BISCAYNE CANAL

The longest of the stub canals in the Miami area is Biscayne Canal, which heads at Red Road and extends 10 miles to Biscayne Bay at Miami Shores. The channel is generally about 70 ft wide and 8 ft deep, but its conveyance capacity is reduced by a number of constrictions and by sections containing shoals.

Table 73 presents the observed chloride concentrations. As compared with Snake Creek Canal, the salt front in Biscayne Canal moved over a longer reach. This is a measure of the relative size and conveyance capacity of the channels.

Heavy weed growth in the middle and upper reaches was usually effective in holding the water in the canal and retarding upstream movement of salt water, but in 1945, during the extreme drought, the channel became completely contaminated. No large supplies are obtained from the canal or from wells nearby.

Opa Locka Canal is a tributary of Biscayne Canal that serves an area in the vicinity of Opa Locka. It becomes contaminated along with the main canal despite the presence of weeds and constrictions. In 1945 contamination extended to the Seaboard Air Line Railroad, which is about at the head of the large channel of the canal. This strong concentration was a real threat to the supply wells of Opa Locka.

Table 73.—*Chloride concentrations in Biscayne Canal, Miami*

[Parts per million. Before October 1, 1941, the values are the highest obtained from either surface or bottom samples (usually the latter); after October 1, 1941, the values are from bottom samples. Mileages in parentheses indicate distance from mouth of canal at Biscayne Bay]

Date	U. S. Highway 1 (0.48 mile)	Northeast 6th Avenue (1.52 miles)	Dixie Highway (2.16 miles)	Northwest 131st Street (2.84 miles)			154th Street (4.29 miles)	Northwest 7th Avenue (4.88 miles)	Northwest 27th Avenue (6.91 miles)	Le Jeune Road (8.41 miles)	Red Road (9.97 miles)
				Prior to control	Below control	Above control					
1940											
Mar. 16	15,780	10,010	56	......	......	......	......	27	24	26	16
Apr. 3	11,760	51	47	......	......	......	......	25	23	25	15
Apr. 14	2,750	11,860	46	......	......	......	......	25	23	25	16
May 3	17,410	16,450	10,740	......	......	......	......	25	22	24	15
May 16	16,360	17,750	12,930	......	......	......	......	3,280	17	21	15
June 5	6,080	290	378	......	......	......	......	24	22	23	18
June 17	9,320	97	65	......	......	......	......	23	24	24	17
July 1	14,960	7,260	60	......	......	......	......	24	23	24	16
July 18	1,390	6,520	62	......	......	......	......	23	21	22	15
Aug. 1	8,640	13,990	520	......	......	......	......	22	20	22	15
Aug. 16	14,480	165	71	......	......	......	......	19	21	21	13
Sept. 4	15,680	13,120	5,140	......	......	......	......	26	20	22	14
Sept. 18	12,680	70	57	......	......	......	......	24	18	18	12
Oct. 3	13,560	63	62	......	......	......	......	27	13	15	10
Oct. 18	14,040	64	49	......	......	......	......	20	18	19	19
Nov. 1	13,900	63	52	......	......	......	......	23	17	19	17
Nov. 15	15,640	59	52	......	......	......	......	22	20	20	18
Dec. 3	16,600	10,980	92	......	......	......	......	25	21	21	17
Dec. 17	12,150	215	69	......	......	......	......	24	19	21	17
1941											
Jan. 18	11,320	71	48	......	......	......	......	21	18	19	15
Jan. 31	17,600	8,540	780	......	......	......	......	23	19	21	16
Feb. 19	15,010	54	43	......	......	......	......	20	18	18	17
Mar. 1	16,690	11,320	37	......	......	......	......	19	18	18	17
Mar. 14	2,025	12,250	40	......	......	......	......	18	17	18	16
Apr. 3	233	11,080	13,750	......	......	......	......	22	19	19	16
Apr. 18	9,520	92	50	......	......	......	......	22	19	19	15

May 1	16,740	14,040	10,980	......	......	......	......	23	20	20	16
May 20	15,540	10,010	56	......	......	......	......	19	19	19	16
June 4	11,910	12,490	3,750	......	......	......	......	21	19	19	16
June 17	18,700	17,080	13,850	......	......	......	......	30	19	19	15
July 3	2,550	315	83	......	......	......	......	19	19	19	16
July 17	95	67	40	......	......	......	......	17	16	17	12
July 30	14,140	10,790	36	......	......	......	......	19	19	18	16
Aug. 18	13,370	8,730	35	......	......	......	......	17	17	17	16
Sept. 3	10,740	7,260	31	......	......	......	......	20	18	18	17
Oct. 1	15,400	54	38	......	......	......	......	17	17	18	17
Oct. 17	15,100	11,200	142	......	......	......	......	17	18	17	16
Oct. 31	11,300	10,500	32	......	......	......	......	18	17	17	16
Nov. 14	13,600	45	35	......	......	......	......	18	18	18	16
Nov. 28	17,800	13,000	34	......	......	......	......	17	19	18	16
Dec. 26	15,100	9,860	31	......	......	......	......	17	17	17	17
1942											
Jan. 3	13,300	14,800	7,260	......	......	......	......	17	17	19	16
Jan. 16	18,000	16,900	12,100	......	......	......	......	17	17	16	16
Feb. 4	18,200	17,200	13,900	......	......	......	......	19	18	19	15
Feb. 17	17,300	16,200	11,900	......	......	......	......	20	17	17	16
Mar. 4	17,400	14,100	3,250	......	......	......	......	19	17	17	17
Mar. 19	17,500	15,500	11,100	......	......	......	......	21	19	16	18
Apr. 2	18,500	17,600	14,000	......	......	......	......	3,620	19	17	18
Apr. 28	68	48	35	......	......	......	......	16	15	14	16
May 8	93	45	37	......	......	......	......	19	16	17	19
May 22	8,640	4,350	37	......	......	......	......	18	18	17	19
June 9	86	29	24	......	......	......	......	16	13	15	14
June 24	66	41	37	......	......	......	......	14	15	13	11
July 9	61	43	36	......	......	......	......	17	14	15	15
July 24	1,975	670	29	......	......	......	......	19	20	20	18
Aug. 6	10,900	6,960	29	......	......	......	......	19	20	18	25
Aug. 22	2,300	51	23	......	......	......	......	15	17	16	17
Sept. 4	278	32	21	......	......	......	......	13	13	11	12
Oct. 7	5,620	11,600	32	......	......	......	......	15	16	16	16
Nov. 9	15,800	17,200	13,900	......	......	......	......	24	17	14	15
Nov. 24	10,800	12,900	2,450	......	......	......	......	18	17	18	15

Table 73.—*Chloride concentrations in Biscayne Canal, Miami*—Continued

Date	U. S. Highway 1 (0.48 mile)	Northeast 6th Avenue (1.52 miles)	Dixie Highway (2.16 miles)	Northwest 131st Street (2.84 miles)			154th Street (4.29 miles)	Northwest 7th Avenue (4.88 miles)	Northwest 27th Avenue (6.91 miles)	Le Jeune Road (8.41 miles)	Red Road (9.97 miles)
				Prior to control	Below control	Above control					
1942											
Dec. 10	17,300	15,200	9,900	....	....	....	....	25	20	15	15
Dec. 23	13,100	13,350	4,020	....	....	....	....	17	16	16	14
1943											
Jan. 6	18,600	15,050	6,350	....	....	....	....	25	19	15	15
Jan. 24	17,940	15,490	9,910	....	....	....	....	18	17	16	14
Feb. 8	14,380	14,770	605	....	....	....	....	15	15	14	14
Feb. 26	18,030	15,250	11,080	....	....	....	....	17	15	14	16
Mar. 15	17,170	16,160	11,710	....	....	....	....	5,140	19	15	13
Apr. 2	14,000	14,700	10,900	....	....	....	....	5,180	23	16	15
Apr. 16	17,500	17,800	13,500	....	....	....	....	1,325	19	15	14
May 5	7,510	4,900	4,050	....	....	....	....	55	16	15	14
May 15	15,400	12,800	1,340	....	....	....	....	35	16	15	....
June 1	16,400	13,900	4,100	....	....	....	....	15	15	15	14
June 19	15,400	12,400	8,930	....	....	....	....	32	17	16	....
July 4	17,800	5,040	7,260	....	....	....	....	21	15	15	16
July 18	17,600	16,100	8,640	....	....	....	....	23	14	15	15
Aug. 4	14,600	7,210	63	....	....	....	....	28	15	15	14
Aug. 21	635	55	41	....	....	....	....	21	16	15	17
Sept. 6	99	71	55	....	....	....	....	21	16	17	17
Sept. 21	....	4,420	35	....	....	....	....	17	15	15	15
Oct. 6	1,090	49	38	....	....	....	....	16	13	14	13
Nov. 2	15,400	83	55	....	....	....	....	18	15	15	16
Nov. 24	16,100	13,900	43	....	....	....	....	14	13	17	12
Dec. 27	17,400	5,140	275	....	....	....	....	19	19	17	16
1944											
Jan. 18	14,100	7,460	40	....	....	....	....	16	17	15	15
Feb. 5	18,100	14,100	7,400	....	....	....	....	19	16	16	14
Feb. 23	11,900	13,900	10,400	....	....	....	....	30	9.0	16	15

