Fate of Groundwater Radionuclides Moving Through Small Community Systems

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Environmental Research Group

Radionuclides in Drinking Water

Workshop on Implementing the Radionuclides Rule

April 3rd 2007

Chelmsford, MA

Acknowledgements

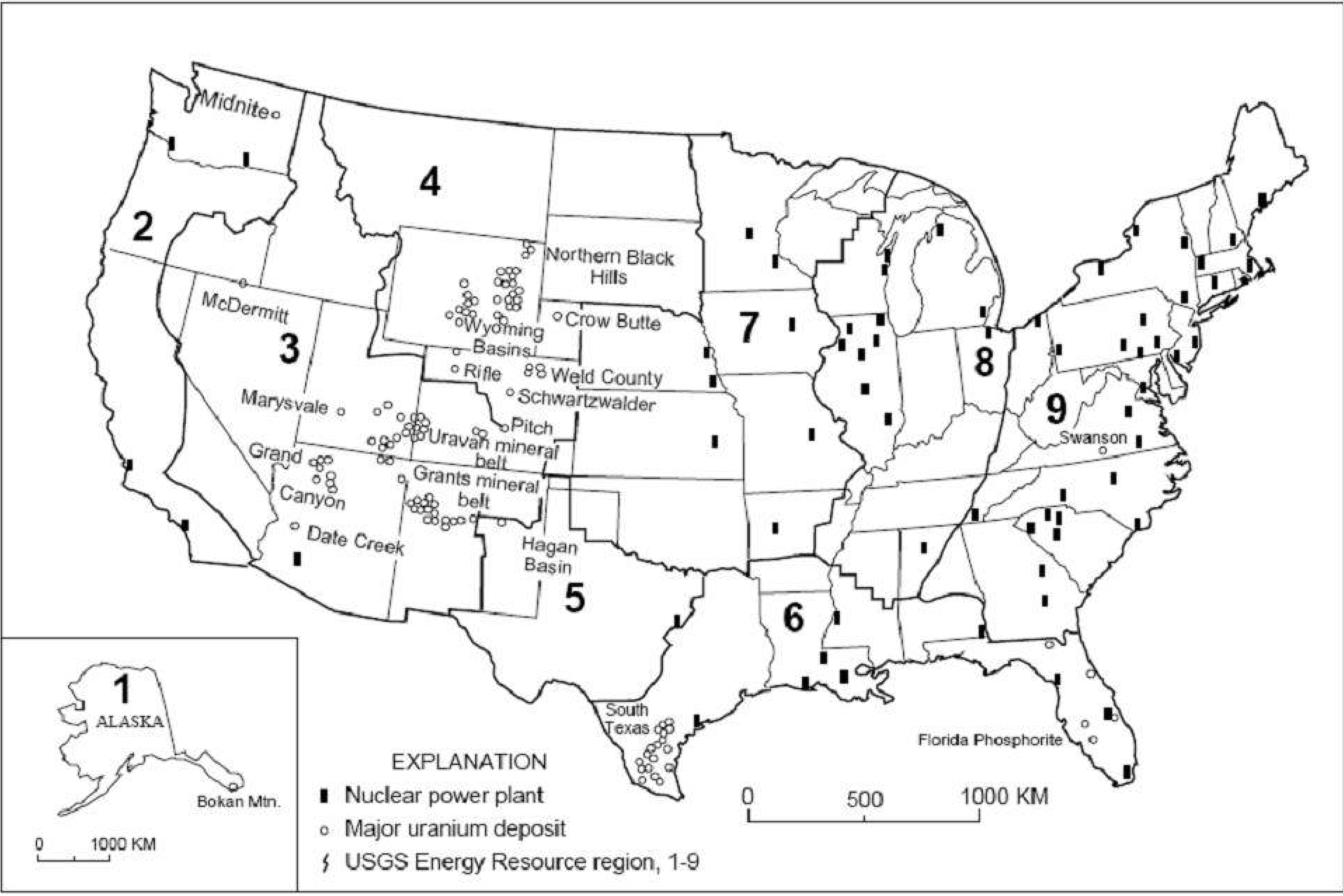
US EPA
NE WTTAC
VT DEC
NH DES
NEIWPCC

and Collaborating Sites

Presentation Available at:

http://www.unh.edu/erg/wttac/

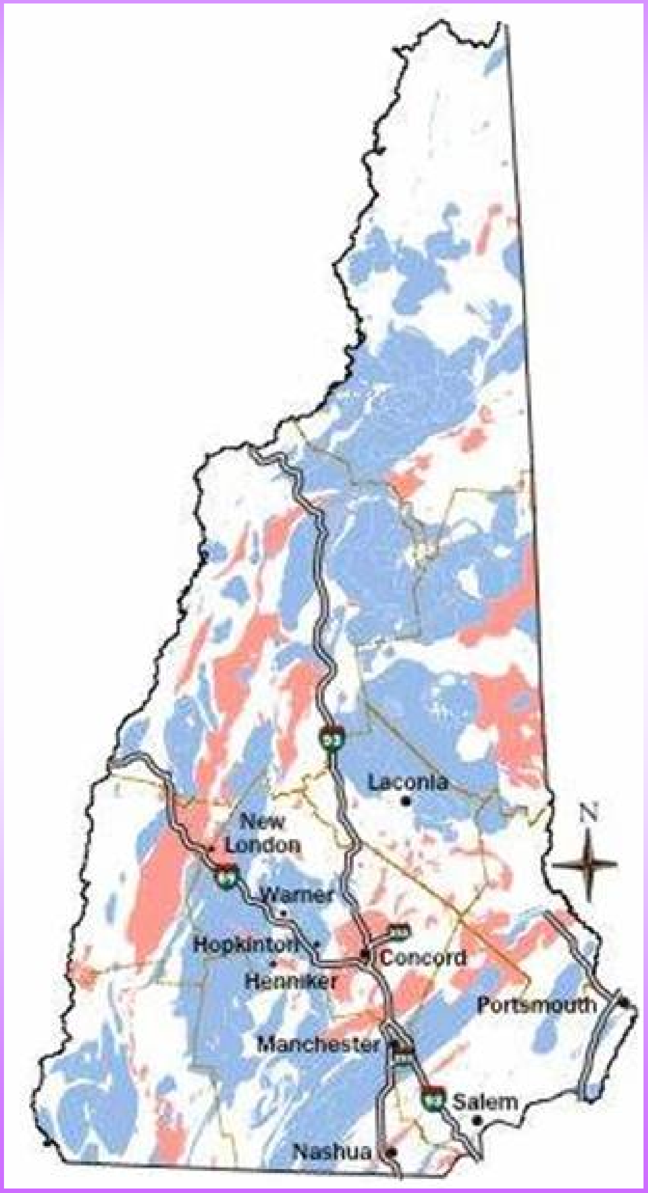
or search for NE WTTAC


Midnite
McDermitt
Northern Black Hills
Crow Butte
Wyoming Basins
Rifle
Weld County
Schwartzwalder
Marysvale
Pitch
Uravan mineral belt
Grand Canyon
Grants mineral belt
Date Creek
Hagan Basin
South Texas
Swanson
Florida Phosphorite
1
2
3
4
5
6
7
8
9
ALASKA
Bokan Mtn.
0 1000 KM
0 500 1000 KM
EXPLANATION
Nuclear power plant
Major uranium deposit
USGS Energy Resource region, 1-9

Radioactivity in Rock in New Hampshire

Igneous Rocks

Two-Mica Granite



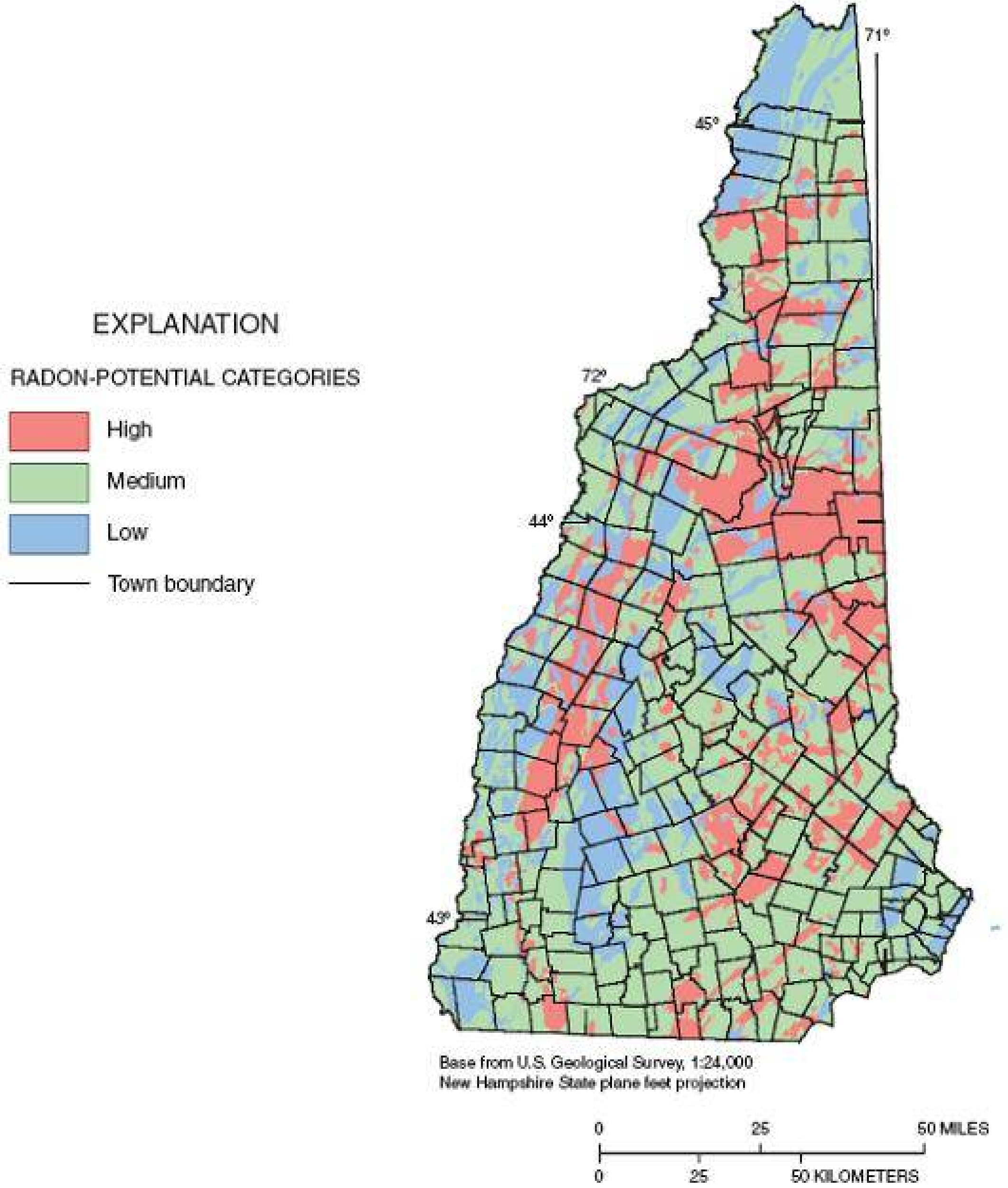
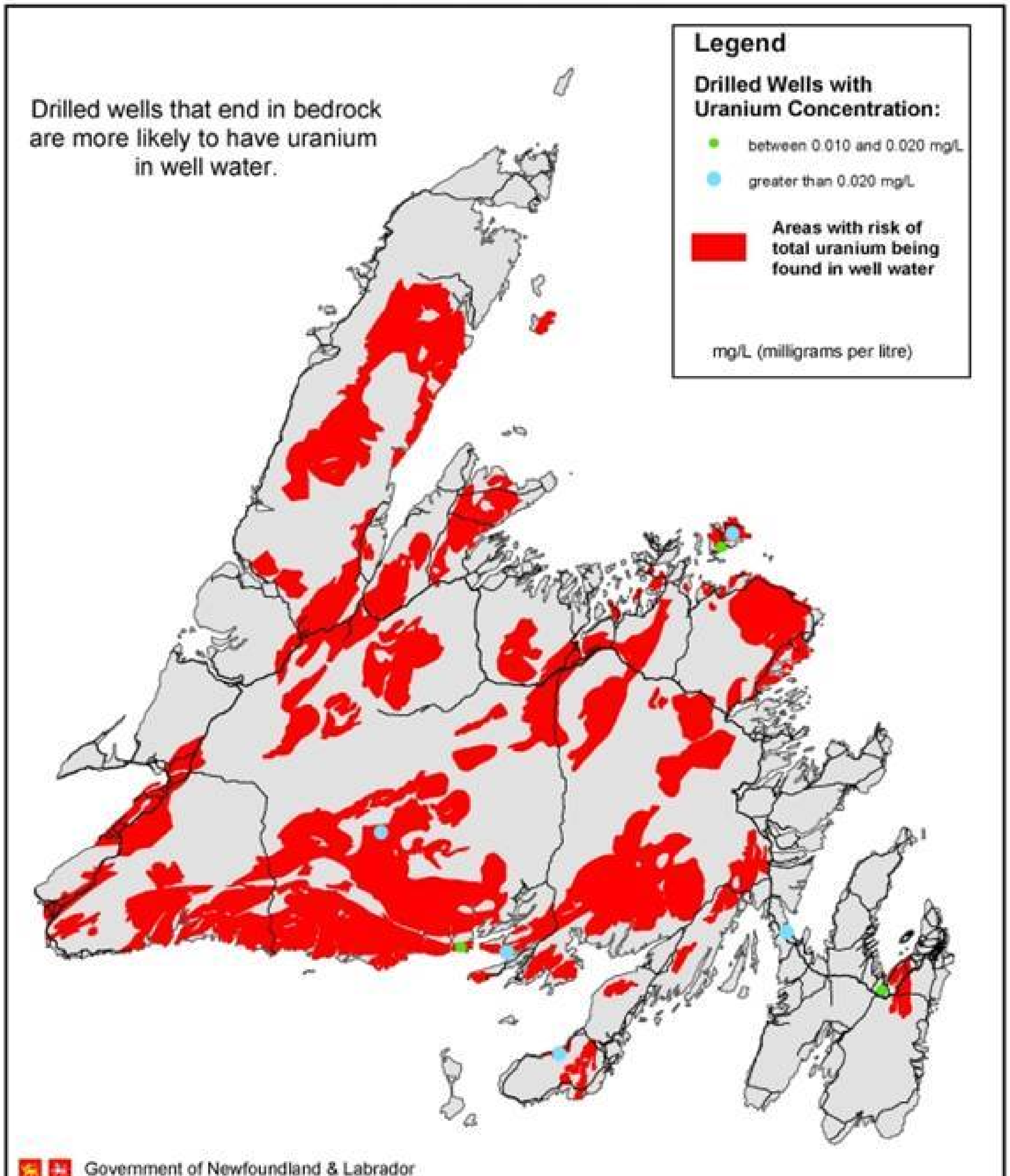
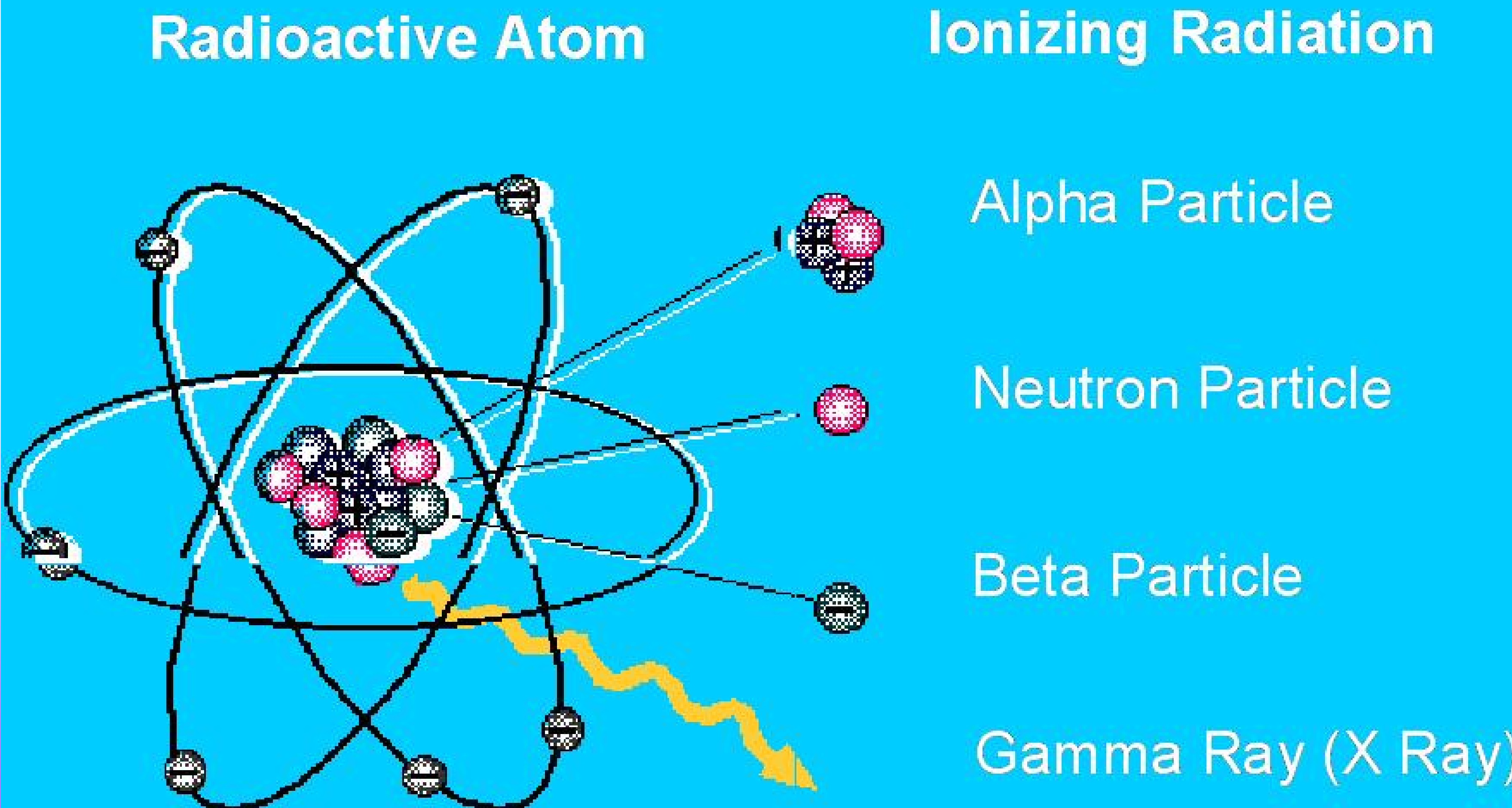


