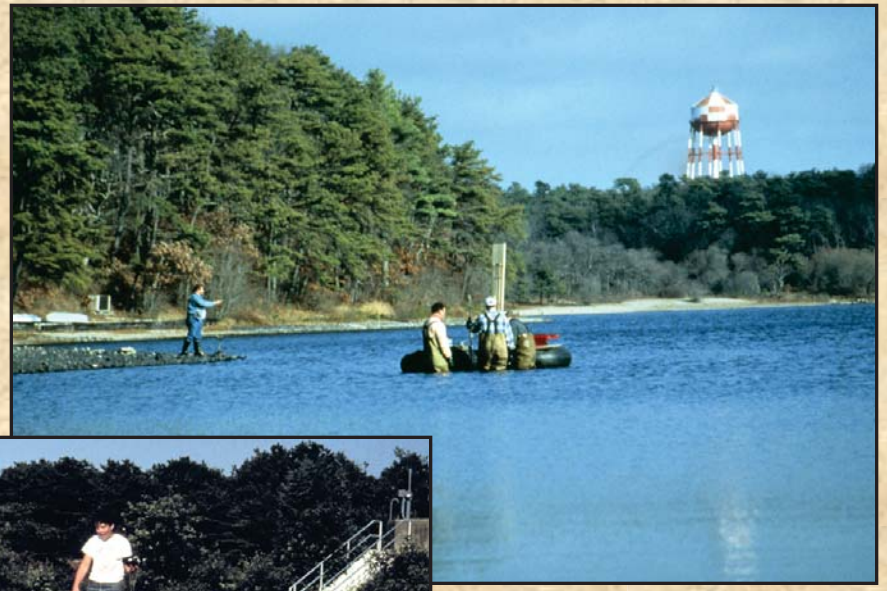
Cape Cod's Billion Dollar Cleanup: The Hydrologic Story

Denis LeBlanc
U.S. Geological Survey



Air Force Center for Environmental Excellence

Army Environmental Center

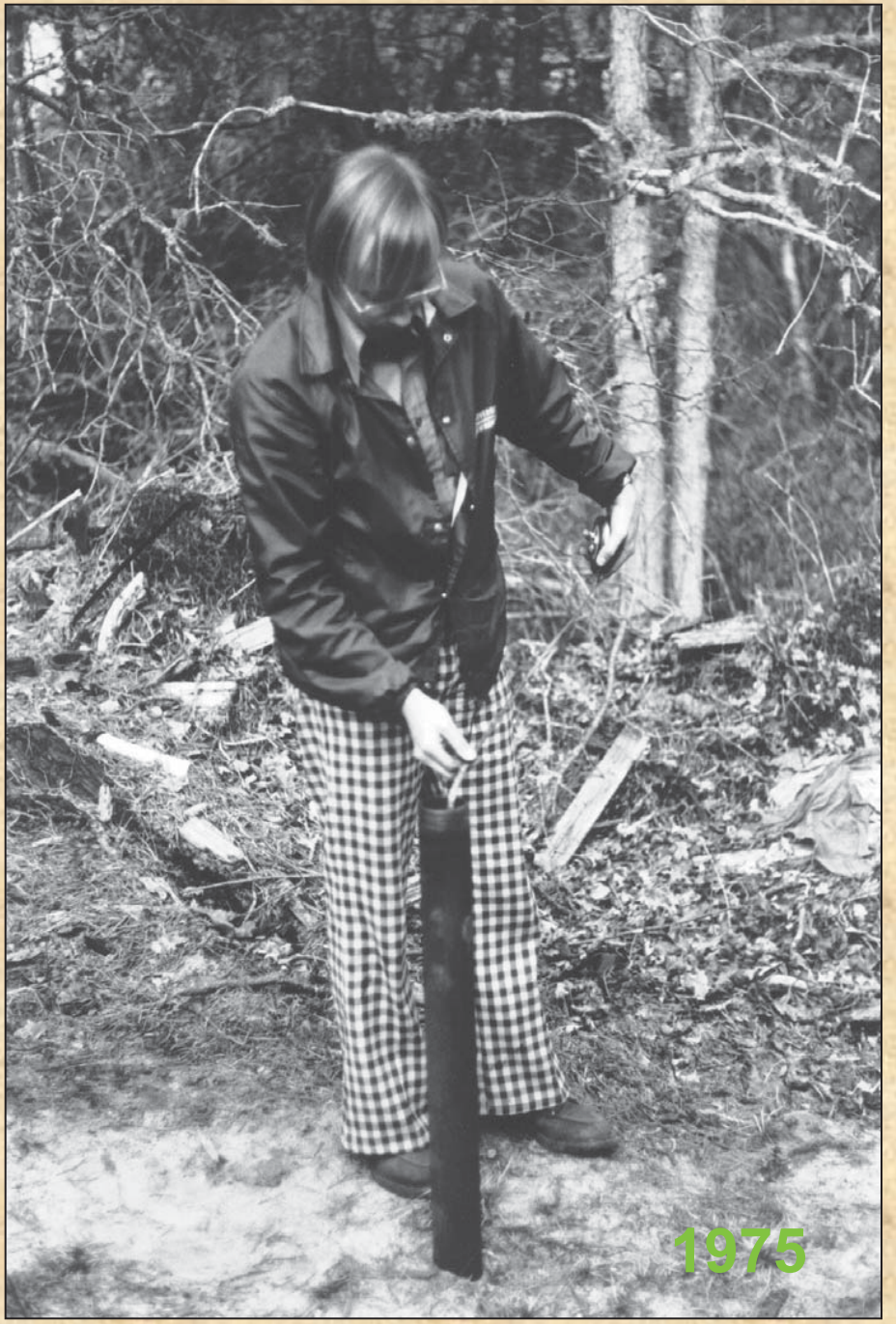
Mass National Guard Environmental & Readiness Center

Toxic Substances Hydrology Program

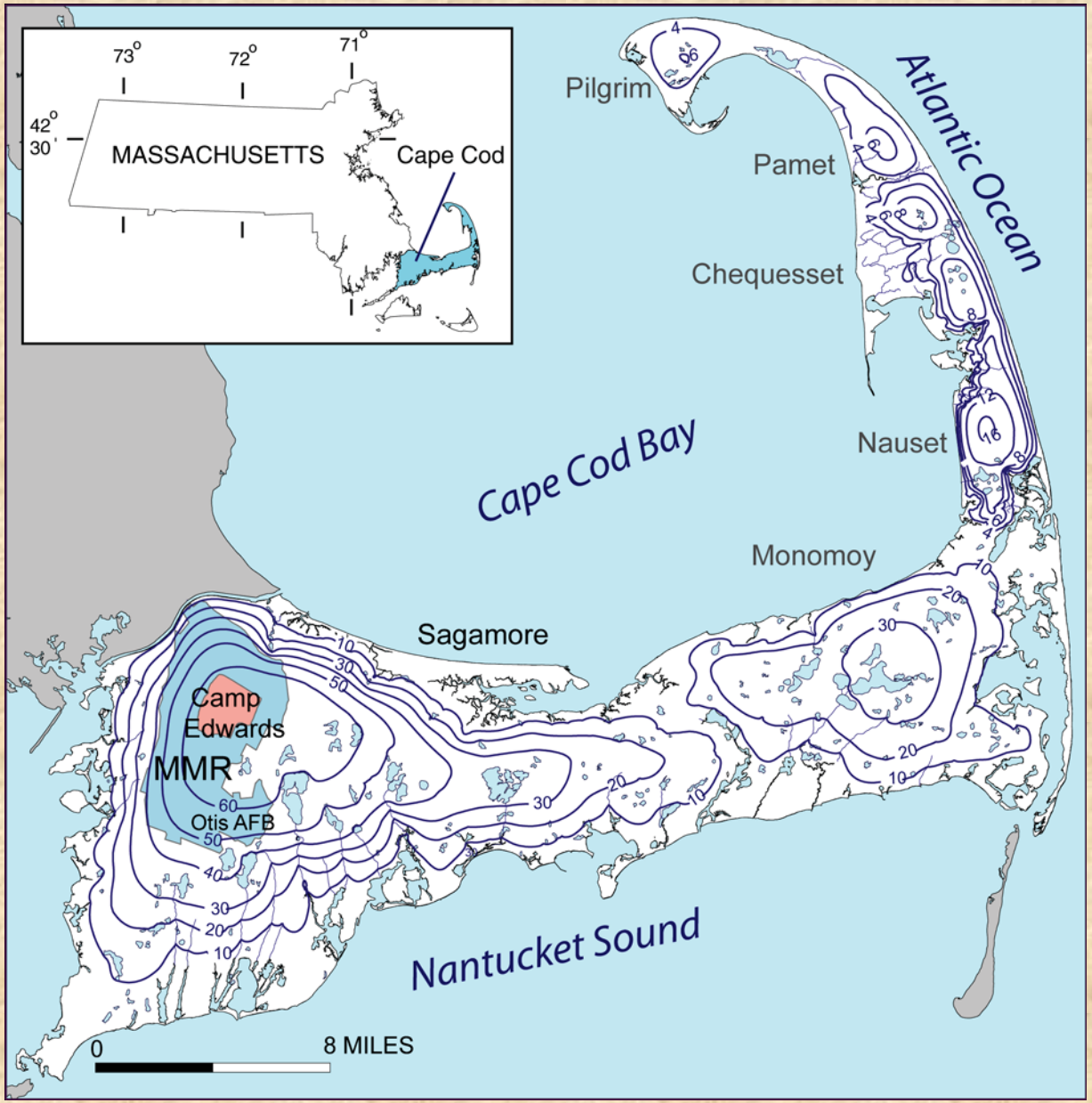
USGS
science for a changing world

Talk Outline

- The Setting
- The Early Years – Discovery and Action!
- Ponds and Plumes
- Predicting Flow Paths
- The Recharge Mosaic
- Today and the Future



