Arsenic in New Jersey Well Water

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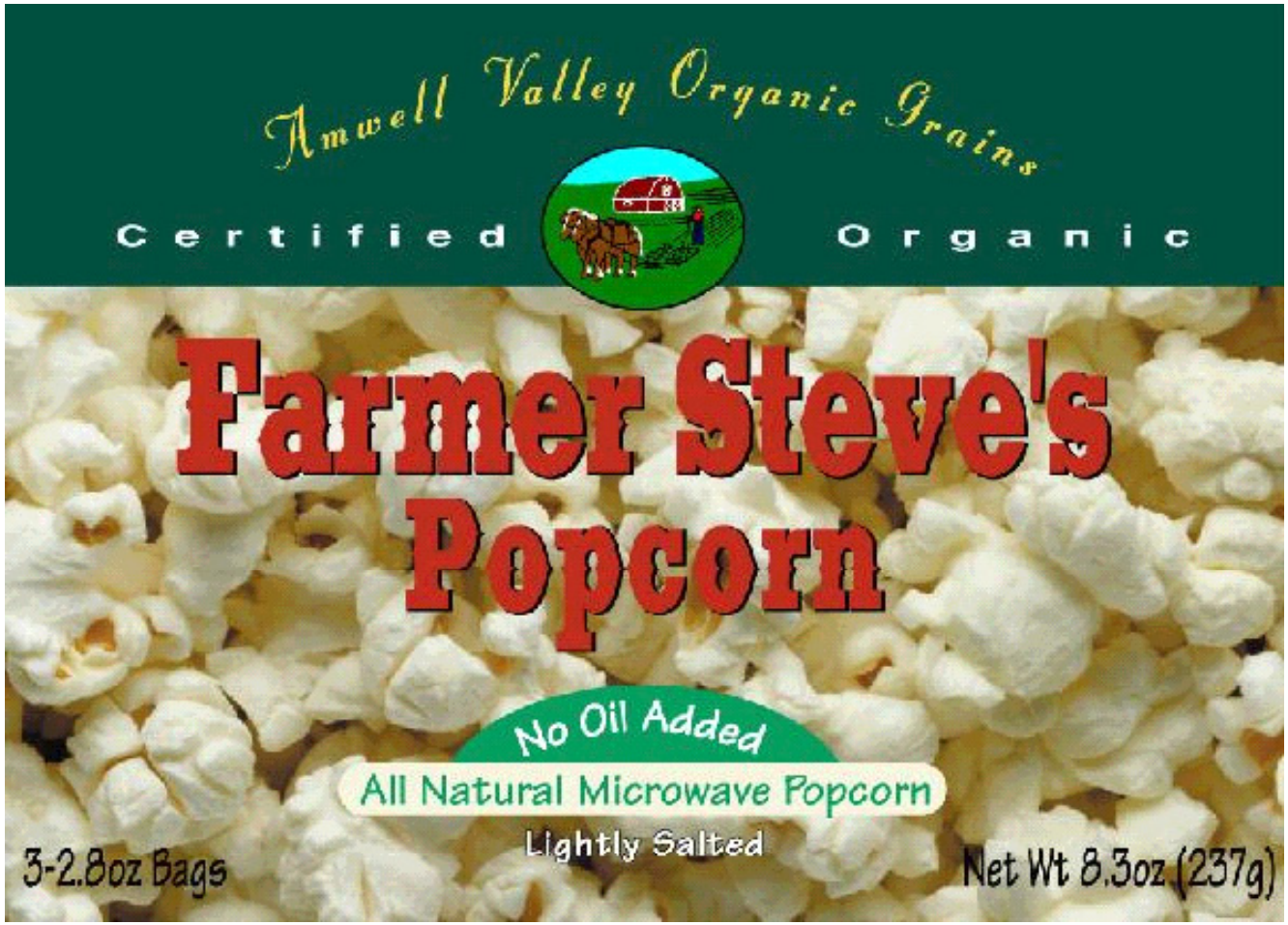
Partial Funding to Support This Investigation was Provided by Farmer Steve



Order Online at www.farmersteve.com

Contents

- Arsenic & Health
- The New Water Standard for Arsenic
- Where's the Arsenic?
- Hydrologic Cycle & Hydrogeology
- Source Investigations
- NJ Geology & Arsenic
- Hydrogeologic Investigations
- Arsenic Speciation in NJ
- Arsenic Remediation Investigations
- Human Exposure Monitoring

Arsenic Health Issues

- Arsenic Causes Cancer in Humans at Doses Close to Drinking Water Concentrations in the United States.

- Unlike Many Other Chemicals, Arsenic Data are Sufficient so that there is No Need to Extrapolate From Animals to Humans or From Very High Doses to Low Doses.

Arsenic Health Effects

Based Mainly on Studies in Taiwan, Argentina, Chile, Bangladesh & Utah

- Cancer - Skin, Bladder, Lung, Kidney, & Liver
- Coronary Heart Disease
- Diabetes
- Skin Lesions - hyperpigmentation & keratosis
- Reproductive - miscarriage, stillbirth & infant mortality
- Respiratory Disease
- Hepatotoxicity
- Neurologic - Peripheral Neuropathy, Epilepsy

Palmer Hyperkeratosis

Planter Hyperkeratosis

Arsenic Health Issues

- The Dose/Response Curve.
- 1 per million excess cancer risk goal verses 3,000 per million excess cancer risk at 10 ppb.
- Is There a Threshold Level?

The Arsenic MCL Story

- 1942 - Level of 50 ppb initially set
- Much Controversy…
- Feb 2002 - USEPA MCL Set at 10 ppb

Christy Whitman Stars in Arsenic and Old Lace

Arsenic MCL in New Jersey….

NJDEP proposed an MCL of 10 ppb in January 2002.

Many comments were received pushing for a lower MCL in New Jersey.

The NJDWQI has recommended that NJ set its MCL for arsenic below 10 ppb.

How Did I Get Interested in Arsenic?

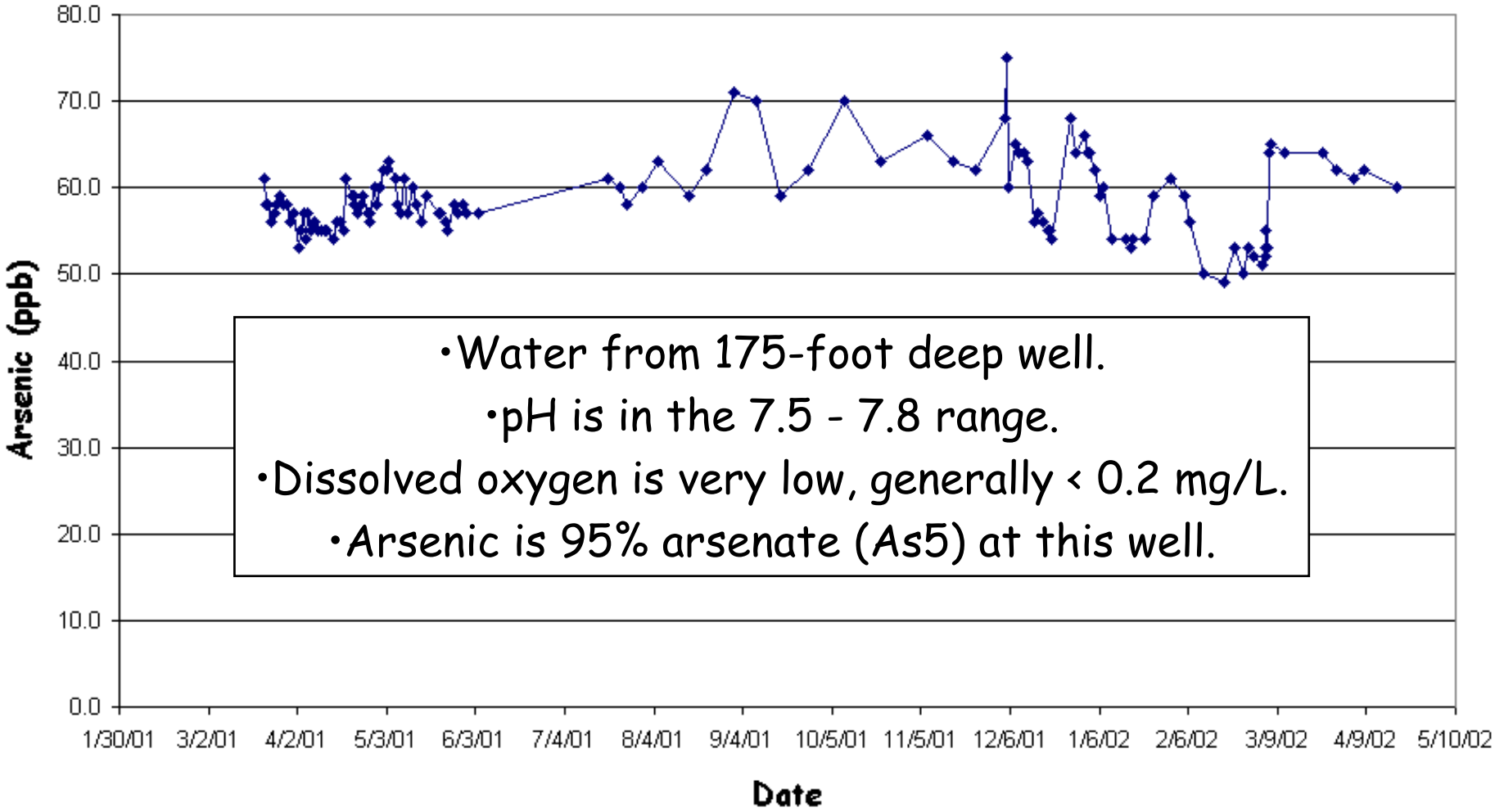
- 1998 - NJGS/USGS Needed Wells in the Piedmont to Sample.
- I volunteered and They Sampled My Well.
- Arsenic at 57 ppb - the Highest Level of All Wells Tested in NJ for the Next 3 Years.
- Confirmed by Multiple Labs & Methods.

MEANWHILE IN MEXICO...

Estamos vayando a la casa de Esteban.

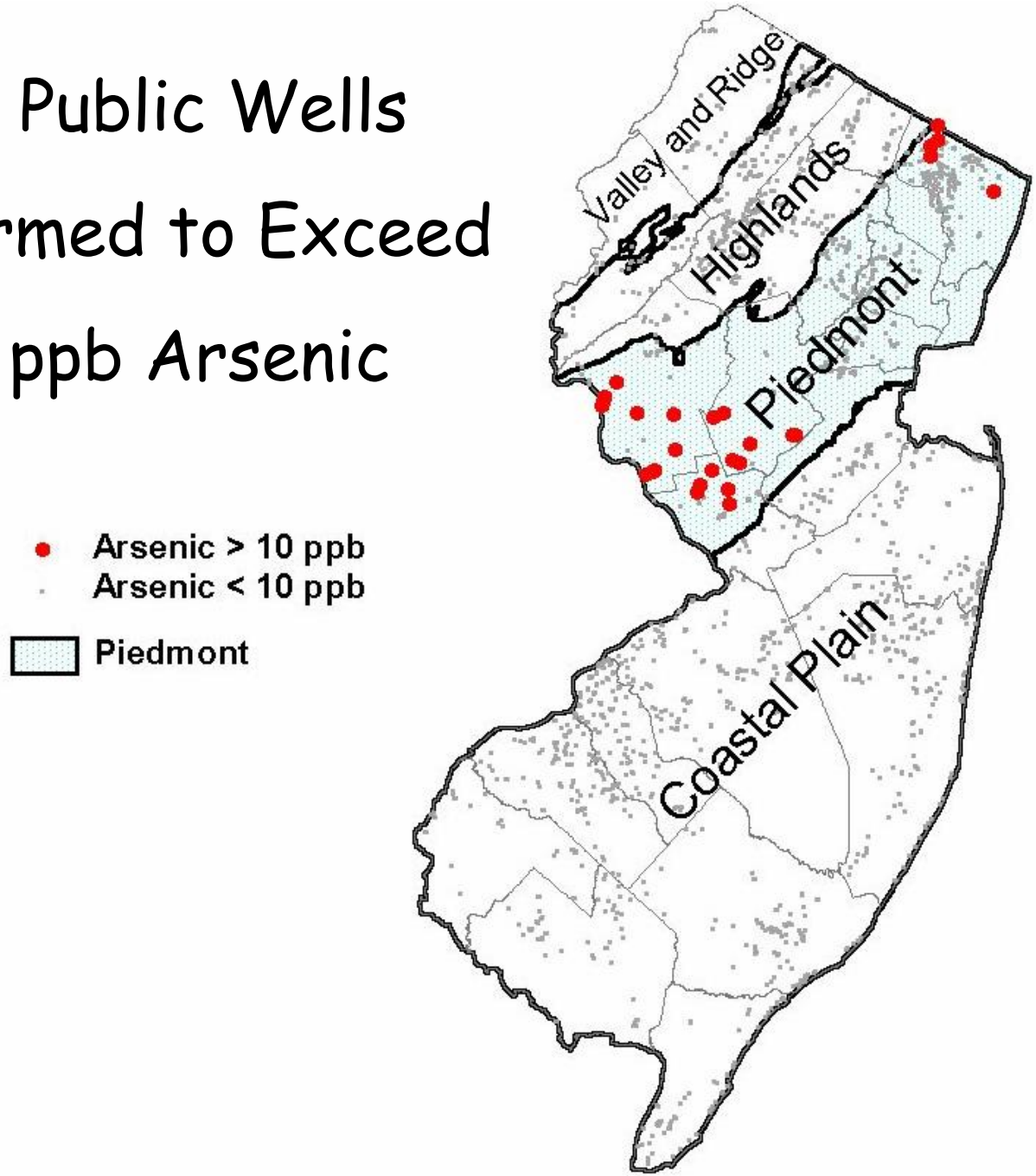
¡No beben el agua!

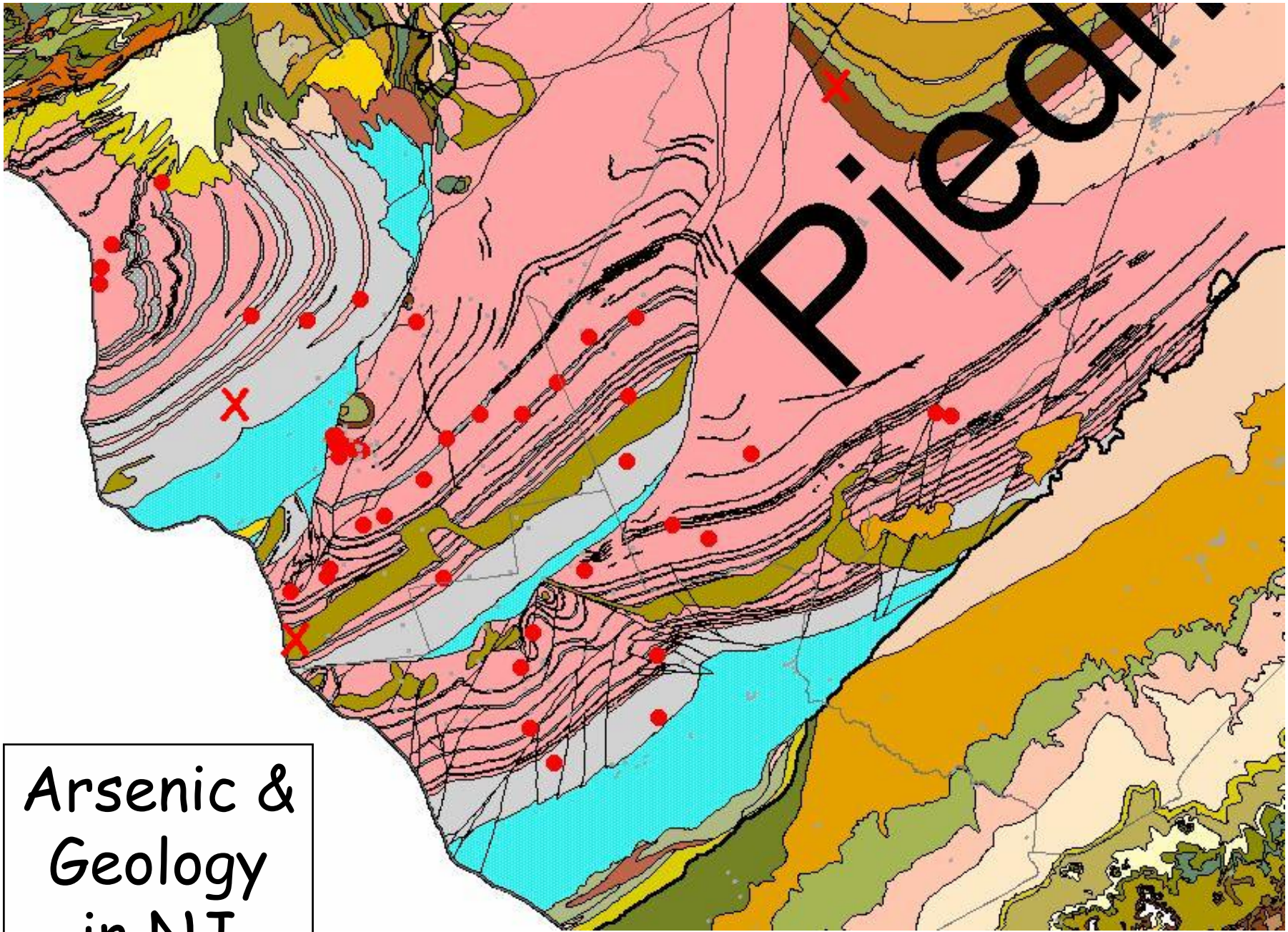
Raw Water Arsenic Concentrations



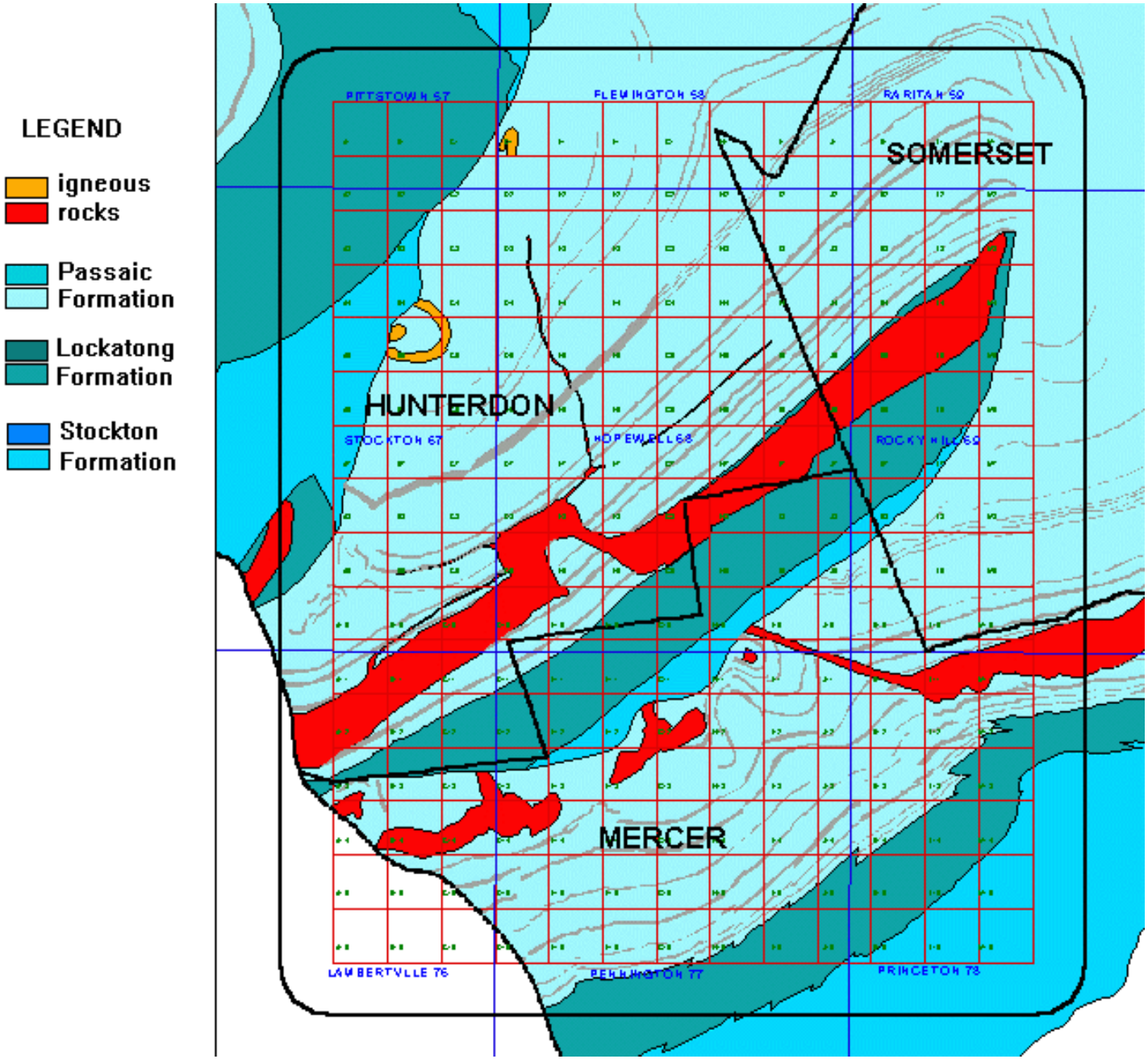
- Water from 175-foot deep well.
- pH is in the 7.5 - 7.8 range.
- Dissolved oxygen is very low, generally < 0.2 mg/L.
- Arsenic is 95% arsenate (As5) at this well.

