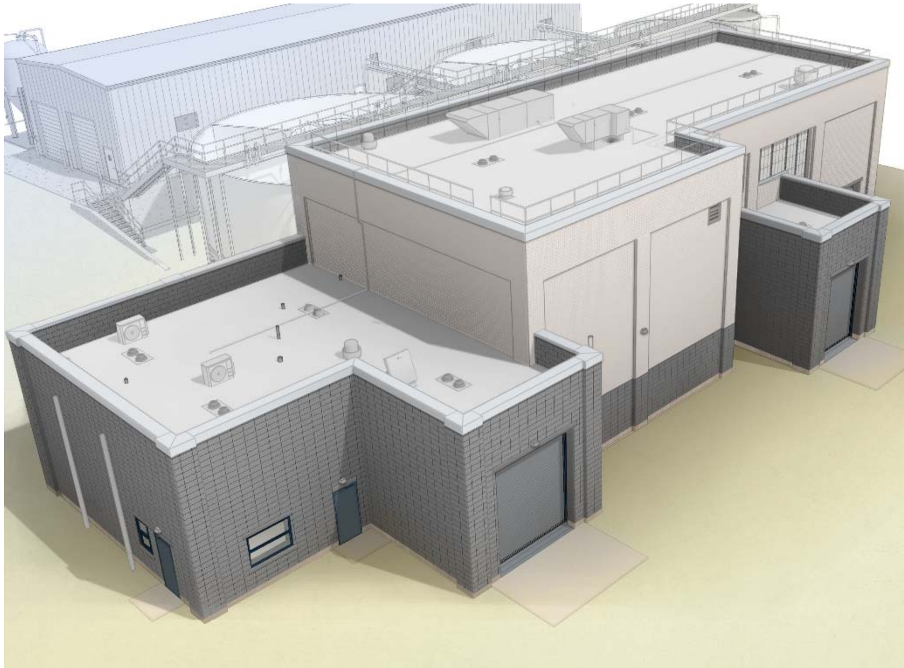


Combe Fill South Superfund Site:

Forty Years to The Finish

Vecteezy.com

January 13, 2021

Combe Fill South Project Team

- Pamela J. Baxter, PhD, CHMM; Remedial Project Manager (US EPA)
- Bradley Williams, PhD; EPA Contract Manager (HDR)
- Patricia Parvis, PG, LSRP; Senior Project Manager (HDR)
- Andrew Watson, PE; Lead Design Engineer (HDR)
- Andrew Wadden, LSRP; RI and Pre-Design Investigation Lead (HDR)

Acknowledgments

Presentation

01 Site History

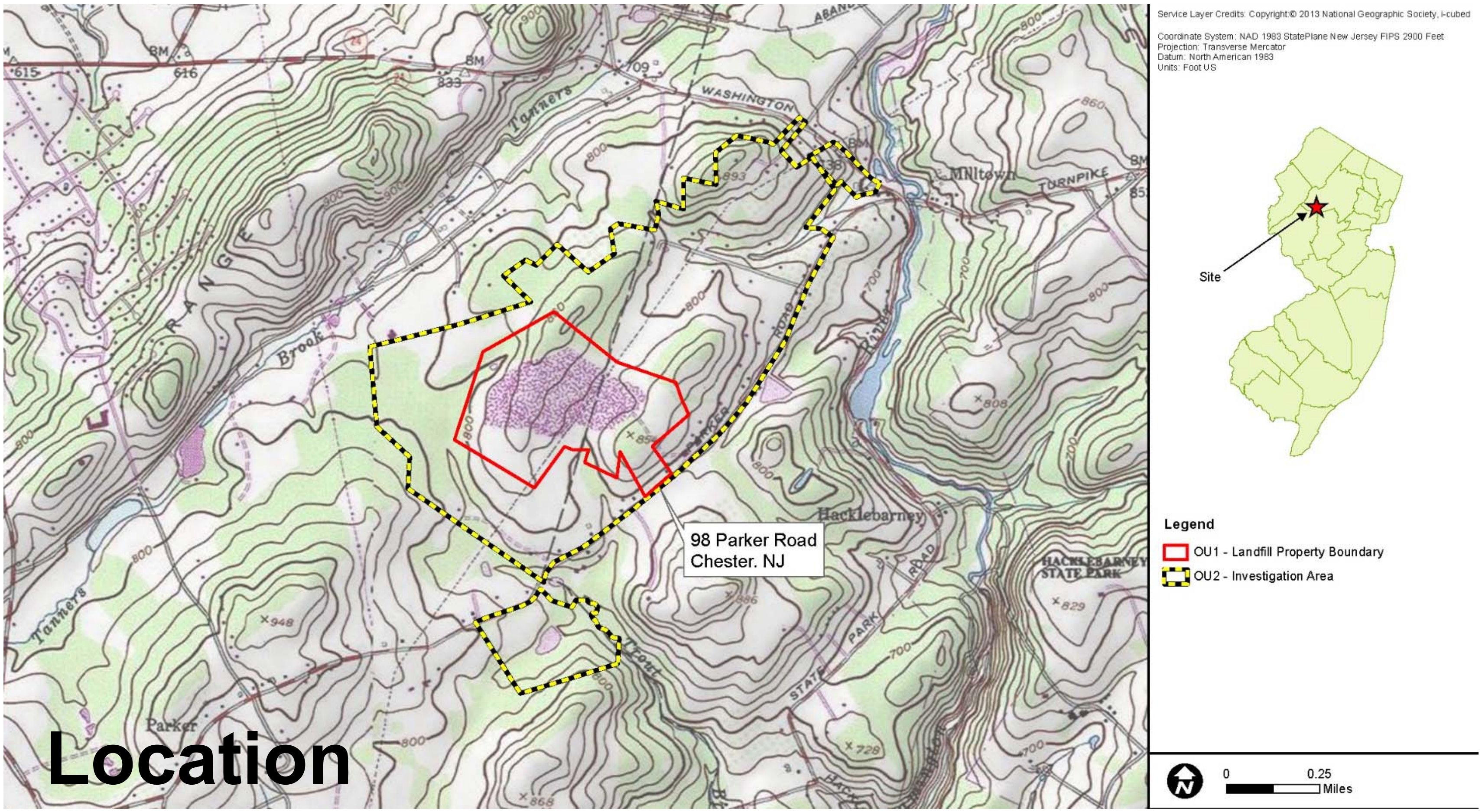
02 Regulatory History

03 Impacts of Evolving Investigative Technologies

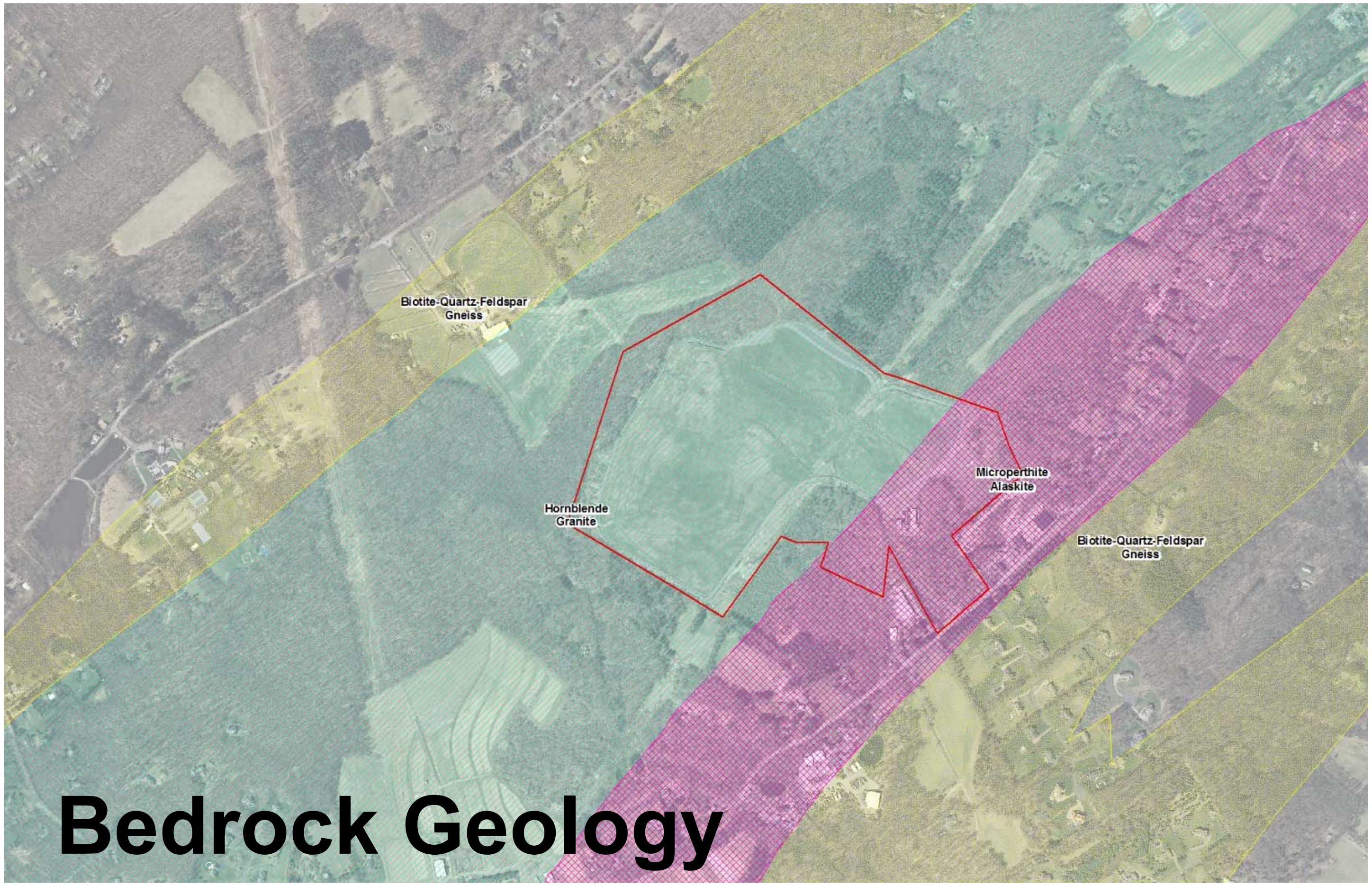
04 Treatment of Emerging Contaminants

01 Site History

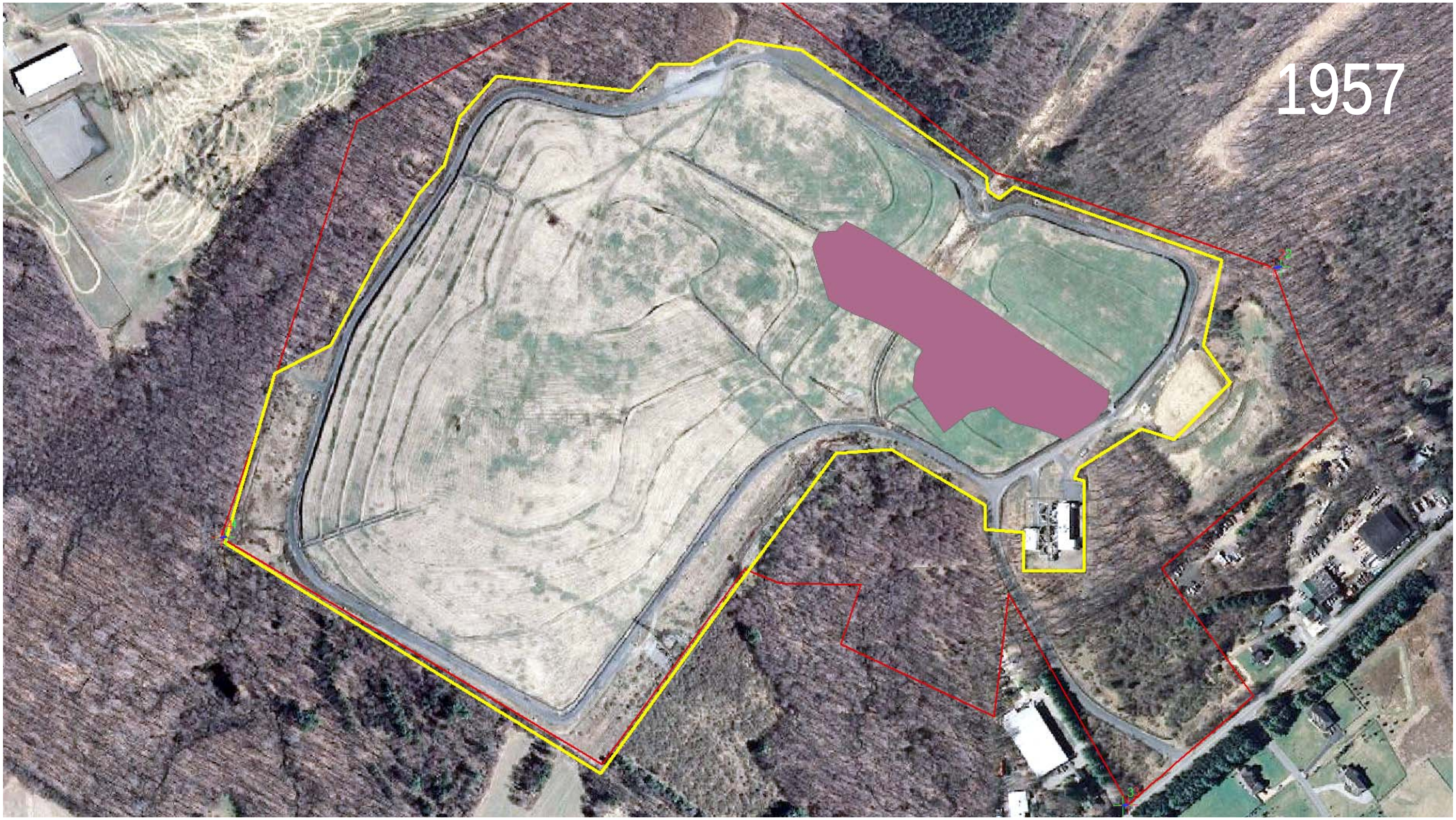
Location

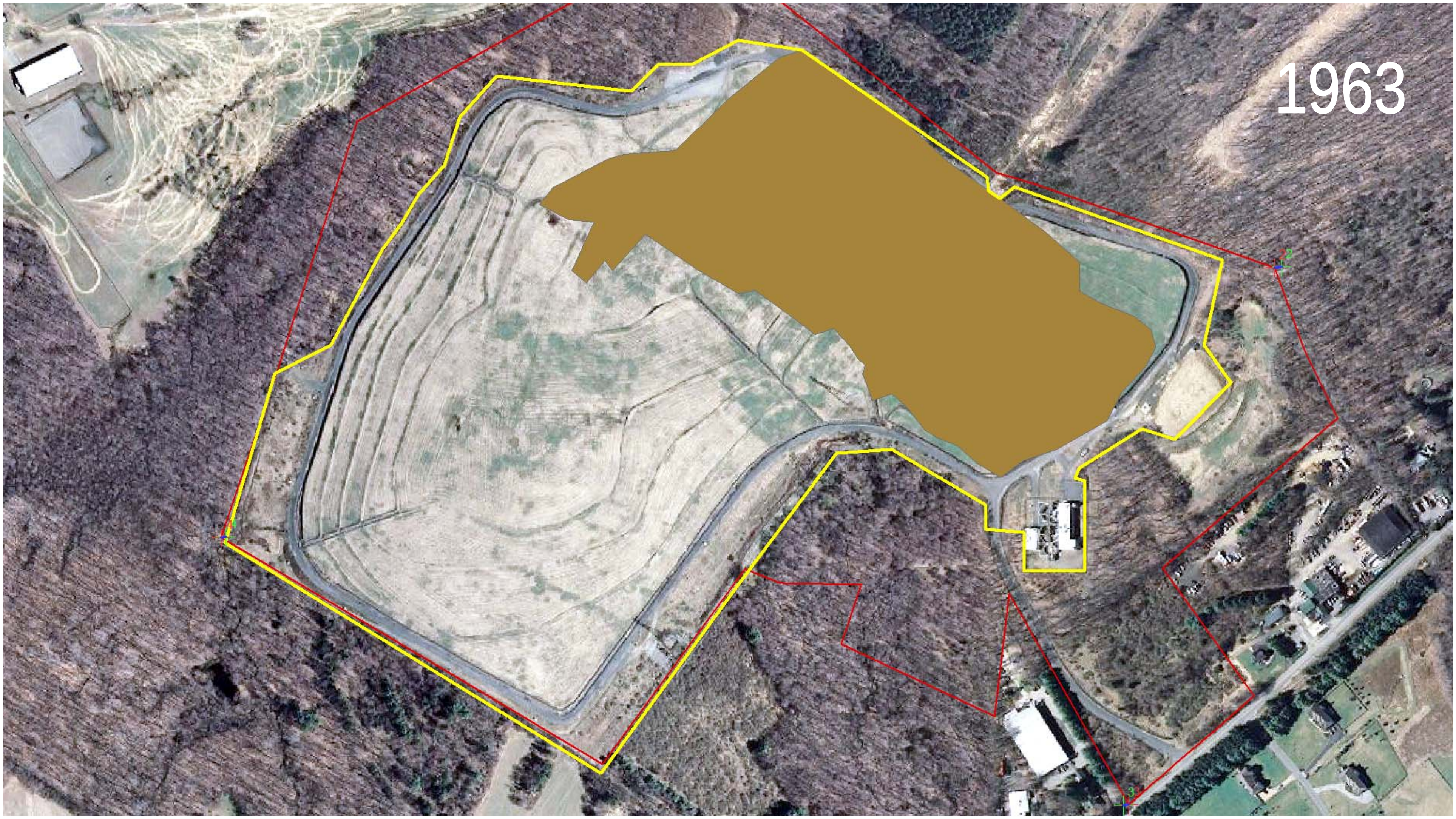


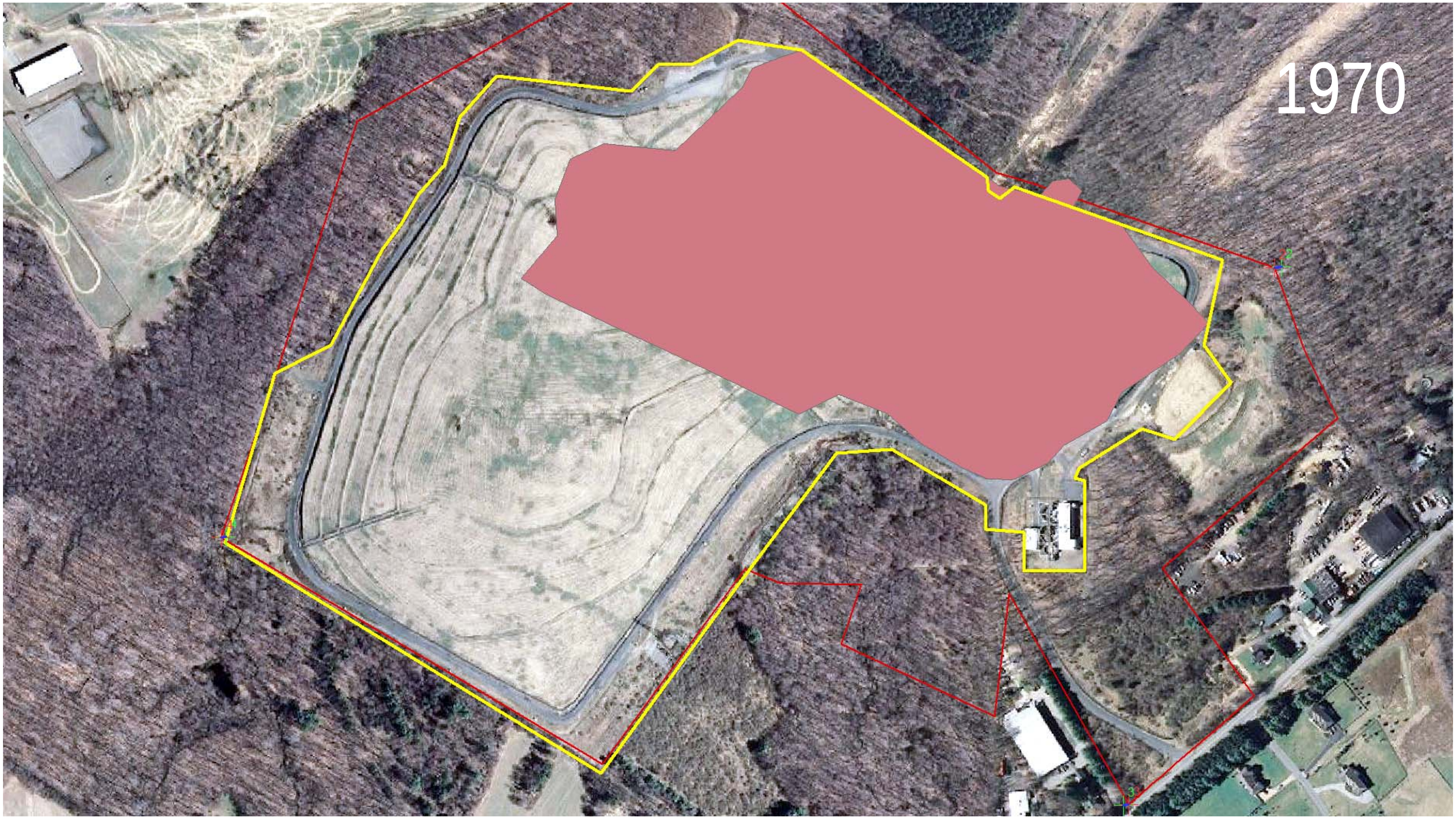
98 Parker Road
Chester. NJ
Service Layer Credits: Copyright:© 2013 National Geographic Society, i-cubed
Coordinate System: NAD 1983 StatePlane New Jersey FIPS 2900 Feet
Projection: Transverse Mercator
Datum: North American 1983
Units: Foot US
Site
Legend
OU1 - Landfill Property Boundary
OU2 - Investigation Area
0
0.25
Miles
WASHINGTON
TURNPIKE
Milltown
Hacklebarney
HACKLEBARNEY STATE PARK
Parker
Tanners
Brook
RANGE
STATE PARK ROAD

