Age Dating of Ground Water in the Cook Inlet Basin

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Two Environmental Tracers Were Used to Estimate Ground-Water "Age"

- ✓ Tritium
- ✓ Chlorofluorocarbons

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Environmental Tracers

- Trace movement of ground water
- Estimate velocity of water movement
- Locate recharge and discharge areas
- Estimate recharge rates
- Refine ground-water-flow models
- Estimate loading of solutes
- Determine ground-water “age”
- In general, to improve understanding of the hydrology and to make better predictions

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Characteristics of an Ideal Environmental Tracer

- Moves with water
- Not subject to
  - Chemical interactions
  - Physical interactions
  - Microbial degradation
- Easy to sample
- Cheap to analyze
- Reproducible results

USGS

Environmental Tracers

- Artificial dye, bromide, chloride
- Stable isotopes: H, He, C, N, O, Si, S, Cl
- Wastewater products: surfactants, caffeine, pharmaceuticals, nitrates
- Pollutants: fuels, MTBE, herbicides
- Air: tritium (^3H), chlorofluorocarbons (CFC's), SF_6

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Apparent Ground-Water Age

- Time elapsed since recharge
- Not the age of the water molecule

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Tritium

- ^{3}H
- Radioactive -- half life of 12.4 years
- Natural precipitation content: 5-20 tritium units
- Testing of atomic bombs
- 2,950 TU in precipitation in Palmer during 1963
- 5-38 TU in precipitation in Anchorage during 1994
- Water containing ^{3}H >1.3 TU is considered “modern” (post 1951)

