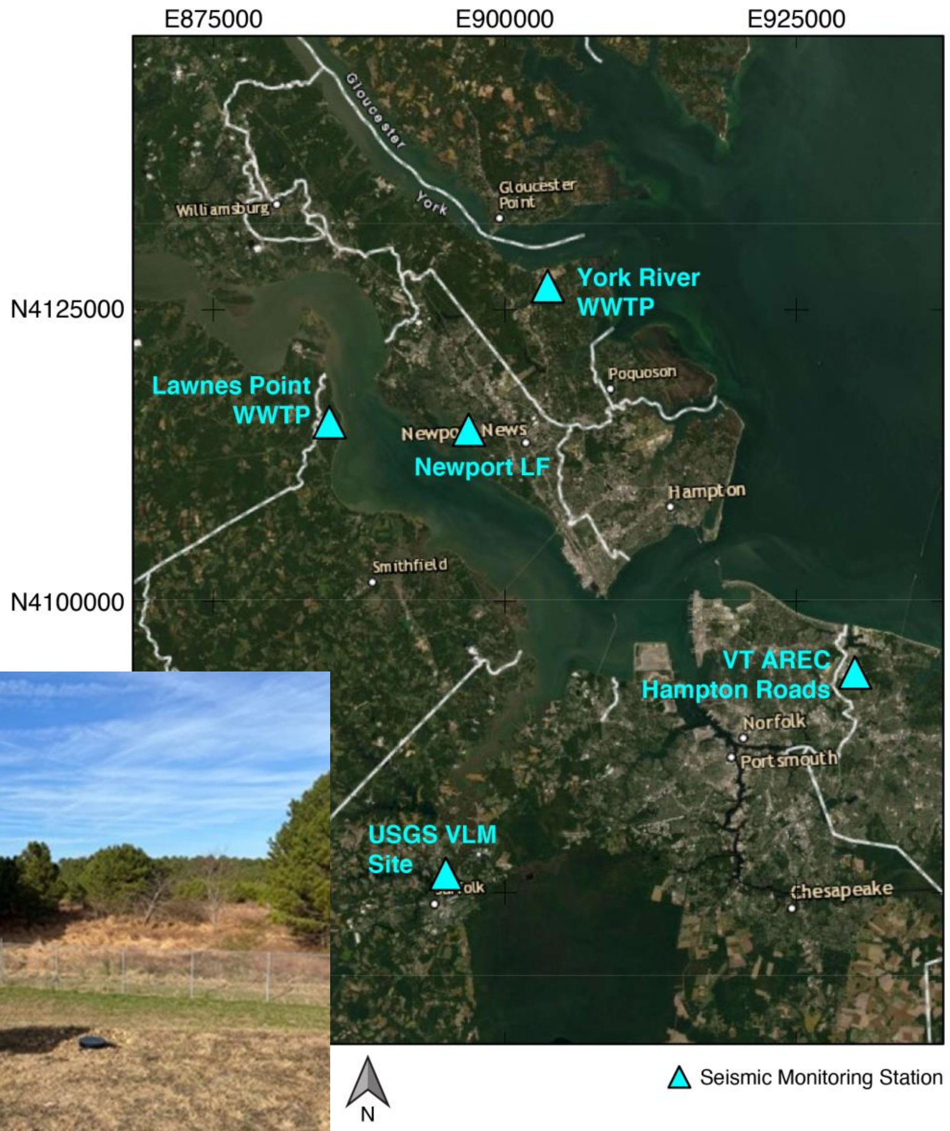
TW-1 vs NP_MAR_01



TW-1	NP_MAR_01
19” diameter borehole	**30”** diameter borehole
12” 304L stainless steel screen	**18”x20”** 316L stainless steel pre-packed screen
Gravel pack only	Si **spherical beads** + gravel pack
Direct mud rotary drilling	**Reverse** circulation mud rotary drilling
Single well casing/screen	Overlap construction
11 screen zones	14 screen zones
380’ of screen	342’ of screen