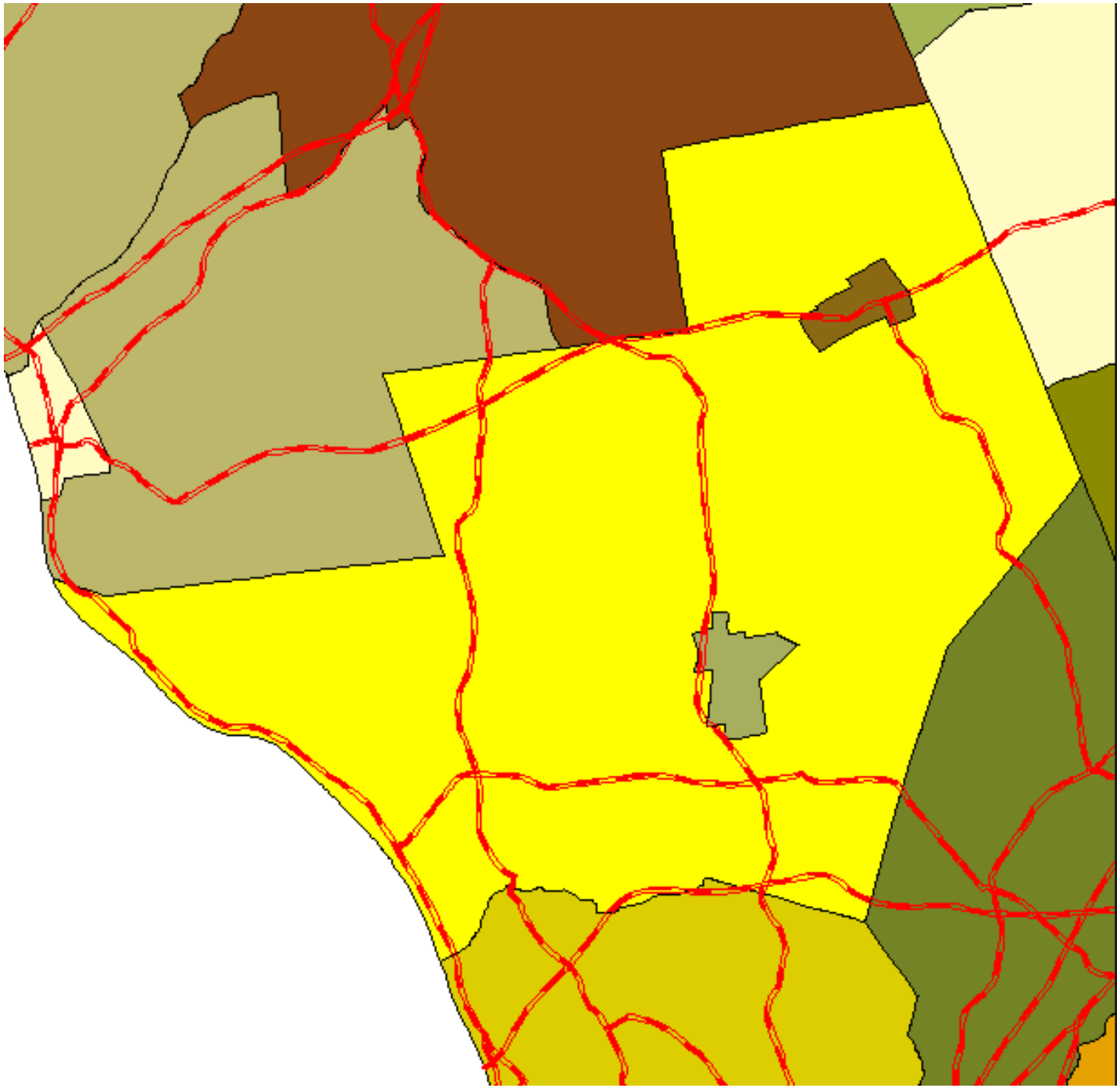
NJ Public Wells Confirmed to Exceed 10 ppb Arsenic

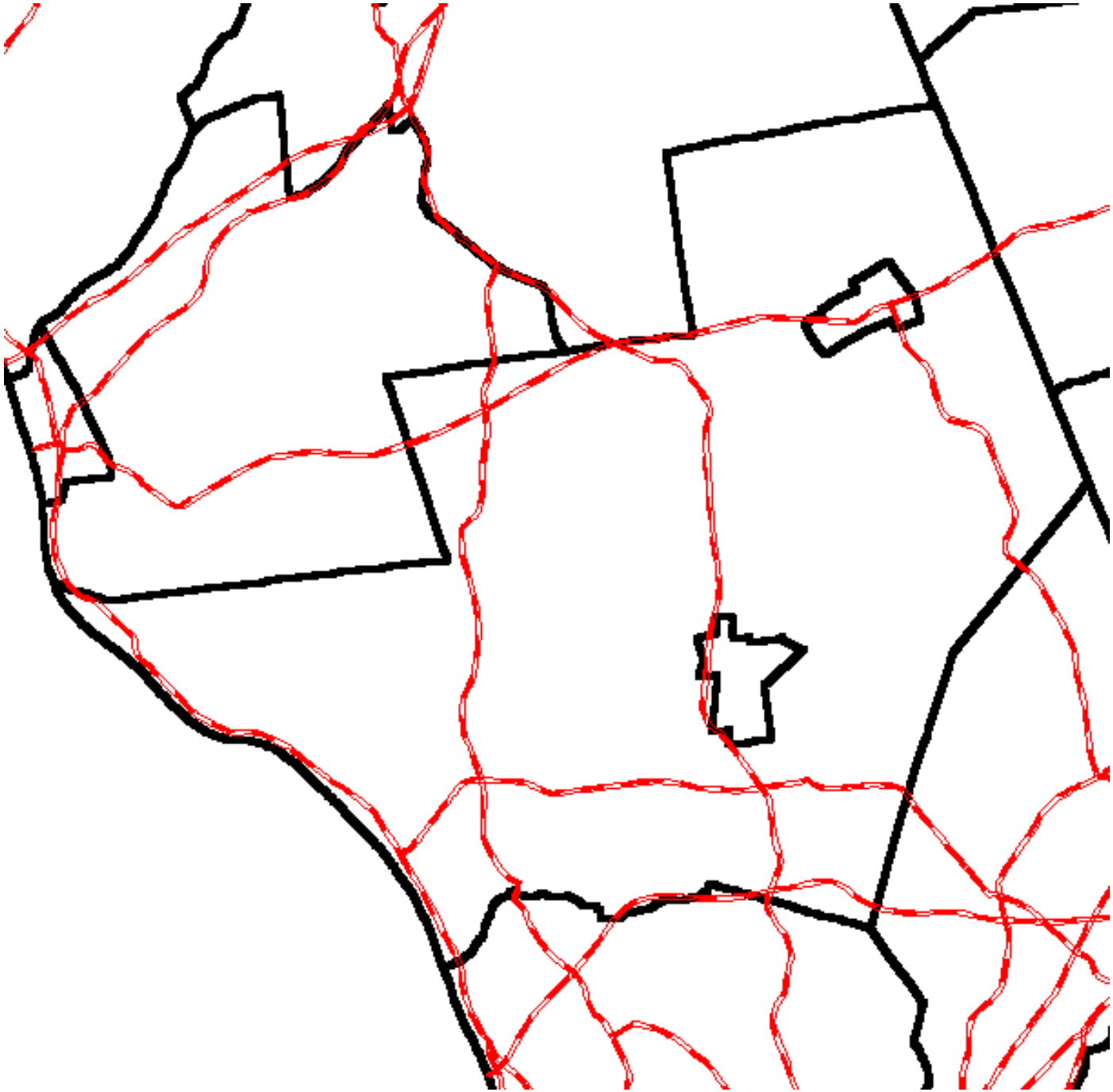


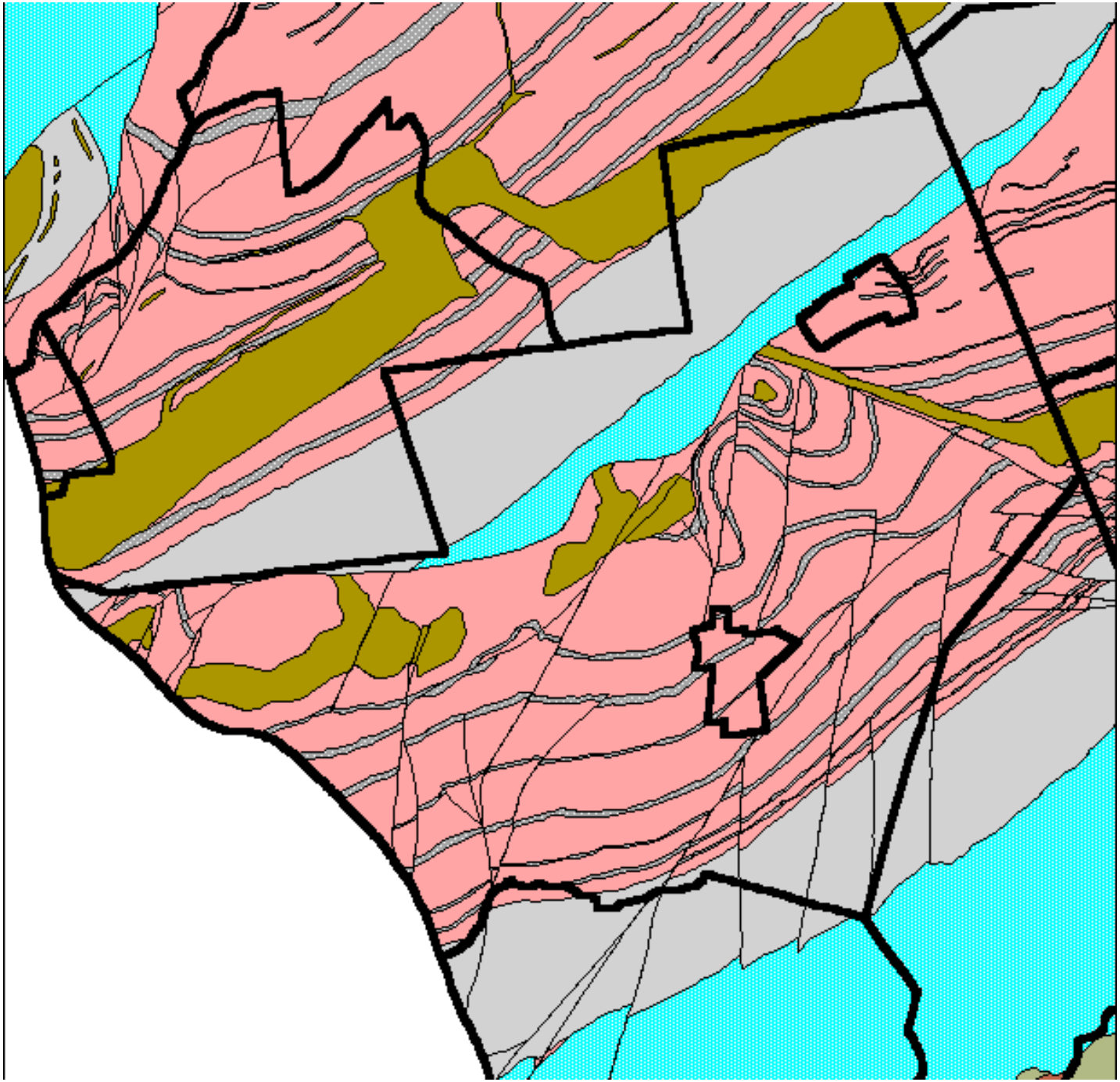


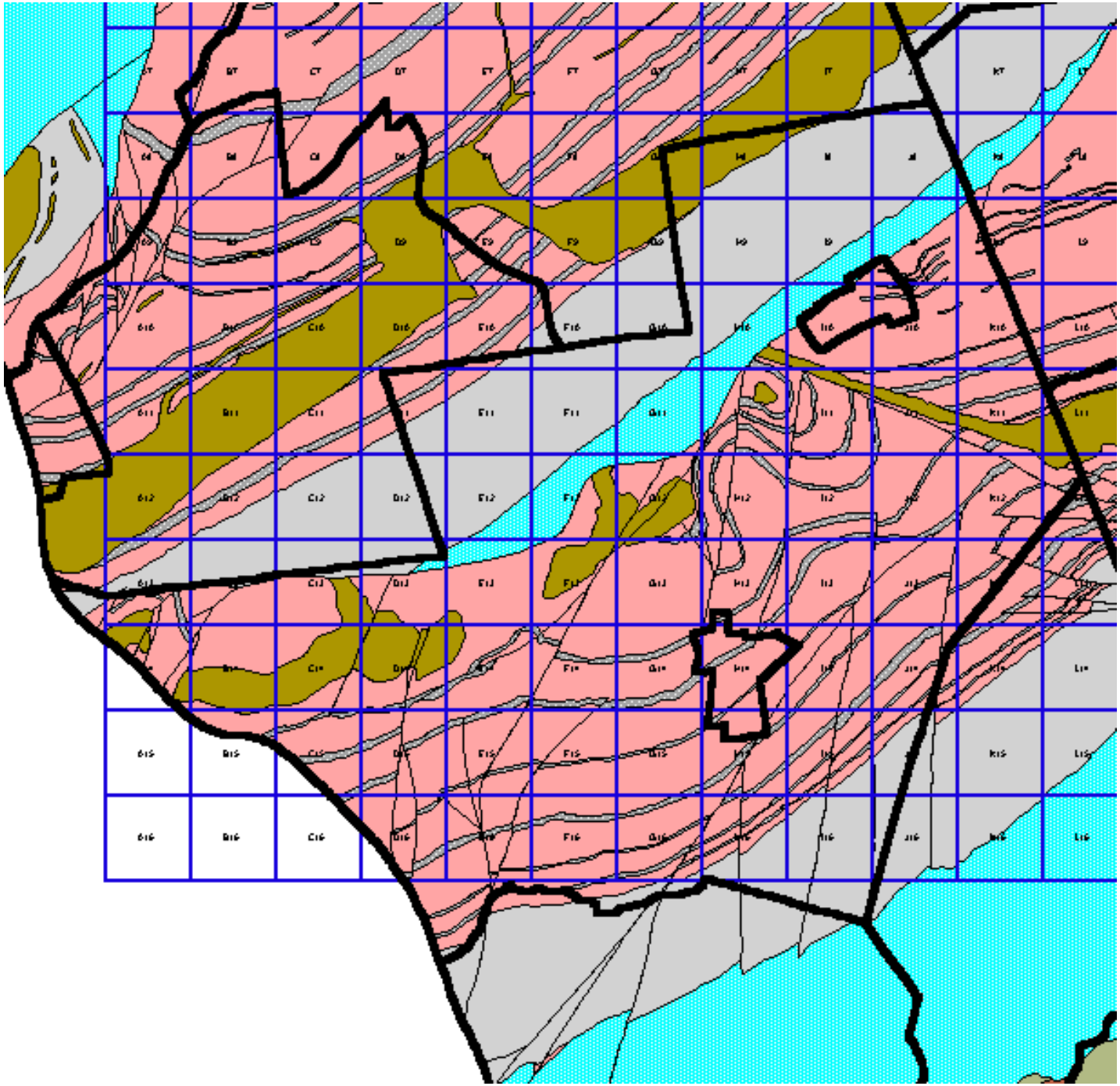
Arsenic & Geology in NJ

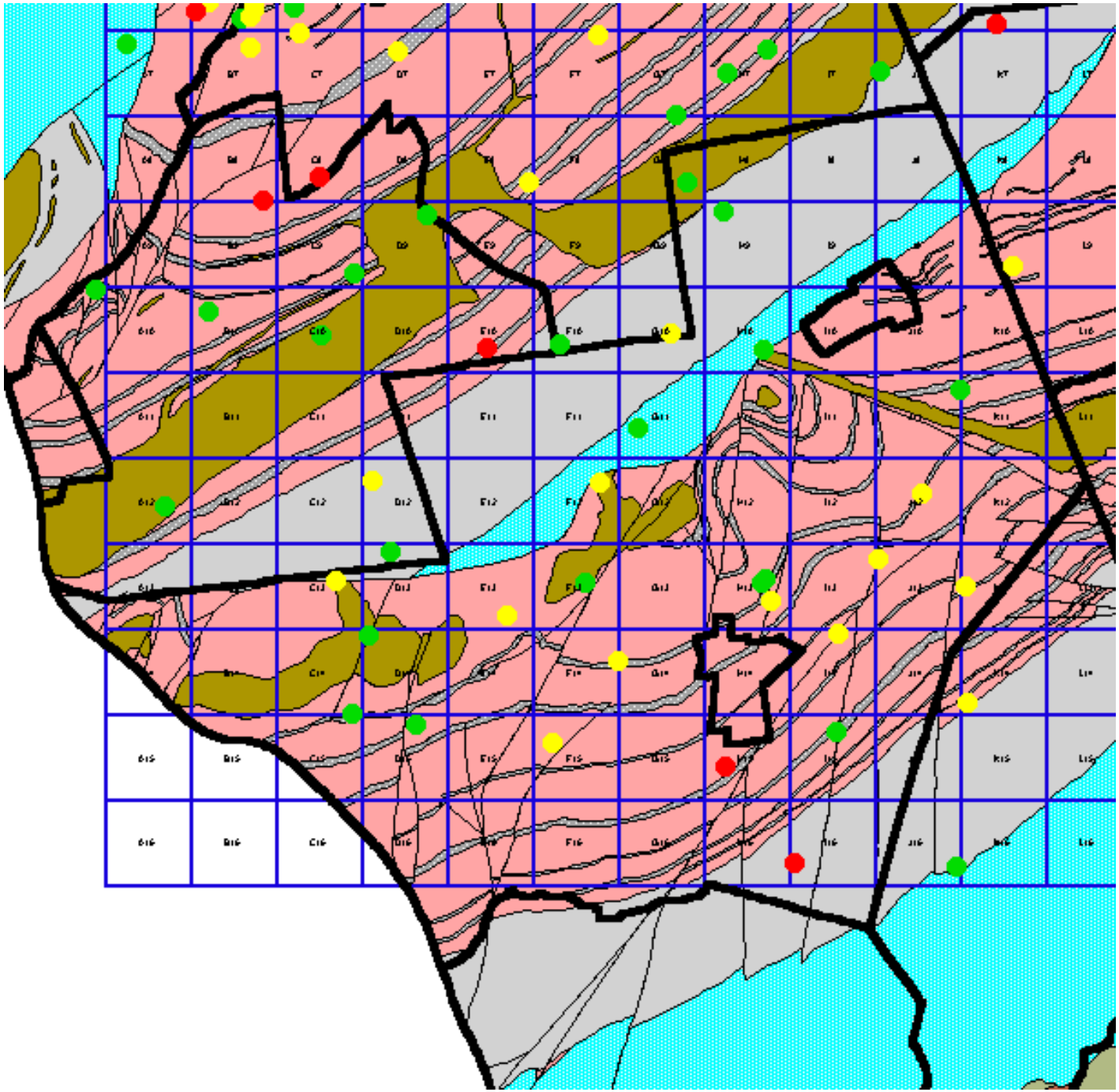

LEGEND
igneous rocks
Passaic Formation
Lockatong Formation
Stockton Formation
SOMERSET
HUNTERDON
MERCER
PITTSTOWN 57
FLEMINGTON 58
RARITAN 59
STOCKTON 67
HOPEWELL 68
ROCKY HILL 69
LAMBERTVILLE 76
PENNINGTON 77
PRINCETON 78