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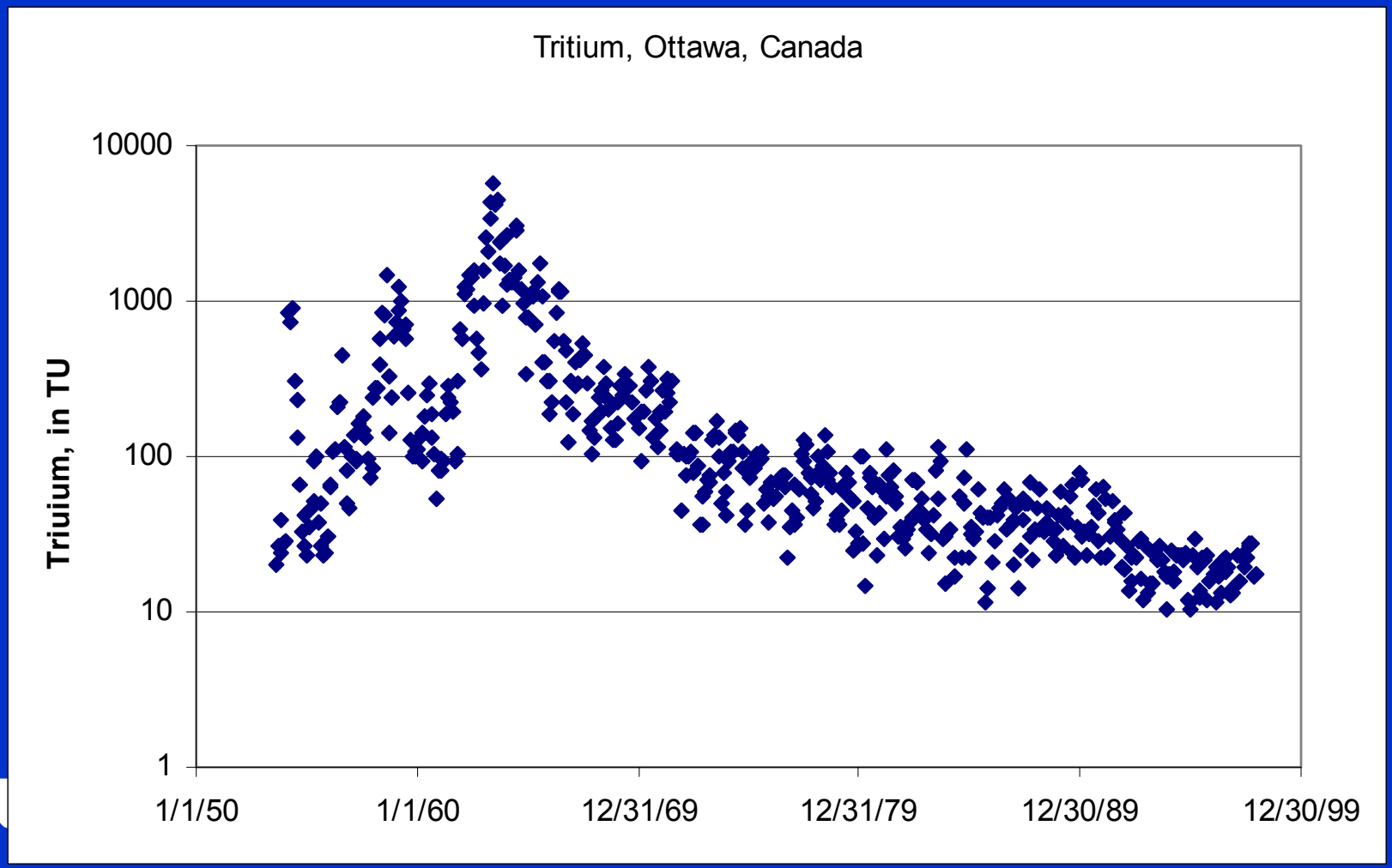