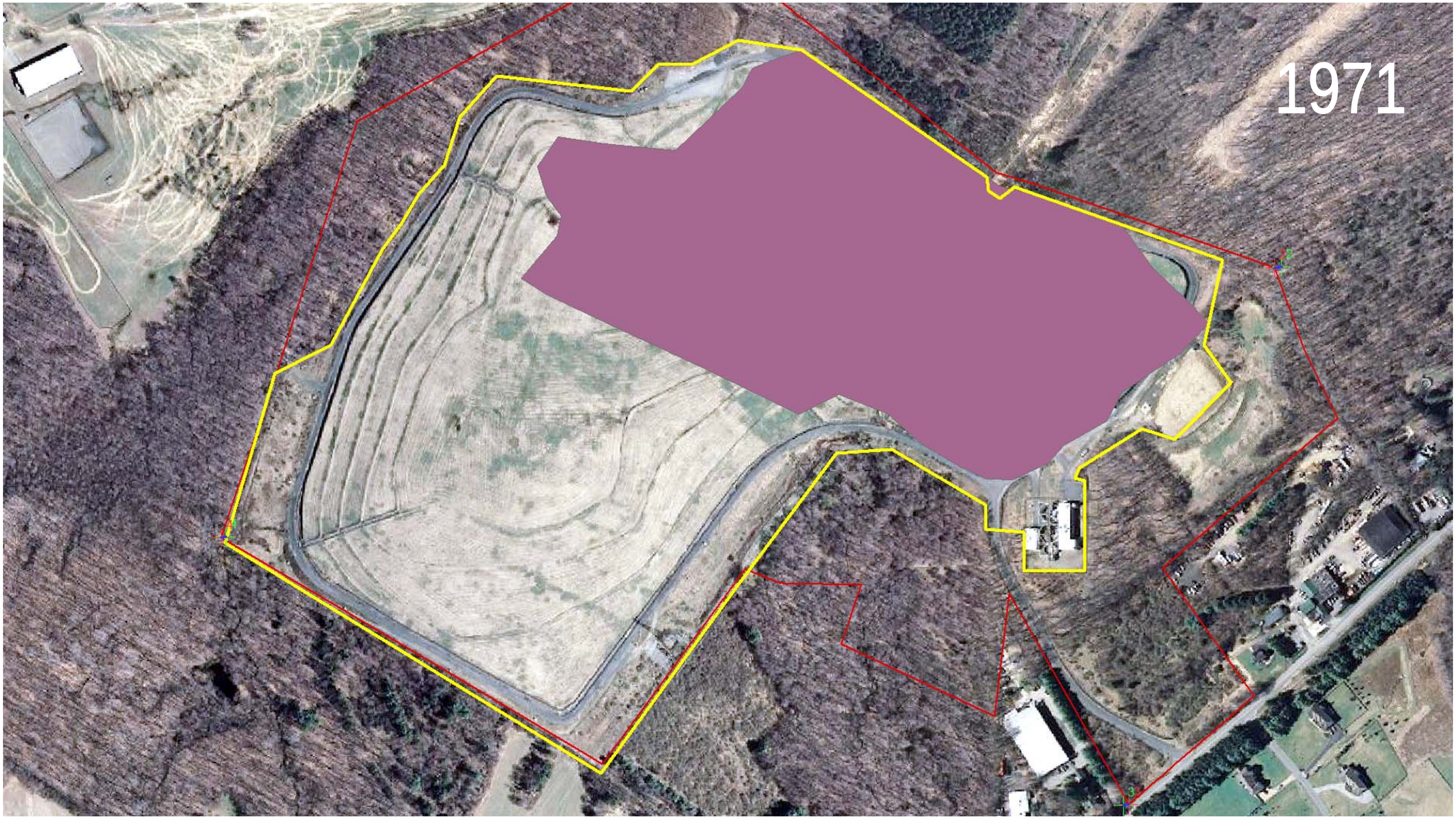


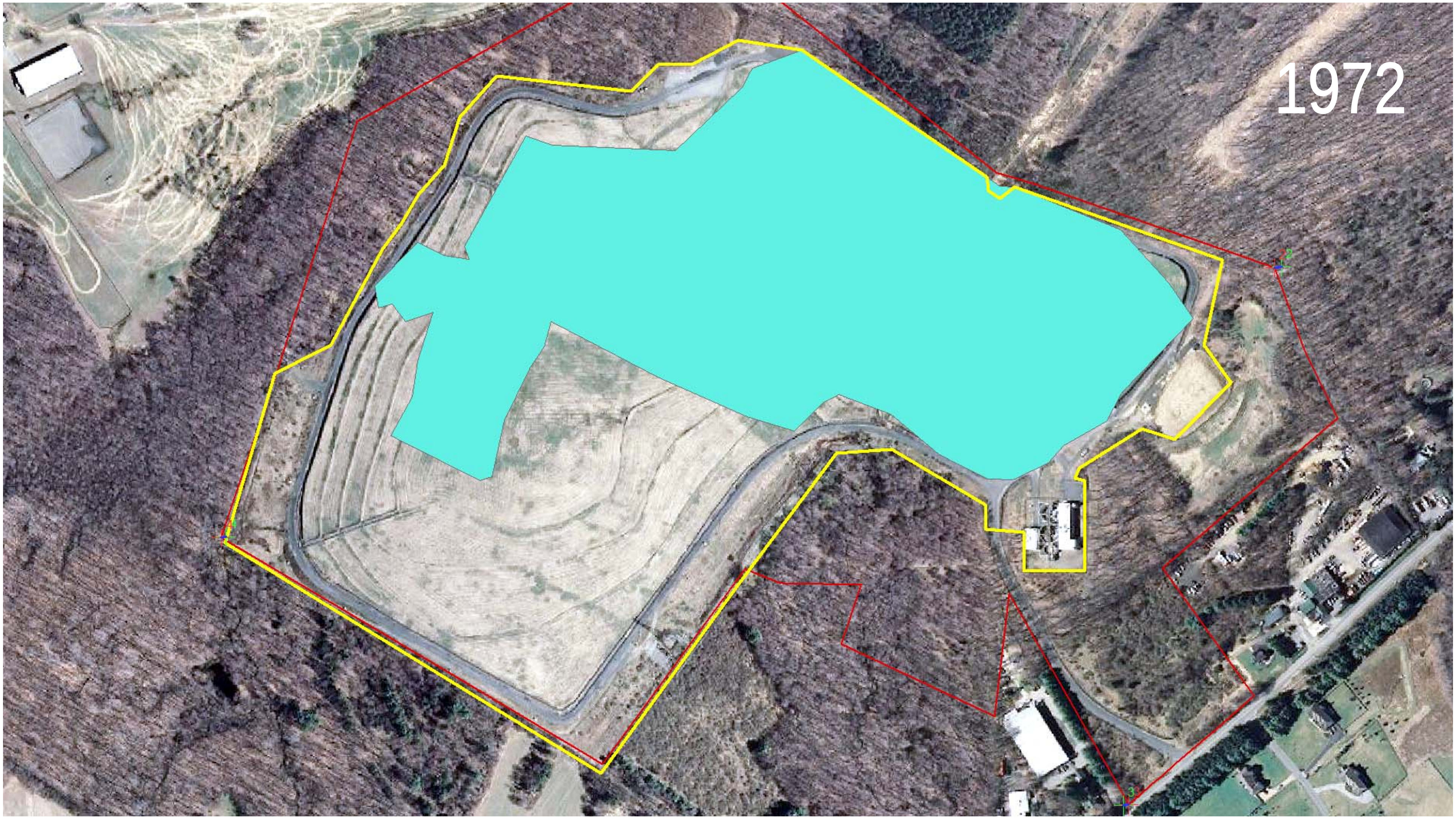
Bedrock Geology

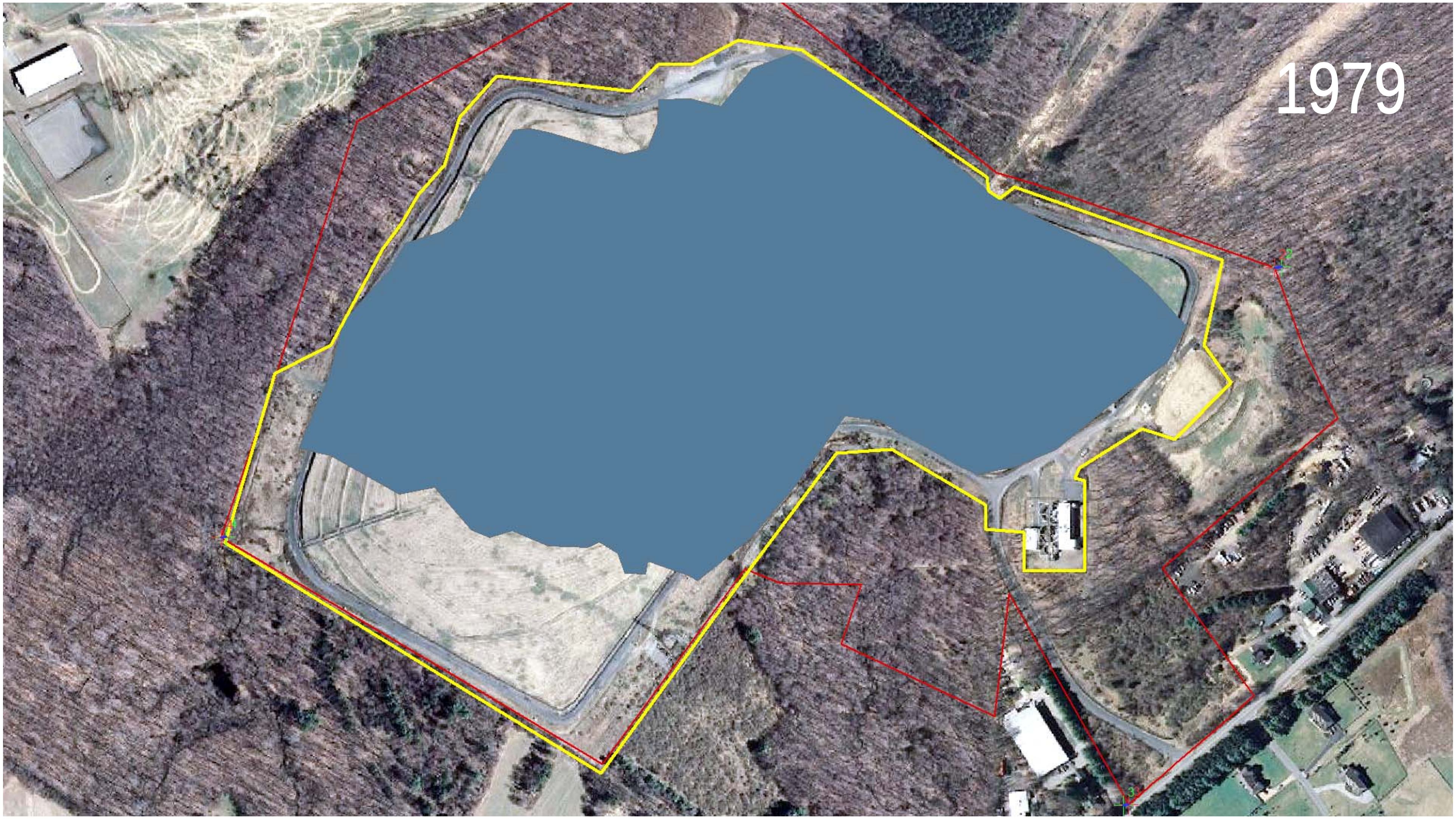

1957


1963

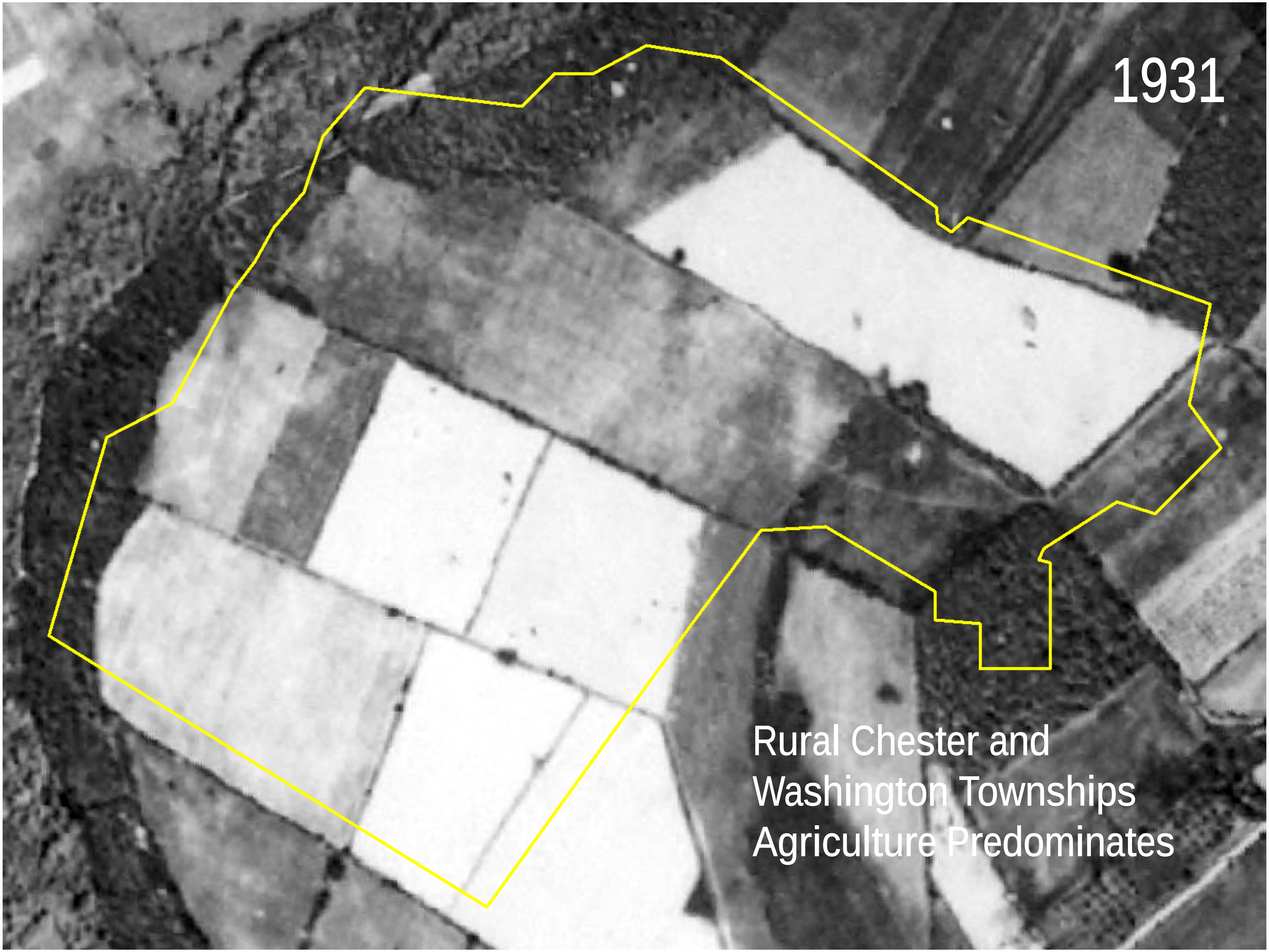

1970


1971


1972

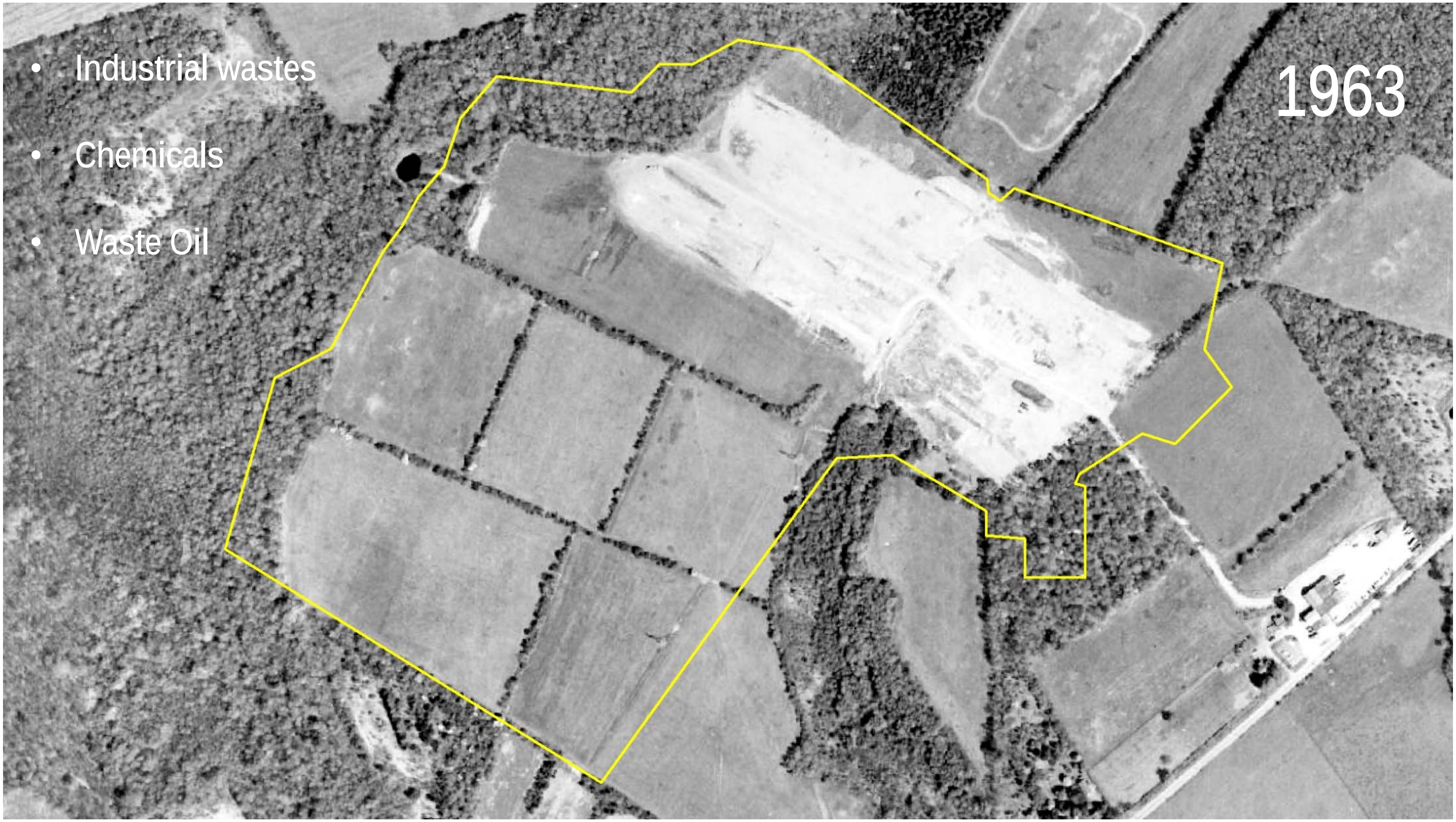

1979

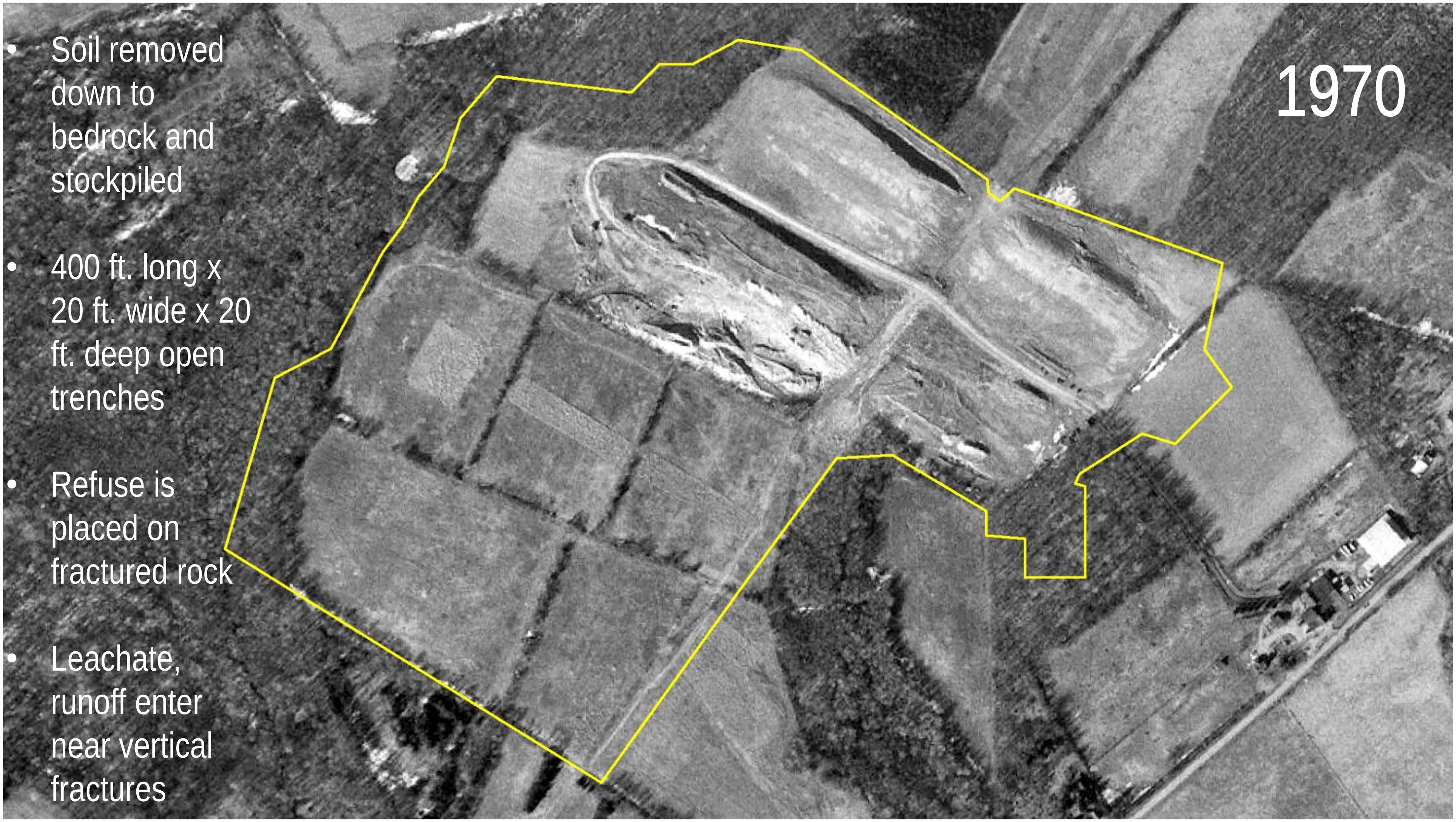

1987

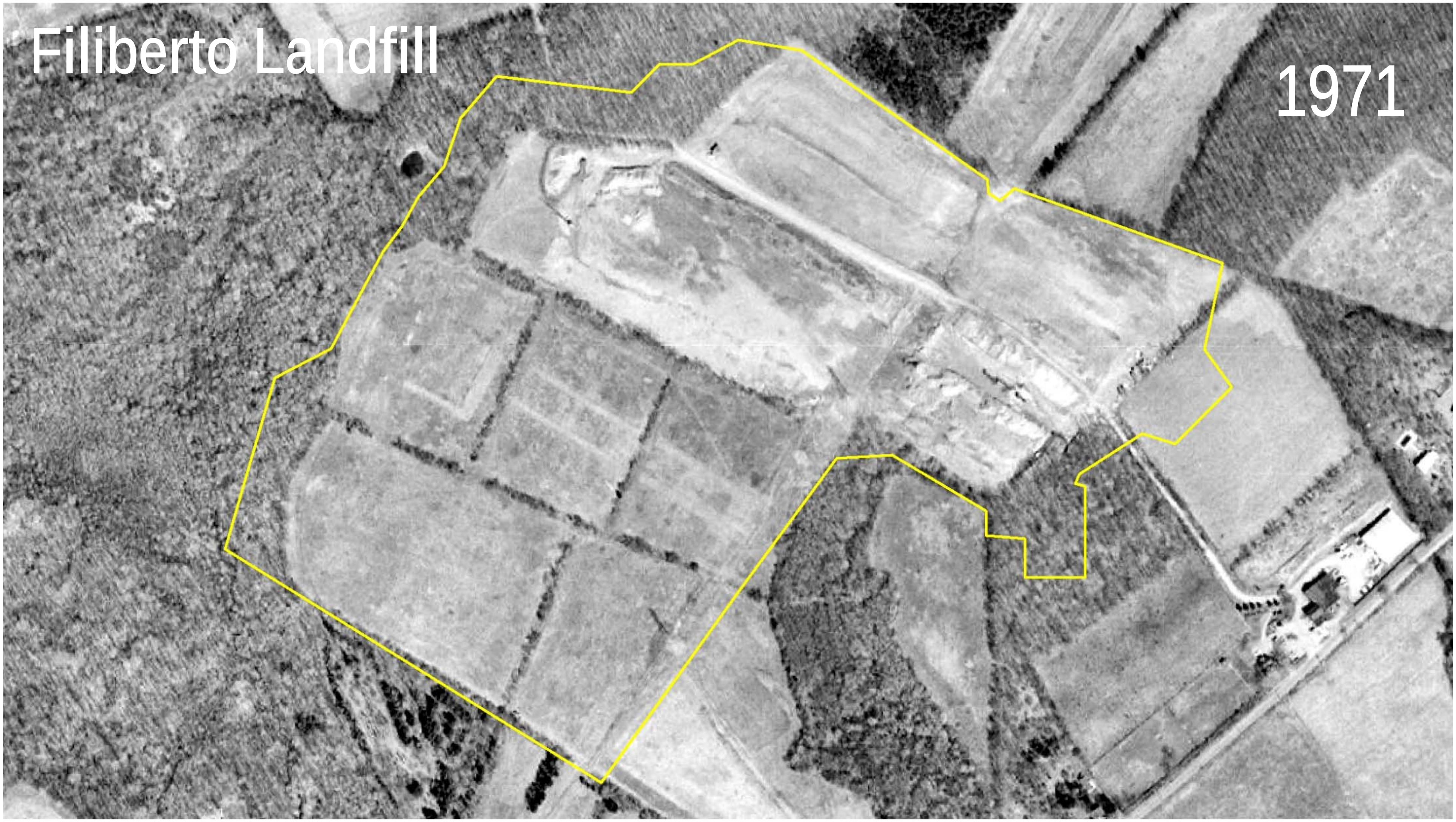

1931
Rural Chester and
Washington Townships
Agriculture Predominates

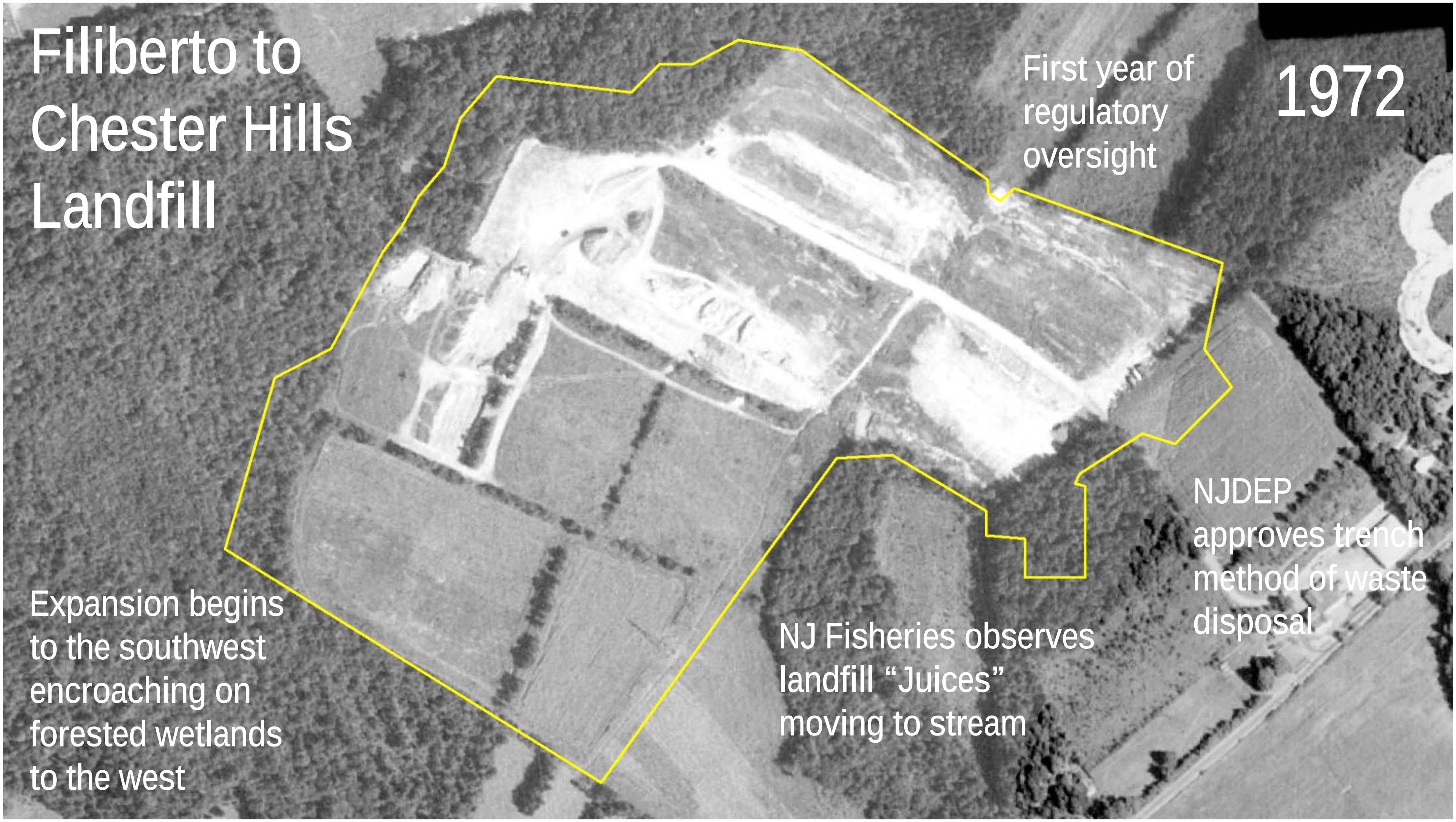
- Opens in the 1940s
- Household wastes
- Sewage sludge
- Septic wastes

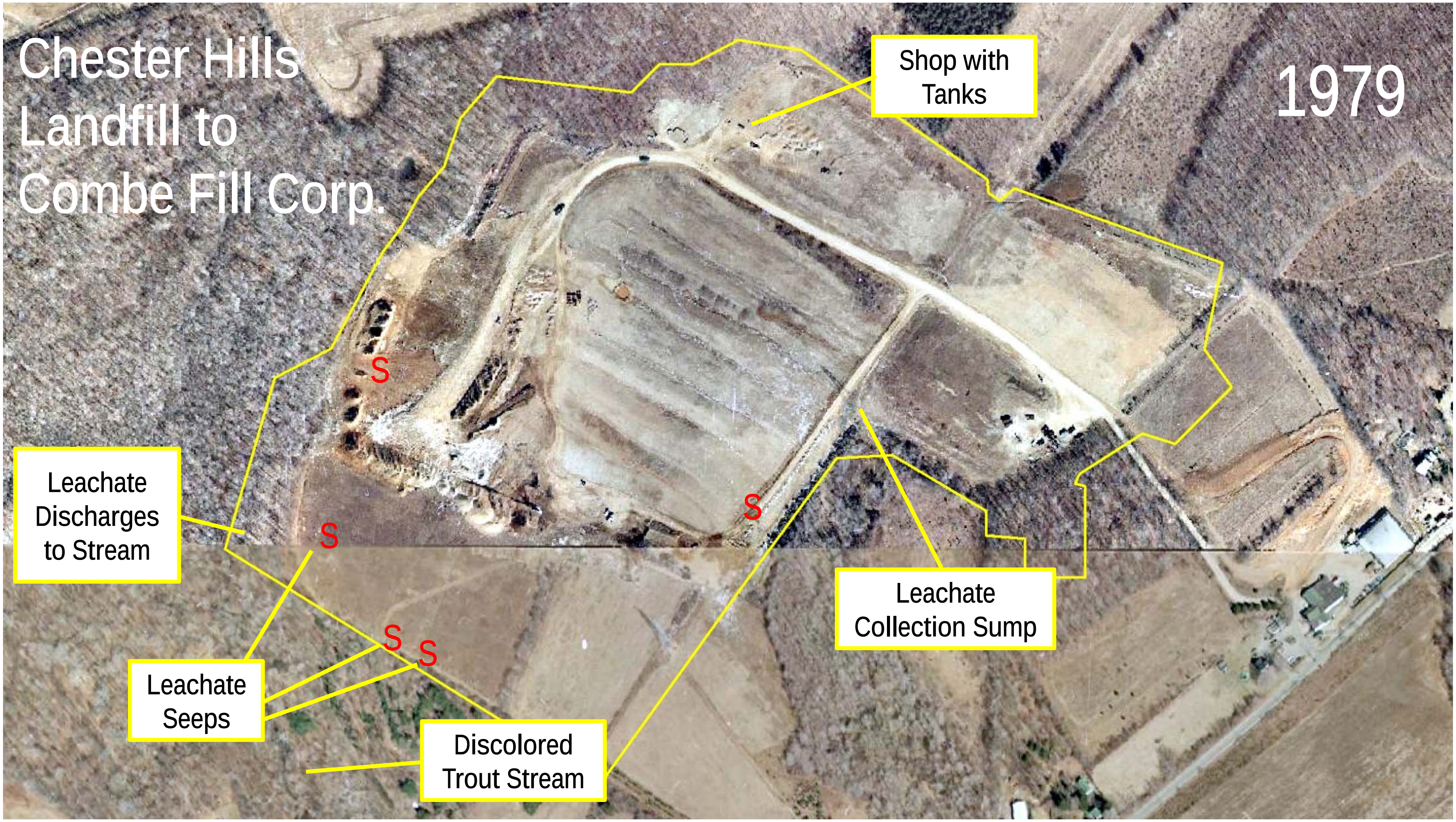
1957


• Industrial wastes
• Chemicals
• Waste Oil
1963


• Soil removed down to bedrock and stockpiled
• 400 ft. long x 20 ft. wide x 20 ft. deep open trenches
• Refuse is placed on fractured rock
• Leachate, runoff enter near vertical fractures
1970

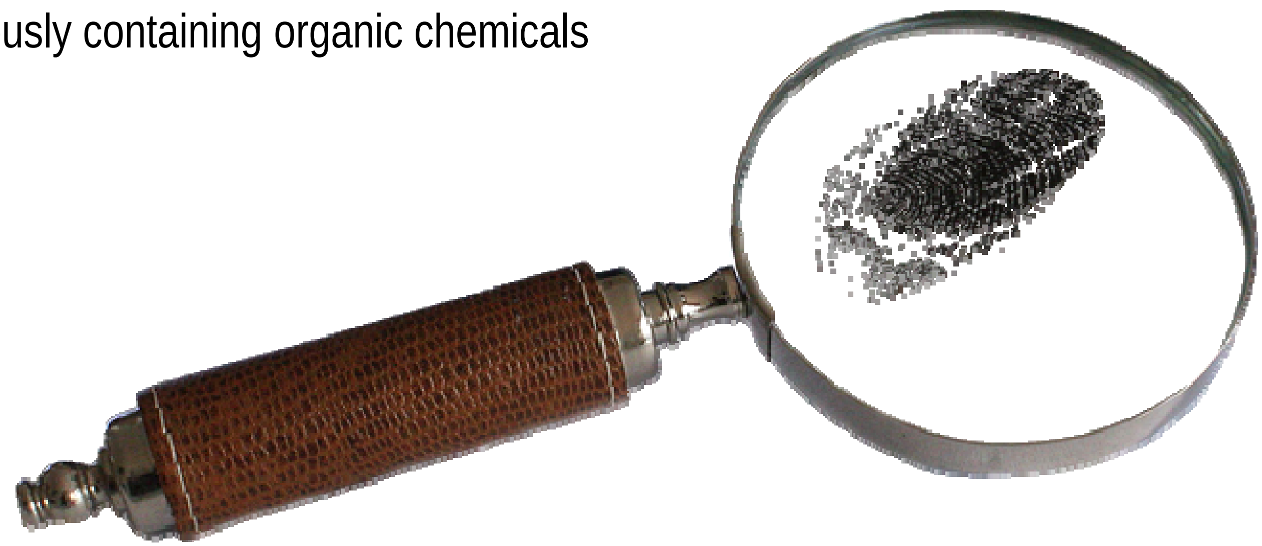

Filiberto Landfill
1971


Filiberto to Chester Hills Landfill
1972
First year of regulatory oversight
Expansion begins to the southwest encroaching on forested wetlands to the west
NJ Fisheries observes landfill “Juices” moving to stream
NJDEP approves trench method of waste disposal


Chester Hills Landfill to Combe Fill Corp.
1979
Shop with Tanks
Leachate Discharges to Stream
Leachate Collection Sump
Leachate Seeps
Discolored Trout Stream
S
S
S
S
S

Discovery

- 1972 - NJDEP issued Certificate to Operate for non-hazardous and municipal solid waste
- 1973 – Fish kills in Trout Brook reported by Division of Fish and Game
- 1973 – First leachate collection and recycling system installed
- 1974 – NJDEP requests installation of monitoring wells
- 1977 – Additional monitoring wells installed
- 1978 – Change in ownership from Chester Hills to Combe Fill Corp.
- 1979 – Runoff from exposed waste observed entering bedrock fractures
- 1981 – Combe Fill Corp. reports acceptance of pharmaceutical waste and fiber drums previously containing organic chemicals



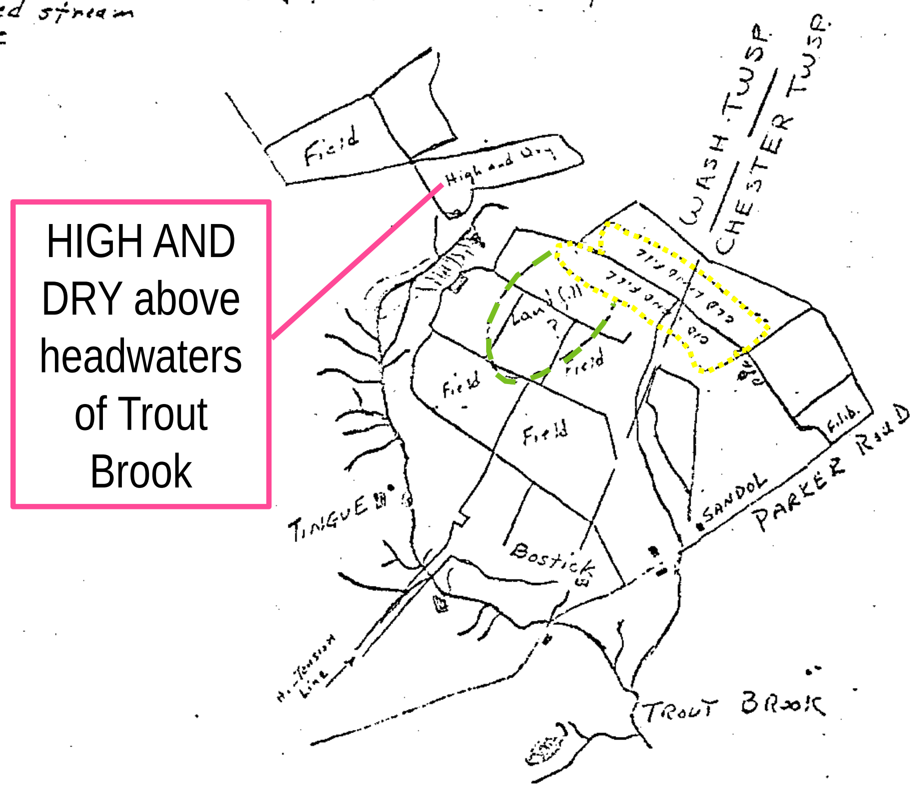
1979 Inspection

FILIBERTO LANDFILL AREA AND ENVIRONS

N

FRESH WATER Pond
Polluted Ponds or Leachate Ponds

FRESH WATER Stream
LANDFill and or septic seepage from ponds or in swamp.
Polluted stream
House
well



100169

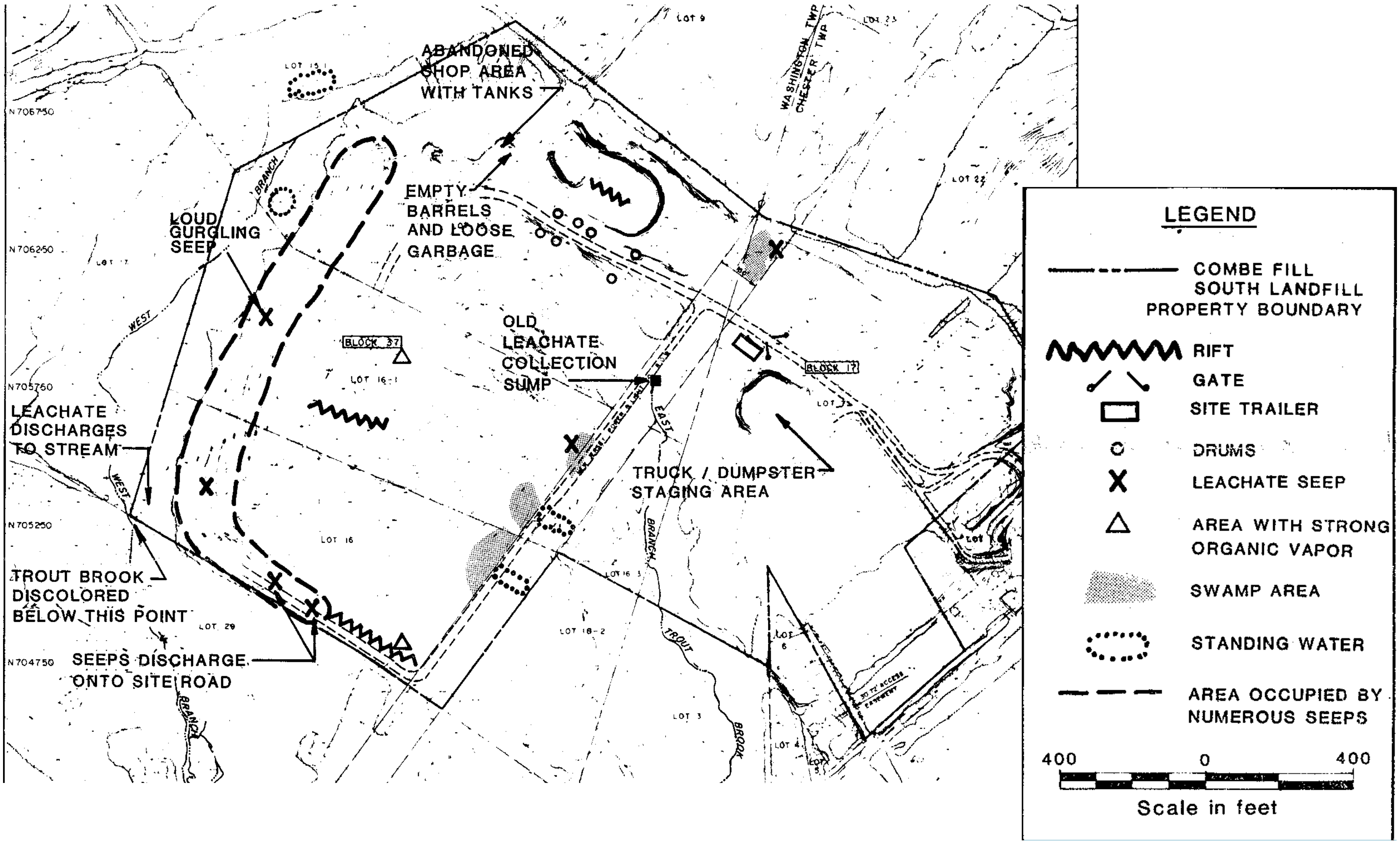
APPROX. SCALE 1:12,000

Discovery

- Jan 1981 – Combe Fill starts clearing forested wetlands to west for additional 100 acres
- March 1981 – Chester and Washington Townships file suit to stop landfilling, judge issues order
- April 1981 – Upper Raritan Watershed Association samples monitoring wells and surface water
- June 1981 – Residents form HALT – Help Stop a Landfill Tragedy - sample 90 wells
- Sept. 1981 – NJDEP issues order to stop landfilling due to groundwater contamination
- 1982 – Reclamation activities cease
- 1983 – Investigations commence

1983-1985 RI/FS, LMS Engineers
on behalf of NJDEP

Site Conditions at Start of Investigations



Denville, N.J. 07834

March 12, 1986

Denville, N.J. 07834

SKilley

President Ronald Reagan
White House
1600 Pennsylvania Avenue N.W.
Washington, D.C. 20500

To The Gipper at the White House

RECEIVED 4/7/86

due 4/10/86

Dear President Reagan:

Approximately five years ago I bought a home in Washington Township, Morris County, New Jersey. The home is supplied by an individual well which is used by me, my wife, and my children.

The home is within a short distance of an abandoned toxic waste site known as Combe Fill South Land Fill. The land fill was closed by order of the State Department of Environmental Protection (hereinafter referred to as D.E.P.) and is listed on the federal toxic waste super fund list for clean up at some time in the future.

We were recently notified in writing by the D.E.P. and the muncipality that our drinking water could be polluted by this land fill and it was recommended that we not drink the water. I have been told by representatives of Washington Township and adjoining Chester Township that the State D.E.P. agreed to supply an alternate source of drinking water to be piped into my home at 11 East Gate Road, Long Valley, New Jersey, along with other homes surrounding the land fill, from a central water source. The D.E.P. has promised this alternate water source by the end of this year.

The purpose of this letter is to request that you and your office do whatever can be done to expedite the installation of this alternate water source.

This request is made on my behalf and on behalf of my wife and my children as well as other affected home owners. We are presently drinking bottled water but are using the well water to shower and to bathe, and I am concerned for my safety and the safety of my family and others. I understand that it will take some time to properly close the land fill, but I hope that work can begin immediately on the alternate water source.