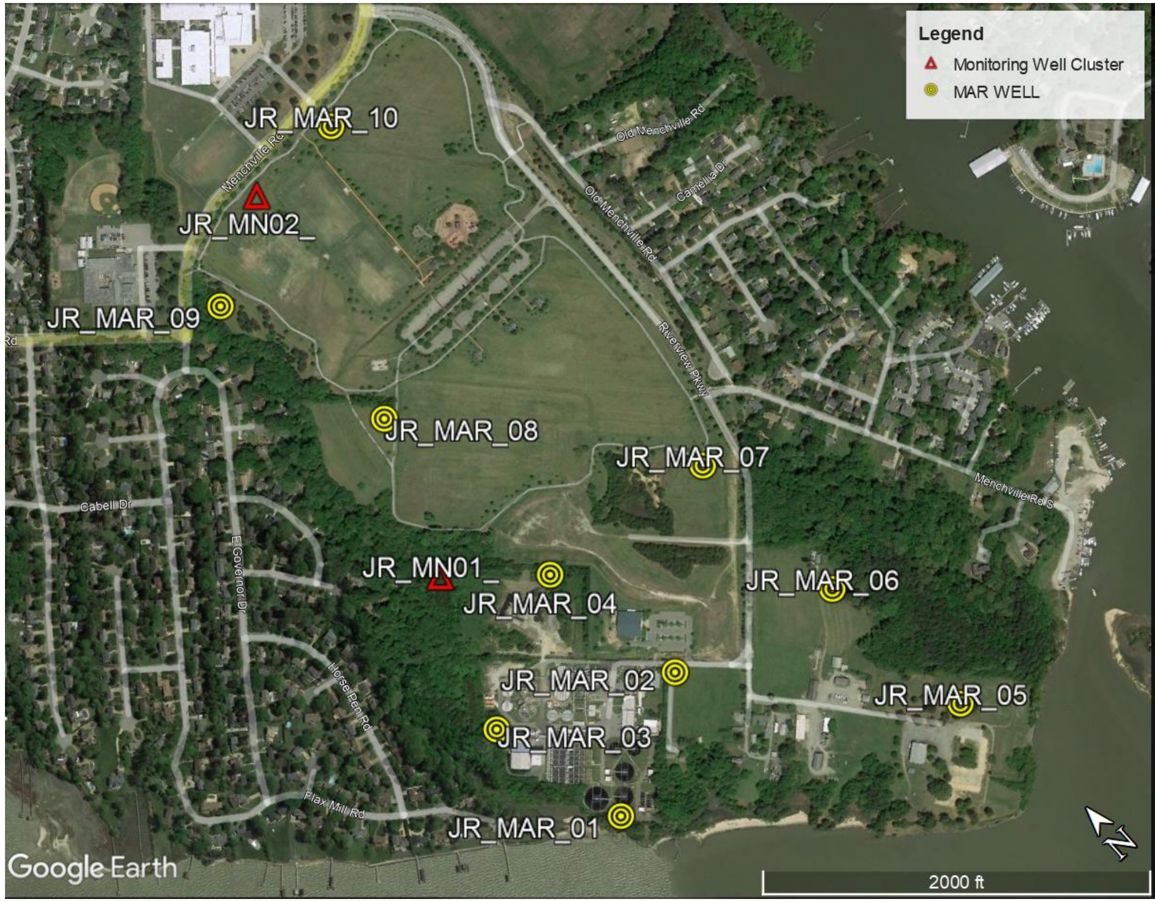


- Collect background data prior to starting JR SWIFT
- Collect data during operation of JR SWIFT
- VT Geosciences/Center for Coastal Studies
- Installed seismic stations
  - Instrument 24” into the ground
  - Battery, data logger/modem, solar charging
- 5 monitoring sites around Hampton Roads



SWIFT Well Installation Program Update

- JR On-Site Wells (3 wells)
  - Bids Reviewed, AC Schultes selected
  - Mobilized to site January 2022
  - Drilling GBHs to submit final designs
- JR Off-Site Wells (7 wells, 8 mws)
  - Procurement package being finalized
  - Advertised for bid February 2022
  - Notice to Proceed May 2022
- Nansemond SWIFT Pre-planning
  - Well siting
  - Property acquisition
  - Drilling logistics pre-planning
- VIP Pre-planning starting 2022



James River SWIFT Well Locations