Mar. 9	17,700	5,230	2,100	....	....	....	....	27	16	15	14
Mar. 28	17,200	11,500	7,900	....	....	....	....	25	17	16	15
Apr. 18	18,500	16,900	14,000	....	....	....	....	2,950	18	16	16
May 8	19,300	16,000	9,030	....	....	....	....	31	19	16	15
May 30	10,200	8,340	55	....	....	....	....	17	17	16	15
June 21	11,800	13,900	7,460	....	....	....	....	18	17	16	15
July 26	17,600	9,670	320	....	....	....	....	38	18	....	....
1945											
May 17	....	....	....	....	....	....	....	12,800	5,900	300	50
June 15	....	....	....	....	....	....	....	21,400	22,400	21,100	14,900
June 29	....	....	....	....	....	....	....	16,900	14,700	8,000	5,200
July 18	....	....	....	....	....	....	....	9,700	980	900	640
July 31	....	....	2,200	....	....	....	....	980	600	530	340
Sept. 2	17,800	15,600	12,800	....	....	....	....	900	290	240	125
Sept. 24	15,400	12,300	4,720	....	....	....	....	550	432	388	43
Oct. 3	....	....	....	....	....	....	....	405	....	....	....
Oct. 10	15,600	....	7,600	....	....	....	....	345	272	265	29
Oct. 15	....	....	....	....	....	....	....	245	....	....	....
Oct. 23	....	....	....	....	....	....	....	242	....	....	....
Nov. 1	15,900	229	232	....	....	....	....	179	135	106	19
Nov. 6	....	....	....	....	....	....	....	197	....	....	....
Nov. 13	....	....	....	....	....	....	....	161	....	....	....
Nov. 20	16,200	12,200	212	....	....	....	....	123	111	107	23
Nov. 27	....	....	....	....	....	....	....	121	....	....	....
Dec. 4	....	....	....	....	....	....	....	117	....	....	....
Dec. 10	15,500	9,670	2,650	....	....	....	....	125	89	203	106
Dec. 20	....	....	....	....	....	....	....	91	....	....	....
Dec. 26	....	....	....	....	....	....	....	81			
1946											
Jan. 2	....	132	128	....	....	....	....	83	77	73	21
Jan. 9	....	....	....	....	....	....	....	80	....	....	....
Jan. 16	....	....	....	....	....	....	....	81	....	....	....
Jan. 23	16,200	14,000	7,560	....	....	....	....	74	99	70	22
Jan. 30	....	....	....	....	....	....	....	68	....	....	....
Feb. 6	....	....	....	472	....	....	....	65	....	....	....
Feb. 13	16,400	15,400	11,000	402	....	....	....	66	62	55	19
Feb. 20	....	....	....	....	282	160		64	....	....	....

Table 73.—*Chloride concentrations in Biscayne Canal, Miami*—Continued

Date	U. S. Highway 1 (0.48 mile)	Northeast 6th Avenue (1.52 miles)	Dixie Highway (2.16 miles)	Northwest 131st Street (2.84 miles)			154th Street (4.29 miles)	Northwest 7th Avenue (4.88 miles)	Northwest 27th Avenue (6.91 miles)	Le Jeune Road (8.41 miles)	Red Road (9.97 miles)
				Prior to control	Below control	Above control					
1946											
Feb. 27	....	....	....	....	13,600	990	....	62	....	....	....
Mar. 6	18,500	15,700	14,400	....	11,400	1,500	43	35	37	31	16
Mar. 13	....	....	....	....	10,400	198	....	48	....	....	....
Mar. 20	....	....	....	....	12,900	174	....	....	....	....	....
Mar. 26	18,900	17,900	17,600	....	15,700	2,150	2,350	935	34	34	18
Apr. 3	....	....	....	....	13,500	925	....	278	....	....	....
Apr. 12	....	....	....	....	14,500	645	....	36	....	....	....
Apr. 17	19,700	18,600	17,800	....	16,400	1,580	67	35	47	36	15
Apr. 24	....	....	....	....	16,600	860	....	39	....	....	....
May 1	20,400	18,700	18,100	....	16,400	2,300	77	39	42	34	17
May 8	....	....	....	....	12,000	157	....	43	....	....	....
May 15	....	....	....	....	11,300	35	....	37	....	....	....
May 22	18,300	15,700	14,200	....	9,080	36	32	34	41	39	16
May 29	....	....	....	....	13,900	395	....	35	....	....	....
June 5	....	....	....	....	10,100	675	....	47	....	....	....
June 12	16,200	6,570	1,000	....	134	670	62	31	33	31	19
June 19	....	....	....	....	85	91	....	47	....	....	....
June 26	....	....	....	....	115	101	....	46	....	....	....
July 3	16,100	178	115	....	99	85	39	42	37	39	18
July 10	....	....	....	....	70	72	....	40	....	....	....
July 17	....	....	....	....	83	76	....	40	....	....	....
July 24	16,200	9,500	110	....	60	60	....	....	....	....	....
July 31	11,500	90	90	....	70	70	....	40	30	20	20
Aug. 14	16,000	13,900	4,200	....	60	60	....	....	....	....	....
Aug. 28	13,000	15,600	9,600	....	50	40	....	20	20	20	20
Sept. 11	13,400	9,000	50	....	50	50	....	....	....	....	....
Sept. 25	16,000	12,900	4,320	....	55	57	....	31	31	29	13
Oct. 9	16,500	12,700	99	....	70	57	....	....	....	....	....

Oct. 23	18,400	15,900	9,500	....	70	70	....	70	70	80	60
Nov. 6	....	14,300	90	....	60	60	....	....	....	....	....
Nov. 13	....	12,000	100	....	70	70	....	....	....	....	....
Nov. 20	18,500	15,500	6,600	....	60	60	....	....	40	30	10
Nov. 27	....	7,500	80	....	60	70	....	....	....	....	....
Dec. 4	....	17,000	12,000	....	250	330	....	....	....	....	....
Dec. 11	17,000	14,900	10,500	....	410	342	....	40	36	32	18
Dec. 18	....	14,500	....	....	70	80	....	....	....	....	....
Dec. 24	....	15,000	8,000	....	130	120	....	....	....	....	....
Dec. 31	17,000	9,400	400	....	60	60	....	40	40	80	20

LITTLE RIVER CANAL

Little River Canal is fairly large and the lower reaches are moderately free of weeds—the pattern of movement of the salt front resembles that of Miami Canal. Table 74 presents the observed chloride concentrations. Little River Canal was uncontrolled until 1946, and the salt front generally was located between the Florida East Coast Railway and NW. 95th Street. No large supply was dependent upon its freshness although a number of adjacent small wells were contaminated and rendered unusable for periods of varying length.

As with Biscayne Canal, Little River Canal was contaminated in 1945 from Biscayne Bay to Red Road, a distance of 8.4 miles. Although the canal channel could have been quickly flushed out in the succeeding wet period, the continuing moderate contamination in the westerly reaches indicated that some contaminated ground water was entering the canal.

A dam was installed at NW. 7th Avenue in 1946 to reduce loss of fresh water to the bay and to act as a barrier to salty water.

Table 74.—*Chloride concentrations in Little River Canal, Miami*

[Parts per million. Before October 1, 1941, the values are the highest obtained from either surface or bottom samples (usually the latter); after October 1, 1941, the values are from bottom samples. Mileages in parentheses indicate from mouth of canal at Biscayne Bay]

Date	U. S. Highway 1 (0.74 mile)	Northeast		North Miami Avenue (1.85 miles)	Northwest 7th Avenue (2.65 miles)			Northwest 95th Street (3.75 miles)	Northwest 27th Avenue (5.34 miles)	Le Jeune Road (6.88 miles)	East 4th Avenue, Hialeah (7.38 miles)	Palm Avenue (7.88 miles)	Red Road (8.38 miles)
		79th Street (0.99 mile)	2nd Avenue (1.60 miles)		Prior to control	Below control	Above control						
1940													
Apr. 3	14,910	....	45	....	37	....	....	34	....	19	....	....	20
Apr. 14	13,990	....	11,320	....	750	....	....	34	....	19	....	....	21
May 3	18,230	....	15,010	....	10,980	....	....	8,880	....	18	....	....	19
May 16	18,890	....	17,170	....	11,910	....	....	9,080	....	18	....	....	19
June 5	14,620	....	125	....	96	....	....	109	....	18	....	....	16
June 17	14,720	....	59	....	46	....	....	39	....	18	....	....	18
July 1	14,720	....	5,360	....	50	....	....	46	....	19	....	....	21
July 18	15,640	....	8,930	....	1,680	....	....	42		18	....	....	20
Aug. 1	17,170	....	13,370	....	6,420	....	....	3,500	21	18	....	....	20
Aug. 16	14,670	....	125	....	101	....	....	48	17	18	....	....	19
Sept. 4	15,100	....	7,700	....	1,130	....	....	32	21	18	....	....	18
Sept. 18	12,540	....	52	....	43	....	....	42	21	16	....	....	15
Oct. 3	11,280	....	52	....	68	....	....	41	19	13	....	....	15
Oct. 18	15,970	....	7,410	....	55	....	....	37	18	18	....	....	18
Nov. 1	7,560	....	42	....	38	....	....	30	19	17	....	....	17
Nov. 15	15,830	....	46	....	37	....	....	31	18	18	....	....	17
Dec. 3	13,320	....	2,310	....	32	....	....	29	19	17	....	....	18
Dec. 17	15,250	....	10,200	....	261	....	....	24	18	17	....	....	19
1941													
Jan. 18	15,640	....	9,910	....	37	....	....	24	17	17	....	....	19
Jan. 31	16,500	....	13,270	....	9,030	....	....	770	21	17	....	....	18
Feb. 19	13,510	....	1,730	....	27	....	....	23	16	18	....	....	18
Mar. 1	14,860	....	7,560	....	29	....	....	26	17	18	....	....	19
Mar. 14	14,380	....	9,320	....	31	....	....	25	17	17	....	....	18
Apr. 3	14,620	....	6,170	....	267	....	....	24	17	17	....	....	17
Apr. 18	13,940	....	7,750	....	28	....	....	25	....	17	....	....	19