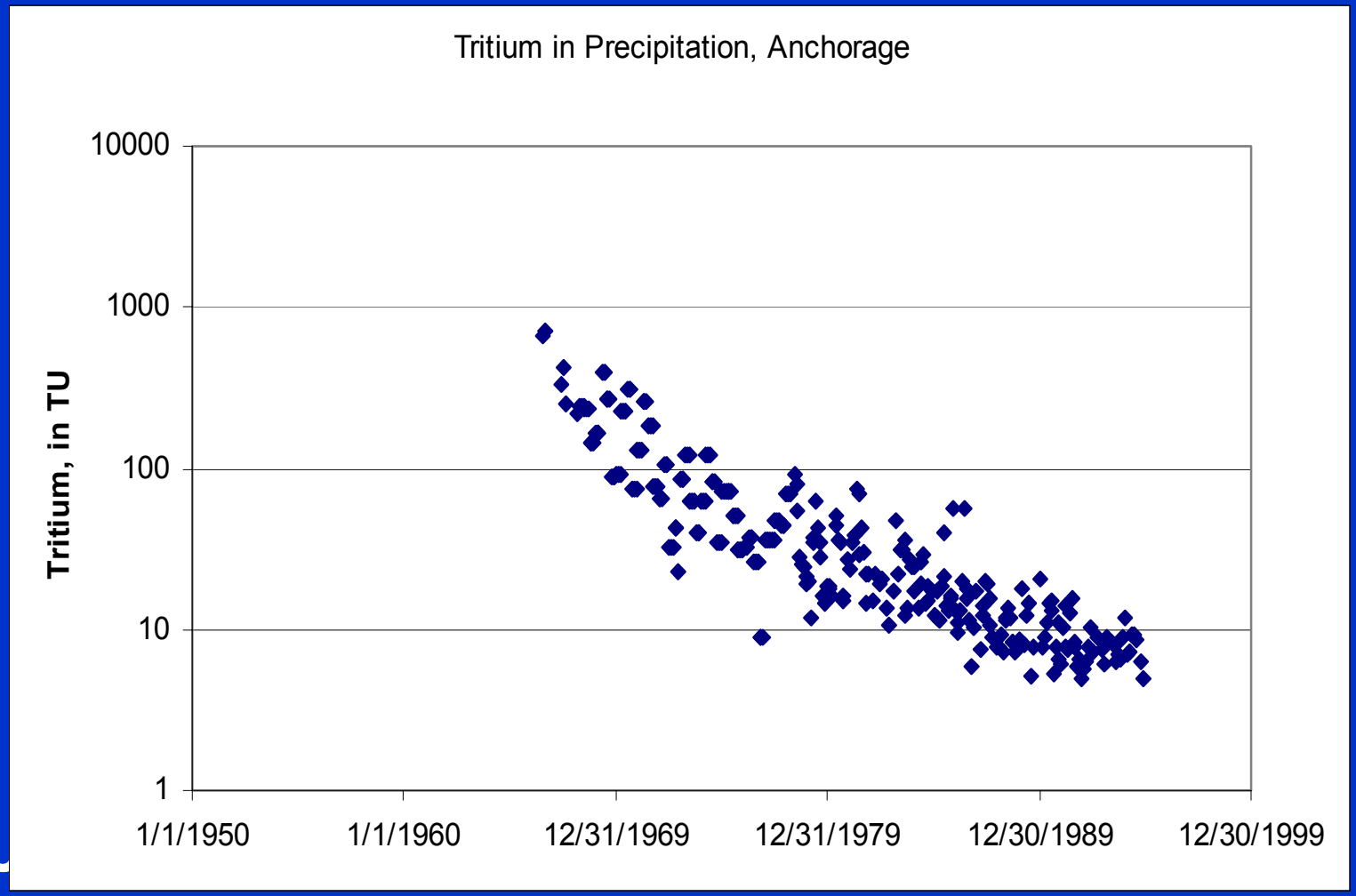
International Atomic Energy Agency, World Meteorological Organization



