TRITIUM ANALYSES OF SHALLOW GROUND WATER IN MISSISSIPPI SPRING 1989 AND 1990

Larry J. Slack
William T. Oakley
U.S. Geological Survey

Introduction

As part of the Federal-State Cooperative Program, the U.S. Geological Survey (USGS) collects, on a systematic basis, data needed for the continuing determination and evaluation of the quantity, quality, and use of water resources in the United States and appraises the availability of ground and surface water through analytical and interpretive investigations. The resulting information forms the foundation for many of the Nation's water resources management and planning activities and allows for the detection of emerging water problems.

The Mississippi Department of Environmental Quality, Office of Pollution Control (OPC), is the principal agency responsible for management and protection of ground water in Mississippi. The OPC administers programs and policies to secure, protect, and preserve the right of citizens to unpolluted waters. Together with the Mississippi Department of Agriculture and Commerce, the OPC is developing a comprehensive program to protect aquifers from surface and shallow-source contamination. The USGS, in cooperation with these agencies, is conducting an investigation to describe the relative susceptibility of major aquifers in Mississippi to surface and shallowsource contamination.

Purpose and Scope

One of the objectives of the Office of Pollution Control's groundwater protection programs is to investigate the relative age of ground water in the principal aquifers in Mississippi that are associated with the Well Head Protection Program. In 1989 and 1990, in cooperation with the OPC, the USGS utilized radioisotope (tritium) dating techniques to assess the relative age of shallow ground water for selected aquifers in the State. This paper summarizes the site information, methods of sampling and analysis, results of the tritium analyses, and other selected water-quality data collected as part of that study.

Use of Tritium as a Tracer

Tritium has been used extensively as a hydrologic tracer since the early 1950's and can be used to indicate the relative age of water (pre- or post-1953). Tritium is particularly useful in groundwater studies because it is relatively unaffected by reactions other than radioactive decay. Tritium is a radioactive isotope of hydrogen with an atomic weight of 3 and a half-life of 12.43 years. Tritium is produced naturally and occurs in a small but nearly constant concentration (Lal and Peters 1967) in the atmosphere. Prior to the initiation of atmospheric testing of large thermonuclear weapons in 1953, the natural tritium content of rainwater was about 1 to 5 tritium atoms per 1018 normal hydrogen atoms (Thatcher 1962, p. 48), or 1 to 5 Tritium Units. In the 1950's and 1960's, tritium concentrations in precipitation in the northern hemisphere increased 2 or 3 orders of magnitude--to about 50 Tritium Units for surface ocean water and to 100's or 1000's of Tritium Units for some continental water (Michel 1989, p. 2).

Site Selection Criteria and Site Information

In April 1989 and in April and May 1990, the USGS collected water samples from 43 shallow wells (less than 500 feet deep) (fig. 1) for tritium analyses; the wells were completed in 17 geologic units in 13 of the 14 principal aquifers in Mississippi (tables 1 and 2). The availability of complete and accurate well-construction information was an essential selection criterion for each site; consequently, first preference was given to public-supply wells for which drillers' logs and geophysical logs are available. Other selection criteria included wells that were in use, had turbine or submersible pumps, and had a yield of at least 25 gallons per minute.

Methods of Sampling and Analysis

To assure that samples were representative of water from the water-bearing unit, the wells were pumped long enough prior to sampling to evacuate at least twice the volume of water standing in the casing. Most of the wells sampled were in daily operation, and some were in continuous operation. Water samples for tritium analysis were collected in a narrow-mouth flint glass bottle with a polyseal cap. The bottle was completely filled, with care taken not to entrain air. The bottle was capped, and the cap was taped to prevent it from loosening during transit.

The samples were shipped to the USGS Laboratory in Denver, Colorado, where they were recorded, repackaged, and forwarded to the University of Miami Tritium Laboratory. At the Tritium Laboratory, the samples were analyzed by an electrolytic enrichment with gas counting method developed by Ostlund and Werner (1961). It is the most sensitive method available through the National Water Quality Laboratory. The lower detection limit is 0.3 picocurie per liter.

Results

Tritium concentrations for the 43 wells (table 3) are in picocuries per liter. For the convenience of the reader, Tritium Units (which were obtained by dividing picocuries per liter by a conversion factor of 3.2) are also shown. Laboratory values for specific conductance, pH, and alkalinity for water from the 43 wells are also included in table 3.