Table 74.—*Chloride concentrations in Little River Canal, Miami*—Continued

Date	U. S. Highway 1 (0.74 mile)	Northeast 79th Street (0.99 mile)	Northeast 2nd Avenue (1.60 miles)	North Miami Avenue (1.85 miles)	Northwest 7th Avenue (2.65 miles)			Northwest 95th Street (3.75 miles)	Northwest 27th Avenue (5.34 miles)	Le Jeune Road (6.88 miles)	East 4th Avenue, Hialeah (7.38 miles)	Palm Avenue (7.88 miles)	Red Road (8.38 miles)
					Prior to control	Below control	Above control						
1941													
May 1	17,270	...	13,120	...	11,180	...	...	2,080	19	18	...	...	18
May 20	15,780	...	10,590	...	6,030	...	...	1,260	17	17	...	...	17
June 4	16,400	...	12,930	...	10,150	...	...	3,620	17	18	...	...	18
June 17	18,660	...	15,640	...	13,170	...	...	9,030	20	19	...	...	17
July 3	16,400	...	9,030	...	130	...	...	1,120	16	17	...	...	17
July 16	3,820	...	33	...	25	...	...	22	15	16	...	...	15
July 30	15,490	...	9,270	...	208	...	...	29	17	16	...	...	19
Aug. 18	16,210	...	5,930	...	28	...	...	23	17	17	...	...	15
Sept. 3	14,670	...	9,910	...	558	...	...	21	16	16	...	...	16
Oct. 1	13,300	...	250	...	25	...	...	22	16	16	...	...	16
Oct. 17	15,700	...	11,500	...	870	...	...	19	16	15	...	...	16
Oct. 31	11,800	...	9,860	...	1,110	...	...	21	16	17	...	...	16
Nov. 14	15,400	...	4,780	...	39	...	...	20	17	17	...	...	17
Nov. 28	15,100	...	8,930	...	245	...	...	21	16	18	...	...	16
Dec. 24	16,900	...	12,400	...	8,640	...	...	21	16	16	...	...	16
1942													
Jan. 3	16,300	...	12,900	...	5,730	...	...	37	17	16	...	...	16
Jan. 16	15,900	...	13,300	...	5,980	...	...	590	17	16	...	...	16
Feb. 4	16,800	...	14,500	...	10,300	...	...	4,520	20	19	...	...	19
Feb. 17	17,300	...	13,200	...	6,370	...	...	3,850	16	18	...	...	17
Mar. 4	17,000	...	8,880	...	1,480	...	...	...	16	16	...	...	17
Mar. 19	17,600	...	13,500	...	7,060	...	...	5,780	16	18	...	...	19
Apr. 2	18,100	...	15,600	...	10,400	...	...	6,860	133	18	...	...	17
Apr. 28	308	...	29	...	22	...	...	18	13	12	...	...	13
May 8	5,930	...	177	...	24	...	...	23	16	15	...	...	14
May 22	13,300	...	7,460	...	26	...	...	24	18	17	...	...	18
June 9	12,400	...	630	...	20	...	...	17	14	16	...	...	13
June 24	5,830	...	28	...	24	...	...	19	15	15	...	...	14

July 9	9,670	....	29	....	25	....	....	19	17	17	....	....	17
July 24	13,100	....	9,520	....	1,200	....	....	23	17	17	....	....	15
Aug. 6	13,000	....	9,220	....	4,650	....	....	21	21	19	....	....	17
Aug. 22	13,800	....	10,300	....	4,500	....	....	17	....	15	....	....	17
Sept. 4	15,200	....	9,670	....	26	....	....	14	14	13	....	....	14
Oct. 7	15,350	....	13,250	....	8,200	....	....	720	13	15	....	....	16
Nov. 9	12,800	....	14,500	....	10,100	....	....	8,050	26	16	....	....	16
Nov. 24	15,750	....	13,700	....	3,920	....	....	29	15	18	....	....	16
Dec. 10	16,550	....	13,900	....	8,750	....	....	3,520	16	17	....	....	17
Dec. 23	14,600	....	14,200	....	6,800	....	....	285	....	17	....	....	18
1943													
Jan. 6	15,650	....	9,300	....	5,650	....	....	119	14	17	....	....	17
Jan. 24	17,270	....	14,330	....	11,810	....	....	8,190	130	19	....	....	17
Feb. 8	16,020	....	12,730	....	730	....	....	33	14	15	....	....	15
Feb. 26	17,560	....	13,800	....	10,890	....	....	5,980	17	15	....	....	18
Mar. 15	....	....	14,910	....	9,470	....	....	10,590	820	18	....	....	16
Apr. 2	14,000	....	15,300	....	11,200	....	....	8,930	4,020	1,010	....	....	18
Apr. 16	15,100	....	16,500	....	10,400	....	....	9,710	840	125	....	....	18
May 5	10,500	....	11,000	....	6,420	....	....	3,650	68	23	....	....	16
May 15	9,570	....	15,700	....	7,510	....	....	3,700	33	17	....	....	13
June 1	12,900	....	10,000	....	182	....	....	198	20	15	....	....	24
June 19	17,200	....	14,300	....	7,410	....	....	2,220	57	16	....	....	18
July 4	17,600	....	8,880	....	6,720	....	....	58	18	15	....	....	15
July 18	17,500	....	7,560	....	4,580	....	....	45	17	15	....	....	14
Aug. 4	16,700	....	9,670	....	7,600	....	....	37	15	23	....	....	16
Aug. 21	13,100	....	12,000	....	2,500	....	....	25	14	15	....	....	13
Sept. 6	14,400	....	755	....	41	....	....	27	15	15	....	....	16
Sept. 21	12,800	....	8,340	....	3,300	....	....	26	14	14	....	....	14
Oct. 6	12,700	10,100	2,020	....	27	....	....	24	12	12	....	....	13
Nov. 2	12,800	....	9,180	....	30	....	....	23	24	14	....	....	16
Nov. 24	15,900	....	12,900	....	3,820	....	....	17	12	13	....	....	12
Dec. 27	17,300	....	13,100	....	8,540	....	....	520	15	16	....	....	16
1944													
Jan. 18	15,600	....	11,000	....	5,140	....	....	980	15	16	....	....	16
Feb. 5	15,500	....	12,200	....	8,290	....	....	5,100	16	16	....	....	19
Feb. 23	15,400	....	13,900	....	9,710	....	....	5,980	19	17	....	....	19
Mar. 9	18,100	....	11,800	....	9,470	....	....	6,620	23	17	....	....	16
Mar. 28	12,500	....	14,200	....	9,220	....	....	....	20	18	....	....	16

Table 74.—*Chloride concentrations in Little River Canal, Miami*—Continued

Date	U. S. Highway 1 (0.74 mile)	Northeast 79th Street (0.99 mile)	Northeast 2nd Avenue (1.60 miles)	North Miami Avenue (1.85 miles)	Northwest 7th Avenue (2.65 miles)			Northwest 95th Street (3.75 miles)	Northwest 27th Avenue (5.34 miles)	Le Jeune Road (6.88 miles)	East 4th Avenue, Hialeah (7.38 miles)	Palm Avenue (7.88 miles)	Red Road (8.38 miles)
					Prior to control	Below control	Above control						
1944													
Apr. 18	18,300	....	16,400	....	12,400	....	....	11,300	312	16	....	....	16
May 8	17,600	....	7,110	....	7,510	....	....	3,850	16	16	....	....	16
May 30	12,700	....	13,900	....	7,850	....	....	3,250	15	15	....	....	15
June 21	17,000	....	8,390	....	1,090	....	....	27	16	16	....	....	17
July 26	14,800	....	7,410	....	562	....	....	418	39	16	....	....	....
1945													
May 16	....	....	....	....	15,600	....	....	14,000	8,200	4,400	3,200	2,100	350
June 15	23,200	....	22,700	....	22,400	....	....	22,400	21,100	19,100	....	17,400	15,600
June 29	....	....	....	....	....	....	....	14,400	11,400	12,200	....	13,700	12,000
July 18	....	....	....	....	15,600	....	....	10,000	2,800	1,200	1,100	920	980
July 31	....	....	14,700	....	7,300	....	....	1,100	760	....	....	....	640
Sept. 2	19,100	....	16,000	....	10,400	....	....	5,900	520	440	....	332	400
Sept. 24	13,800	....	9,670	....	530	....	....	465	482	552	....	....	243
Oct. 3	....	....	....	....	540	....	....	....	....	....	....	....	....
Oct. 10	15,400	....	13,500	....	6,820	....	....	860	368	440	....	....	260
Oct. 16	....	....	....	....	2,220	....	....	....	....	....	....	....	....
Oct. 23	....	....	....	....	1,100	....	....	....	....	....	....	....	....
Nov. 1	14,600	....	332	....	300	....	....	560	370	415	....	....	145
Nov. 6	....	....	....	....	360	....	....	....	....	....	....	....	....
Nov. 13	....	....	....	....	305	....	....	....	....	....	....	....	....
Nov. 20	15,600	....	12,600	....	542	....	....	252	265	322	....	....	159
Nov. 27	....	....	....	....	280	....	....	....	....	....	....	....	....
Dec. 6	....	....	....	....	5,730	....	....	....	....	....	....	....	....
Dec. 10	15,400	....	12,100	....	6,820	....	....	192	....	....	....	....	....
Dec. 20	....	....	....	....	5,680	....	....	....	....	....	....	....	....
Dec. 26	....	....	....	....	415	....	....	....	....	....	....	....	....
1946													
Jan. 2	14,300	....	196	....	171	....	....	162	170	177	....	....	62
Jan. 9	....	....	....	....	165	....	....	....	....	....	....	....	....