1987
Waiting on remedial design

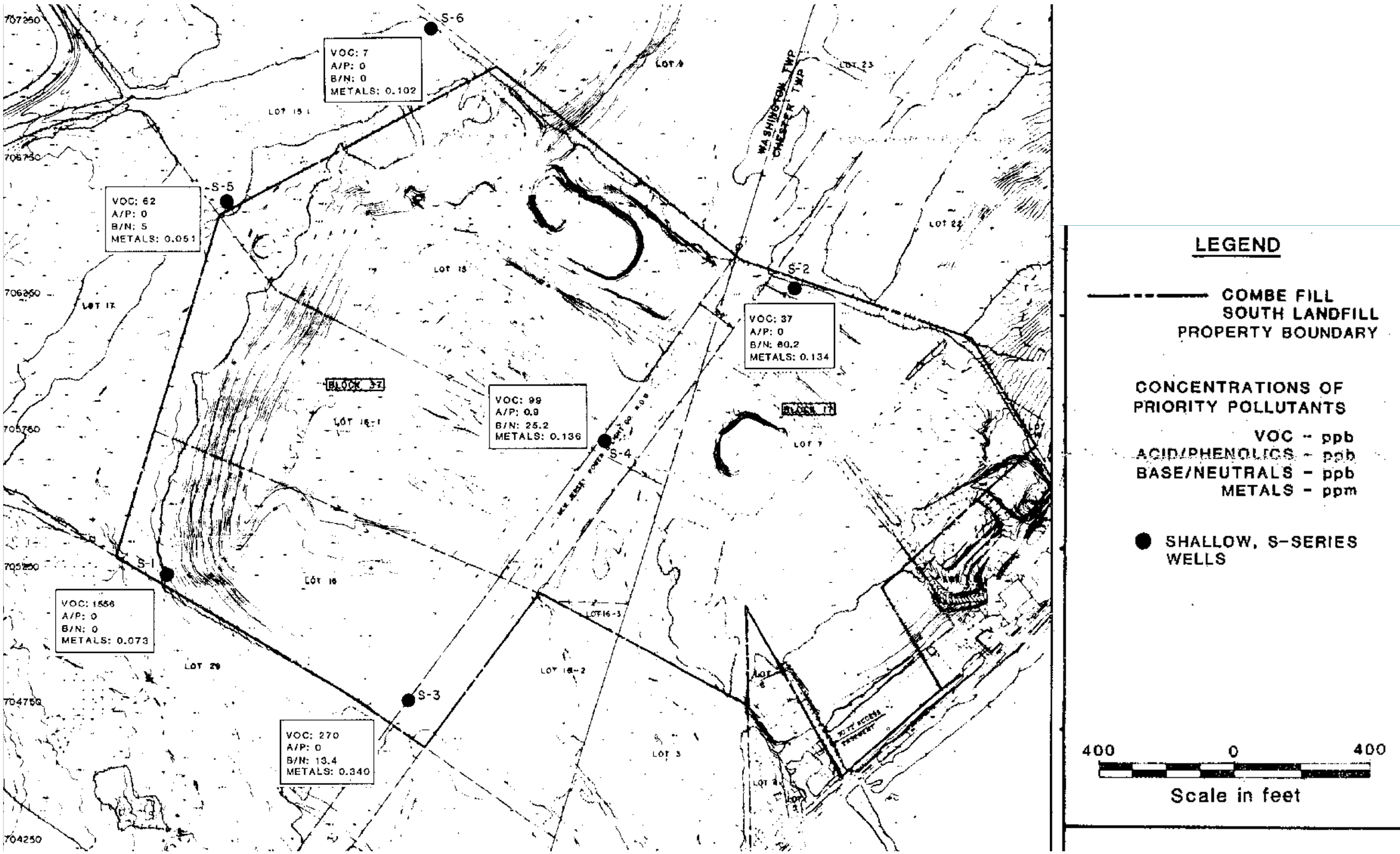

1995
Landfill cap under
construction 1995-1996


2006
I thought we were finished?
What's going on to the north?


2007
Landfill cap extension completed

1983-1985 RI/FS, LMS Engineers
on behalf of NJDEP

1980s Shallow Well Data



1980s Shallow Well Data

TABLE 4-11 (Page 1 of 3)

SUMMARY OF SHALLOW MONITORING WELLS PRIORITY POLLUTANTS

Combe Fill South Landfill

PARAMETER	S-1	S-2	S-3	S-4	S-5	S-6
DATE SAMPLED	9/4/85	9/5/85	8/29/85	9/4/85	8/28/85	8/28/85
VOLATILES, ppb						
Benzene	64.7	BM @ 4.4	80.2	BM @ 4.4	ND	BM @ 4.4
Chlorobenzene	ND	30.3	21.1	18.2	ND	ND
Chloroethane	ND	ND	BM @ 10	62.0	ND	ND
Chloroform	ND	ND	ND	ND	57.5	ND
1,1-Dichloroethane	65.2	ND	51.4	BM @ 4.7	ND	ND
1,2-Dichloroethane	ND	ND	ND	6.10	ND	ND
1,1-Dichloroethylene	ND	ND	ND	ND	ND	ND
1,2-Dichloropropane	ND	ND	BM @ 6	ND	ND	ND
Ethylbenzene	ND	ND	BM @ 7.2	ND	ND	ND
Methylene chloride[a]	56.0	4.44	18.4	8.2	4.67	4.67
Tetrachloroethylene	ND	ND	BM @ 4.1	ND	ND	ND
Toluene	1370	ND	68.2	ND	ND	ND
Trans-1,2-dichloroethylene	ND	ND	8.02	ND	ND	ND
Trichloroethylene	ND	ND	4.04	ND	ND	ND
Vinyl chloride	ND	ND	BM @ 10	ND	ND	ND
ACID/PHENOLICS, ppb						
2,4-Dimethylphenol	ND	ND	ND	ND	ND	ND
2-Nitrophenol	ND	ND	ND	ND	ND	ND
Phenol	ND	ND	ND	BM @ 1.5	ND	ND

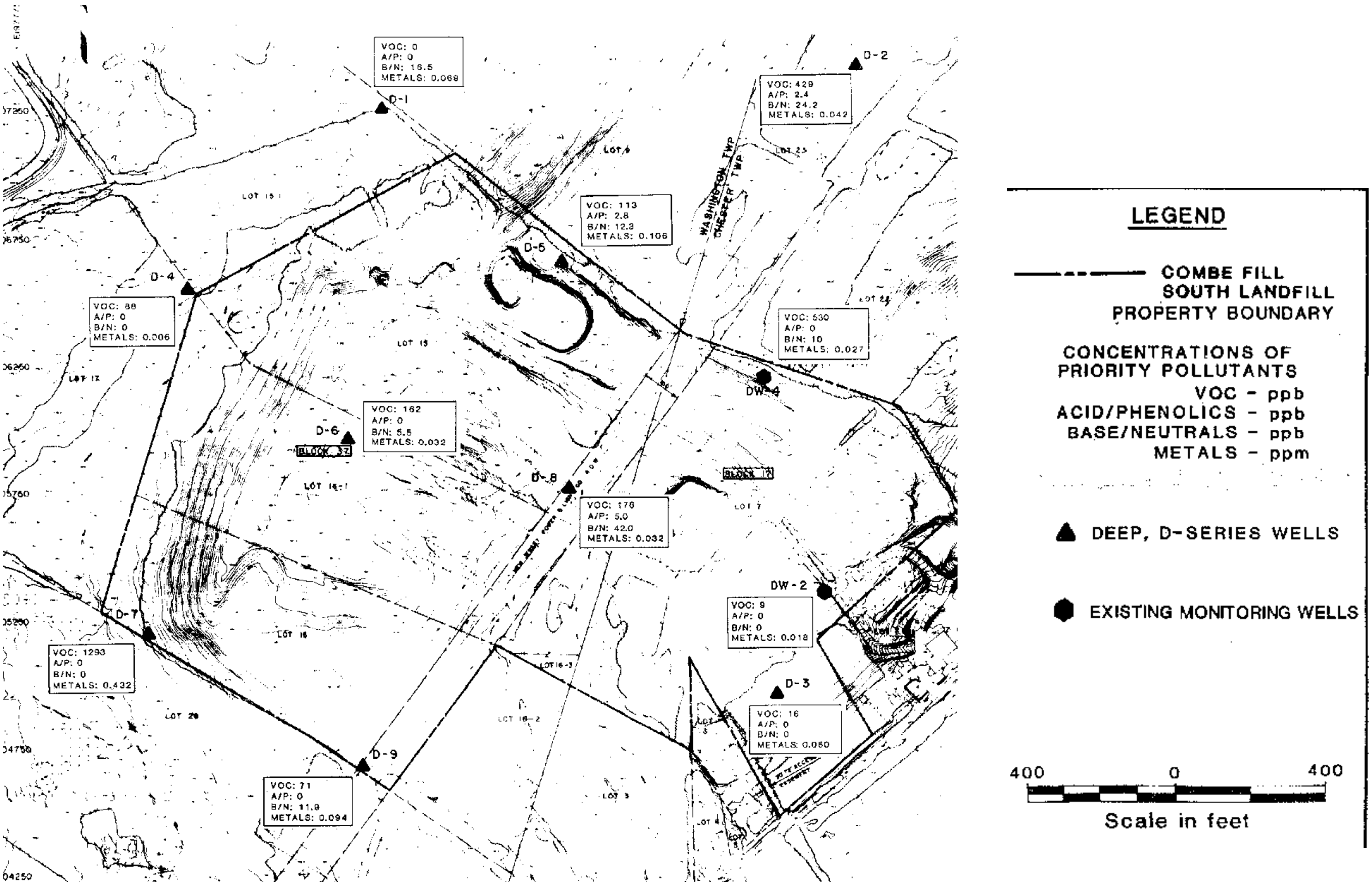
ND = Not detected.
BM = Below method detection limit.

- Limited Priority Pollutant List
- High Detection Limits
- Different Contaminants of Concern

1983-1985 RI/FS, LMS Engineers
on behalf of NJDEP

1983-1985 RI/FS, LMS Engineers
on behalf of NJDEP

1980s Deep Well Data



1980s Deep Well Data

TABLE 4-12 (Page 1 of 2)

SUMMARY OF PRIORITY POLLUTANTS
DEEP MONITORING WELLS

Combe Fill South Landfill

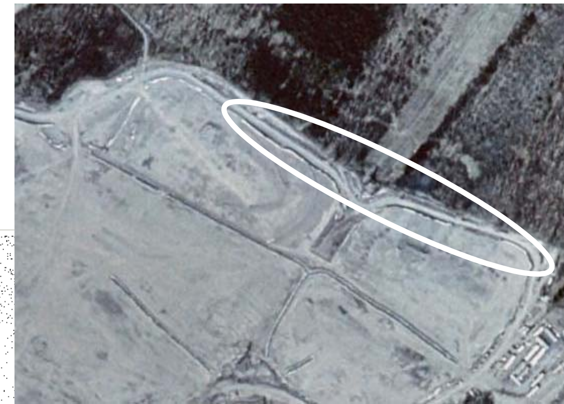
PARAMETER	D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8	D-9	DW-2	DW-4
DATE SAMPLED	8/28/85	8/28/85	9/4/85	8/28/85	8/28/85	8/29/85	9/4/85	9/4/85	9/4/85	9/5/85	9/5/85
VOLATILES, ppb											
Benzene	ND	ND	ND	ND	16.9	39.1	66.4	31.5	18.6	ND	252
Chlorobenzene	ND	ND	ND	ND	ND	BM @ 6	9.88	10.8	ND	ND	BM @ 6
Chloroethane	ND	ND	ND	ND	ND	ND	22.5	74.3	BM @ 10	ND	ND
Chloroform	ND	209	ND	82.6	ND	ND	ND	ND	ND	ND	155
1,1-Dichloroethane	ND	6.41	ND	ND	10.6	BM @ 4.7	ND	14.8	30.2	ND	ND
1,2-Dichloroethane	ND	7.98	ND	ND	40.5	37.2	ND	11.2	4.54	ND	14.2
1,1-Dichloroethylene	ND	6.41	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloropropane	ND	ND	ND	ND	ND	ND	ND	BM @ 6	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND	ND	ND	34.2	11.7	ND	ND	ND
Methylene chloride[a]	5.92	176.07	16.0	ND	9.77	ND	20.0	18.8	12.6	9.3	20.6
Tetrachloroethylene	ND	14.3	ND	ND	6.89	BM @ 4.1	ND	ND	ND	ND	5.58
Toluene	ND	ND	ND	ND	ND	ND	1140	ND	ND	ND	ND
Trans-1,2-dichloroethylene	ND	ND	ND	5.40	25.8	47.5	ND	ND	ND	ND	17.5
Trichloroethylene	ND	8.34	ND	ND	2.72	26.0	ND	ND	ND	ND	56.8
Vinyl chloride	ND	ND	ND	ND	ND	BM @ 10	ND	ND	ND	ND	BM @ 10
ACID/PHENOLICS, ppb											
2,4-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	3.12	ND	ND	ND
2-Nitrophenol	ND	ND	ND	ND	ND	ND	ND	BM @ 3.7	ND	ND	ND
Phenol	ND	2.35	ND	ND	2.75	ND	ND	ND	ND	ND	ND
BASE/NEUTRALS, ppb											
Bis (2-chloroethyl) ether	ND	ND	ND	ND	ND	ND	ND	BM @ 5.9	ND	ND	ND
Bis (2-ethylhexyl) phthalate	BM @ 11	ND	ND	BM @ 10	ND	BM @ 11	ND	BM @ 10	BM @ 10	ND	ND
1,2-Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND	5.58	1.92	ND	ND
1,4-Dichlorobenzene	ND	BM @ 4.6	ND	ND	BM @ 4.5	ND	ND	14.2	ND	ND	ND
Di-ethyl phthalate	ND	ND	ND	ND	BM @ 10	ND	ND	BM @ 10	ND	ND	ND
Di-n-butyl phthalate	BM @ 11	ND	ND	BM @ 10	BM @ 10	ND	ND	BM @ 10	BM @ 10	ND	BM @ 10
Di-n-octyl phthalate	BM @ 11	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Isophorone	ND	21.9	ND	ND	ND	ND	ND	ND	ND	ND	ND
Naphthalene	ND	ND	ND	ND	ND	ND	ND	3.24	ND	ND	ND
N-nitrosodiphenylamine	ND	ND	ND	ND	ND	ND	ND	BM @ 2	ND	ND	ND

[a]Corrected based on analysis of QA/QC samples.
ND = Not detected.

- Limited Priority Pollutant List
- High Detection Limits
- Different COCs

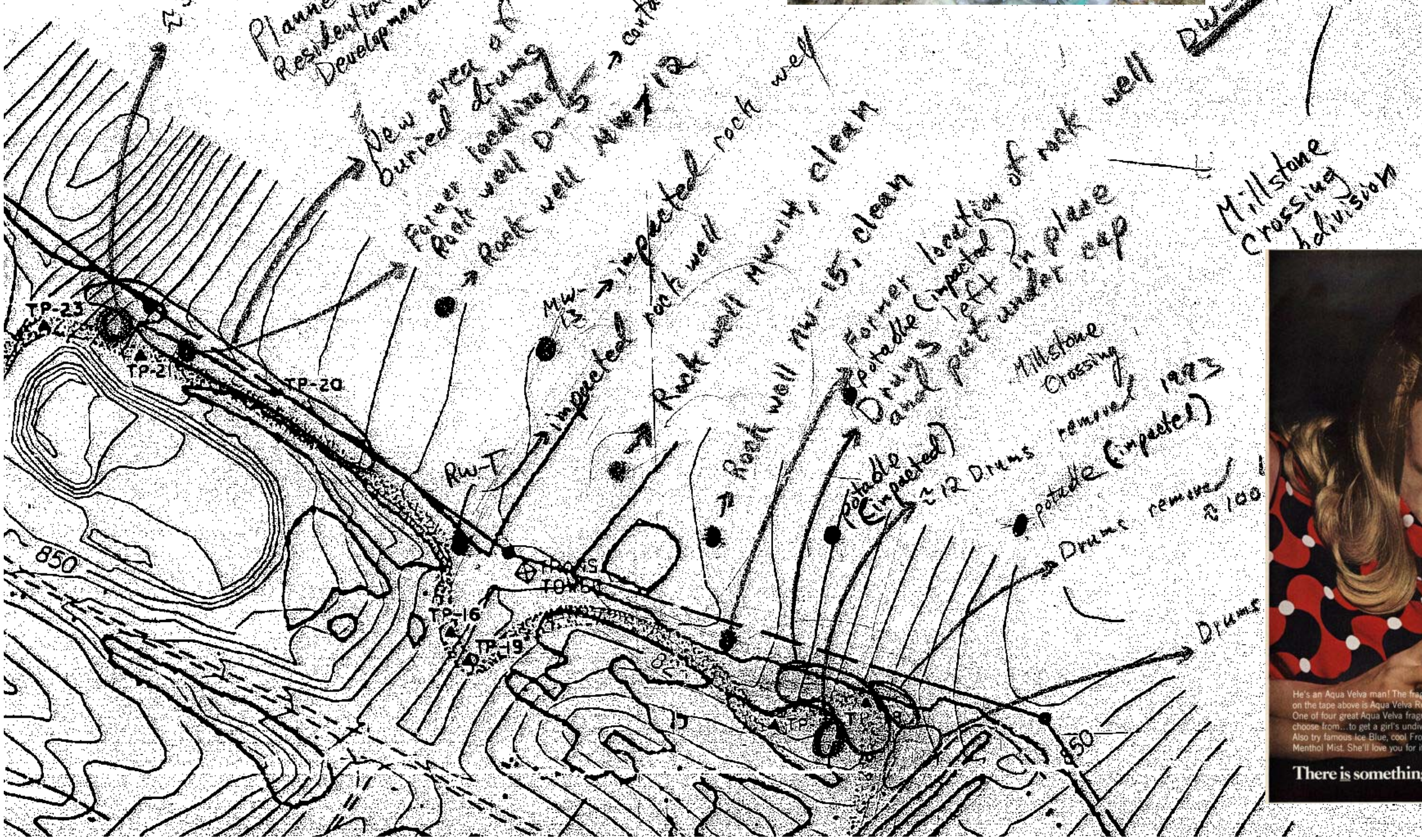
1983-1985 RI/FS, LMS Engineers on behalf of NJDEP

1993 to 1995
Lions and Tigers and Buried Drums, Oh My!



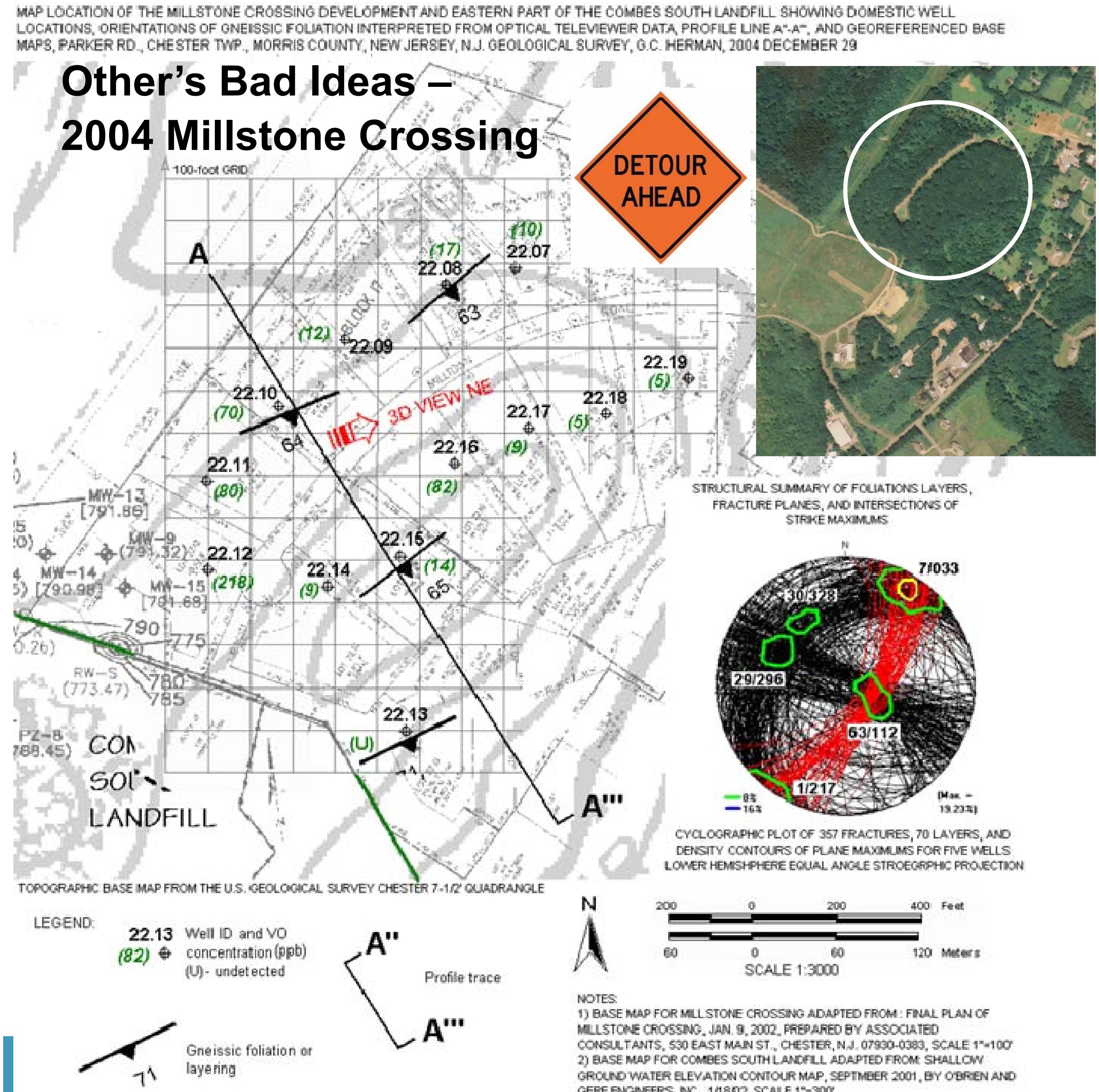
- 150, 55-gallon drums discovered during cap construction
- Logs show drums found as early as 1988

1993 to 1995
Lions and Tigers and Buried Drums, Oh My!



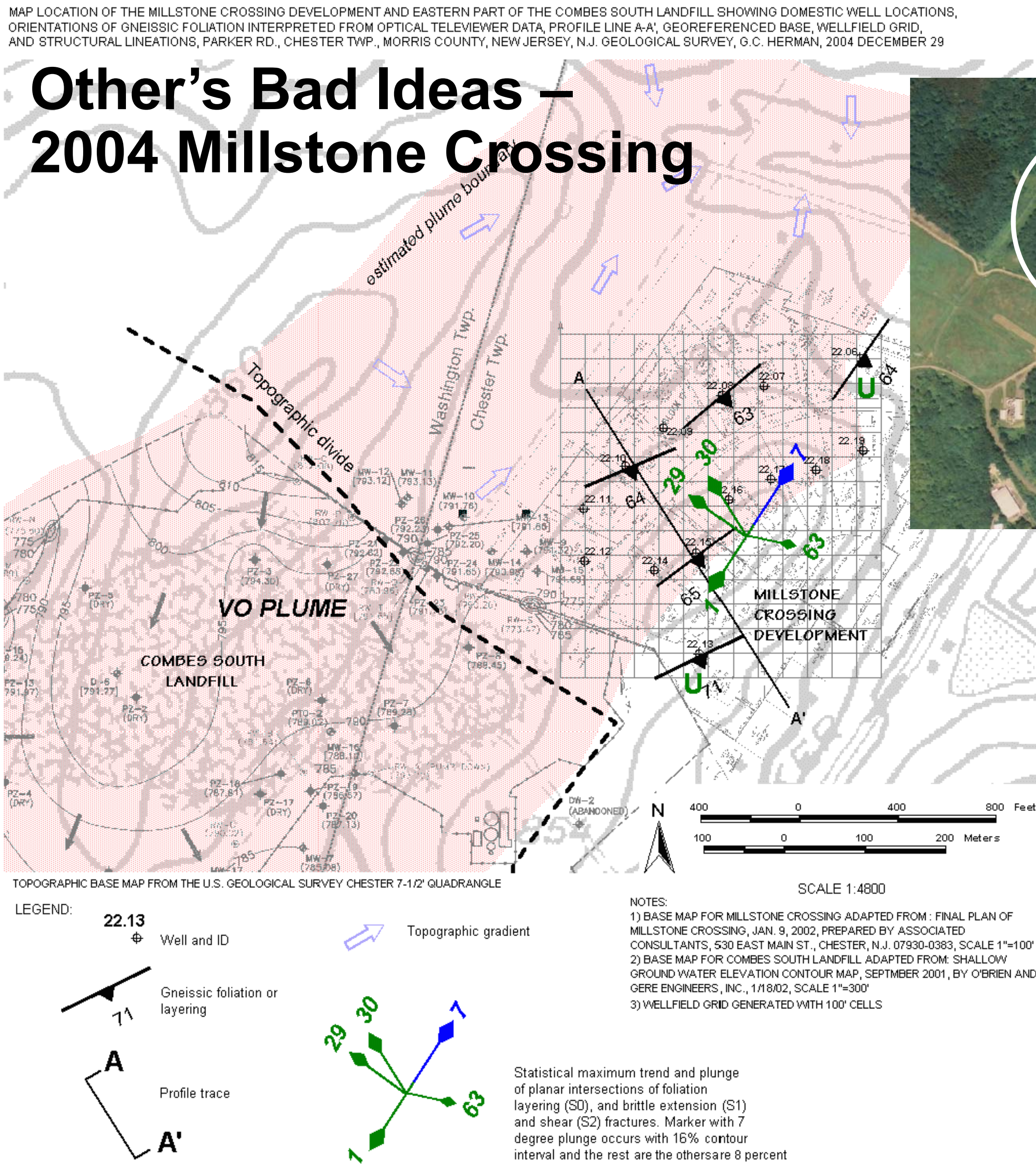
- Drum of "Aqua Velva" is a prelude of things to come

Other's Bad Ideas – 2004 Millstone Crossing



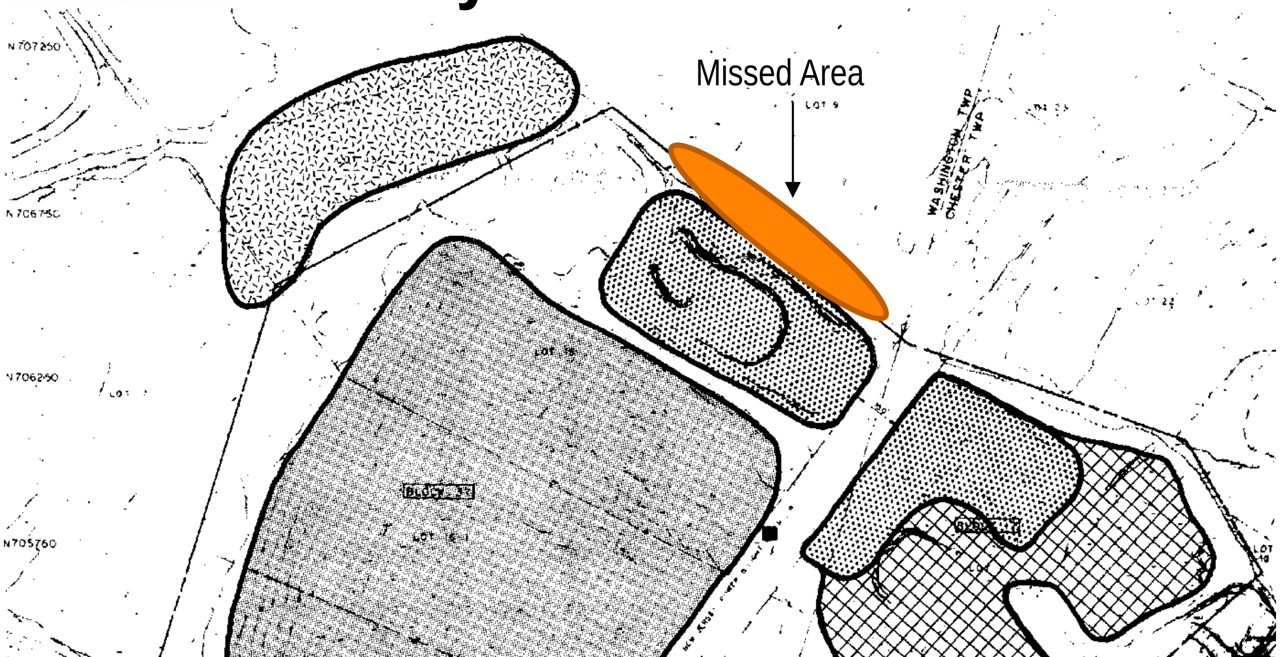
- Residential Developer Installed Potable Wells to 750 ft. bgs NE of Landfill
- Uncased, Open Boreholes Created New Vertical Conduits

Other's Bad Ideas – 2004 Millstone Crossing

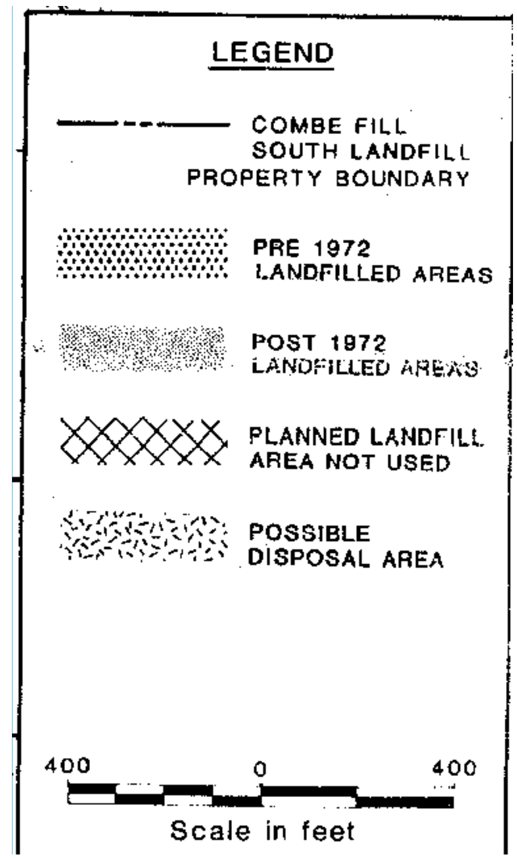


- 2004 NJGS hydrogeological interpretation
- Optical televiewer
- Fluid-temperature
- Fluid electrical-conductivity
- Heat-pulse flow meter geophysical logs
- Five of the 15, 6-inch diameter domestic wells developed in Middle Proterozoic gneissic bedrock

Discovery of North Waste Cell



- Discovered by NJDEP in 2001 during soil gas probe installation
- Test pit investigation 2003 to 2004
- Remediation 2006 to 2007



Discovery of North Waste Cell

- Not apparent from site history – no documentation
- Not obvious on aerial photographs
- Very close to previous buried drum discoveries
- August 1966 New York Times found buried within

Discovery of North Waste Cell

- Start of Remedial Action June 2006
- Excavation, Characterization, Off-Site Disposal
- 27,327 Tons Non-Hazardous Soil and Debris
- Backfill (left, foreground)
- Extension of Cap over Excavated Area in 2007

Treasures of the North Waste Cell

- "Warehouses" of off-spec personal care products – first appearance of the *primary contaminant of concern*
- Baby Magic Baby Lotion
  - 15 deaths in US
  - > 1% Hexachlorophene banned 1972
- Mennen shaving cream
- Over-the-counter medications
  - Pills
  - Liquids
  - Aerosols

Treasures of the North Waste Cell

- Poison (Cyanide)
  - Not a contaminant of concern
- Chloroflourocarbons
  - Were COCs at the start of 2011 RI
  - Not COCs at the time of the 2018 ROD
- Simple PRP identification
  - Names and addresses of PRPs on labels
  - Majority of PRPs were Morris County, New Jersey pharmaceutical companies

Treasures of the North Waste Cell

- Pharmaceutical constituents
  - Barbiturates (some experimental)
  - Phenobarbital on product labels
  - Phenobarbital in potable wells
  - Butylbarbital
  - Animal tranquilizers
- Backhoe buckets of pills
  - Who knows what was in those?

Treasures of the North Waste Cell

- Experimental Chemical #993
- Hydrocyanic Acid
- North Waste Cell Conclusion:
  - Likely primary source of 1,4-Dioxane from personal care products and pharmaceuticals; not present as a solvent stabilizer
  - Source of phenobarbital
  - Source of chlorofluorocarbons
  - Variety of pharmaceuticals – what does the future hold for these potential COCs currently without standards and lacking carcinogenicity data?

02 Regulatory History

OU1 Remediation Timeline

- 1983 - Listed on NPL
  - o Hazardous Ranking score 49 ≥28
- 1984 - 1985 - RI/FS performed by NJDEP
- 1986 - OU1 Record of Decision
- 1993 - Submittal of final Design Report
- January 1993 - Commencement of construction
- September 1997 - Completion of construction Conducted 1-year operation and functional period
  - o Construction cost approx. $26 M
- July 30, 2009 - EPA took over RI/FS OU2 activities from NJDEP
- June 30, 2011 - NJDEP issued a detailed closeout report of OU1.

Aerial view of treatment plant under construction – August 25, 1994 NJDEP Closeout Report 6/2011

Original OU1 – 1986 ROD

- Alternate water supply
- Landfill capping
- Landfill gas collection
- Pump and treat, discharge to Trout Brook
- Stormwater management
- Site Security
- Periodic monitoring
- Supplemental FS for deep aquifer
- April 17, 2006 ESD
  - Revision to the passive landfill gas system

Aerial view of landfill looking west during construction – May 30, 1995 NJDEP Closeout Report 6/2011

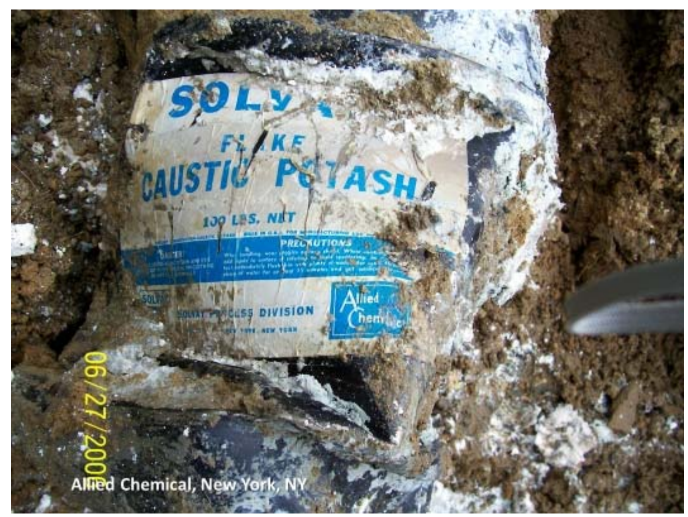
- Estimated capital cost - $46,060,700, and estimated O&M cost - $673,000 for first five years.