Massachusetts Military Reservation



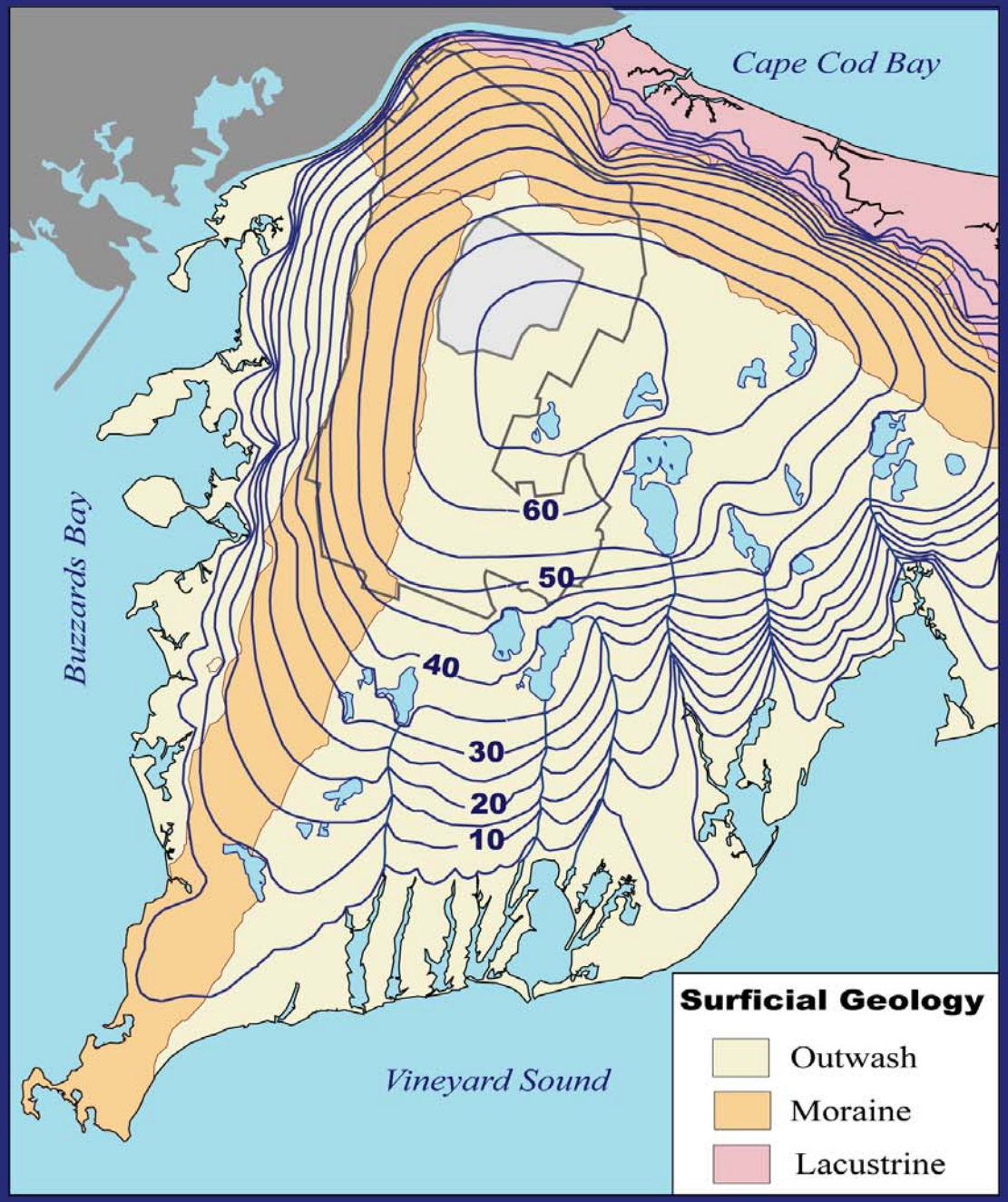
MA ARNG
Camp Edwards

Coast
Guard

National
Cemetery

Otis ANG Base

Environmental
Programs

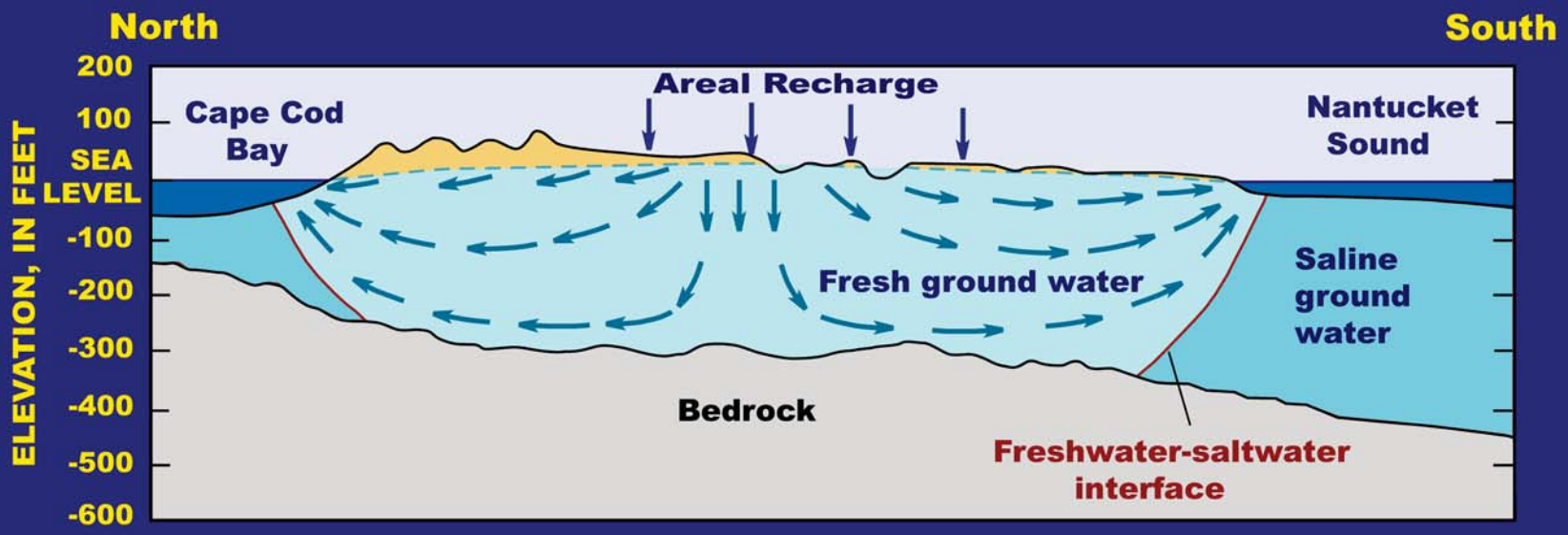


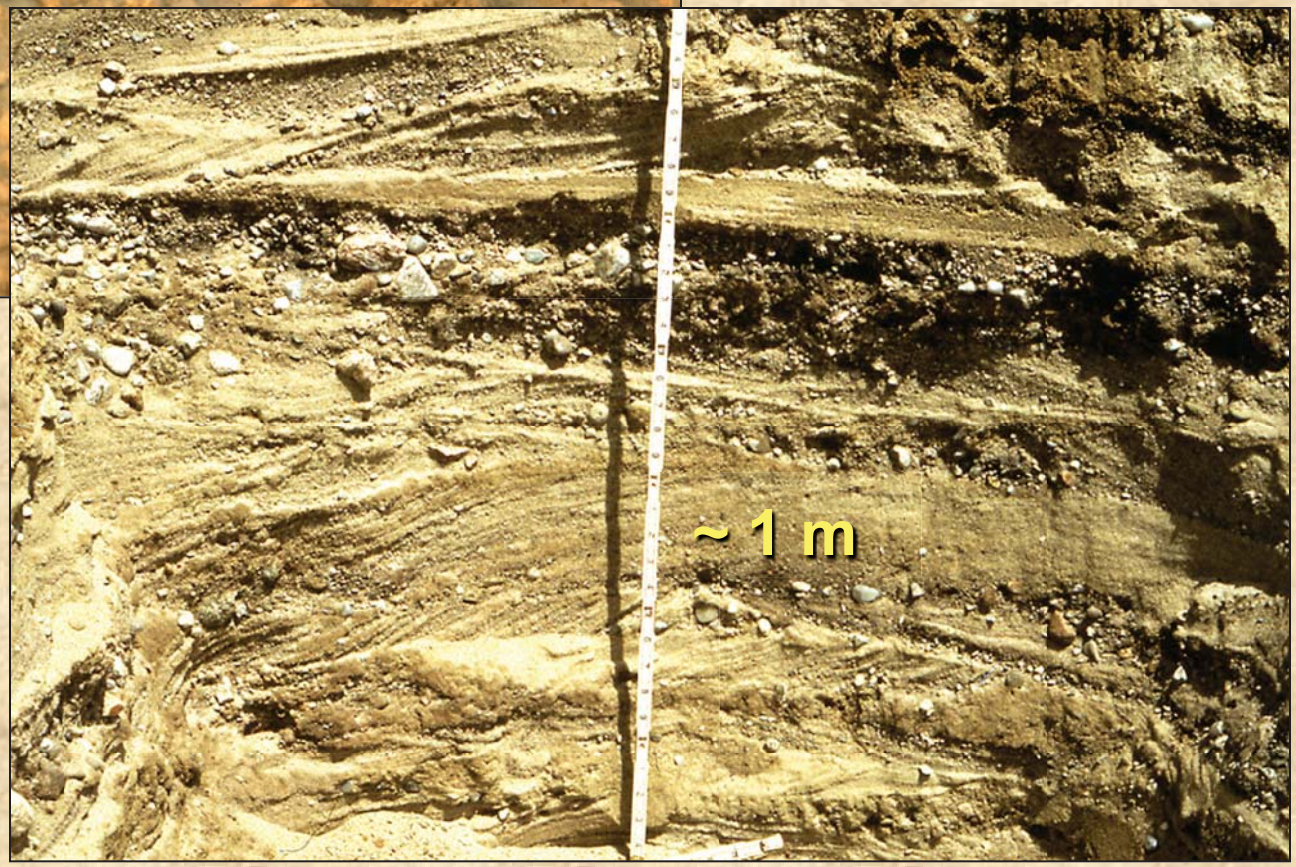
Water-table altitude, ft

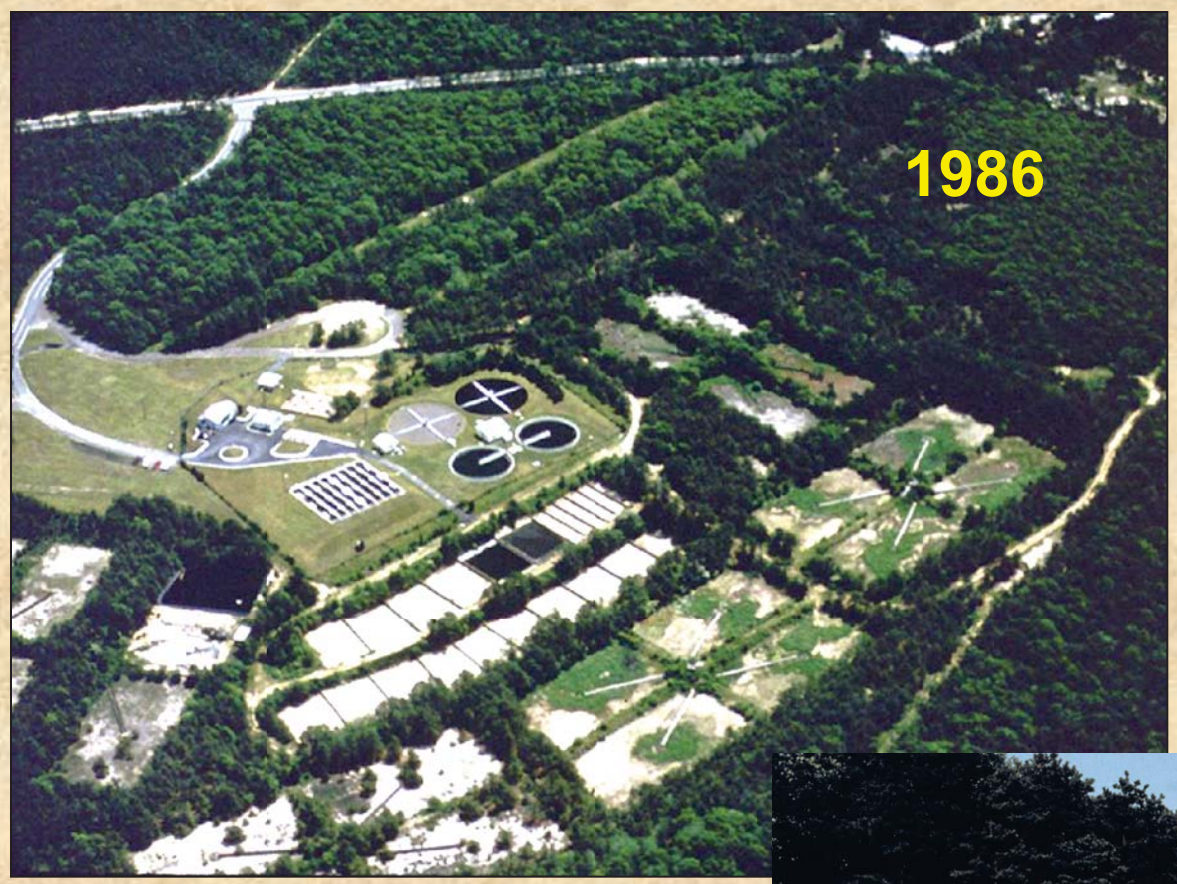
20

0 5 MILES

Generalized Hydrologic Section of Western Cape Cod

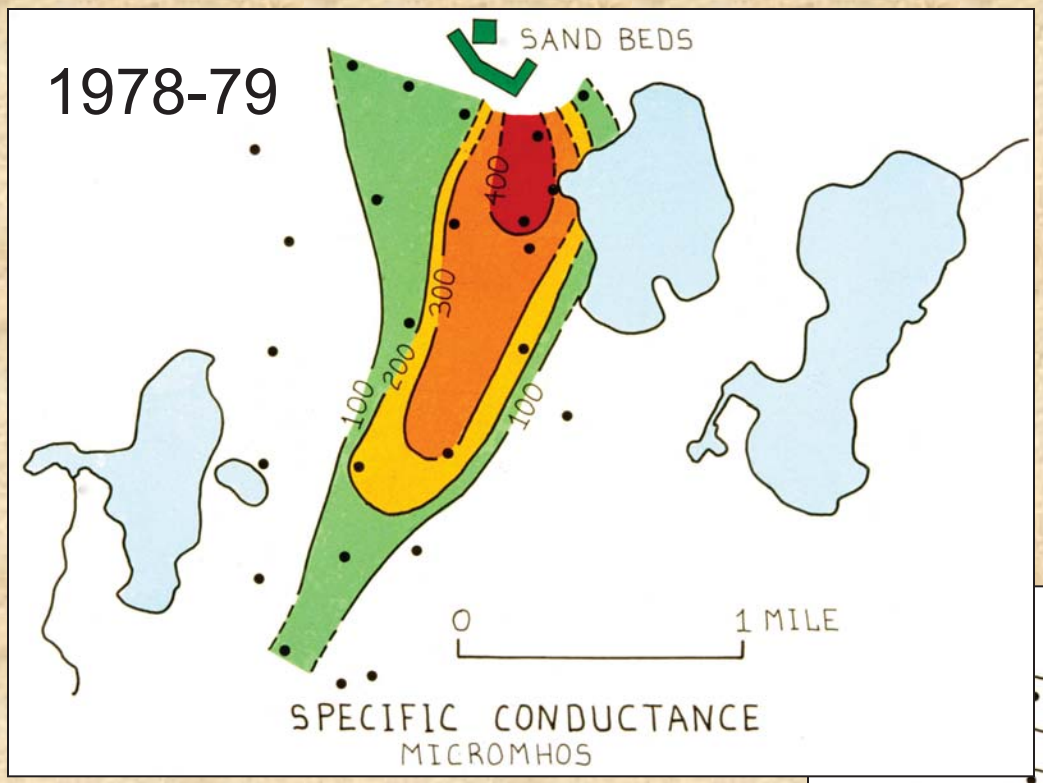


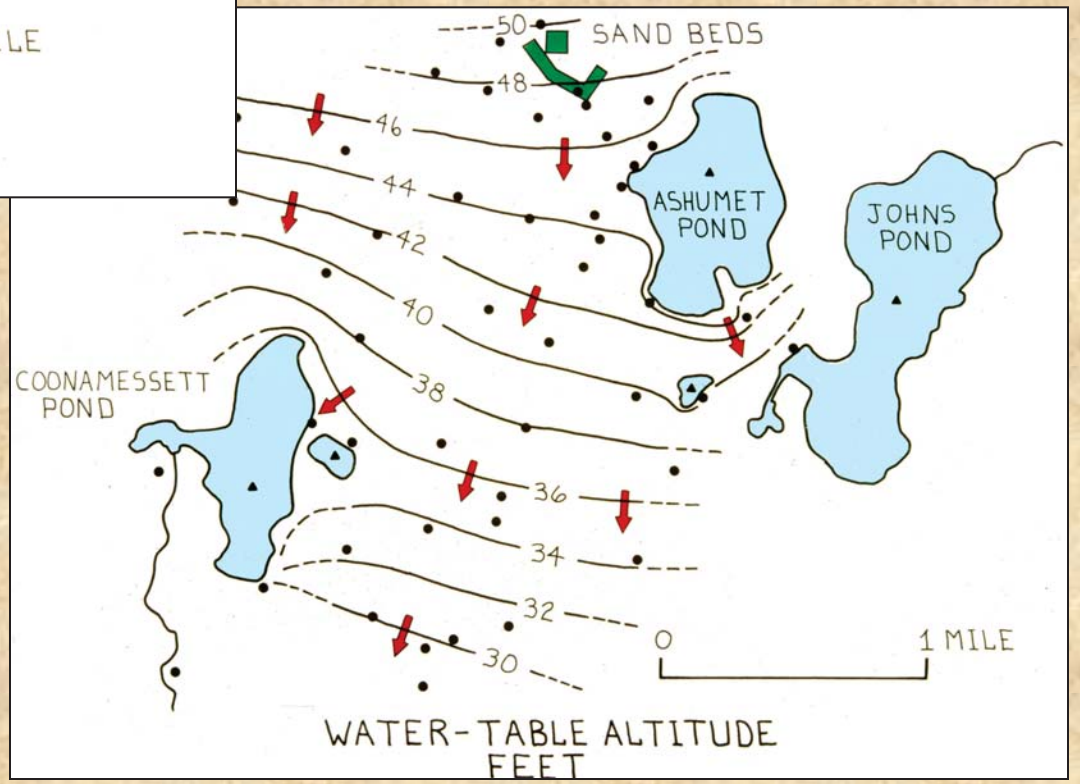

~ 1 m

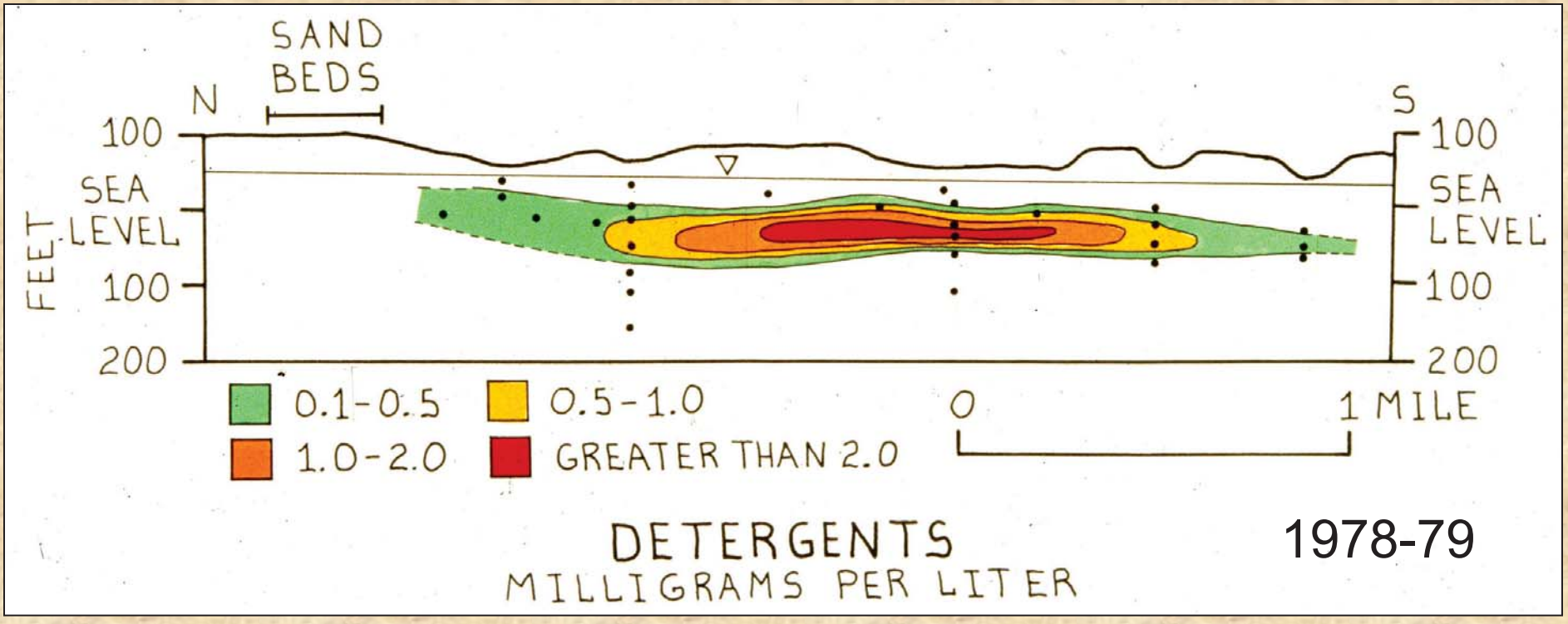


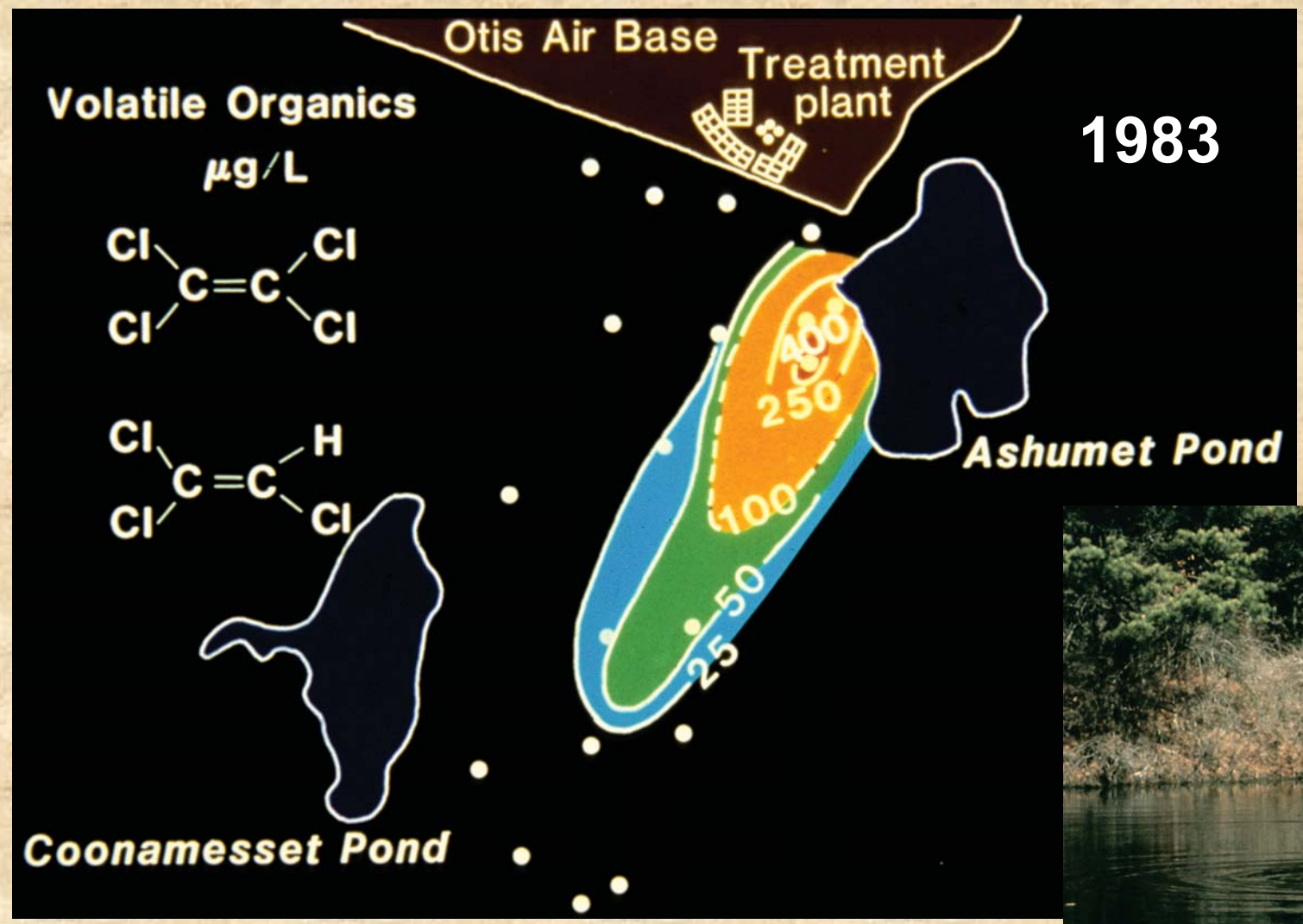
Operated from
1936 to 1995

MMR Wastewater Treatment Plant


1978-79
SAND BEDS
400
300
200
100
100
0
1 MILE
SPECIFIC CONDUCTANCE
MICROMHOS


50
48
46
44
42
40
38
36
34
32
30
SAND BEDS
ASHUMET POND
JOHNS POND
COONAMESSETT POND
0
1 MILE
WATER-TABLE ALTITUDE
FEET

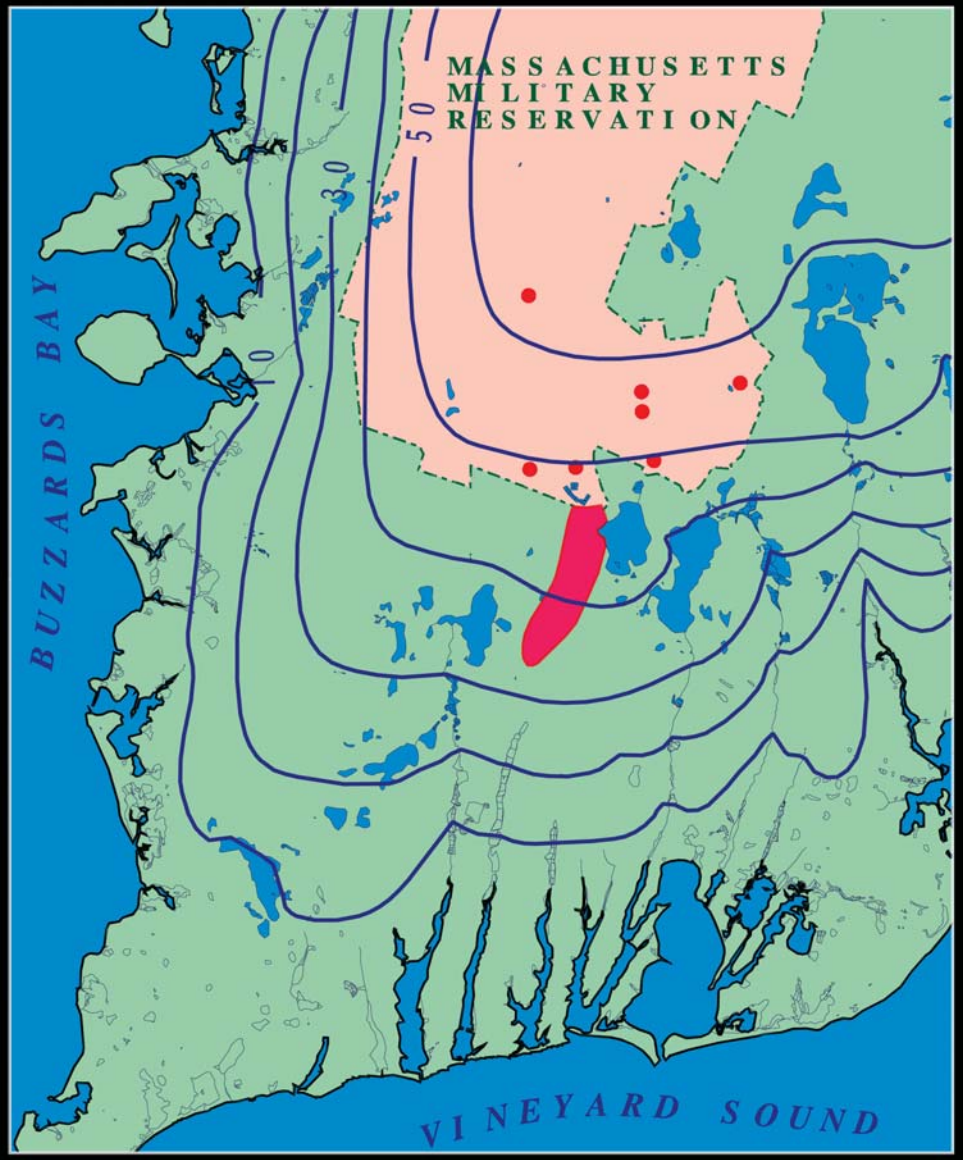

SAND BEDS
N
S
100
SEA LEVEL
100
200
FEET
0.1-0.5
0.5-1.0
1.0-2.0
GREATER THAN 2.0
0
1 MILE
DETERGENTS
MILLIGRAMS PER LITER
1978-79



USGS
science for a changing world

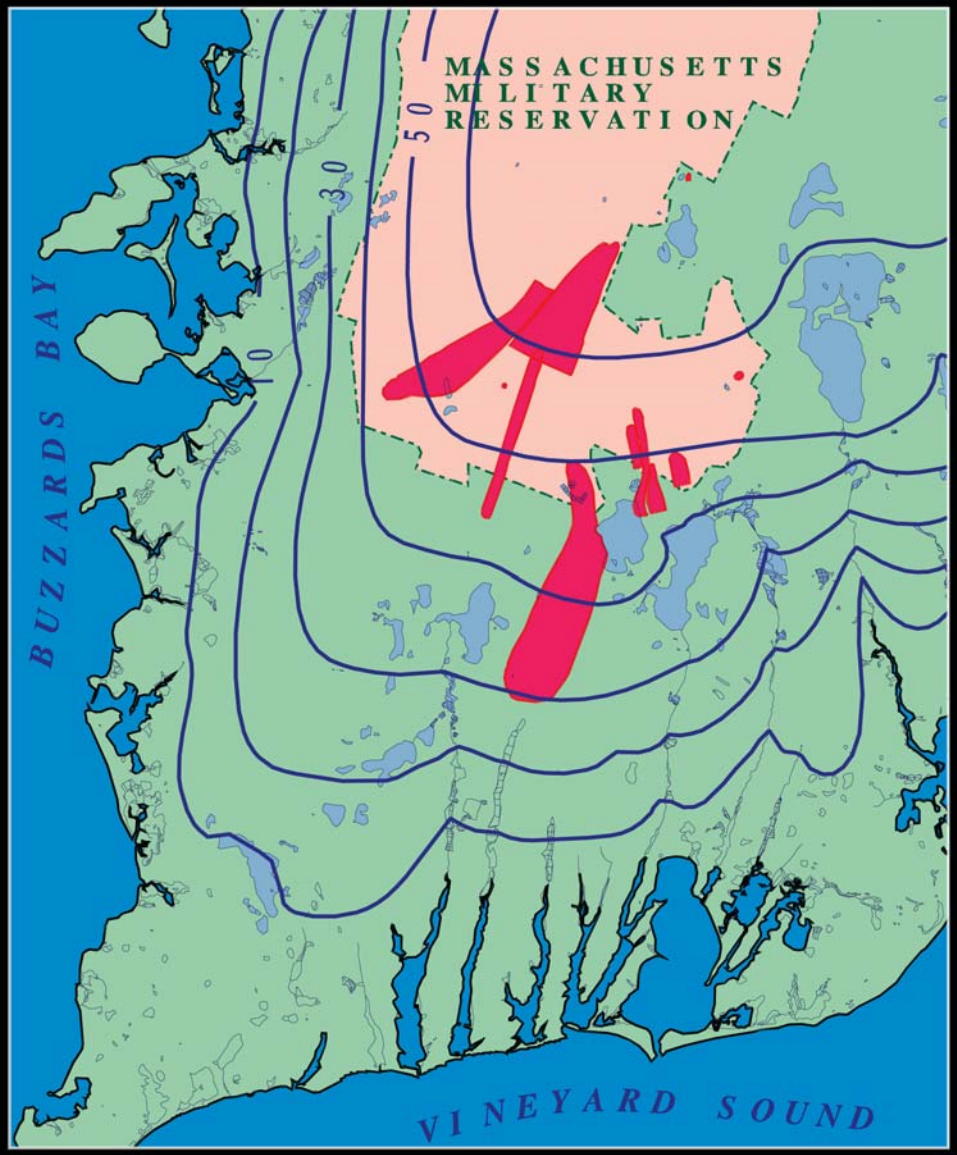
Toxic Substances Hydrology Program

MMR PLUMES (1983)