Jan. 16	....	....	....	....	....	6,720	1,260	....	....	....	....	....	....
Jan. 23	16,500	....	13,800	....	....	12,100	1,370	232	66	68	....	....	71
Jan. 30	....	....	....	....	....	10,500	200	....	....	....	....	....	....
Feb. 6	....	....	....	....	....	8,050	425	....	....	....	....	....	....
Feb. 13	15,800	....	12,400	....	....	11,300	380	106	48	50	....	....	57
Feb. 20	....	....	....	....	....	11,300	155	....	....	....	....	....	....
Feb. 27	....	....	....	....	....	13,400	138	....	....	....	....	....	....
Mar. 6	17,100	....	12,300	....	....	10,600	172	53	48	43	....	....	48
Mar. 13	....	....	....	....	....	11,100	116	....	....	....	....	....	....
Mar. 20	....	....	....	....	....	14,000	119	....	....	....	....	....	....
Mar. 26	18,700	....	16,000	....	....	15,700	227	53	40	42	....	....	43
Apr. 3	....	....	....	....	....	12,900	122	....	....	....	....	....	....
Apr. 12	....	....	....	....	....	14,400	167	....	....	....	....	....	....
Apr. 17	19,800	....	17,700	....	....	15,400	320	52	42	38	....	....	36
Apr. 24	....	....	....	....	....	14,600	220	....	....	....	....	....	....
May 1	19,800	....	17,200	....	....	15,000	540	72	44	35	....	....	33
May 8	....	....	....	....	....	14,200	440	....	....	....	....	....	....
May 15	....	....	....	....	....	12,000	132	....	....	....	....	....	....
May 22	18,700	....	13,500	....	....	10,200	71	49	41	45	....	....	47
May 29	....	....	....	....	....	14,700	422	....	....	....	....	....	....
June 5	....	....	....	....	....	11,600	432	....	....	....	....	....	....
June 12	17,600	....	11,000	....	....	7,850	120	49	35	32	....	....	41
June 19	....	....	....	....	....	69	68	....	....	....	....	....	....
June 26	....	....	....	....	....	86	83	....	....	....	....	....	....
July 3	15,900	....	123	....	....	65	68	57	67	71	....	....	40
July 10	....	....	....	....	....	77	81	....	....	....	....	....	....
July 17	....	....	....	....	....	92	87	....	....	....	....	....	....
July 24	19,300	18,000	10,800	....	....	350	160	....	....	....	....	....	....
July 31	17,000	16,000	440	180	....	90	70	70	70	60	....	....	60
Aug. 14	16,600	16,200	12,900	10,700	....	6,500	5,500	....	....	....	....	....	....
Aug. 28	14,700	14,800	12,700	12,000	....	9,300	8,200	660	60	70	....	....	70
Sept. 11	14,800	14,500	10,100	7,200	....	150	140	70	....	....	....	....	....
Sept. 25	12,500	13,600	10,400	8,730	....	490	412	77	71	74	....	....	83
Oct. 9	16,400	16,300	12,200	10,300	....	330	275	76	....	....	....	....	....
Oct. 23	16,400	16,700	13,900	12,000	....	4,100	1,700	80	110	110	....	....	120
Nov. 6	....	....	....	10,100	....	110	130	60	....	....	....	....	....

Table 74.—*Chloride concentrations in Little River Canal, Miami*—Continued

Date	U. S. Highway 1 (0.74 mile)	Northeast 79th Street (0.99 mile)	Northeast 2nd Avenue (1.60 miles)	North Miami Avenue (1.85 mile)	Northwest 7th Avenue (2.65 miles)			Northwest 95th Street (3.75 miles)	Northwest 27th Avenue (5.34 miles)	Le Jeune Road (6.88 miles)	East 4th Avenue Hialeah (7.38 miles)	Palm Avenue (7.88 miles)	Red Road (8.38 miles)
					Prior to control	Below control	Above control						
1946													
Nov. 13	....	....	....	4,800	....	100	90	70	....	....	....	....	....
Nov. 20	16,000	15,500	12,000	9,800	....	3,200	3,100	70	50	50	....	....	50
Nov. 27	....	....	....	6,500	....	100	100	60	....	....	....	....	....
Dec. 4	....	....	....	13,000	....	9,500	8,800	90	....	....	....	....	....
Dec. 11	16,800	16,600	13,600	12,200	....	7,260	6,340	180	49	44	....	....	38
Dec. 18	....	....	....	9,600	....	2,200	1,500	60	....	....	....	....	....
Dec. 24	....	....	....	11,000	....	5,800	5,000	70	....	....	....	....	....
Dec. 31	16,000	15,000	9,400	10,000	....	1,800	1,700	50	40	50	....	....	60

TAMIAMI CANAL

The contamination of Tamiami Canal is directly associated with that of Miami Canal, which it joins just above NW. 27th Avenue. Table 75 presents the observed chloride concentrations. The fluctuation of the salt front is less than that of most of the other large secondary canals, owing to the sustained flow in Tamiami Canal and to the relatively steep gradient. Tamiami Canal is a threat to the municipal well field in Miami Springs because it passes the well field on the south (fig. 184) and thereby provides a source of contamination from that direction.

Ordinarily, salty water did not progress inland farther than Red Road, but in 1945 contamination was found 4.9 miles above the mouth of the canal. The Florida East Coast Railway (F.E.C.) Canal, a tributary of Tamiami Canal, extends north toward the well fields. A real threat to the water supply existed several times during the 1943–45 drought period and Tamiami Canal was dammed in 1946 below its confluence with F. E. C. Canal to prevent contamination of the well field via F. E. C. Canal.

Table 75.—*Chloride concentrations in Tamiami Canal, Miami*

[Parts per million. Before October 1, 1941, the values are the highest obtained from either surface or bottom samples (usually the latter); after October 1, 1941, the values are from bottom samples. Mileages in parentheses indicate distance from mouth of canal at Miami Canal]

Date	Northwest South River Drive (0.09 mile)	Northwest 37th Avenue (0.90 mile)	Le Jeune Road (1.27 miles)	Red Road (3.21 miles)	Florida East Coast Railway (4.64 miles)			West Flagler Street (4.87 miles)
					Prior to control	Below control	Above control	
1940								
Mar. 8	205	75	....	....	....	....	....	....
Apr. 3	95	27	26	19	....	....	....	....
Apr. 14	395	29	26	20	....	....	....	....
May 3	1,175	61	43	18	....	....	....	....
May 16	2,475	730	478	19	....	....	....	....
June 5	111	61	205	19	....	....	....	....
June 17	90	157	191	18	....	....	....	....
July 1	88	91	111	18	....	....	....	....
July 18	89	67	61	17	....	....	....	....
Aug. 1	39	33	34	19	....	....	....	....
Aug. 16	39	27	26	16	....	....	....	....
Sept. 4	161	45	30	17	....	....	....	....
Sept. 18	29	22	18	16	....	....	....	....
Oct. 3	33	23	19	13	....	....	....	....
Oct. 18	31	25	20	17	....	....	....	....
Nov. 1	29	28	22	16	....	....	....	....
Nov. 15	20	17	17	16	....	....	....	....
Dec. 3	32	21	21	17	....	....	....	....
Dec. 17	25	21	21	17	....	....	....	....
1941								
Jan. 18	21	18	18	19	....	....	....	....
Jan. 31	23	21	18	17	....	....	....	....
Feb. 19	26	20	18	18	....	....	....	....
Mar. 1	21	20	20	19	....	....	....	....
Mar. 14	27	21	21	17	....	....	....	....
Apr. 3	25	23	20	18	....	....	....	....
Apr. 18	28	23	20	20	....	....	....	....

May 1	20	19	19	19	......	......	......	......
May 20	69	23	21	18	......	......	......	......
June 4	1,420	395	285	18	......	......	......	......
June 17	650	570	300	19	......	......	......	......
July 2	90	101	42	17	......	......	......	......
July 15	29	23	21	15	......	......	......	......
July 30	27	24	22	15	......	......	......	......
Aug. 18	19	20	20	16	......	......	......	......
Sept. 3	23	22	18	17	......	......	......	......
Oct. 1	23	19	19	16	......	......	......	......
Oct. 17	21	19	19	18	......	......	......	......
Oct. 31	21	19	19	16	......	......	......	......
Nov. 14	21	19	19	18	......	......	......	......
Nov. 28	19	18	19	17	......	......	......	......
Dec. 24	24	18	19	17	......	......	......	......
1942								
Jan. 3	24	20	19	19	......	......	......	......
Jan. 16	72	33	21	18	......	......	......	......
Feb. 4	620	129	23	19	......	......	......	......
Feb. 17	470	28	24	19	......	......	......	......
Mar. 4	63	22	19	18	......	......	......	......
Mar. 19	520	38	32	20	......	......	......	......
Apr. 2	600	207	163	18	......	......	......	......
Apr. 28	38	25	23	16	......	......	......	......
May 8	47	34	29	18	......	......	......	......
May 22	65	42	31	19	......	......	......	......
June 9	23	22	27	17	......	......	......	......
June 24	22	21	25	17	......	......	......	......
July 9	23	20	22	17	......	......	......	......
July 24	23	22	21	16	......	......	......	......
Aug. 6	23	17	23	19	......	......	......	......
Aug. 22	21	......	18	16	......	......	......	......
Sept. 4	21	......	19	15	......	......	......	......
Oct. 7	15	......	17	15	......	......	......	......
Nov. 9	159	......	23	18	......	......	......	......
Nov. 24	20	......	18	17	......	......	......	......

Table 75.—*Chloride concentrations in Tamiami Canal, Miami*—Continued

Date	Northwest South River Drive (0.09 mile)	Northwest 37th Avenue (0.90 mile)	Le Jeune Road (1.27 miles)	Red Road (3.21 miles)	Florida East Coast Railway (4.64 miles)			West Flagler Street (4.87 miles)
					Prior to control	Below control	Above control	
1942								
Dec. 10	1,500	....	147	16	....	....	....	....
Dec. 23	1,800	....	138	17	....	....	....	....
1943								
Jan. 6	132	....	34	18	....	....	....	....
Jan. 23	2,700	....	740	18	....	....	....	....
Feb. 8	525	....	86	16	....	....	....	....
Feb. 26	5,380	....	187	16	....	....	....	....
Mar. 15	7,750	....	4,250	16	....	....	....	....
Apr. 2	8,830	....	5,530	17	....	....	....	....
Apr. 16	11,300	....	9,080	33	....	....	....	....
May 5	2,450	....	2,125	29	....	....	....	....
May 15	1,390	....	1,780	15	....	....	....	....
June 1	1,970	....	372	16	....	....	....	....
June 19	8,000	....	5,090	17	....	....	....	....
July 4	1,970	....	495	19	....	....	....	....
July 18	755	....	210	17	....	....	....	....
Aug. 4	2,150	....	255	17	....	....	....	....
Aug. 21	660	....	222	18	....	....	....	....
Sept. 6	425	....	63	19	....	....	....	....
Sept. 21	74	....	53	16	....	....	....	....
Oct. 6	163	....	44	14	....	....	....	....
Nov. 2	63	....	27	26	....	....	....	....
Nov. 24	33	....	29	16	....	....	....	....
Dec. 27	40	....	32	18	....	....	....	....
1944								
Jan. 18	29	....	22	19	....	....	....	....
Feb. 5	182	....	26	18	....	....	....	....
Feb. 23	2,420	....	750	18	....	....	....	....