Enforcement

Cost Recovery –

- In 1985, EPA filed an application in bankruptcy court seeking reimbursement of Superfund monies spent at the Site to date.
  - Since limited funds remained in the bankruptcy estate, EPA and CFC reached a settlement in which CFC paid $50,000 in May 1986 to resolve EPA's Superfund claims.
- 2005 - Initial settlement resulted with former owner/operators paid NJDEP and EPA $12,500,000 in costs

Alleghaney Chemical, Butler, NJ



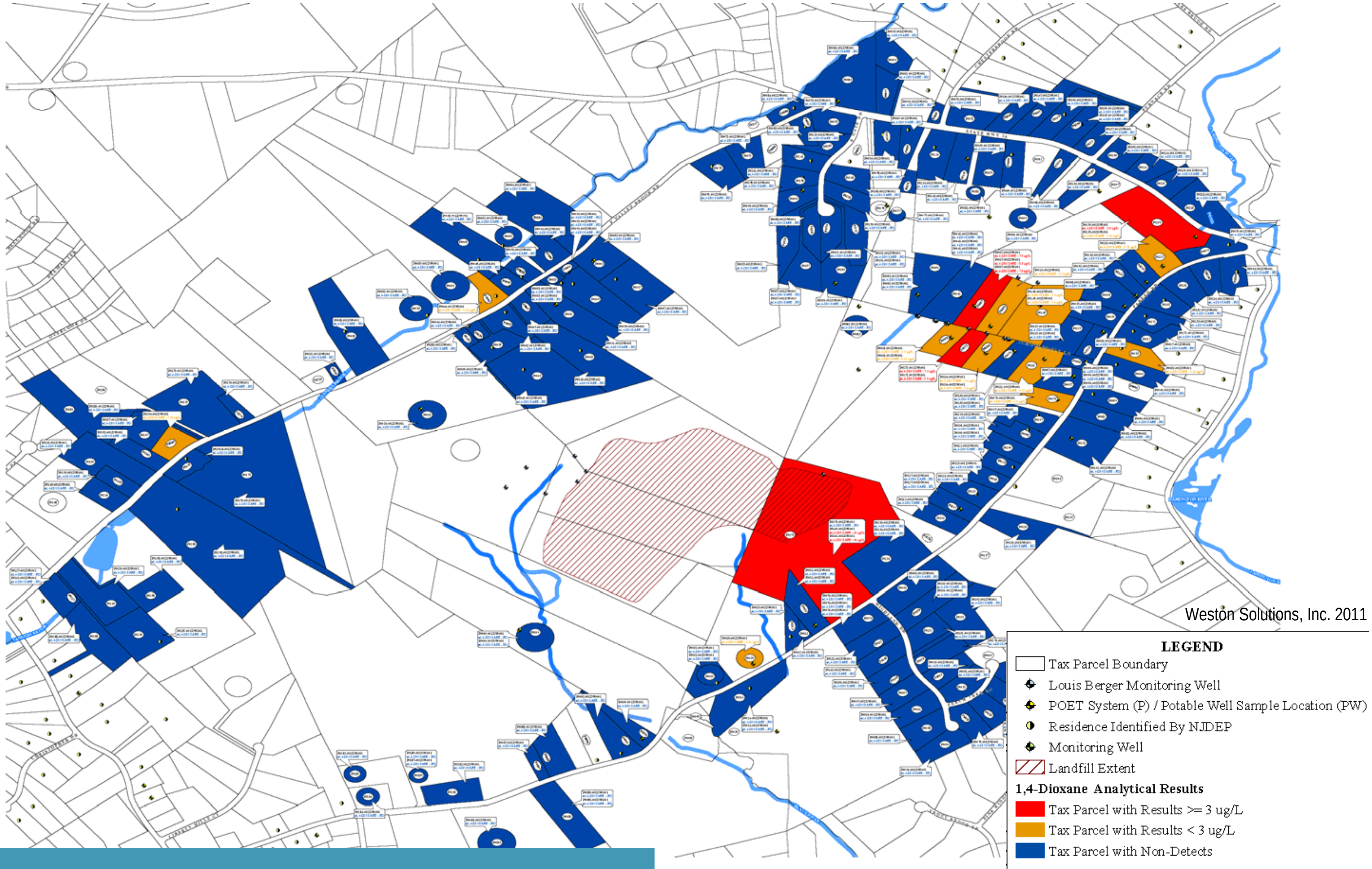
Allied Chemical, New York, NY

Enforcement

Cost Recovery –

- 2009 - Second settlement
  - 300 private parties and municipalities
  - EPA paid $69 million in past costs
  - $3.2 M paid to the state for natural resource damages
  - NJDEP paid $27 million annuity to fund O&M and future work

2011 Potable Well Sampling

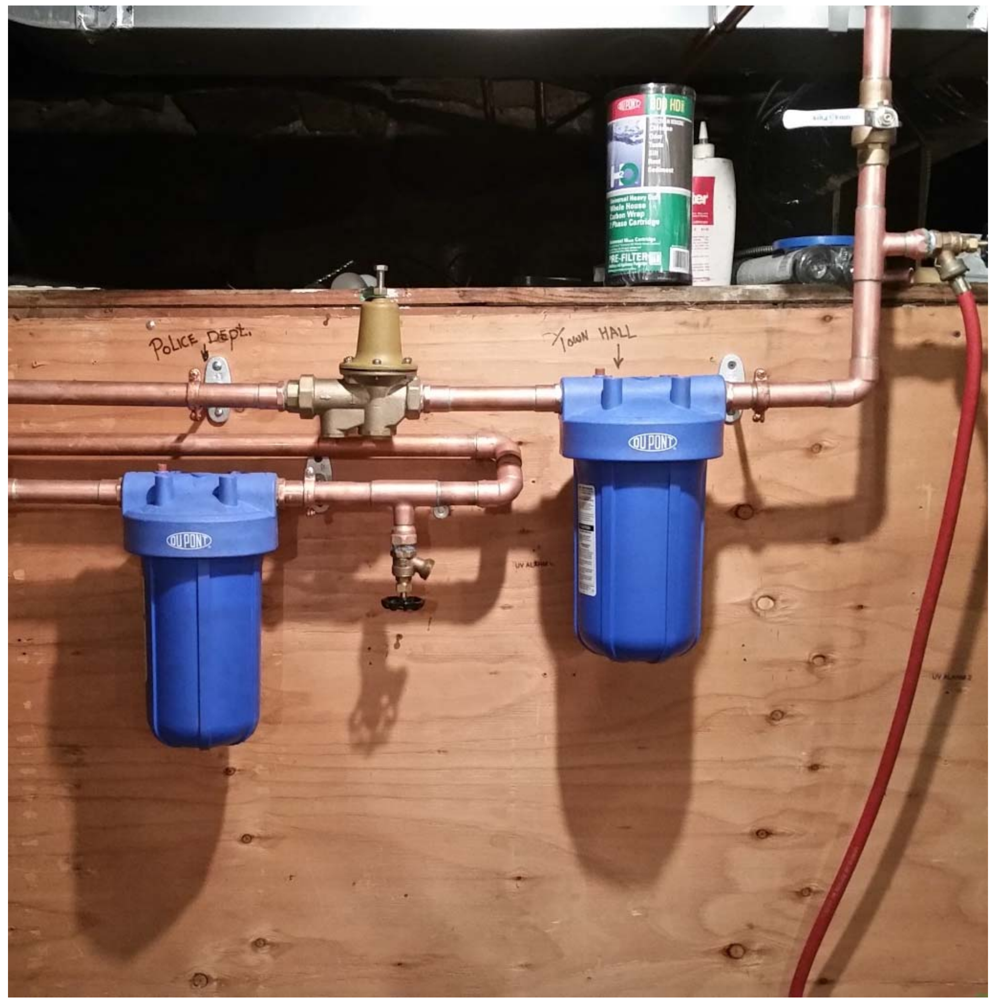


1,4 Dioxane Treatability Study for Private Wells

- EPA, via Environmental Restoration, LLC (ER), conducted a treatability study
  - To evaluate treatment of 1,4 dioxane in domestic water from residential wells
  - Used combination of ozone addition and ultraviolet radiation
    - Phase 1 - bench scale study of the treatment system
    - Phase 2 - pilot test of the system
    - Phase 3 – pilot scale test at the CFS landfill

1,4 Dioxane Treatability Study for Private Wells

- Results
  - Bench scale - system was effective in removing 1,4 dioxane
    - » Depending on influent concentrations, may require multiple passes through the system
  - Pilot test - 4 locations sampled, only two had detectable influent concentrations
    - » System was able to reduce the low results to non-detectable, but influent levels were much lower than anticipated.



1,4 Dioxane Treatability Study for Private Wells

Figure 1.0 Front view of system showing the ozone generator, carbon post-filter and system controls:

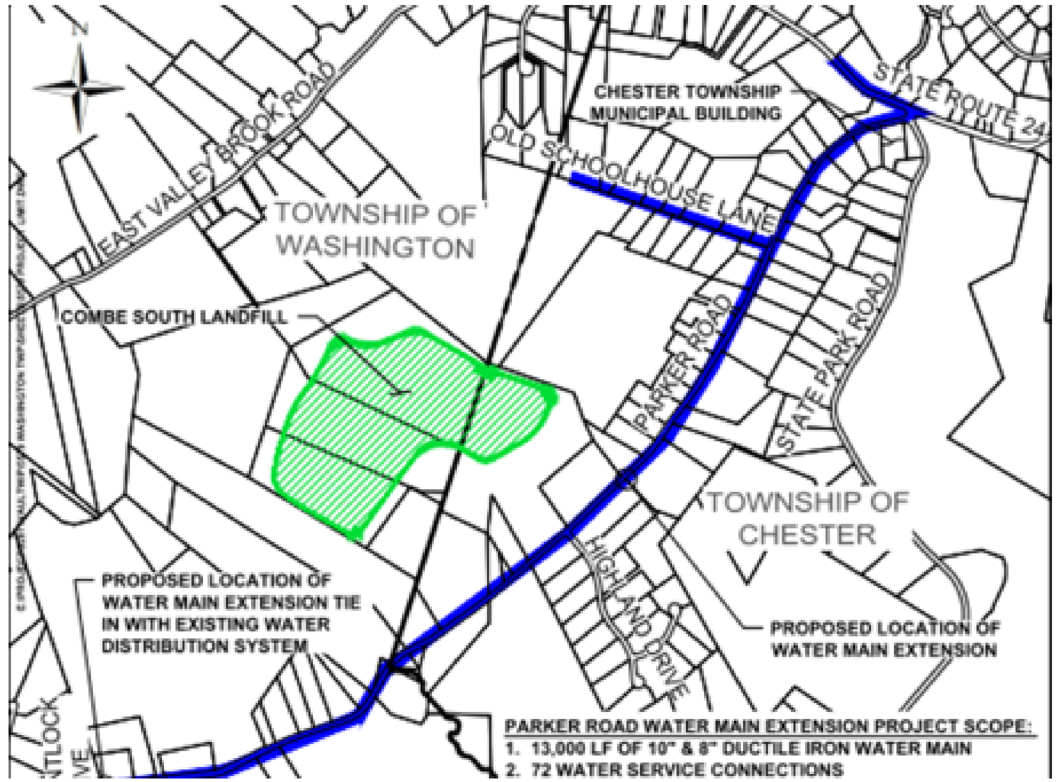
- Pilot test at CFS landfill

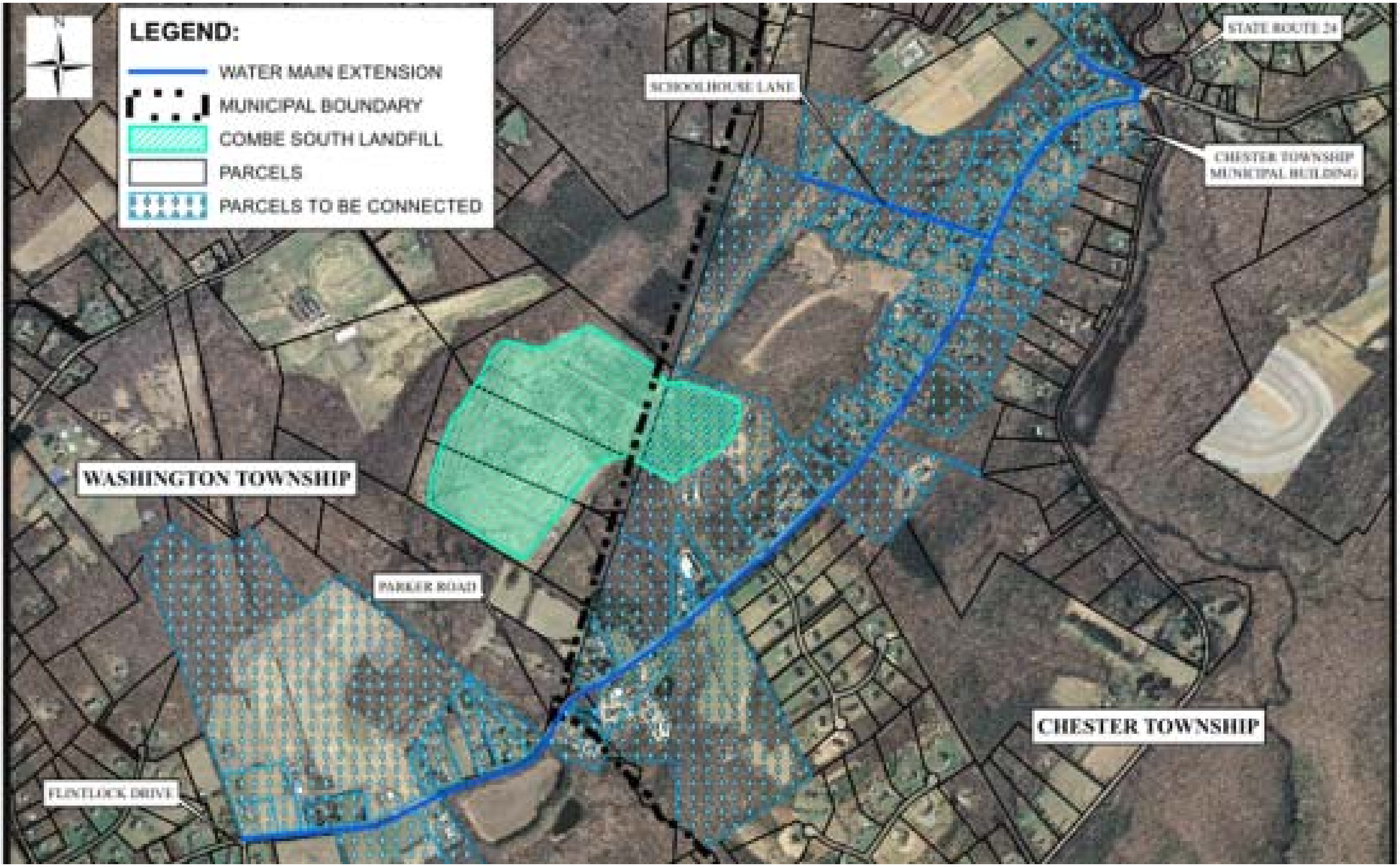
Figure 1.1 Rear view of system showing pre-filter, ozone contact thank and UV lamp chamber:

- Reduced 1,4-dioxane to ND

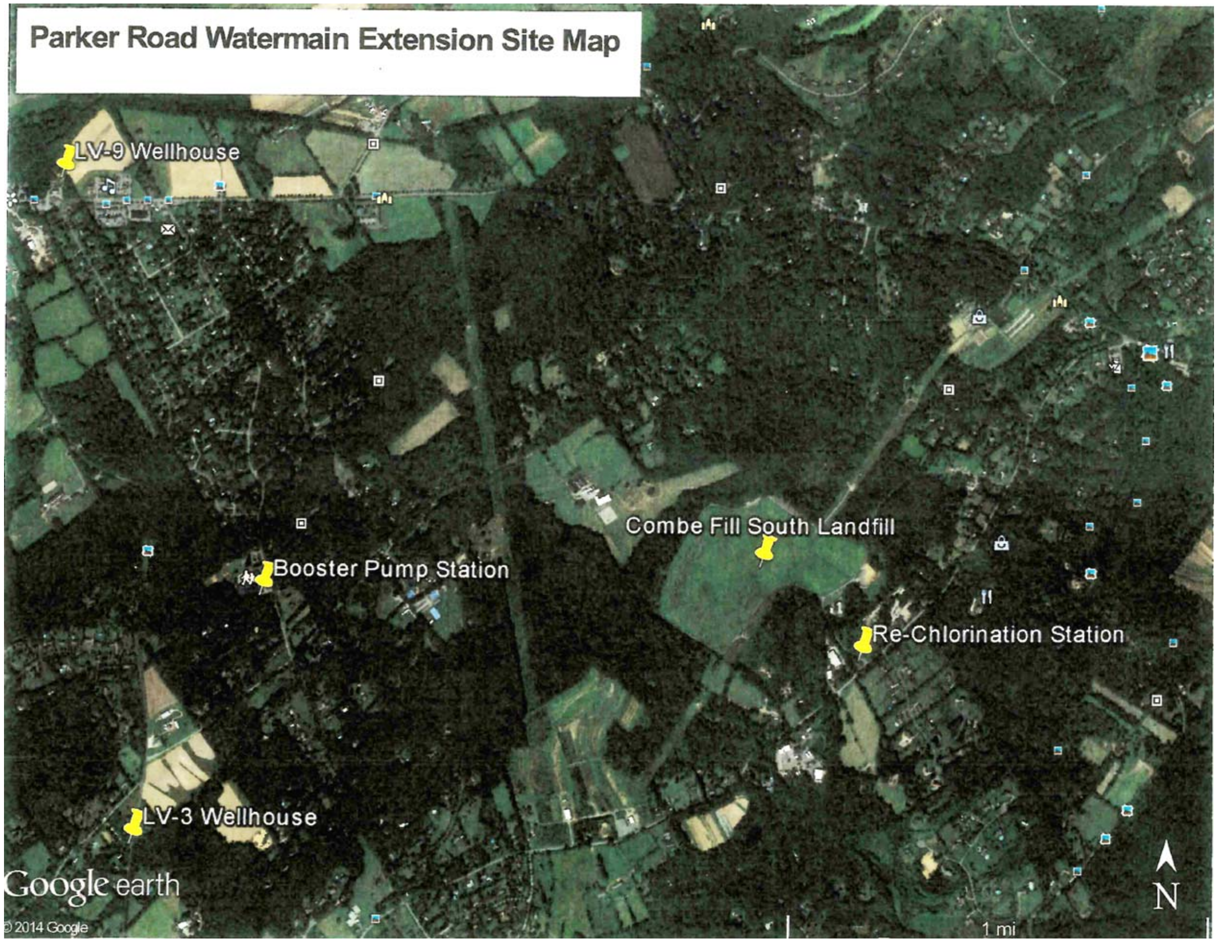
Public Water Supply

- 2010 - EPA took over waterline activities from NJDEP April 2010
- 2010 - 2011 - EPA conducted predesign activities
- 2011 - 2013 - Conducted design and permitting activities
- July 2013 - Commencement of waterline construction activities
- April 2015 - Waterline startup
- June 2015 - Remedial construction completion
- July 15, 2015 - Remedial action completion of waterline activities
  - o Construction Cost: approximately $9 million





N
LEGEND:
WATER MAIN EXTENSION
MUNICIPAL BOUNDARY
COMBE SOUTH LANDFILL
PARCELS
PARCELS TO BE CONNECTED
STATE ROUTE 24
SCHOOLHOUSE LANE
CHESTER TOWNSHIP MUNICIPAL BUILDING
WASHINGTON TOWNSHIP
PARKER ROAD
CHESTER TOWNSHIP
FLINTLOCK DRIVE


Parker Road Watermain Extension Site Map
LV-9 Wellhouse
Combe Fill South Landfill
Booster Pump Station
Re-Chlorination Station
LV-3 Wellhouse
Google earth
© 2014 Google
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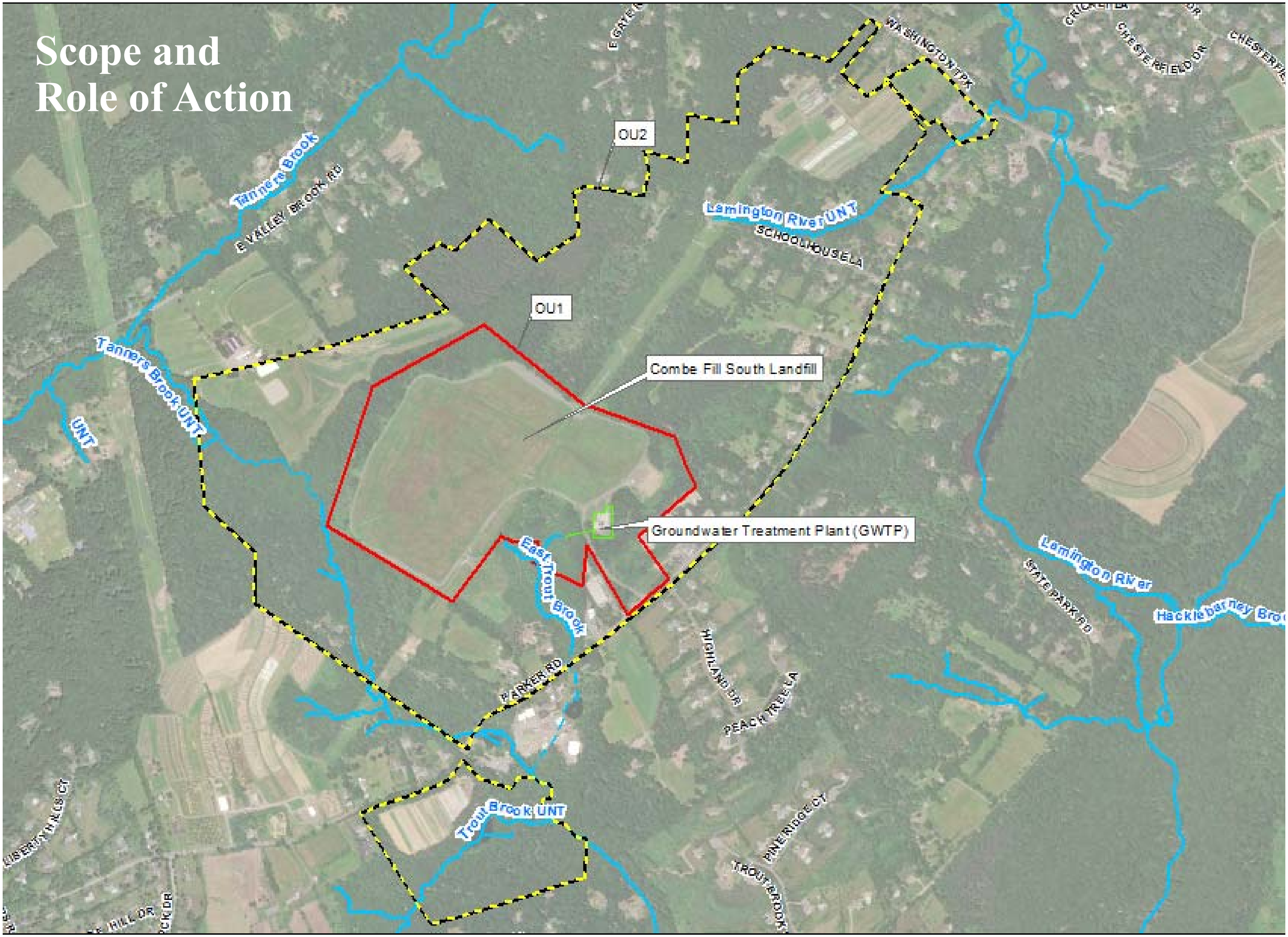
JOHN DEERE
AZ-500B



Scope and Role of Action
OU2
OU1
Combe Fill South Landfill
Groundwater Treatment Plant (GWTP)
Tanners Brook
E VALLEY BROOK RD
Tanners Brook UNT
UNT
Lamington River UNT
SCHOOLHOUSE LA
WASHINGTON TPK
East Trout Brook
PARKER RD
Trout Brook UNT
HIGHLAND DR
PEACH TREE LA
PINE RIDGE CT
Lamington River
STATE PARK RD
CHESTERFIELD DR

Remedial Action Objectives

- RAOs for the OU1 ROD amendment
  - Limit migration of contaminated groundwater and leachate from OU1 to OU2
  - Enhance the treatment plant to reduce concentrations of 1,4-dioxane being discharged to surface water
  - Reduce the toxicity, mobility and volume of contamination in the North Waste Cell to reduce impact on groundwater
  - Prevent exposure to contaminated groundwater

- RAO for OU2 Interim remedy
  - Prevent current and future exposure to human receptors
    - (via ingestion, dermal contact and inhalation) to site-related contaminants in groundwater and surface water at concentrations in excess of federal and state standards

OU1 ROD Amendment and Interim OU2 ROD

OU1 ROD Amendment and Interim OU2 ROD issued September 28, 2018

- OU1-G3 Selected Remedy: Addition of new bedrock extraction wells, upgrade OU1 GWET system, source area removal, and LTM/ICs
    - Capital Cost - $10,457,289
    - Annual O&M Cost - $920,360
    - Present Worth Cost - $21,933,592
    - Time Frame >30 years

- OU2-G2 Selected Remedy: Long-term monitoring/institutional controls
    - Capital Cost - $0
    - Annual O&M Cost - $111,200
    - Present Worth Cost - $ 781,100
    - Time Frame - 10 years

Remedial Design Activities

- September 2018 - EPA contracted HDR to conduct RD activities
- Design changes
  - Designed for a new treatment plant facility
  - Eliminated excavation of North Waste Cell area

- Estimated Costs
  - Construction - $23,455,533
  - O&M - $847,777
- January 2021 - Submittal of final RD

- USACE will conduct RA activities

03 Impacts of Evolving Investigative Technologies

Evolving Technology

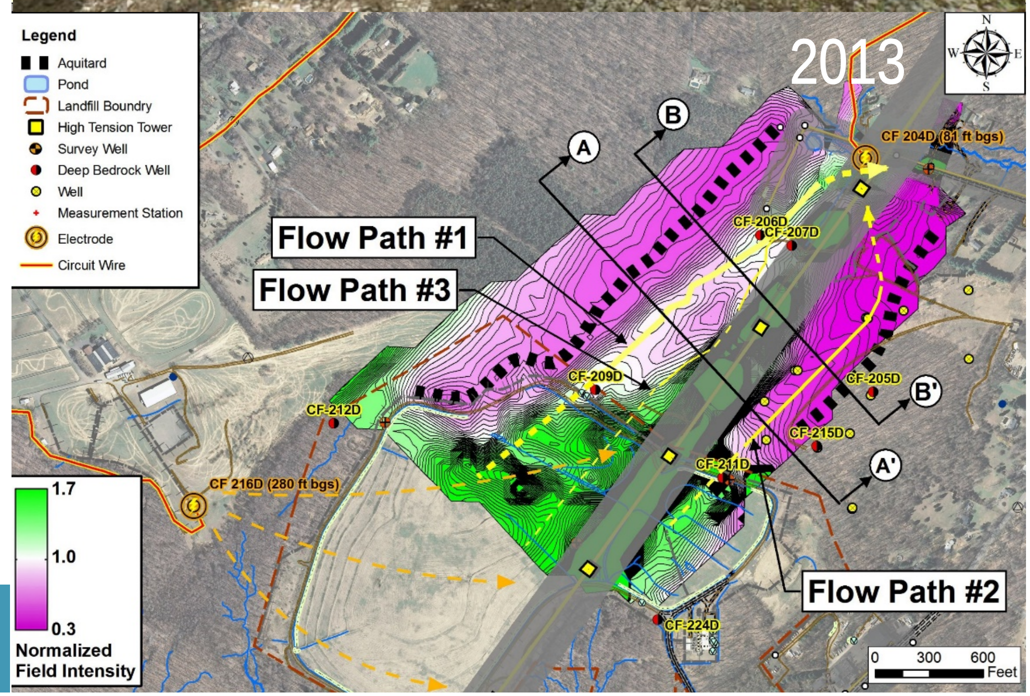
Cause of and solution to site problems post-cap/GWET

1. Lab methods/detections

- 1,4-Dioxane detections
- PFAS
- Changed direction of site history

2. Geophysics

- Identified nature/extent of contamination
- Extraction well network design



Evolving Technologies

- Laboratory Methods & Detection Limits
- Geophysical Methods
  - Bedrock fracture location
  - Downhole testing

Laboratory Testing

- Large technology improvement over course of project
- Impact on site history
  - Changing list of COCs
  - 1,4-Dioxane became leading COC and drove much of 2018 RI/FS and 2020 RD
  - Incorporate PFAS treatment into 2020 RD
  - Future contaminants???
- Challenges created
  - Evolving lab methods
  - Evolving toxicity data and regulatory standards

1980's

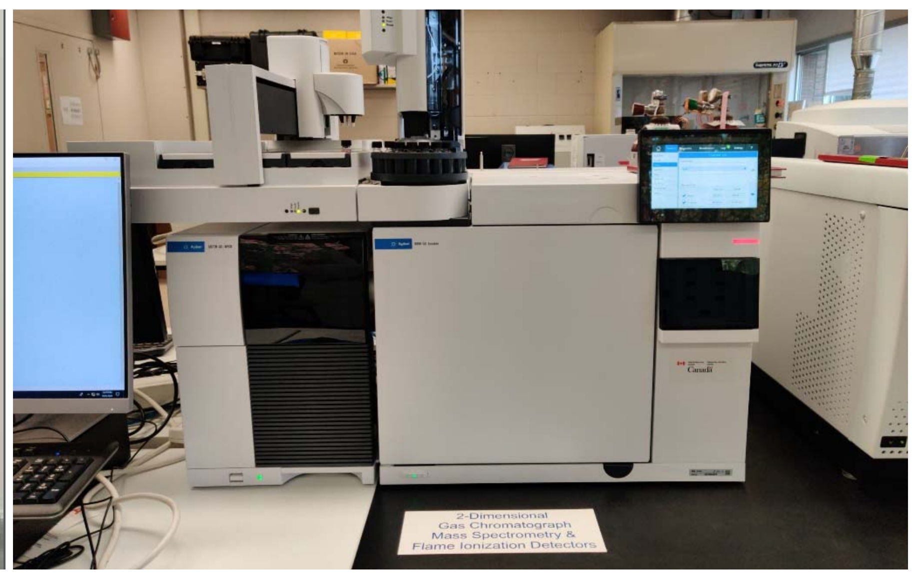
2018

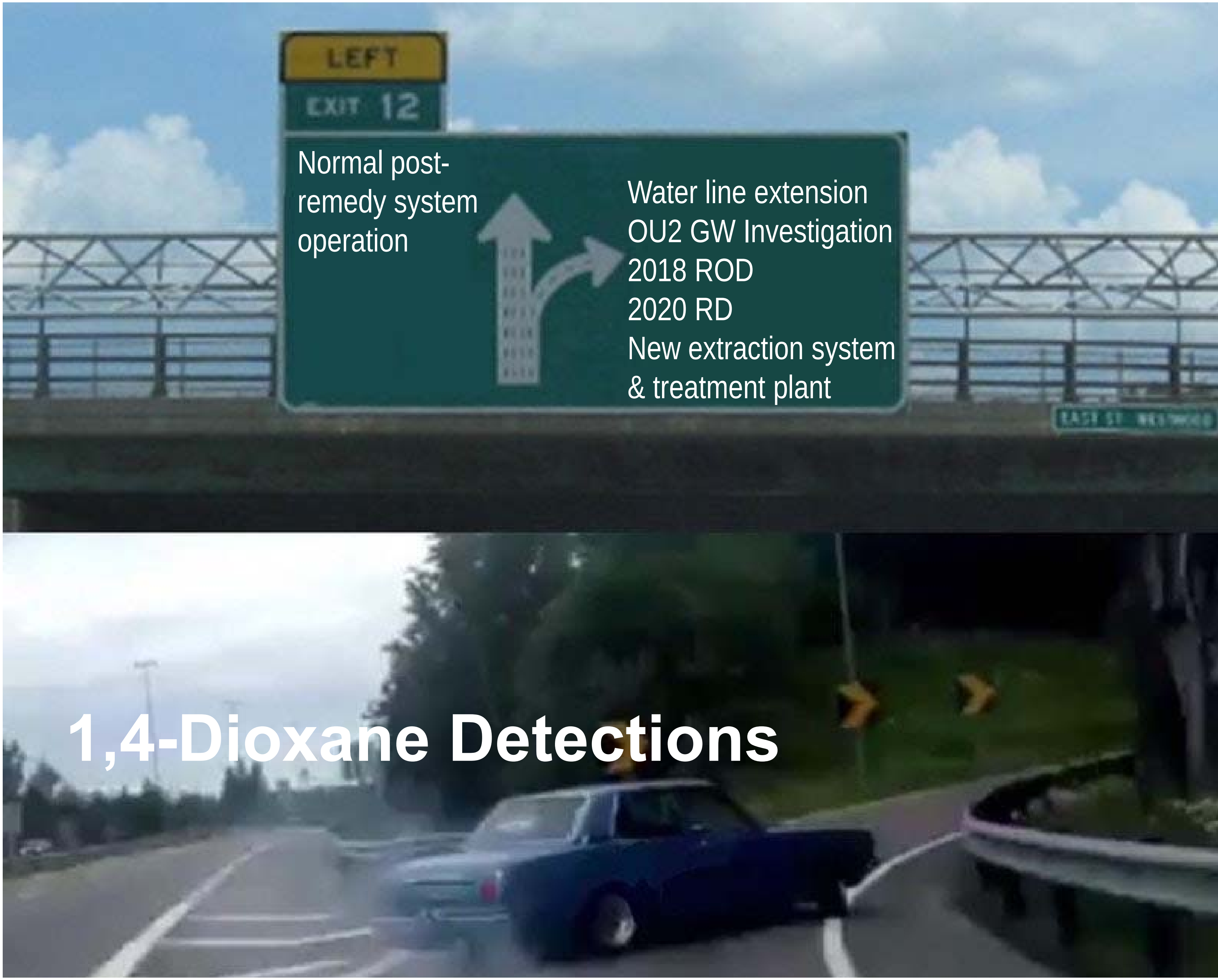
1980's

- Priority pollutant list
- COCs no longer included
  - Freon
  - Methylene chloride
  - Tert-butyl alcohol
  - Chlorobenzenes
  - Ethyl ether

2010's

- TCL/TAL
- Revised COCs
  - 1,4-Dioxane
  - Benzene
  - TCE
  - DEHP
  - Alpha-BHC
  - Lead
  - Chromium
  - TICs: phenobarbital




LEFT
EXIT 12
Normal post-remedy system operation
Water line extension
OU2 GW Investigation
2018 ROD
2020 RD
New extraction system & treatment plant
1,4-Dioxane Detections

Challenge: 1,4-Dioxane's Moving Target

Media	Year	Standard or Criterion (ppb)	Citation
Groundwater	2008	10	Ground water quality standard (NJDEP), based on higher PQL
Groundwater	2010	6.1	Tap water screening level based on 1 x 10^{-6} excess cancer risk (EPA)
Groundwater	2010	3	Interim specific ground water criterion (NJDEP)
Groundwater	2010	0.35	Revised interim specific ground water criterion (NJDEP)
Groundwater	2014	0.67	Tap water screening level based on 1 x 10^{-6} excess cancer risk (EPA)
Groundwater	2015	0.4	Draft interim specific ground water criterion (NJDEP)
Groundwater	2018	0.4	Ground water quality standard (NJDEP)
Soil	2006	58/260/0.006 (ppm)	Site-specific calculated criteria (res, non-res, impact to gw) (NJDEP)
Surface Water	2003	22,000	Ecological Screening Levels (EPA Region 5)
Sediment	2003	119	Ecological Screening Levels (EPA Region 5)

PFAS – 2019/2020

- First sampling at the site in November 2019
  - Plant influent sample
- Quickly incorporated PFAS analysis into future PDI work
  - packer testing
  - pump testing
  - full round of monitoring wells in 2020
- Incorporated into design based on anticipated promulgation of standards

Analyte	NJDEP GWQS (ng/l)	EPA Health Advisory (ng/l)	Influent PF-INF-20191120-0 11/20/2019	Influent (Dup) PF-INF-20191120-1 11/20/2019	Effluent PF-EFF-20191120-0 11/20/2019	Field Blank PF-FB-20191120-0 11/20/2019
PFNA	13		< 4.0 UJ	< 4.0 UJ	< 4.0 UJ	< 4.0 UJ
PFOS	13		**15.3 J**	**16.5 J**	7.47 J	< 4.0 UJ
PFOA	14		**28.0 J**	**28.9 J**	**29.6 J**	< 4.0 UJ
Sum of PFOS and PFOA		70	43.3 J	45.4 J	37.1 J	< 4.0 UJ