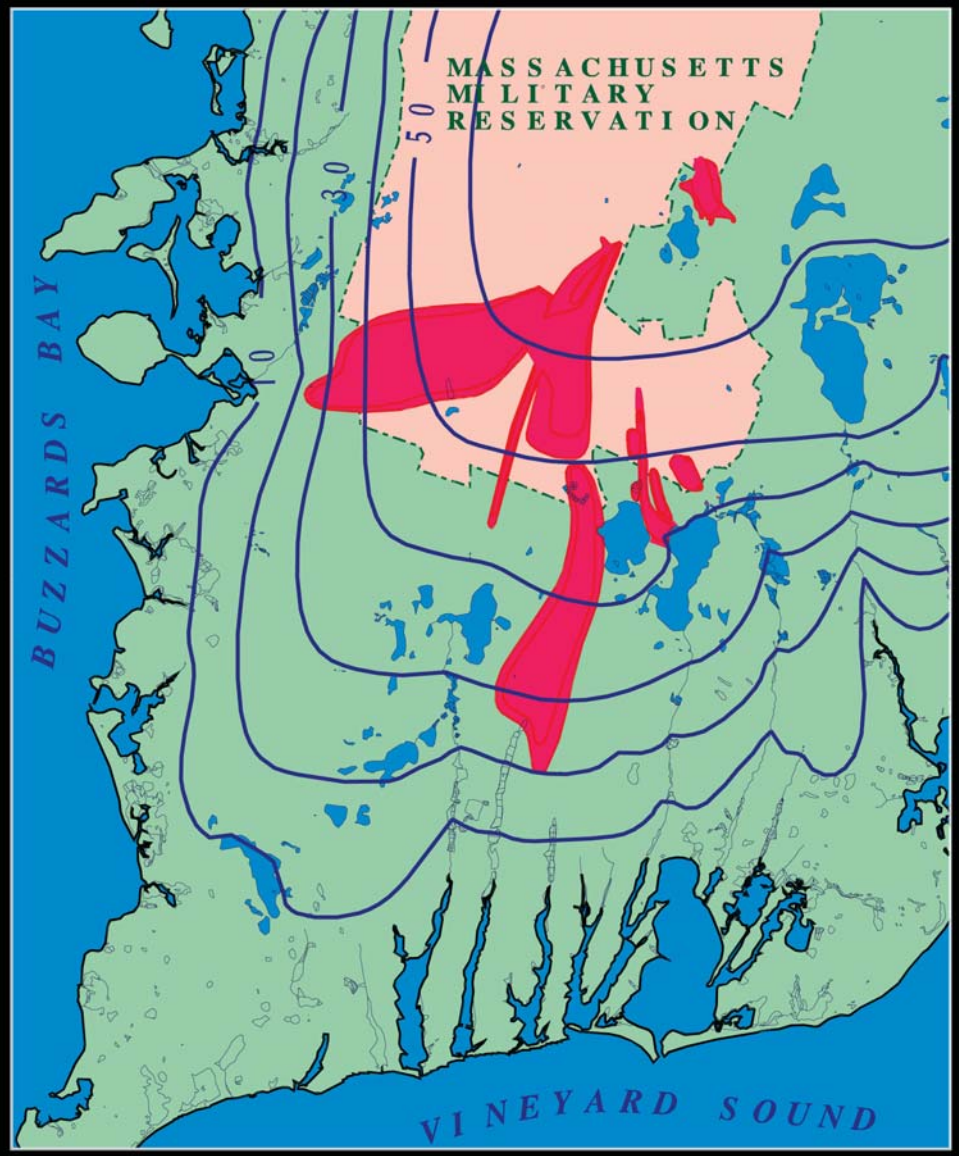
0 2 4 MILES

MMR PLUMES (1991)

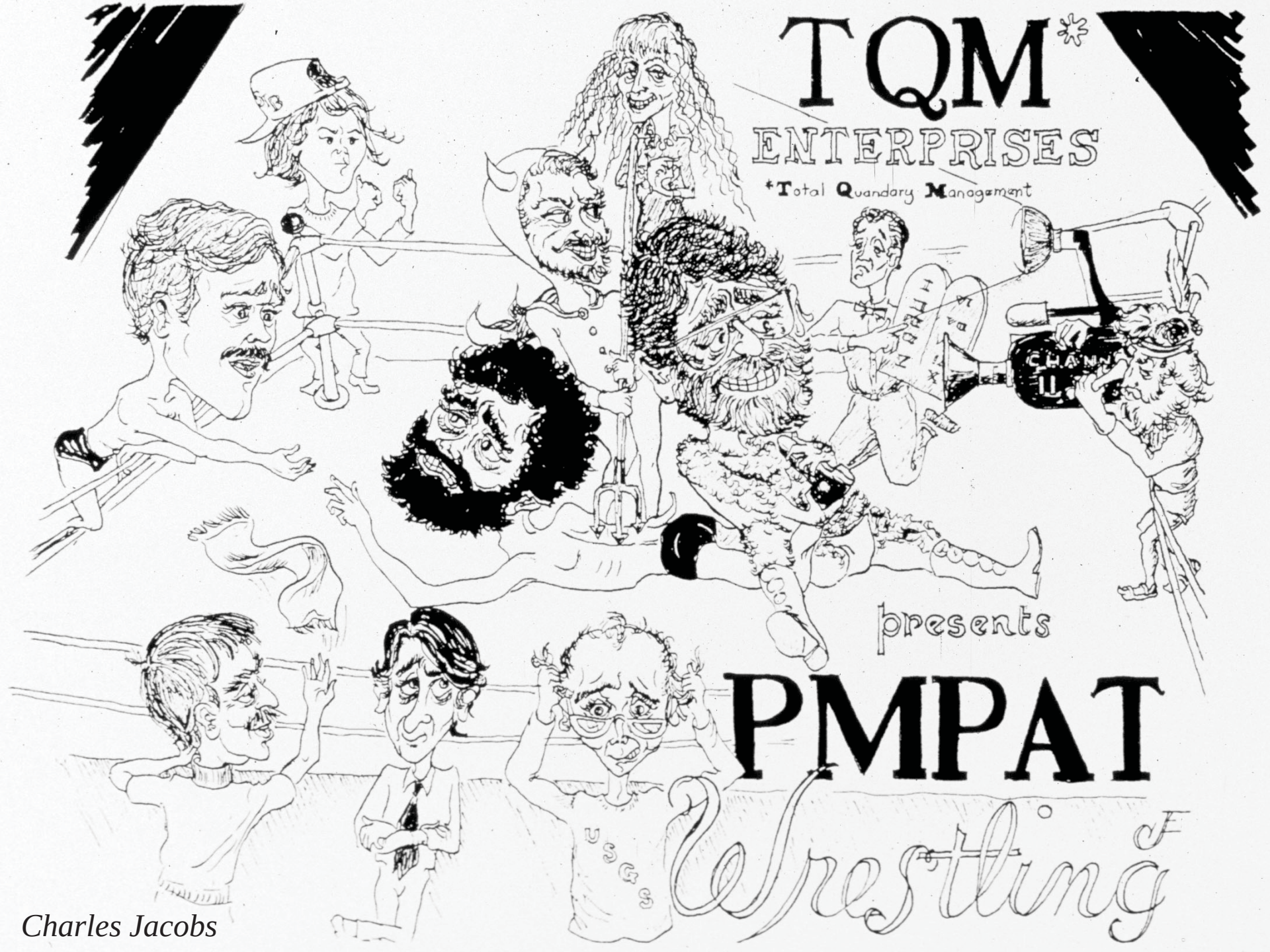


0 2 4 MILES

MMR PLUMES (1994)

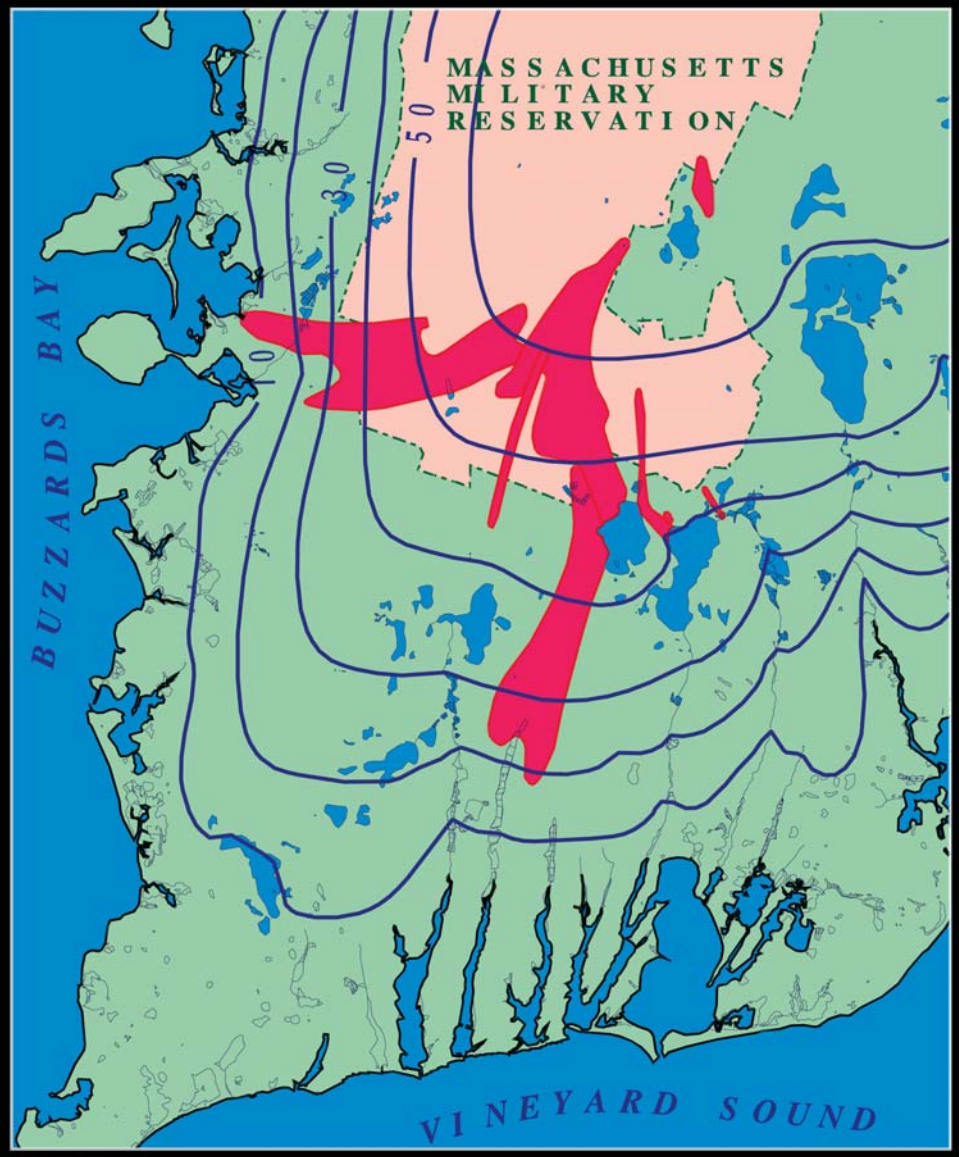


0 2 4 MILES



Charles Jacobs

MMR PLUMES (1996)

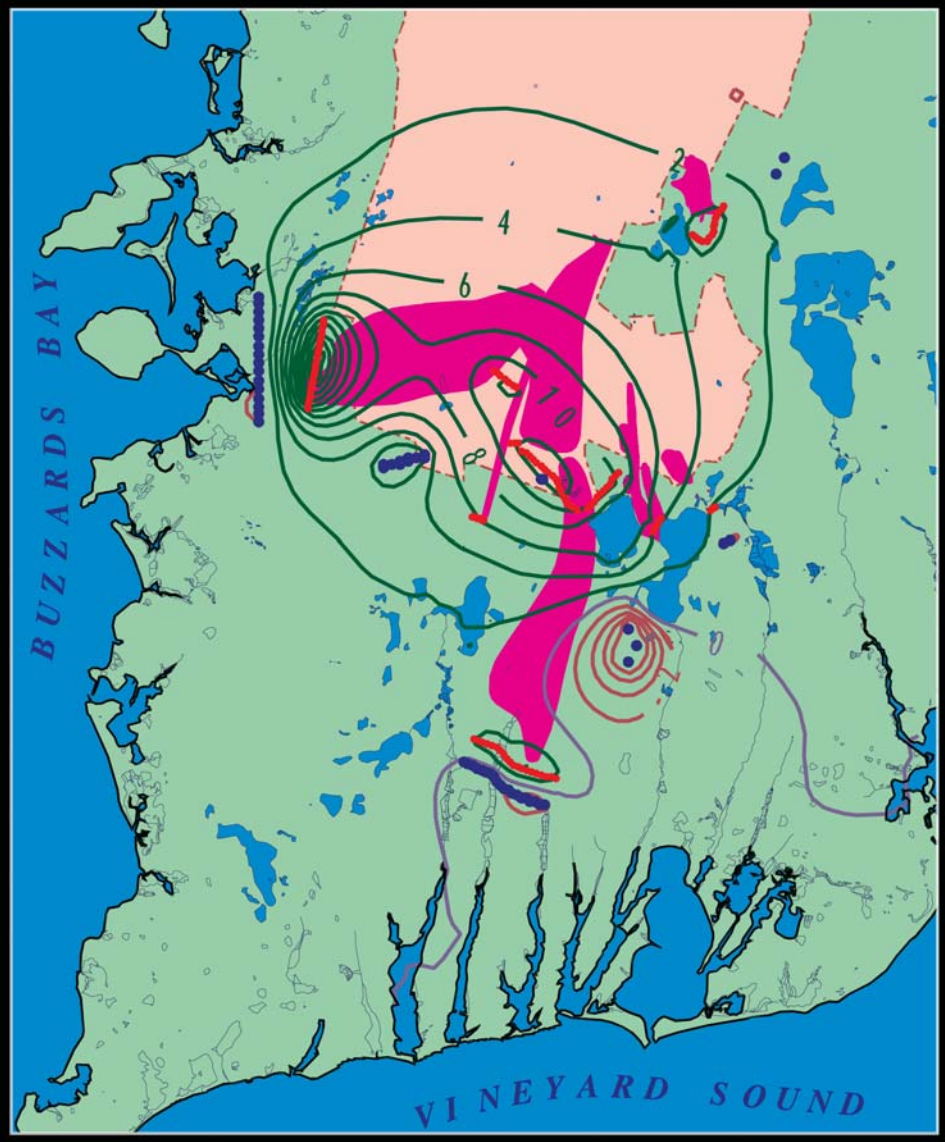


1996 Proposed Treatment System

"…the National Guard Bureau proposes to replace the natural groundwater flow system with an artificially controlled one that is powered by pumps and electricity."

Thomas Cambareri
Barnstable County Hydrologist
February 9, 1996

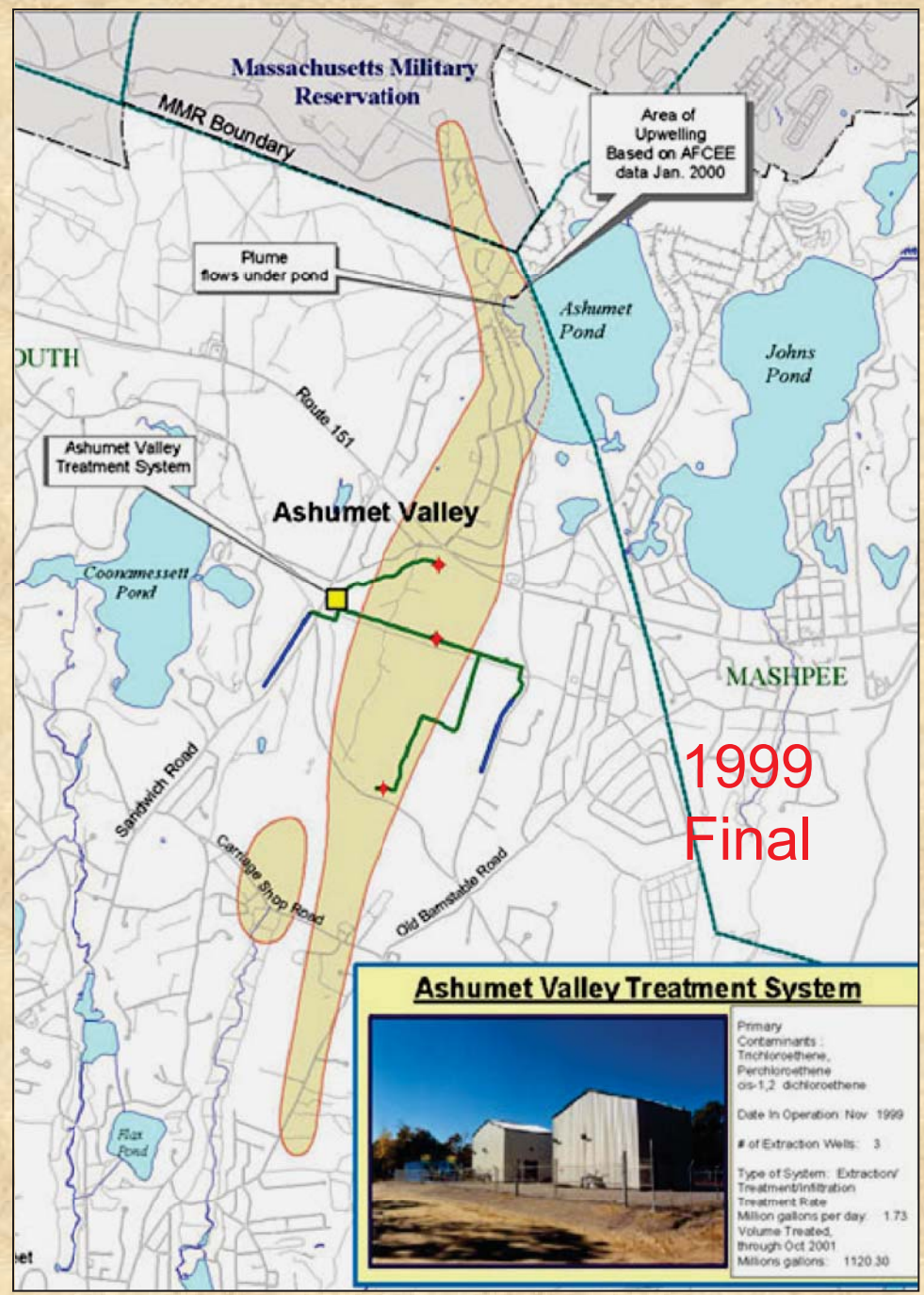
DRAWDOWNS PREDICTED BY USGS REGIONAL MODEL