Mar. 9	6,030	....	1,750	18	....	....	....	....
Mar. 28	12,200	....	7,900	21	....	....	....	....
Apr. 18	3,850	....	3,100	17	....	....	....	....
May 8	10,900	....	8,540	92	....	....	....	....
May 30	1,180	....	378	17	....	....	....	....
June 21	9,570	....	....	19	....	....	....	....
July 26	....	....	....	18	....	....	....	....
Sept. 11	3,800	....	....	....	....	....	....	....
Oct. 4	....	....	1,700	41	....	....	....	....
Nov. 8	....	....	180	130	....	....	....	....
Dec. 21	....	....	318	20	....	....	....	....
1945								
Jan. 26	9,860	....	2,600	19	....	....	....	....
Feb. 27	....	....	5,800	20	....	....	....	....
Apr. 7	....	....	12,200	22	....	....	....	....
Apr. 16	....	....	....	5,980	19	....	....	....
Apr. 27	....	....	13,700	5,090	....	....	....	....
May 23	....	....	....	....	20	....	....	....
June 14	....	....	....	10,500	....	....	....	....
June 28	....	....	....	10,000	280	....	....	....
July 17	....	....	13,900	3,500	....	....	....	121
Aug. 1	11,000	....	5,600	200	....	....	....	95
Aug. 30	....	....	4,400	76	....	....	....	28
Sept. 24	418	....	318	21	30	....	....	....
Oct. 4	....	....	....	....	21	....	....	....
Oct. 11	620	....	275	29	....	....	....	19
Oct. 16	....	....	....	....	20	....	....	....
Oct. 23	....	....	....	....	19	....	....	....
Nov. 2	75	....	163	25	18	....	....	....
Nov. 14	....	....	....	....	18	....	....	....
Nov. 21	28	....	86	27	19	....	....	....
Dec. 11	53	....	36	23	27	....	....	....
1946								
Jan. 3	29	....	87	19	20	....	....	....
Jan. 24	31	....	67	22	21	....	....	....
Feb. 14	900	....	247	21	22	....	....	....

Table 75.—*Chloride concentrations in Tamiami Canal, Miami*—Continued

Date	Northwest South River Drive (0.09 mile)	Northwest 37th Avenue (0.90 mile)	Le Jeune Road (1.27 miles)	Red Road (3.21 miles)	Florida East Coast Railway (4.64 miles)			West Flagler Street (4.87 miles)
					Prior to control	Below control	Above control	
1946								
Mar. 7	1,510	....	755	19	19	....	....	....
Mar. 21	....	....	....	....	....	21	19	....
Mar. 28	13,400	....	8,440	23	....	20	20	
Apr. 4	....	....	....	....	....	32	29	....
Apr. 11	....	....	....	....	....	19	19	....
Apr. 18	11,500	....	8,100	260	....	19	22	....
Apr. 25	....	....	....	....	....	18	32	....
May 2	13,300	....	11,000	4,280	....	19	19	....
May 9	....	....	....	....	....	19	18	....
May 16	....	....	....	....	....	20	19	....
May 23	7,210	....	2,260	27	....	23	21	....
May 30	....	....	....	....	....	20	20	....
June 6	....	....	....	....	....	20	19	....
June 13	520	....	288	21	....	25	20	....
June 20	....	....	....	....	....	20	20	....
June 27	....	....	....	....	....	19	19	....
July 4	85	....	137	23	....	20	25	....
July 11	....	....	....	....	....	19	19	....
July 18	....	....	....	....	....	30	18	....
July 25	120	....	220	30	....	....	....	....
Aug. 1	110	....	120	....	....	....	20	....
Aug. 8	150	....	....	....	....	....	....	....
Aug. 15	570	....	160	20	....	20	20	....
Aug. 23	80	....	....	....	....	....	....	....
Aug. 29	40	....	70	20	....	20	20	....
Sept. 12	30	....	50	20	....	....	....	....
Sept. 26	31	....	24	20	....	....	....	....
Oct. 10	32	....	45	....	....	....	....	....

Oct. 24	50	....	50	20	....	....	20	....
Nov. 14	40	....	....	....	....	....	....	....
Nov. 21	40	....	30	20	....	20	20	....
Nov. 28	30	....	....	....	....	....	....	....
Dec. 5	40	....	....	....	....	....	....	....
Dec. 12	50	....	40	30	....	10	10	....
Dec. 19	40	....	....	....	....	....	....	....
Dec. 26	60	....	....	....	....	....	....	....
1947								
Jan. 3	40	....	40	30	....	20	20	....

SEMINOLE LAKE

Just east of Red Road and connected with Tamiami Canal, is Seminole Lake (fig. 184), a rock pit covering an area of about 100 acres. Like Palmer Lake, it becomes contaminated throughout in extremely dry periods and offers another means for salty water to approach the well field. In dry periods, only a low ground-water divide exists between Seminole Lake and the municipal supply wells. If this divide were dissipated in a prolonged dry spell and if the cone of depression in the water table extended to the Lake, it would supply salty water to the well field.

CORAL GABLES CANAL

Table 76 presents the observed chloride concentrations in Coral Gables Canal. Ordinarily, the canal is strongly salty upstream to U. S. Highway 1 (2.2 miles from Biscayne Bay), which is at the head of the large channel. The channel narrows at this point, and farther upstream it has a fairly low capacity because of shoals and constrictions. The typical upstream limit of contamination is in the vicinity of Bird Road (3.18 miles from the bay). In 1945, however, salty water was found at the Florida East Coast Railway bridge west of Red Road (5.4 miles by canal from Biscayne Bay).

On either side of U. S. Highway 1, stub canals branch off from Coral Gables Canal to form scenic waterways, which have contributed to the salt-water contamination of the adjoining areas.

Table 76.—*Chloride concentrations in Coral Gables Canal, Miami*

[Parts per million. Before October 1, 1941, the values are the highest obtained from either surface or bottom samples (usually the latter); after October 1, 1941, the values are from bottom samples. Mileages in parentheses indicate distance from mouth of canal at Biscayne Bay]

Date	Ingraham Highway (0.84 mile)	Hardee Drive (1.44 miles)	Miller Road (1.96 miles)	U. S. Highway (2.21 miles)	East Spur west end (2.34 miles)	Granada Boulevard (2.78 miles)	Bird Road (3.18 miles)	Red Road (4.06 miles) Prior to control	Red Road (4.06 miles) Below control	Red Road (4.06 miles) Above control	West Spur south end (4.50 miles)	Ludlum Road (4.96 miles)	F.E.C. Railway Bridge (5.41 miles)	Coral Way (5.63 miles)
1940														
Apr. 3	15,010	2,900	410	322	....	55	16	15	....	....	....	....	....	....
Apr. 14	16,360	16,260	2,850	1,150	....	129	19	16	....	....	....	....	....	....
May 3	17,890	16,550	2,920	2,580	....	358	20	15	....	....	....	....	....	....
May 16	18,230	17,120	4,820	4,350	....	3,000	790	15	....	....	....	....	....	....
June 5	12,730	8,880	292	255	....	47	17	15	....	....	....	....	....	....
June 17	14,770	11,370	350	288	....	57	17	16	....	....	....	....	....	....
July 1	16,020	13,750	465	368	....	57	16	15	....	....	....	....	....	....
July 18	17,120	14,140	780	530	....	109	17	15	....	....	....	....	....	....
Aug. 1	19,470	16,740	13,560	10,590	....	4,420	28	16	....	....	....	....	....	....
Aug. 16	17,750	15,300	167	101	....	39	15	15	....	....	....	....	....	....
Sept. 4	14,480	15,150	4,180	1,040	....	85	17	15	....	....	....	....	....	....
Sept. 18	14,240	12,930	9,180	1,780	....	69	17	17	....	....	....	....	....	....
Oct. 3	12,830	10,400	5,730	820	....	69	18	15	....	....	....	....	....	....
Oct. 18	15,400	13,700	10,790	6,270	....	94	18	15	....	....	....	....	....	....
Nov. 1	13,420	11,470	7,410	1,550	....	102	17	15	....	....	....	....	....	....
Nov. 15	13,320	10,890	2,500	452	....	67	17	16	....	....	....	....	....	....
Dec. 3	14,280	13,700	542	425	....	76	19	17	....	....	....	....	....	....
Dec. 17	12,830	10,590	1,770	1,580	....	61	19	16	....	....	....	....	....	....
1941														
Jan. 18	15,730	13,120	302	190	....	47	18	15	....	....	....	....	....	....
Jan. 31	16,020	13,610	6,470	5,330	....	62	18	15	....	....	....	....	....	....
Feb. 19	15,680	11,470	9,520	1,750	....	47	19	15	....	....	....	....	....	....
Mar. 1	14,140	11,910	368	318	....	47	19	15	....	....	....	....	....	....
Mar. 14	15,250	13,510	6,520	522	....	57	17	15	....	....	....	....	....	....
Apr. 3	15,350	14,140	1,260	680	....	51	18	15	....	....	....	....	....	....
Apr. 18	12,830	11,710	950	320	....	41	19	15	....	....	....	....	....	....