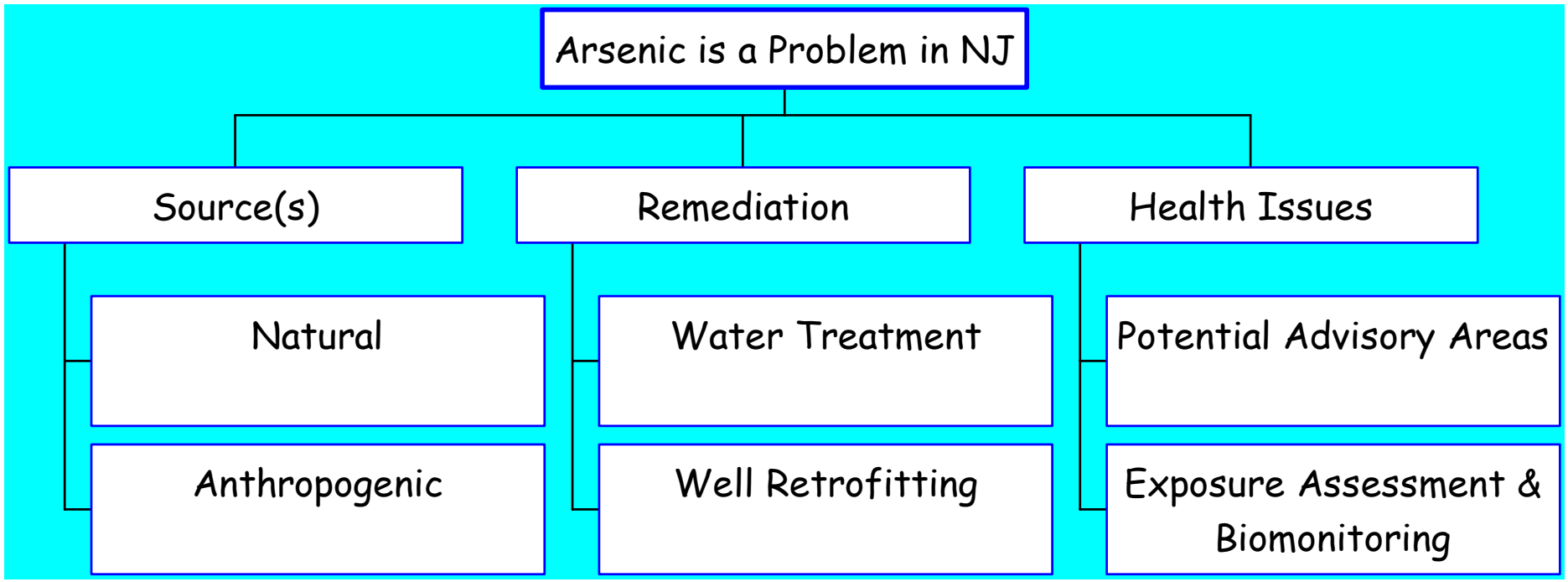








Action Plan


Arsenic is a Problem in NJ
Source(s)
Remediation
Health Issues
Natural
Anthropogenic
Water Treatment
Well Retrofitting
Potential Advisory Areas
Exposure Assessment & Biomonitoring

Source Investigation

Anthropogenic (Man Made)

- 15 Million Pounds of Arsenic Used in NJ as Pesticides from 1900 – 1980
- Also Used as a Wood Preservative

Natural

- Arsenic is a Fairly Abundant Element
- Found in Pyrite Crystals in NJ

Source Investigation

- Ambient Data
- Public Well Data
- Rock Core
- Packer Tests
- Heat Pulse Flow Meter

Hydrologic Cycle

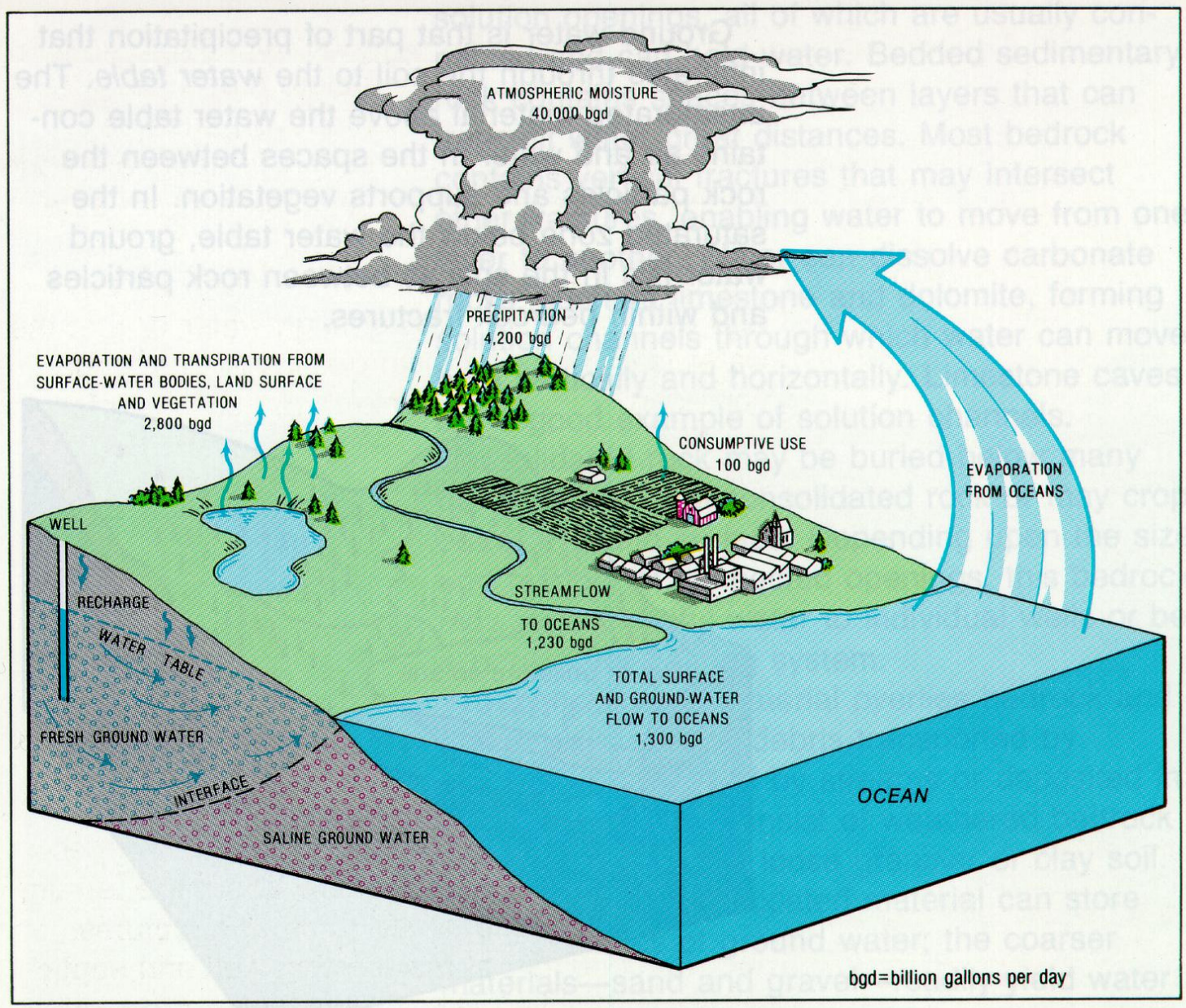
- King Solomon (1000 BC)

"All the rivers run into the sea, yet the sea is not full…"

- Leonardo da Vinci (1452-1519)

"...all the sea and rivers have passed through the mouth of the Nile an infinite number of times…"

The Hydrologic Cycle



The continuous hydrologic cycle.

Where Does the Well Water in Hopewell Come From?

a) An underground river from Canada.

b) An underground river from the Adirondacks.

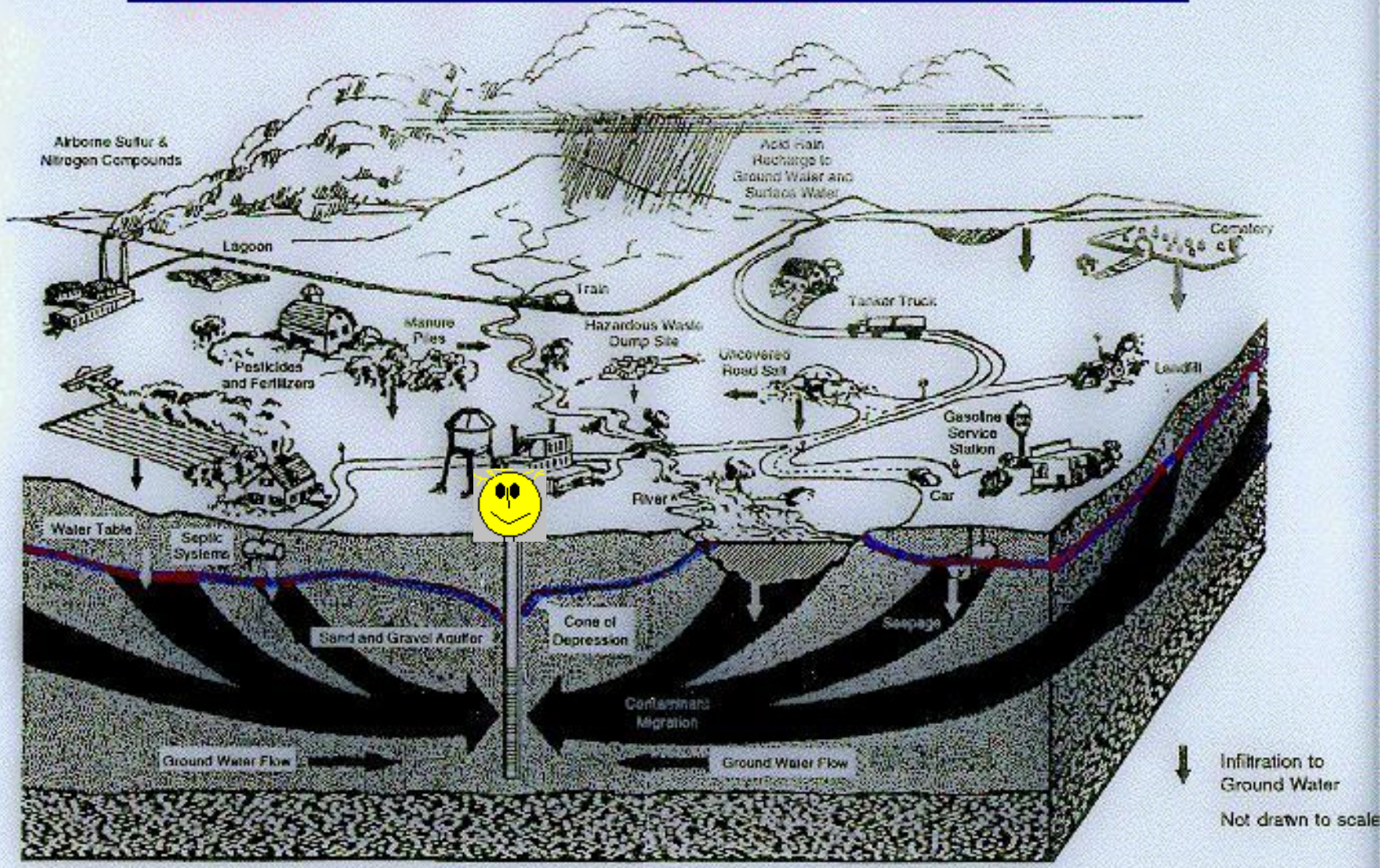
c) An underground river from the Poconos.

d) None of the above.

The correct answer is d) None of the above.

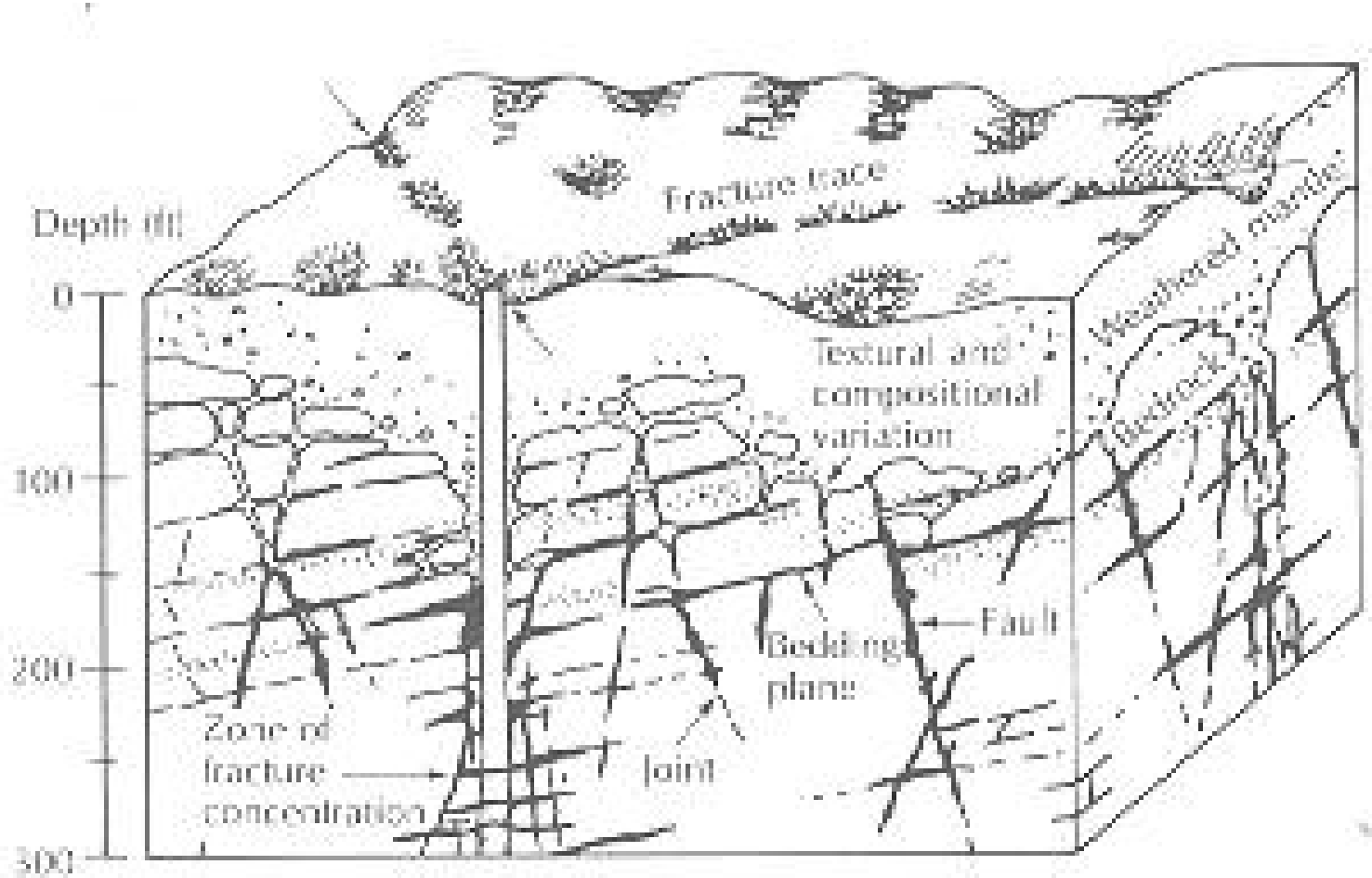
Our well water actually comes from recharge at the land surface.

WHAT IS A WELL HEAD?

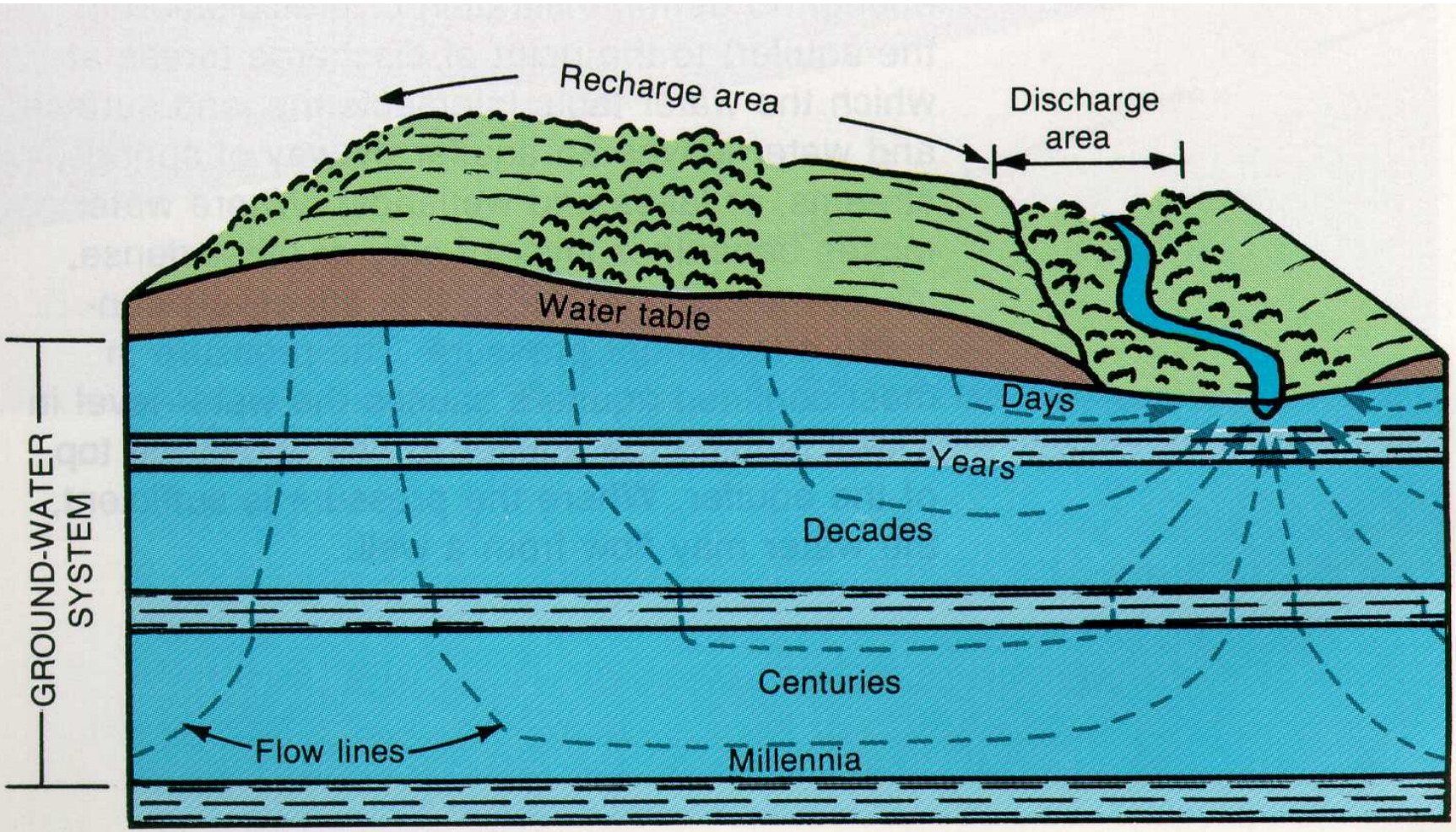


Some potential sources of ground water contamination. Source: Adapted from Paly and Steppacher, n.d.