Figure 2. Areal distribution of radon-potential categories in New Hampshire used for statistical analyses. Mapped bedrock units (Lyons and others, 1997) were grouped for relative potential of producing radon gas.

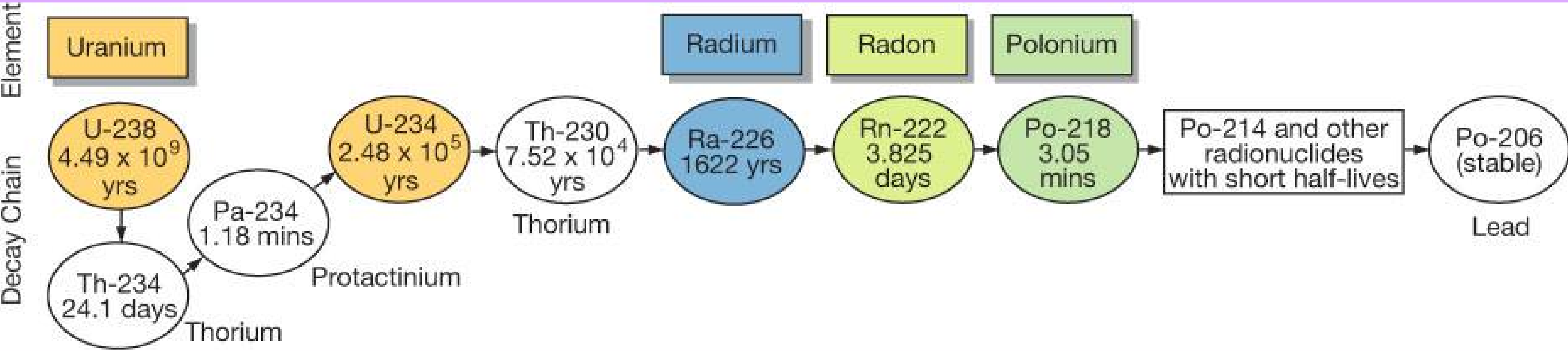
Areas of Potential Uranium Concentration in Well Water



Radiation



Radioactive Atom
Ionizing Radiation
Alpha Particle
Neutron Particle
Beta Particle
Gamma Ray (X Ray)