May 1	14,670	12,060	228	143	....	28	17	16	....	....	....	....	....	....
May 20	15,100	13,070	3,300	428	....	64	21	16	....	....	....	....	....	....
June 4	18,940	16,980	7,650	8,440	....	770	20	18	....	....	....	....	....	....
June 17	18,850	17,120	11,710	5,040	....	990	28	15	....	....	....	....	....	....
July 2	15,830	13,510	612	405	....	47	17	16	....	....	....	....	....	....
July 14	17,170	15,200	348	315	....	37	18	15	....	....	....	....	....	....
July 30	16,120	13,420	680	320	....	39	17	16	....	....	....	....	....	....
Aug. 18	18,850	17,750	1,210	203	....	33	16	15	....	....	....	....	....	....
Sept. 3	18,700	17,460	14,820	2,225	....	30	18	15	....	....	....	....	....	....
Oct. 1	12,600	13,000	2,780	610	....	18	16	15	....	....	....	....	....	....
Oct. 17	14,800	12,100	3,300	820	....	17	16	15	....	....	....	....	....	....
Oct. 31	14,700	14,000	2,800	310	....	21	17	15	....	....	....	....	....	....
Nov. 14	15,300	15,300	2,250	500	....	19	16	18	....	....	....	....	....	....
Nov. 28	15,600	16,000	10,100	9,910	....	18	17	16	....	....	....	....	....	....
Dec. 24	15,200	14,400	3,350	352	....	20	17	15	....	....	....	....	....	....
1942														
Jan. 3	16,900	15,800	9,370	3,380	....	45	18	15	....	....	....	....	....	....
Jan. 16	17,000	15,500	12,800	8,640	....	136	18	15	....	....	....	....	....	....
Feb. 4	17,600	16,800	15,400	9,620	....	54	23	15	....	....	....	....	....	....
Feb. 17	16,700	16,600	7,160	3,320	....	790	21	15	....	....	....	....	....	....
Mar. 4	17,600	16,300	7,410	2,000	....	38	17	15	....	....	....	....	....	....
Mar. 19	18,000	11,100	11,900	4,820	....	136	25	15	....	....	....	....	....	....
Apr. 2	17,000	15,900	11,400	7,900	....	710	23	15	....	....	....	....	....	....
Apr. 28	14,100	13,300	1,020	119	....	36	16	13	....	....	....	....	....	....
May 8	12,500	10,000	2,125	365	....	33	19	15	....	....	....	....	....	....
May 22	13,900	12,700	2,300	392	....	71	20	18	....	....	....	....	....	....
June 9	12,600	10,600	161	89	....	18	17	14	....	....	....	....	....	....
June 24	13,500	11,600	442	348	....	22	18	16	....	....	....	....	....	....
July 9	12,800	11,700	3,150	206	....	49	18	17	....	....	....	....	....	....
July 24	16,400	14,800	....	1,050	....	33	19	16	....	....	....	....	....	....
Aug. 6	14,600	14,200	....	570	....	57	20	16	....	....	....	....	....	....
Aug. 22	15,900	14,300	....	2,400	....	29	17	15	....	....	....	....	....	....
Sept. 4	16,400	16,400	....	163	....	14	14	14	....	....	....	....	....	....
Oct. 7	15,300	14,350	....	6,100	....	17	14	16	....	....	....	....	....	....
Nov. 9	16,800	15,750	....	9,400	....	2,100	16	15	....	....	....	....	....	....
Nov. 24	15,350	13,550	....	255	....	....	17	15	....	....	....	....	....	....

Table 76.—*Chloride concentrations in Coral Gables Canal, Miami*—Continued

Date	Ingraham Highway (0.84 mile)	Hardee Drive (1.44 miles)	Miller Road (1.96 miles)	U. S. Highway (2.21 miles)	East Spur west end (2.34 miles)	Granada Boulevard (2.78 miles)	Bird Road (3.18 miles)	Red Road (4.06 miles)			West Spur south end (4.50 miles)	Ludlum Road (4.96 miles)	F.E.C. Railway Bridge (5.41 miles)	Coral Way (5.63 miles)
								Prior to control	Below control	Above control				
1942														
Dec. 10	15,750	15,000	....	5,600	....	138	15	13	....	....	....	....	....	....
Dec. 23	12,850	13,400	....	4,380	....	111	15	15	....	....	....	....	....	....
1943														
Jan. 6	17,450	....	....	4,420	....	680	17	15	....	....	....	....	....	....
Jan. 23	18,180	17,410	....	11,860	....	3,100	17	14	....	....	....	....	....	....
Feb. 8	16,120	15,920	....	2,075	....	83	16	14	....	....	....	....	....	....
Feb. 26	16,500	17,460	....	3,120	....	199	15	14	....	....	....	....	....	....
Mar. 15	18,270	16,690	....	5,580	....	2,650	23	14	....	....	....	....	....	....
Apr. 2	17,200	15,200	....	7,900	....	5,040	2,700	15	....	....	....	....	....	....
Apr. 16	19,700	19,000	....	10,800	....	4,350	3,250	15	....	....	....	....	....	....
May 5	18,400	15,600	....	7,900	....	5,040	2,720	16	....	....	....	....	....	....
May 15	19,400	19,200	....	2,600	....	915	56	15	....	....	....	....	....	....
June 1	19,800	16,900	....	5,380	....	2,750	93	14	....	....	....	....	....	....
June 19	18,500	16,800	....	10,200	....	7,560	3,880	21	....	....	....	....	....	....
July 4	19,500	6,860	....	2,425	....	700	145	14	....	....	....	....	....	....
July 18	16,900	15,300	....	935	....	370	17	14	....	....	....	....	....	....
Aug. 4	....	16,000	....	4,280	....	2,000	58	13	....	....	....	....	....	....
Aug. 21	....	16,900	....	9,810	....	4,900	1,630	18	....	....	....	....	....	....
Sept. 6	....	14,200	....	2,270	....	428	22	13	....	....	....	....	....	....
Sept. 21	....	9,080	....	1,280	....	55	37	14	....	....	....	....	....	....
Oct. 6	....	12,200	....	2,980	....	113	16	13	....	....	....	....	....	....
Nov. 2	....	11,300	....	418	....	95	20	14	....	....	....	....	....	....
Nov. 24	....	14,600	....	565	....	111	17	14	....	....	....	....	....	....
Dec. 27	12,700	12,700	....	2,300	....	740	51	15	....	....	....	....	....	....
1944														
Jan. 18	17,000	16,700	....	6,520	....	111	20	15	....	....	....	....	....	....
Feb. 5	16,600	14,600	....	1,830	....	610	25	16	....	....	....	....	....	....
Feb. 23	17,100	15,600	....	10,400	....	5,180	1,660	15	....	....	....	....	....	....

Mar. 9	16,400	14,400	....	4,720	....	860	328	16	....	....	....	....	....	....
Mar. 28	18,800	....	....	11,500	....	8,440	5,680	17	....	....	....	....	....	....
Apr. 18	18,800	17,500	....	4,300	....	3,280	1,110	6.0						
May 8	19,700	18,200	....	13,600	....	7,560	5,330	19	....	....	....	....	....	....
May 30	17,500	16,700	....	6,270	....	820	245	16	....	....	....	....	....	....
June 21	20,800	18,700	....	12,900	....	6,920	2,800	16	....	....	....	....	....	....
July 26	19,100	18,500	....	4,120	....	815	35	17	....	....	....	....	....	....
Sept. 11	700	....	....	8,600	....	3,300	1,080	22	....	....	....	....	....	....
Oct. 3	....	....	....	12,600		10,000	6,700	20	....	....	....	....	....	....
Nov. 8	....	....	....	8,540	....	2,280	30	28	....	....	....	....	....	....
Dec. 21	16,900	15,700	....	10,100	....	5,280	1,850	15	....	....	....	....	....	....
1945														
Jan. 25	....	....	....	11,420	....	4,950	710	19	....	....	....	....	....	....
Feb. 26	....	....	....	....	....	6,080	2,720	....	....	....	....	....	....	....
Feb. 27	....	....	....	10,100	....	5,700	3,000	37	....	....	....	....	....	....
Apr. 6	....	....	....	11,400	....	6,220	3,250	25	....	....	....	....	....	....
Apr. 27	....	....	....	13,800	....	8,490	....	1,800	....	....	....	....	....	....
June 14	....	....	....	16,400	....	13,400	9,700	6,200	....	....	....	7,200	1,100	19
June 28	....	....	....	....	....	....	9,800	2,100	....	....	....	5,100	680	....
July 17	....	....	....	14,000	....	10,400	6,200	2,200	....	....	....	3,000	....	21
Aug. 1	19,100	18,000	....	11,000	....	8,400	5,700	640	....	....	....	160	....	67
Aug. 30	....	....	....	14,000	....	....	7,300	230	....	....	....	60	....	....
Sept. 24	15,000	11,600	....	3,150	....	760	51	60	....	....	....	43	....	....
Oct. 4	....	....	....	3,320	....	....	....	....	....	....	....	....	....	....
Oct. 11	16,900	16,000	....	11,500	....	2,560	58	28	....	....	....	22	....	....
Oct. 16	....	....	....	10,100	....	....	....	....	....	....	....	....	....	....
Oct. 23	....	....	....	5,630	....	....	....	....	....	....	....	....	....	....
Nov. 2	13,800	13,800	....	1,050	....	154	40	25	....	....	....	19	....	....
Nov. 7	....	....	....	3,450	....	....	....	....	....	....	....	....	....	....
Nov. 14	....	....	....	1,890	....	....	....	....	....	....	....	....	....	....
Nov. 21	14,700	13,900	....	6,720	....	2,550	74	21	....	....	....	18	....	....
Nov. 30	....	....	....	6,420	....	....	....	....	....	....	....	....	....	....
Dec. 5	....	....	....	8,830	....	....	....	....	....	....	....	....	....	....
Dec. 11	14,400	10,500	....	2,350	....	358	60	19	....	....	....	19	....	....
Dec. 19	....	....	....	9,710	....	....	....	....	....	....	....	....	....	....
Dec. 27	....	....	....	5,280	....	....	....	....	....	....	....	....	....	....