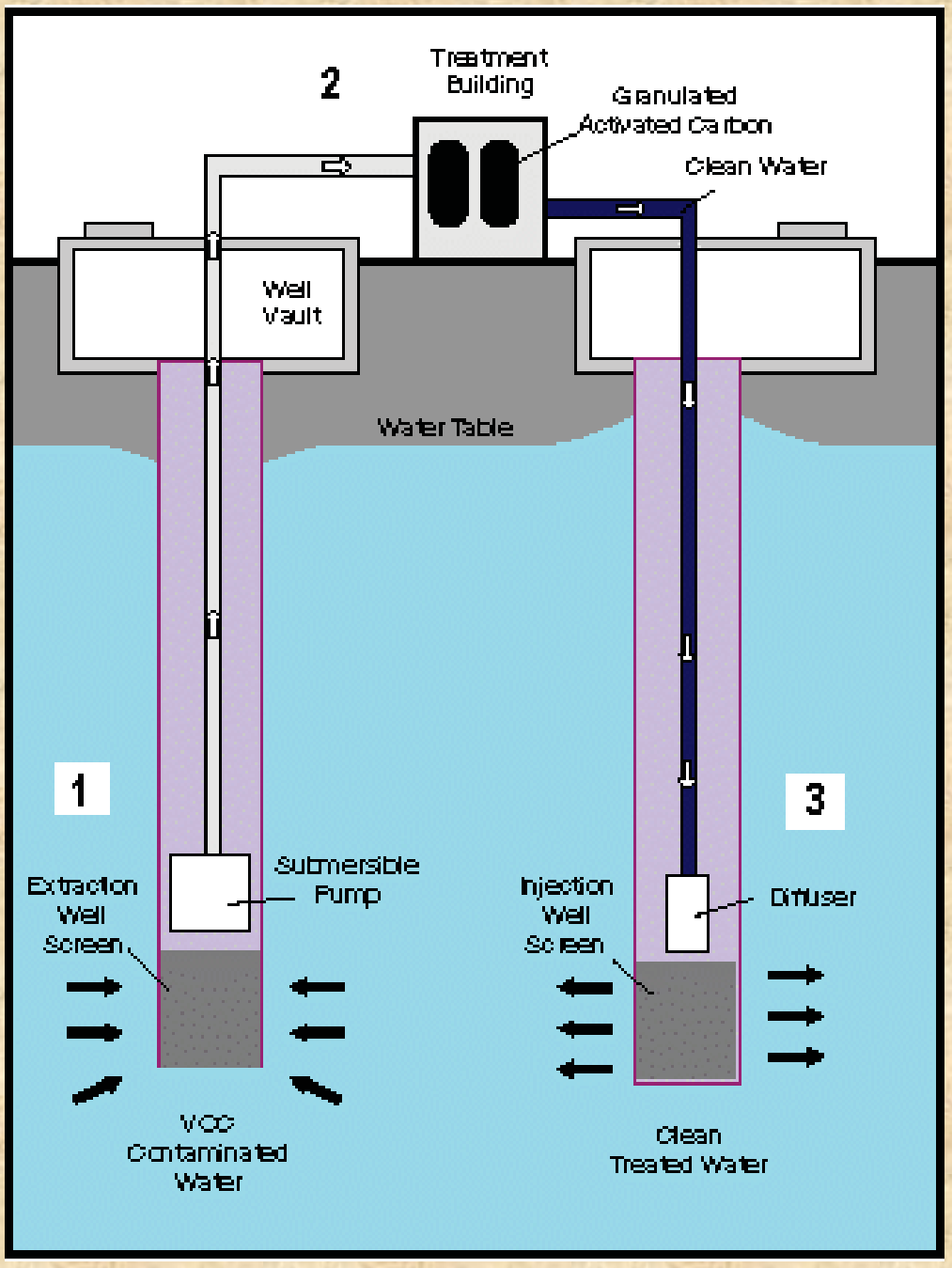
0 2 4 MILES

1996
Plan
MMR
ASHUMET POND
ASHUMET VALLEY PLUME
EXTRACTION WELLS
INJECTION WELLS
0

1998
Plan
MMR
ASHUMET POND
INJECTION WELLS
ASHUMET VALLEY PLUME
EXTRACTION WELLS
INJECTION WELLS
0
1 MILE

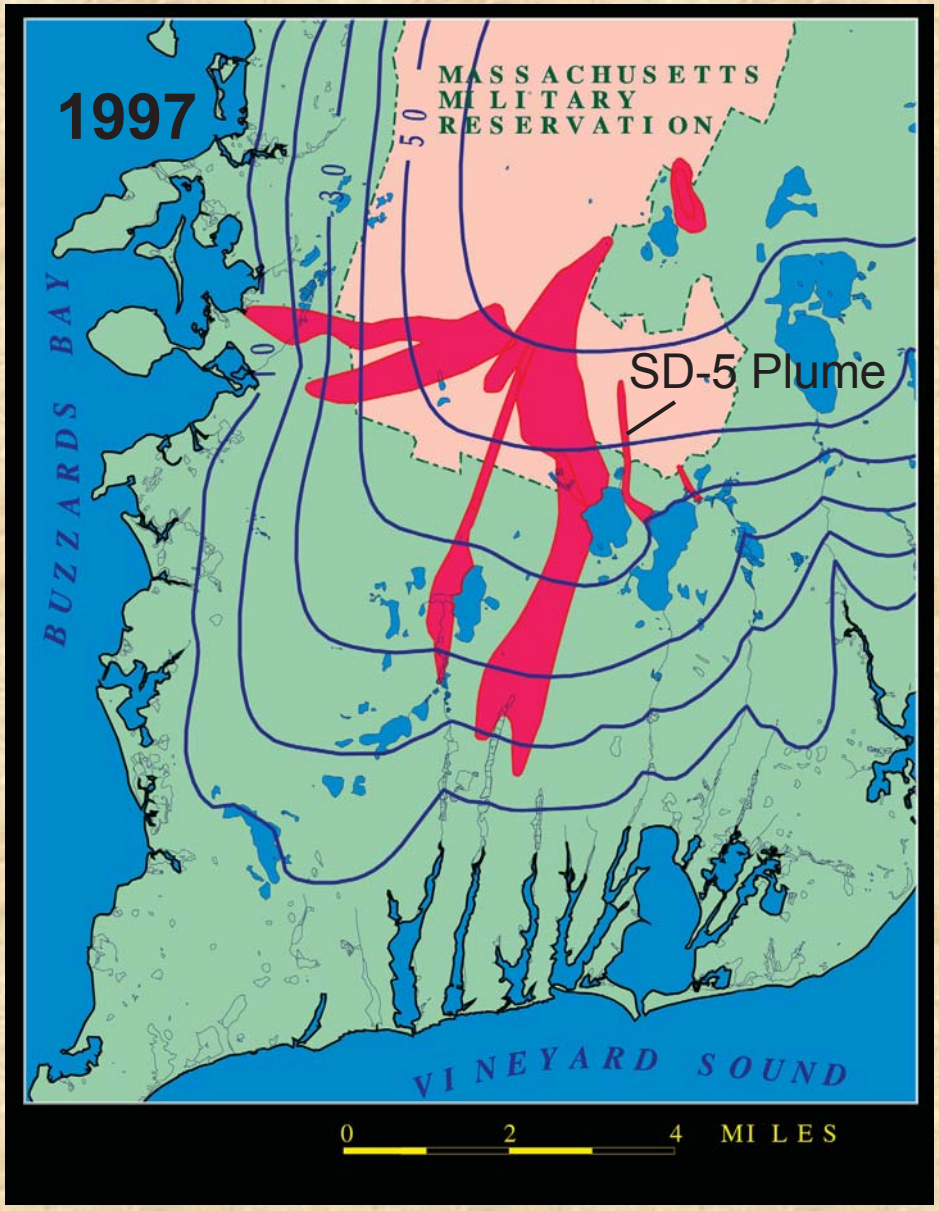

Massachusetts Military Reservation
MMR Boundary
Area of Upwelling Based on AFCEE data Jan. 2000
Plume flows under pond
Ashumet Pond
Johns Pond
Route 151
Ashumet Valley Treatment System
Ashumet Valley
Coonamessett Pond
MASHPEE
1999
Final
Sandwich Road
Carriage Shop Road
Old Barnstable Road
Flax Pond
Ashumet Valley Treatment System
Primary Contaminants : Trichloroethene, Perchloroethene cis-1,2 dichloroethene
Date In Operation: Nov 1999
# of Extraction Wells: 3
Type of System: Extraction/ Treatment/Infiltration
Treatment Rate Million gallons per day: 1.73
Volume Treated, through Oct 2001 Millions gallons: 1120.30

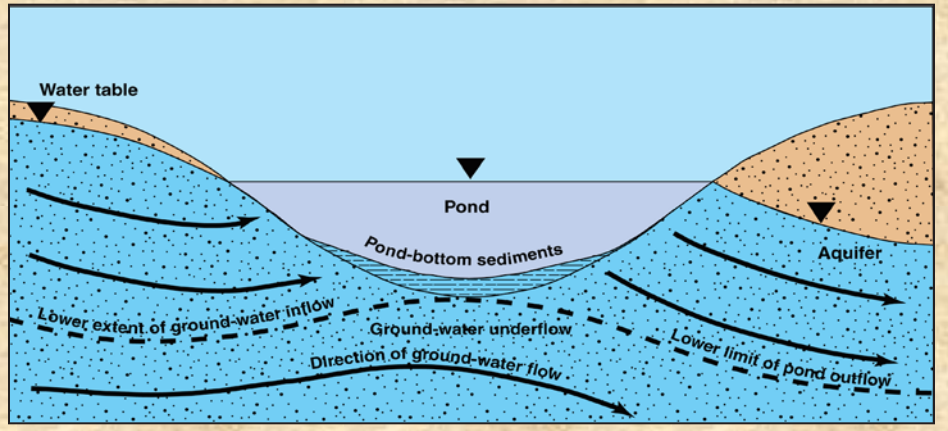
AFCEE
IRP



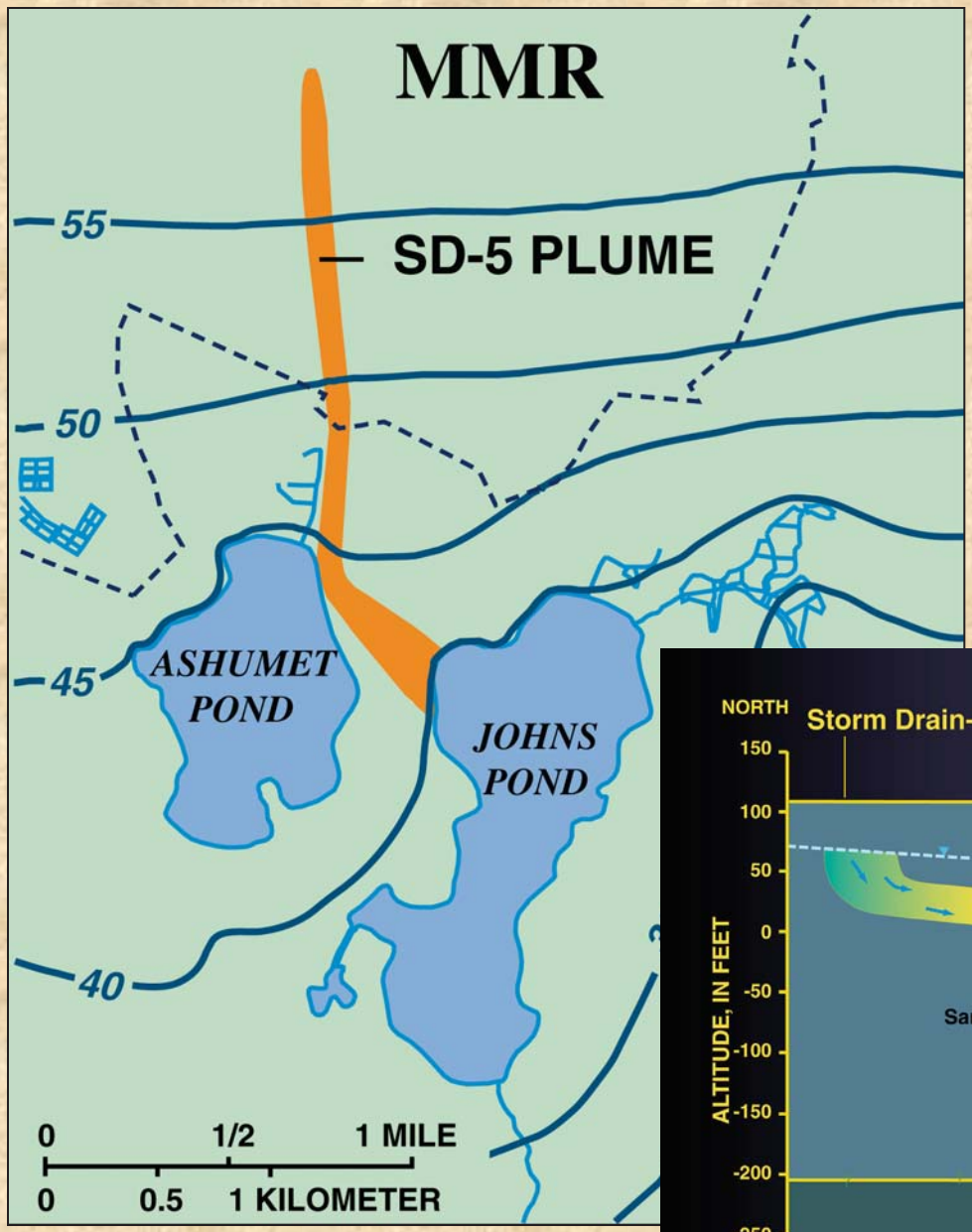
Why Pump and Treat Works at the MMR

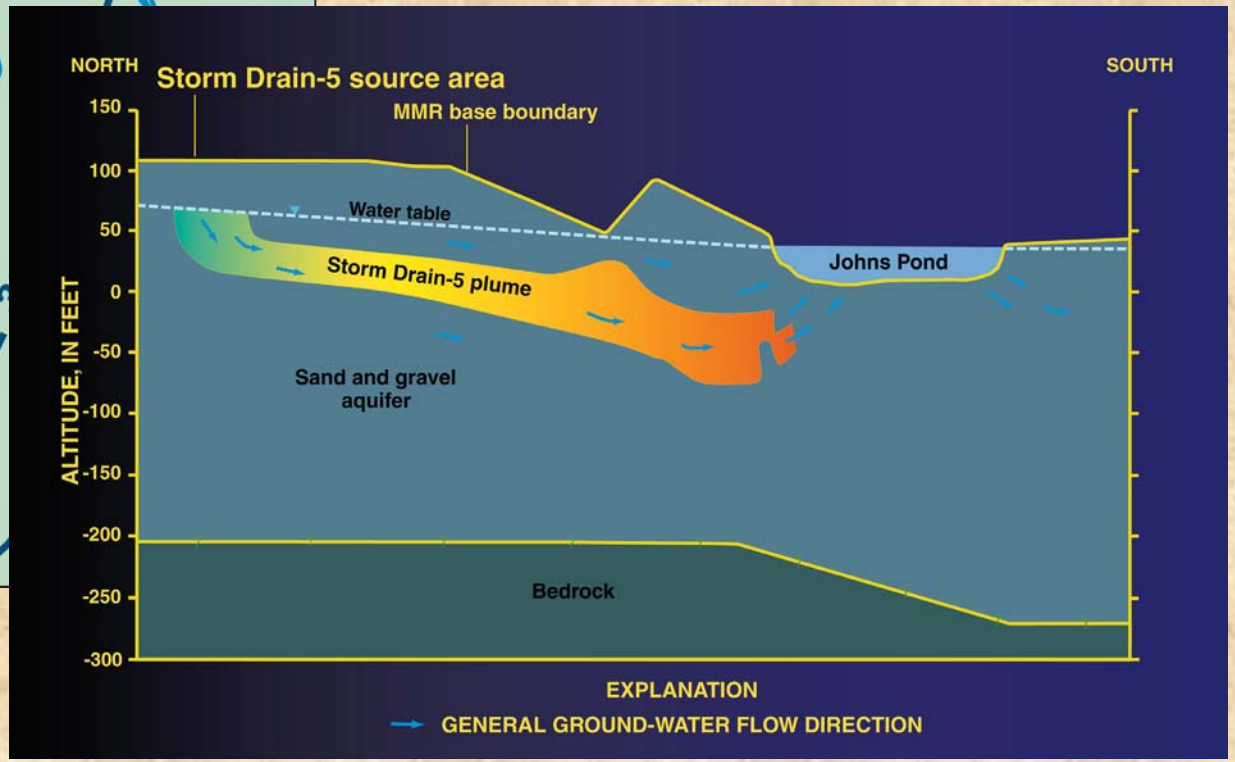
- Sources mostly removed from unsaturated zone
- No known DNAPL below water table
- Permeable aquifer has few fine zones
- Quartz sands have little sorptive capacity
- High recharge and ground-water flow rates
- Large dilute “trace-level organic” plumes