International Atomic Energy Agency, World Meteorological Organization



Current “Bomb Peak” Concentration

- 1999-1963 = 36 years
- Tritium half life = 12.4 years
- About 3 half lives → 1/8 of the 1963 “bomb-peak” concentration

- 2,950 TU / 8 = 369 TU

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Current Tritium Concentration for "Old" Water

- Pre-1952
- 1999-1952 = 47 years
- About 4 half lives → 1/16 of pre-1952 concentration
- 5 TU/16 = 0.3 TU to 20 TU/16 = 1.3 TU
- < 1.3 tritium units

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Tritium – Sampling and Analysis

- Water was collected in two copper tubes and two 500 ml bottles
- Analyzed by Lamont-Doherty Earth Observatory
- Sample degassed of helium, stored for up to 12 months, tritium concentration determined from the amount of in-grown helium-3, $^{3}He/^{4}He$ ratio, N_2, Neon, $^{3}H/\ ^{1}H$ ratio
- Age was estimated by Lamont-Doherty

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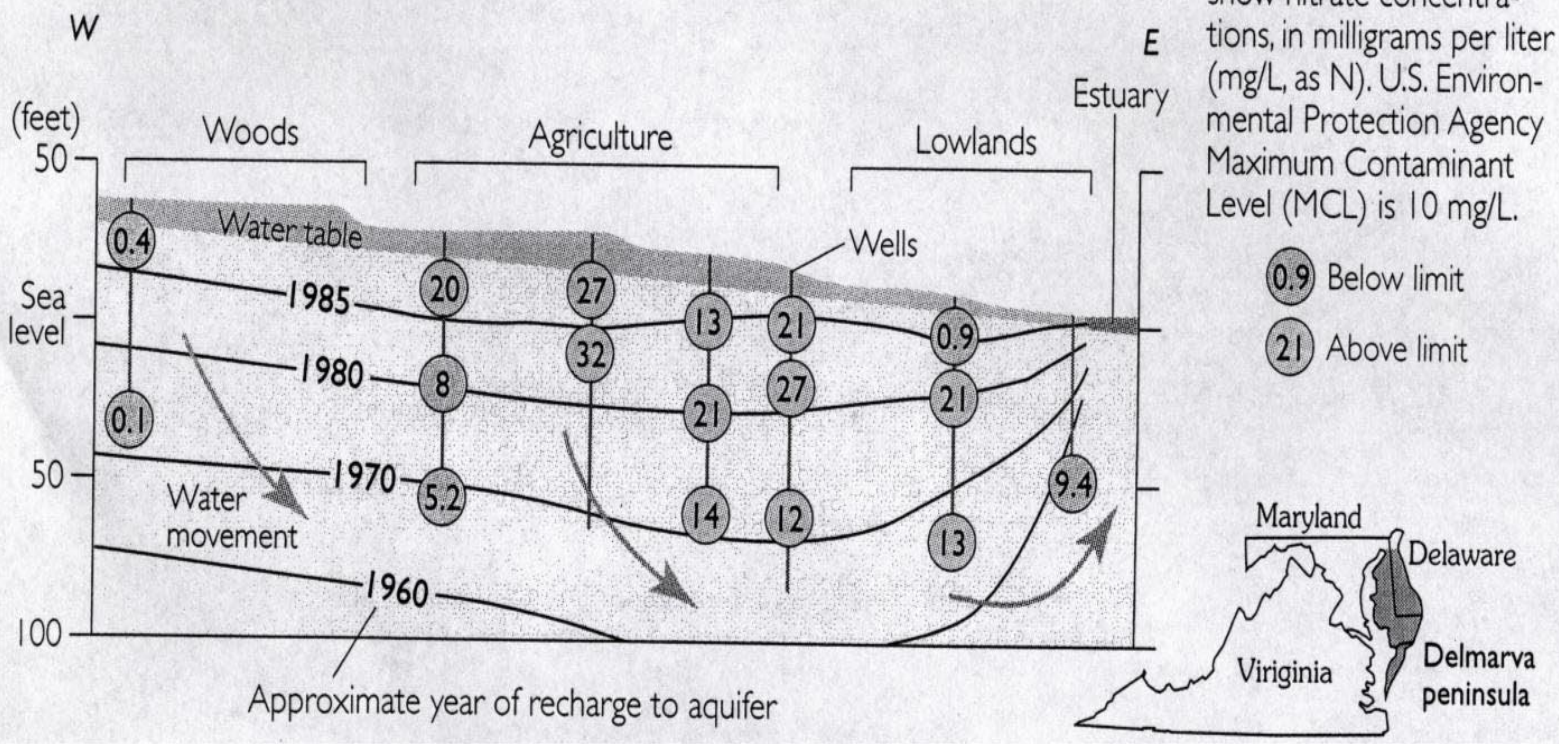
CFCs and nitrate concentrations were measured between June 1989 and January 1990 on a section of the Delmarva Peninsula, in the Fairmount watershed. Ground-water dating reveals a pattern of high nitrate concentrations moving slowly toward the estuary.



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Tritium Concentrations (N=32)

	Tritium (Tritium units)	Tritium error, 1 standard deviation (Tritium units)
Minimum	0.1	0.2
Median	12.5	0.3
Maximum	34.6	2.1

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Apparent age, based on tritium (N=32)

	Apparent age (Years)	Age error, 1 standard deviation (Years)
Minimum	0.3	0.2
Median	19.1	0.5
Maximum	58	29.3

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Two Environmental Tracers Were Used to Estimate Ground-Water "Age"

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Chlorofluorocarbons

- CFC-11 (trichlorofluoromethane or freon-11)
  $CFCl_3$
- CFC-12 (dichlorodifluoromethane)
  CF_2Cl_2
- CFC-113 (1,1,2-trichlorotrifluoroethane)
  $C_2F_3Cl_3$

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Characteristics of Chlorofluorocarbons

- Man-made (1930's-1996)
- Little spatial variability in atmosphere
- Temperature and pressure affects solubility in water
- Some sorption by peat and organic materials
- Some degradation by bacteria