Table 76.—*Chloride concentrations in Coral Gables Canal, Miami*—Continued

Date	Ingraham Highway (0.84 mile)	Hardee Drive (1.44 miles)	Miller Road (1.96 miles)	U. S. Highway (2.21 miles)	East Spur west end (2.34 miles)	Granada Boulevard (2.78 miles)	Bird Road (3.18 miles)	Red Road (4.06 miles)			West Spur south end (4.50 miles)	Ludlum Road (4.96 miles)	F.E.C. Railway Bridge (5.41 miles)	Coral Way (5.63 miles)
								Prior to control	Below control	Above control				
1946														
Jan. 3	16,100	14,400	....	4,200	....	770	52	17	....	....	....	17	....	....
Jan. 10	....	....	....	3,180	....	....	....	....	....	....	....	....	....	....
Jan. 17	....	....	....	6,270	....	....	....	....	....	....	....	....	....	....
Jan. 24	18,200	16,700	....	9,860	....	3,920	1,390	....	23	18	....	18		
Jan. 31	....	....	....	8,640	....	....	....	....	32	18	....	....	....	....
Feb. 7	....	....	....	6,770	....	....	....	....	21	18	....	....	....	....
Feb. 14	17,600	15,600	....	11,700	....	8,500	4,800	....	37	17	....	17	....	....
Feb. 21	....	....	....	8,540	....	....	....	....	48	17	....	....	....	....
Feb. 28	....	....	....	6,720	....	....	....	....	21	19	....	....	....	....
Mar. 7	17,200	14,800	....	8,490	....	5,630	4,100	....	33	19	....	15	....	....
Mar. 14	....	....	....	8,930	....	....	....	....	31	17	....	....	....	....
Mar. 21	....	....	....	15,200	....	....	....	....	32	17	....	....	....	....
Mar. 28	19,400	17,500	....	5,830	....	4,220	2,480	....	1,180	16	....	28	....	....
Apr. 4	....	....	....	13,900	....	....	....	....	565	22	....	....	....	....
Apr. 11	....	....	....	13,300	....	....	....	....	66	20	....	....	....	....
Apr. 18	19,700	18,300	....	14,200	....	9,520	5,280	....	422	19	....	18	....	....
Apr. 25	....	....	....	10,100	....	....	....	....	175	38	....	....	....	....
May 2	19,200	17,400	....	13,200	....	9,960	7,160	....	560	24	....	20	....	....
May 9	....	....	....	15,400	....	....	....	....	230	19	....	....	....	....
May 16	....	....	....	8,290	....	....	....	....	56	17	....	....	....	....
May 23	19,800	18,800	....	10,800	....	4,480	1,720	....	40	25	....	18	....	....
May 30	....	....	....	11,400	....	....	....	....	32	19	....	....	....	....
June 6	....	....	....	6,170	....	....	....	....	18	27	....	....	....	....
June 13	14,900	13,300	....	1,800	....	390	57	....	17	19	....	19	....	....
June 20	....	....	....	2,720	....	....	....	....	16	23	....	....	....	....
June 27	....	....	....	1,840	....	....	....	....	16	17	....	....	....	....
July 4	17,400	15,800	....	3,120	....	795	310	....	17	16	....	15	....	....
July 11	....	....	....	2,580	....	....	....	....	15	15	....	....	....	....
July 18	....	....	....	....	....	....	....	....	18	16	....	....	....	....
July 25	....	16,700	....	1,200	....	370	30	....	20	20	....	....	....	....

Aug. 1	16,000	13,000	....	700	....	260	30	....	20	20	....	....	....	....
Aug. 15	16,500	14,300	....	8,600	....	1,200	1,100	....	20	20	....	....	....	....
Aug. 29	17,700	14,800	....	4,300	....	....	70	....	20	20	....	....	....	....
Sept. 12	15,600	12,600	....	1,800	....	....	20	....	20	20	....	....	....	....
Sept. 26	15,800	13,400	....	15,200	....	4,120	104	....	21	18	....	....	....	....
Oct. 10	16,200	12,800	....	6,320	....	1,440	64	....	16	17	....	....	....	....
Oct. 24	15,000	14,100	....	8,600	....	5,000	100	....	20	20	....	....	....	....
Nov. 7	....	....	....	10,100	10,400	....	3,100	....	20	20	330	....	....	....
Nov. 14	....	....	....	10,500	....	6,800	1,000	....	20	20	....	....	....	....
Nov. 21	16,000	15,000	....	13,500	....	5,500	900	....	10	10	....	....	....	....
Nov. 28	....	....	....	5,500	....	2,800	80	....	10	10	....	....	....	....
Dec. 5	....	....	....	11,500	....	7,800	4,100	....	40	10	....	....	....	....
Dec. 12	14,000	13,000	....	9,400	13,500	6,200	2,300	....	10	10	880	....	....	....
Dec. 19	....	....	....	10,500	....	3,900	350		20	20	....	....	....	....
Dec. 26	....	....	....	13,000	....	5,800	1,000	....	20	10	....	....	....	....
1947														
Jan. 3	14,500	11,500	....	2,800	11,000	960	100	....	20	10	150	....	....	....

SNAPPER CREEK CANAL

Snapper Creek Canal is the southernmost of the secondary canals and it traverses one of the least populated sections in the area. Its channel is relatively small, and it is constricted at a number of locations. Table 77 presents the observed chloride concentrations. The intersection of Red Road and North Kendall Drive was usually the farthest inland point of contamination. In 1945, however, salty water moved upstream, despite the shoals and weeds, and was found at Palmetto Road, 4.8 miles inland and west of U. S. Highway 1. A control was placed in the canal at Ingraham Highway in 1946, which effectively stopped inland movement of salty water despite the cavernous nature of the limestone in the area.

In most years, the channel is flushed completely of salty water during the wet period.

Table 77.—*Chloride concentrations in Snapper Creek Canal, Miami*

[Parts per million. Before October 1, 1941, the values are the highest obtained for either surface or bottom samples (usually the latter); after October 1, 1941, the values are from bottom samples. Mileages in parentheses indicate distance from mouth of canal at Biscayne Bay]

Date	Ingraham Highway (0.91 mile)			Parrot Jungle (1.33 miles)	Huttig Bridge (2.03 miles)	North Kendall Drive and Red Road (2.70 miles)	U. S. Highway 1 (3.79 miles)	Palmetto Road (4.78 miles)
	Prior to control	Below control	Above control					
1941								
Mar. 2	5,330	....	....	....	....	15	15	14
Mar. 14	37	....	....	....	....	14	14	15
Apr. 3	151	....	....	....	....	14	15	15
Apr. 18	234	....	....	....	....	15	16	....
May 1	272	....	....	....	....	14	14	14
May 20	1,100	....	....	....	....	16	14	15
June 4	17,460	....	....	....	....	16	17	....
June 17	17,030	....	....	....	....	16	15	....
July 2	650	....	....	....	....	17	15	15
July 14	153	....	....	....	....	15	13	14
July 30	412	....	....	....	....	17	15	14
Aug. 18	1,180	....	....	....	....	15	16	14
Sept. 3	15,590	....	....	....	....	15	13	14
Oct. 1	187	....	....	....	....	13	13	13
Oct. 17	10,100	....	....	....	....	14	14	14
Oct. 31	322	....	....	....	....	15	16	14
Nov. 14	2,290	....	....	....	....	15	14	15
Nov. 28	14,400	....	....	....	....	14	14	13
Dec. 24	378	....	....	....	....	14	14	13
1942								
Jan. 3	15,200	....	....	....	....	15	14	12
Jan. 16	15,200	....	....	....	....	13	13	13
Feb. 4	3,280	....	....	....	....	13	13	13
Feb. 17	1,940	....	....	....	....	14	13	13
Mar. 4	335	....	....	....	....	14	14	14
Mar. 19	1,550	....	....	....	....	15	13	13
Apr. 2	3,380	....	....	....	....	14	13	13
Apr. 28	4,180	....	....	....	....	15	15	15
May 8	278	....	....	....	....	16	15	16
May 22	412	....	....	....	....	17	18	16

Table 77.—*Chloride concentrations in Snapper Creek Canal, Miami*—Continued

Date	Ingraham Highway (0.91 mile)			Parrot Jungle (1.33 miles)	Huttig Bridge (2.03 miles)	North Kendall Drive and Red Road (2.70 miles)	U. S. Highway 1 (3.79 miles)	Palmetto Road (4.78 miles)
	Prior to control	Below control	Above control					
1942								
June 9	116					15	15	15
June 24	155					14	14	14
July 9	145					16	15	14
July 24	7,310					16	15	15
Aug. 6	2,425					17	14	18
Aug. 22	2,700					13	13	13
Sept. 4	211					13	14	14
Oct. 7	10,550					14	14	13
Nov. 9	15,950					15	15	16
Nov. 24	880					15	14	13
Dec. 10	1,450					15	13	14
Dec. 23	1,430					15	14	14
1943								
Jan. 6	15,100					13	14	12
Jan. 23	16,550					14	14	12
Feb. 8	1,050					14	12	13
Feb. 26	1,460					14	12	11
Mar. 15	15,680					17	15	13
Apr. 2	15,000					16	13	12
Apr. 16	20,000					17	13	15
May 5	18,700					17	12	13
May 15	4,680					14	14	14
June 1	19,700					16	13	14
June 16								14
June 19	17,500					16	16	
July 4	9,270					15	15	14
1944								
Sept. 7	18,200					22	23	
Oct. 3	18,400			14,900	4,850	26		
Nov. 9	14,100			35	20	16		
Dec. 21	1,850			50	24	14		
1945								
Jan. 25	15,500			34	21	14		
Feb. 26				8,540	33			
Feb. 27	16,000			2,400	27	15		
Apr. 6	17,700			11,700	53	17		
Apr. 27	20,400			13,400	6,600	245		
May 1	21,600							
June 12				22,200	17,400	10,000	9,200	29
June 28					16,700	3,900	5,900	20
July 17				14,900		2,400	1,800	2,700
Aug. 1	3,600			1,400	560	420	1,300	160
Aug. 30				13,400	1,600	1,000	560	17
Sept. 24	10,800			200	90	57	23	18
Oct. 4	7,110							
Oct. 11	10,900			145	61	41	21	18
Oct. 16	1,480							
Oct. 23	14,600							
Nov. 2	302			121	75	35	21	23
Nov. 7	300							
Nov. 14	275							
Nov. 21	6,080			109	50	28	20	19