Well Drilled into Fractured Rock Aquifer



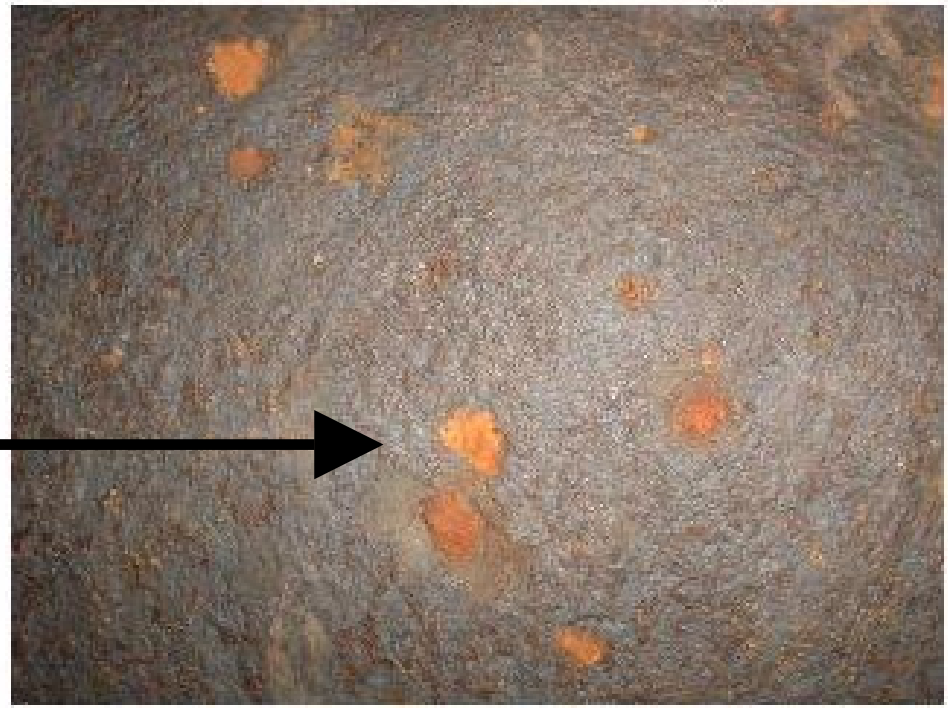
IGURE 7.32. Concentration of groundwater along zones of fracture concentrations in



Direction and rate of ground-water movement.

Unweathered Pyrite Crystals on Freshly Broken Bedrock Surface

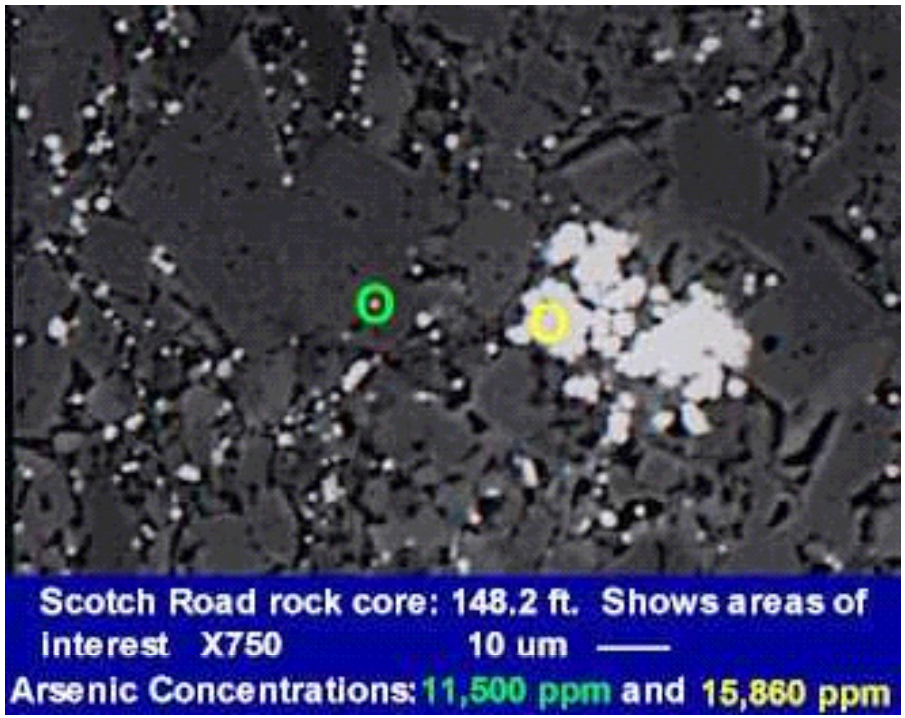
Weathered Pyrite Crystals on Weathered Bedrock Fracture Surface



prize

Core Sample From Hopewell Township, New Jersey

Scanning electron micrograph of a thin section

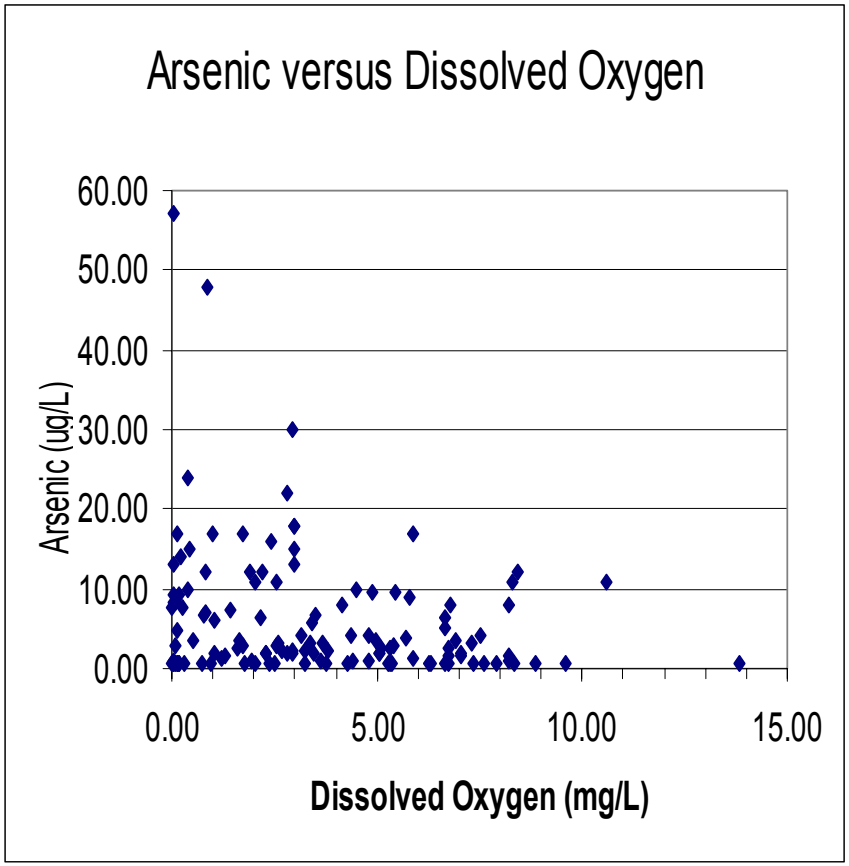


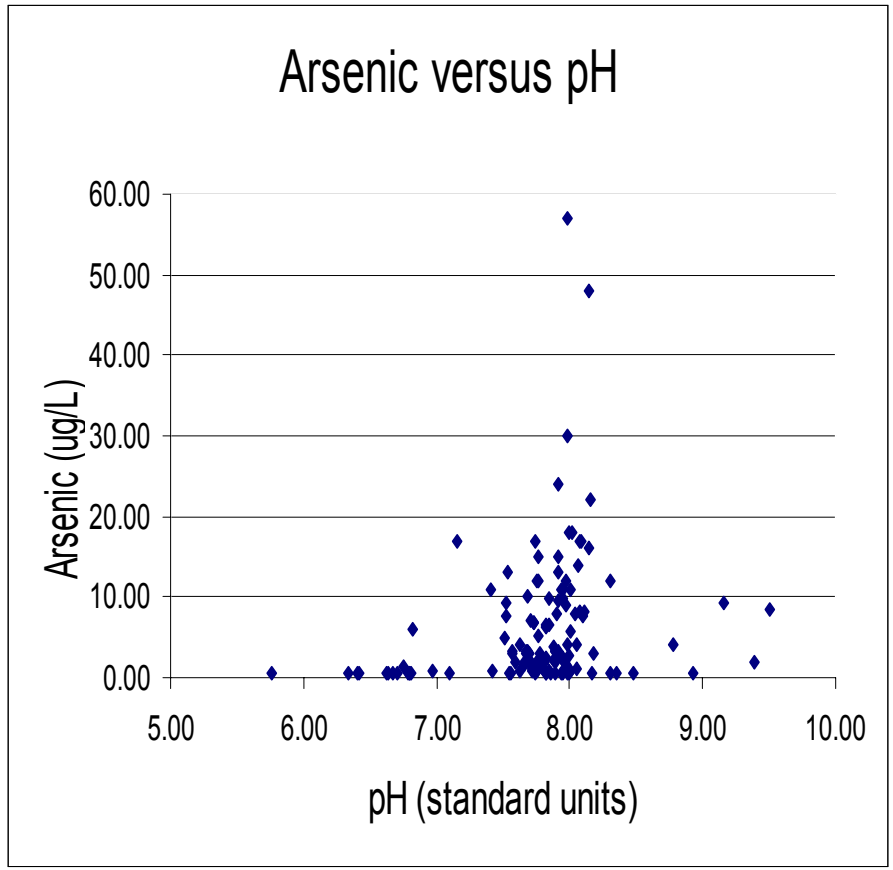
Magnified 750X

- Sample of black shale from 148.2 feet below land surface
- Pyrite in green circle has 11,500 ppm arsenic
- Pyrite in yellow circle has 15, 860 ppm arsenic
- Nearby well water has arsenic concentrations

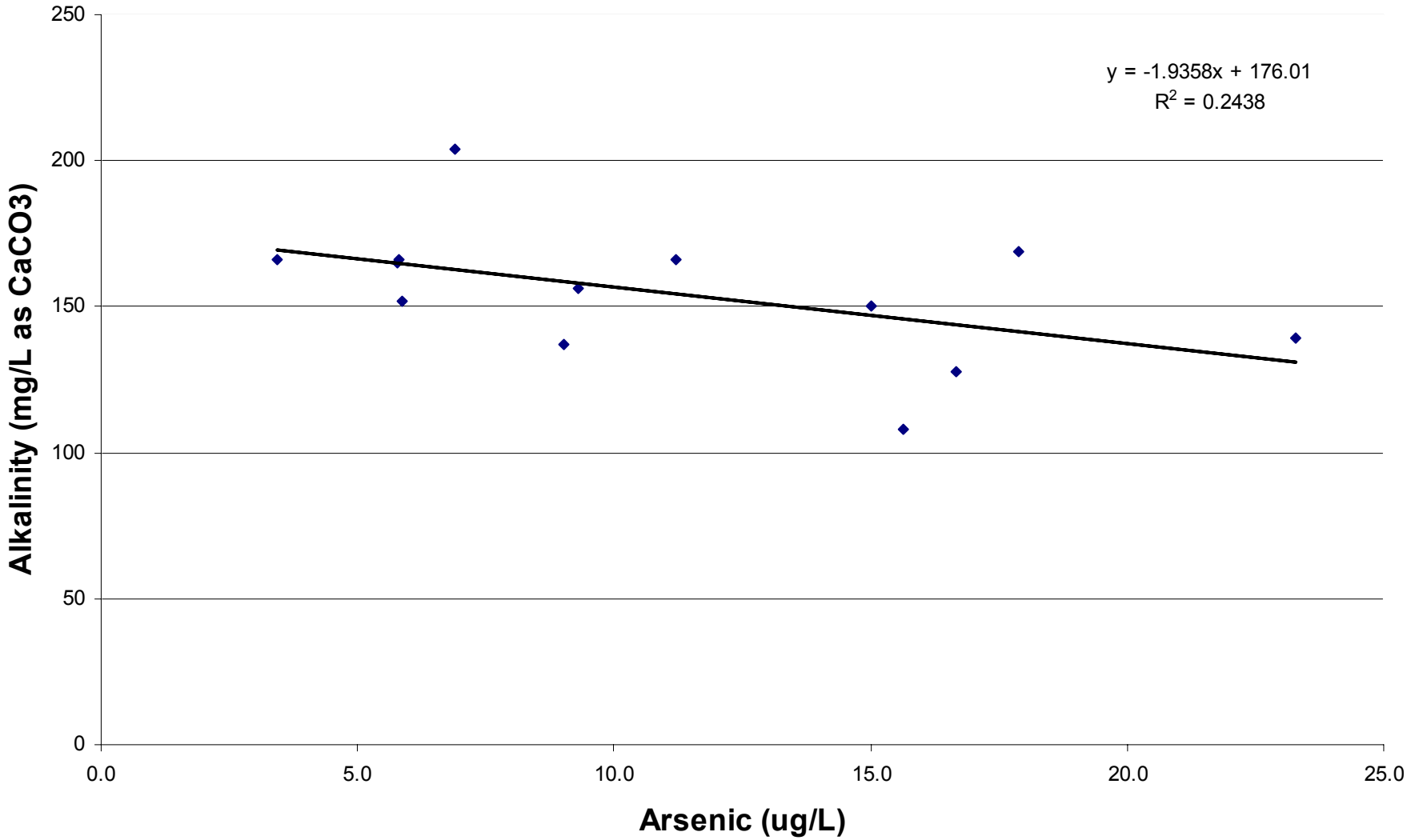
Slide courtesy of Mike Serfes, NJGS

Gray Shale Bedrock of the Lockatong Formation





Arsenic versus dissolved oxygen and pH from study area. This is a compilation of data from all the formations sampled. Note that a DO < 3 mg/L increases the probability (visual assessment) of having an arsenic concentration greater than 10 ug/L. A pH between 7.5 and 8.2 may also be an optimal range for arsenic mobility. More work needs to be done to better define these and other indicators.


Alkalinity versus Arsenic at Stony Brook
y = -1.9358x + 176.01
R2 = 0.2438
Alkalinity (mg/L as CaCO3)
Arsenic (ug/L)
250
200
150
100
50
0
0.0
5.0
10.0
15.0
20.0
25.0

Arsenic Species:
As3 (arsenite) & As5 (arsenate)

- Arsenic species testing is not commercially available

- Arsenic species affects treatment ability

Arsenic Speciation in New Jersey

Cooperative study testing the wells with the highest arsenic levels in NJ.

NJGS, USGS, Stevens Institute of Technology, and the Environmental and Occupational Health Sciences Institute of UMDNJ/Rutgers.

Tested 28 wells (public and residential) with the highest known arsenic levels in NJ. Four labs using a variety of speciation methods found very comparable results.

Only 4 wells (14%) had As3 above 2 ppb. All of these wells were in the Lockatong Fm.

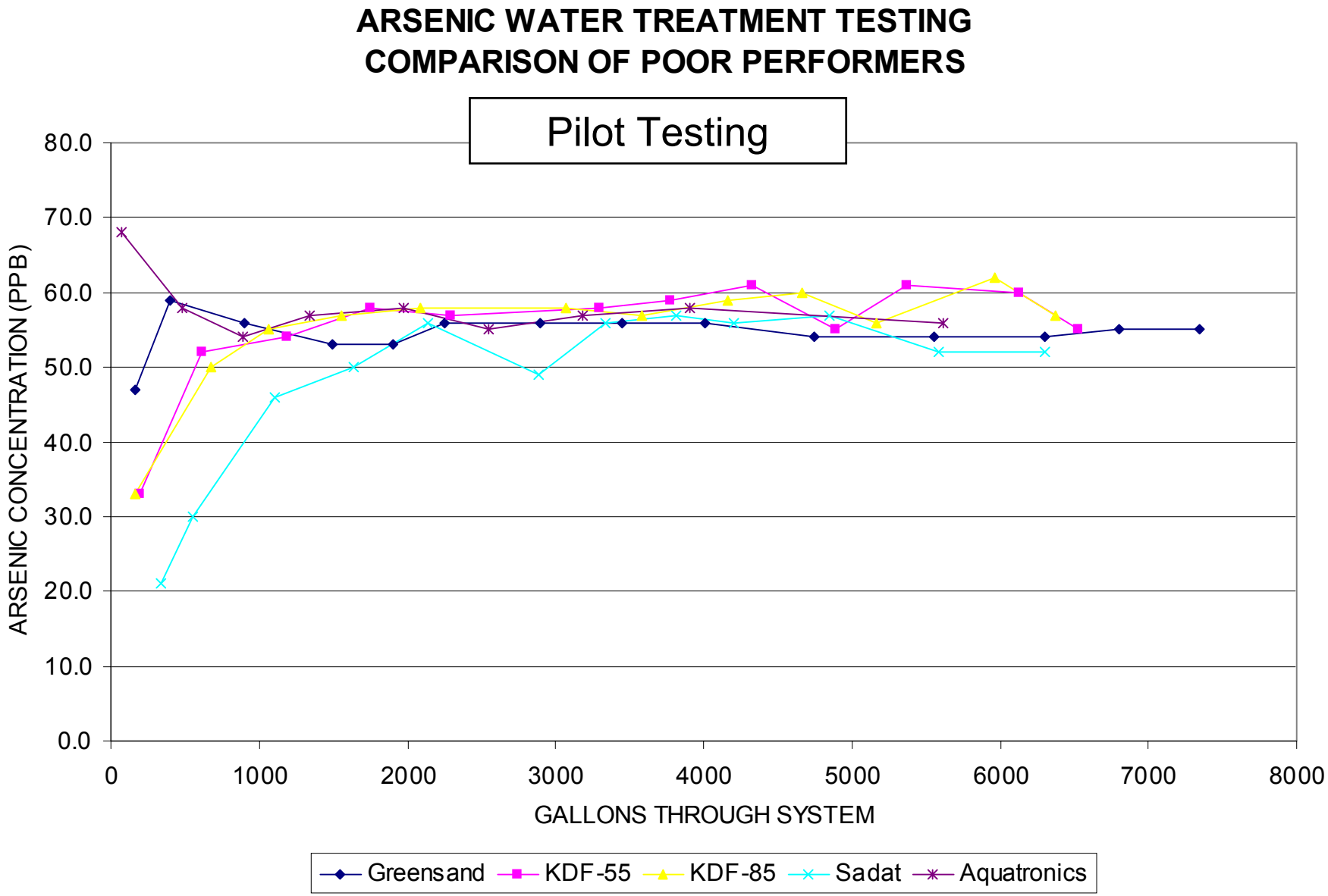
Remediation Issues

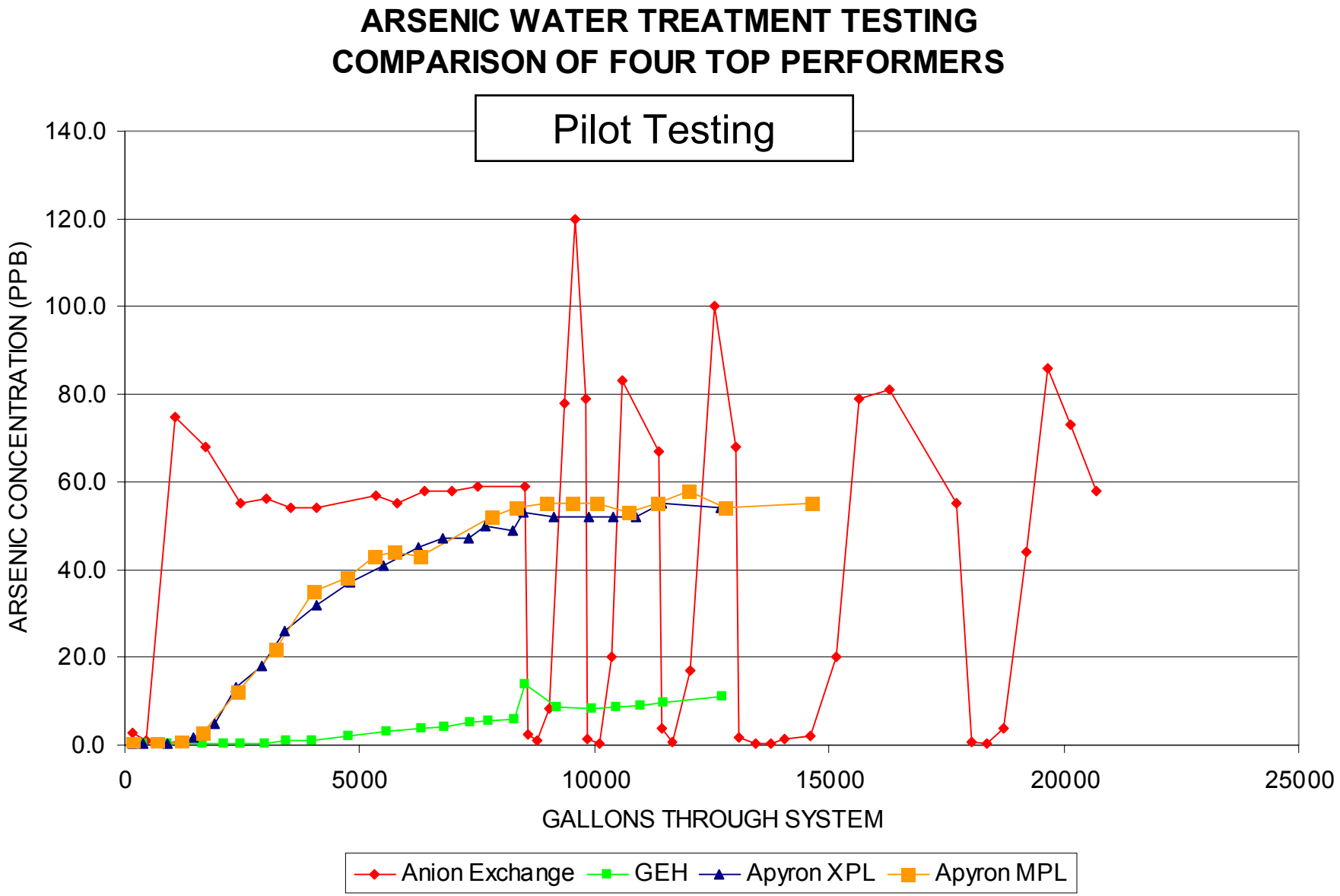
- Water Treatment
- Point of Use vs Point Of Entry
- Treat Whole House or Just Drinking Water
- Arsenic Species (As5, As3)
- Well Retrofitting
- Well Sampling Alerts
- Homeowner's Arsenic Guide

Treatment Technologies Tested

- Reverse Osmosis for Point of Use
- Granular Ferric Hydroxide (GEH, GFH)
- Anion Exchange Resin
- Apyron Aqua-Bind XP
- Apyron Aqua-Bind MP
- Greensand
- KDF-55
- KDF-85
- Granular Ferric Oxide (GFO)
- Other Experimental Media

We have not tested everything.