Challenges Overcome & Lessons Learned

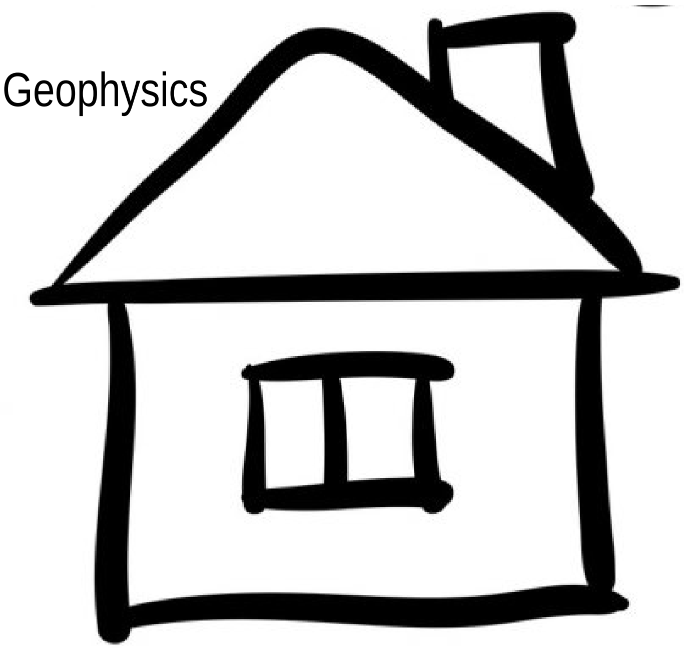
- Changing standards late in submittal cycles
- 2018 RI/FS
  - NJDEP 1,4-Dioxane GWQS promulgated at 0.4 ug/L in 2018
  - RL for RI samples 0.5 ug/L
- 2020 RD
  - NJDEP PFAS GWQS promulgated in 2020
- Keep up with evolving research on emerging contaminants including regulatory standards and proposed standards, laboratory methods and treatment options
- Work with labs to determine RLs of COCs

Geophysical Testing

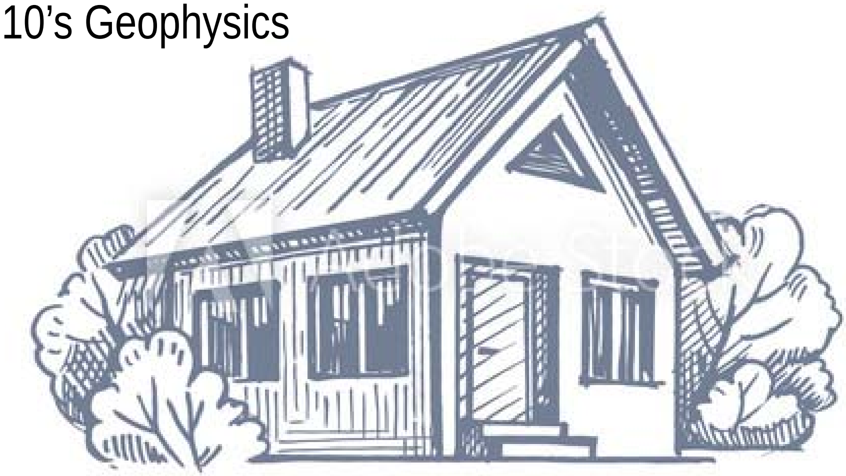
- Geophysical Technologies
  - Surface geophysics
    - Electromagnetic survey to multi-stage approach
      - Resistivity and Willowstick
  - Downhole geophysical testing improvements
  - FLUTe profiling & Multiport Wells

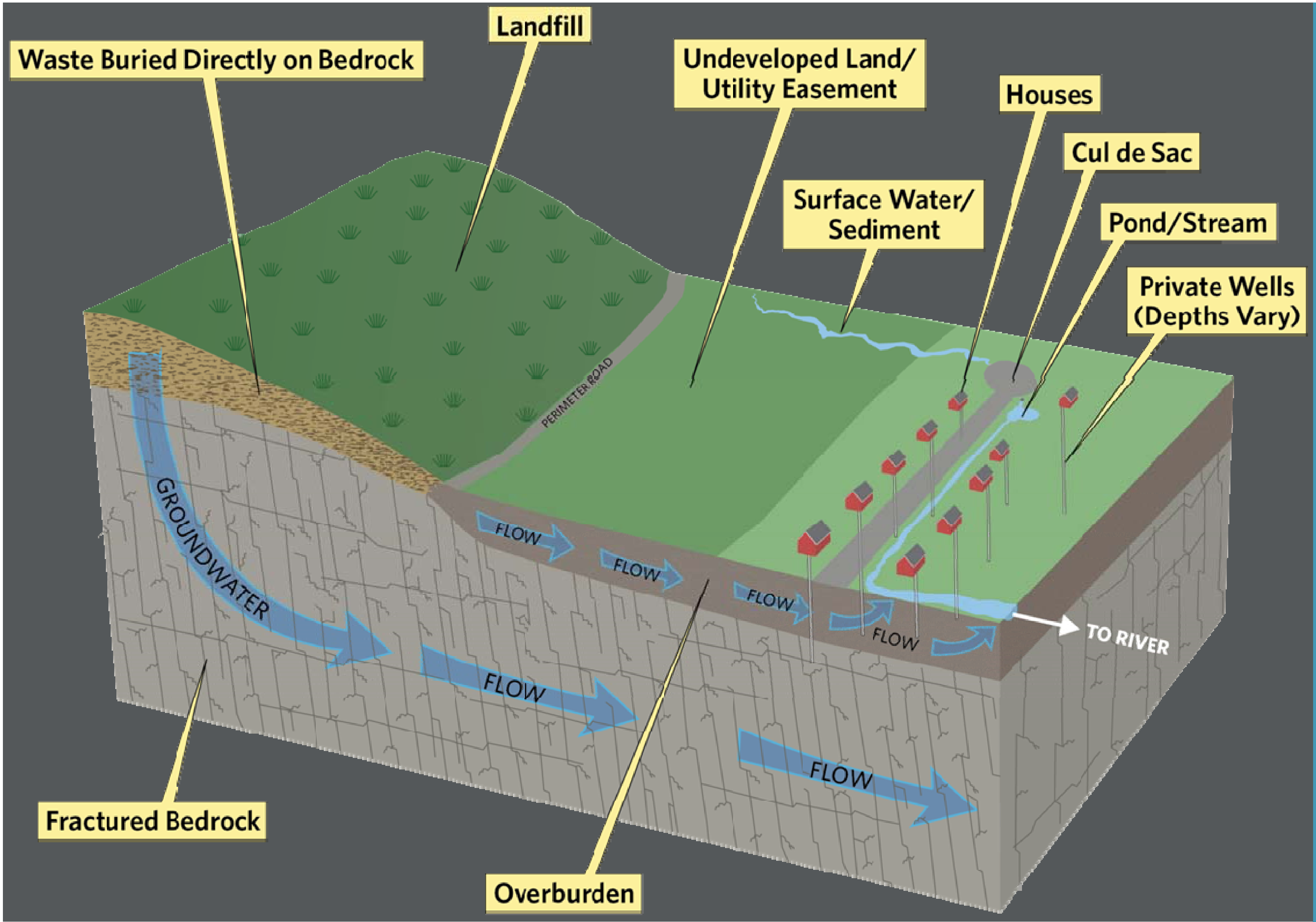
- Impact on site
  - Target specific fractures for further geophysical testing (horizontally and vertically)
  - Delineate bedrock contamination – MW locations
  - Design extraction well network

1980’s Geophysics



2010’s Geophysics



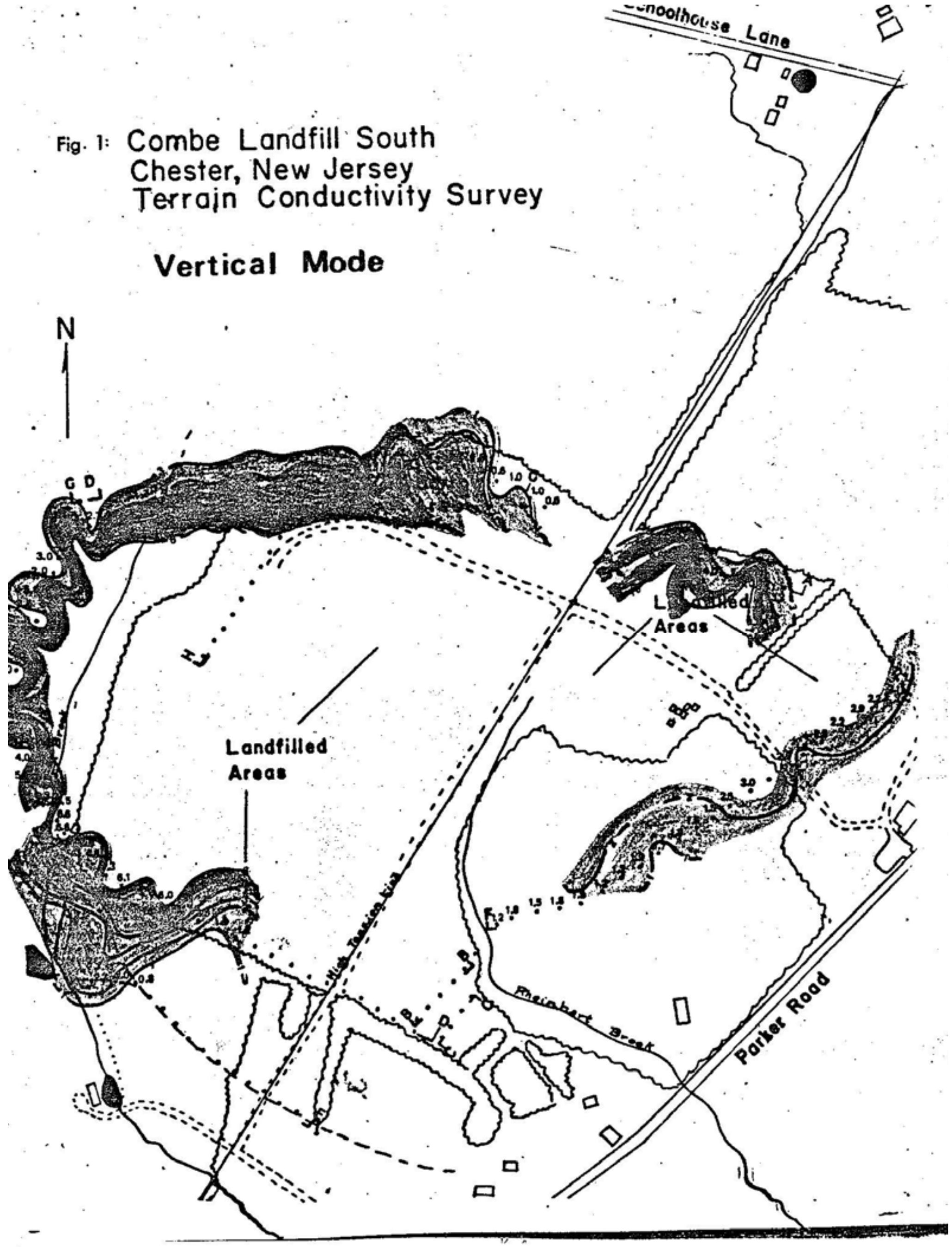


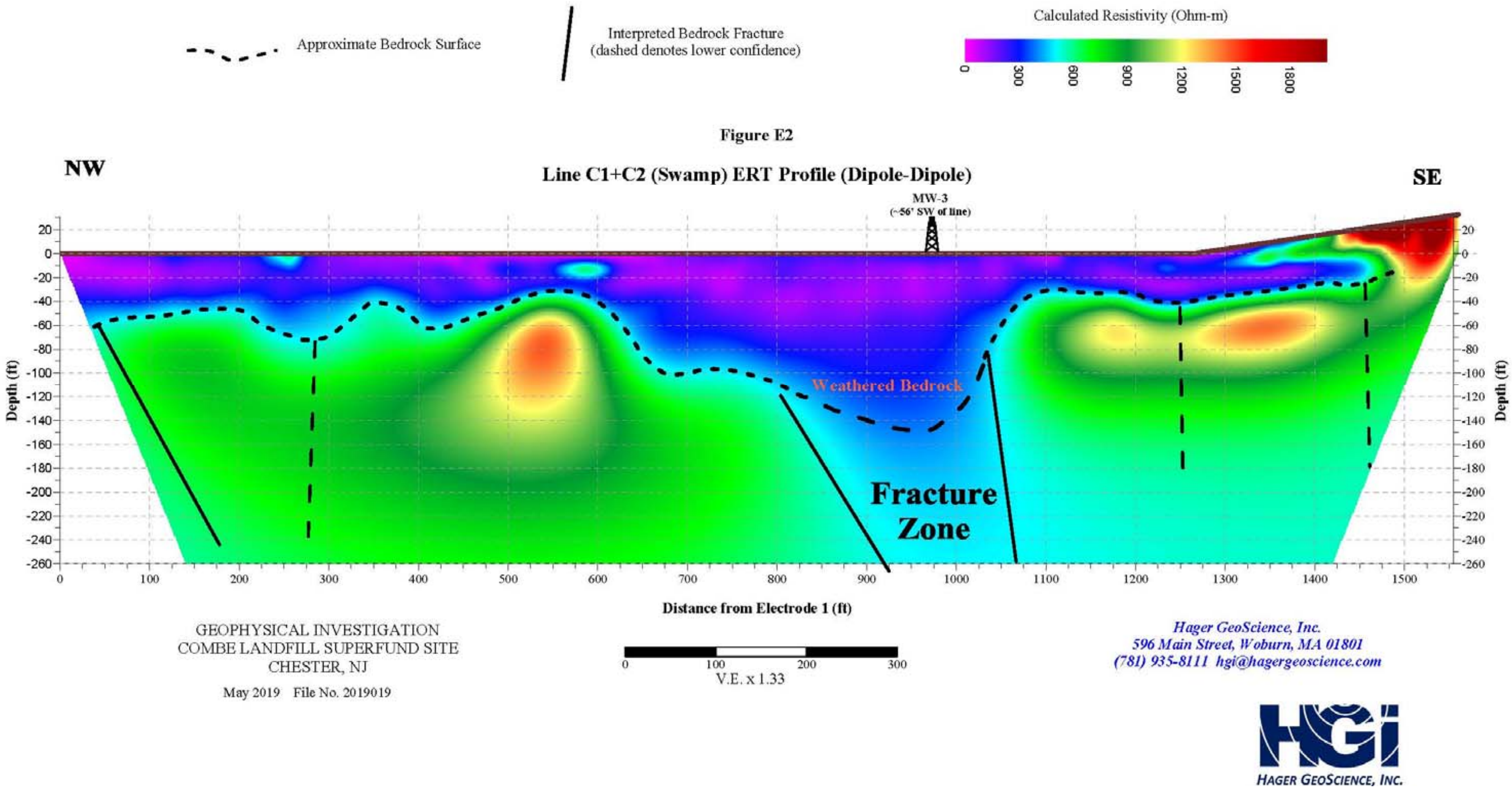
2018 RI/FS - Conceptual Site Model

Geophysics

- 1986 RI
  - Electromagnetic terrain conductivity (EM)
  - Downhole geophysics
  - Packer testing

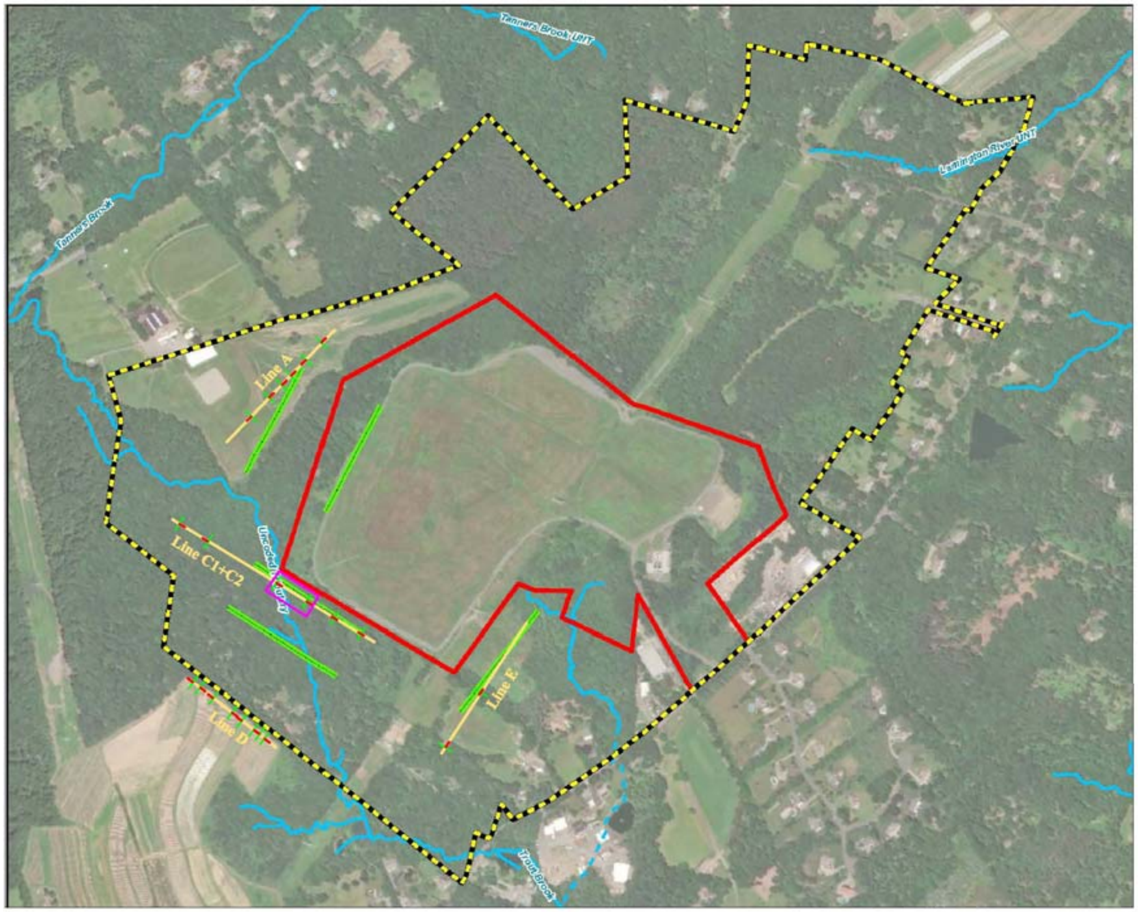
- 2020
  - Surface geophysics staged approach
    - Resistivity
    - Willowstick Electromagnetic Survey
  - Downhole geophysics
  - FLUTe profiling
  - Packer testing

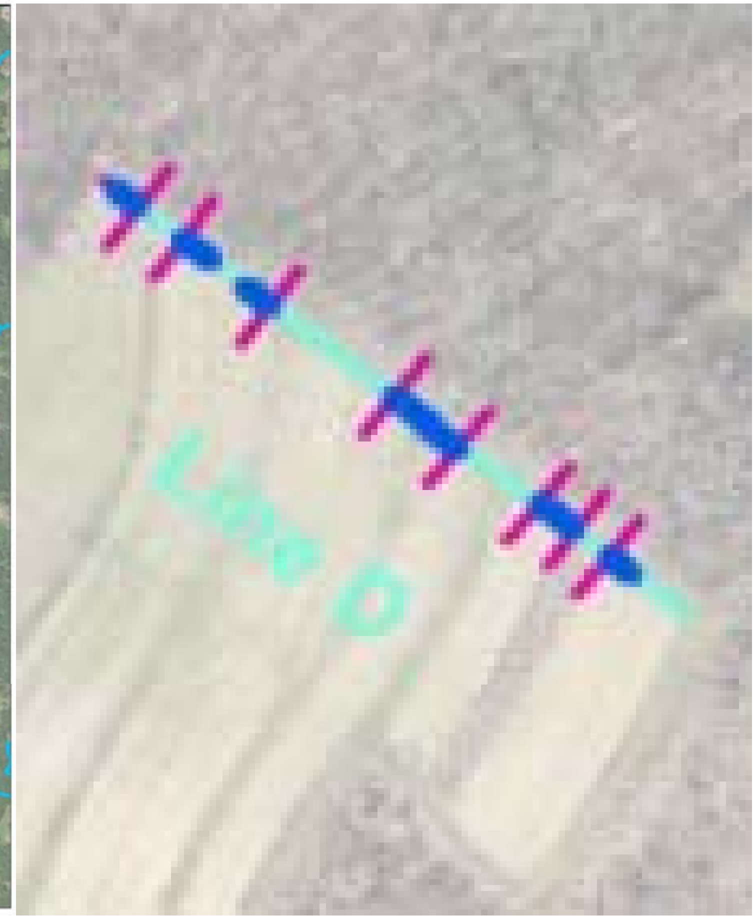




Resistivity

Surface Geophysics – Step 1



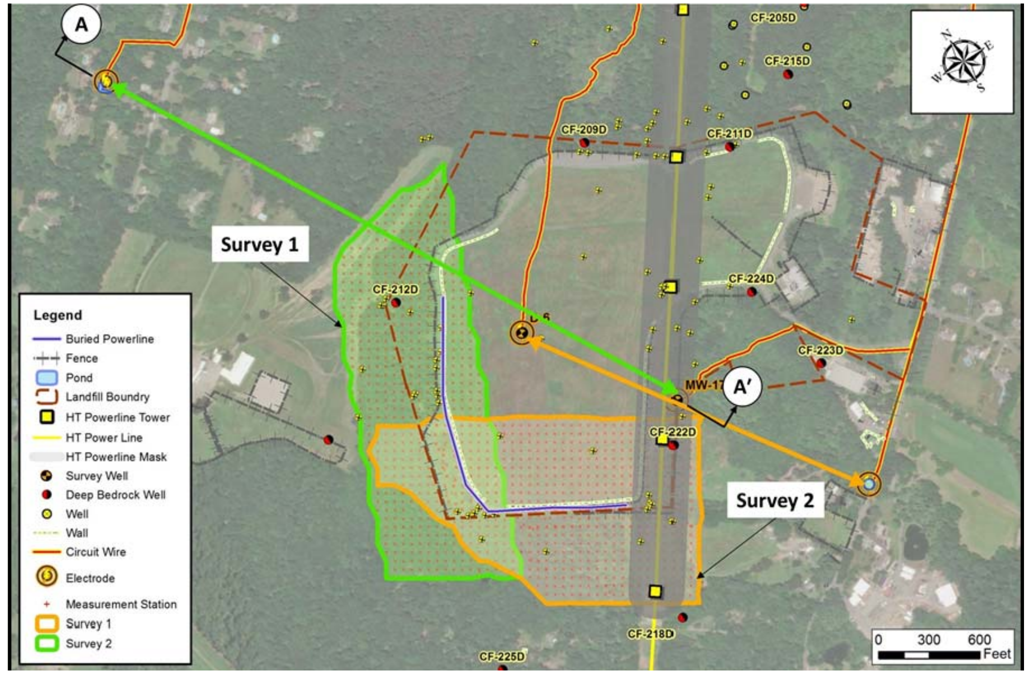


Resistivity

Location of fractures along transect/ERT lines
Direction/Dip of fractures

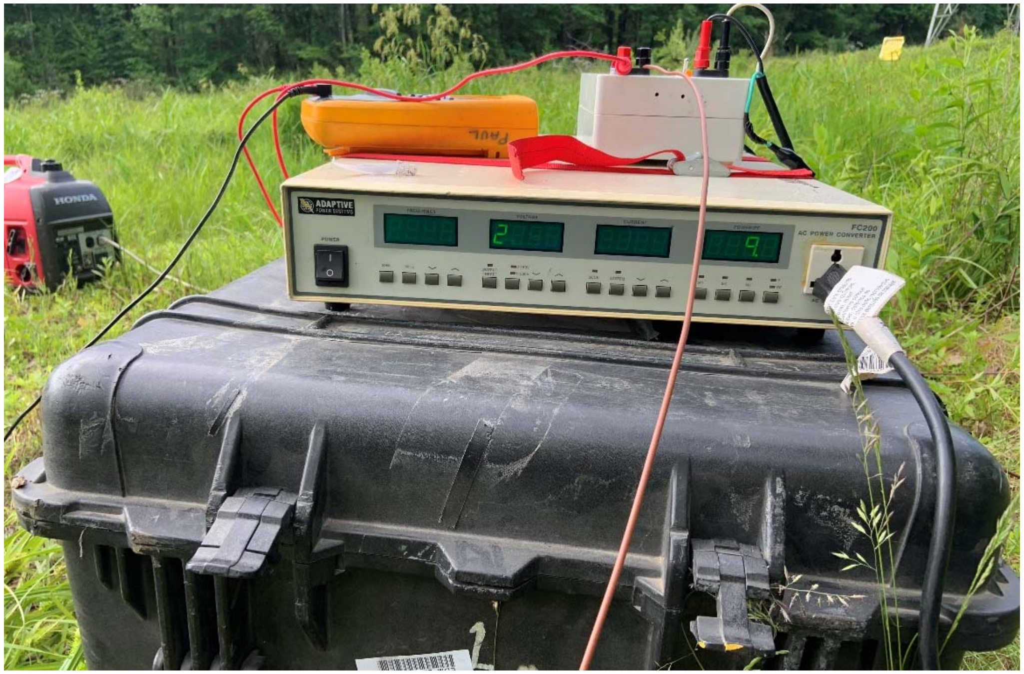
Willowstick
Surface Geophysics - Step 2

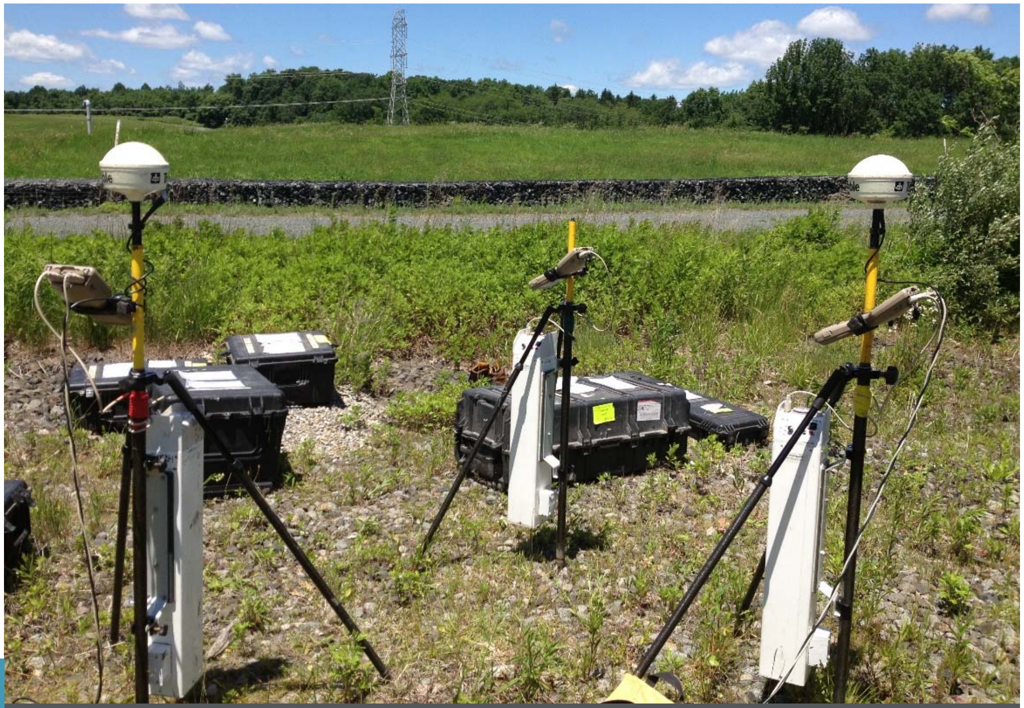
- Provides results over larger area
- Establish survey area based on results of resistivity
- Identify electrode placement



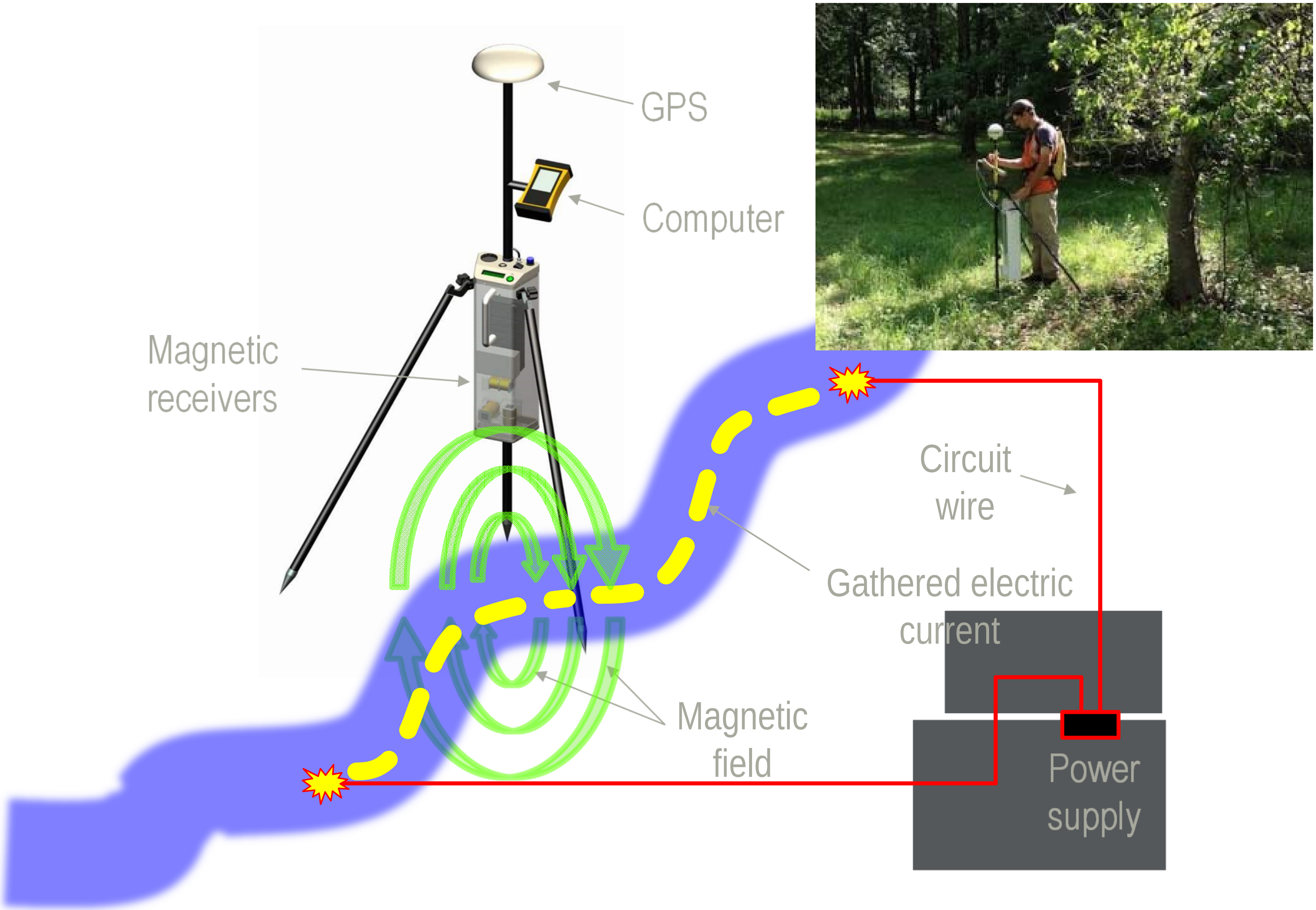
Willowstick Technology

- Electric current introduced to ground via 2 electrodes
- Current will flow through conductive portions of bedrock, i.e. water bearing fractures
- Magnetic field measurements on ground surface can track the flow of electric current
- Data reduced to determine fracture locations





Magnetometric Resistivity Instrument



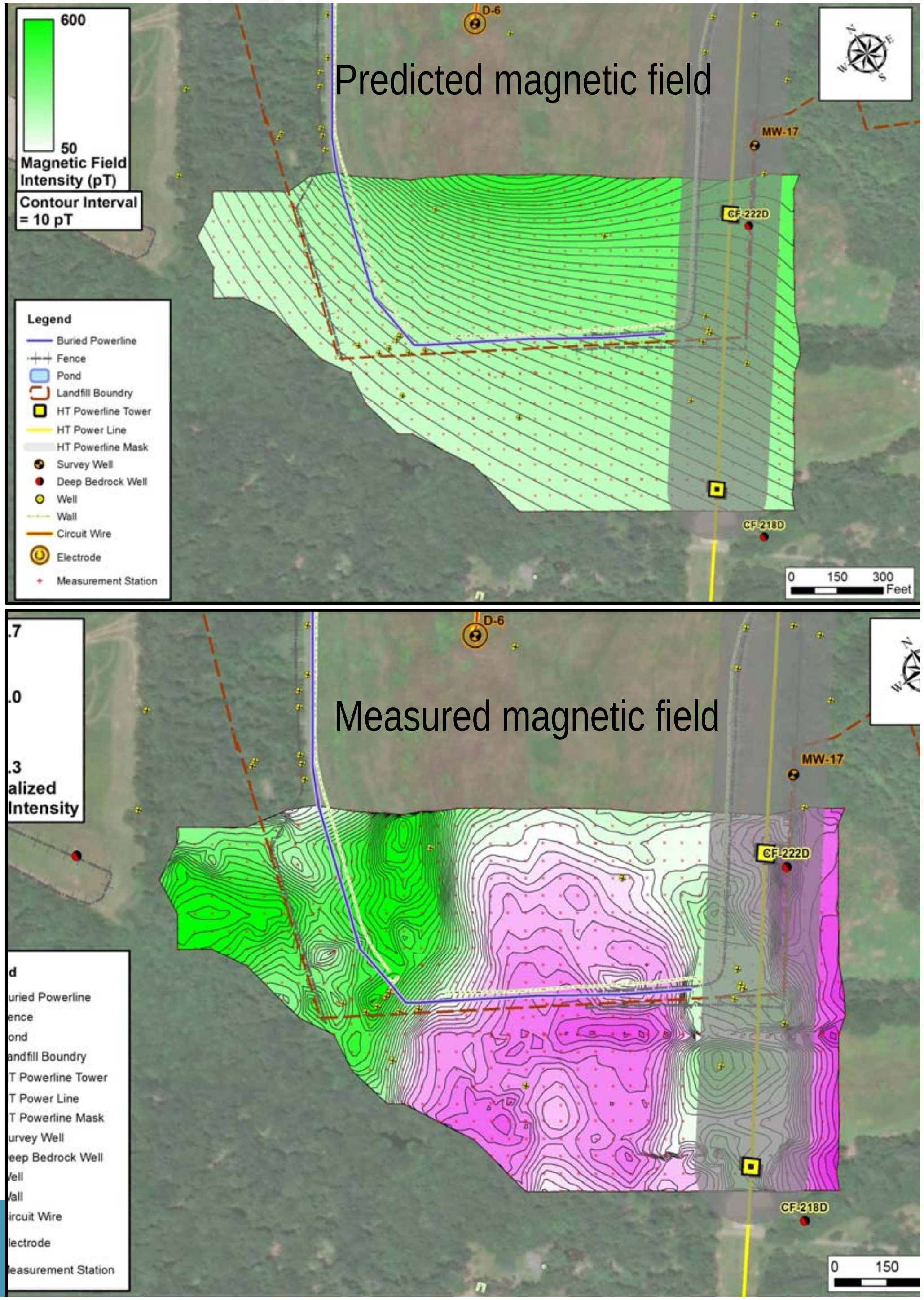
Willowstick

Step 2

- Predicted magnetic field

vs.