The Geology and Progeny of Uranium

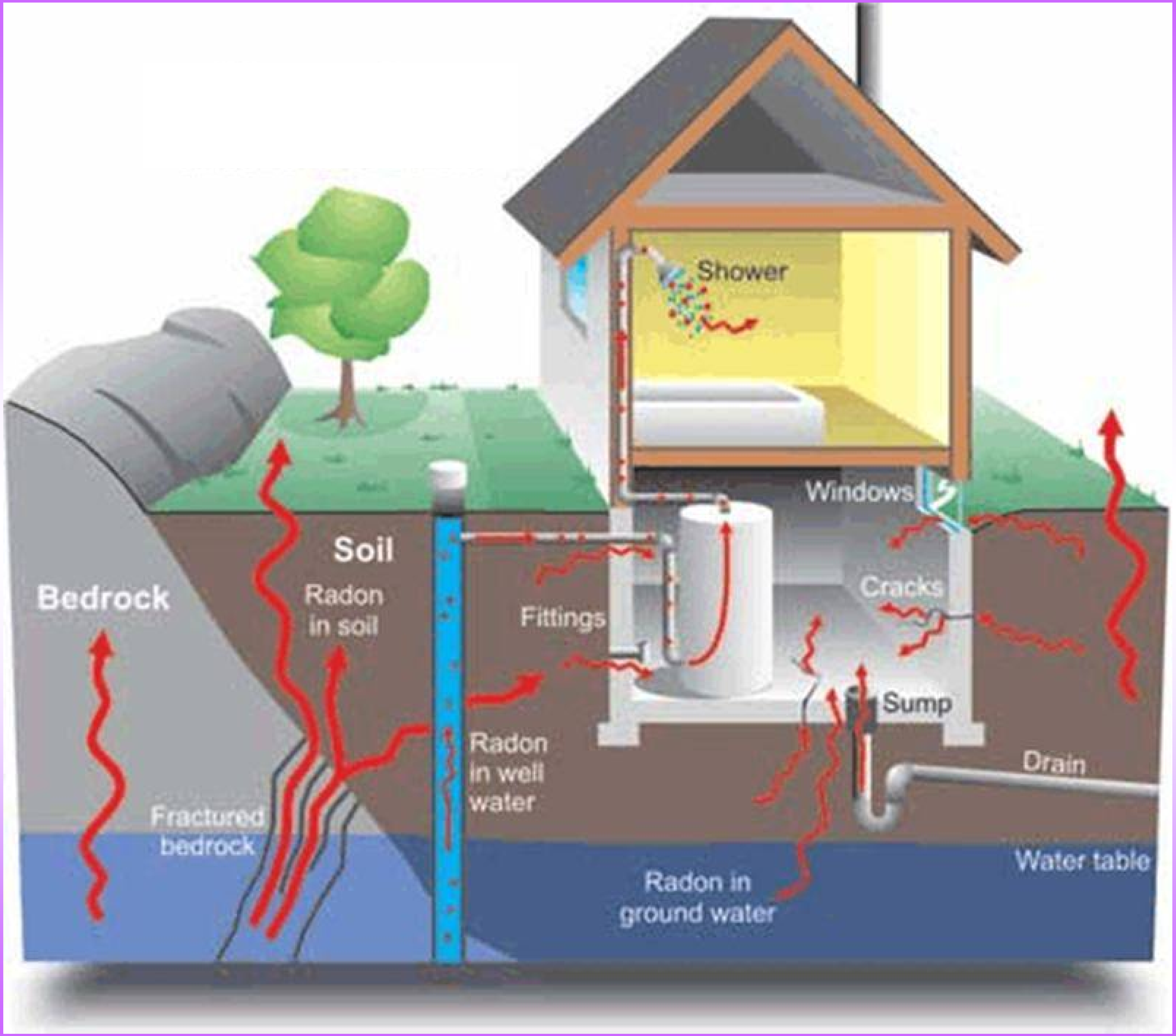
URANIUM 238 (U238) RADIOACTIVE DECAY

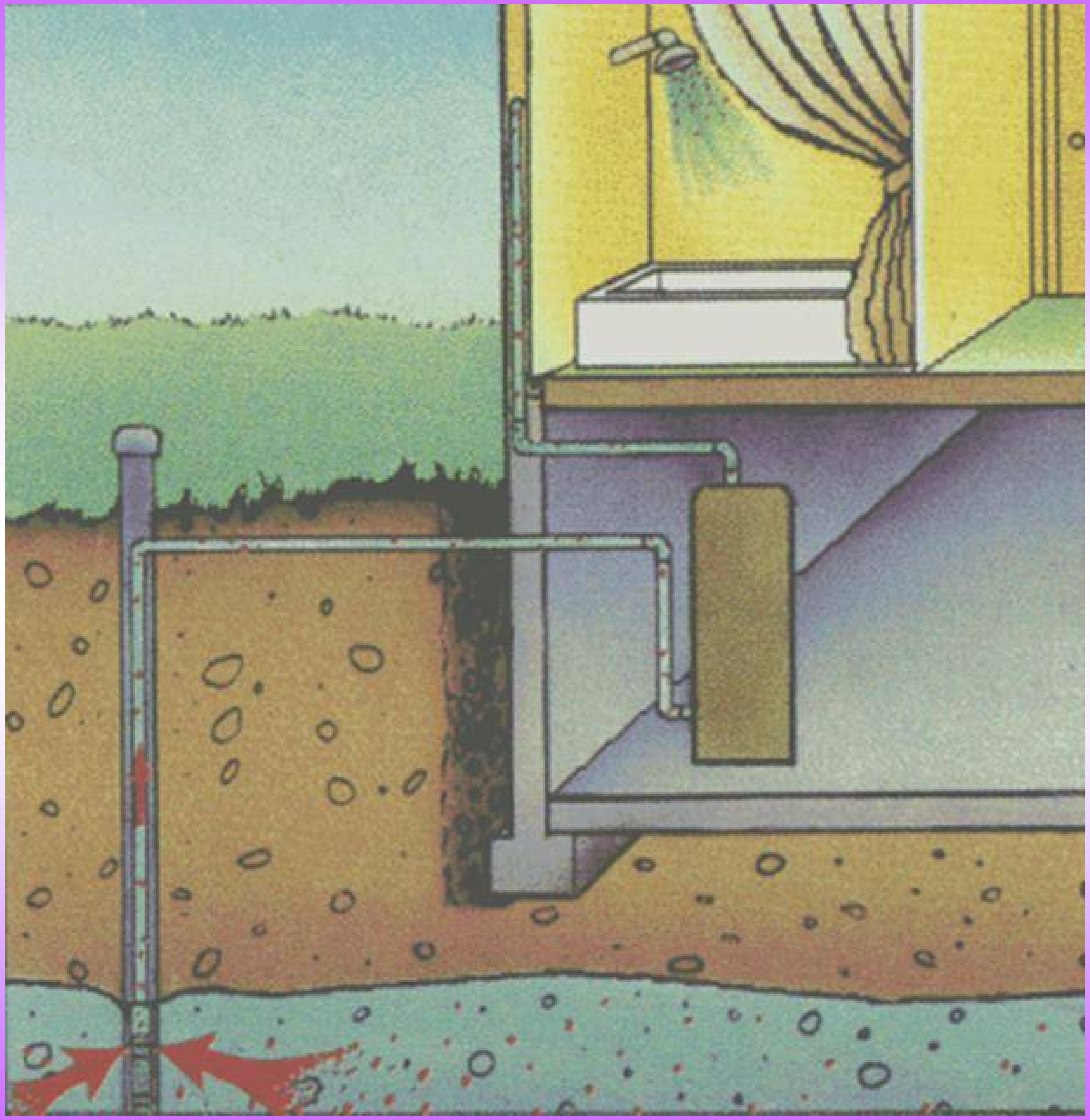
type of radiation	nuclide	half-life
	uranium-238	4.47 billion years
α		
	thorium-234	24.1 days
β		
	protactinium-234m	1.17 minutes
β		
	uranium-234	245000 years
α		
	thorium-230	8000 years
α		
	radium-226	1600 years
α		
	radon-222	3.823 days
α		
	polonium-218	3.05 minutes
α		
	lead-214	26.8 minutes
β		
	bismuth-214	19.7 minutes
β		
	polonium-214	0.000164 seconds
α		
	lead-210	22.3 years
β		
	bismuth-210	5.01 days
β		
	polonium-210	138.4 days
α		
	lead-206	stable

GROUND WATER CONTAMINATION IN THE UNITED STATES

Pollutants	Found in No. of States
Nitrates	49
Volatile organic substances	48
Petroleum products	46
Metals	45
Pesticides	43
Brine/salinity	37
Synthetic organic substances	36
Arsenic	28
Other substances	26
Other agricultural chemicals	23
Radioactive material	23
Fluoride	20
Other inorganic substances	15

UN FAO, Control of Water Pollution from Agriculture",
www.fao.org/docrep/W2598E/w2598e00.htm (US EPA, 1994)


Shower
Windows
Soil
Bedrock
Radon
in soil
Fittings
Cracks
Sump
Radon
in well
water
Drain
Fractured
bedrock
Water table
Radon in
ground water



Technical Advisory Committee (TAC)

- NEIWPCC
- NH DES
- VT DEC
- CT DEP
- ME DEP
- NE WTTAC

TAC Objectives

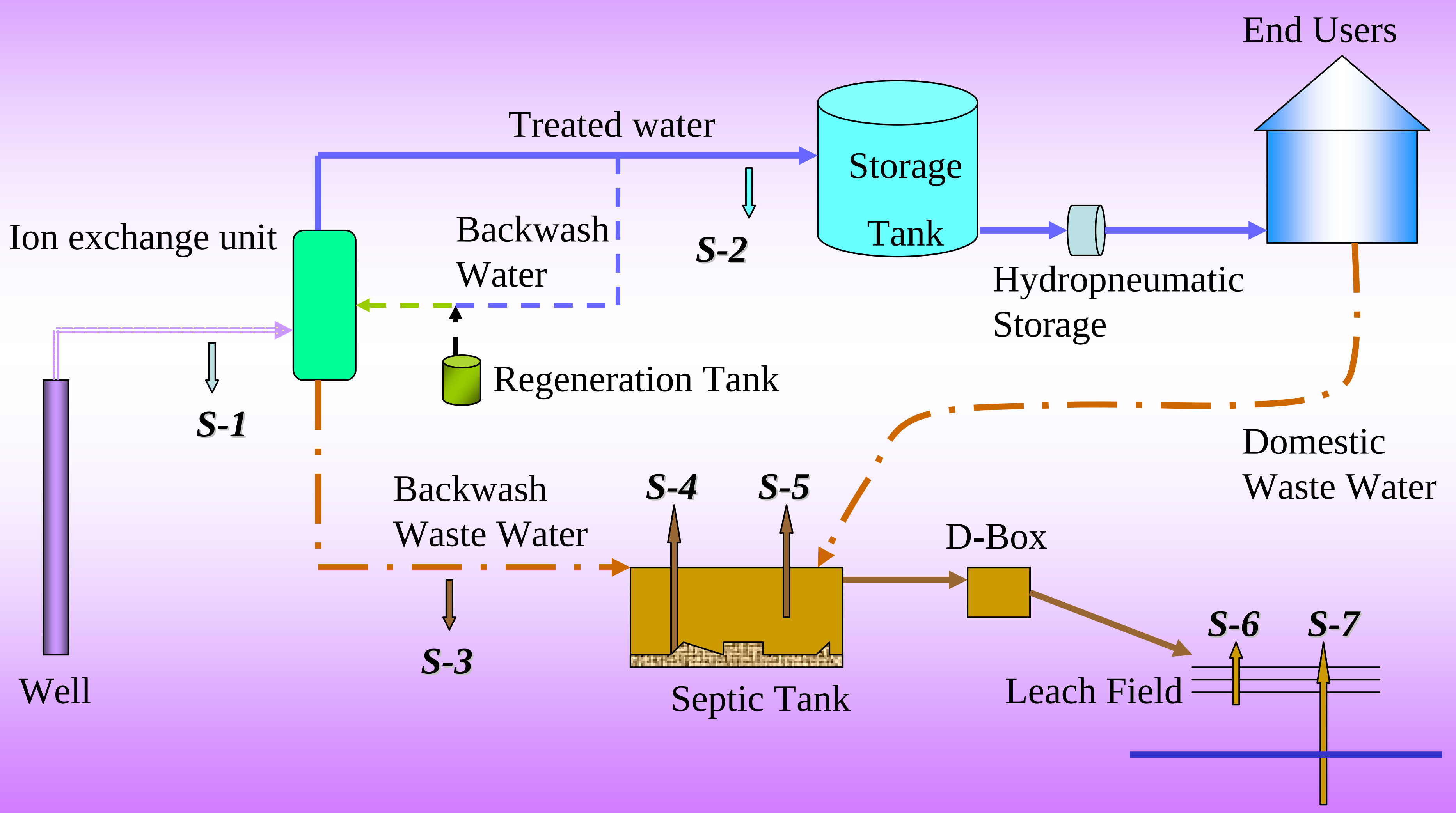
- Define the problem
- Number of systems currently affected
- Site specific characteristics
- Number of systems to be affected following implementation of the Radionuclides Rule
- Review QAPP

Site	RI - South Kingstown	CT - Morris	CT - Brookfield	VT - Colchester
Community or Private	COM	COM	COM	Private Home
System Population	175	40	132	1
Description	nursing home	elderly housing		adult

Site	NH - Fitzwilliams	NH - Canaan	NH - Pelham	NH - Pelham	NH - Pelham
Community or Private	COM	NTNC	NTNC	Private Home	COM
System Population	45	530	100 employees	3	24
Description	18 units	high school	shopping mall	2 adults/1 infant	22 elderly housing

Radionuclide Fate and Transport Study

Generic Monitoring Locations



Liquid Samples

1. Bedrock Groundwater
2. Treatment Unit Backwash
3. Finished Water
4. Household Wastewater Stream
5. Septic Tank Sludge/Scum/Liquid – Time since pumping/backwash
6. Septic Tank Effluent - Time since pumping/backwash
7. Vadose Zone Soil Moisture
8. Shallow Groundwater – Up- and Downgradient

Solid Samples

1. Bedrock
2. Native Soil
3. Leach Field Soil
4. Soil – In plume

Target Analytes - Liquids

Analyte
Gross Alpha
Gross Alpha less Radon and Uranium
Gross Beta
Radium - 226
Radium - 228
Uranium – assuming the activity of natural Uranium is 6.77 x 10^{-7} Ci/gm
Uranium as U^{308}

Target Analytes - Solids

Analyte
Gross Alpha
Gross Beta
Radium - 226
Radium - 228
Uranium as U^{308}

Analytical Methods - Liquids

Analyte	Method	Detection Limit
Gross Alpha	EPA 900.0	10 - 2.0
Gross Alpha less Radon and Uranium	EPA 900.0	10 - 2.0
Gross Beta	EPA 900.0	10 – 1.9
Radium - 226	SM 7500 – Ra B	0.1
Radium - 228	EPA Ra - 05	1.0 - 0.5
Uranium – assuming the activity of natural Uranium is 6.77 x 10^{-7} Ci/gm	ASTM D2907-97	0.5
Uranium as U^{308}	ASTM D2907-97	0.7

Analytical Methods - Solids

Analyte	Method	Detection Limit
Gross Alpha	EPA 900.0 (modified)	7.7 – 0.3
Gross Beta	EPA 900.0 (modified)	4.3 – 0.6
Radium - 226	SM 705 (modified)	0.7 – 0.01
Radium - 228	EPA Ra-05 (modified)	1.3 – 0.8
Uranium as U^{308}	ASTM D2907-97 (modified)	10 - 4

POU/POE systems shown to remove uranium include reverse osmosis, distillation, special adsorbent media (such as titanium dioxide) and anion exchange.

Residuals

The more effective the coagulant or adsorbent, the higher is the radioactivity in the residuals. (Clifford, 2001)

Ion Exchange Softening for Radium Removal	600 pCi/L spent brine 20 pCi/g dry resin
Coag-Filt w/ MnO_2(s) for Radium Removal	21,000 pCi/g dry MnO_2(s)
Fe(III) Coag-Filtration for Uranium Removal	800 pCi/g $Fe(OH)_3$(s)
Anion Exchange for Uranium Removal	80,000 pCi/L spent brine (30,000 BV run length)

Selected Sites

- Morris, CT – Elderly Housing
- Middleton Springs, VT – Elementary School
- Bedford, NH – Residential
- Pelham, NH – Apartment Complex

Site Bedrock

Site	Surficial Geology	Well Depth	Geology at Depth
NH - Pelham Old Lawrence Road	Till (Pleistocene)	Well #2 575 ft Well #3 625 ft	Ayer Granite
NH - Bedford English Woods	Till (Pleistocene)	Well #1 473 ft	Rangeley Formation (Silurian)
NH - Bedford English Woods	Till (Pleistocene)	Well #4 65 ft	Light gray biotite-muscovite Schist
CT - Morris			Ratlum Mountain Schist
CT - Morris			Schist Granofels
VT - Middletown Springs	Till		Biotite/Garnet Types

	Gross Alpha (pCi/L)	Ra 226 + Ra 228 (pCi/L)
Morris, CT	4.5	4.2
Middleton Springs, VT - Short	25	16.6
Middleton Springs, VT - Long	240	68
Pelham, NH	88	14
Bedford, NH	12	10.5
Criteria	15	5