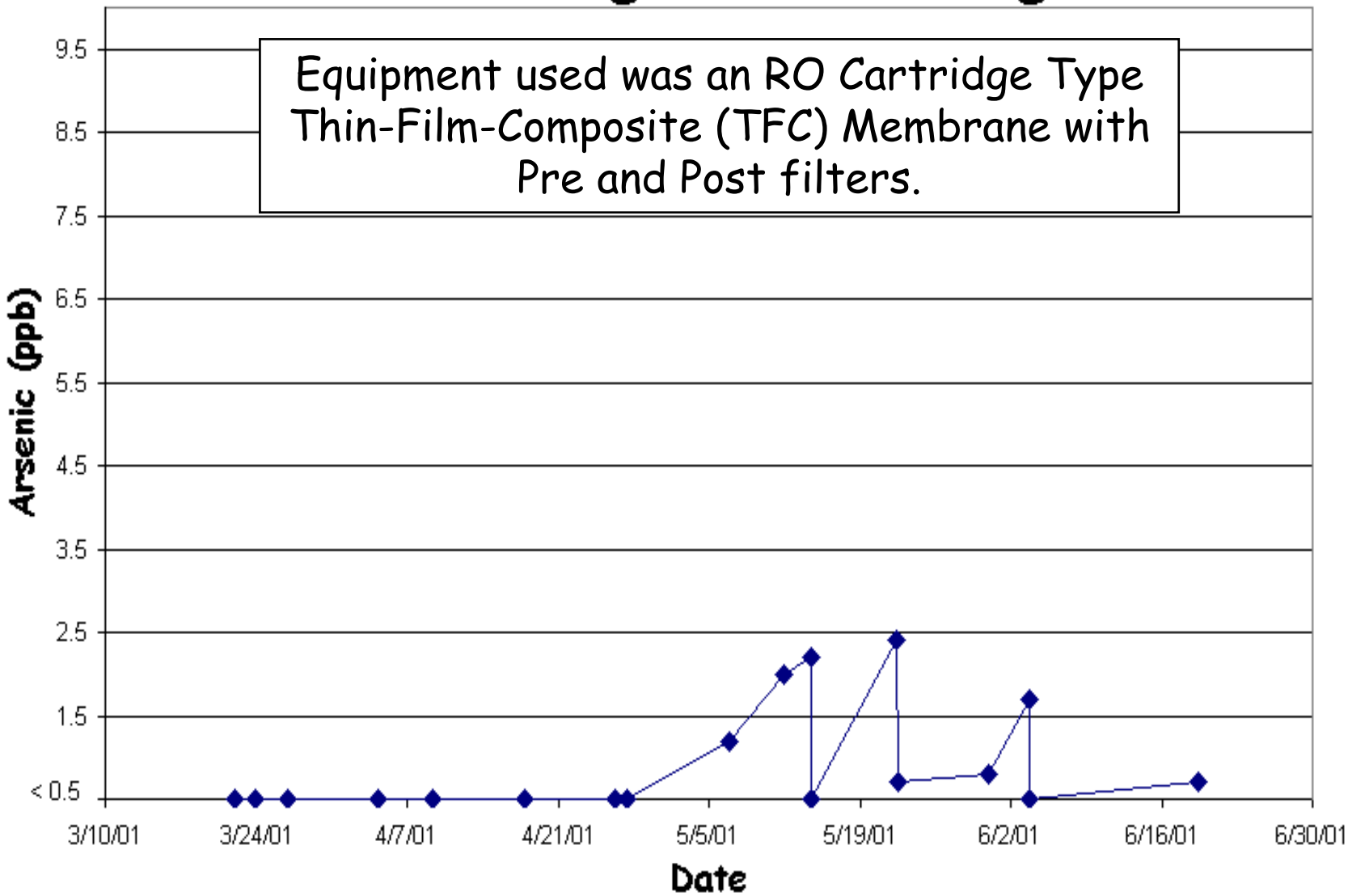

ARSENIC WATER TREATMENT TESTING
COMPARISON OF POOR PERFORMERS
Pilot Testing
ARSENIC CONCENTRATION (PPB)
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0
1000
2000
3000
4000
5000
6000
7000
8000
GALLONS THROUGH SYSTEM
Greensand
KDF-55
KDF-85
Sadat
Aquatronics


ARSENIC WATER TREATMENT TESTING
COMPARISON OF FOUR TOP PERFORMERS
Pilot Testing
ARSENIC CONCENTRATION (PPB)
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
0
5000
10000
15000
20000
25000
GALLONS THROUGH SYSTEM
Anion Exchange
GEH
Apyron XPL
Apyron MPL

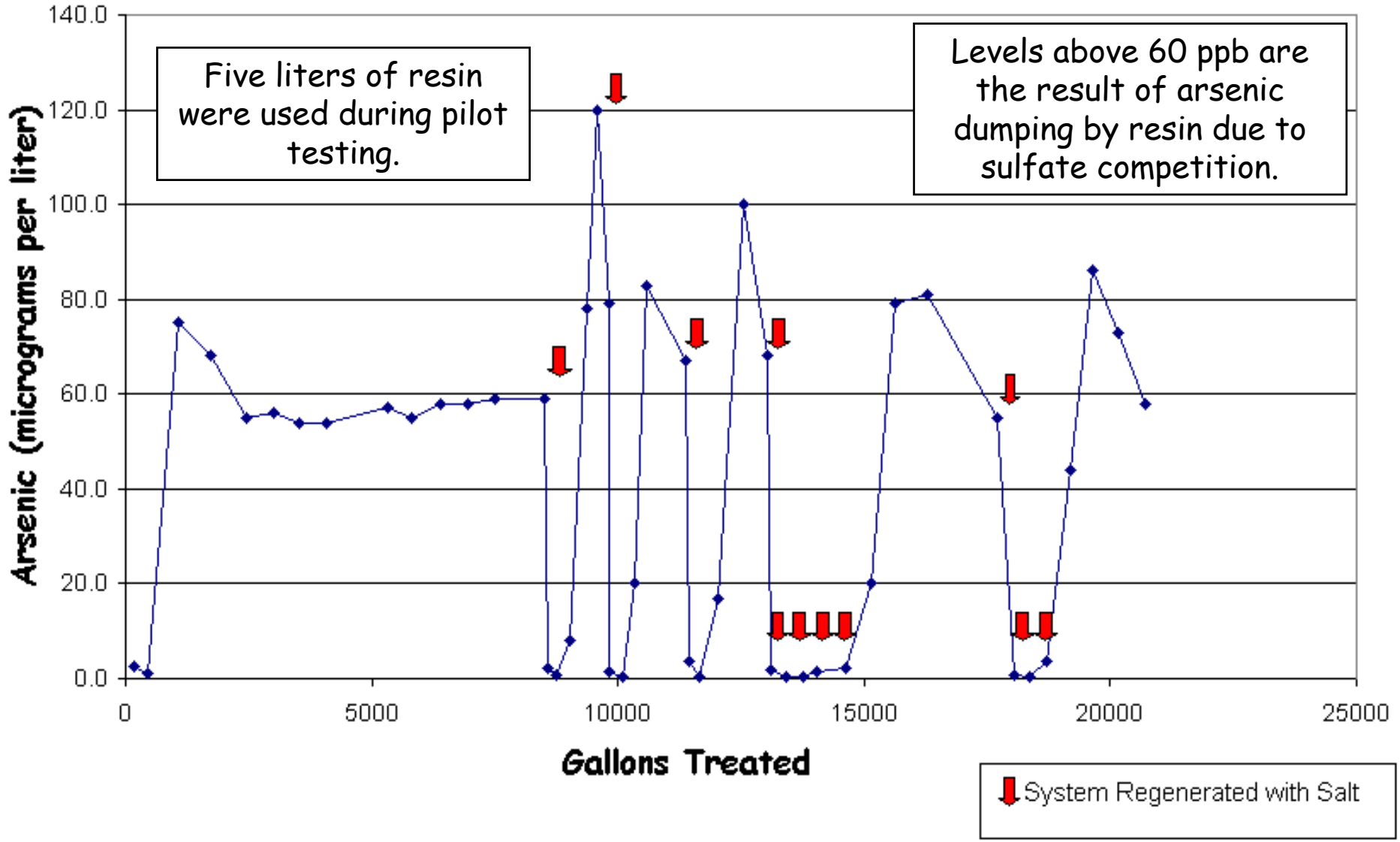
What's Needed in an Arsenic Water Treatment System for a Home?

- User Friendliness
- Low Maintenance
- Cost Effectiveness
- Efficiency
- Safety

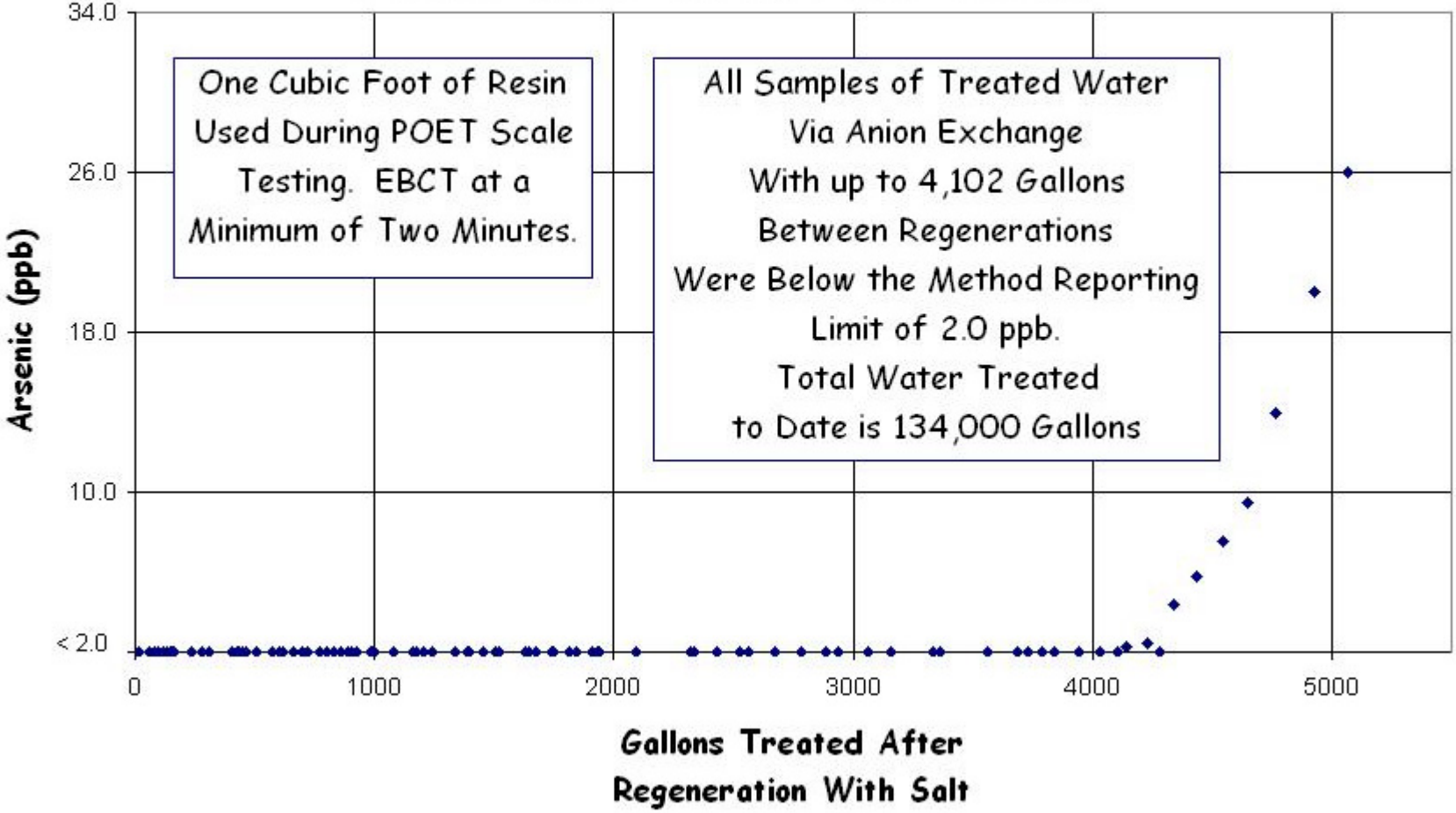
Reverse Osmosis Treated Water During Pilot Testing



Anion Exchange Treated Water During Pilot Testing



Anion Exchange
(Strong Base Anion Type II Resin)
Treated Water During POET Testing



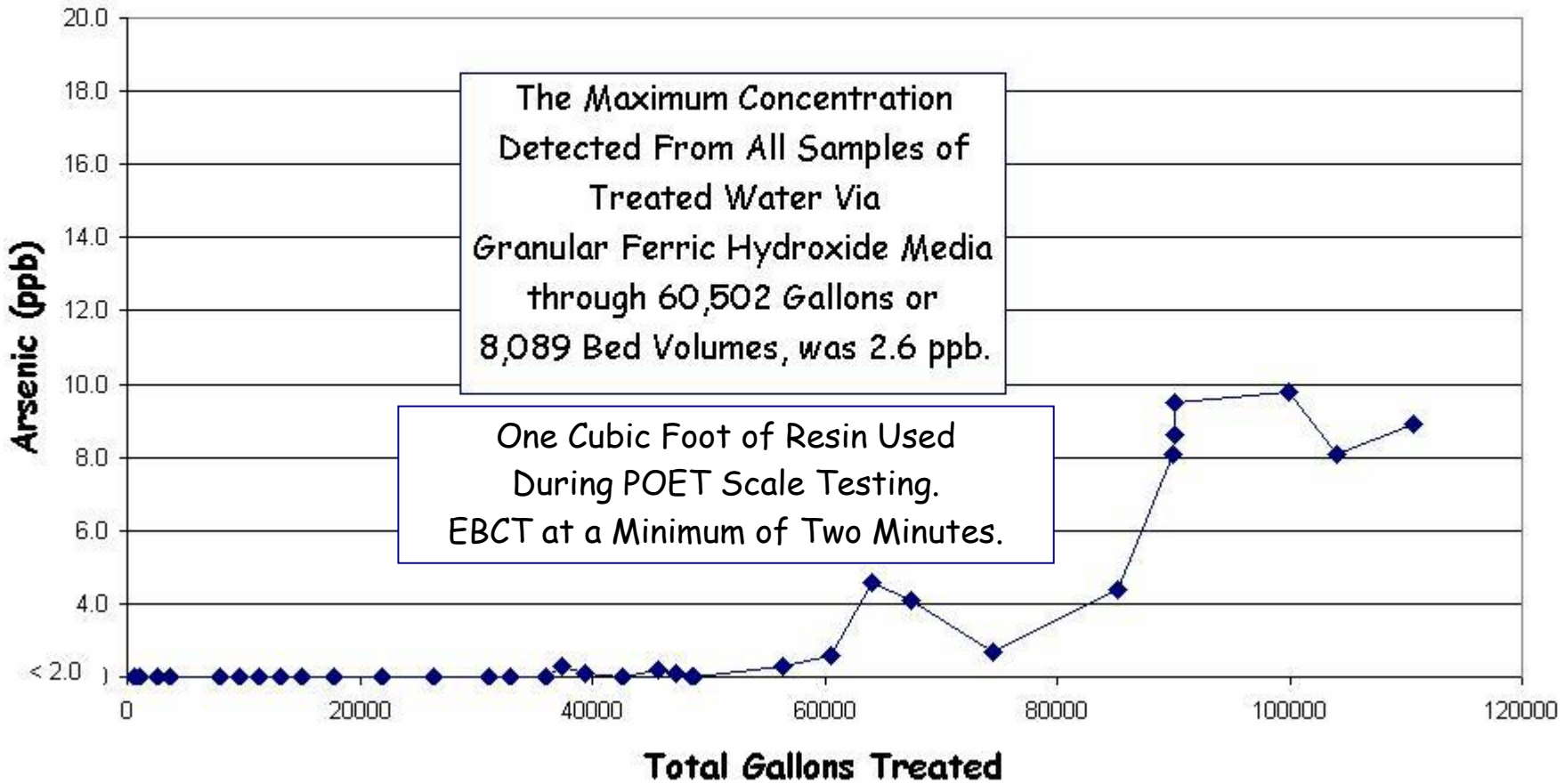
Anion Exchange Treatment Notes:

Anion Exchange treats only arsenate (As5). Pre-treatment is required if arsenite (As3) is present. Treated water pH is in the 5.0 - 6.8 range when regenerated properly.

System is regularly regenerated with salt. If the system is not regenerated on the proper schedule, "dumping" of arsenic into the treated water, at levels above the raw water concentration, will occur due to sulfate, nitrate, or other anion loading.

Because this system does not remove As3, it is not recommended for use in NJ. It should only be used if As5 has been determined to be the predominant species in the water. Pre-treatment systems to convert As3 to As5 are available, but are not recommended for the average home because of their high cost, complexity, and need for maintenance.