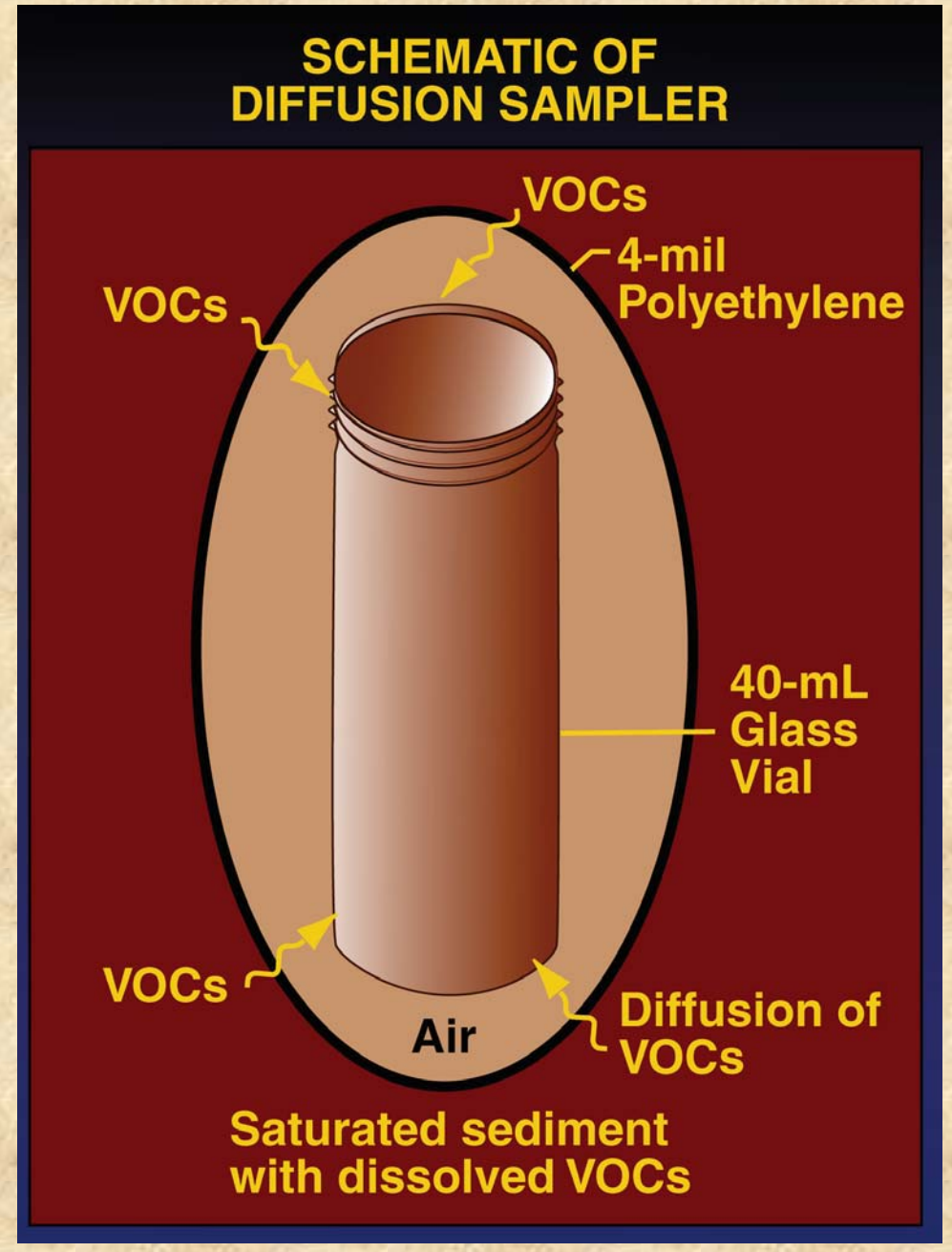


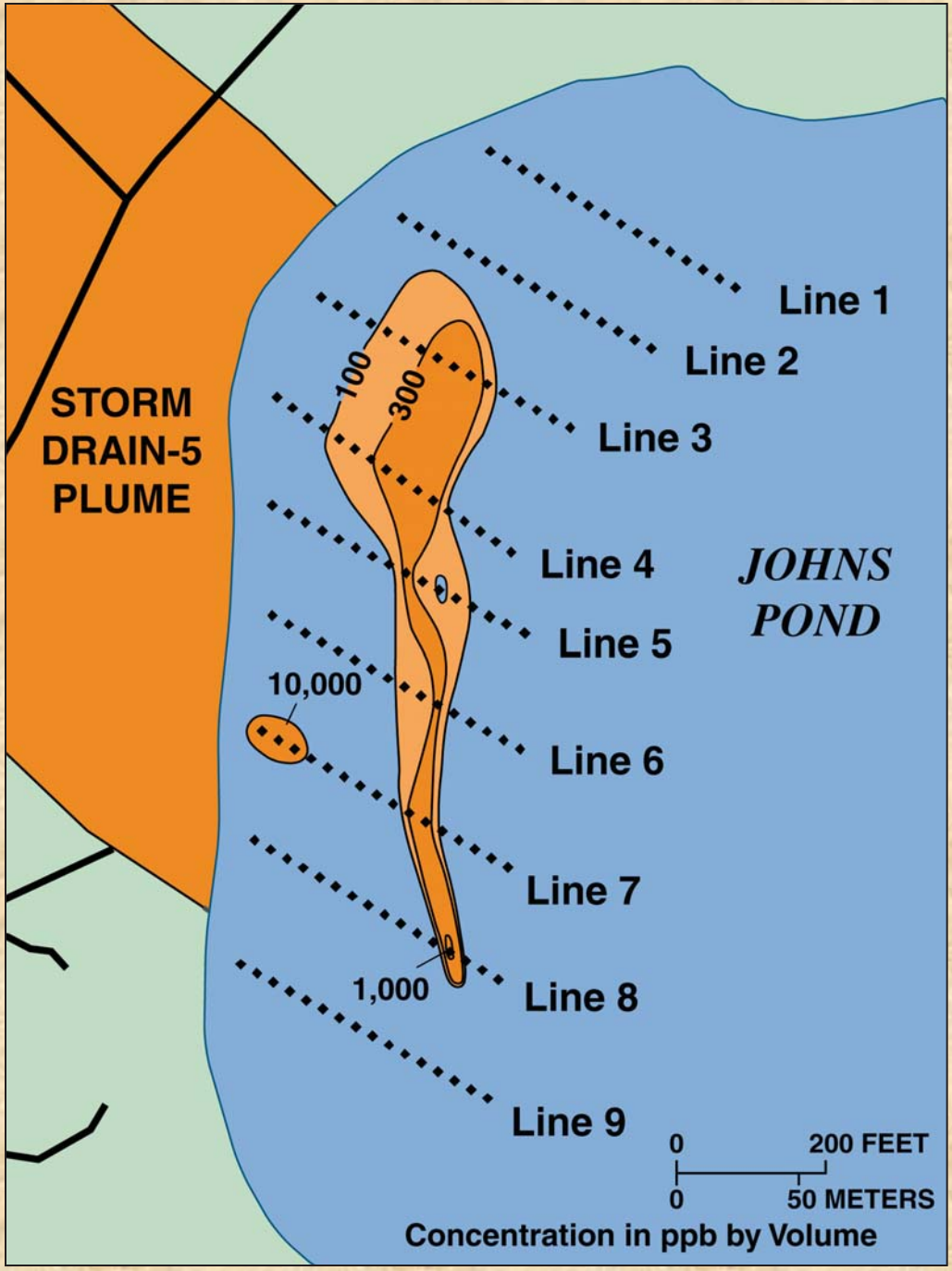


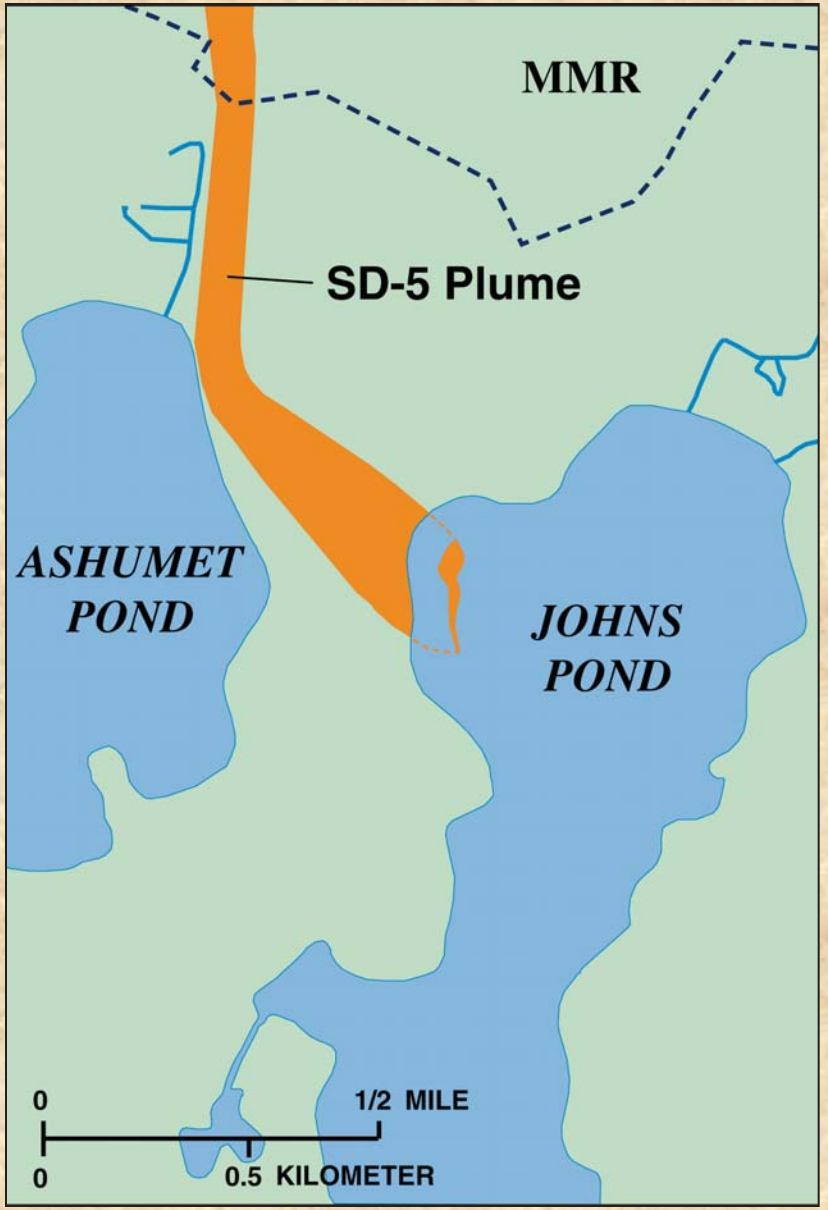
Ground-Water Flow-Through Kettle Ponds


MMR
SD-5 PLUME
55
50
45
40
ASHUMET POND
JOHNS POND
0
1/2
1 MILE
0
0.5
1 KILOMETER

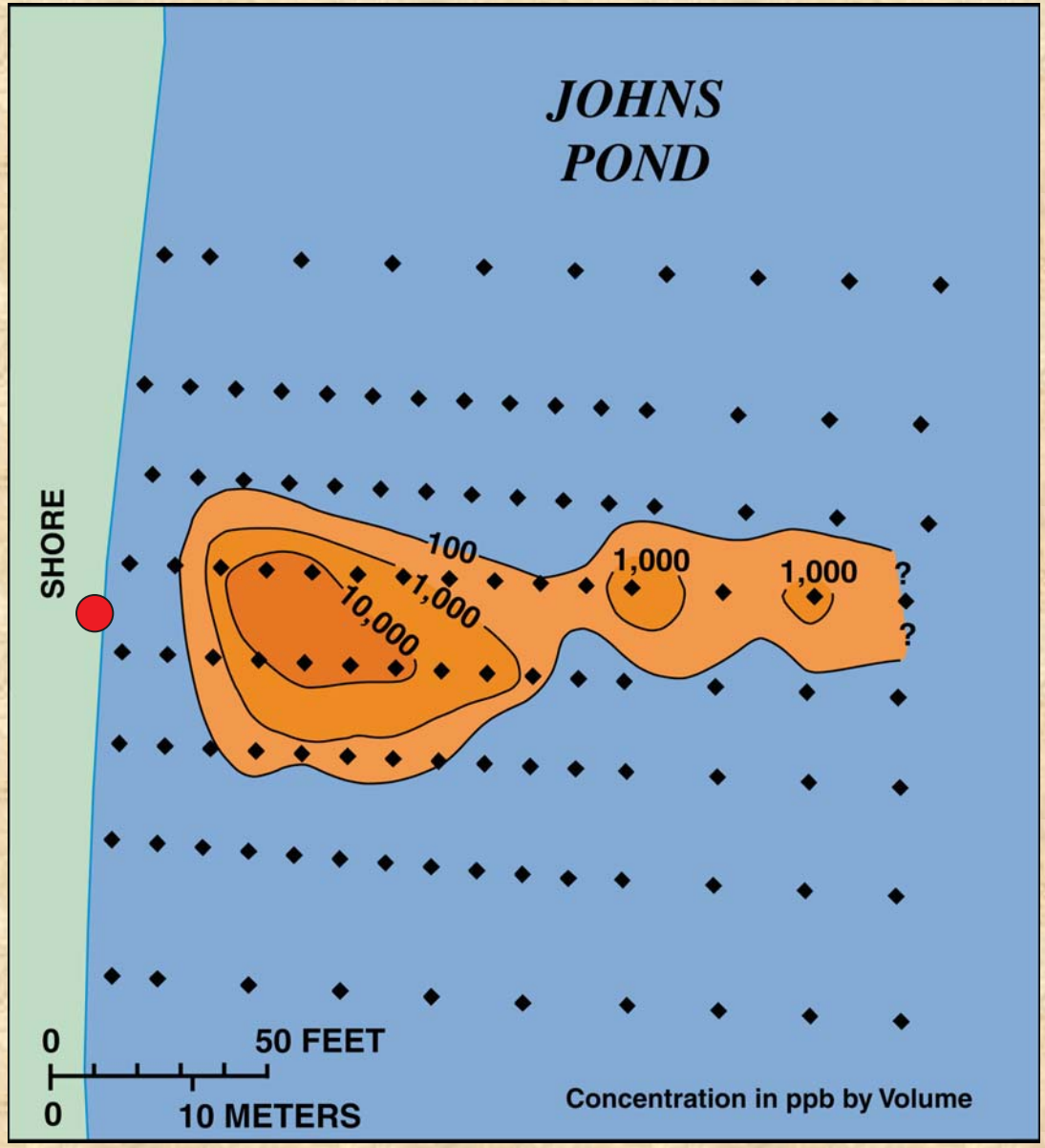

NORTH
SOUTH
Storm Drain-5 source area
MMR base boundary
Water table
Storm Drain-5 plume
Johns Pond
Sand and gravel aquifer
Bedrock
ALTITUDE, IN FEET
150
100
50
0
-50
-100
-150
-200
-250
-300
EXPLANATION
GENERAL GROUND-WATER FLOW DIRECTION

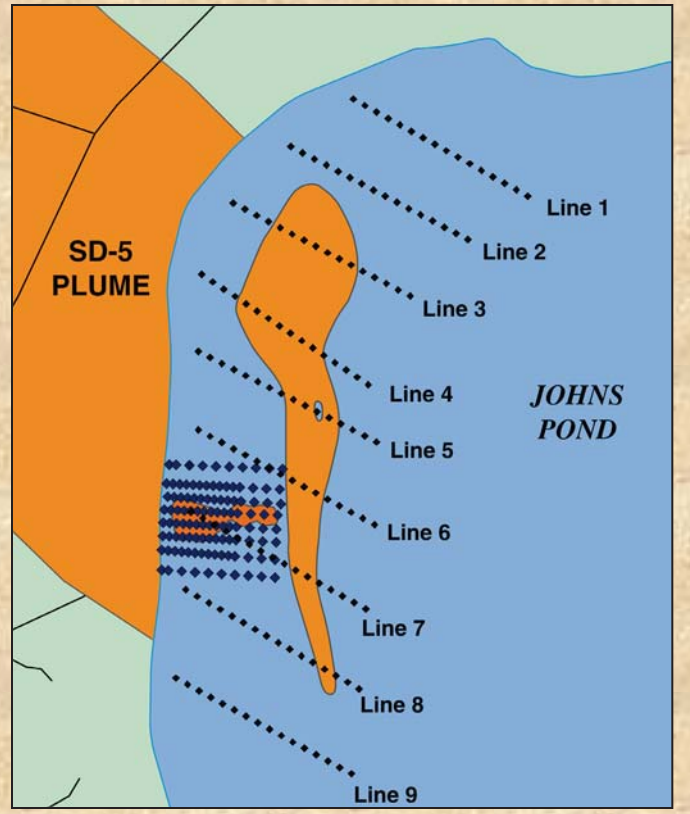

SCHEMATIC OF
DIFFUSION SAMPLER
VOCs
4-mil
Polyethylene
VOCs
40-mL
Glass
Vial
VOCs
Air
Diffusion of
VOCs
Saturated sediment
with dissolved VOCs

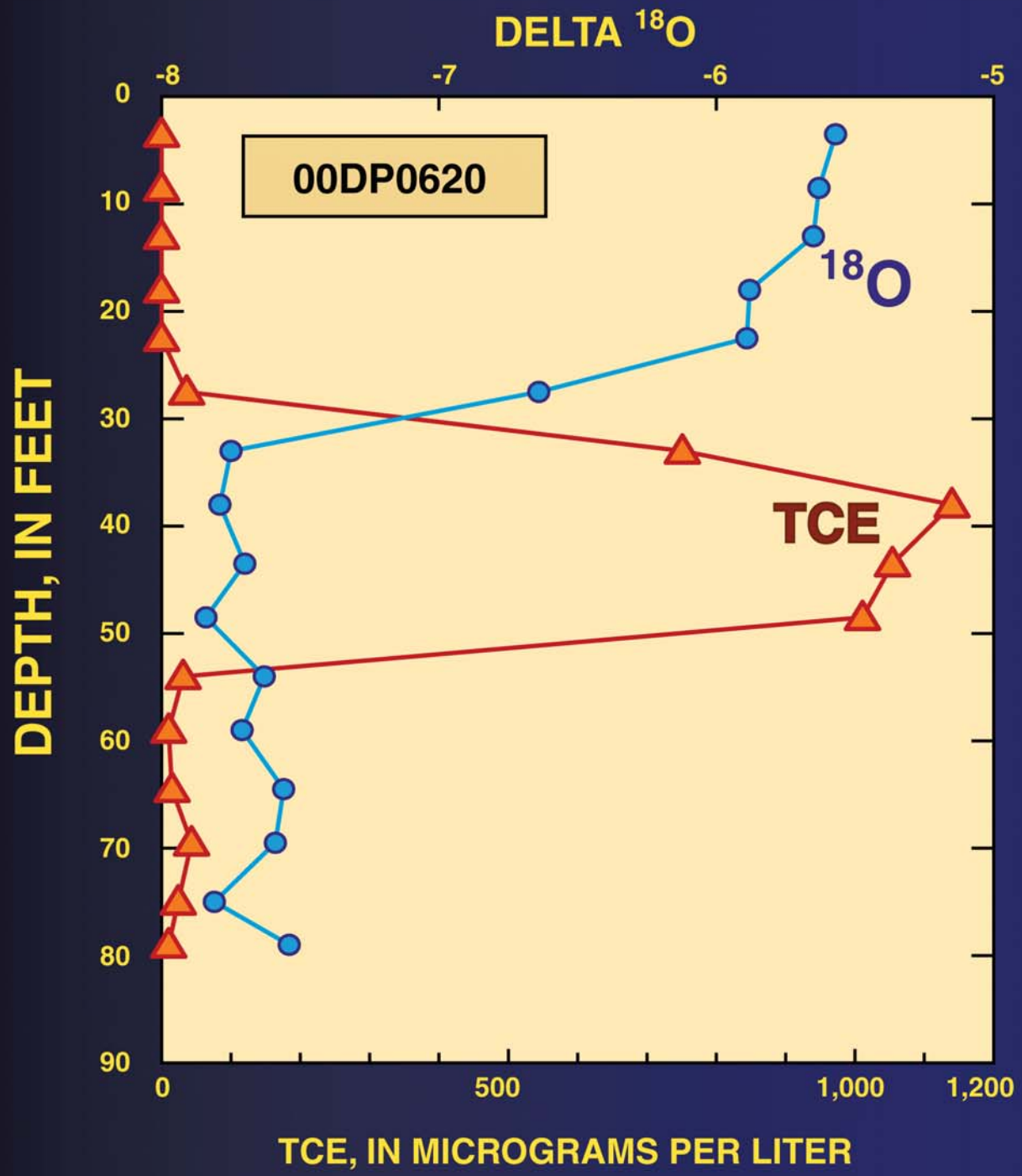




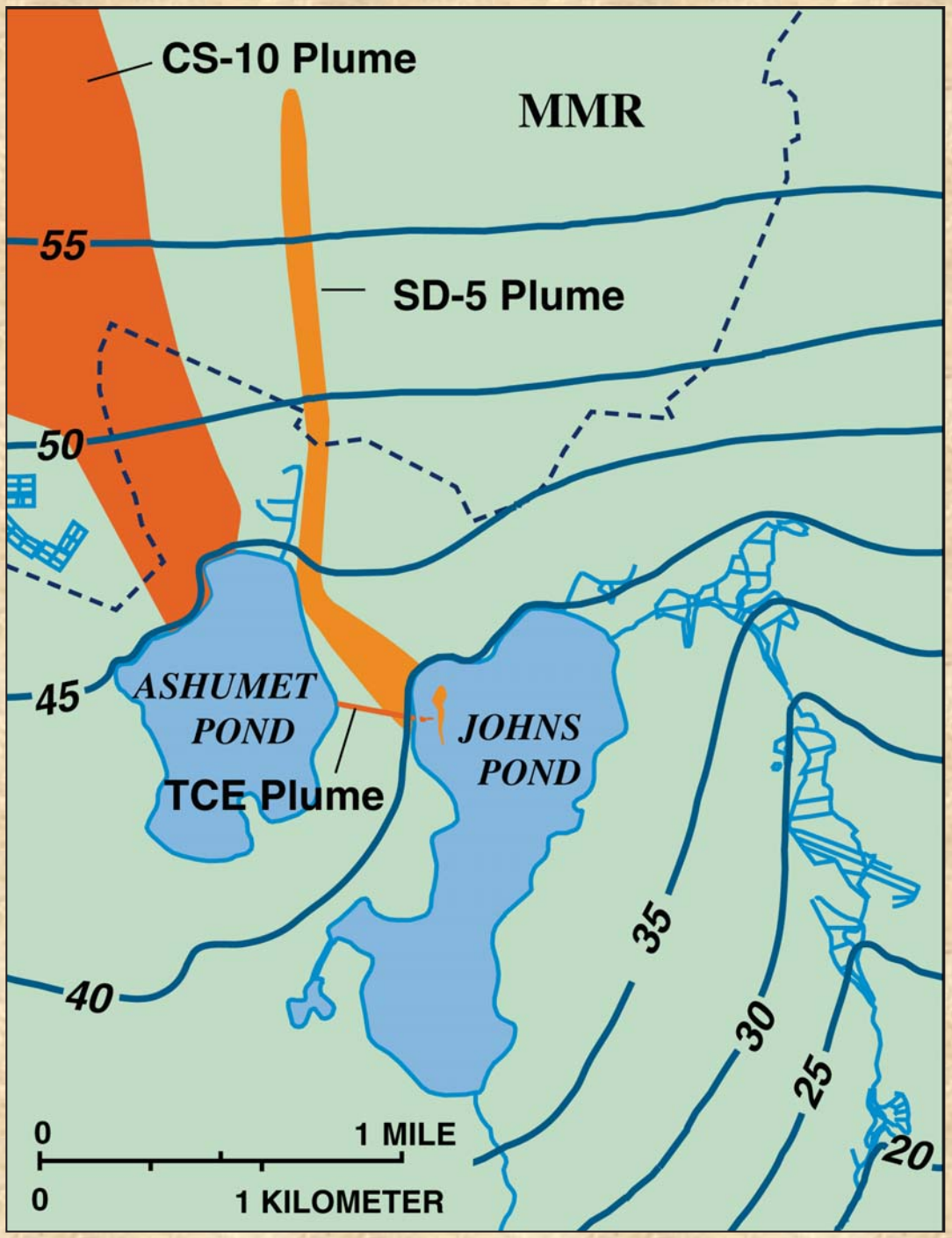
For TCE, 50 µg/L in water ≈ 1,000 ppb by volume in air

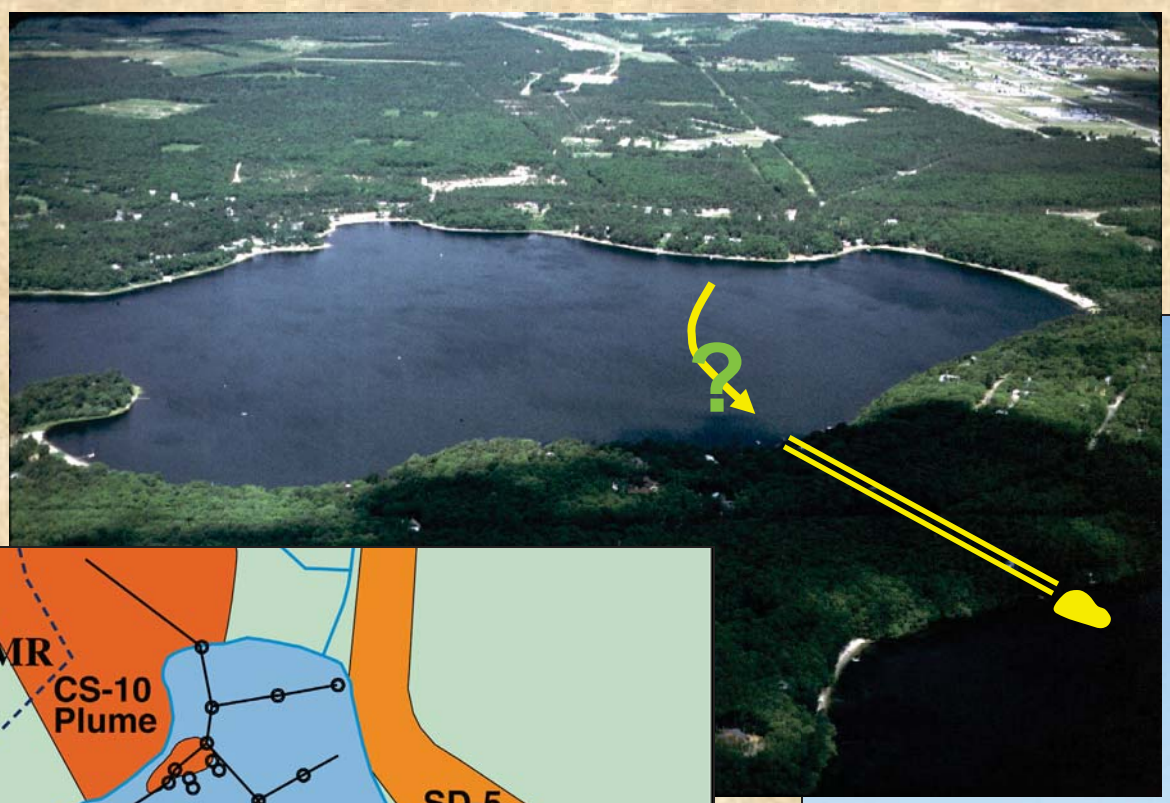

JOHNS
POND
SHORE
100
1,000
10,000
1,000
1,000
?
?
0
50 FEET
0
10 METERS
Concentration in ppb by Volume

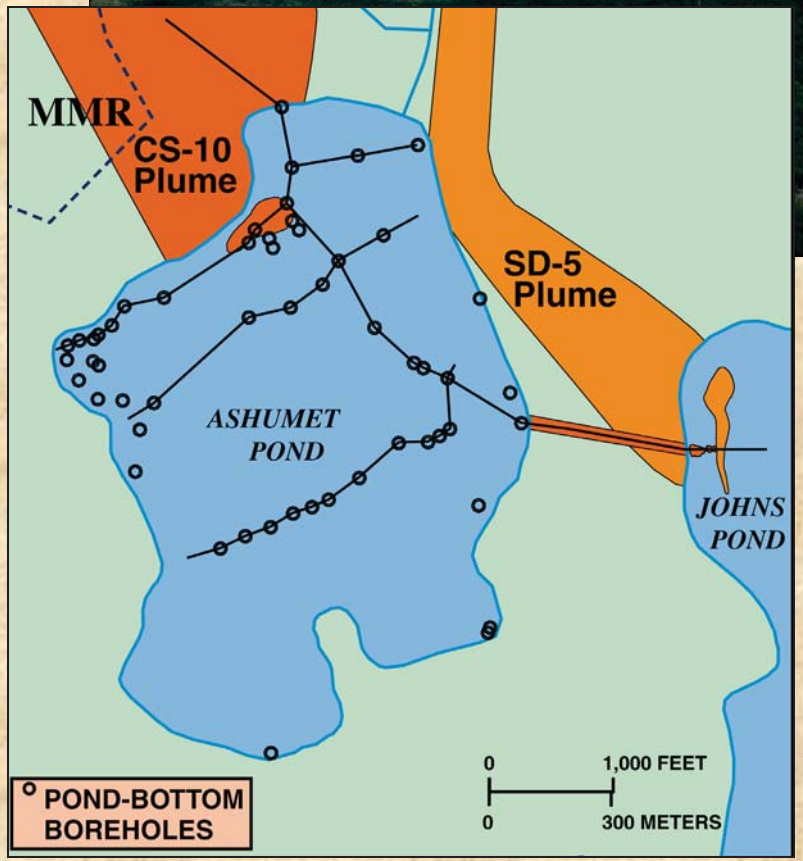

SD-5
PLUME
Line 1
Line 2
Line 3
Line 4
Line 5
Line 6
Line 7
Line 8
Line 9
JOHNS
POND