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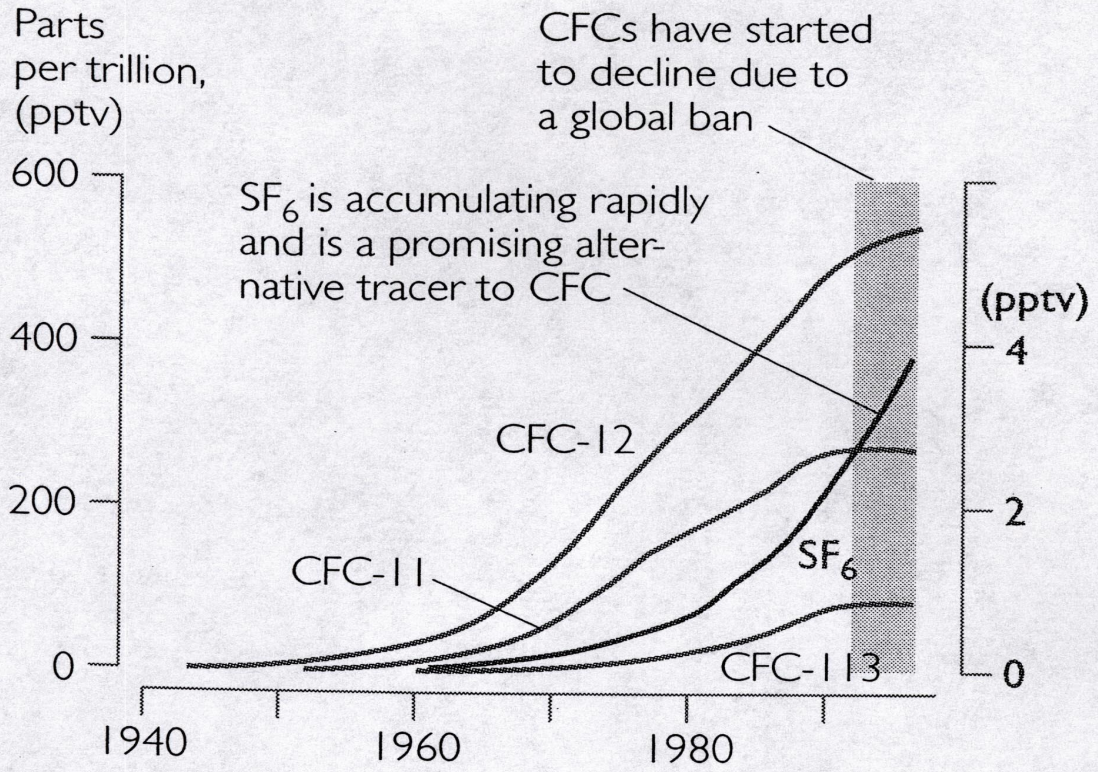

CFCs and sulfur hexafluoride (SF_6) concentrations (mixing ratios) for air over North America during the last 50 years.