Tritium concentrations less than about 1 picocurie per liter are considered to represent water with natural or background levels of tritium for ground water in Mississippi (R.L. Michel, USGS, oral commun., September 13, 1989). Values greater than 1 picocurie per liter are considered to represent post-1953 water, which is commonly referred to as "modern water" or "bornb tritium water." The limited amount of tritium data obtained during this study precludes drawing conclusions about the typical concentrations for any given aquifer.

Tritium concentrations ranged from less than 0.3 (the lower detection limit) to 42 picocuries per liter. Tritium concentrations in water from 24 of the wells were less than the lower detection limit. In about 40 percent of the wells, tritium concentrations were greater than 1 picocurie per liter, indicating modern (post-1953) water. The largest concentrations of tritium detected in ground water during this study are approximately equal to that in present-day (1991) precipitation in the area (or about 10 Tritium Units, R.L. Michel, USGS, written commun., January 26, 1991).

The median and mean depth, specific conductance, pH, and alkalinity values were substantially smaller for the wells with modern water than for wells with older (pre-1953) water. Wells with modern water had depths ranging from 96 feet to 360 feet, a median depth of 187 feet, and a mean depth of 196 feet. Water from these modern-water wells had specific conductance values ranging from 20 to 558 uS/cm (microsiemens per centimeter at 25 degrees Celsius), a median of 66 uS/cm, and a mean of 144 uS/cm. Water from these wells had pH values ranging from 5.3 to 7.5, a median pH of 5.9, and a mean pH of 6.3. Water from these wells had alkalinity values (as CaCO3) ranging from 2 to 288 mg/L (milligrams per liter), a median of 10 mg/L, and a mean of 56 mg/L.

Wells with pre-1953 water had depths ranging from 138 feet to 483 feet, a median depth of 277 feet, and a mean of 278 feet. Water from these wells had specific conductance values ranging from 30 uS/cm to 938 uS/cm, a median of 339 uS/cm, and a mean of 320 uS/cm. Water from these wells had pH values ranging from 6.2 to 8.6, a median pH of 7.6, and a mean pH of 7.4. Water from these wells had alkalinity values (as CaCO3) ranging from 7 mg/L to 299 mg/L, a median of 158 mg/L, and a mean of 135 mg/L.

Summary

In April 1989 and in April and May 1990, the U.S. Geological Survey collected water samples from 43 shallow wells (less than 500 feet deep) for tritium analyses; the wells are completed in 13 of the 14 principal aquifers in Mississippi. Tritium concentrations ranged from less than 0.3 to 42 picocuries per liter. Tritium concentrations in water from about 40 percent of the wells were greater than 1 picocurie per liter, indicating modern (post-1953) water. The median and mean depth, specific conductance, pH, and alkalinity values were substantially smaller for the wells with modern water than for wells with older (pre-1953) water.

References

Lal, D., and B. Peters. 1967. Cosmic ray produced radioactivity on the earth, in Flugge, S. ed. Encyclopedia of Physics. 46/2: 551-612.

Michel, R.L. 1989. Tritium deposition in the continental United States, 1953-83: U.S. Geological Survey Water-Resources Investigations Report 89-4072.

Ostlund, H.G., and E. Werner. 1961. The electrolytic enrichment of tritium and deuterium for natural tritium measurements: Tritium in the Physical and Biological Sciences, Proceedings. 1: 95-105.

Thatcher, L.L. 1962. The distribution of tritium fallout in precipitation over North America: International Association of Science Hydrology Bulletin. 7, no. 2: 48.

Wasson, B.E. 1986. Sources for water supplies in Mississippi: Mississippi Research and Development Center.