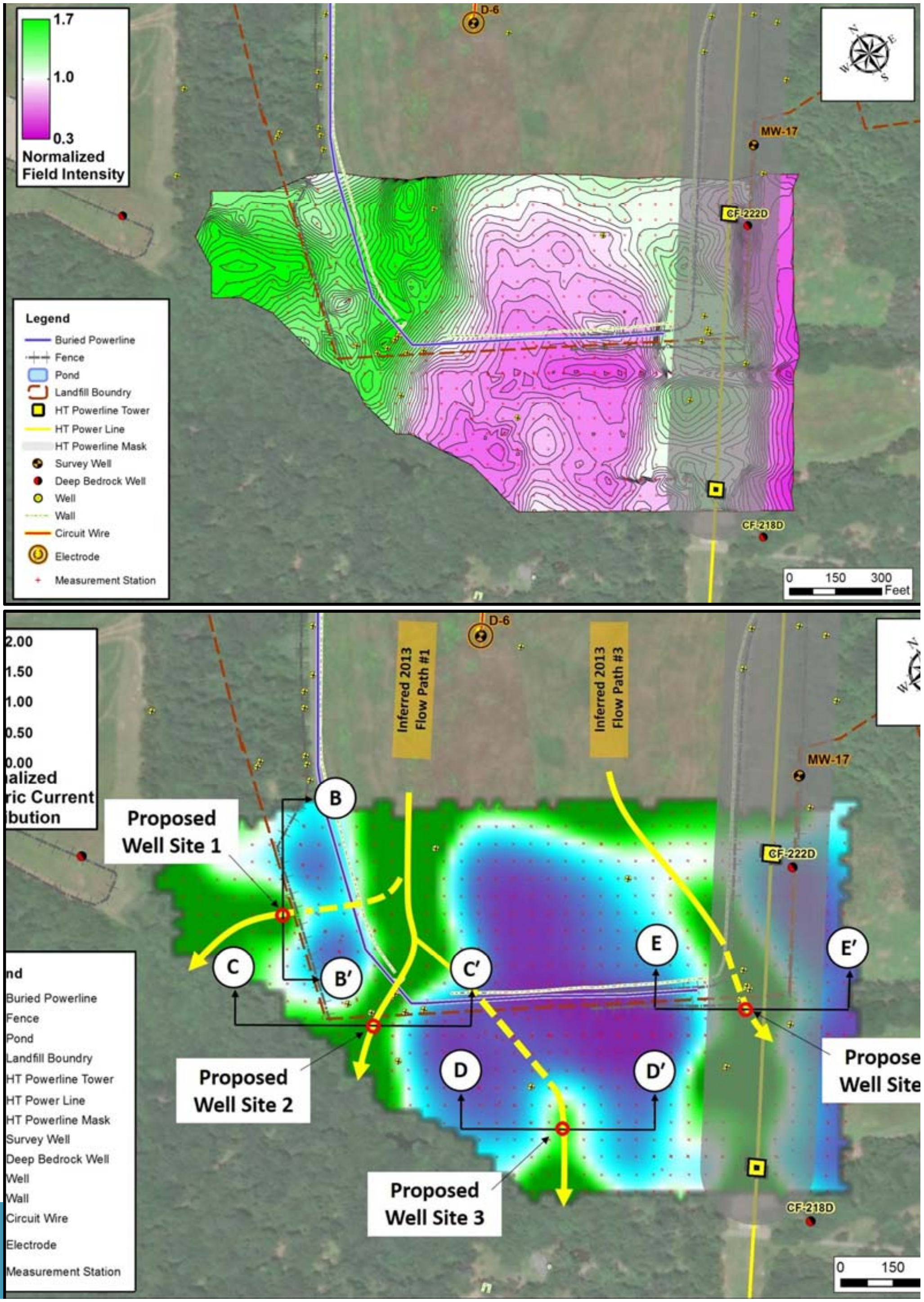
- Actual magnetic field detected
- Differences indicate flow paths



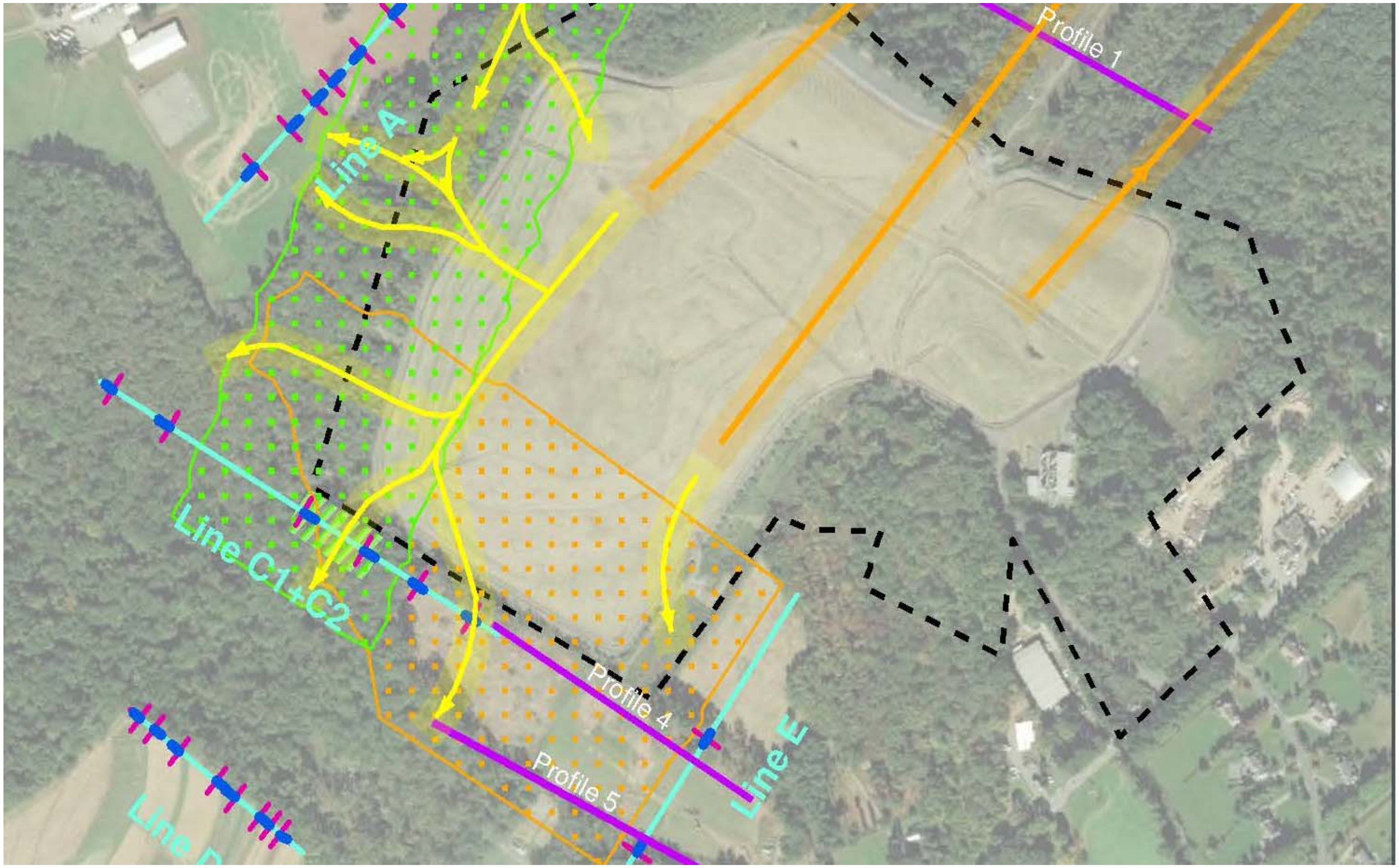
Willowstick

Step 2

- Data interpretation leads to identifying fracture locations



Magnetometric Resistivity Study at Combe Fill South Landfill OU2



Surface Geophysics Results

Resistivity & Willowstick

Challenges Overcome & Lessons Learned

Geophysics

- Avoid field work in summer or after large storms
- Effects of terrain, man-made features on results
  - Power lines
  - Fences
  - Buried utilities
  - Buried waste
- Wire theft
- Works best in areas with limited development/surrounding population

Downhole Geophysics

Downhole geophysics, FLUTe hydraulic profiling and packer testing

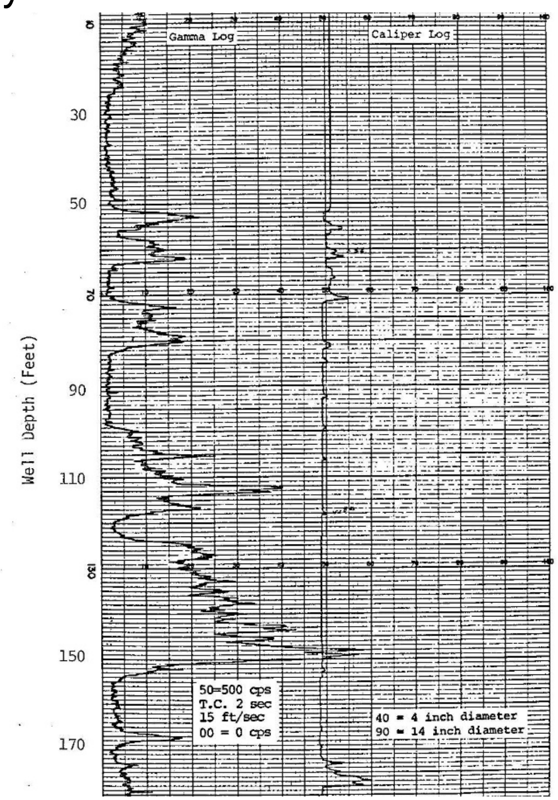
Downhole geophysics

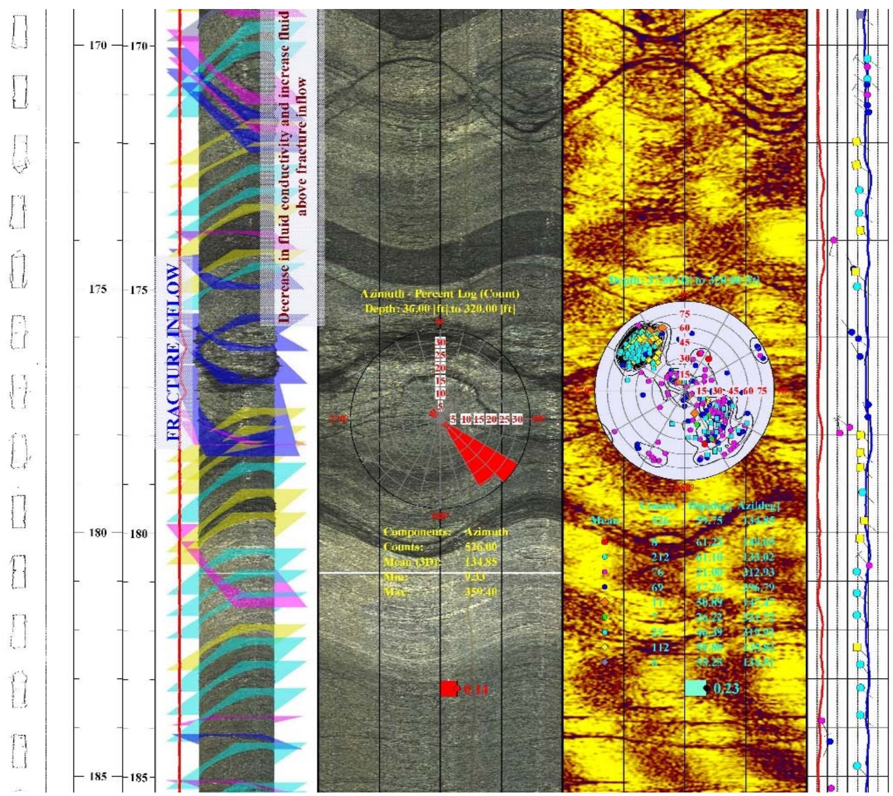
1986 RI

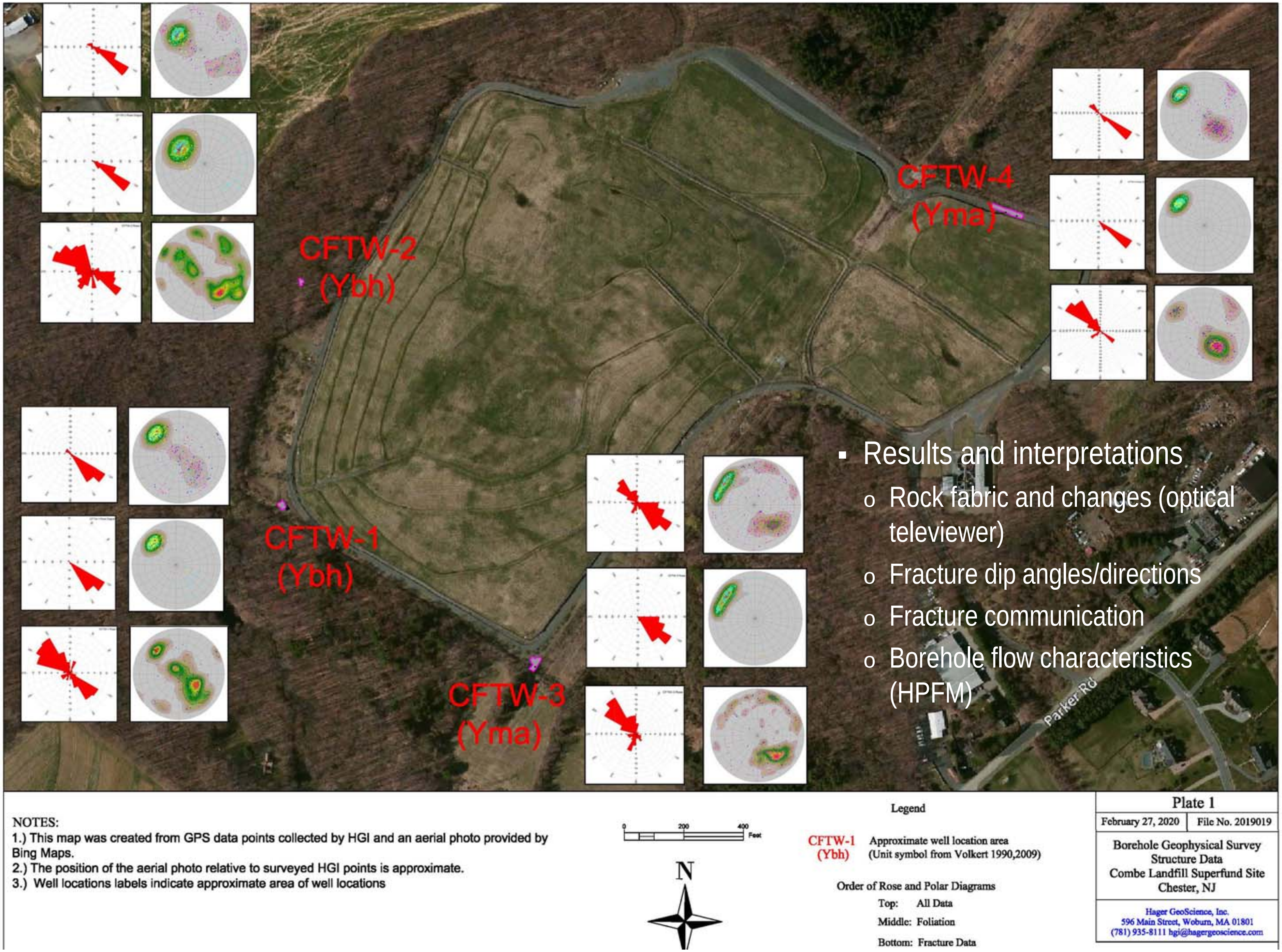
- Gamma
- Resistance
- Spontaneous potential
- Caliper
- Temperature
- Density

2018 RI

- Same as 1986 plus
- Heat-pulse flow meter
- Acoustic televiewer
- Optical televiewer







- Results and interpretations
  - Rock fabric and changes (optical televiewer)
  - Fracture dip angles/directions
  - Fracture communication
  - Borehole flow characteristics (HPFM)

FLUTe Hydraulic Profiling

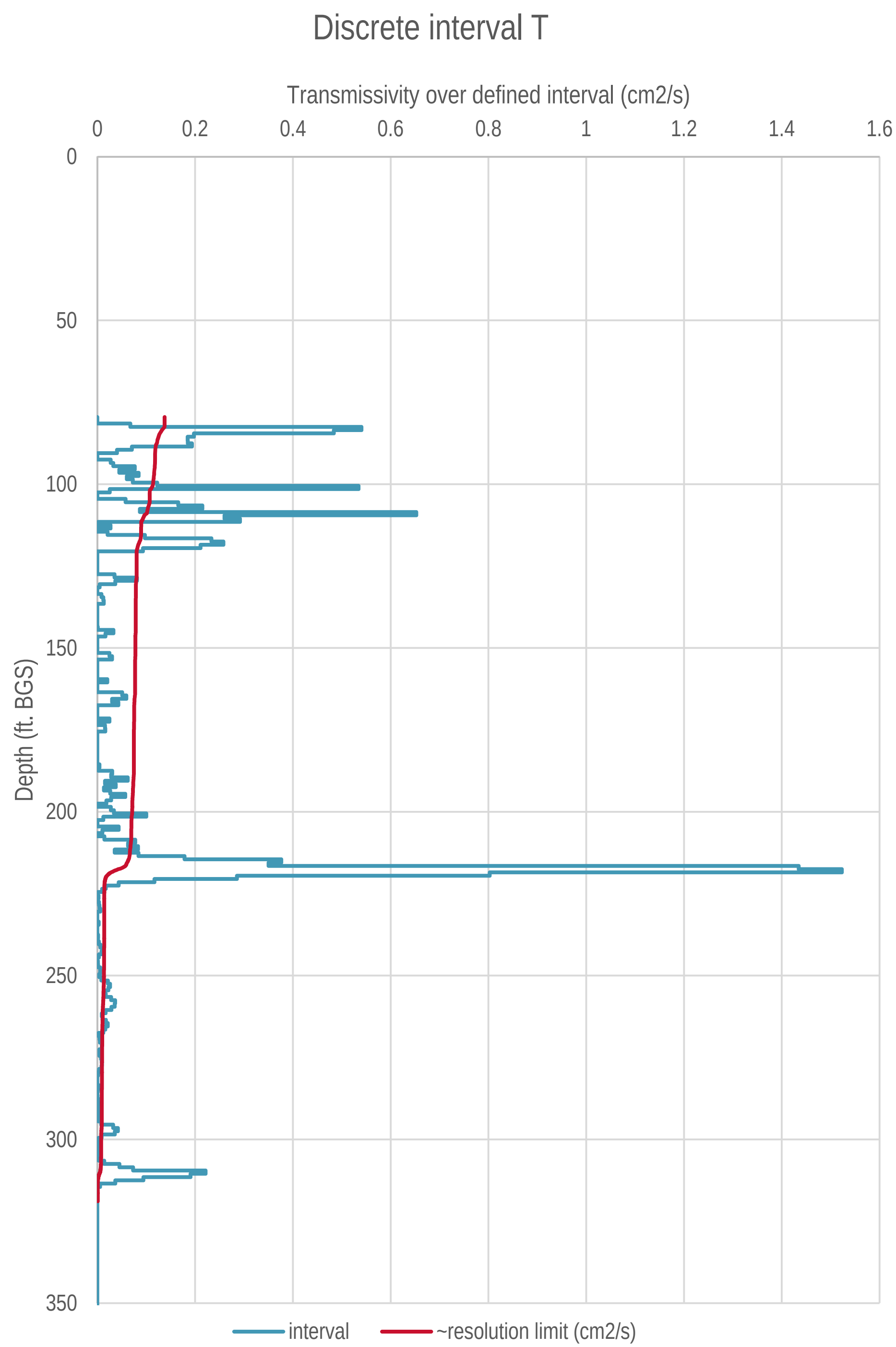
Additional downhole geophysical testing method

Water FLUTe Systems

Multiport well system allowing for depth-discrete sample intervals within same borehole

FLUTe Hydraulic Profiling

- Rate of liner installation changes when fractures are sealed by liner
- FLUTe uses data to calculate transmissivities of fractures



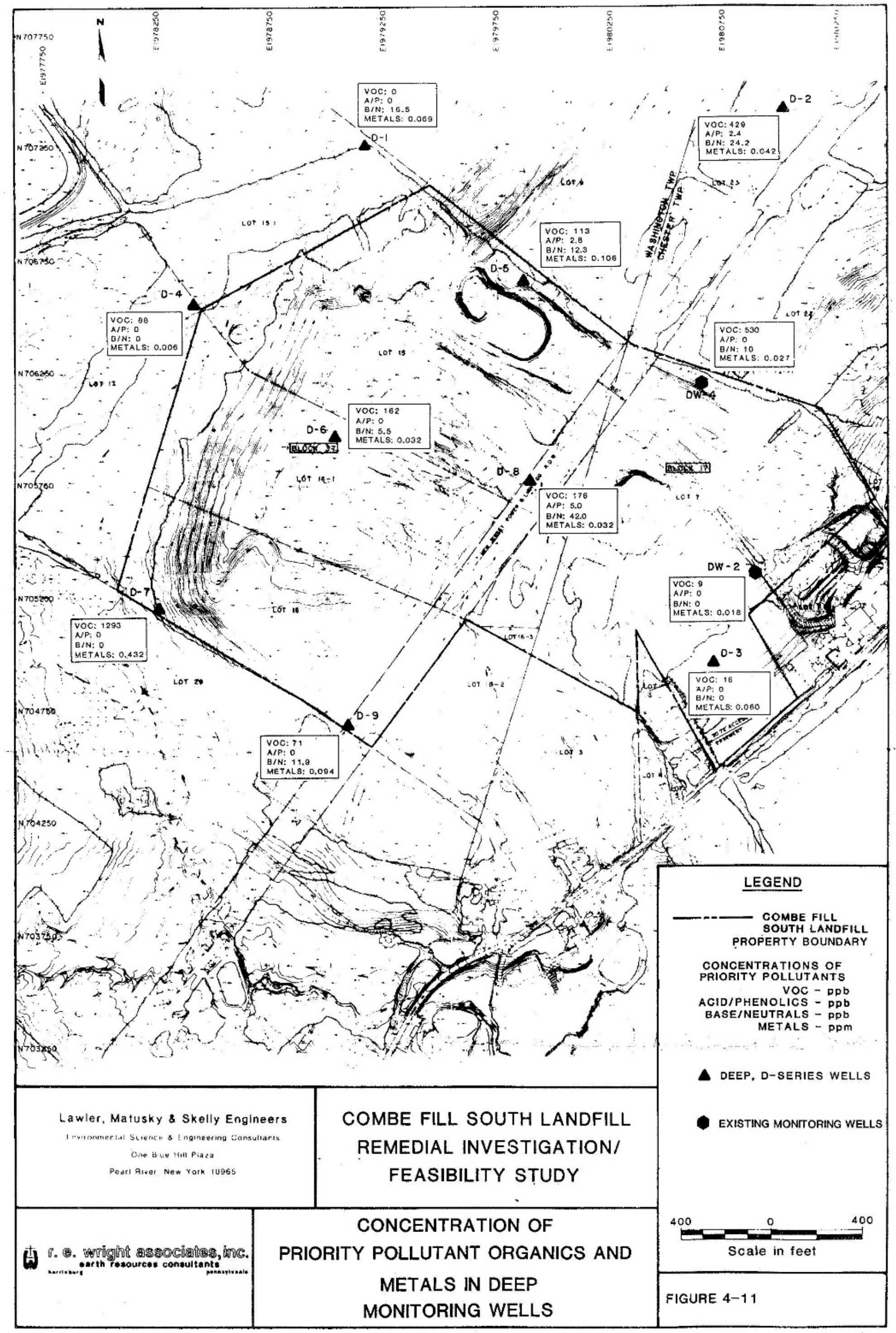
FLUTe Lessons Learned & Challenges

- High bedrock head pressures
  - Heavy mud or grout required for installation
  - Scaffold to overcome artesian heads for installation

- Sampling issues over time
  - Clogging ports
  - Changing head pressures
  - Leaking systems

Started From…

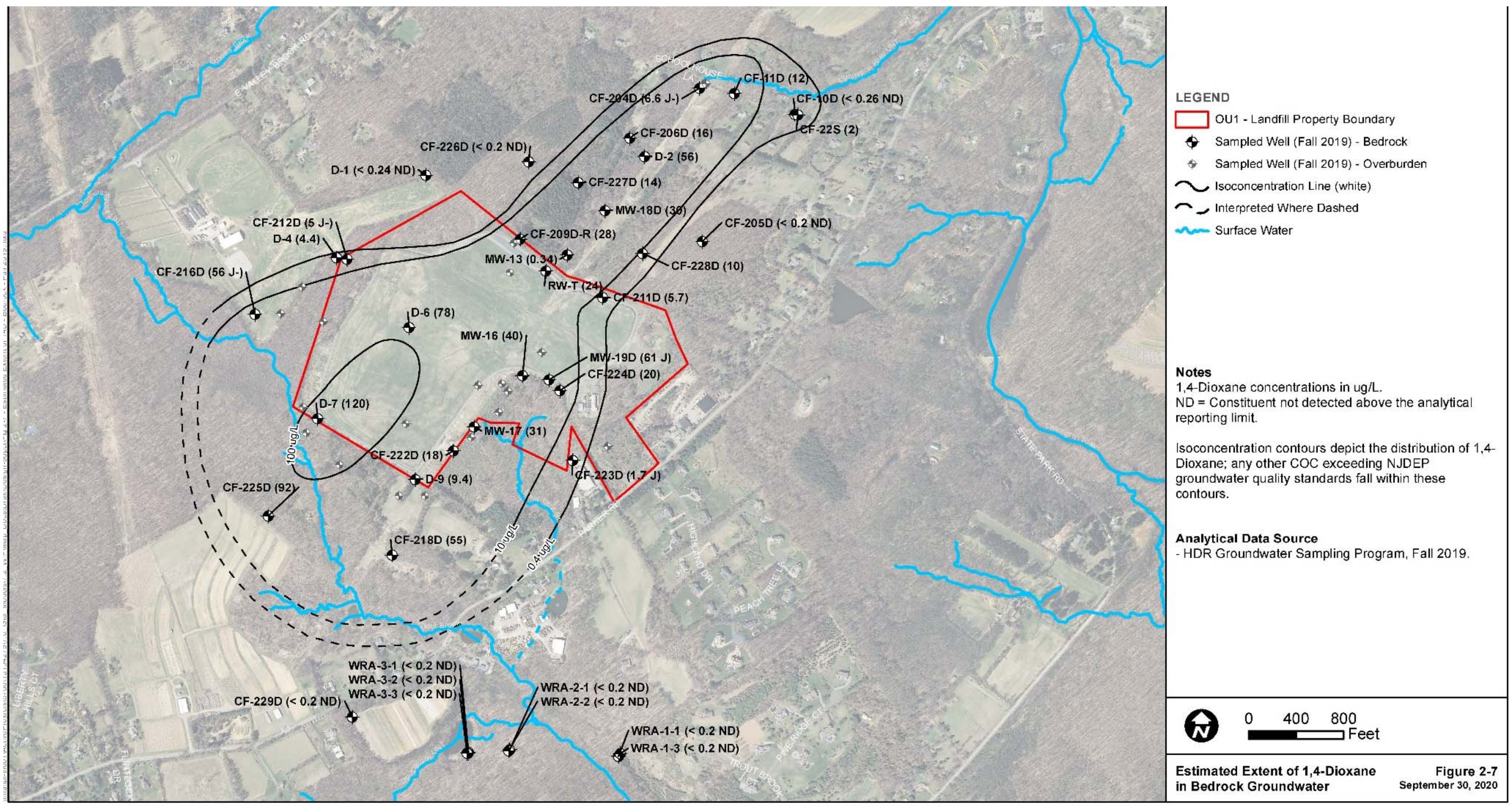
- Solid, foundational understanding of site geology/hydrogeology



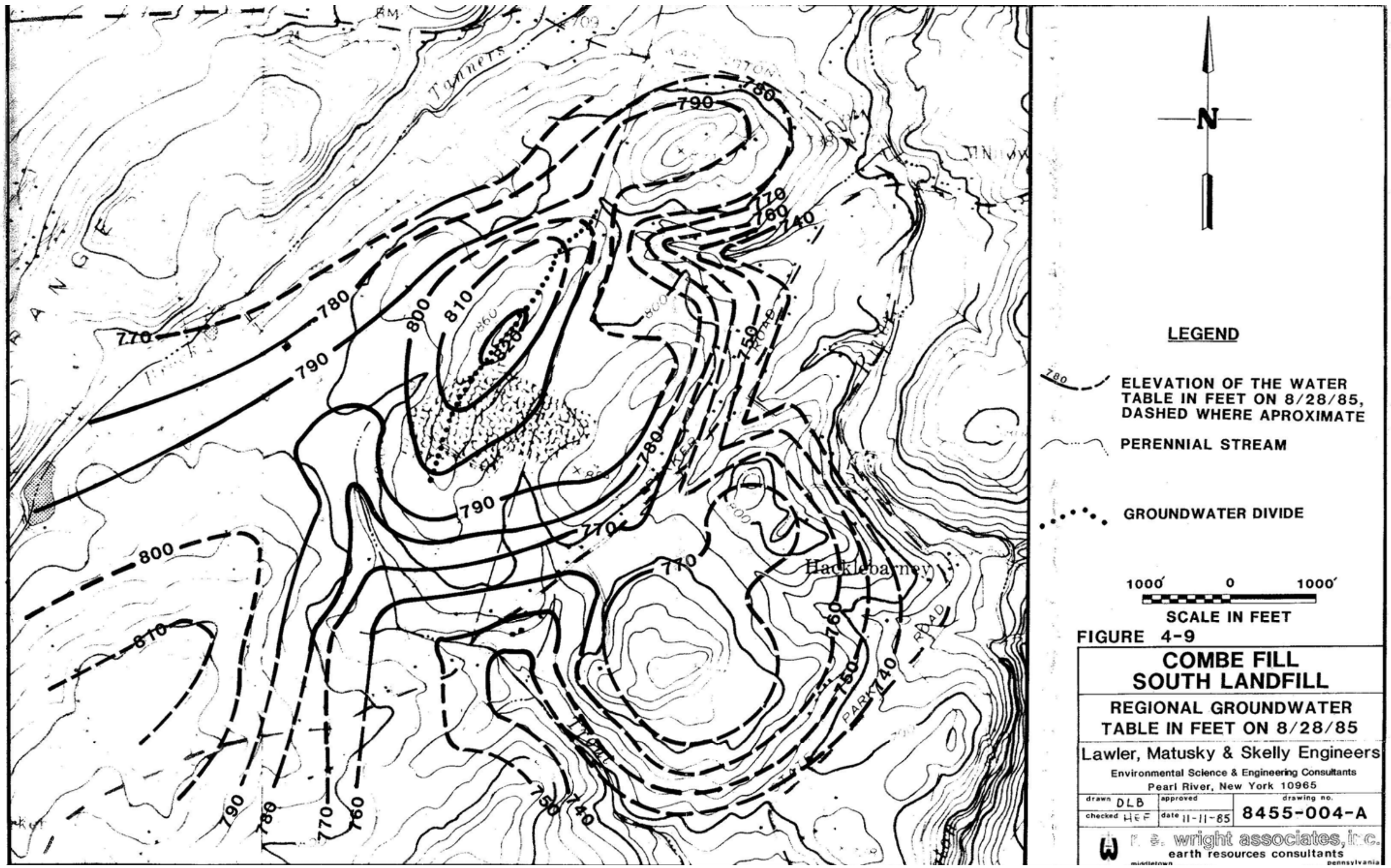
4-69A

Now we are here…

- RI/FS
  - o Locate multiport monitoring wells for RI/FS
    - Extent of 1,4-Dioxane contamination