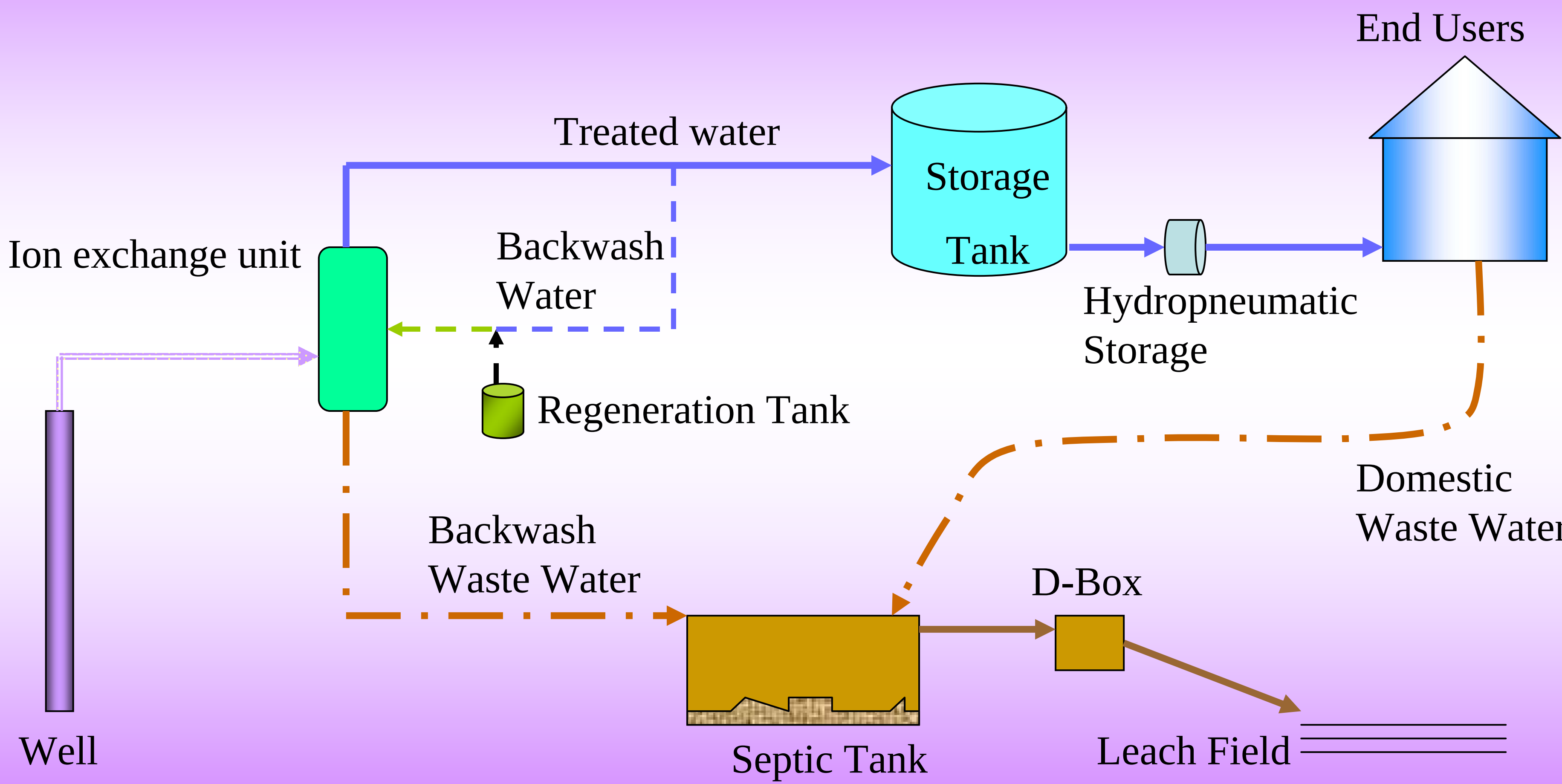
Radionuclides Rule

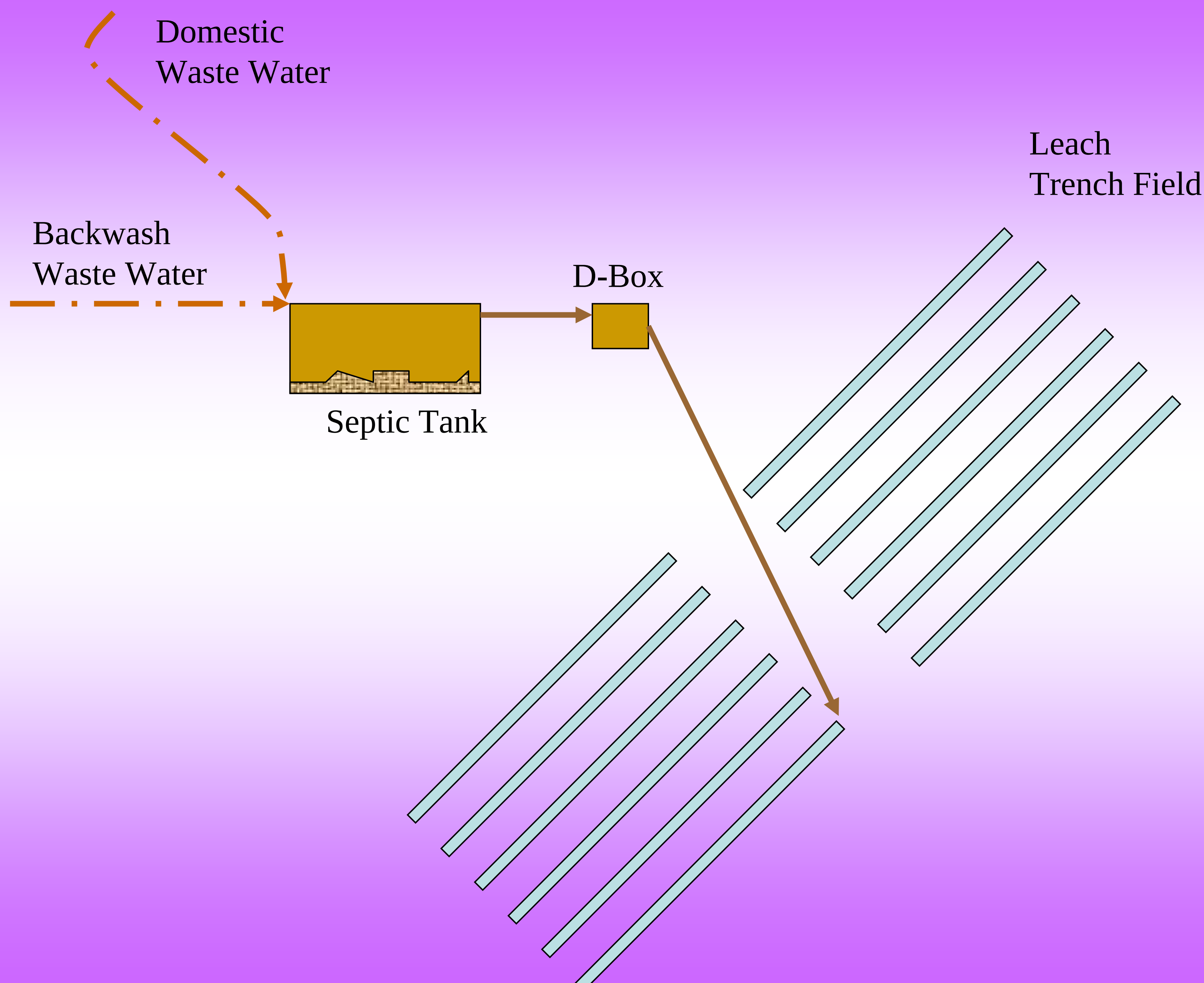
Combined radium 226 and 228	5 pCi/L
Gross alpha particle activity	15 pCi/L
Uranium	30 ug/L
Beta particle activity	4 mrem/yr

Morris, CT Site

Morris, CT System
Community Building (~100 gpd)

- Bedrock well
- Submersible pump
- Ion exchange
- ~2 - 5,000 gal atmospheric storage tanks
- 200 gal septic tank
- Linear leach trench

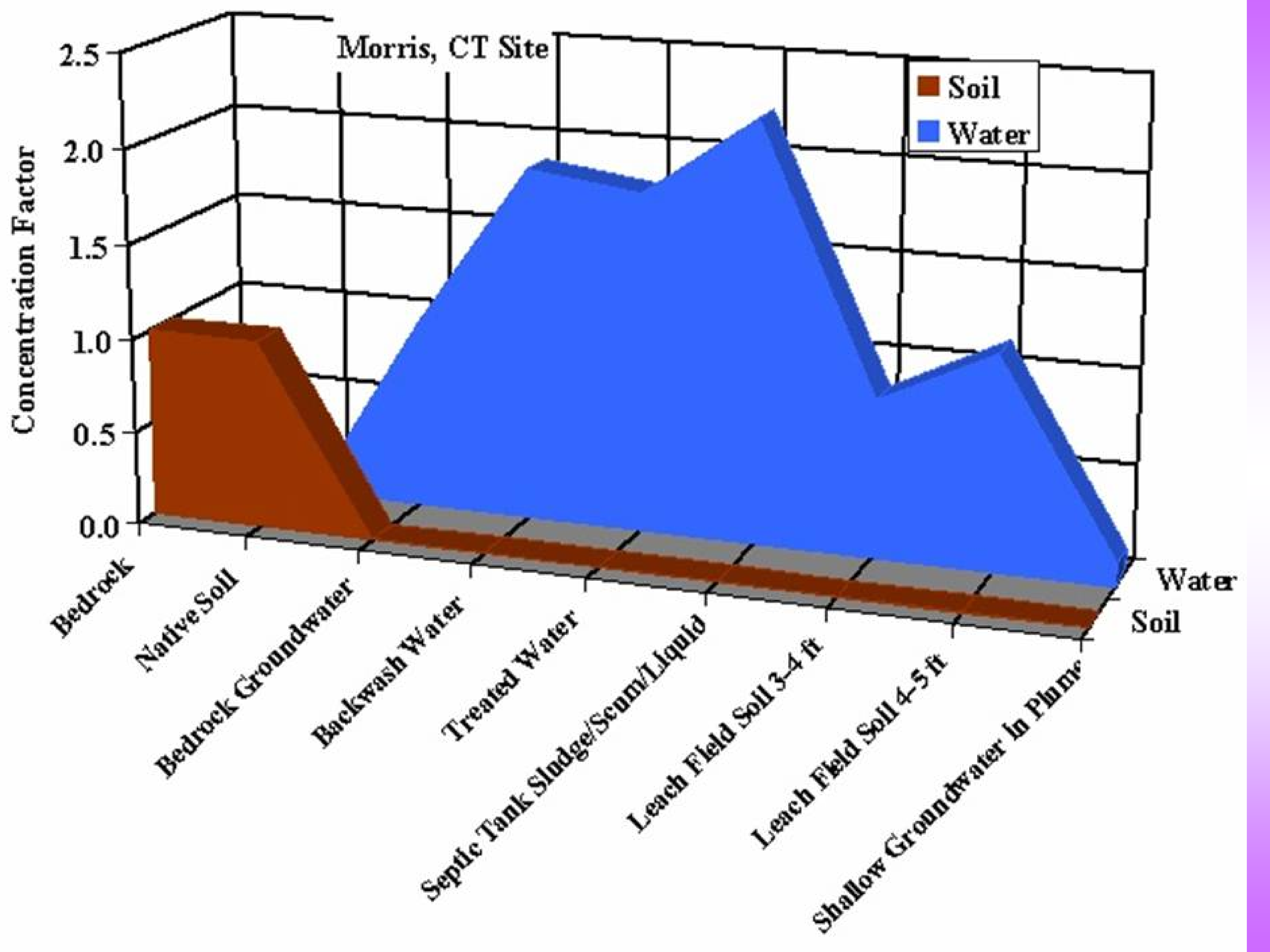

End Users
Treated water
Storage
Tank
Ion exchange unit
Backwash
Water
Hydropneumatic
Storage
Regeneration Tank
Domestic
Waste Water
Backwash
Waste Water
D-Box
Well
Septic Tank
Leach Field



Domestic
Waste Water
Leach
Trench Field
Backwash
Waste Water
D-Box
Septic Tank

Morris, CT Groundwater

Gross Alpha (pCi/l)	Gross Alpha less Rn & U (pCi/l)	Gross Beta (pCi/l)	Radium 226 (pCi/l)	Radium 228 (pCi/l)	Uranium* (pCi/l)	Uranium (ug/l)
4.5	3.5	4.0	0.7	0.0	1.0	1.4