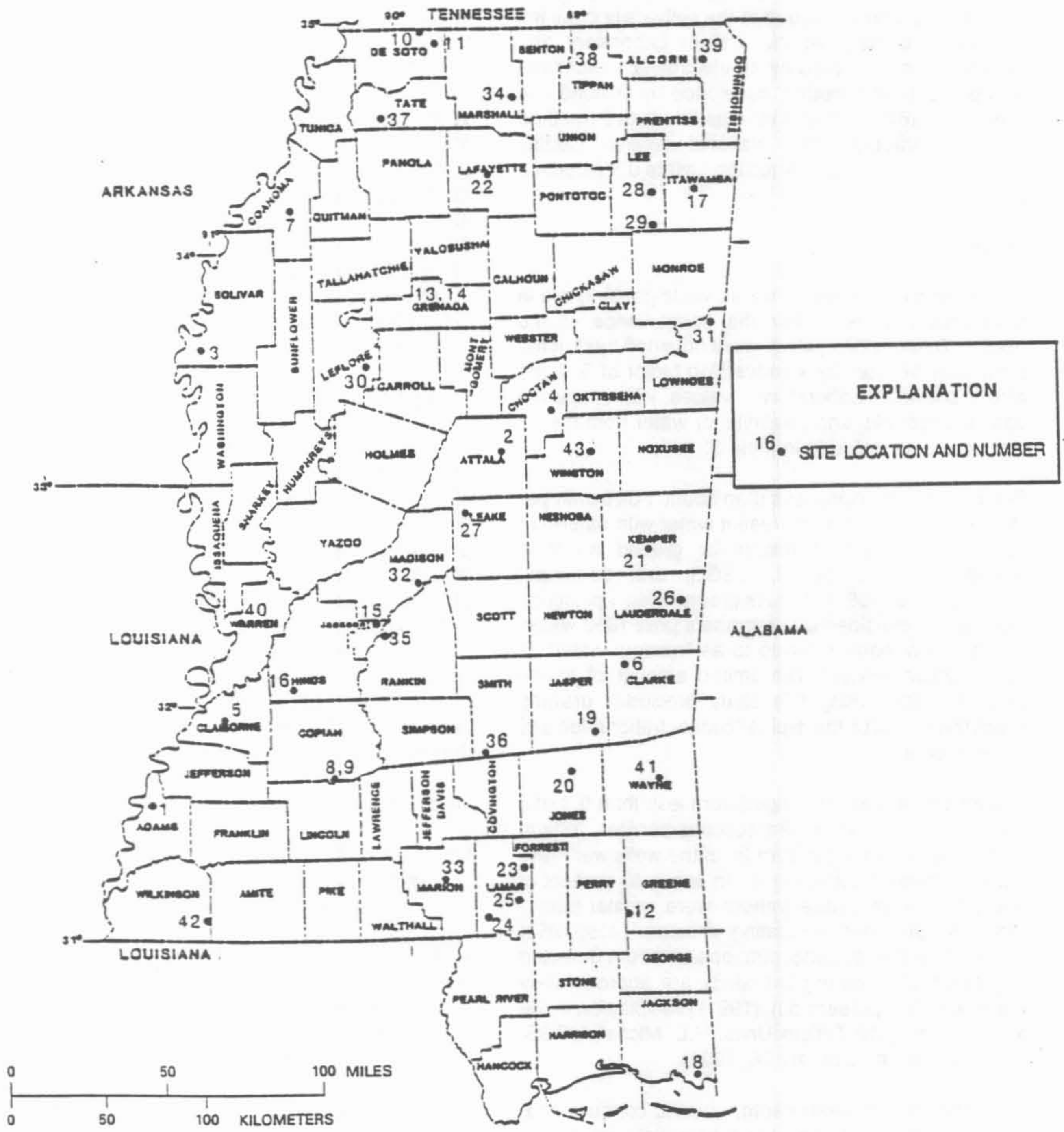

Figure 1 - Location of ground-water sites with tritium analyses.

Table 1. Geologic units and principal aquifers in Mississippi

[Modified from Wasson, 1986; only geologic unit codes for units tabulated in table 2 are listed]

Erathem	System	Series	Group	Geologic unit code	Geologic unit	Principal aquifer or aquifer system
	Quaternary	Holocene			Quaternary alluvium	
		and		MRVA	Mississippi River	Mississippi River
		Pleistocene			valley alluvium	alluvial aquifer
		Pleistocene			Loess	
					Terrace deposits	
		Pliocene		CRNL	Citronelle Formation	Citronelle aquifers
				GRMF	Graham Ferry Formation	
		Miocene			Pascagoula Formation	
					Hattiesburg Formation	Miocene aquifer system
					Catahoula Sandstone, upper part	
				CTHLL	Catahoula Sandstone, lower part	
				MOCN	Deposits of Miocene age	
		Oligocene	Vicksburg		Bucatunna Formation	
			Group	WRBR	Waynesboro sand lentil	
					Byram Formation	Oligocene aquifer
					Glendon Limestone	system
					Marianna Formation	
					Mint Spring Formation	
					Forest Hill Formation	
Cenozoic		Eocene	Jackson		Yazoo Clay	
	Tertiary		Group		Moodys Branch Formation	
			Claiborne	CCKF	Cockfield Formation	Cockfield aquifer
			Group		Cook Mountain Formation	
				SPRT	Sparta Sand	Sparta aquifer
					Zilpha Clay	
					Winona Sand	
				TLLT	Tallahatta Formation	Winona-Tallahata
					Neshoba Sand Member	aquifer
					Basic City Shale Member	
					Meridian Sand Member	
				MUWX	Meridian Sand Member	Meridian-upper Wilcox
					and Wilcox Group, upper part	aquifer
					Wilcox Group, upper part	
					Hatchetigbee Formation	
		Paleocene	Wilcox		Tuscahoma Formation	
			Group	WLCXM	Wilcox Group, middle part	
					Nanafalia Formation	
					Fearn Springs Member	
				WLCXL	Wilcox Group, lower part	Lower Wilcox aquifer
			Midway		Naheola Formation	
			Group		Porters Creek Clay	
					Matthews Landing Marl Member	
					Clayton Formation	
Mesozoic					Prairie Bluff Chalk	
					and Owl Creek Formation	
	Cretaceous	Upper	Selma	RPLY	Ripley Formation	Ripley aquifer
		Cretaceous	Group		Demopolis Chalk	
					Coffee Sand	Coffee Sand aquifer
					Mooreville Chalk	
					Arcola Limestone Member	
				EUTW	Eutaw Formation	
					Tombigbee Sand Member	Eutaw-McShan
			Tuscaloosa		Eutaw Formation, lower part	aquifer
			Group	MCSN	McShan Formation	
				GORD	Gordo Formation	
					Coker Formation	Tuscaloosa aquifer
					Massive sand	system
		Lower			Undifferentiated	
		Cretaceous				
					Undifferentiated	
Paleozoic				PLZC	Paleozoic Erathem	Paleozoic aquifer
						system