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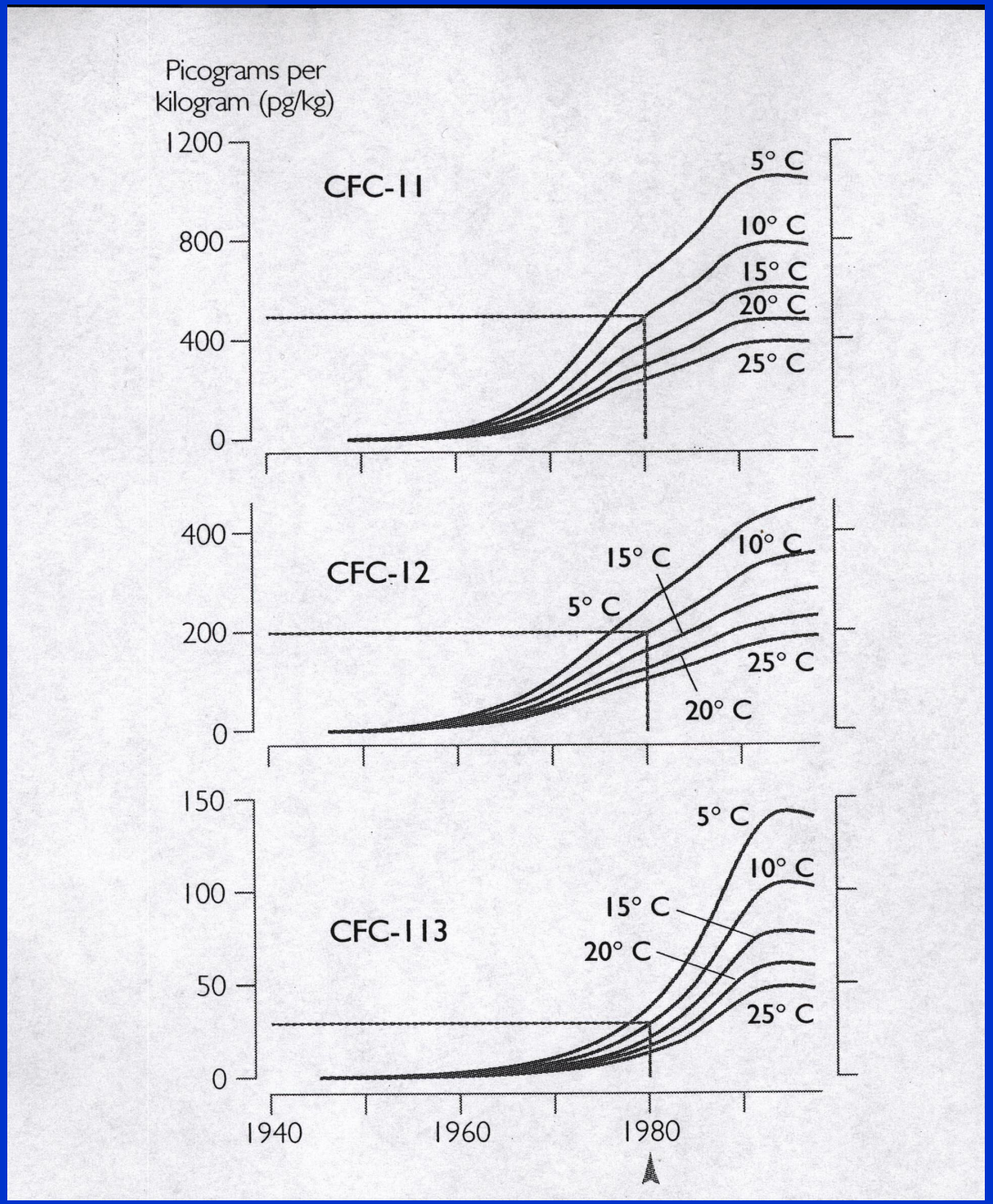
Concentrations of CFC-11, CFC-12, and CFC-113 in Water Recharged in Equilibrium With Air, 1940-2000



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CFC – Sampling and Analysis

- Custom-built sampler used to obtain 5 samples without contacting air and flame-sealed into glass bottles
- Custom-built purge-and-trap gas chromatograph with electron capture detection
- Detection level about 0.3 picograms per kilogram (0.3×10^{-12} g/kg; 0.3 parts per quadrillion; 0.0000003 ppb)

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Chlorofluorocarbons, in picograms per kilogram

[20,000 Parts Per Quadrillion = 20 Parts Per Trillion = 0.02 Parts Per Billion]

	CFC-11	CFC-12	CFC-113
Minimum	Not detected	Not detected	Not detected
Maximum	20,000	3,000	100
Median	20	100	5