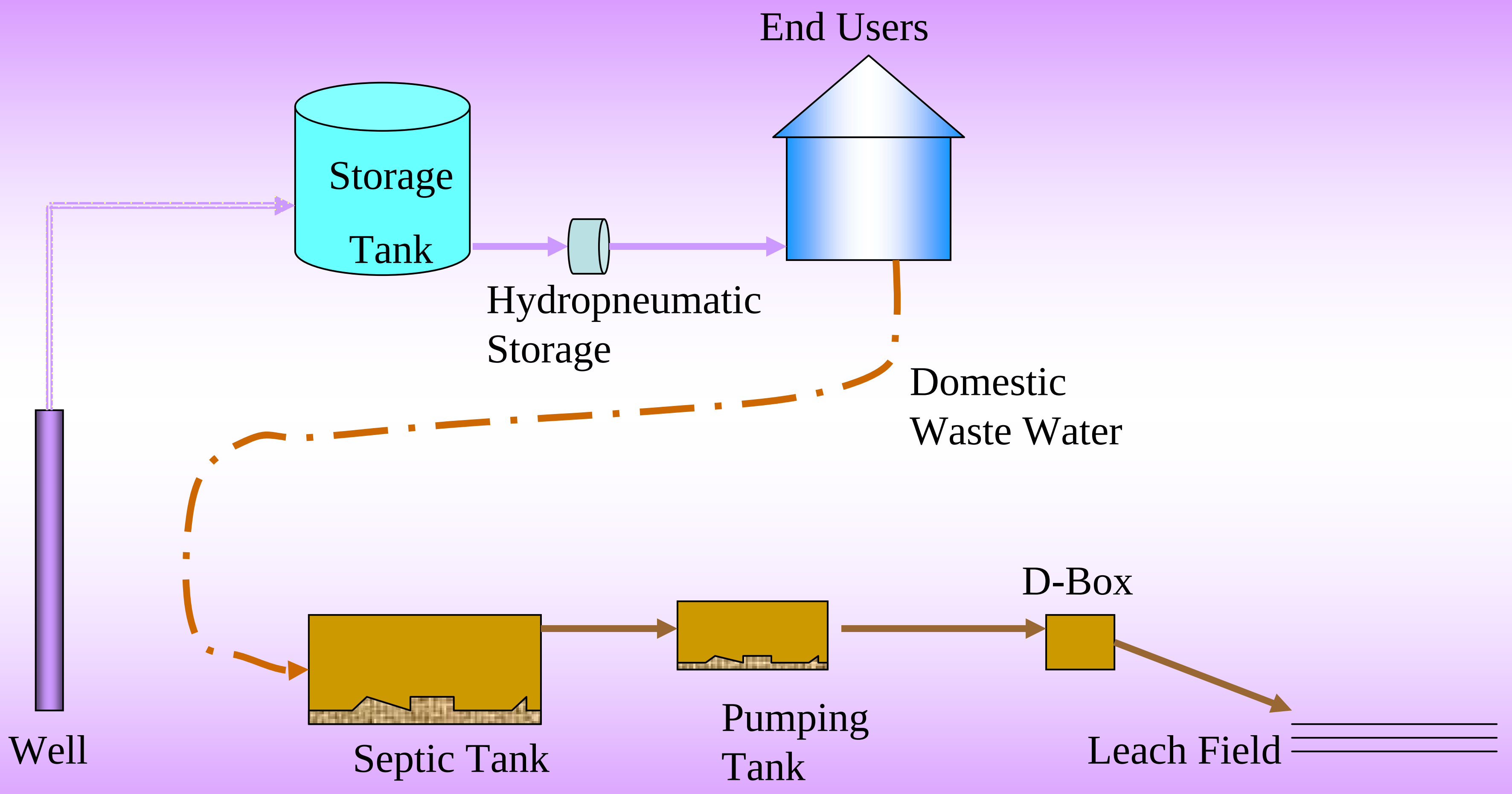


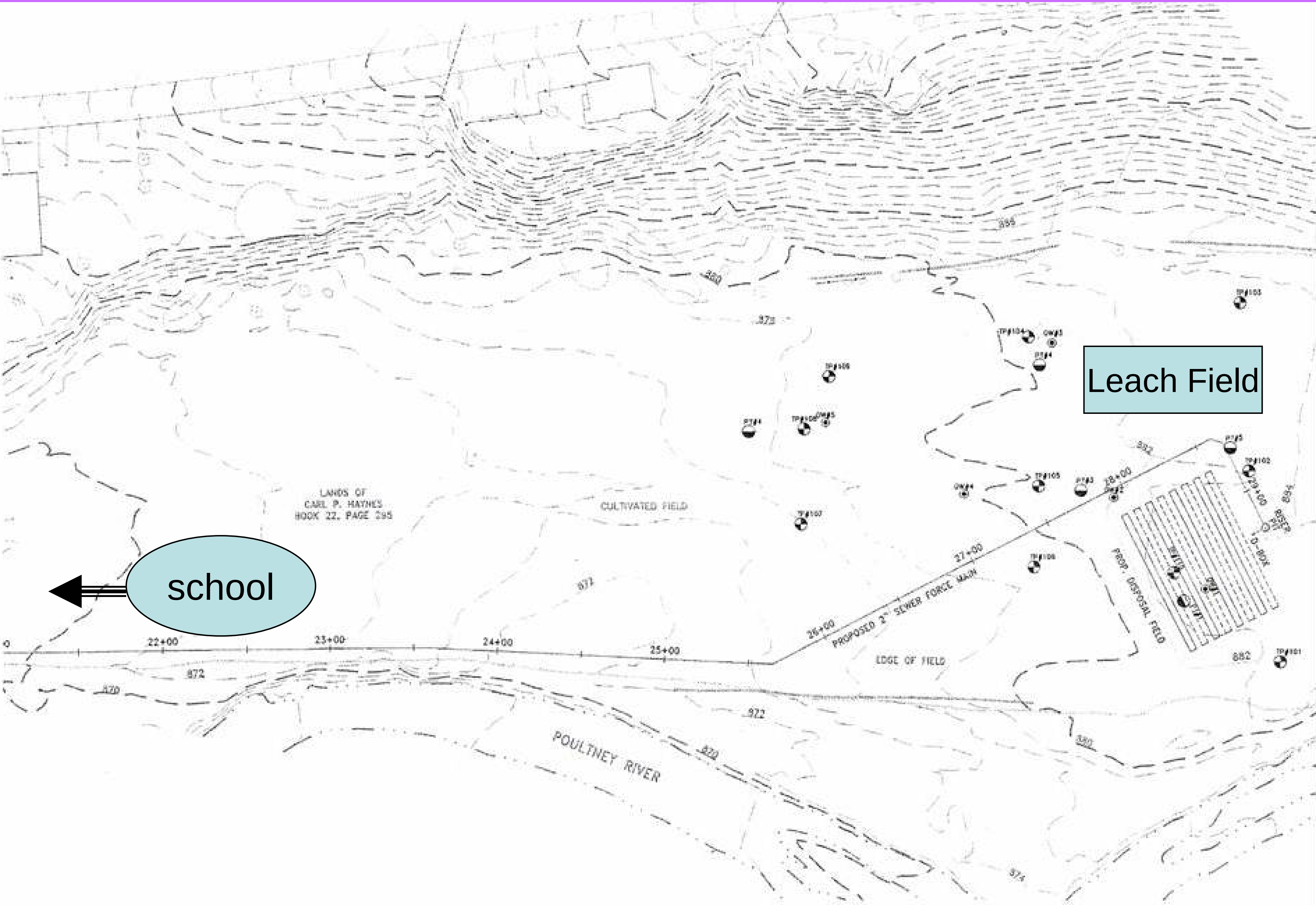
Morris, CT Site
Soil
Water
Concentration Factor
2.5
2.0
1.5
1.0
0.5
0.0
Bedrock
Native Soil
Bedrock Groundwater
Backwash Water
Treated Water
Septic Tank Sludge/Scum/Liquid
Leach Field Soil 3-4 ft
Leach Field Soil 4-5 ft
Shallow Groundwater In Plume
Water
Soil

Middleton Springs, VT Site

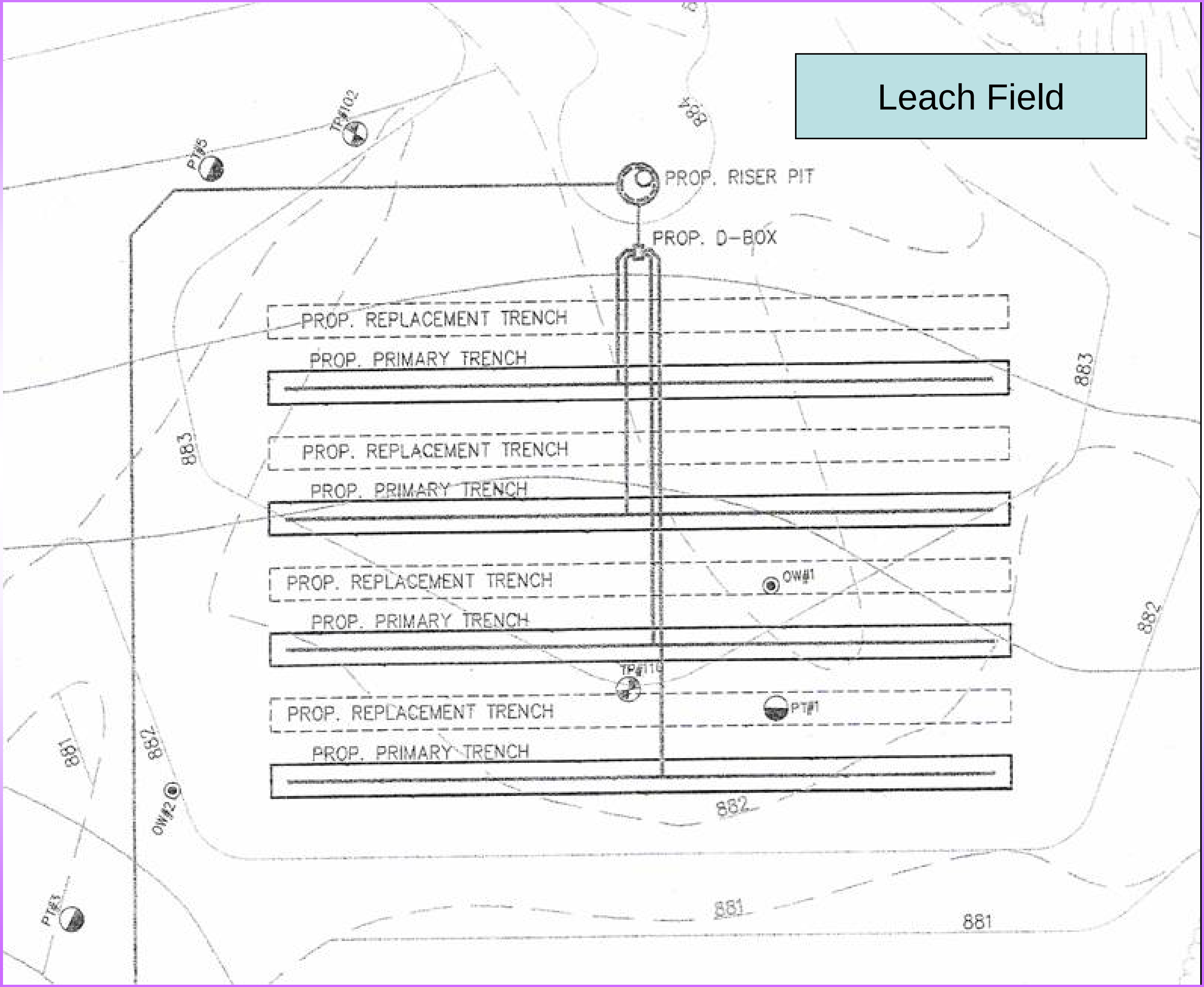
Middleton Springs, VT System Elementary School (68 students, 9 faculty, 9 staff, ~1,000 gpd)

- Bedrock well
- Submersible pump
- 6,000 gal atmospheric storage
- 4 – 100 gal hydropneumatic storage tanks
- 10,000 gal septic tank
- 4,000 pumping tank
- Leach field trench system


End Users
Storage
Tank
Hydropneumatic
Storage
Domestic
Waste Water
D-Box
Well
Septic Tank
Pumping
Tank
Leach Field