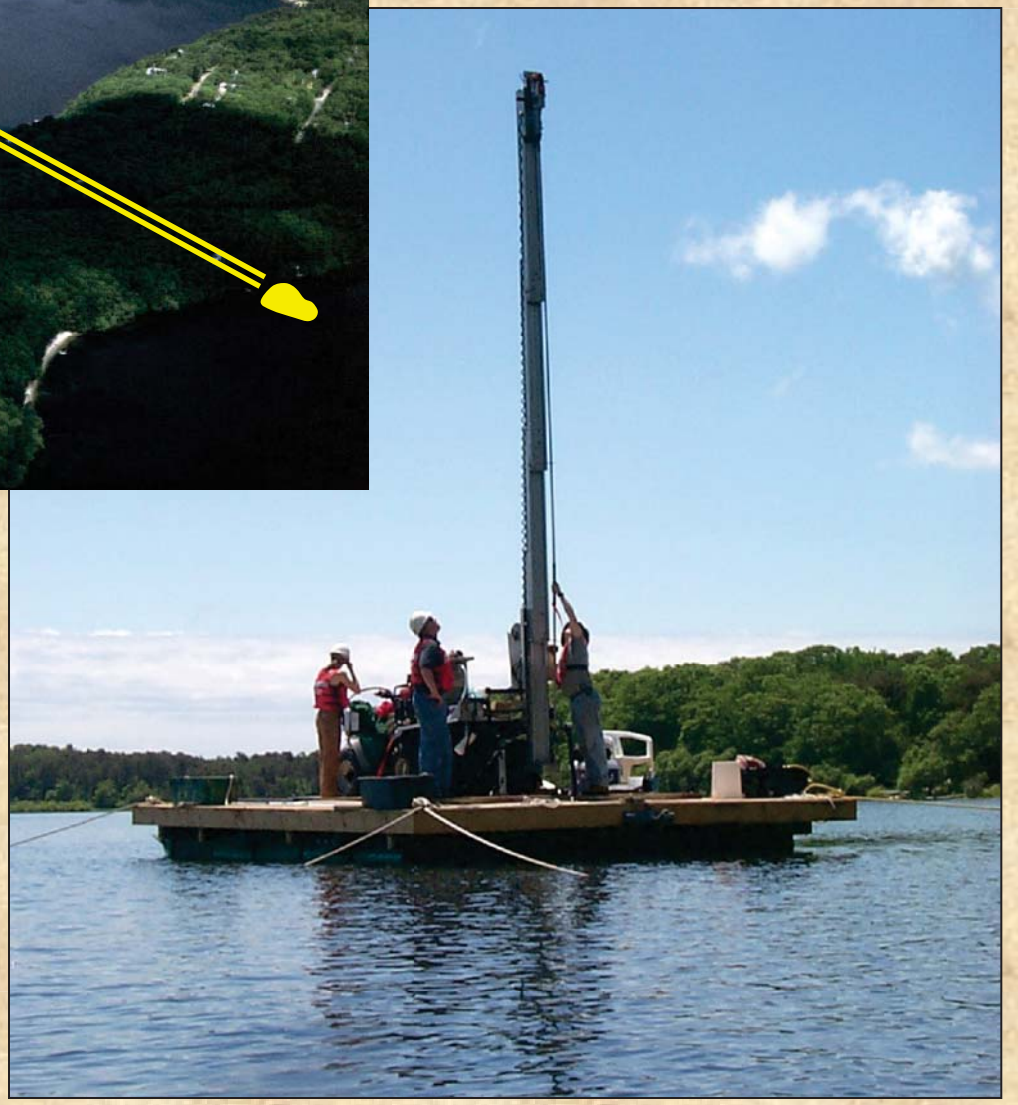

DELTA 18O
-8
-7
-6
-5
00DP0620
18O
TCE
DEPTH, IN FEET
0
10
20
30
40
50
60
70
80
90
0
500
1,000
1,200
TCE, IN MICROGRAMS PER LITER

USGS

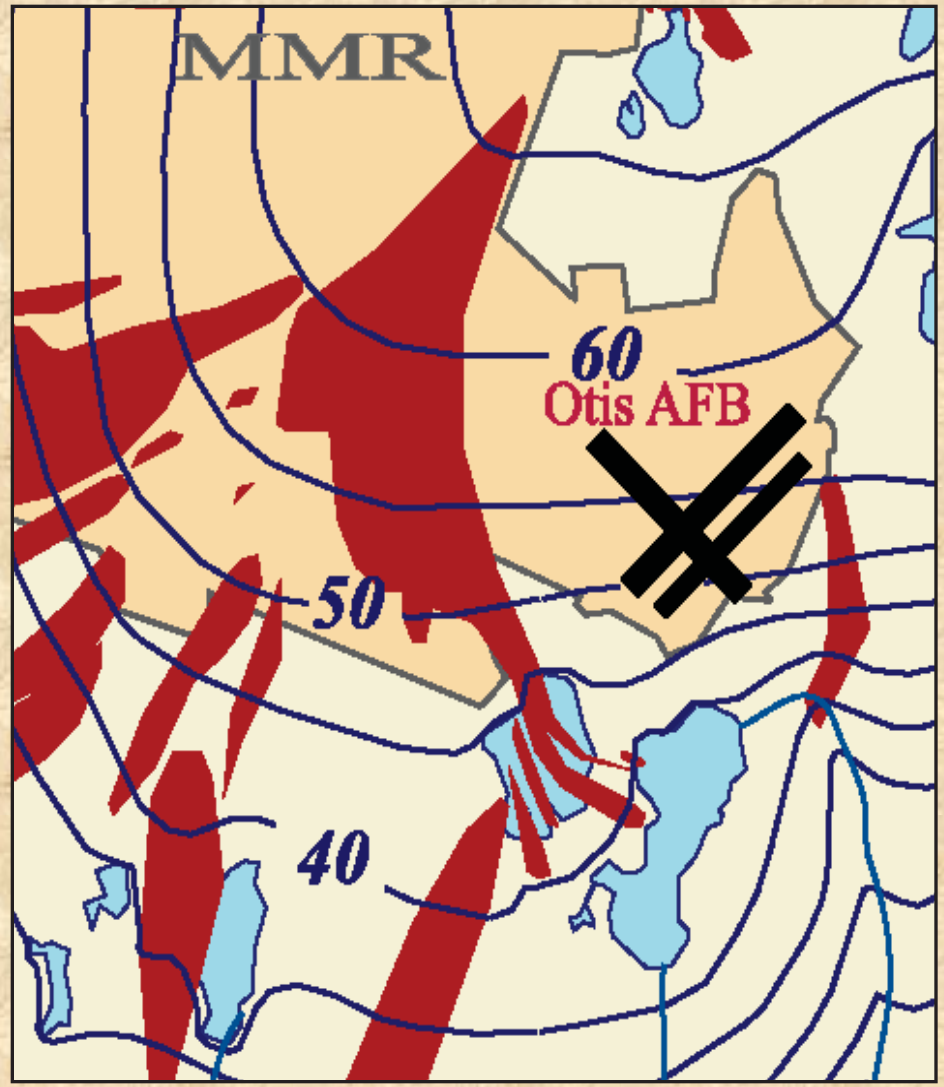

CS-10 Plume
MMR
55
SD-5 Plume
50
45
ASHUMET
POND
JOHNS
POND
TCE Plume
40
35
30
25
20
0
1 MILE
0
1 KILOMETER



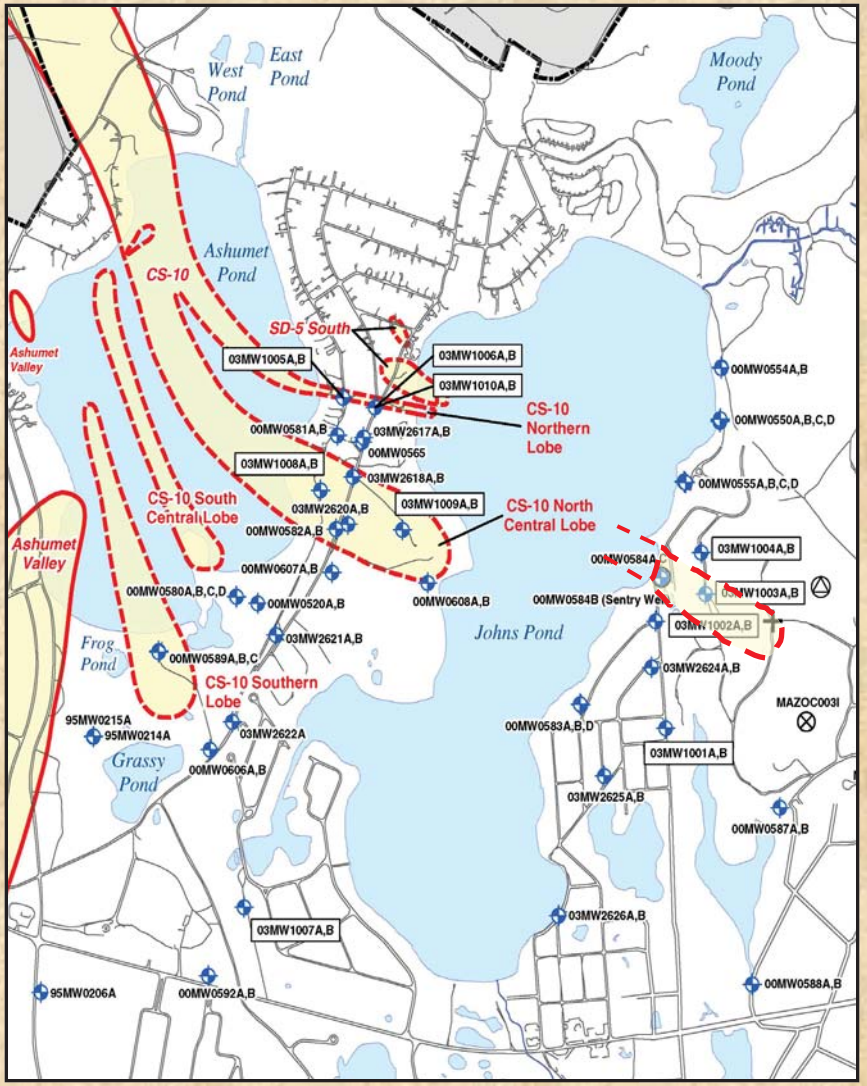

MMR
CS-10
Plume
SD-5
Plume
ASHUMET
POND
JOHNS
POND
0
1,000 FEET
0
300 METERS
POND-BOTTOM
BOREHOLES



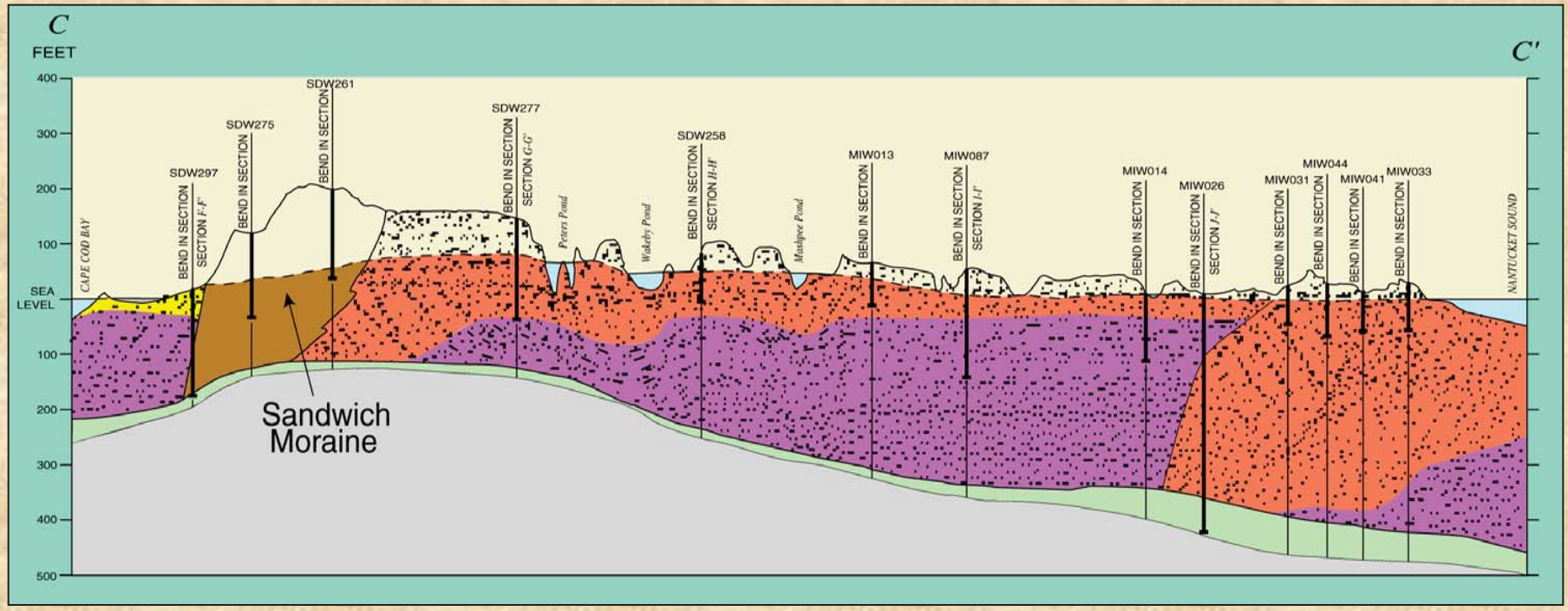
2005

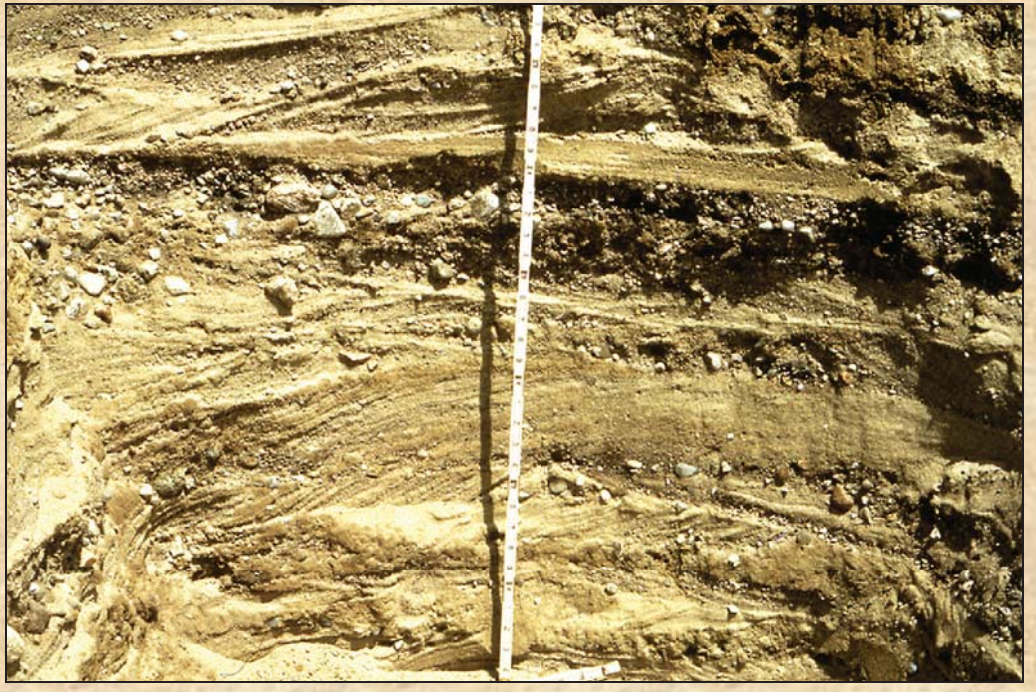


2 Miles



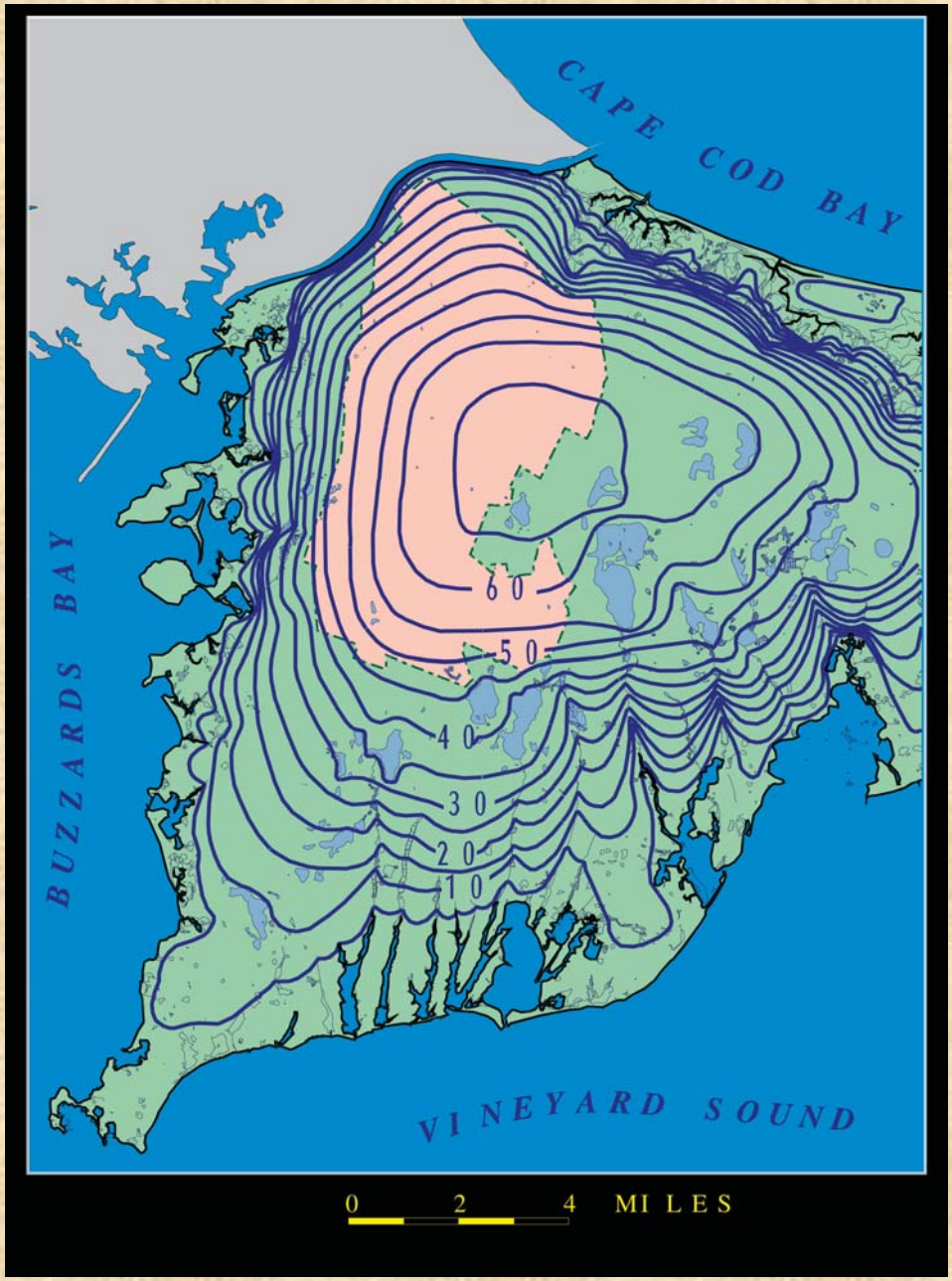
0.5 Miles


C
C'
FEET
400
300
200
100
SEA LEVEL
100
200
300
400
500
CAPE COD BAY
NANTUCKET SOUND
SDW297
BEND IN SECTION
SECTION F-F'
SDW275
BEND IN SECTION
SDW261
BEND IN SECTION
SDW277
BEND IN SECTION
SECTION G-G'
Peters Pond
Wakeby Pond
SDW258
BEND IN SECTION
SECTION H-H'
Mashpee Pond
MIW013
BEND IN SECTION
MIW087
BEND IN SECTION
SECTION I-I'
MIW014
BEND IN SECTION
MIW026
BEND IN SECTION
SECTION J-J'
MIW031
BEND IN SECTION
MIW044
BEND IN SECTION
MIW041
BEND IN SECTION
MIW033
BEND IN SECTION
Sandwich Moraine