Granular Ferric Hydroxide (GFH ™) Treated Water During POET Testing



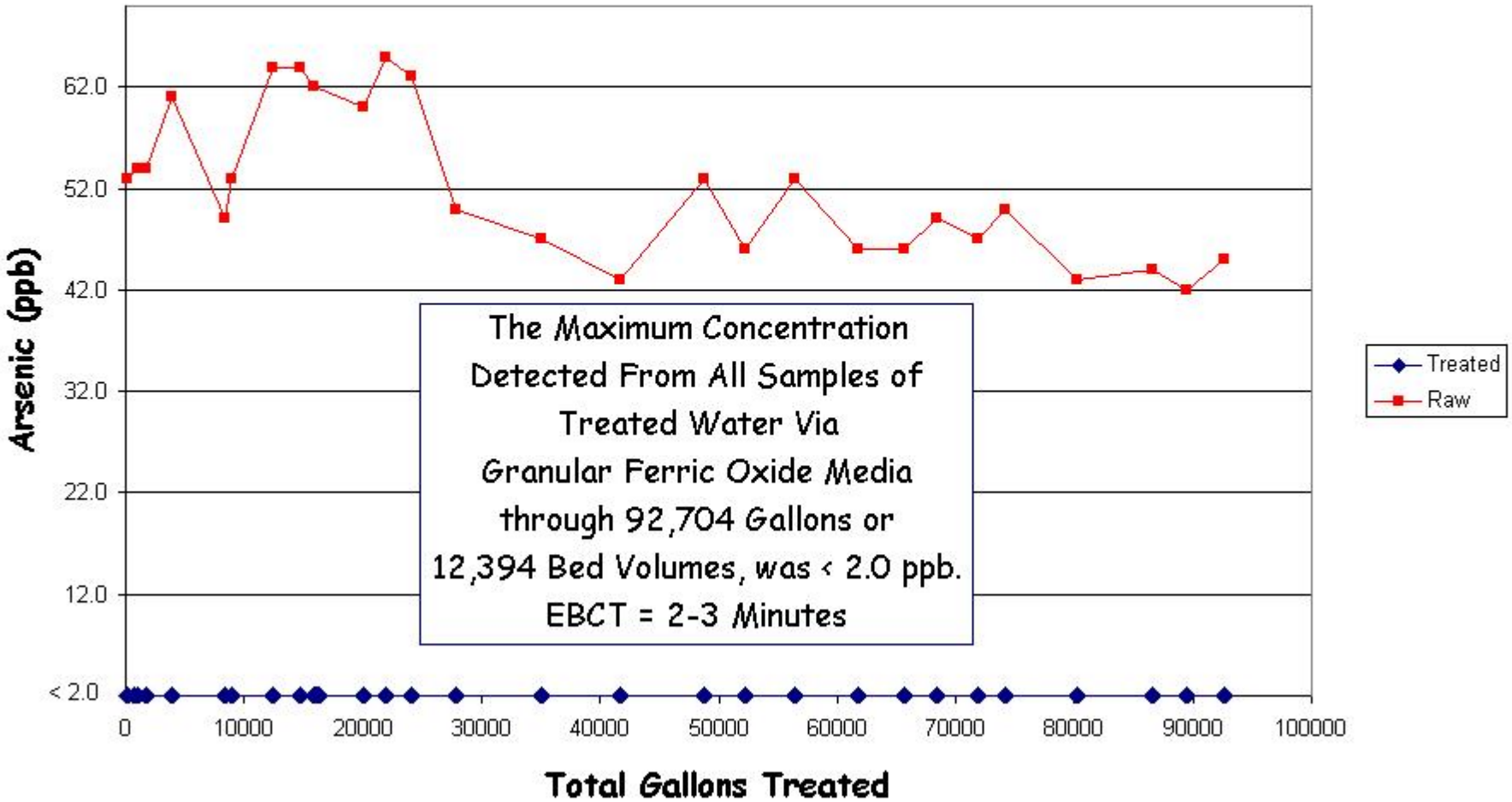
Granular Ferric Hydroxide Treatment Notes:

This media treats both arsenate (As5) and arsenite (As3) without pre-treatment in NJ.

Low maintenance.

No arsenic is returned to the environment near the home.

Granular Ferric Oxide
Treated Water During POET Testing



Granular Ferric Oxide Treatment Notes:

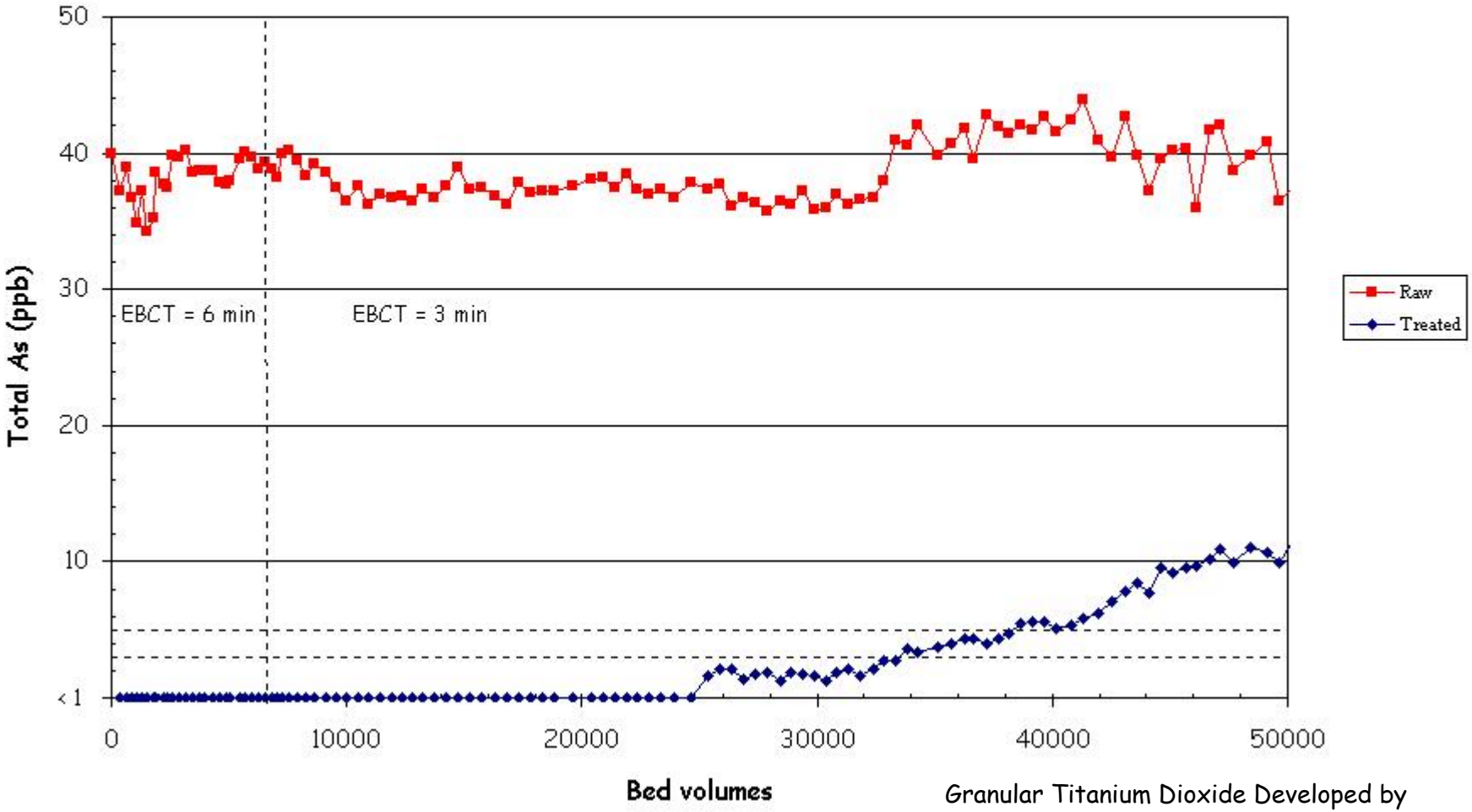
This media treats both arsenate (As5) and arsenite (As3) without pre-treatment in NJ.

The media ships dry and is less dense than GFH.

Low maintenance.

No arsenic is returned to the environment near the home.

Granular Titanium Dioxide Treated Water During Recent Pilot Testing



Granular Titanium Dioxide Developed by
Stevens Institute of Technology,
Hoboken, New Jersey

DRAFT

New Jersey Geological Survey

Informational Circular

Arsenic Water Treatment for Residential Wells in New Jersey

Arsenic in Well Water

Arsenic has been found to occur in well water of the Piedmont Physiographic Province of New Jersey (Figure 1) at levels exceeding the drinking water standard. For more information on the occurrence of arsenic in New Jersey, see our Information Circular on Arsenic in New Jersey Ground Water.

PIEDMONT PHYSIOGRAPHIC PROVINCE
Fig 1

Arsenic in well water is colorless, odorless, and tasteless. The only way to identify its presence in water is to have the water specifically tested for arsenic.

Arsenic is a toxic element that is known to increase the risk of adverse health effects in people who drink water containing it. These impacts include cancer of the skin, bladder, lung, kidney, nasal passages, liver and prostate. Arsenic is a known human carcinogen. It also causes increased risk of cardiovascular disease, peripheral neuropathy, and diabetes. Though the major exposure pathway for arsenic in residential well water is drinking and cooking with the untreated water, there may also be significant exposures from other uses of water in the home (for example, bathing, showering, and brushing teeth). The United States Environmental Protection Agency lowered the arsenic drinking water standard from 50 parts per billion (ppb) to 10 ppb on February 22, 2002.

Sample your well water for arsenic. If you have your own well and live in the shaded area of the map in Figure 1, you should have your well water tested for arsenic. Water testing labs can usually be found in the yellow pages under "Laboratories-Testing" or "Water Analysis." A list of certified labs can also be found on the Private Well Testing Act web site at http://www.state.nj.us/dep/pwta/. Use a lab that is certified to test drinking water for arsenic. The best test methods are EPA Methods 200.8 (ICP/M
Standard Methods 3[illegible]
EPA Method 200.7 (IC
recommended due to
detection limits and E
the approved list. Use
method detection limit
lower. The lab will re
Although arsenic in N
been found to occur in
referred to as As3 and
species are difficult an
available at this time.
important to choose a
removes both arsenic

Re-sample your well
you have tested your w
is reported to be greate
should re-test to confirm
obtaining a treatment system.

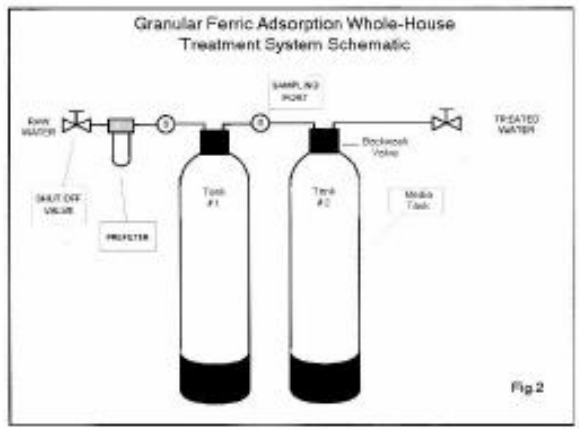
Arsenic Water Treatment Research

The NJ Department of Environmental Protection has conducted research to determine the most efficient, cost effective, user friendly, and environmentally sound water treatment technologies to remove arsenic from residential well water in New Jersey. Arsenic removal requires special considerations. Water softeners and granular activated carbon do not remove arsenic. For technical information regarding arsenic water treatment research, see our Information Circular on Arsenic Water Treatment Research for Residential Wells.

Treatment Options

valves should be set to backwash the media once per week, each tank on a separate day. The backwash line should be piped to a suitable disposal location according to local plumbing codes.

A water sample should be obtained from the sampling tap between the two tanks a few days after installation to confirm that the system is working properly. This initial test should find less than 3 ppb of arsenic, which will indicate the system is adequate. After this, a water sample should be obtained between the two tanks 6 months after installation and every 3 months thereafter to determine when the arsenic is breaking through Tank #1. When the arsenic level at this sampling tap reaches 3 ppb, it is time to schedule maintenance of the system which involves media replacement for



"A whole-house granular ferric adsorption system is the preferred treatment technology because it effectively removes both arsenic species from all water in the home, it is easy to operate and maintain, and the arsenic is not returned to the environment via regeneration."

Granular Ferric Adsorption Whole-House Treatment System Schematic

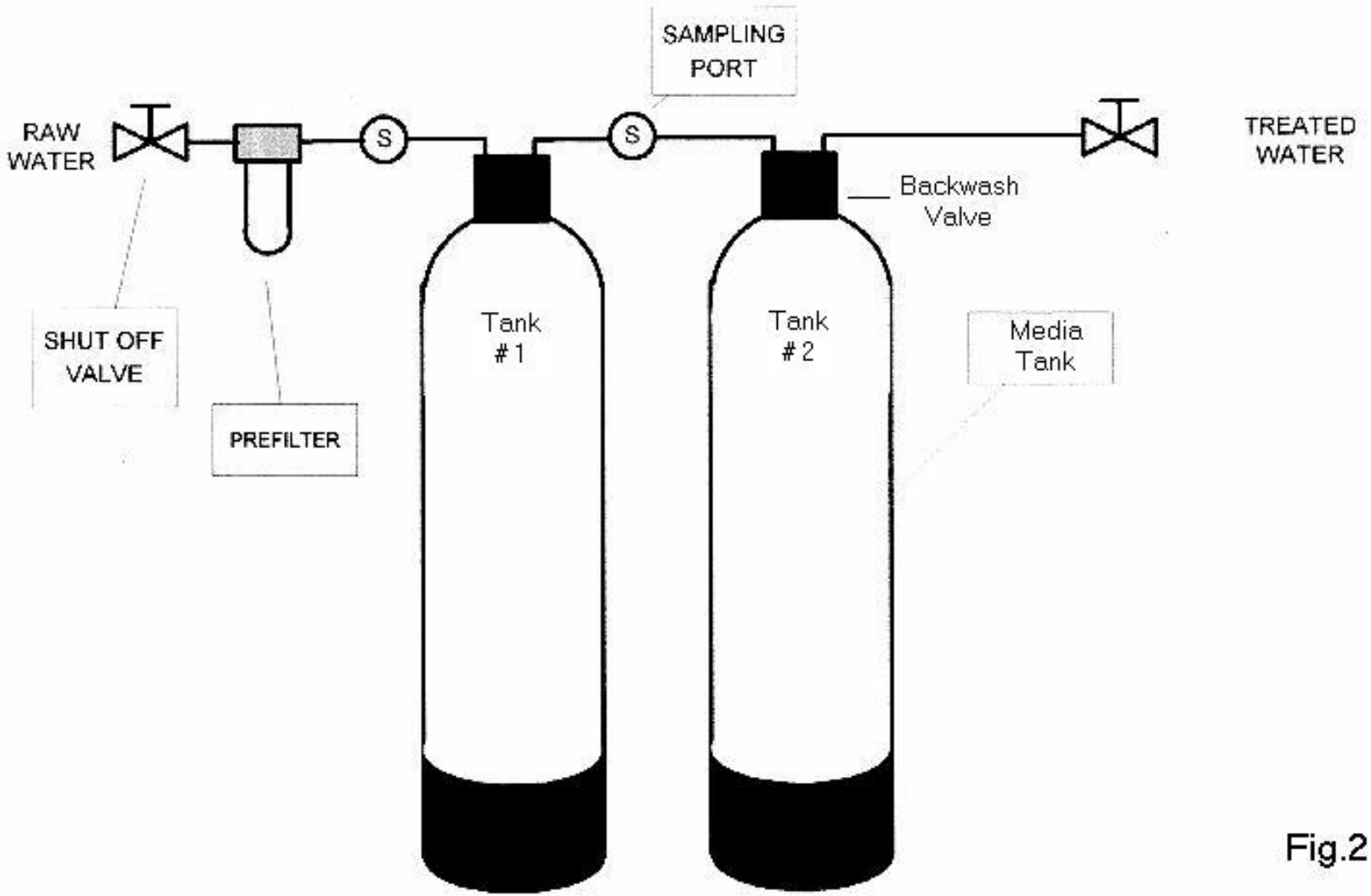


Fig.2

Point-of-Use Treatment Issues:

Reverse Osmosis and Adsorption Media Cartridges may be viable options.

Disadvantages:

•arsenic exposure may continue in the home from other water uses, especially drinking from other taps, and

•it is not uncommon for homeowners to over run the useful life of point-of-use cartridges.

Human Exposure to Arsenic and Biomonitoring of the Families with the Highest Known Arsenic Levels in New Jersey Well Water – Preliminary Data

Brian Buckley, PhD, Principal Investigator, EOHSI &
Steve Spayd, MPH Student
University of Medicine and Dentistry of NJ
School of Public Health

Environmental and Occupational Health Sciences Institute EOHSI
A joint institute of Rutgers, The State University of New Jersey and UMDNJ-Robert Wood Johnson Medical School

UMDNJ SCHOOL OF PUBLIC HEALTH
University of Medicine & Dentistry of New Jersey

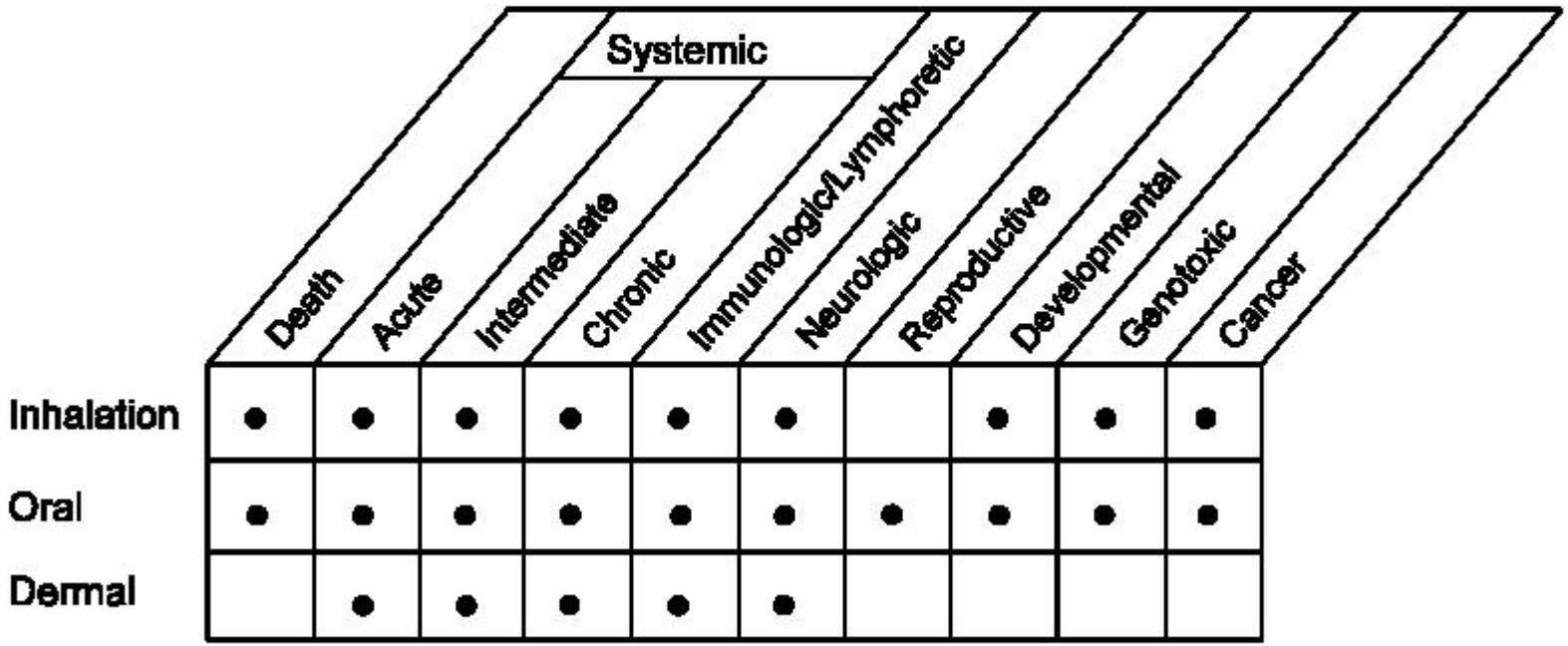
prize

Why an Interest in Exposures From Other Than Drinking or Cooking With the Water?

- Though drinking and cooking with arsenic contaminated water is obviously the main exposure pathway in the home, other exposure pathways may exist (e.g., showering & brushing teeth).

- Because even low levels of exposure are estimated to result in typically unacceptable cancer risks, these other exposures may represent a significant risk when arsenic water concentrations are above a certain level.