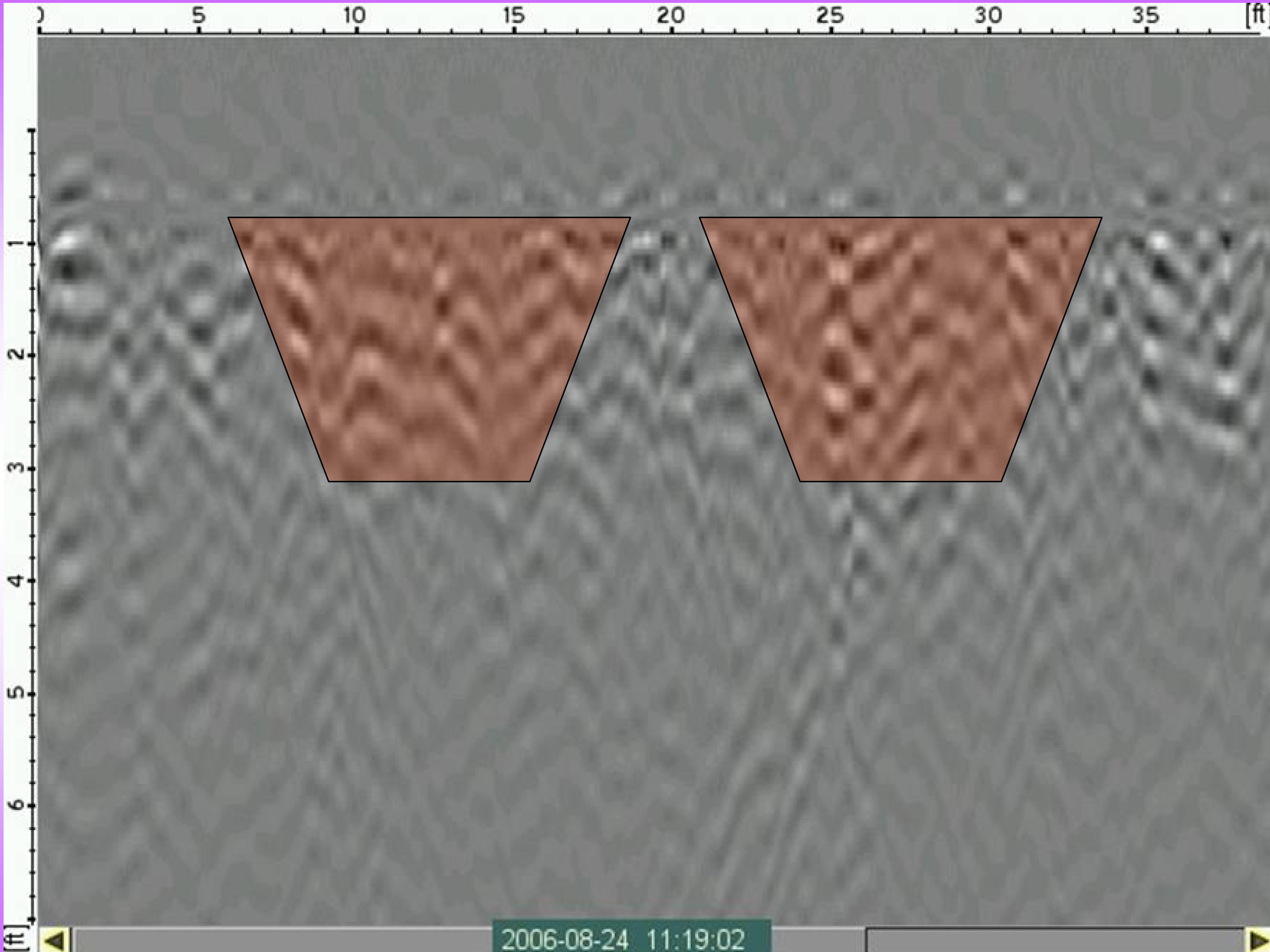

Leach Field
school
LANDS OF
CARL P. HAYNES
BOOK 22, PAGE 295
CULTIVATED FIELD
PROPOSED 2" SEWER FORCE MAIN
PROP. DISPOSAL FIELD
EDGE OF FIELD
POULTNEY RIVER
D-BOX
22+00
23+00
24+00
25+00
26+00
27+00
28+00
29+00

Leach Field



PROP. RISER PIT
PROP. D-BOX
PROP. REPLACEMENT TRENCH
PROP. PRIMARY TRENCH
PROP. REPLACEMENT TRENCH
PROP. PRIMARY TRENCH
PROP. REPLACEMENT TRENCH
PROP. PRIMARY TRENCH
PROP. REPLACEMENT TRENCH
PROP. PRIMARY TRENCH
884
883
883
882
882
882
881
881
881
PT#5
TP#102
OW#1
OW#2
PT#1
PT#3
TP#110


MALÅ
RAMAC

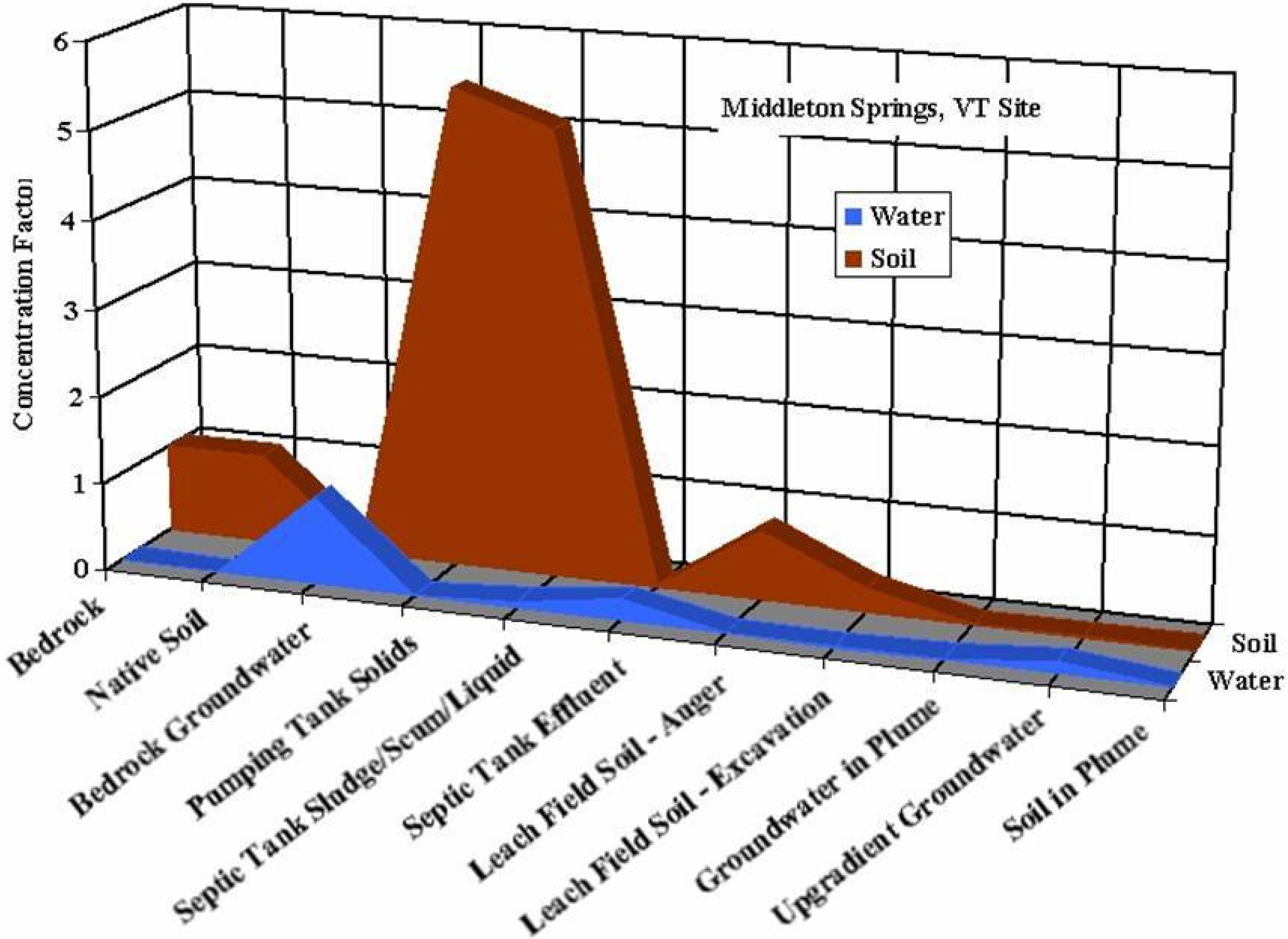

5 10 15 20 25 30 35 [ft]
1 2 3 4 5 6 [ft]
2006-08-24 11:19:02


70D


6X6 POLARIS

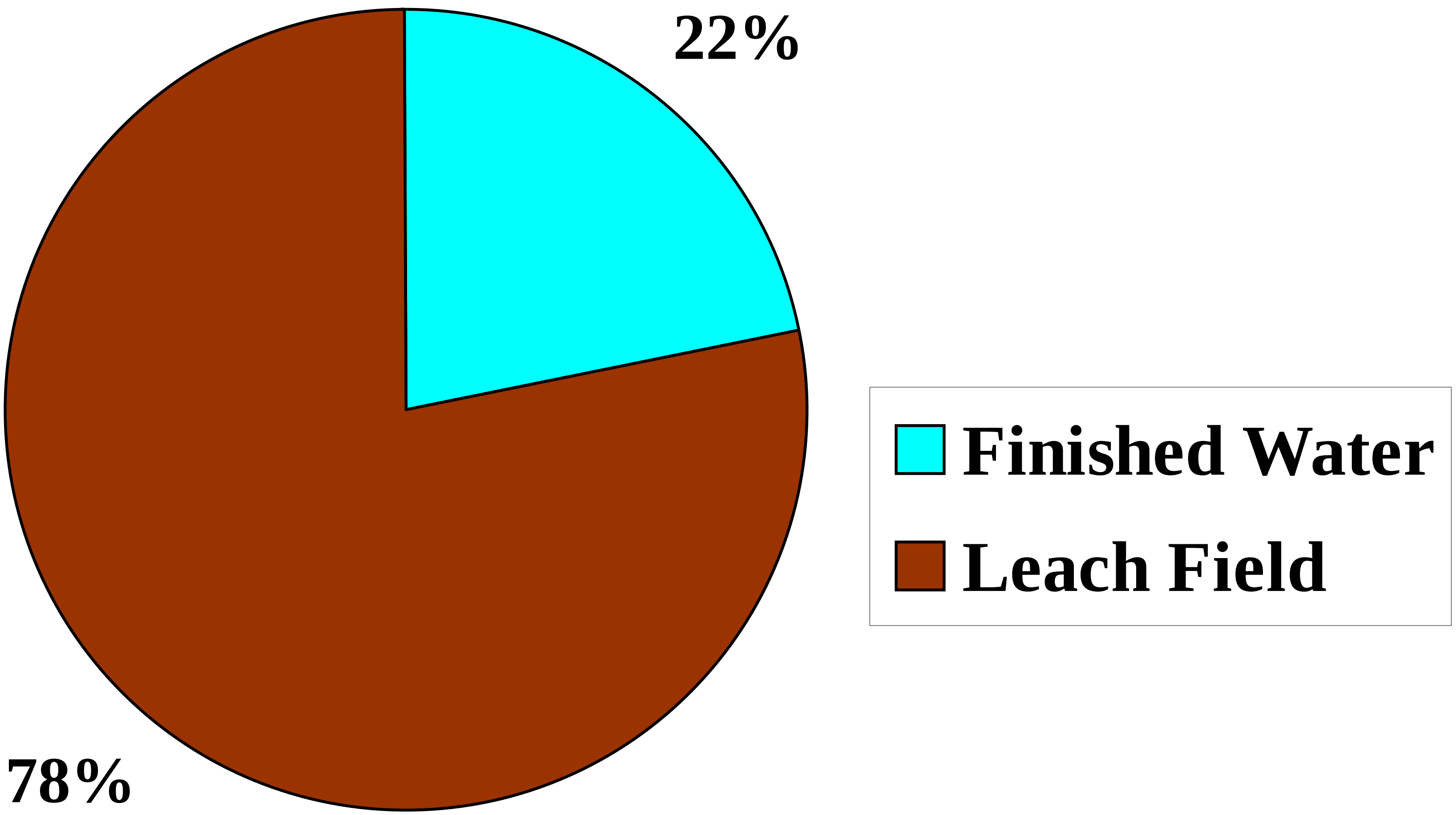
Middleton Springs, VT Groundwater

Gross Alpha (pCi/l)	Gross Alpha less Rn & U (pCi/l)	Gross Beta (pCi/l)	Radium 226 (pCi/l)	Radium 228 (pCi/l)	Uranium* (pCi/l)	Uranium (ug/l)
39	25	7.1	2.2	0.7	14	20
11	5	49	0.9	0.0	5.5	8.1
240	50	43	18	0.6	190	280



Middleton Springs, VT Site
Water
Soil
Concentration Factor
0
1
2
3
4
5
6
Bedrock
Native Soil
Bedrock Groundwater
Pumping Tank Solids
Septic Tank Sludge/Scum/Liquid
Septic Tank Effluent
Leach Field Soil - Auger
Leach Field Soil - Excavation
Groundwater in Plume
Upgradient Groundwater
Soil in Plume
Soil
Water