Table 2. Summary of site information

[Util, Utilities; W A, Water Association]

Site number	County	Local well number	Owner or operator	Latitude	Longitude	Depth of well (feet)	Depth to top of open interval (feet)	Geologic unit code (see table 1)
1	ADAMS	D045	BROADMOORE UTIL	31°35'38"	91°21'32"	150	135	MOCN
2	ATTALA	H023	ETHEL	33°07'30"	89°28'01"	210	170	TLLT
3	BOLIVAR	R074	SCOTT	33°35'24"	91°04'37"	483	431	CCKF
4	CHOCTAW	H030	ACKERMAN	33°18'46"	89°10'34"	101	64	WLCXM
5	CLAIBORNE	L079	PORT GIBSON	31°57'19"	90°58'52"	170	110	CTHLL
6	CLARKE	A002	ENTERPRISE	32°10'19"	88°49'09"	250	220	MUWX
7	COAHOMA	J009	CLARKSDALE	34°12'12"	90°34'15"	357	307	SPRT
8	COPIAH	V019	WESSON	31°42'29"	90°23'14"	332	292	CTHLL
9	COPIAH	V025	WESSON	31°42'37"	90°23'10"	360	320	CTHLL
10	DE SOTO	D022	MINERAL WELLS W A	34°59'10"	89°51'30"	272	237	SPRT
11	DE SOTO	H073	FAIRHAVEN W A	34°55'59"	89°47'35"	254	214	SPRT
12	GREENE	N044	MCLAIN	31°05'05"	88°48'58"	180	140	MOCN
13	GRENADA	H010	GRENADA	33°46'43"	89°48'00"	172	132	MUWX
14	GRENADA	H013	GRENADA	33°41'52"	89°43'35"	170	145	MUWX
15	HINDS	H178	BEST WESTERN	32°23'18"	90°08'46"	380	320	CCKF
16	HINDS	S016	UTICA	32°05'40"	90°35'58"	298	258	CTHLL
17	ITAWAMBA	H021	FULTON	34°16'28"	88°23'33"	274	223	GORD
18	JACKSON	Q420	PASCAGOULA	30°22'47"	88°30'29"	346	266	GRMF
19	JASPER	Q002	HEIDELBERG	31°53'35"	88°59'06"	360	300	CCKF
20	JONES	C167	LAUREL	31°42'32"	89°06'52"	322	268	CTHLL
21	KEMPER	N016	KIPLING W A	32°40'51"	88°40'26"	178	138	WLCXL
22	LAFAYETTE	F023	OXFORD	34°21'55"	89°30'40"	96	71	MUWX
23	LAMAR	E209	N LAMAR W A	31°17'30"	89°24'10"	187	147	CRNL
24	LAMAR	J276	N LUMBERTON W A	31°05'14"	89°35'53"	202	160	CRNL
25	LAMAR	L093	PROGRESS W A	31°09'30"	89°25'11"	264	222	MOCN
26	LAUDERDALE	J125	TOOMSUBA W A	32°28'10"	88°31'38"	240	200	WLCXL
27	LEAKE	A006	THOMASTOWN	32°51'56"	89°40'03"	246	206	SPRT
28	LEE	H093	MOORE-RICH W A	34°15'46"	88°36'58"	360	300	EUTW
29	LEE	O115	CASON W A	34°06'24"	88°36'49"	300	250	MCSN
30	LEFLORE	L154	GREENWOOD	33°30'50"	90°11'00"	220	160	SPRT
31	LOWNDES	B030	CALEDONIA	33°41'00"	88°19'30"	323	283	GORD
32	MADISON	U028	DEPT OF WILDLIFE	32°33'50"	89°55'10"	211	171	CCKF
33	MARION	L002	COLUMBIA	31°14'48"	89°48'50"	140	110	MOCN
34	MARSHALL	P065	LAKE CENTER	34°41'20"	89°21'59"	113	83	MUWX
35	RANKIN	F067	REFLECTION APTS	32°19'36"	90°06'33"	350	330	CCKF
36	SMITH	P013	OKATOMA W A	31°47'46"	89°34'26"	241	201	CTHLL
37	TATE	F048	STRAYHORN W A	34°36'06"	90°04'33"	316	276	SPRT
38	TIPPAH	D014	TIPPLERSVILLE W A	34°53'59"	88°54'37"	190	130	RPLY
39	TISHOMINGO	D052	BURNSVILLE	34°50'33"	88°19'22"	280	230	PLZC
40	WARREN	E023	VICKSBURG	32°24'31"	90°53'02"	122	82	MRVA
41	WAYNE	N155	WAYNESBORO	31°39'55"	88°38'45"	138	88	WSBR
42	WILKINSON	O023	CENTREVILLE W A	31°05'14"	91°03'57"	208	168	CRNL
43	WINSTON	F001	BOND W A	33°07'44"	88°57'38"	206	181	WLCXL