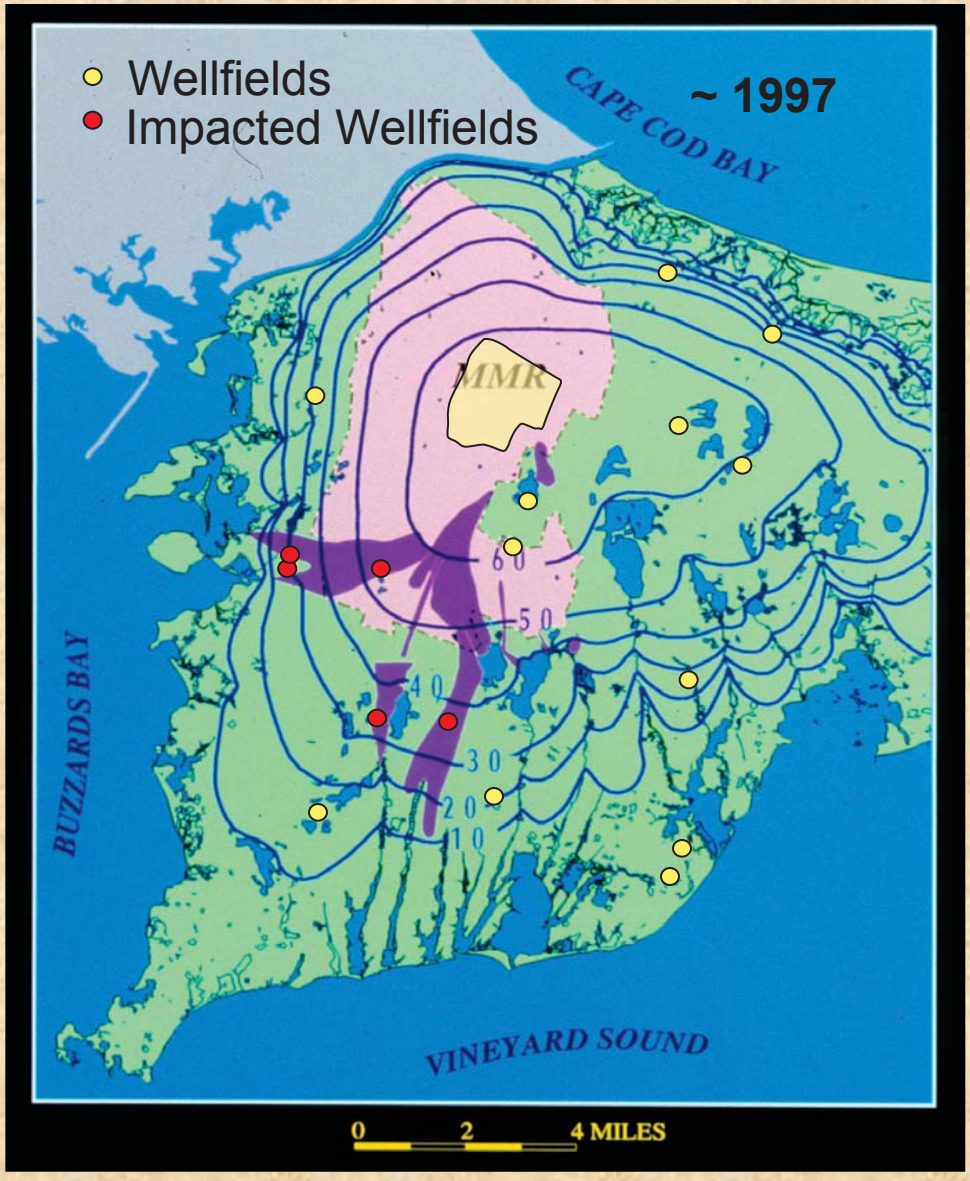


Cape Cod Recharge

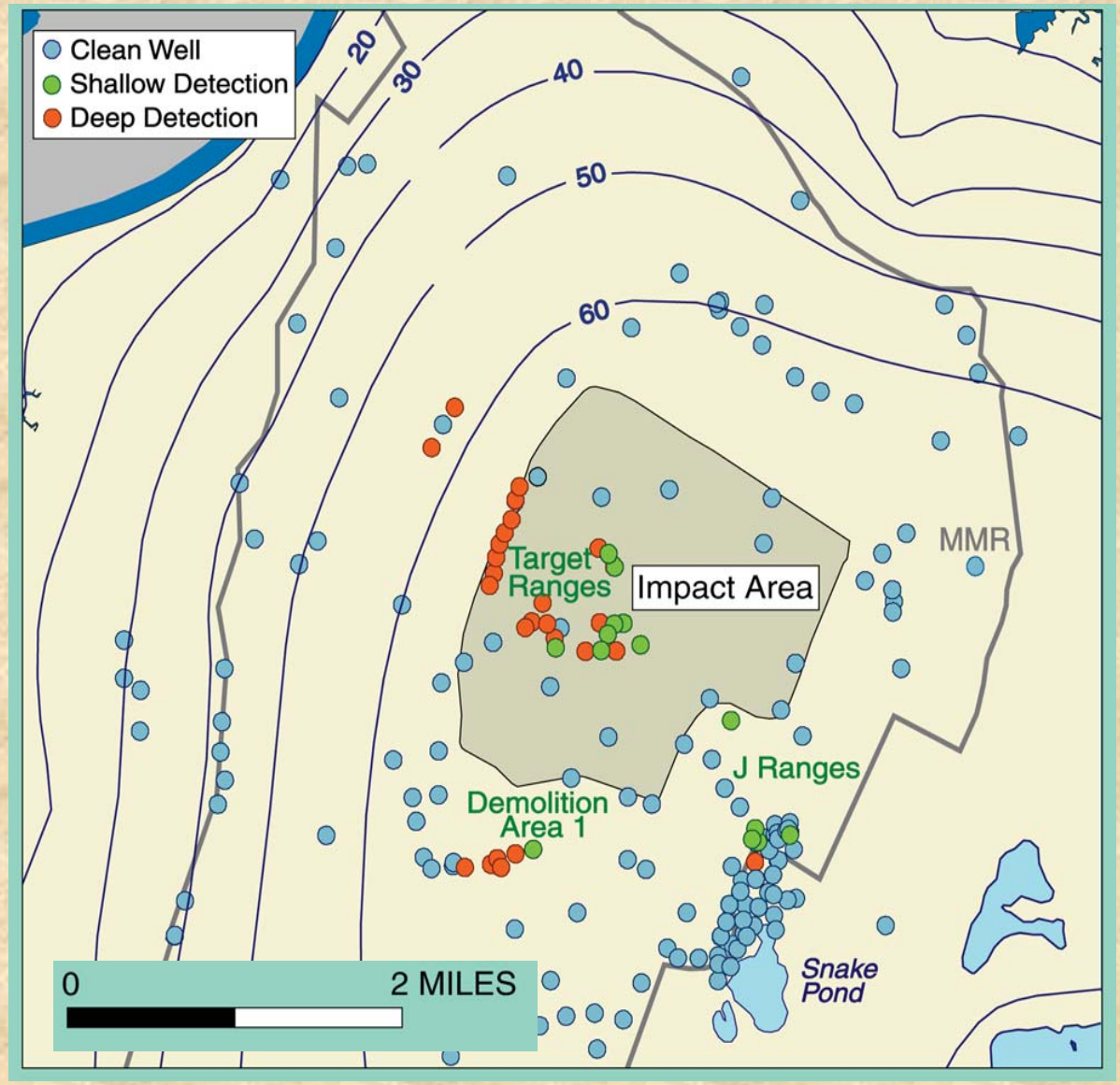
1985	22 in/yr
1998	26 in/yr
2007	27-32 in/yr



Public Water-Supply Wells



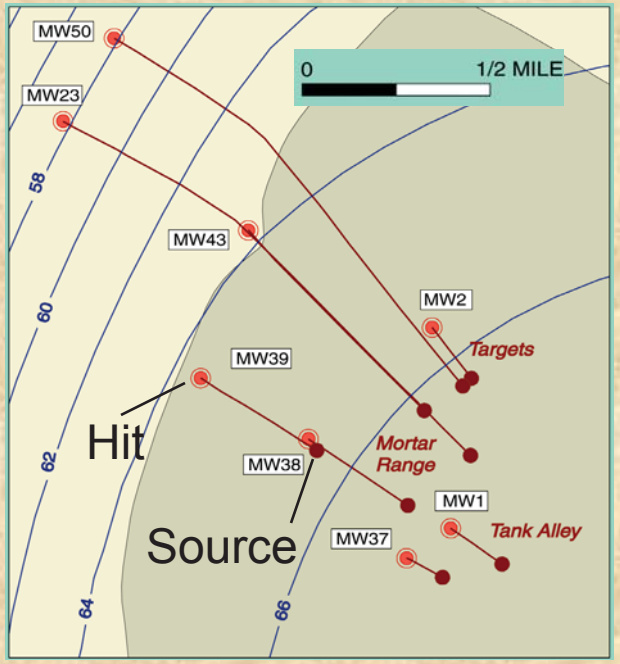
RDX Detections April 2000



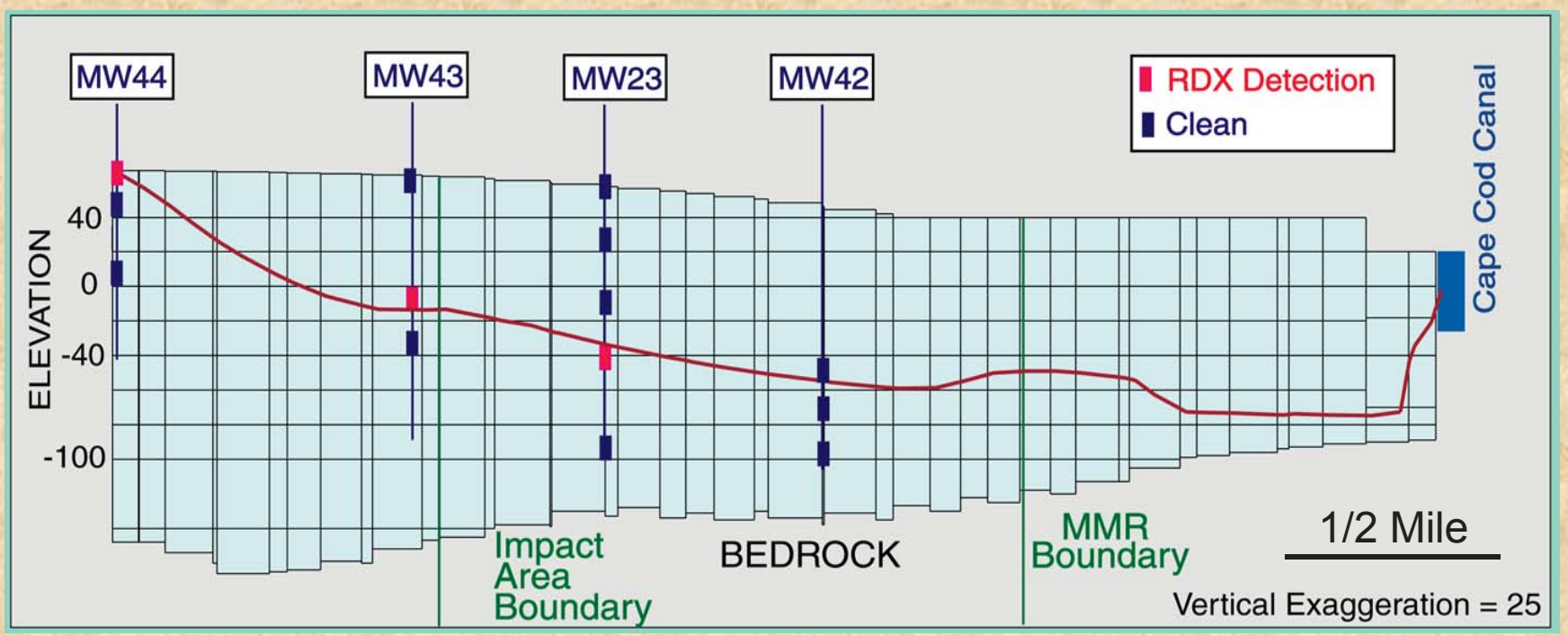
"Are You Sure the Kennedys Live Around Here?"

"After 62 years of shelling on New England's summer playground, the EPA orders the military to hold its fire"

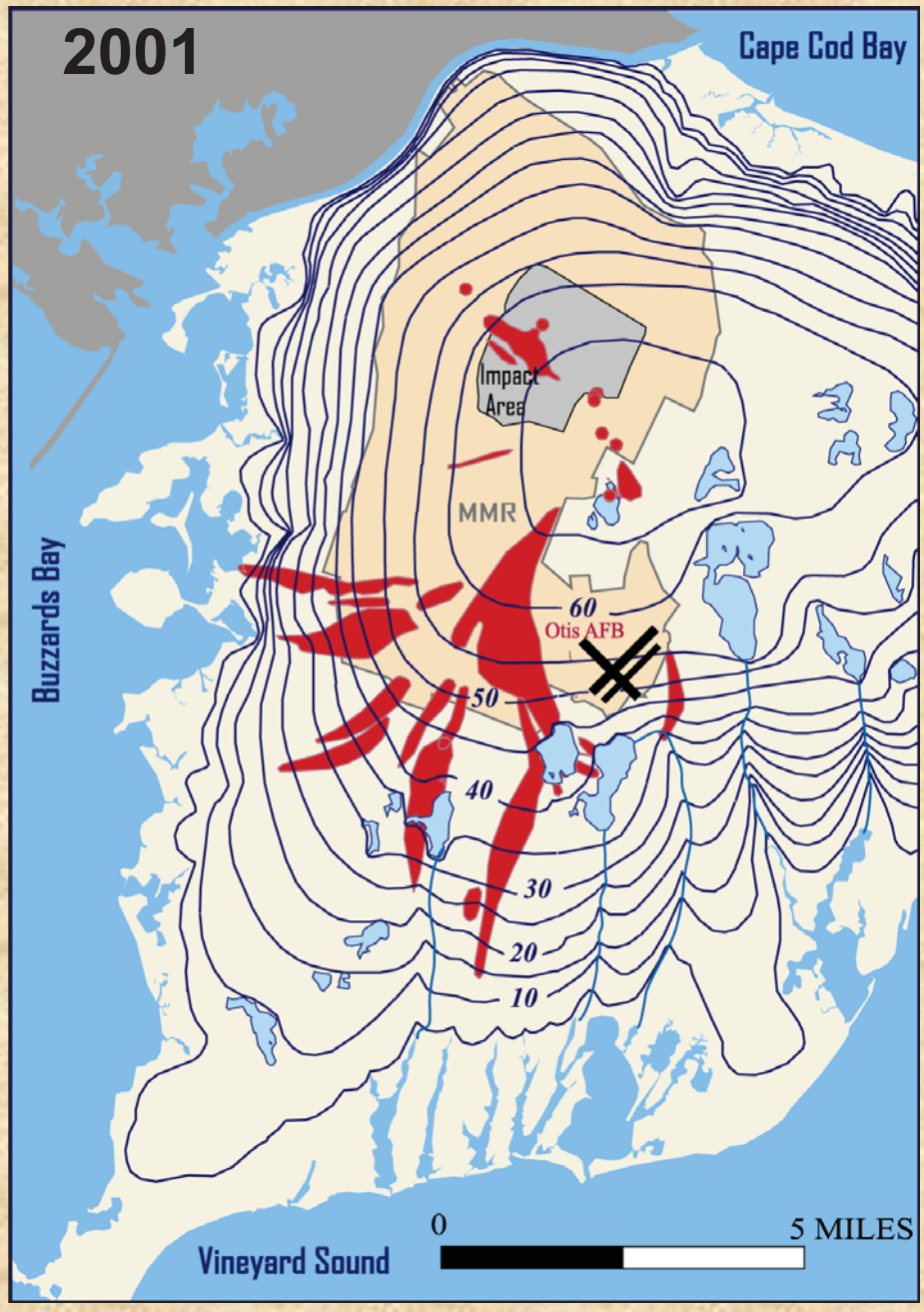
Outside Magazine, August 1997

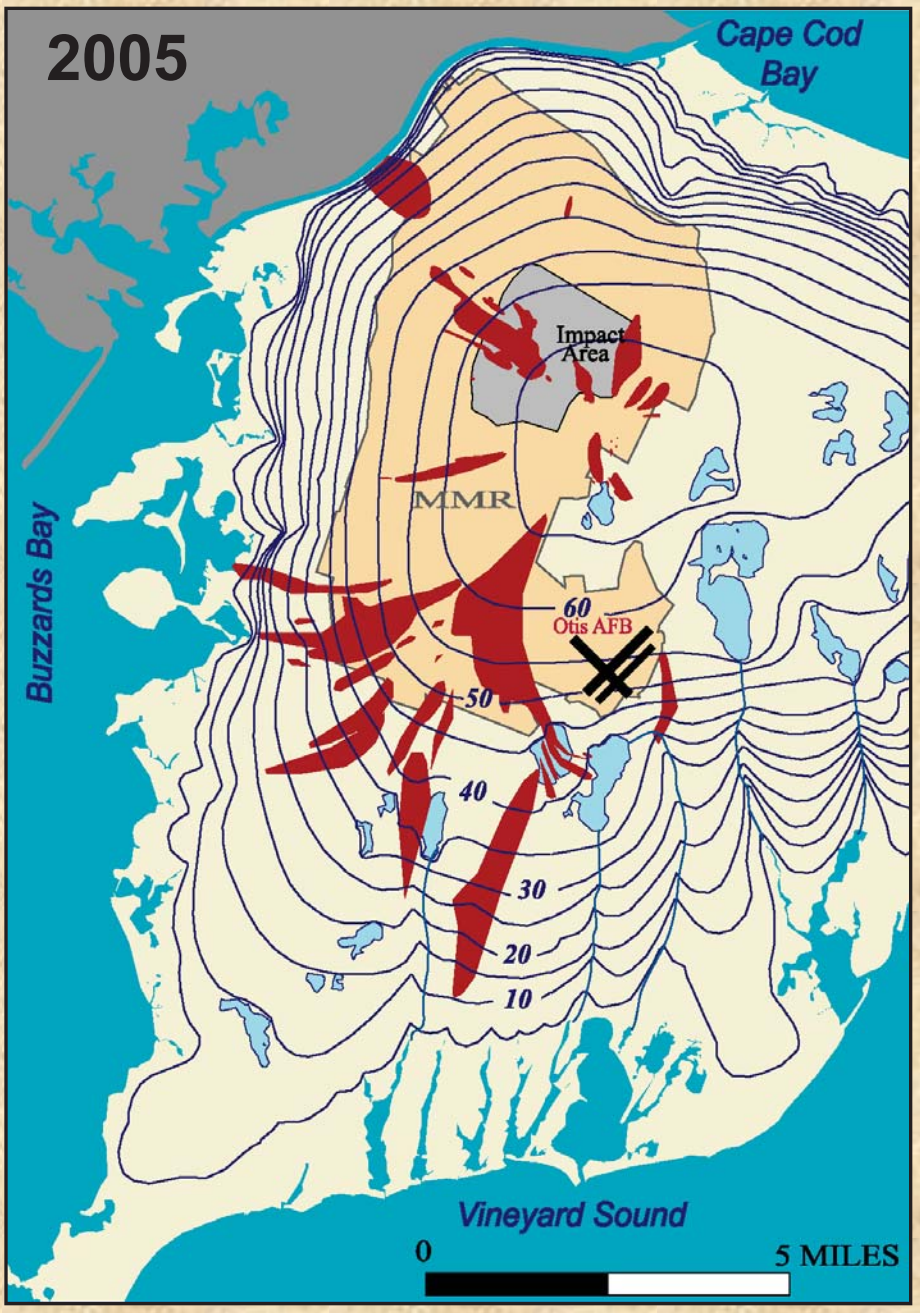

MW50
MW23
MW43
MW2
MW39
MW38
MW1
MW37
0
1/2 MILE
58
60
62
64
66
Targets
Mortar Range
Tank Alley
Hit
Source

24


MW44
MW43
MW23
MW42
RDX Detection
Clean
Cape Cod Canal
ELEVATION
40
0
-40
-100
Impact Area Boundary
BEDROCK
MMR Boundary
1/2 Mile
Vertical Exaggeration = 25