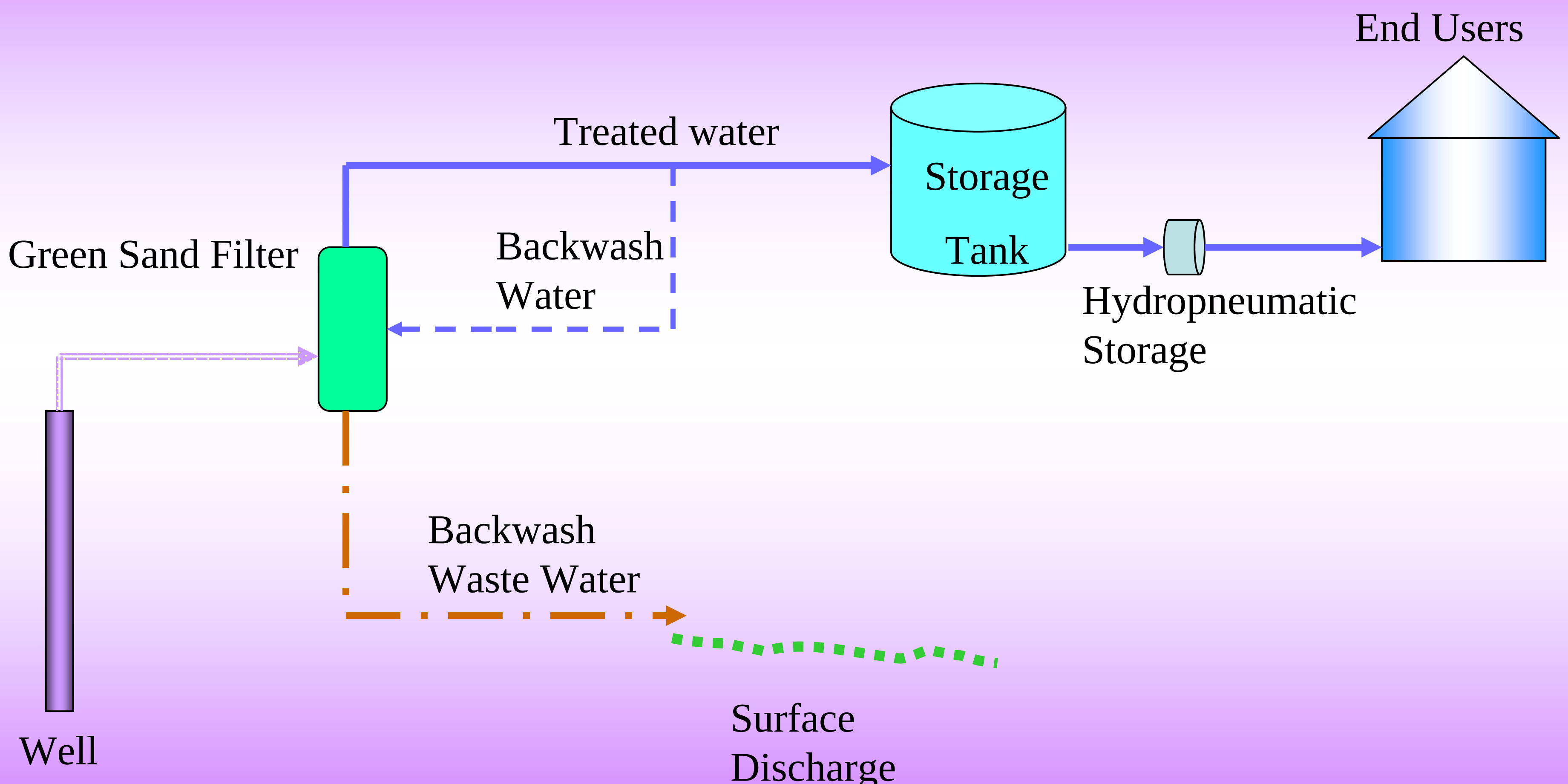
Middleton Springs, VT Radionuclides Fate



Bedford, NH Site

Bedford, NH System
Residential Community (pop. 50, 19 service connections)

- 2 Bedrock wells (473 ft and 65 ft)
- Submersible pumps
- Green sand filter (Manganese)
- Atmospheric storage
- Hydropneumatic storage
- Backwash directly to “pit”



End Users
Treated water
Storage
Tank
Green Sand Filter
Backwash
Water
Hydropneumatic
Storage
Backwash
Waste Water
Surface
Discharge
Well

Bedford, NH Bedrock

Sample Description	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Radium 226 (pCi/g)	Radium 228 (pCi/g)	Uranium as U238 (mg/kg)
Bedrock (Mt. Miner @ 250 ft)	12	28	1.0	0.0	<4
Bedrock (Mt. Miner @ 400 ft)	16	25	1.4	0.8	<4
Native Soil – Aug 2005	14	22	1.8	0.1	<4
Native Soil – Jul 2006 – sample 1	5.3	16	1.0	1.4	<4
Native Soil – Jul 2006 – sample 2	8.8	23	0.5	2.3	<4

Bedford, NH Groundwater

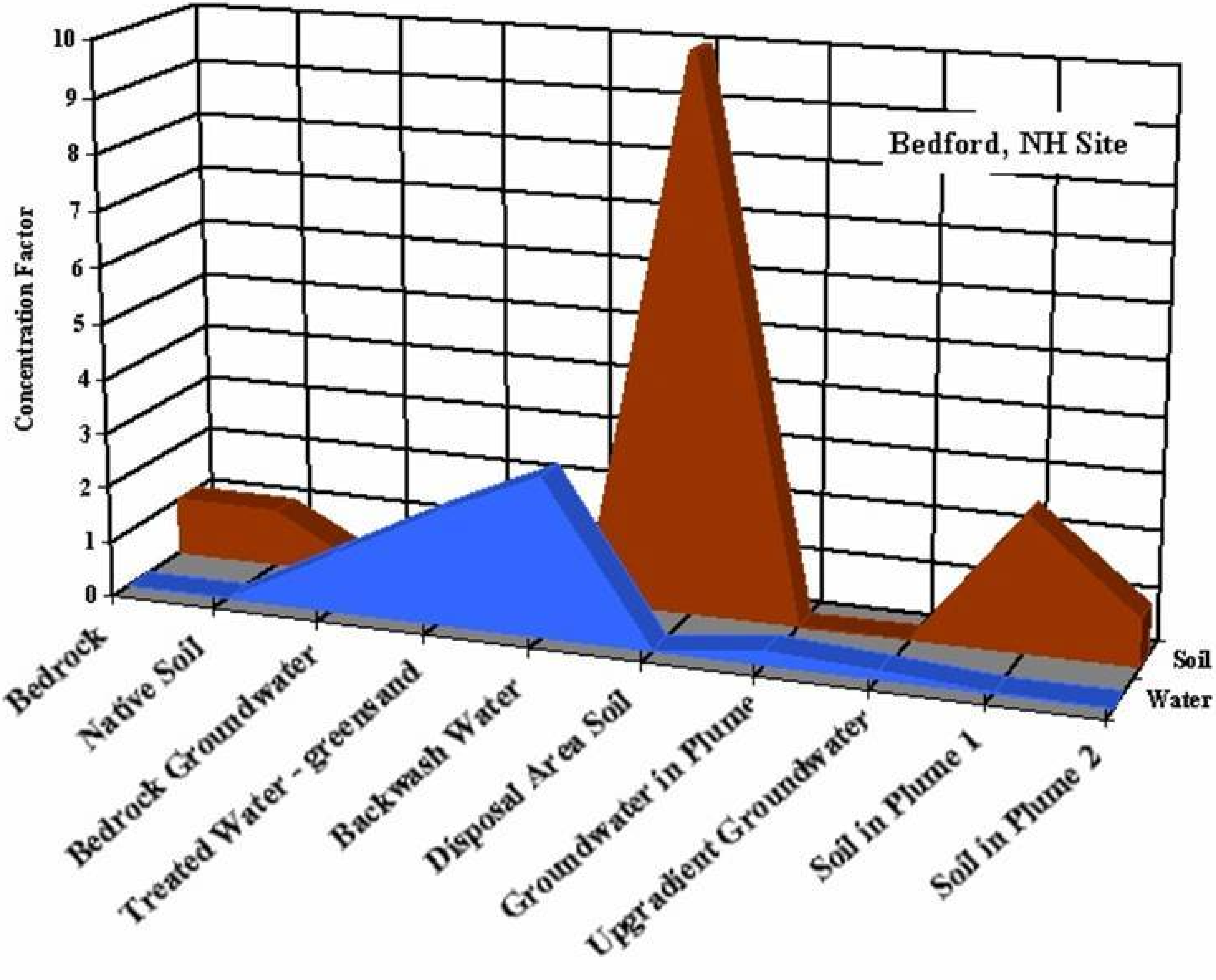
Gross Alpha (pCi/l)	Gross Alpha less Rn & U (pCi/l)	Gross Beta (pCi/l)	Radium 226 (pCi/l)	Radium 228 (pCi/l)	Uranium* (pCi/l)	Uranium (ug/l)
12	6.0	6.4	4.5	0.6	6.2	9.2
23	4.0	30	1.0	0.8	19	28

Well House and Treatment - Bedford, NH

Well House and Discharge Pit - Bedford, NH

Downgradient of Discharge Pit - Bedford, NH

Upgradient of Discharge Pit - Bedford, NH

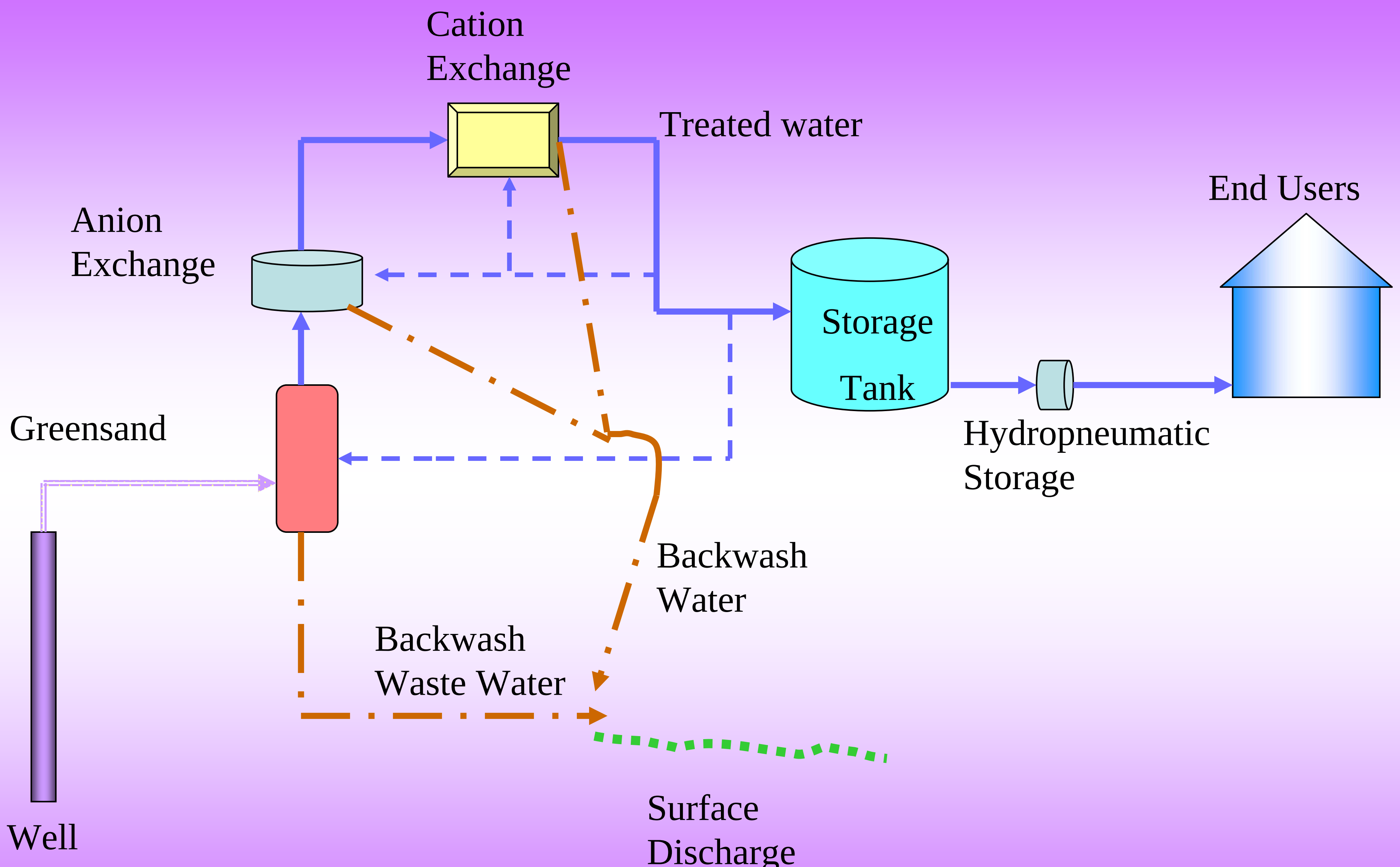


Bedford, NH Site
Concentration Factor
10
9
8
7
6
5
4
3
2
1
0
Bedrock
Native Soil
Bedrock Groundwater
Treated Water - greensand
Backwash Water
Disposal Area Soil
Groundwater in Plume
Upgradient Groundwater
Soil in Plume 1
Soil in Plume 2
Soil
Water

Pelham, NH Site

Pelham, NH System
Apartment Complex (pop. 25, 22 service connections)

- 2 Bedrock wells (575 ft and 625 ft)
- Submersible pumps
- Greensand
- Anion Exchange Unit (Chloride form)
- Cation Exchange Unit (Sodium form)
- Atmospheric storage
- Hydropneumatic storage
- Backwash directly to “pit”


Cation
Exchange
Treated water
End Users
Anion
Exchange
Storage
Tank
Greensand
Hydropneumatic
Storage
Backwash
Water
Backwash
Waste Water
Surface
Discharge
Well

Treatment System Maintenance

Backwash:

- Greensand twice per week
- Cation Exchange unit four times per week
- Anion Exchange every two weeks