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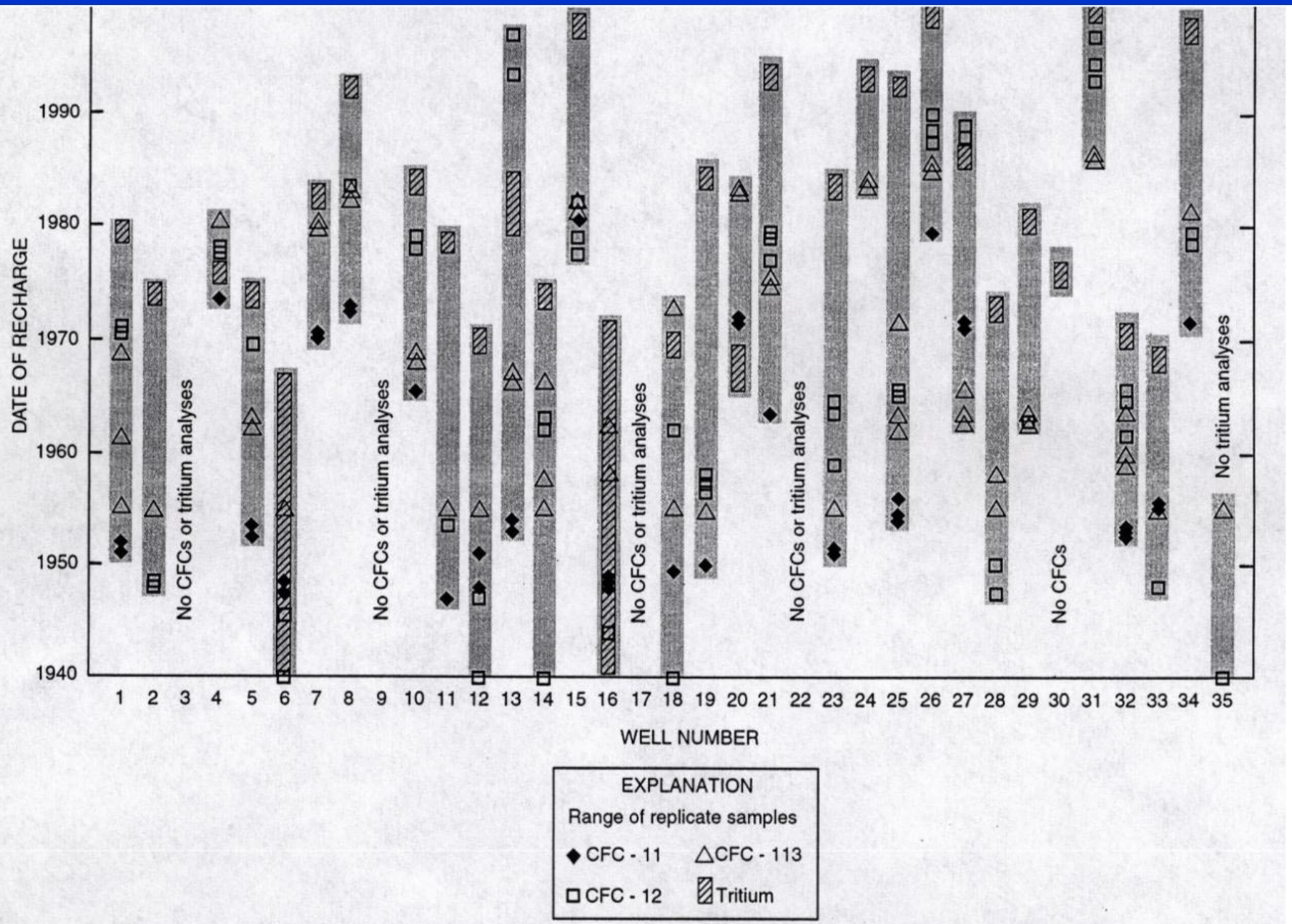
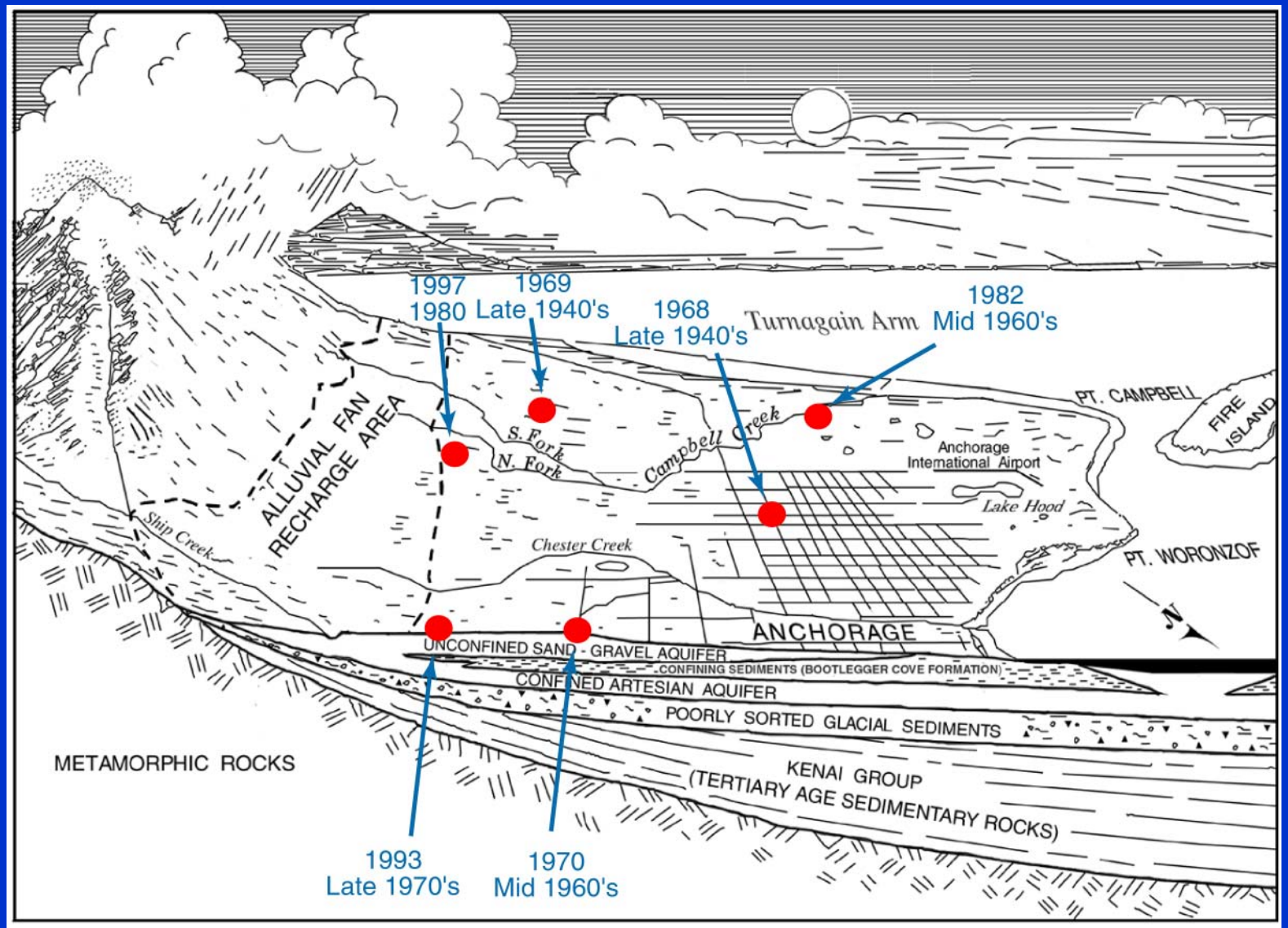


Figure 5. Dates of recharge determined with chlorofluorcarbon and tritium analyses.



Approximate year of recharge: $\frac{\text{Tritium}}{\text{CFC's}}$

Water-management Implications of Having "Modern" Water

- Water recharge is from "local" infiltration of precipitation and streamflow
- The aquifer is "vulnerable" to contamination from shallow sources

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