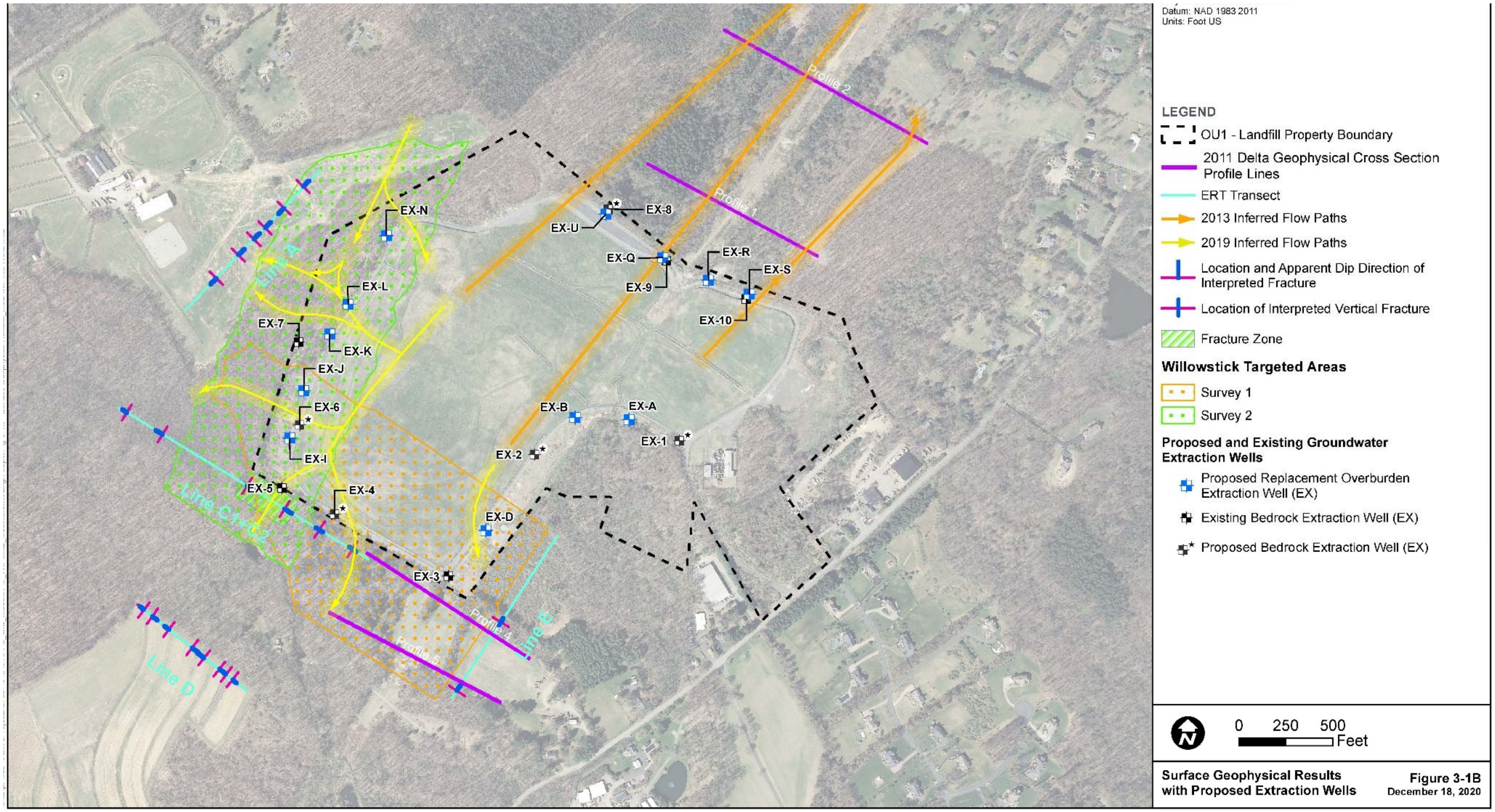


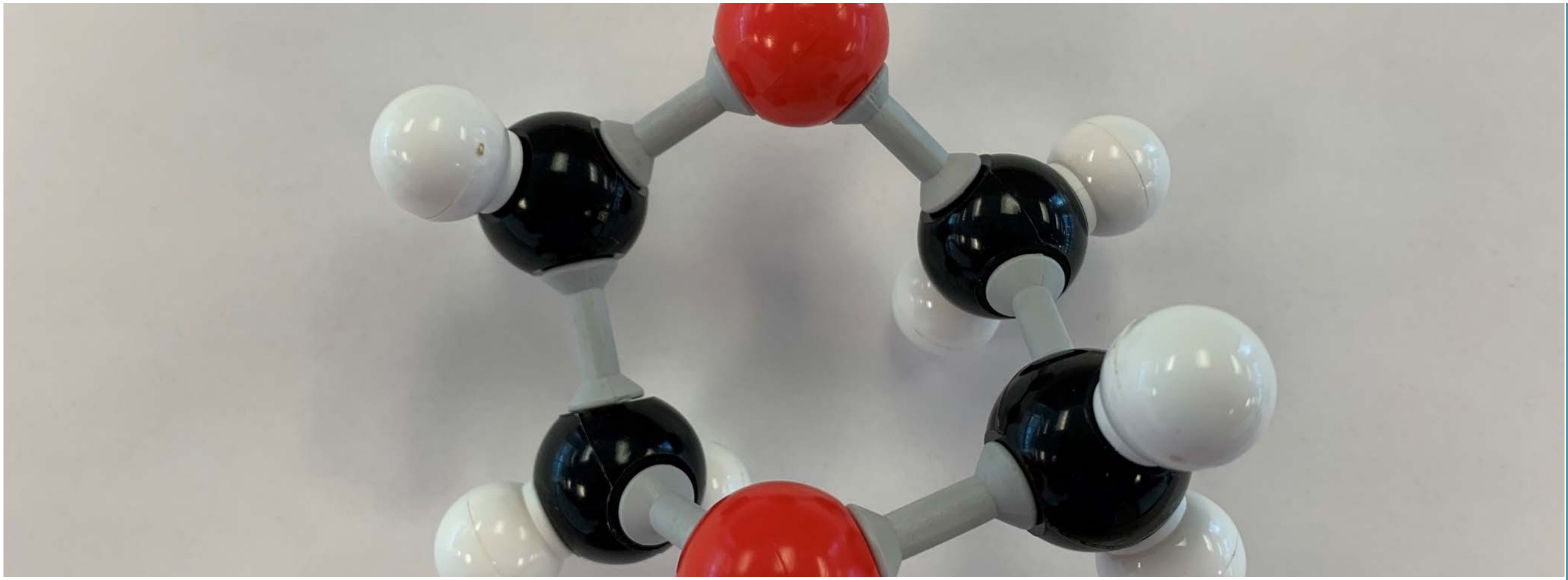
Started From…



Now we are here…

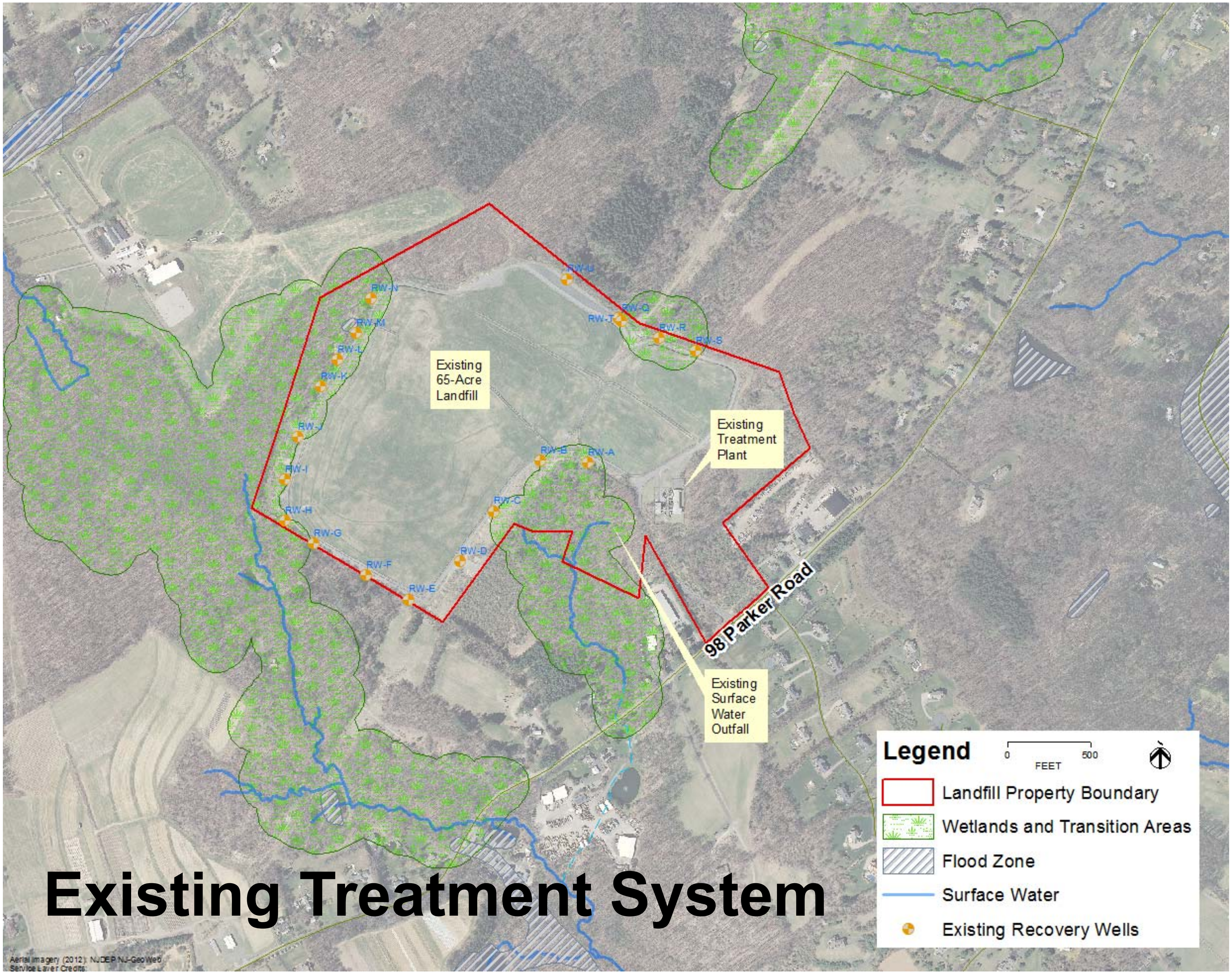
- RD
  - Design extraction network
    - Well locations & pumping rates





04 Treatment of Emerging Contaminants

Existing Treatment System



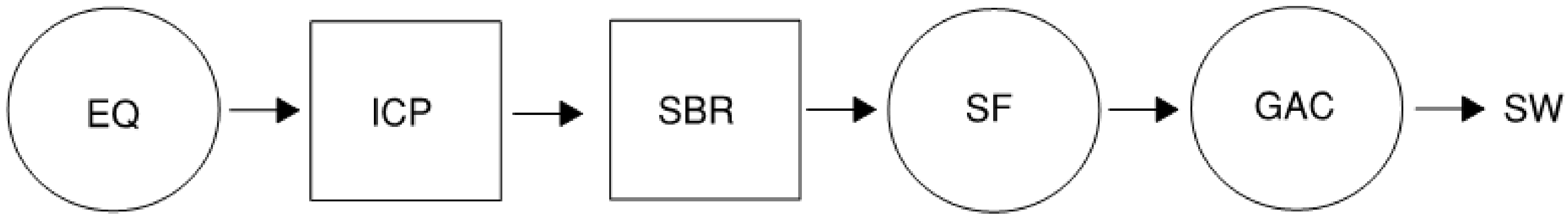
Existing Groundwater Treatment System

- Treats groundwater extracted from shallow recovery wells around the landfill perimeter
- Treatment capacity design is 120 gpm, but operating at 70 gpm since start-up
- Treatment for organic (volatile and semi-volatile) and inorganic (heavy metals) contaminants
- NJDEP currently provides O&M of the treatment system and landfill

Purpose of New Design

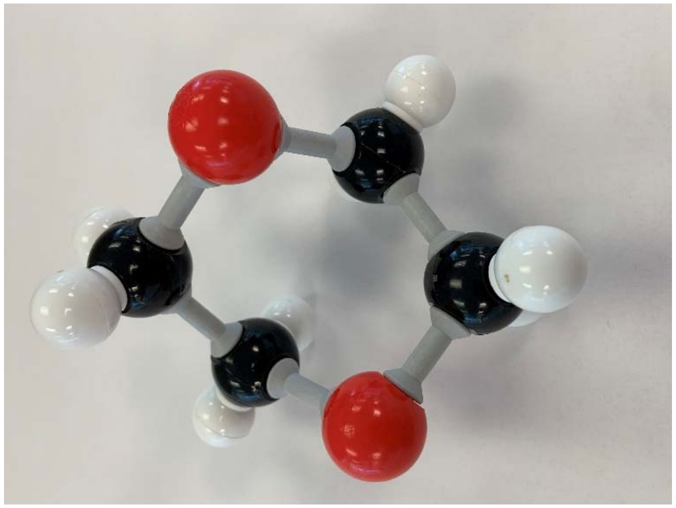
- Increase groundwater capture from overburden and bedrock aquifers to keep contamination within the OU1 landfill property
- Add groundwater treatment for 1,4-dioxane and PFAS
- Evaluate redesign of existing treatment building vs new construction
- OU2 interim remedy is long-term monitoring

Existing Treatment Plant Process Flow Diagram



1,4-Dioxane Background

- Colorless liquid with a faint, sweet odor
- Used as a solvent stabilizer, textiles, paints, and personal care products, to name a few.
- Hydrophilic and miscible in water
- Probably human carcinogen with a one in a million (10^{-6}) risk level of 0.35 µg/l.
- NJ GWQS is 0.4 µg/l.



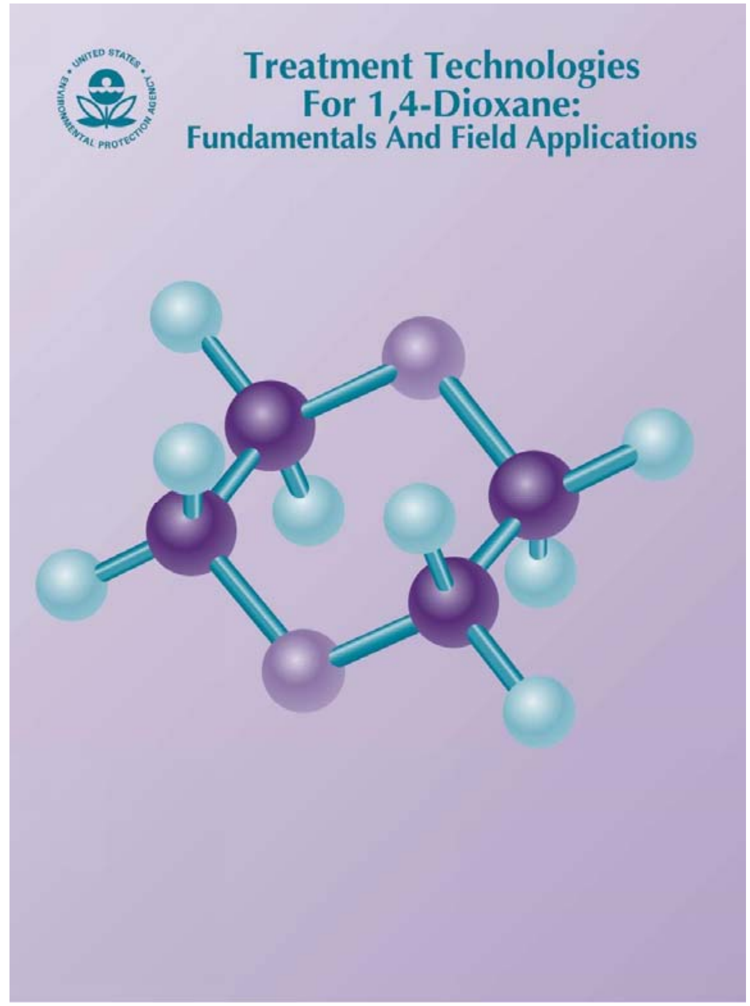
Property	1,4-dioxane
Molecular Weight	88.1
Melting Point (°C at 760 mm Hg)	11.8
Boiling Point (°C at 760 mm Hg)	101.1
Flash Point (°C at 760 mm Hg)	5 to 18
Density (g/mL at 20°C)	1.0329
Water Solubility (mg/L at 20°C)	Miscible
Vapor Density (air=1)	3.03
Octanol-Water Partition Coefficient (KOW)	0.27
Vapor Pressure (mm Hg at 20°C)	30
Henry's Law Constant (atm m3/mole)	4.88×10^{-6}

Source: EPA, 2006

Ex-Situ 1,4-Dioxane Treatment Technologies

- Adsorption
- Biological Treatment
- Advanced Oxidation Processes (AOP)

“I have not failed.
I've just found 10,000 ways
that won't work.”
— Thomas A. Edison



Ex-Situ 1,4-Dioxane Treatment Alternatives

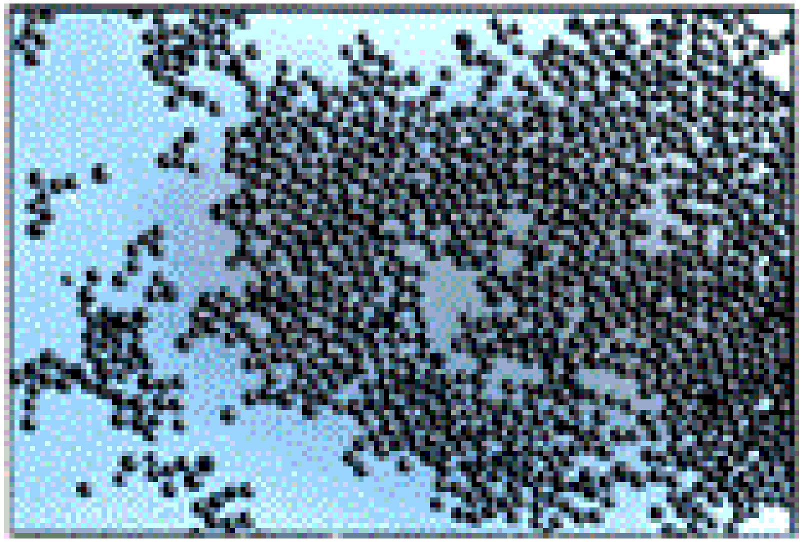
- Adsorption
  - 2017 Ambersorb 563™ pilot
- Advanced Oxidation Processes (AOP)
  - 2012 NJDEP Pilot Studies
  - 2019 Fenton's Reagent bench
  - 2019 Sodium Persulfate bench
  - 2019 UV/Peroxide (3 bench)
  - 2020 UV/Peroxide pilot (Trojan UV)
- Biological Treatment (co-metabolic)
  - 2019 NJIT's DD4 and propane bench
  - 2019 DD4, PH-06, and CB1190 and propane

Adsorption

Physical adherence or bonding of ions and molecules onto the surface of another molecule.

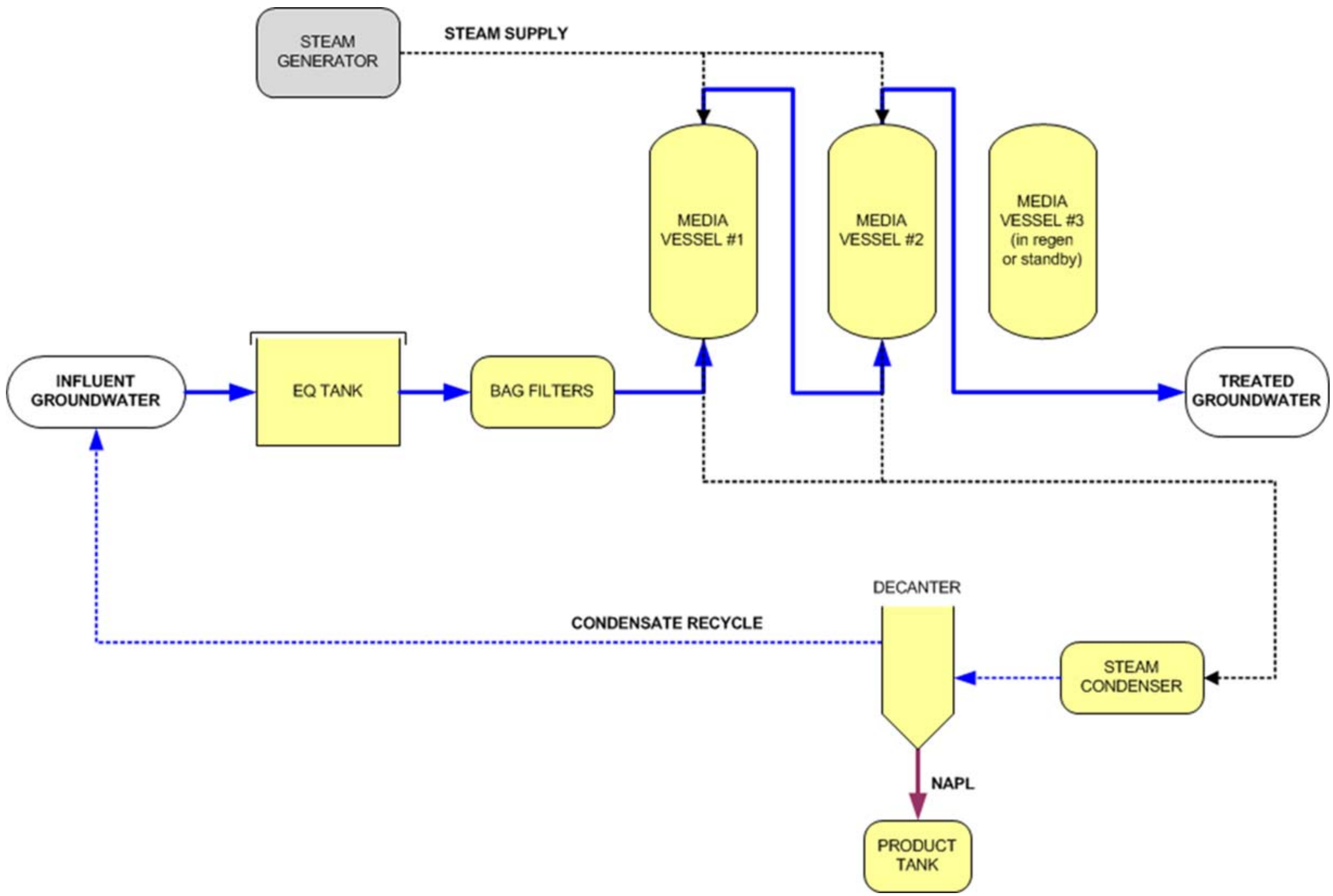
Applications include:

- Granular Activated Carbon (GAC)
  - Not effective at low concentrations and short contact times; however, GAC has been demonstrated to have adsorption capacity at high concentrations and extended contact times.
- Carbonaceous Resin – AMBERSORB 563™
  - AMBERSORB 563™ is a synthetic resin material that is proprietary to DOW Chemical and Emerging Compounds Treatment Technologies, Inc. (ECT)



AMBERSORB 563™ Pilot Study

- ECT performed a one-month pilot study during February 2017.
  - Tested raw influent, treated effluent, and elevated 1,4-dioxane concentrations from monitoring well CF-209D.
  - Demonstrated the resin regeneration process.
- The pilot test consistently yielded effluent concentrations less than 0.4 µg/l.
- AMBERSORB 563™ showed good adsorption capacity, but was impacted by other organic compounds, resulting in the need for pre-treatment.



Source: ECT2 (https://www.ect2.com/)

Biological Treatment

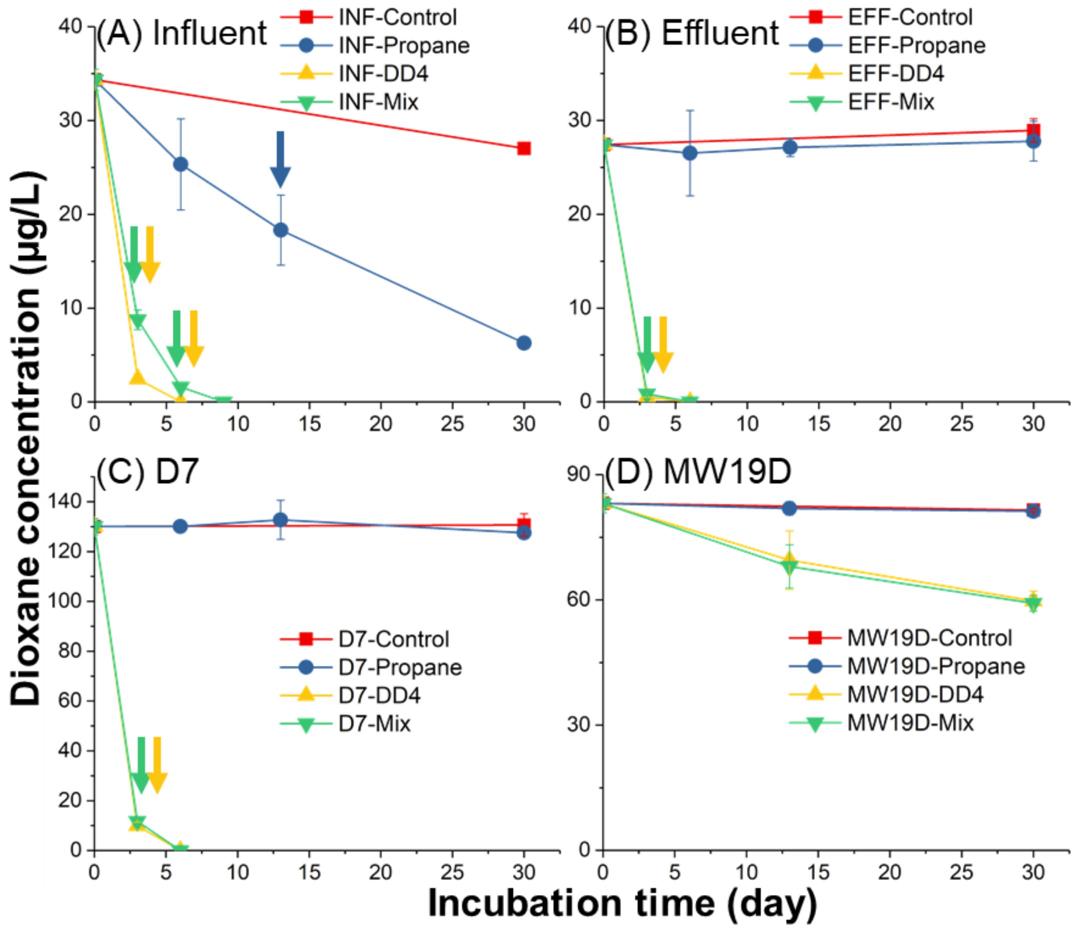
The use of microorganisms to detoxify or remove organic or inorganic compounds from the environment.

Applications include:

- Metabolic
  - Direct consumption
  - 1,4-Dioxane metabolizers CB1190 & PH-06
- Cometabolic
  - Indirect consumption
  - 1,4-Dioxane cometabolizer Azoarus (DD4) (NJIT – Dr. Mengyan Li)

Biological Treatment Phase 1 Study

- Objective: to screen and evaluate the suitability and effectiveness of various cultures and consortia to remove the target contaminants to a desirable level.
- DD4 (NJIT), PH-06 & CB1190 mix, tested in microcosm with propane and control



Contact Mengyan Li: https://people.njit.edu/faculty/ianli

AOP

The oxidation of organic material in water via hydroxyl radicals (˚OH)

Applications include:

- Fenton's chemistry – Hydrogen peroxide (H_2O_2) and ferrous iron (typically iron(II) sulfate ($FeSO_4$)
- Hydrogen peroxide (H_2O_2) and ultraviolet (UV) light
- H_2O_2 and ozone (O_3) based treatment (HiPOx)
- Photocatalytic oxidation using titanium dioxide (TiO_2) and UV light

2012 NJDEP Pilot Studies

- Purifics Photo-Cat Pilot Test 1 (May/ November 2012)
  - Titanium dioxide (TiO2)/ultraviolet (UV) light
- Kerfoot Pilot Test (Nanozox™) (August 2012)
  - Hydrogen peroxide (H2O2) and Ozone (O_3)
  - The Nanozox™ system uses a pulsed injection of gaseous microbubbles of ozone without leaving any detectable byproducts

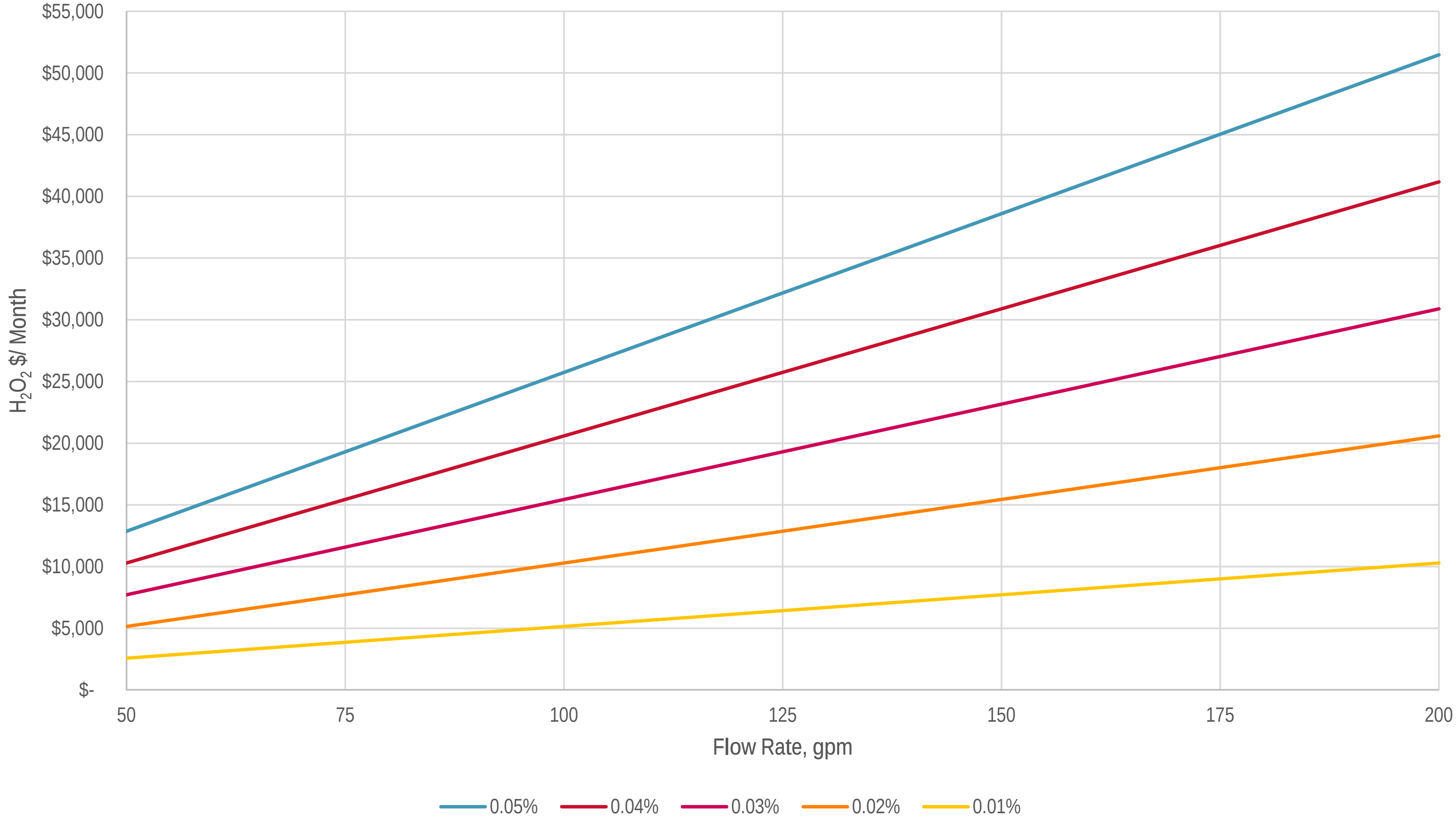
Fenton’s Reagent Bench Test Study

- Catalyst – Ferrous Sulfate ($FeSO_4$) in acidified solution (pH 2.0) with nitric acid (HNO_3)
- Oxidant – H_2O_2
- Evaluated samples from the treatment plant influent and effluent water.
  - Oxidant doses: 100 (0.01%), 500 (0.05%), and 1,000 (0.1%) mg/l.
  - Contact times: 30, 60, and 120 minutes.
- Fenton’s chemistry was able to successfully destroy 1,4-dioxane to concentrations less than 0.4µg/l.

Fenton's Reagent Bench Test

GWET Effluent Sample									
Oxidant Dose (mg/L)	Sample	Reaction Time (min)	Conc. (ug/L)	Sample	Reaction Time (min)	Conc. (ug/L)	Sample	Reaction Time (min)	Conc. (ug/L)
100 (low)	1	30	16.4	4	60	1.78	7	120	1.65
500 (medium)	2		0.2 U	5		0.2 U	8		0.1 U
1,000 (high)	3		0.2 U	6		0.1 U	9		0.2 U
Control			25.2						

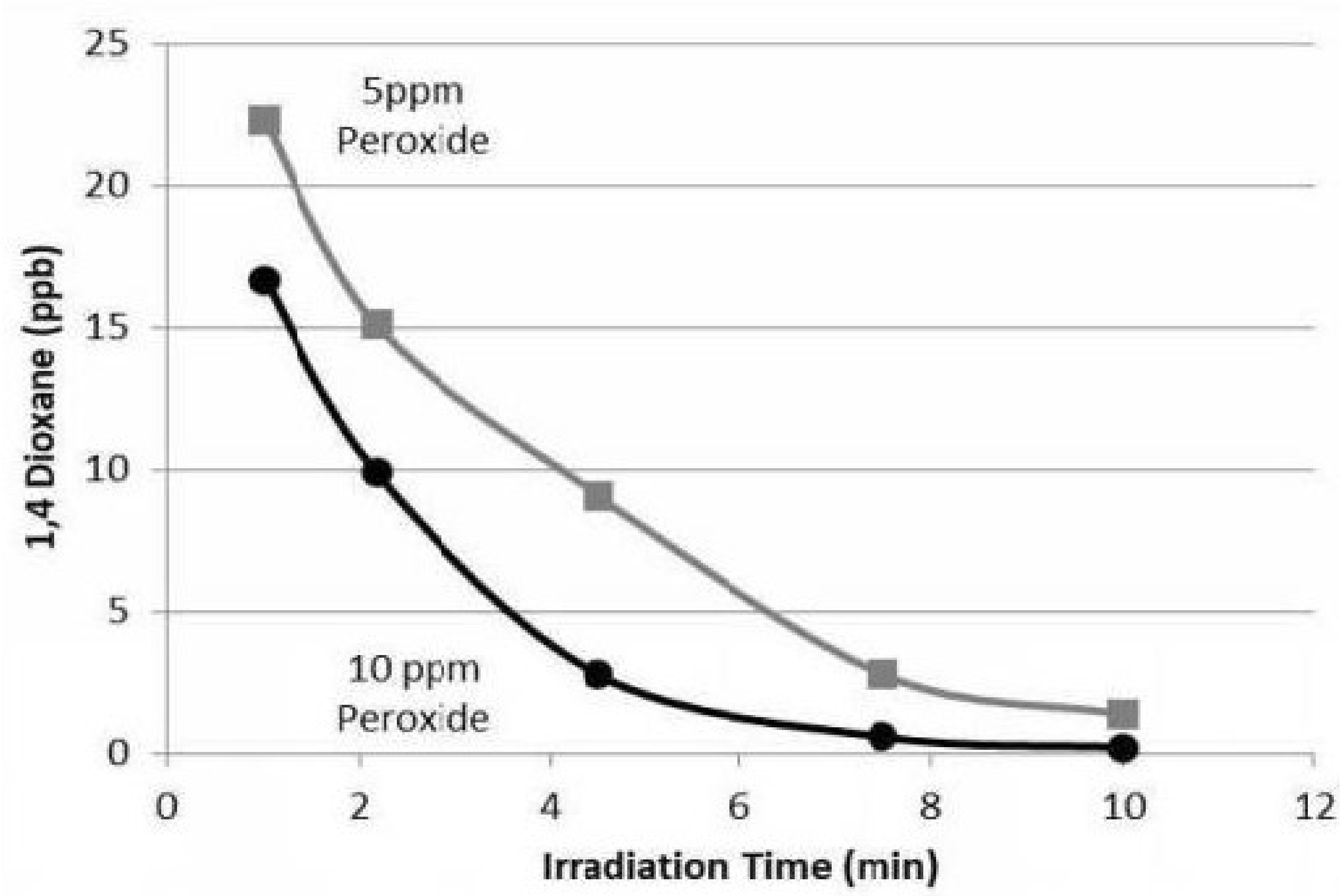
Monthly H_2O_2 Cost vs Flow Rate



Hydrogen Peroxide and UV

- Low Pressure vs Medium Pressure lamps
- UVT at various stages within the treatment train
- Peroxide dose and other design factors
- Multiple technology vendors:
  - Atlantium Technologies, Ltd. – Performed collimated beam, low pressure bench test (2019)
  - Calgon UV – Performed medium-pressure bench test (2019)
  - Trojan UV – Performed preliminary evaluation (2019) and low-pressure lamp field pilot test in 2020

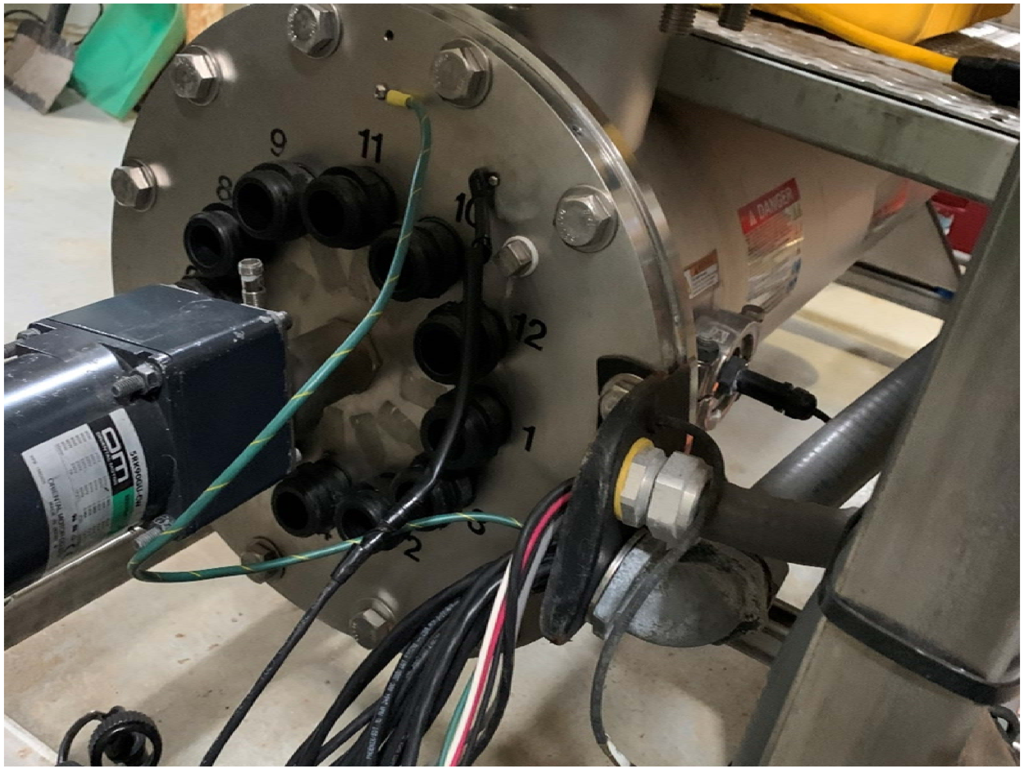
Atlantium Bench Test



Calgon UV Bench Test

Trojan UV Pilot Test

- 1-Month pilot test using a low-pressure UV lamps.
- Tested water from post-lamella clarifier, post sand-filters, and during a system-wide pump test.
- Varied UV lamp intensity, peroxide dosage from 10 mg/l to 400 mg/l, and flow rate from 5 to 10 gpm.