Well House and Treatment - Pelham, NH

Discharge to Ground - Pelham, NH

Discharge Pit - Pelham, NH

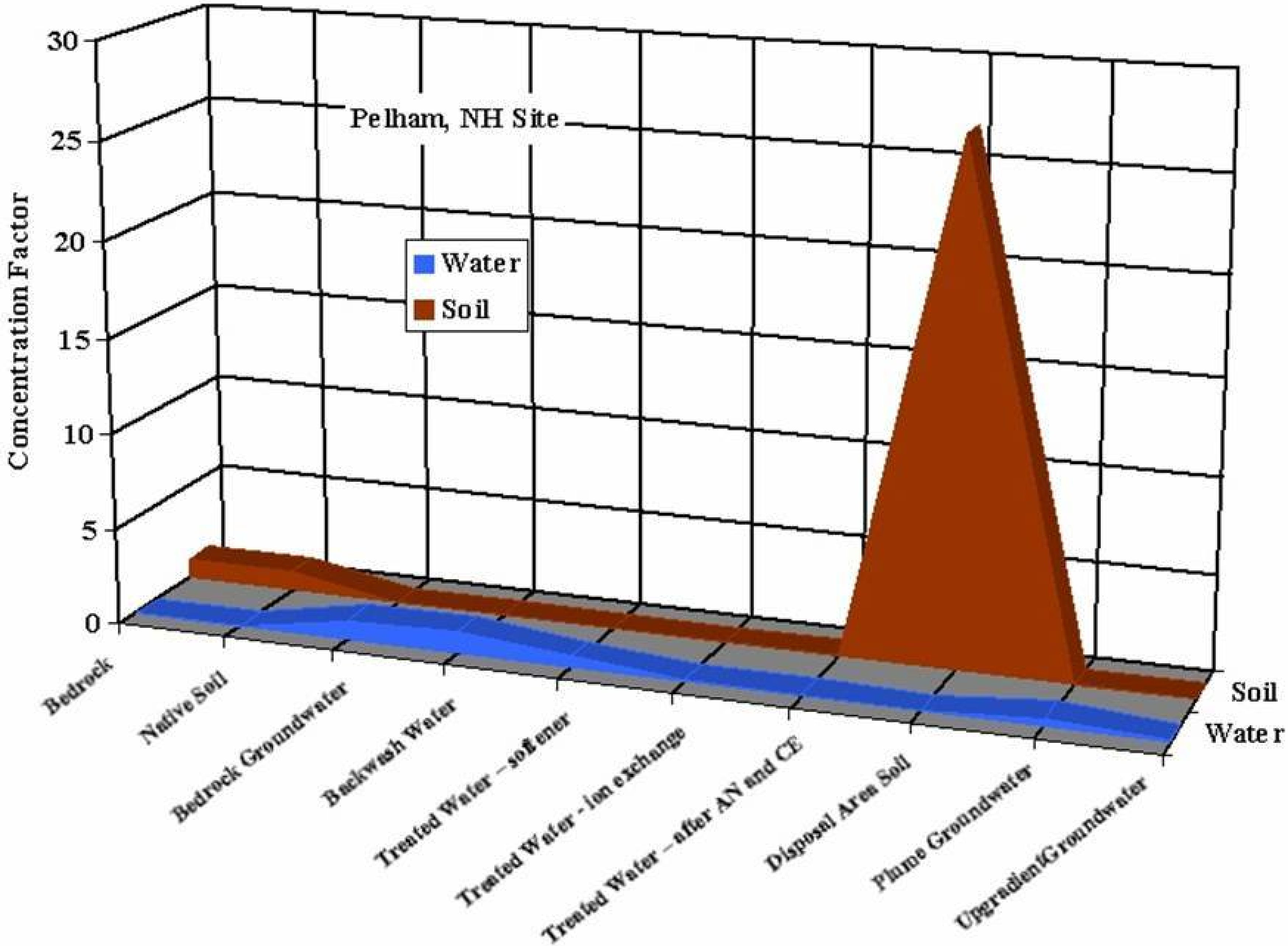
Downstream of Discharge Pit - Pelham, NH

Pelham, NH Bedrock

Sample Description	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Radium 226 (pCi/g)	Radium 228 (pCi/g)	Uranium as U238 (mg/kg)
Bedrock (Schist @ 160 ft)	9.8	26	1.4	0.8	<4
Bedrock (Ayer Granite @ 340 ft)	35	61	7.0	0.3	17
Bedrock (Sherburne Rd @ 300 ft)	8.9	19	0.9	0.0	<4
Bedrock (Sherburne Rd @ 500 ft)	3.5	14	1.0	0.7	<4
Native Soil	8.1	8.3	2.5	0.3	<4

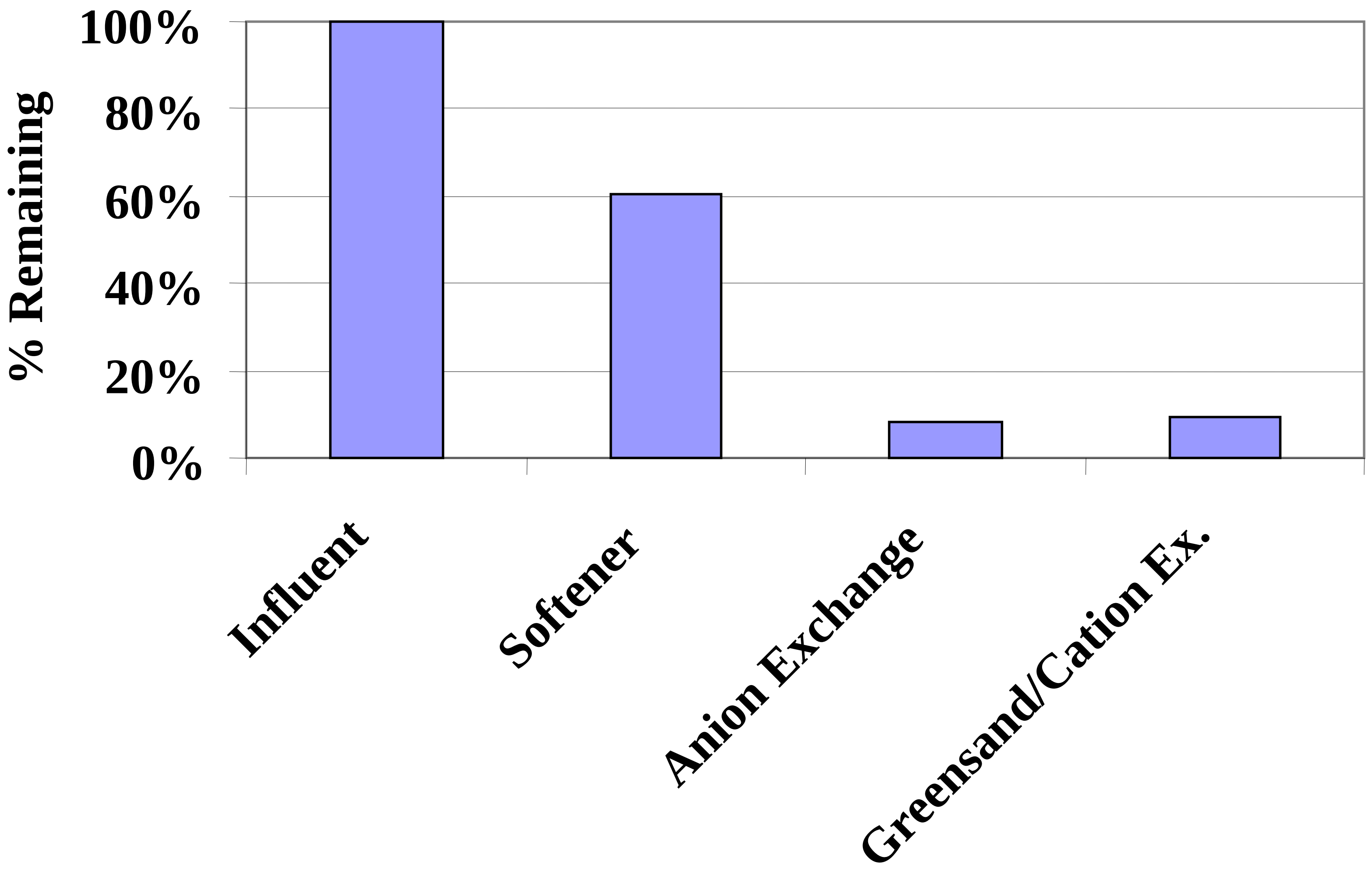
Pelham, NH Groundwater

Gross Alpha (pCi/l)	Gross Alpha less Rn & U (pCi/l)	Gross Beta (pCi/l)	Radium 226 (pCi/l)	Radium 228 (pCi/l)	Uranium* (pCi/l)	Uranium (ug/l)
91	11	20	1.7	0.5	80	120
84	11	30	3.3	1.4	73	110

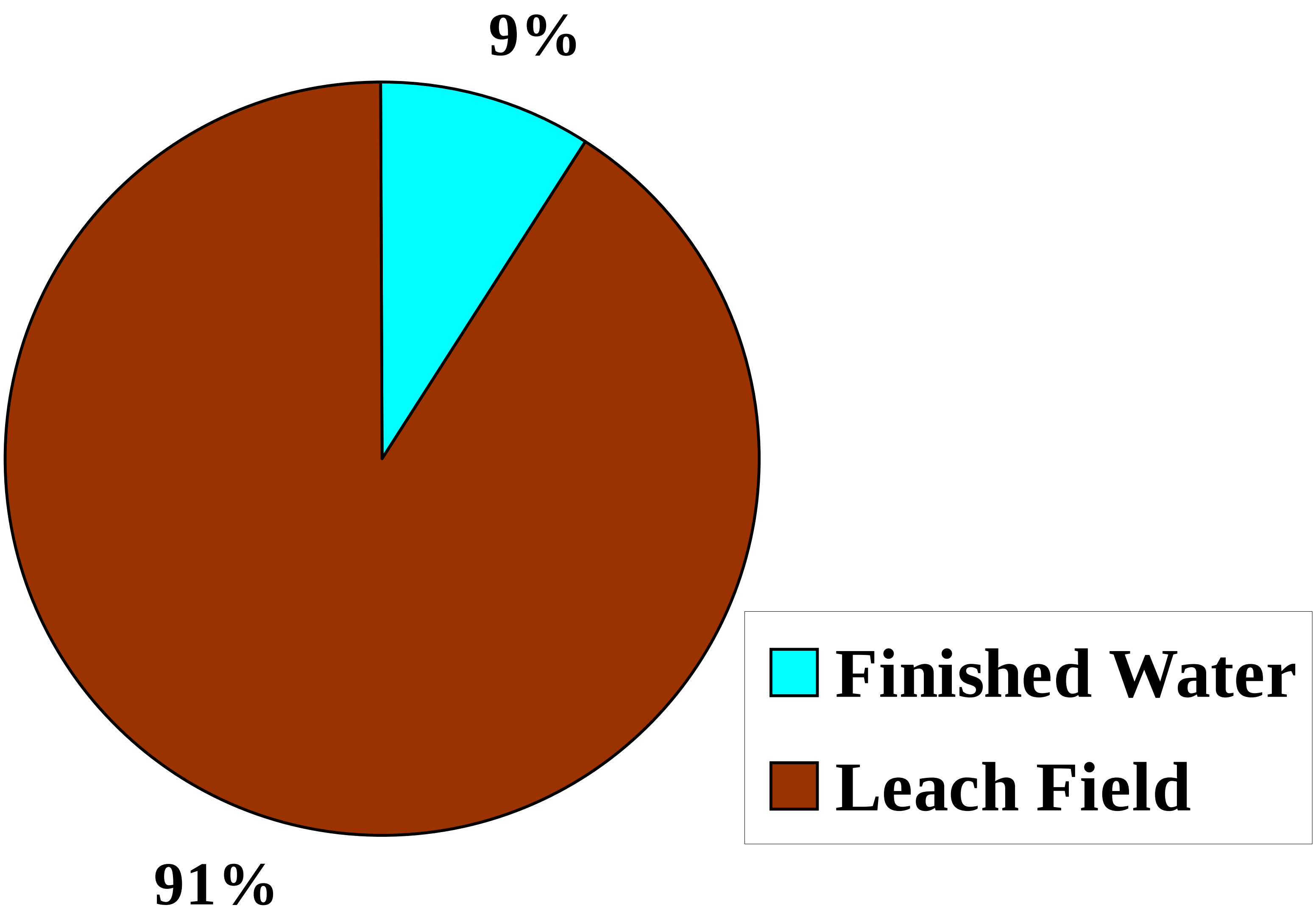


Pelham, NH Site
Concentration Factor
30
25
20
15
10
5
0
Water
Soil
Bedrock
Native Soil
Bedrock Groundwater
Backwash Water
Treated Water – softener
Treated Water - ion exchange
Treated Water – after AN and CE
Disposal Area Soil
Plume Groundwater
Upgradient Groundwater
Soil
Water

Post-Treatment Alpha Plus Beta Pelham, NH



Pelham, NH Radionuclides Fate



Test Name	EPA Standards
Compliance Gross Alpha*	15 pCi/L**
Uranium	30 ug/L (approx 20 pCi/L)***
Radium 226 + Radium 228	5 pCi/L
Radon	Proposed 300/4,000 pCi/L (CFR Nov. 1999)

*Compliance gross alpha equals the concentration of analytical gross alpha minus the concentration of Uranium

** pCi/L (picocuries per liter)

*** micrograms per liter (ug/L) can be converted to pCi/L by multiplying the U (mg/L) by 0.67.

Conclusions

- Radioactive species tend to associate with solids (soils, sediment)
- Anion Exchange system very effective at removing radioactive species
- Leach fields have an enormous capacity for radioactivity without reaching levels of concern
- TENORM waste not moving in groundwater
- Pumping strategies may impact radioactivity level from the well