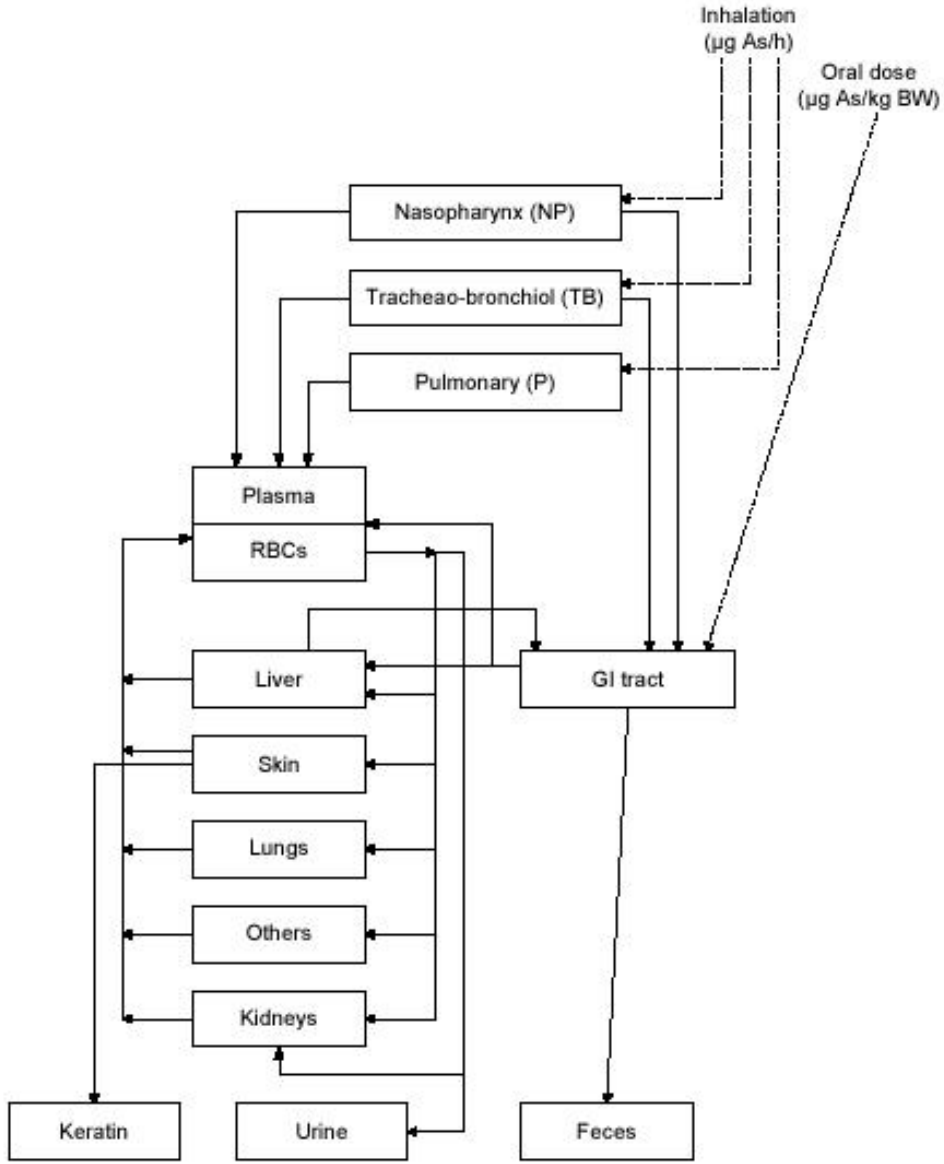
Figure 2-9. Existing Information on Health Effects of Inorganic Arsenic



Human

Source: ATSDR

Figure 2-7. Parameters Used in the Mann PBPK Model for Humans



Source: Mann et al. 1996b

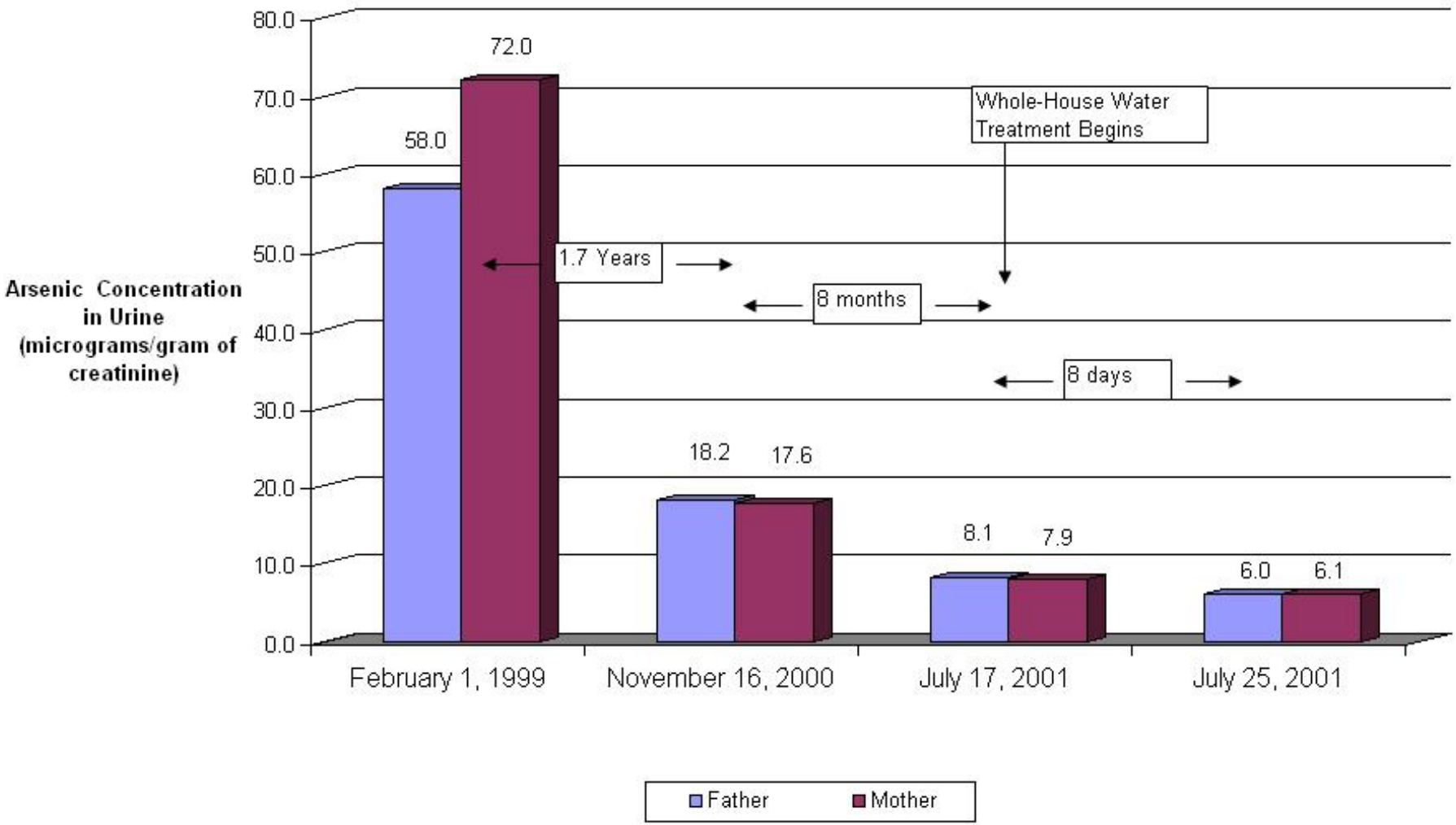
Human Exposure Study Design

- Identify the families with the highest known arsenic levels in NJ well water.
- Obtain samples of urine, blood, and hair before and after arsenic exposure is reduced.
- Some families still drinking the arsenic contaminated water, some families drinking and cooking with bottled water or Point-of-Use treated water, and some families obtaining whole-house (Point-of-Entry) treatment of their water.
- Continue biomonitoring with time.
- Compare results between the different groups to see if there is a significant difference.

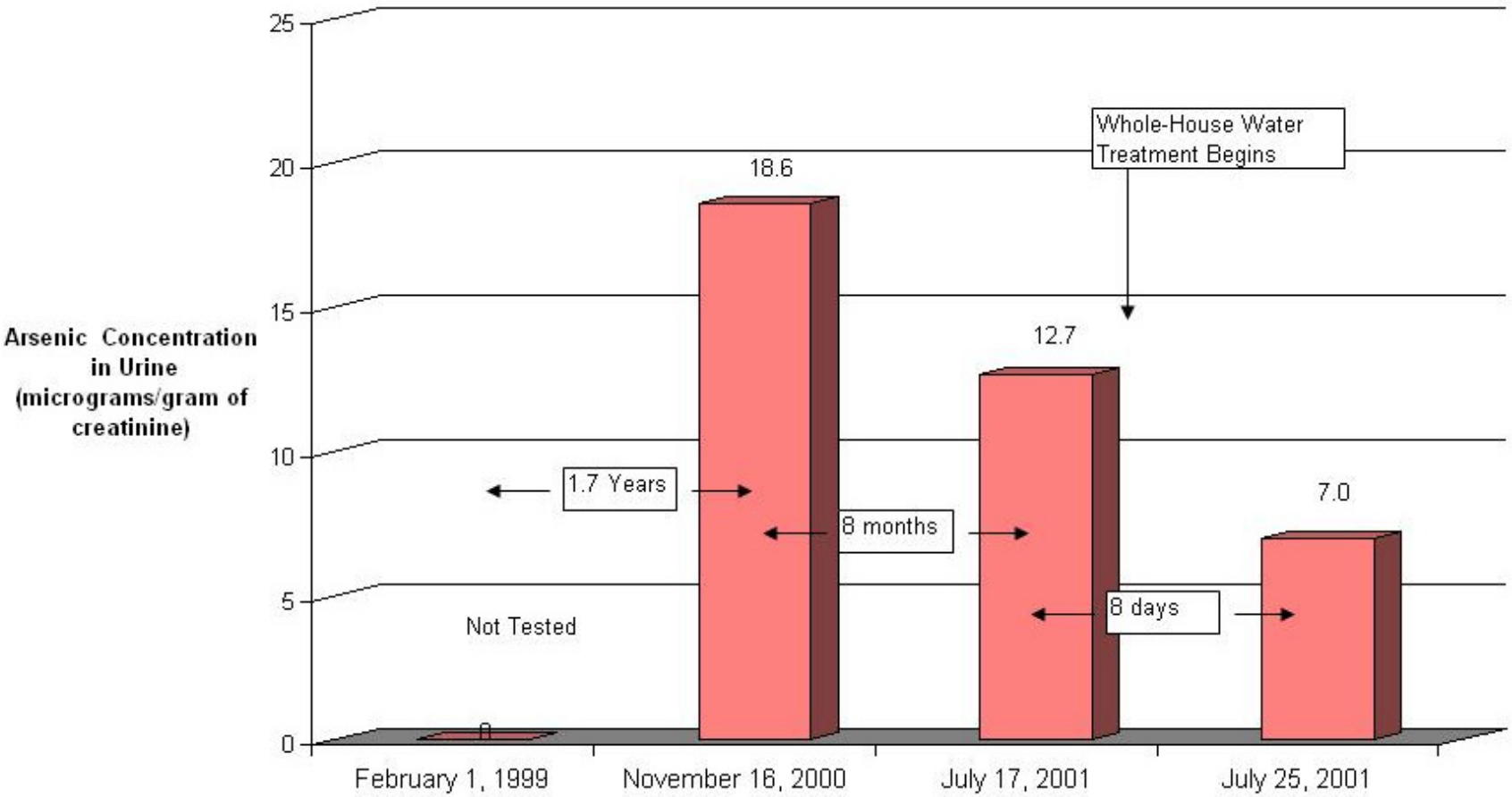
What are "Normal" Levels of Arsenic in Humans?

Table 4 Relationship of Drinking Water, Blood, and Urine Arsenic Levels (mcg/L)					
Drinking Water	**Blood**	**Urine, Total As**	**Urine, Inorganic As + DMA+MMA**	**Location**	**Data Source**
600	-	-	583	San Pedro, Chile	Biggs, et al., 1997
500	-	100	-	Millard County, Utah, USA	Calderon, et al., 1999
401	-	178	-	Fairbanks, Alaska, USA	Harrington, et al., 1978
393	13.3	-	-	Edison, California, USA	Valentine, et al., 1979
215	9.0	-	320	S.A. Cobres, Argentina	Concha, et al., 1998
200	8.0	274	261	S.A. Cobres, Argentina	Vahter, et al., 1995
123	4.2	84	-	Hidden Valley, Nevada, USA	Valentine, et al., 1979
100	-	70	-	Millard County, Utah, USA	Calderon, et al., 1999
98	4.3	-	-	Fallon, Nevada, USA	Valentine, et al., 1979
75	-	45	-	Fairbanks, Alaska, USA	Harrington, et al., 1978
51	5.1	40	-	Virginia Foothills, Nevada, USA	Valentine, et al., 1979
40	1.5	55	45	Santa Rosa de los P.G., Argentina	Vahter, et al., 1995
31	-	41	-	Fairbanks, Alaska, USA	Harrington, et al., 1978
30	-	28	-	Hermosillo, Sonora, Mexico	Wyatt, et al., 1997
15	-	-	59	Toconao, Chile	Biggs, et al., 1997
14	1.5	34	24	Olacapato, Argentina	Vahter, et al., 1995
11	-	38	-	Fairbanks, Alaska, USA	Harrington, et al., 1978
10	-	10	-	Millard County, Utah, USA	Calderon, et al., 1999
9	-	14	-	Hermosillo, Sonora, Mexico	Wyatt, et al., 1997
2.5	1.2	20	13	Tolar Grande, Argentina	Vahter, et al., 1995
1.9	-	19	8.6	Anaconda, Montana, USA	Hwang, et al., 1997
0.7	0.9	10	-	Rosario de Lerma, Argentina	Concha, et al., 1998