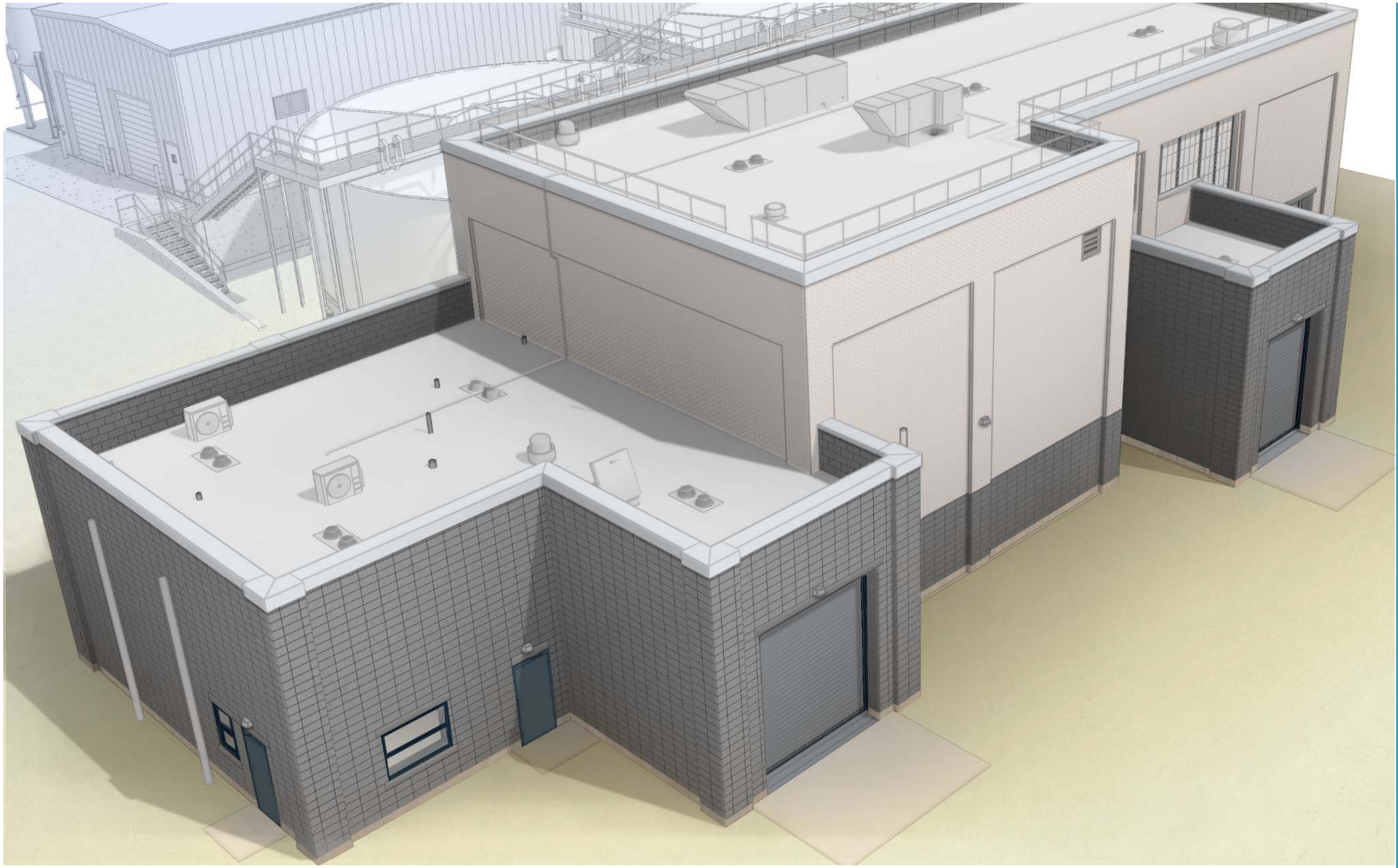


Trojan UV Pilot Test Results

Run Location	Flow Rate, gpm	Peroxide Dose, mg/l	Lamp Intensity	Sample ID	Field Parameters				Lab Results	
					UVT	Temp, °C	pH	Turbidity, NTU	1,4-dioxane	% Reduction
Post-Lamella Clarifier	5	10	100	CF-LC-IN-10-100-20200317-0	61.7	13.88	8.15	37.2	18	-
	5	10	100	CF-LC-EF-10-100-20200317-0	65.4	14.14	8.11	35.1	1.7	91%
	5	20	100	CF-LC-IN-20-100-20200317-0	60.5	13.93	8.41	37.2	19	-
	5	20	100	CF-LC-EF-20-100-20200317-0	65.3	14.08	8.24	35.6	0.59	97%
	5	30	100	CF-LC-IN-30-100-20200317-0	60.8	14.16	8.06	39.8	19	-
	5	30	100	CF-LC-EF-30-100-20200317-0	63.9	13.81	7.92	37.5	0.18	99%
	5	40	100	CF-LC-IN-40-100-20200317-0	57.5	12.72	8.86	36.8	19	-
	5	40	100	CF-LC-EF-40-100-20200317-0	63	13.72	8.59	39.4	0.19	99%
Post-Sand Filter	5	10	100	CF-SF-IN-10-100-5-20200324-0	84.8	12.25	8.39	6.16	36	-
	5	10	100	CF-SF-EF-10-100-5-20200324-0	91.5	12.47	7.26	5.75	0.25	99%
	10	20	100	CF-SF-IN-20-100-10-20200324-0	84.5	10.34	7.84	7.41	31	-
	10	20	100	CF-SF-EF-20-100-10-20200324-0	90.3	11.33	7.65	8.36	0.23	99%
	10	50	100	CF-SF-IN-50-100-10-20200324-0	85	13.94	8.08	6.56	34	-
	10	50	100	CF-SF-EF-50-100-10-20200324-0	89.4	12.35	7.55	6.22	0.079	100%

Technology Comparison

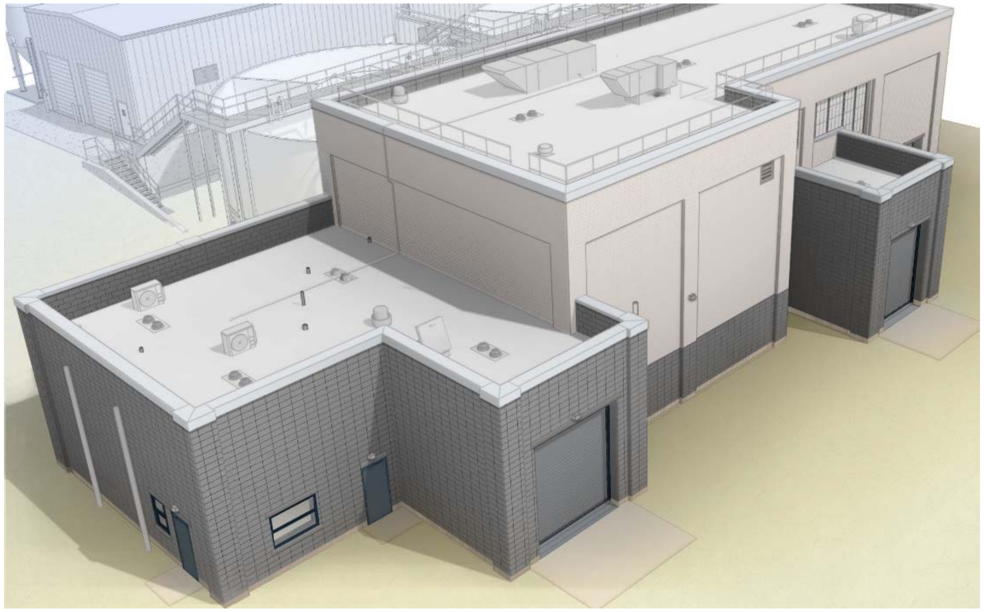
Technology	Pros	Cons
Adsorption technology using regenerable resin.	• Consistently achieved treatment goal. • Easy to operate/ regenerable in place. • Does not require use of chemicals for treatment.	• Produces waste stream requiring disposal. • Proprietary technology.
AOP via Fenton's Reagent	• Able to achieve treatment goal. • Non-proprietary technology.	• Requires large volumes of chemicals for treatment.
AOP treatment using UV and H_2O_2	• Reliably met treatment goals. • Multiple competing technology vendors. • Small footprint and easily scalable.	• Higher electric usage. • Chemical storage required. • UV bulb replacement
Bioaugmentation of Propanotrophs (NJIT - DD4 bacteria species)	• Sustainable, green remediation. • Low carbon footprint depending on food source used.	• Sensitive to environmental factors. • DD4 is unproven at full scale application and requires further R&D.



Proposed Groundwater Treatment System

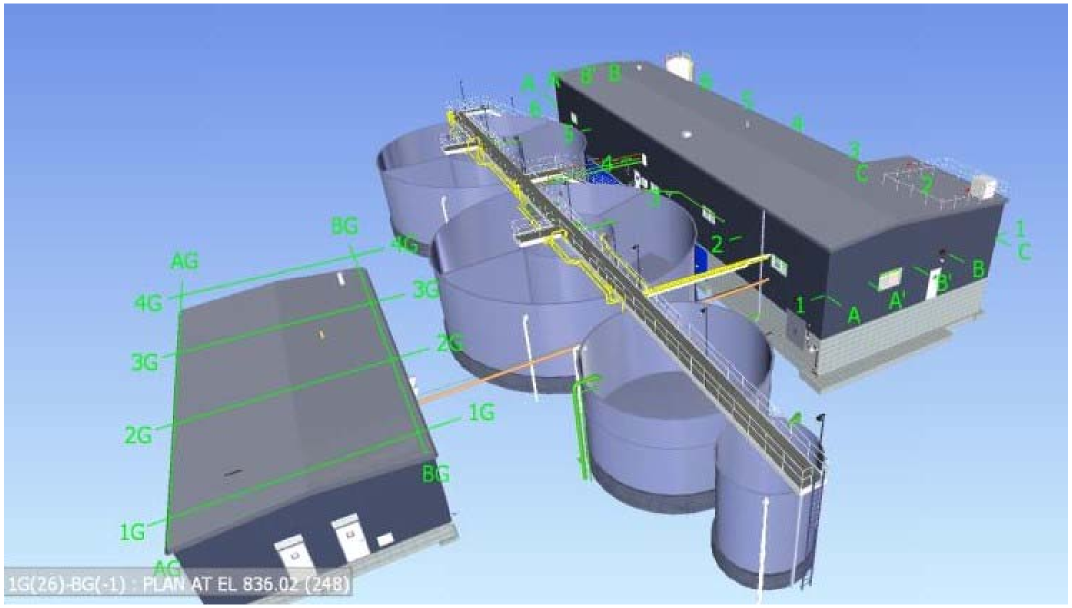
Proposed Design

- Design flowrate of 450 gpm from 22 groundwater extraction wells (overburden and bedrock aquifers) around the landfill
- Optimized treatment system to remove 1,4-dioxane and PFAS from extracted groundwater using UV/peroxide and GAC
- New construction adjacent to the existing building/ exterior tanks
- Reuse and retrofitting of some existing infrastructure

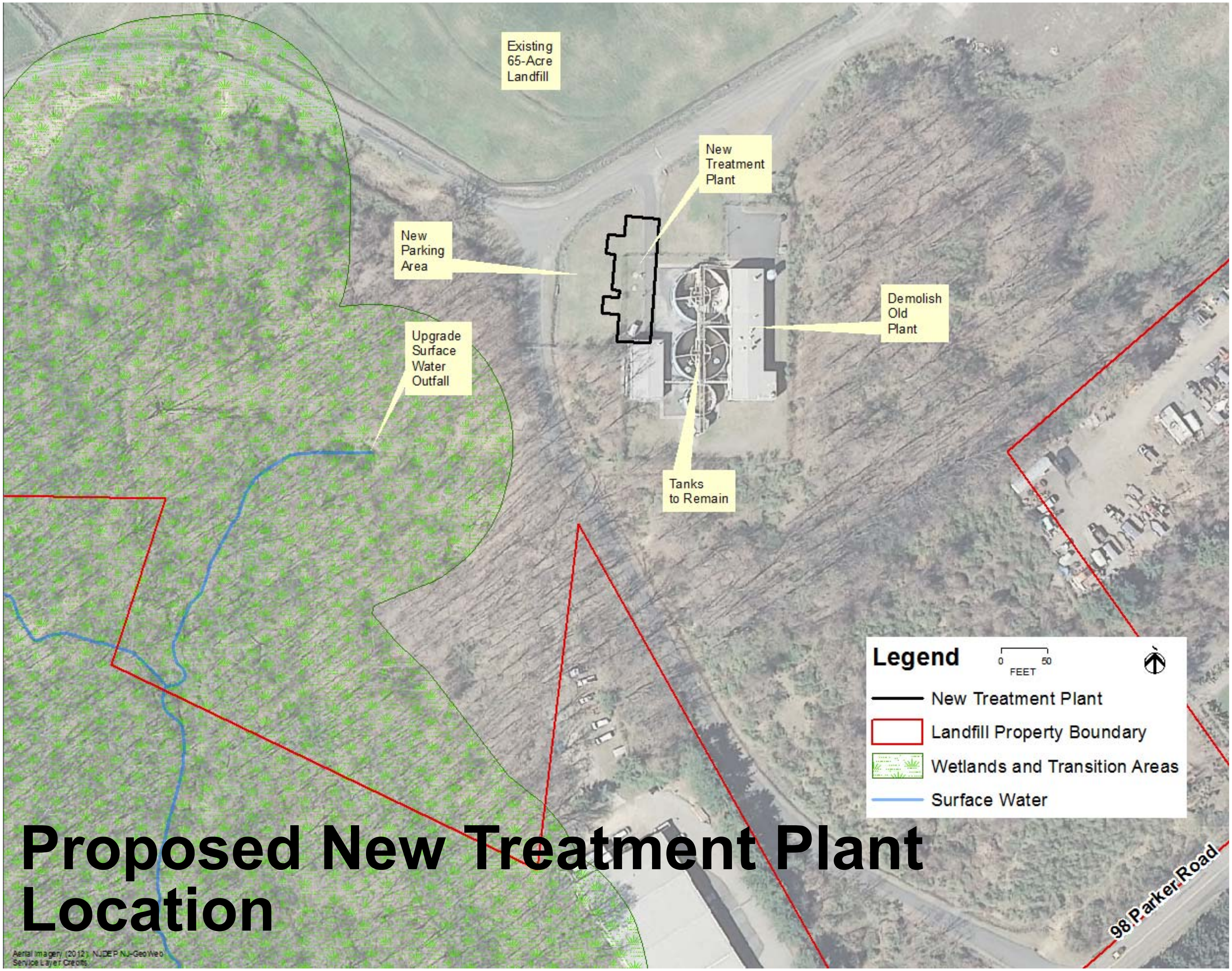


Engineering Design Tools

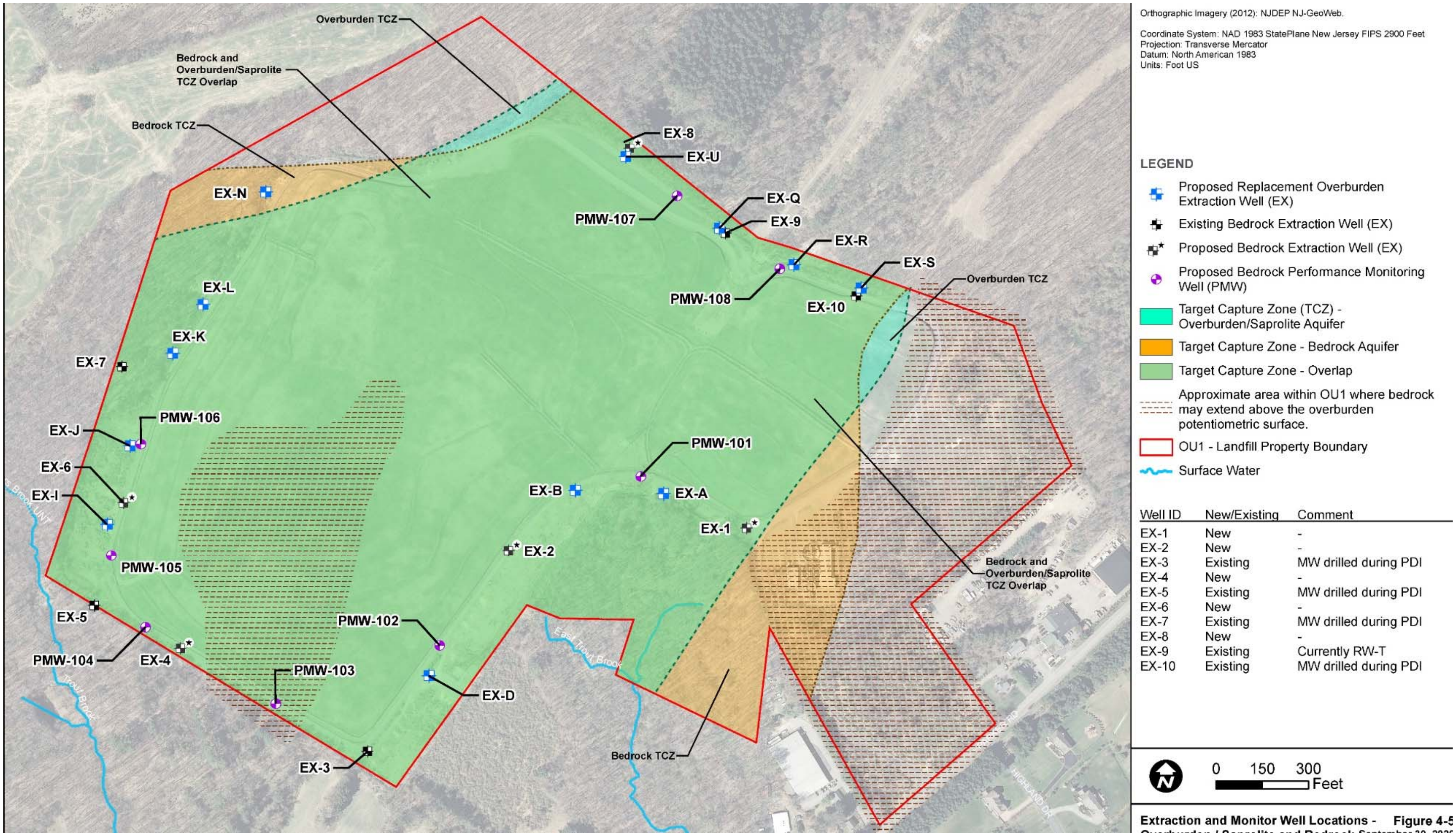
- LiDAR 3D scan of existing facility
- Autodesk Suite
  - Navisworks/ ReCap
  - Revit/ CAD
  - BIM 360



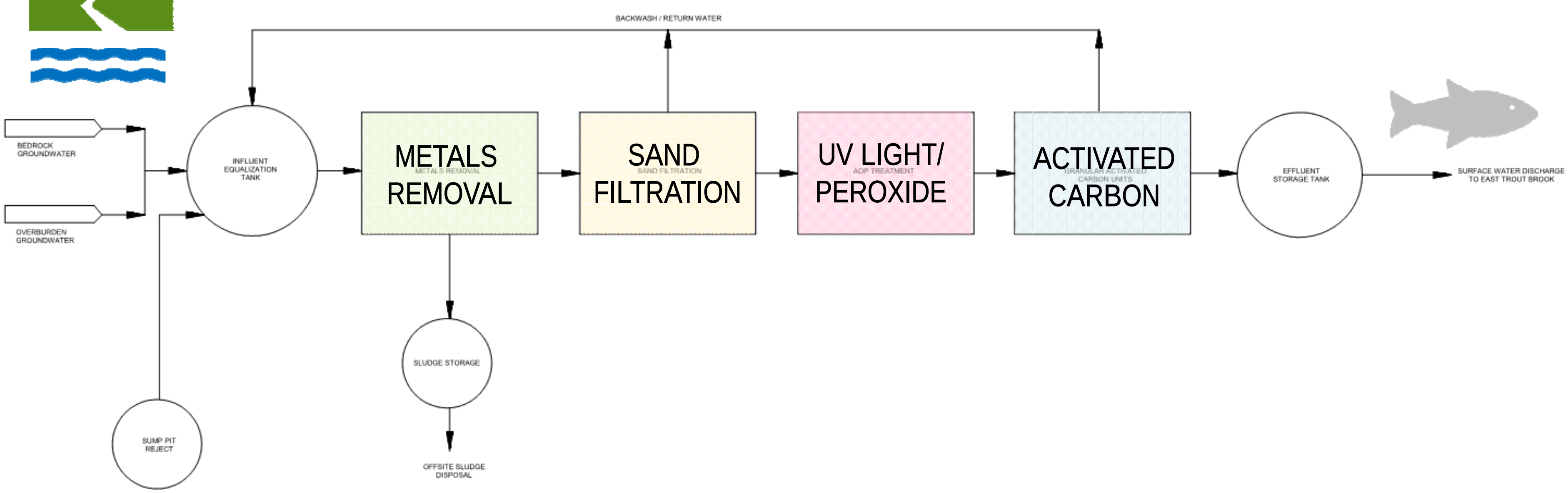
Proposed New Treatment Plant Location

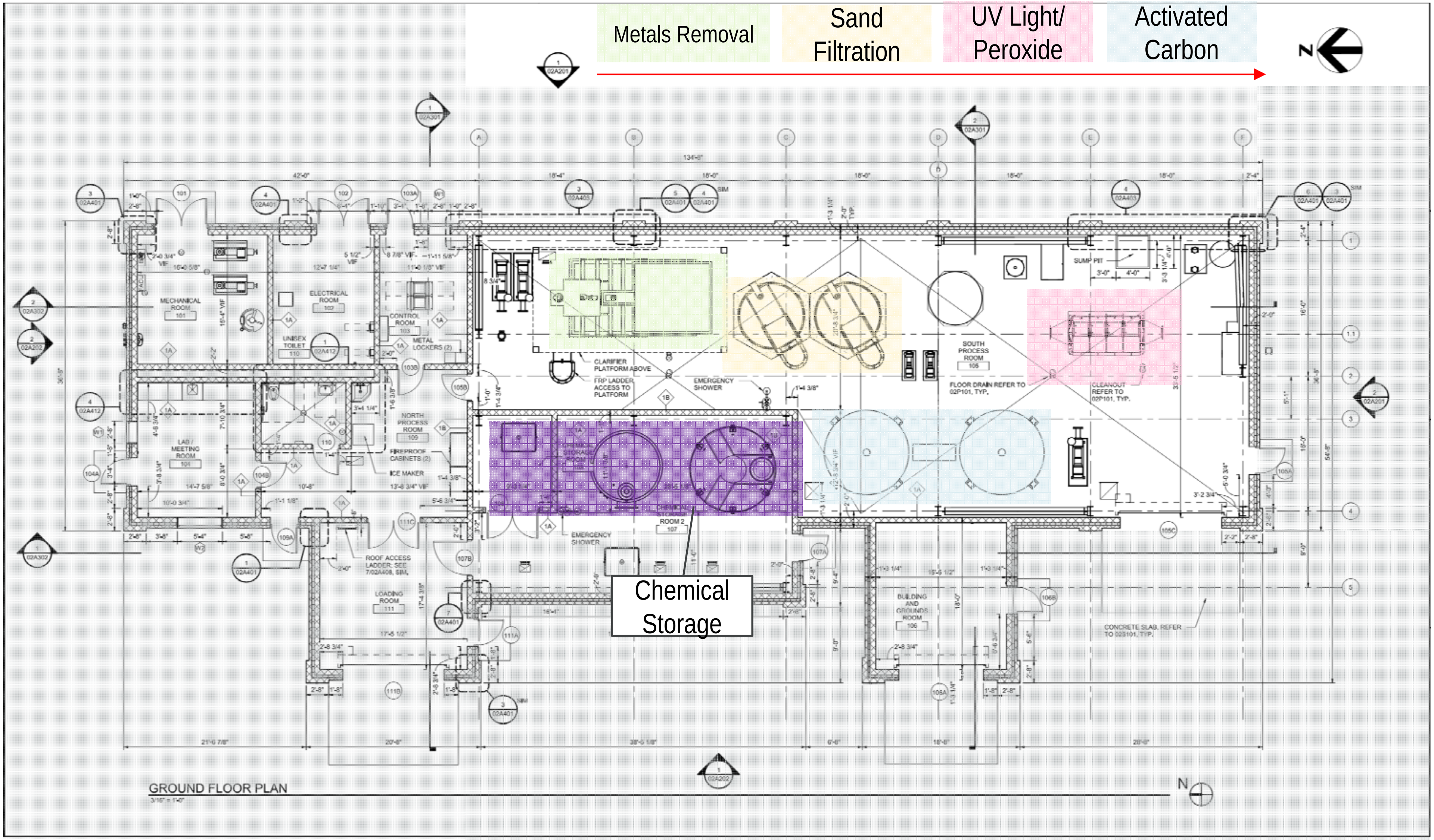


Proposed Extraction System



Proposed Treatment Plant Process Flow Diagram





Metals Removal
Sand Filtration
UV Light/ Peroxide
Activated Carbon
N
Chemical Storage
MECHANICAL ROOM 101
ELECTRICAL ROOM 102
CONTROL ROOM 103
UNISEX TOILET 110
METAL LOCKERS (2)
NORTH PROCESS ROOM 109
LAB / MEETING ROOM 104
FIREPROOF CABINETS (2)
ICE MAKER
LOADING ROOM 111
ROOF ACCESS LADDER: SEE 7/02A408, SIM.
CLARIFIER PLATFORM ABOVE
FRP LADDER ACCESS TO PLATFORM
EMERGENCY SHOWER
CHEMICAL STORAGE ROOM 2 107
SOUTH PROCESS ROOM 105
SUMP PIT
FLOOR DRAIN REFER TO 02P101, TYP.
CLEANOUT REFER TO 02P101, TYP.
BUILDING AND GROUNDS ROOM 106
CONCRETE SLAB, REFER TO 02S101, TYP.
134'-8"
GROUND FLOOR PLAN
3/16" = 1'-0"

Lessons Learned/ Takeaways

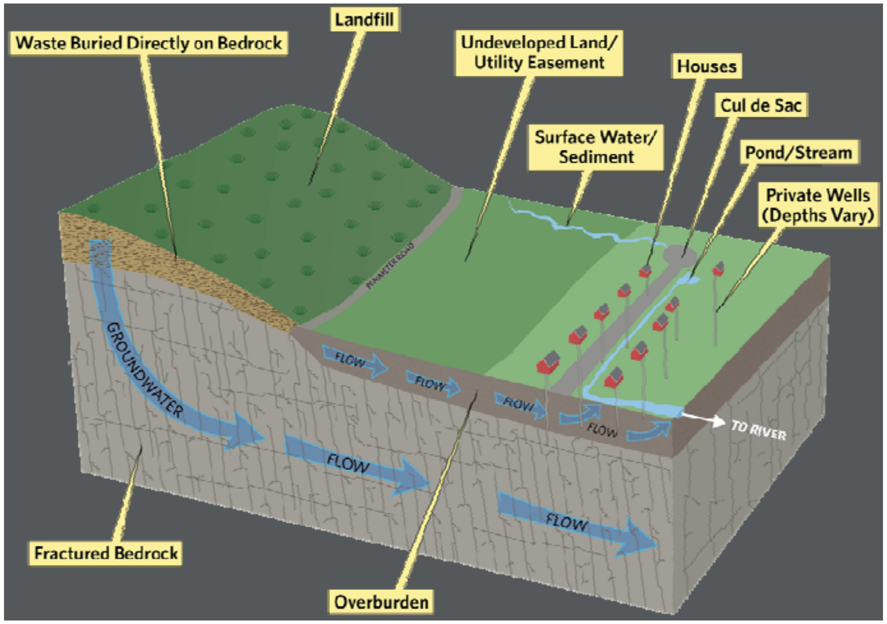
- Read
- Go to the Site
  - Take pictures and notes
- Ask Questions
  - Technical vendors can teach you
- <u>TALK TO THE OPERATOR!!</u>

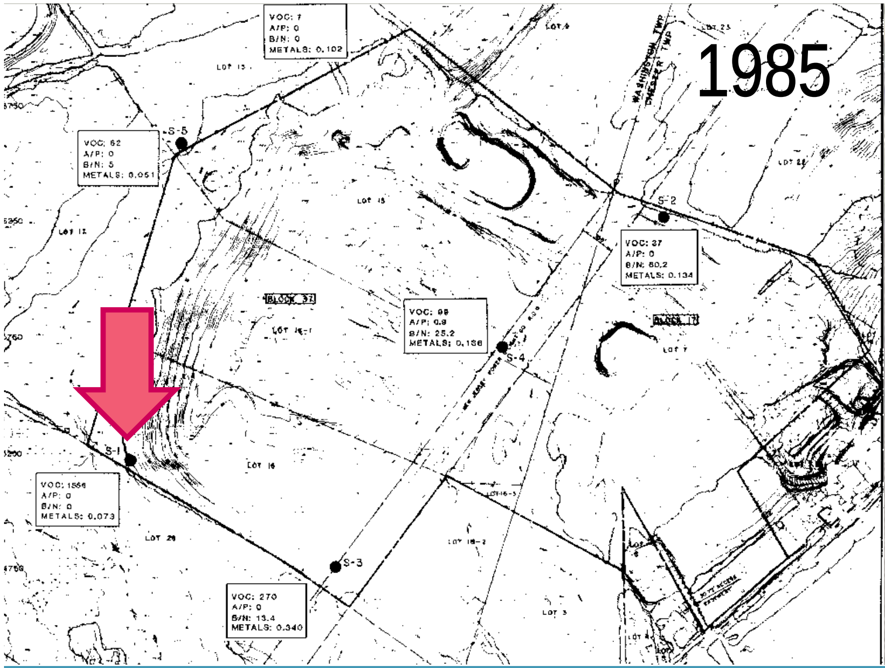
So… What has changed over time?

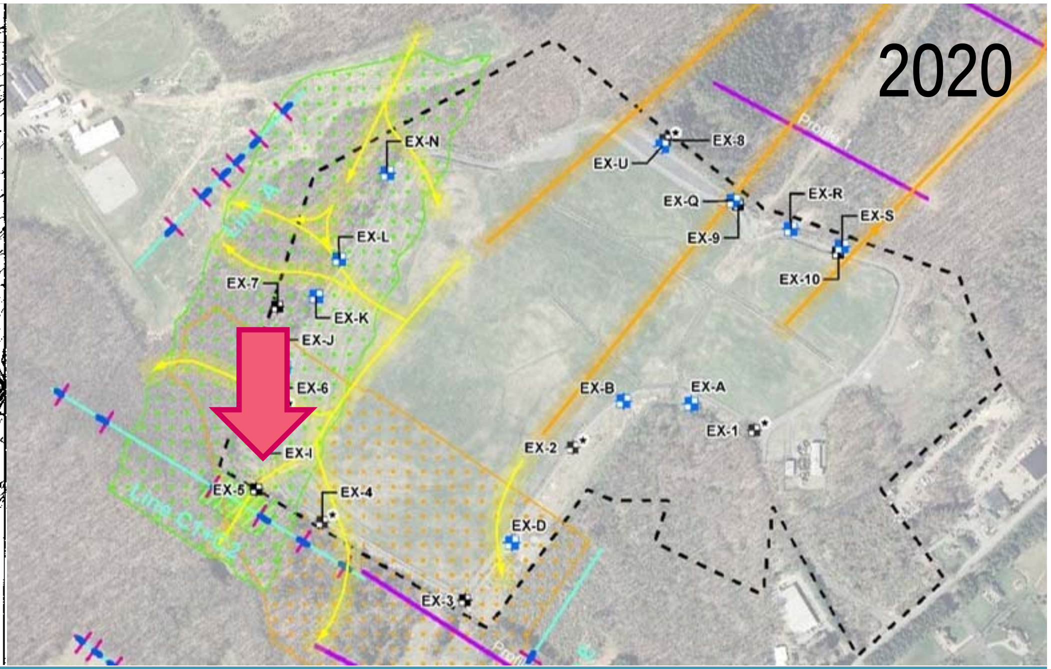
- The COCs (time passing, natural degradation, emerging contaminants previously unknown, improvements in laboratory detection limits)
- The treatability technologies (vast improvements in relatively short period of time)
- The groundwater containment strategy
  - Number, locations, and pumping rates of extraction wells (deep vs. shallow)
- Higher resolution investigative technologies (improvements in downhole instruments, new inventions such as FLUTe and Willowstick)

What has stayed the same?

- Conceptual Site Model (CSM)
- Tried and true hydrogeologic methods – e.g., pump tests, potentiometric surface maps from water levels
- Lengthy process of investigation and design
- Stakeholders add to complexity
- This is only the beginning of THE FINISH!







Questions?