Table 3. Values for tritium and selected water-quality properties and constituents for ground water

[pCi/L, picocuries per liter; TU, tritium units; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; <, less than]

Site number	Date	Tritium concentration (pCi/L)	Tritium concentration (TU)	Specific conductance (µS/cm)	pH (units)	Alkalinity (mg/L as $CaCO_3$)
1	04-20-89	41	13	558	7.4	288
2	04-20-90	<.3	<.1	80	6.5	28
3	05-03-90	<.3	<.1	340	8.5	168
4	04-18-89	20	6.2	117	5.5	8
5	04-20-89	4.3	1.3	486	7.0	246
6	04-25-90	<.3	<.1	450	8.5	242
7	04-26-89	<.3	<.1	465	7.2	251
8	04-19-89	34	11	61	5.6	7
9	04-19-89	38	12	40	5.6	6
10	04-23-90	2.0	.6	66	7.2	25
11	04-23-90	6.8	2.1	67	7.5	19
12	04-17-90	<.3	<.1	354	8.6	163
13	04-23-90	<.3	<.1	354	7.6	161
14	04-25-89	<.3	<.1	338	7.5	148
15	04-26-90	<.3	<.1	537	8.5	228
16	04-20-89	<.3	<.1	581	7.2	179
17	04-19-89	<.3	<.1	65	6.2	24
18	04-18-89	<.3	<.1	938	7.9	299
19	04-25-90	<.3	<.1	678	8.3	263
20	04-16-90	<.3	<.1	154	7.1	65
21	04-21-89	31	9.7	36	5.3	2
22	04-25-89	42	13	85	5.7	13
23	04-19-89	14	4.4	23	5.7	5
24	04-19-89	31	9.7	20	5.5	3
25	04-19-89	<.3	<.1	30	6.2	11
26	04-25-90	<.3	<.1	245	8.0	113
27	04-20-90	<.3	<.1	80	6.5	14
28	04-24-90	.6	.2	390	8.2	108
29	04-24-90	<.3	<.1	335	8.0	158
30	04-25-89	.9	.3	455	7.2	234
31	04-20-89	<.3	<.1	65	6.2	25
32	04-26-90	13	4.1	145	7.0	36
33	04-19-89	12	3.8	43	5.8	9
34	04-24-90	30	9.4	37	6.7	10
35	04-19-90	<.3	<.1	507	8.4	211
36	04-16-90	28	8.8	53	5.9	4
37	04-25-89	<.3	<.1	91	6.3	38
38	04-18-89	<.3	<.1	370	7.8	192
39	04-19-89	<.3	<.1	61	6.2	20
40	04-20-89	17	5.3	503	7.1	258
41	05-03-90	<.3	<.1	327	8.3	159
42	05-04-90	21	6.6	99	6.4	14
43	04-25-90	<.3	<.1	33	6.6	7