4,500 FT

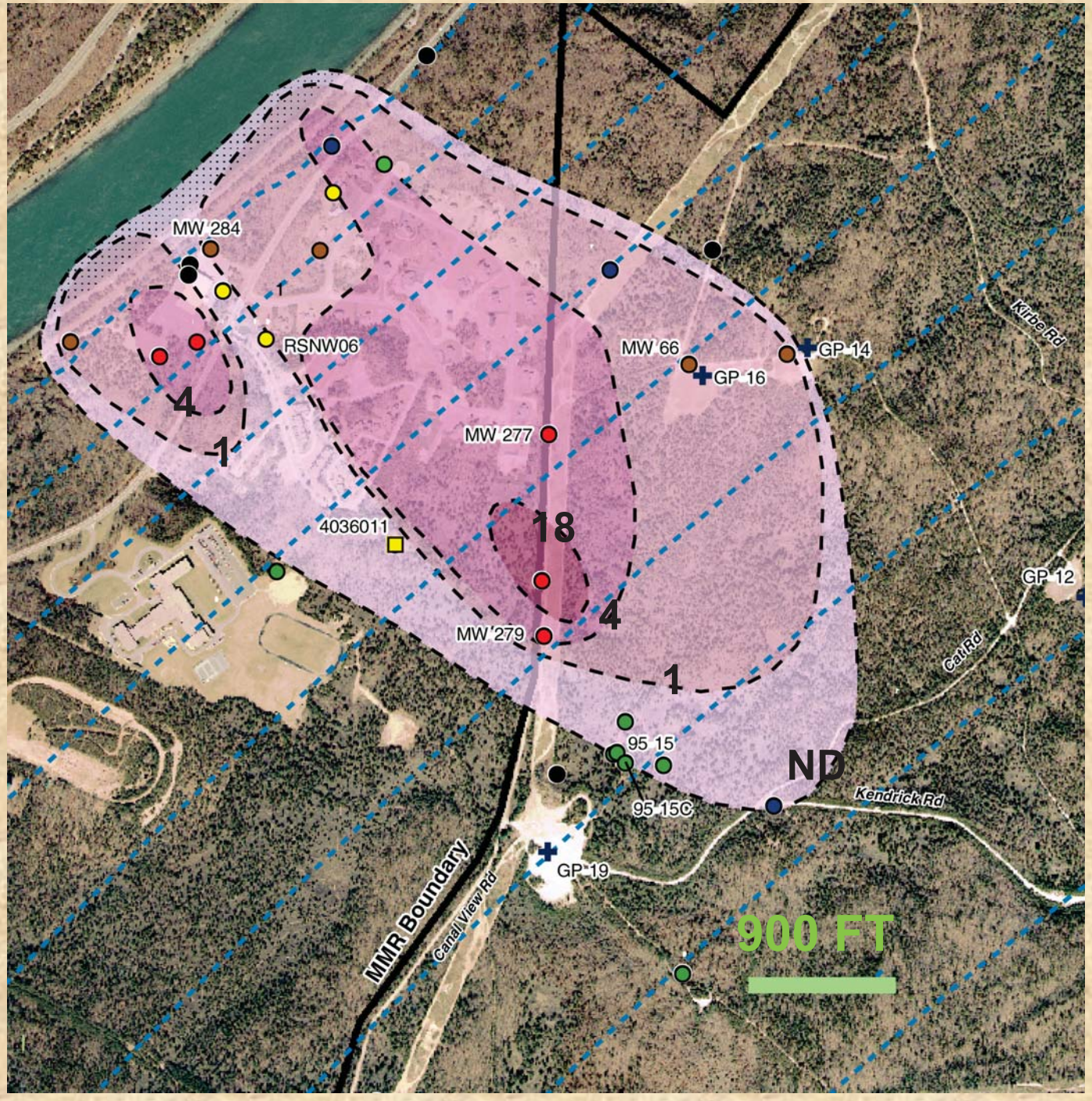

2001
Cape Cod Bay
Buzzards Bay
Impact Area
MMR
60
Otis AFB
50
40
30
20
10
Vineyard Sound
0
5 MILES


2005
Cape Cod Bay
Buzzards Bay
Impact Area
MMR
60
Otis AFB
50
40
30
20
10
Vineyard Sound
0
5 MILES

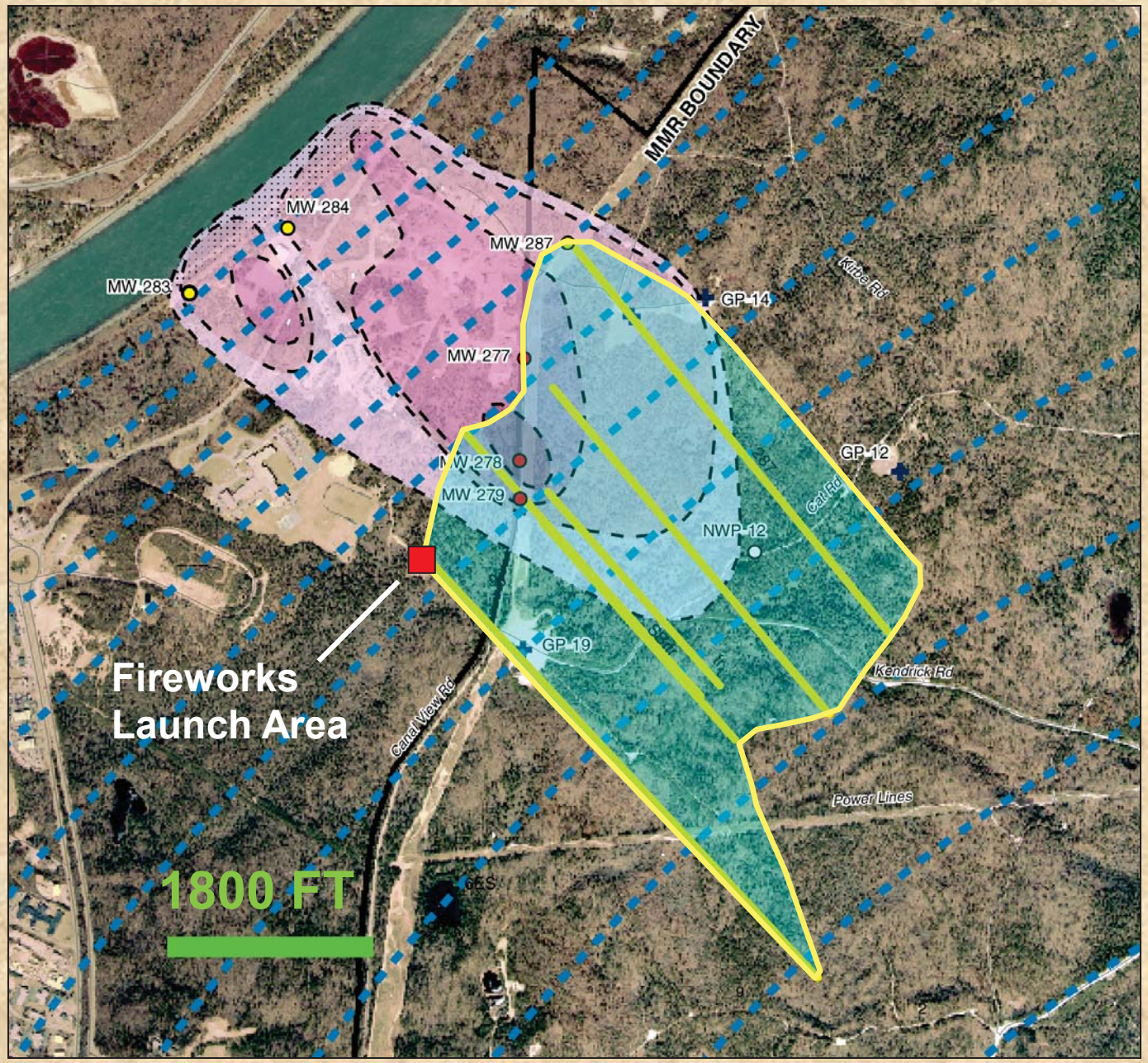
Perchlorate Plume

Dec. 2003

µg/L



Particle Backtracks from Wells with Perchlorate Detections



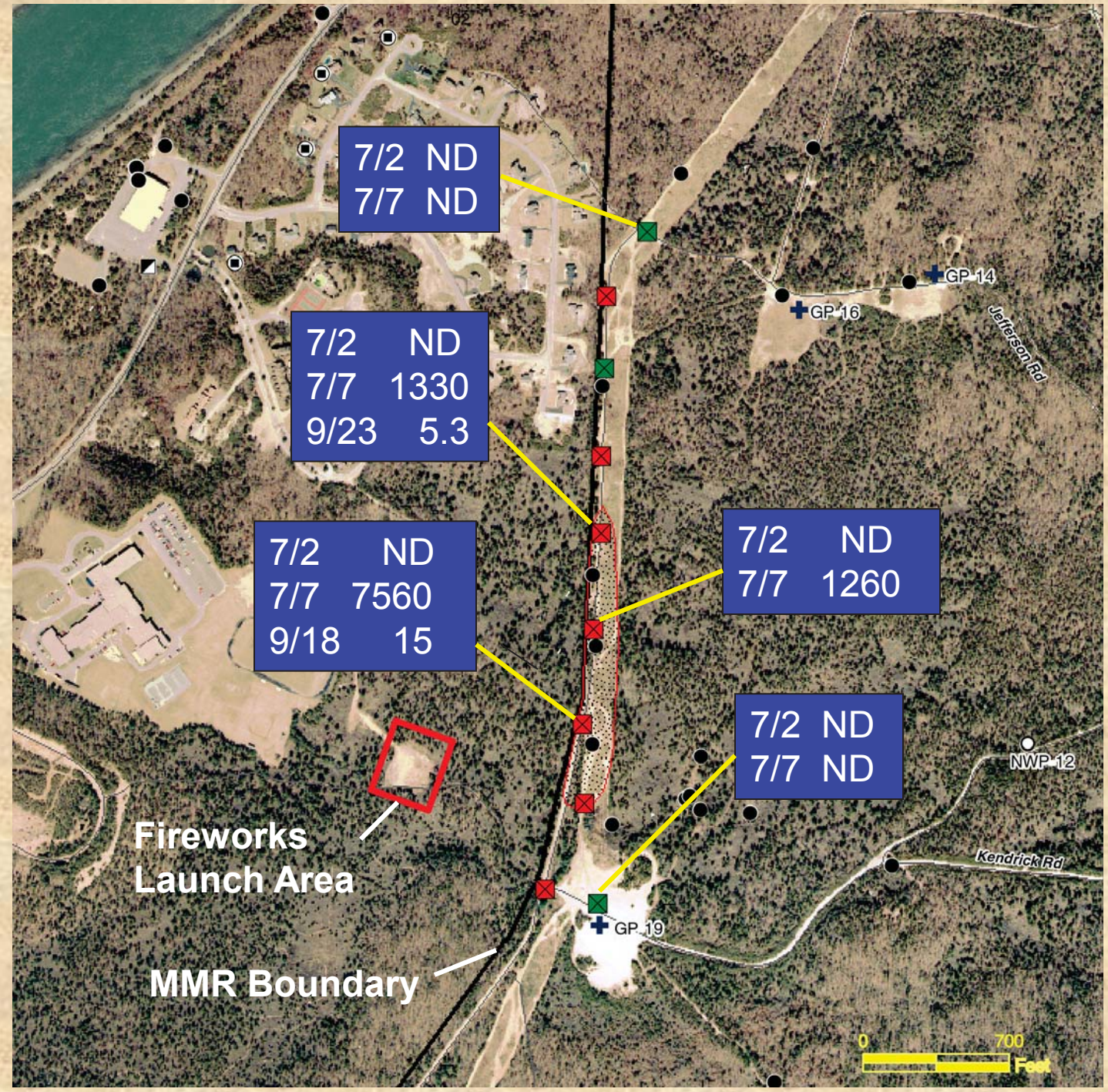
July 5, 2003

Perchlorate in Soils

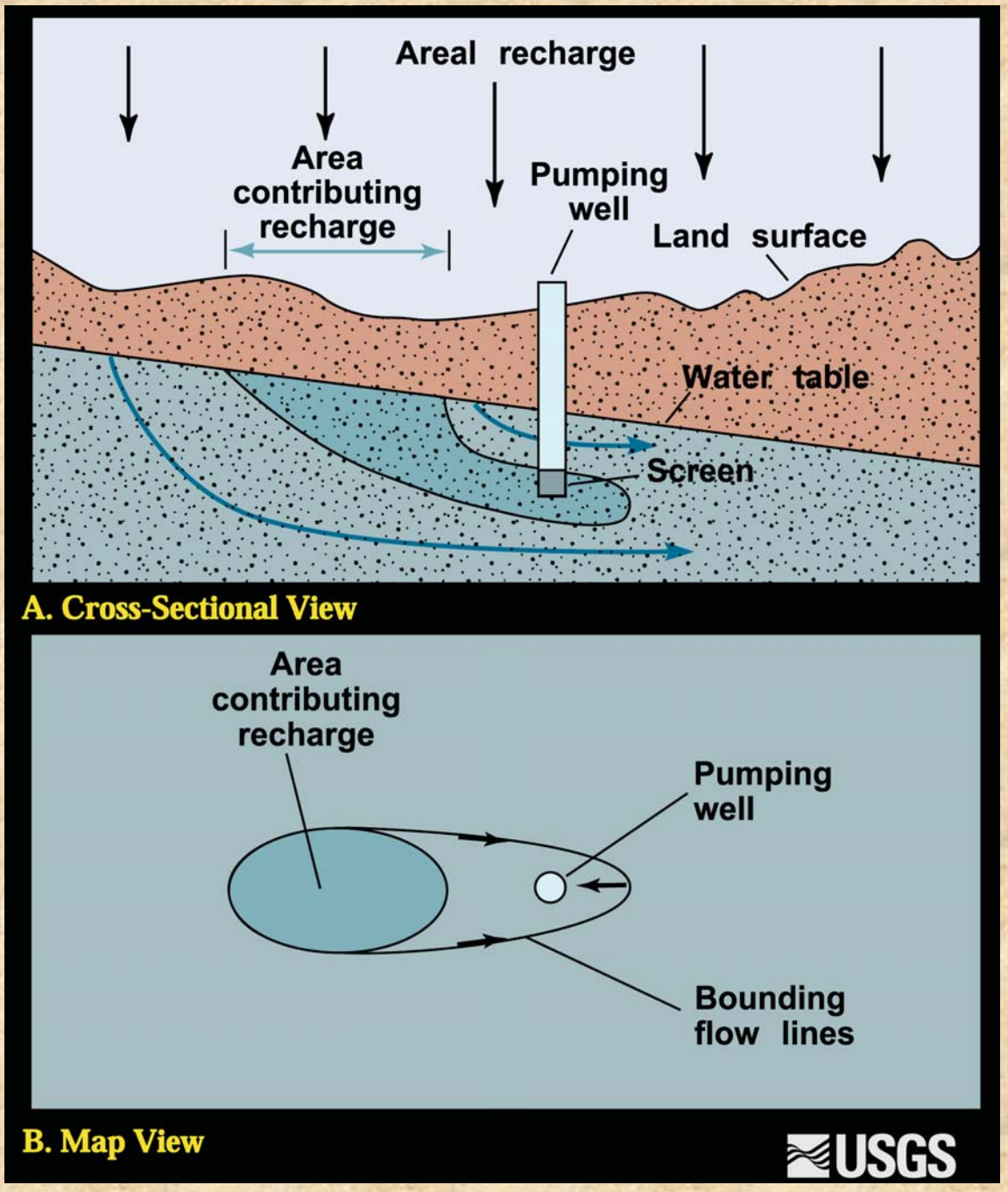
µg/Kg

2003

Fireworks debris 10/23/03 302 - 34,200 µg/Kg

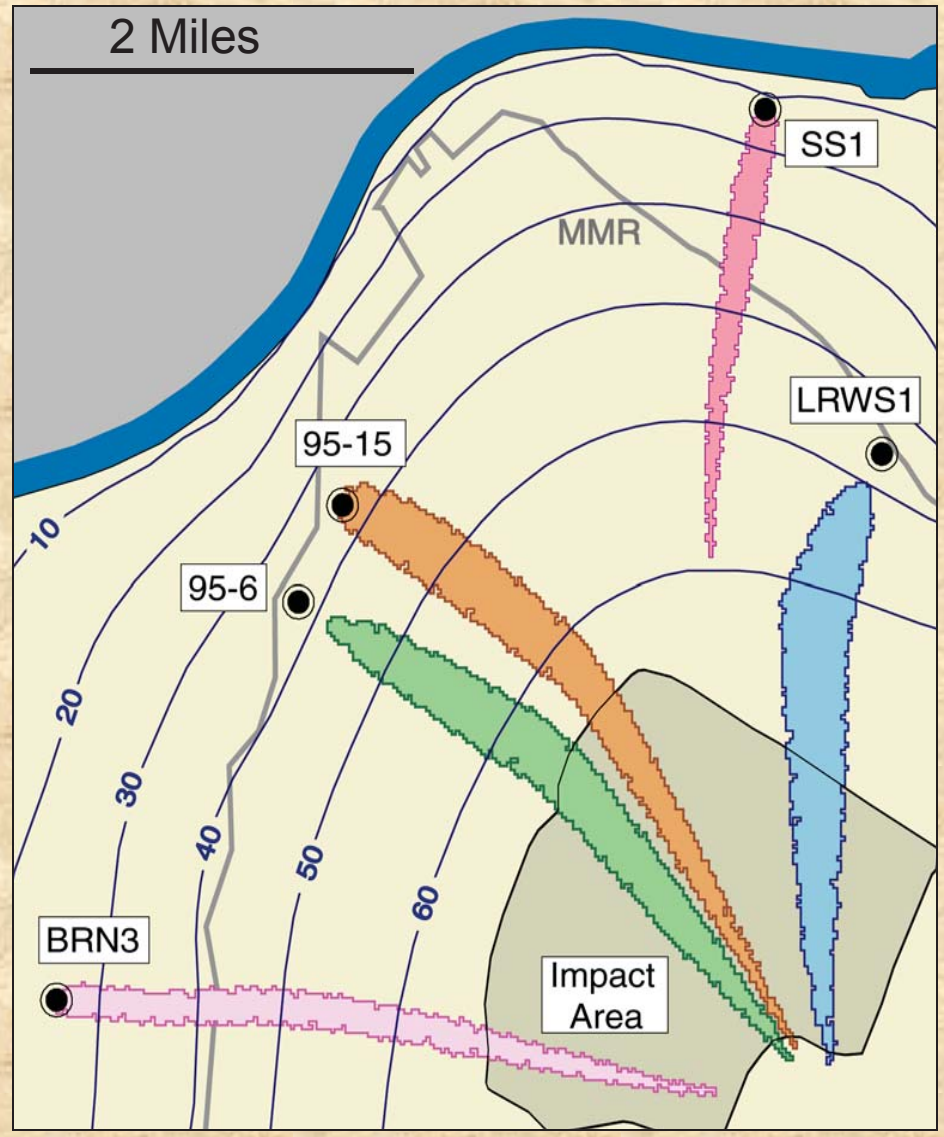


Area Contributing Recharge to a Pumping Well

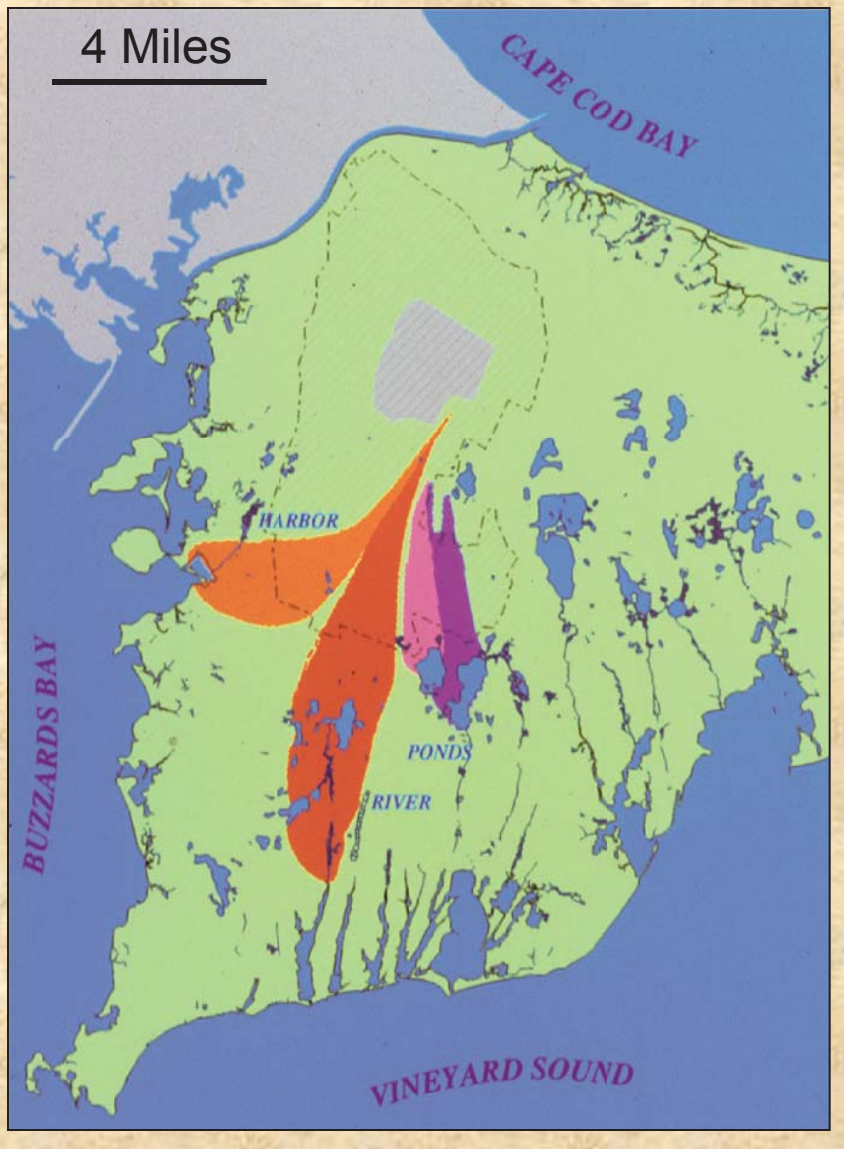


Ground-Water Contributing Areas

Pumping Wells



Ponds, Rivers, and Bays



The Ground-Water Recharge Mosaic

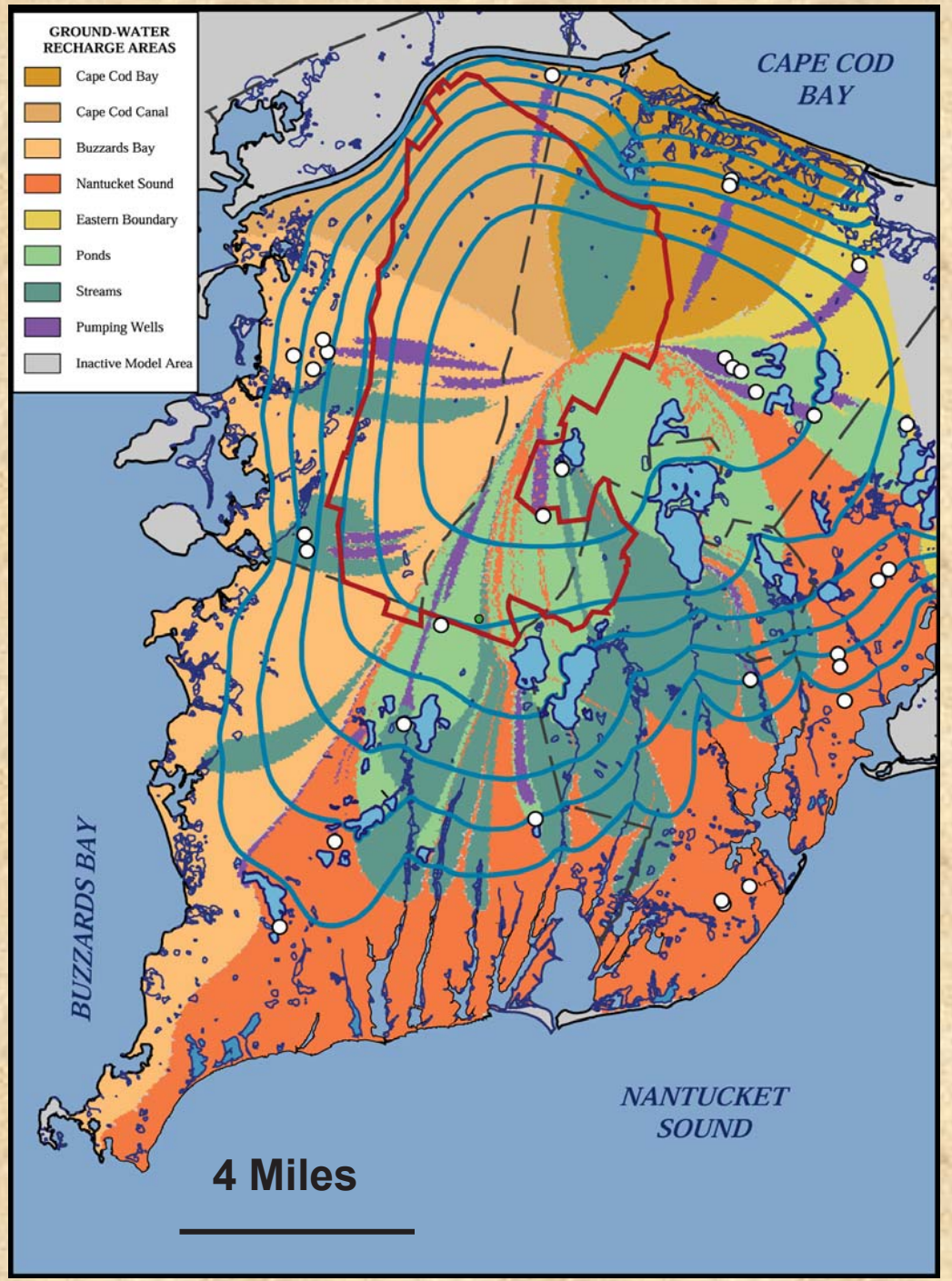
Water Budget

In:

Natural recharge	180 Mgal/d
Onsite systems	7 Mgal/d

Out:

Wells	10 Mgal/d
Streams	64 Mgal/d
Coast	113 Mgal/d



Plumes and Treatment Systems

Massachusetts Military Reservation

April 2007

- Solvents and Fuels
- Explosives and Perchlorate
- Extraction Well
- Injection Well or Infiltration Gallery

Source: AFCEE/IRP and AEC/IAGWSP
April 4, 2007

Current (2007) Ground-Water Treatment Systems

	IRP	IAGWSP
Major contaminants	Solvents and Fuels	Perchlorate and Explosives
No. of Plumes Being Treated	11	3
No. of Extraction Wells	53	9
Total Extraction Rate (Mgal/d)	17.5	1.2

Sagamore Lens of Cape Cod Aquifer (2003)

(Cape Cod Canal to the Bass River)

Natural Recharge (MGal/d)	252
Pumping for Water Supply(MGal/d)	17.3
Wastewater Recharge (MGal/d)	14.8

Hydro Head Scratchers

- What is the Recharge Rate?
- How Does “Subtle” Geologic Structure Affect the Plumes?
- How Fast Are Contaminants Transported in the Unsaturated Zone?
- How Can Future Plume Cleanup Decisions Better Incorporate Water-Supply Planning?

The Future

- Influent of the Treatment Systems Will Approach Non-Detect Levels
- Plumes Will Still Be Present, but Dilute and Patchy
- Focus Will Be Plume Management in Context of Water Supply
- Activists Will Be Water-Supply Managers and Local Officials

http://ma.water.usgs.gov/capecodtoxics