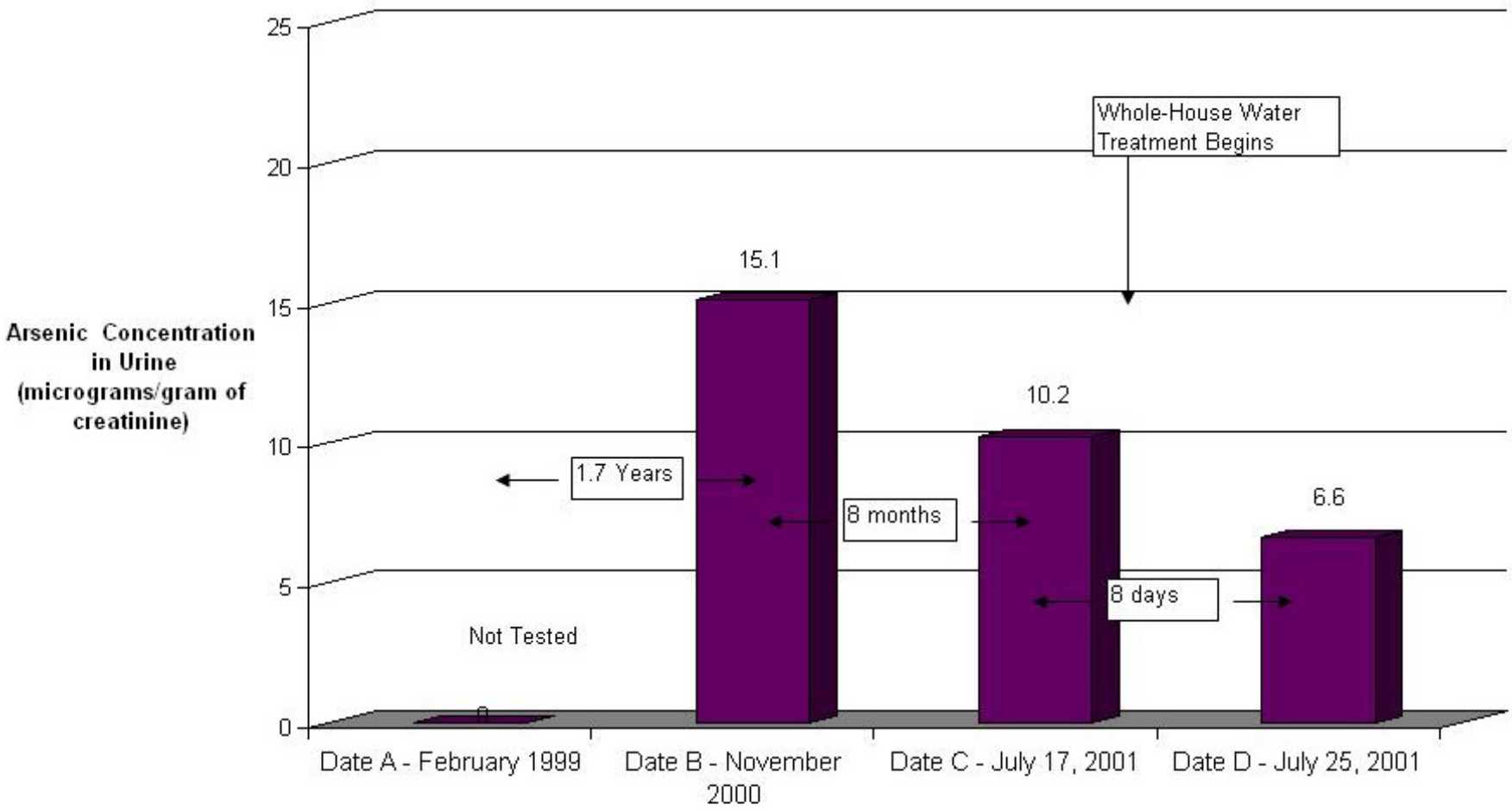
Father & Mother
Urine Data



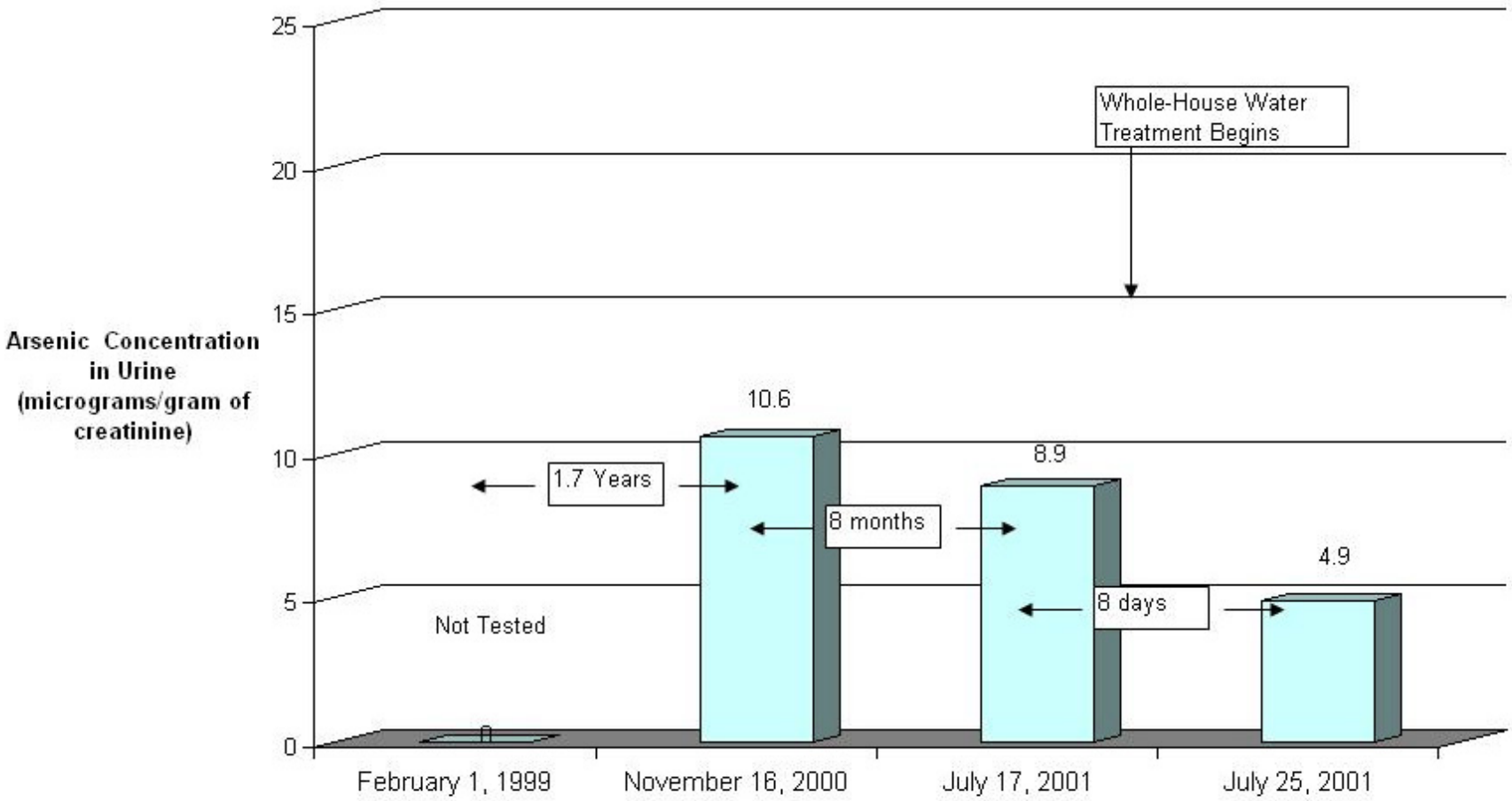
Daughter #4
Urine Data

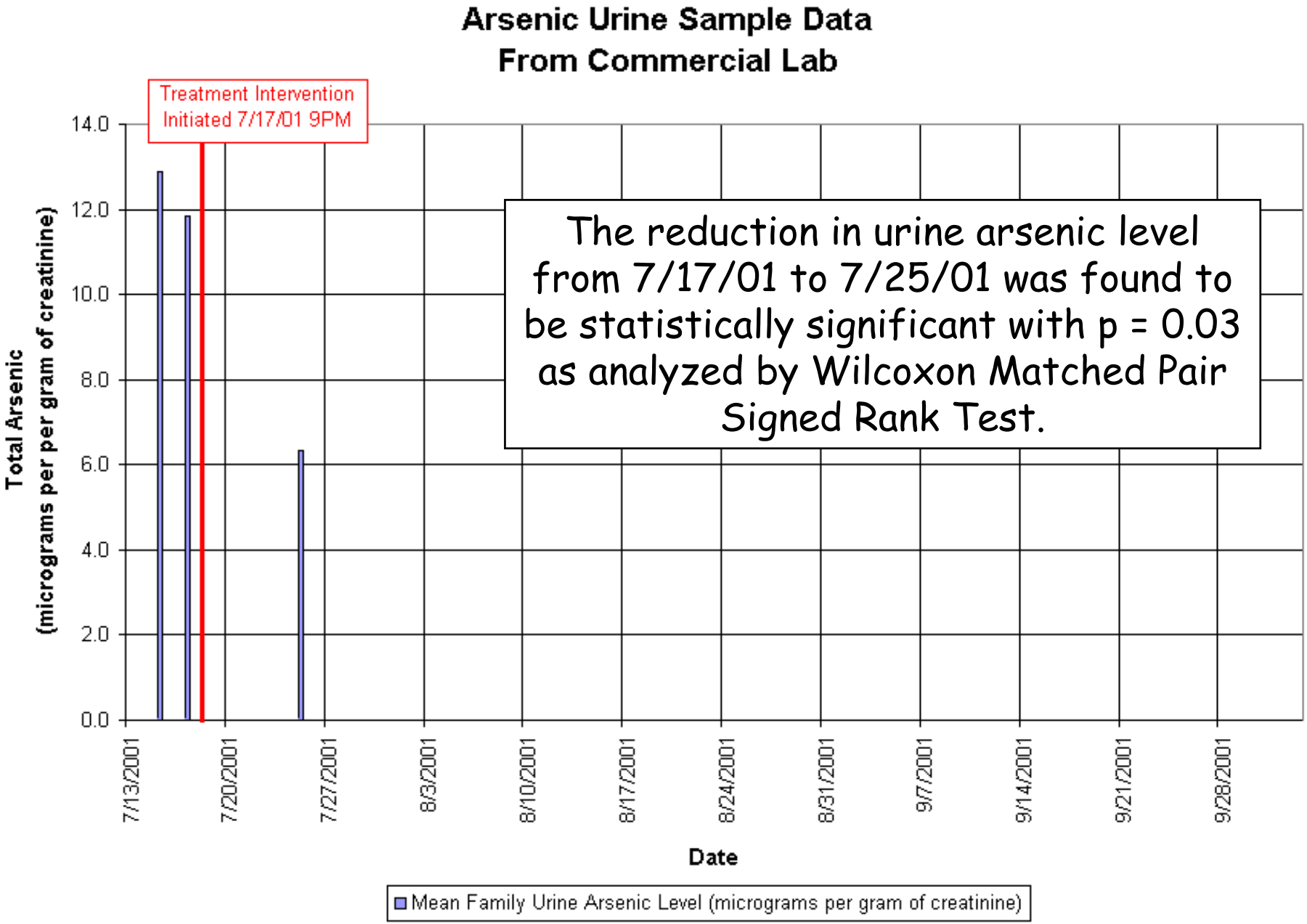


Daughter #3
Urine Data

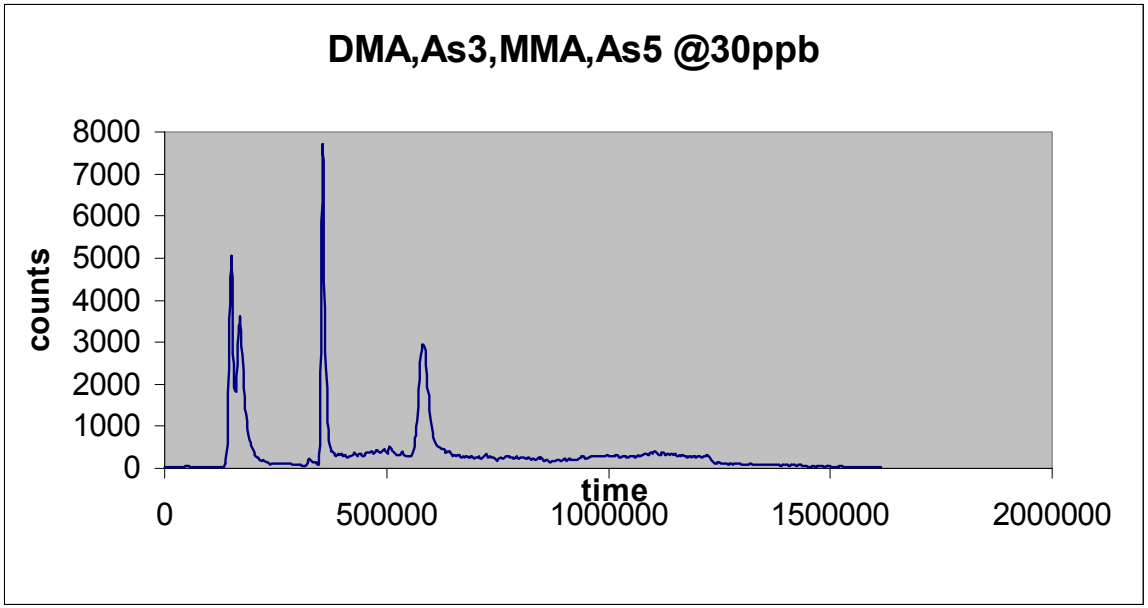


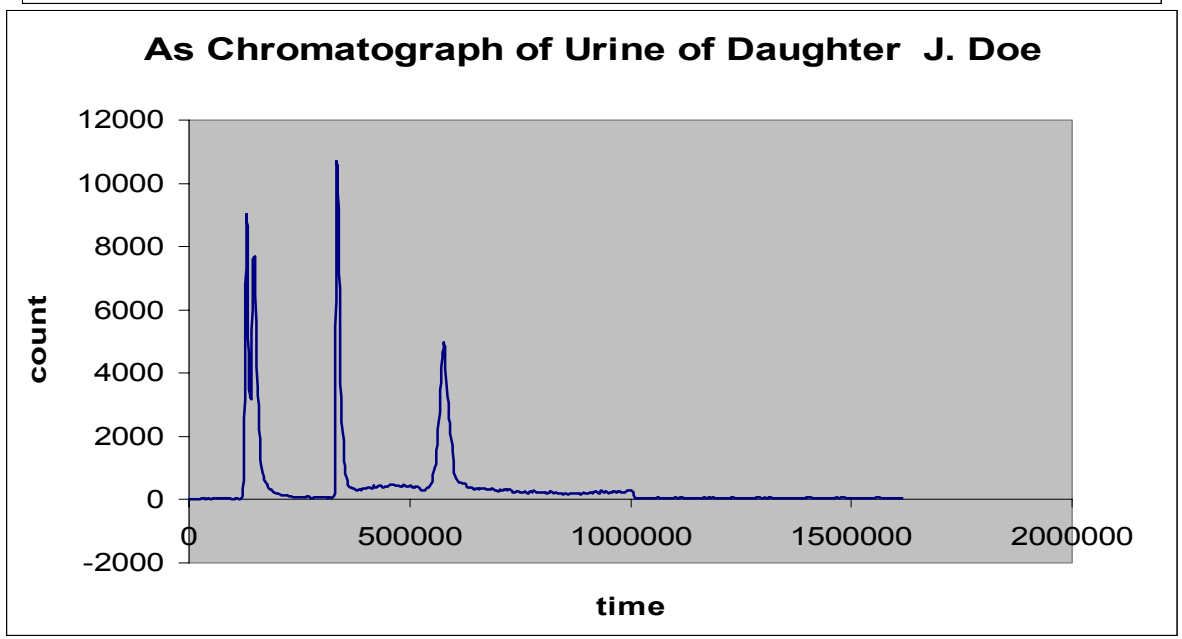
Daughter #2
Urine Data




Arsenic Urine Sample Data
From Commercial Lab
Treatment Intervention
Initiated 7/17/01 9PM
The reduction in urine arsenic level from 7/17/01 to 7/25/01 was found to be statistically significant with p = 0.03 as analyzed by Wilcoxon Matched Pair Signed Rank Test.
Total Arsenic
(micrograms per per gram of creatinine)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
7/13/2001
7/20/2001
7/27/2001
8/3/2001
8/10/2001
8/17/2001
8/24/2001
8/31/2001
9/7/2001
9/14/2001
9/21/2001
9/28/2001
Date
Mean Family Urine Arsenic Level (micrograms per gram of creatinine)

Arsenic Speciation





The Latest Arsenic Biomonitoring Data

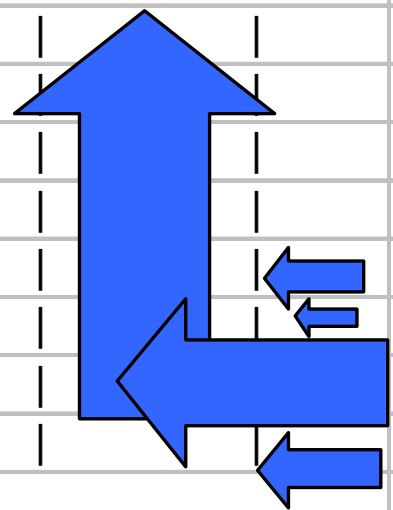
Not Available Yet


STOTHOFF
WELL DRILLING

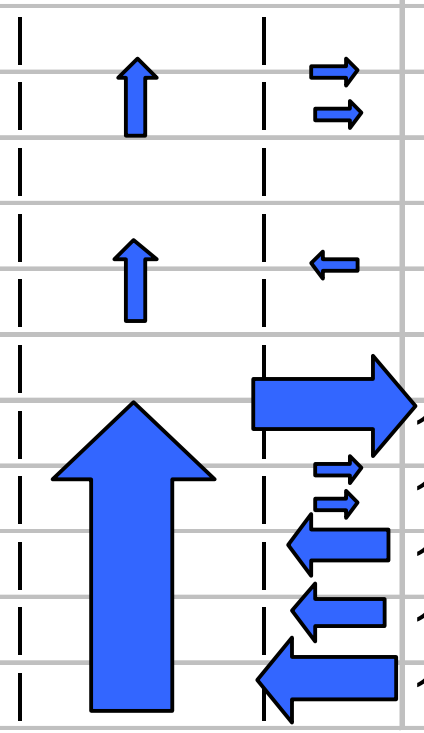
Water Quality From Packer Test

Pump Below Packer		Pump Above Packer	
Depth	Arsenic	Depth	Arsenic
62-175	58 ppb	50-61	47 ppb
82-175	58 ppb	50-81	50 ppb
122-175	58 ppb	50-121	52 ppb
142-175	58 ppb	50-141	53 ppb
158-175	57 ppb	50-161	55 ppb

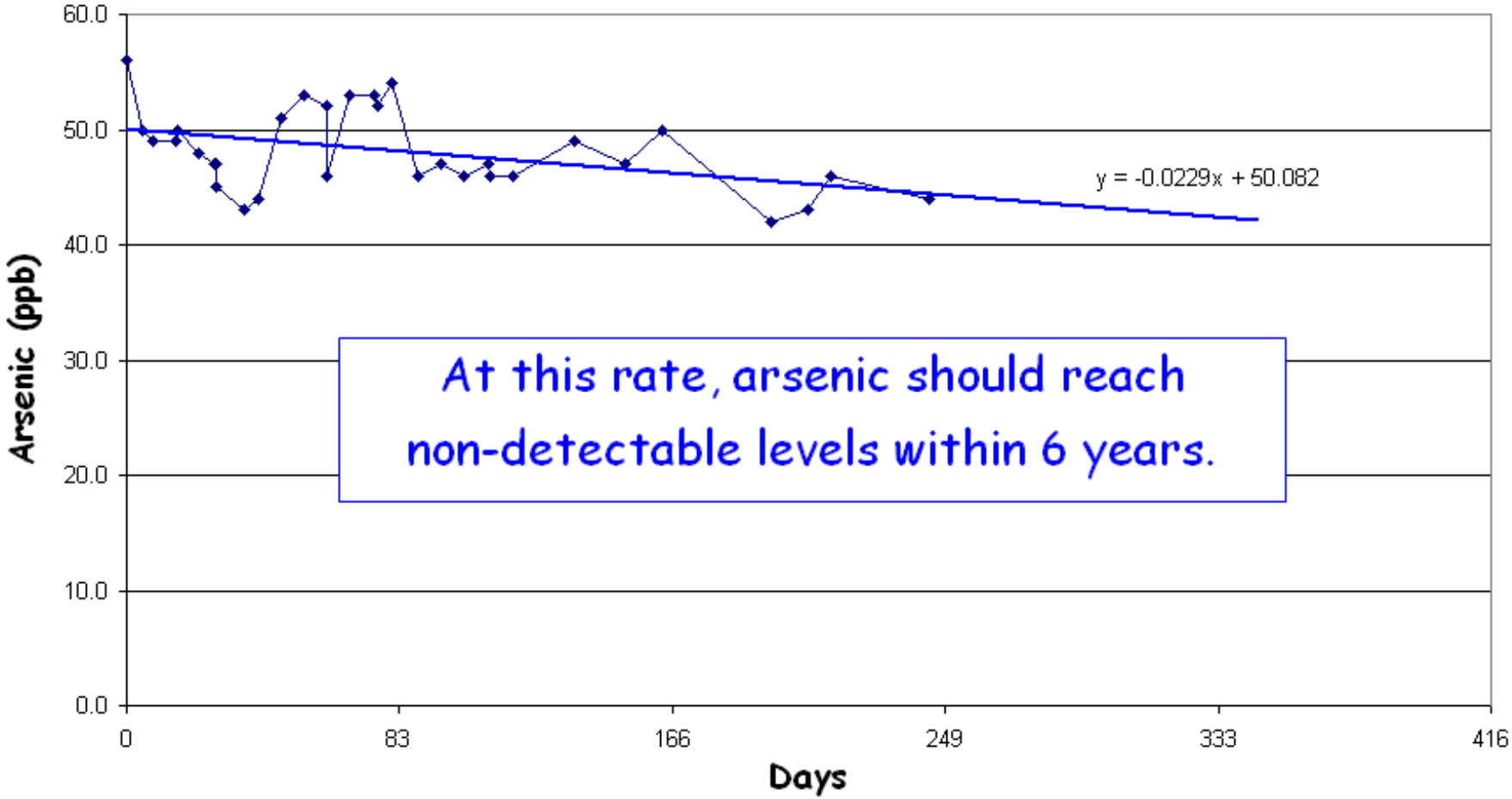
Heat Pulse Flow Meter Data

Data Summary			
Pumping at 11.3 GPM			
Depth [ft]	Relative		Major Joints on Caliper
Median Flow Rate [gpm]			
		Borehole Schematic	
45.00	7.50		48 **
56.05	7.66		55 *
102.00	7.70		99 ***
116.00	7.62		100 *******
130.10	7.62		114 *** & 126 ***
150.00	6.25		143 ****
164.05	5.37		155 *****
168.05	1.68		165 ***************

Heat Pulse Flow Meter Data

Data Summary			
	Non-Pumping		
Depth [ft]	Median Flow Rate [gpm]		Major Joints on Caliper
		Borehole Schematic	
48.10	0.27		48 **
52.00	0.88		55 *
56.05	1.48		
62.10	1.01		69 *
98.05	0.94		72 *****
102.10	2.92		99 ***
116.05	3.48		100 *******
130.10	4.01		114 *** & 126 ***
150.10	2.82		143 ****
164.00	1.69		155 *****
168.05	0.00		165 **********

Raw Water Arsenic Concentrations
Since Grouting the Well to a Depth of 94 Feet



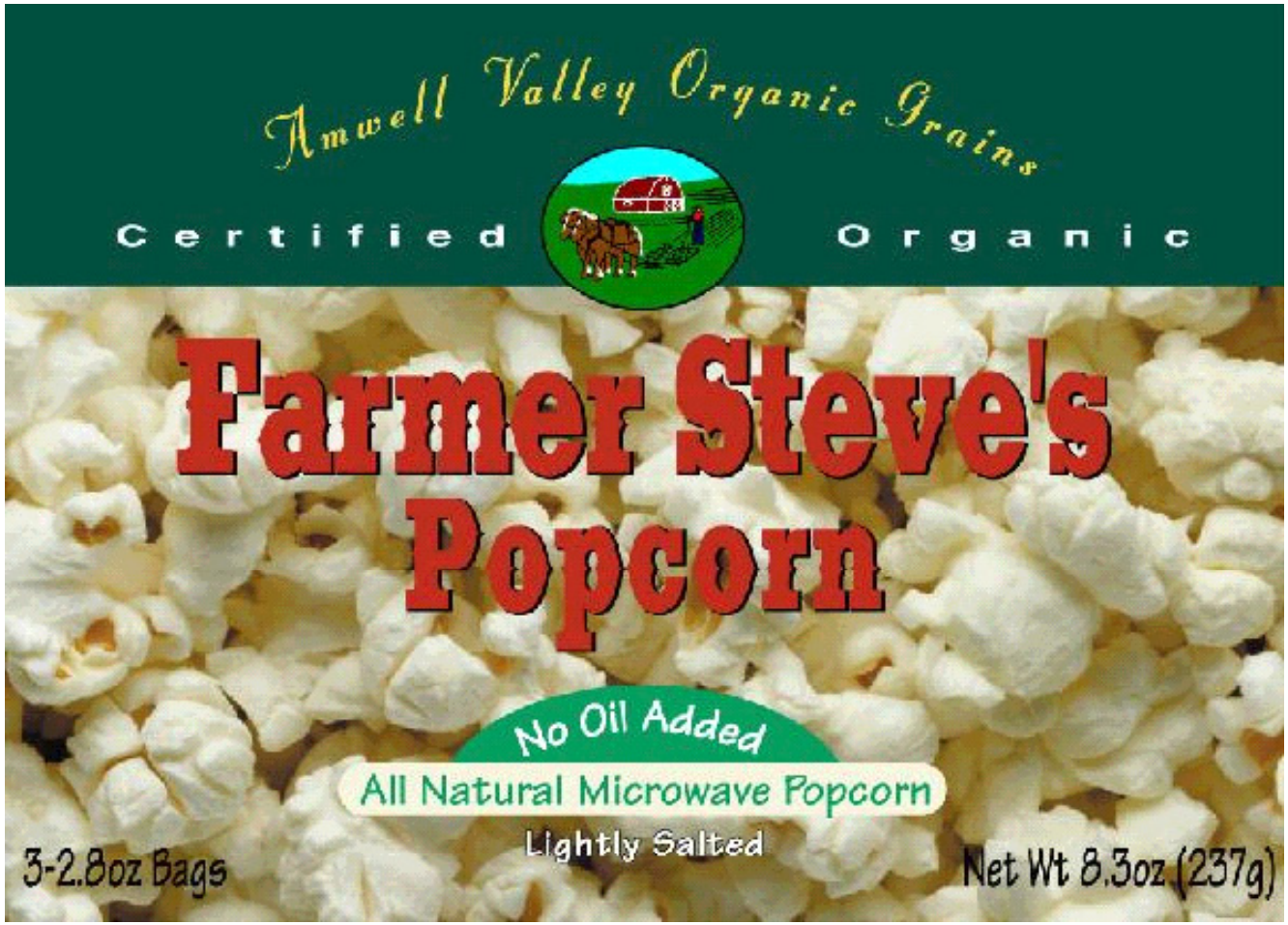
Summary

- Levels of arsenic in New Jersey residential wells range up to 200 ppb.
- As3 is a problem at 10-20% of the wells.
- The arsenic in well water appears to be attributed to natural geologic sources in the Piedmont Physiographic Province.
- More than a dozen arsenic water treatment technologies have been tested.
- Based on our studies to date, granular ferric adsorption is currently the preferred treatment choice in New Jersey.
- An arsenic human exposure study is ongoing and may indicate the need for whole-house treatment above a certain level of arsenic in well water.

Acknowledgements

Any Questions?

Partial Funding to Support This Investigation was Provided by Farmer Steve



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