Table 77.—*Chloride concentrations in Snapper Creek Canal, Miami*—Continued

Date	Ingraham Highway (0.91 mile)			Parrot Jungle (1.33miles)	Huttig Bridge (2.03 miles)	North Kendall Drive and Red Road (2.70 miles)	U. S. Highway 1 (3.97 miles)	Palmetto Road (4.78 miles)
	Prior to control	Below control	Above control					
1945								
Nov. 29	292	....	....	....	....	....	....	....
Dec. 5	....	14,400	11,700	....	....	....	....	....
Dec. 11	....	8,730	19	18	18	18	20	....
Dec. 19	....	14,100	32	....	....	....	....	....
Dec. 27	....	11,700	19	....	....	....	....	....
1946								
Jan. 3	....	13,400	19	18	....	16	19	17
Jan. 10	....	9,220	21	....	....	....	....	....
Jan. 17	....	15,000	24	....	....	....	....	....
Jan. 24	....	14,700	32	32	....	19	18	17
Jan. 31	....	13,900	25	....	....	....	....	....
Feb. 7	....	14,000	22	....	....	....	....	....
Feb. 14	....	17,100	76	23	....	19	17	18
Feb. 21	....	15,400	42	....	....	....	....	....
Feb. 28	....	17,200	29	....	....	....	....	....
Mar. 7	....	12,400	18	17	....	16	15	16
Mar. 14	....	17,500	30	....	....	....	....	....
Mar. 21	....	18,800	240	....	....	....	....	....
Mar. 28	....	16,800	38	29	....	20	20	17
Apr. 4	....	18,200	260	....	....	....	....	....
Apr. 11	....	18,100	74	....	....	....	....	....
Apr. 18	....	16,900	220	38	....	21	14	16
Apr. 25	....	19,400	237	....	....	....	....	....
May 2	....	20,500	2,320	35	....	30	37	26
May 9	....	17,600	52	....	....	....	....	....
May 16	....	6,770	31	....	....	....	....	....
May 23	....	3,850	39	37	....	20	21	15
May 30	....	14,300	40	....	....	....	....	....
June 6	....	5,180	54	....	....	....	....	....
June 13	....	5,430	45	39	....	19	25	32
June 20	....	4,180	46	....	....	....	....	....
June 27	....	3,050	52	....	....	....	....	....
July 4	....	123	32	33	....	16	16	15
July 11	....	7,850	42	....	....	....	....	....
July 18	....	11,020	57	....	....	....	....	....
July 25	....	230	40	....	....	....	....	....
Aug. 1	....	350	40	40	....	20	20	....
Aug. 15	....	14,400	30	....	....	....	....	....
Aug. 29	....	11,100	30	....	....	....	....	....
Sept. 12	....	830	630	50	....	....	....	....
Sept. 26	....	15,900	640	60	....	38	27	....
Oct. 10	....	16,300	1,590	43	....	27	17	....
Oct. 24	....	14,500	6,200	36	....	21	25	....
Nov. 7	....	15,500	610	40	....	....	....	....
Nov. 14	....	15,500	16,000	60	....	20	....	....
Nov. 21	....	15,500	15,000	40	....	20	20	....
Nov. 28	....	2,100	3,000	60	....	....	....	....
Dec. 5	....	14,000	14,000	40	....	....	....	....
Dec. 12	....	14,500	13,000	40	....	40	40	....
Dec. 19	....	6,800	11,000	50	....	....	....	....
Dec. 26	....	15,000	13,000	50	....	....	....	....
1947								
Jan. 3	....	190	130	30	....	30	20	....

FORT LAUDERDALE AREA

LOWER NEW RIVER BASIN

When drought conditions became extreme in the spring of 1945, salty water moved steadily inland in the tidal portion of New River basin. Extensive areas of swamp and slough were contaminated and some of the native jungle growth was killed. The water in the tidal channels could not be used for irrigation, with the result that groves and farms suffered from excessive dryness. It was feared that the municipal well field of Fort Lauderdale might become contaminated because some of the wells are located only about 1½ miles north of the tidal section of North New River Canal. The Florida Power and Light Company developed a new well farther away from Dania Cutoff Canal to obtain feed-water for the power plant near Dania when the chloride content of the original well became excessive.

The power company had made regular salinity observations in the vicinity of the power plant since the plant was built but these observations were too limited to indicate the entire intrusion pattern. In 1945, the Geological Survey started periodic observations, their frequency depending upon local conditions. Samples were taken at the bottoms of the channels at various strategic locations and as near as possible to time of high tide.

The worst period of salt contamination occurred in 1945 when strongly salty water was found for several months in the whole tidal portion of the basin. Closed controls and locks in North New River and South New River Canals prevented the salt front from penetrating farther inland. Concentrations at the downstream side of these controls were 40 to 60 percent of that of sea water, and essentially normal sea water occupied the lower reaches. Water that was about 25 percent as salty as sea water was found above the easternmost control in South New River Canal and was believed to extend a short distance upstream. This was a result of the occurrence of negative heads and condition of the control, which was not constructed to hold negative heads. Runoff in both canals was limited to a small amount of leakage through the controls.

The 1945 condition was considered to be the extreme of the period of observation, but the highest chloride concentrations were found in April 1946 (see fig. 187). Slightly higher concentrations were observed at a few of the stations at other times but the series of samples collected for this date contained the maximum concentrations at the most locations. The control and lock in South New River Canal at Davie had been repaired since the 1945 intrusion, and the concentration upstream was relatively low. The concentration of 75 ppm upstream from the control and lock in North New River Canal was higher than that of water from the

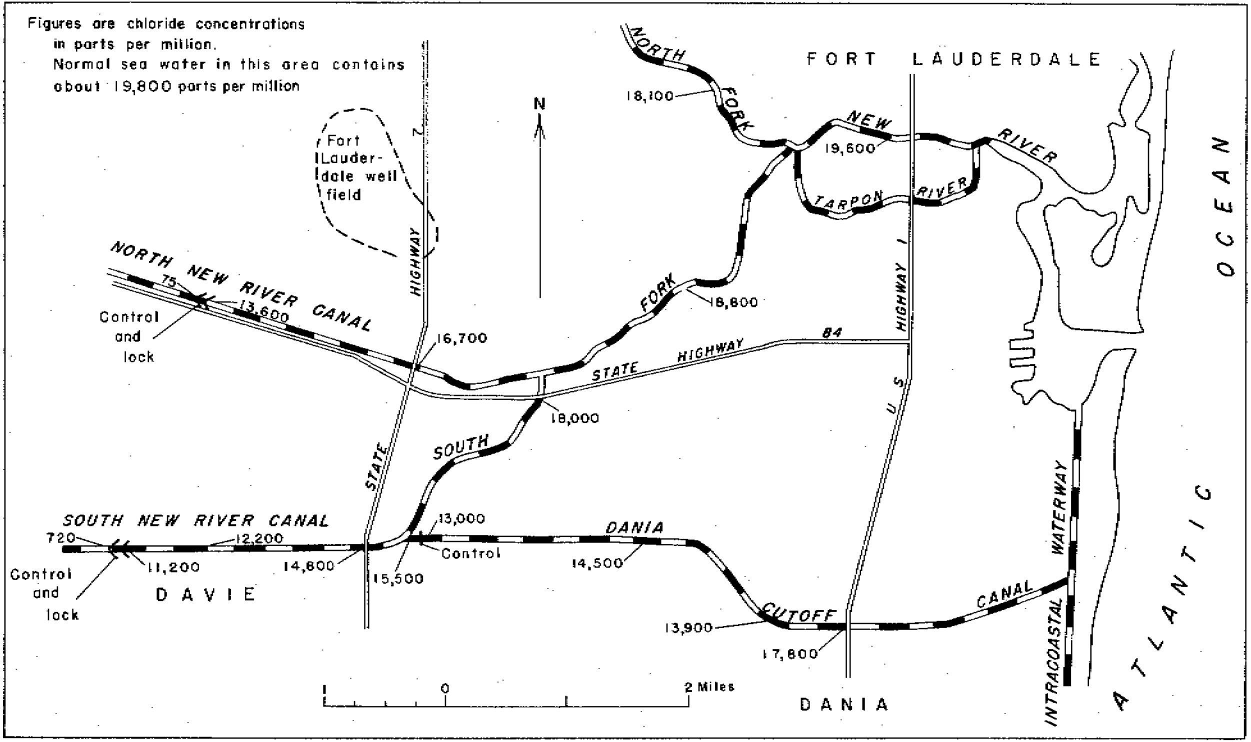


Figure 187. — Map showing chloride concentrations at sampling stations in lower New River basin, April 30, 1946.

Everglades to the west but was not an indication of local contamination. When ice-age seas withdrew from southern Florida, large quantities of salty water were trapped in the rock and remained there throughout the ensuing centuries. This residual salty ground water seeps into the middle reaches of the canal and causes a small amount of contamination under most conditions of flow. The degree of contamination varies inversely with the discharge of the canal.

Heavy rains and subsequent large fresh-water runoff force the salty water downstream and in flood periods the salty water may be completely flushed out of the basin. Salty water, however, is usually present in the channels in the vicinity of Fort Lauderdale. No samples were collected from New River Sound and the Intracoastal Waterway but it may be assumed that they are nearly always salty, although they could become brackish under extreme flood conditions.

MIDDLE RIVER BASIN

No regular sampling was done in Middle River basin but miscellaneous observations of North Branch and South Branch at the West Dixie Highway showed chloride concentrations as high as 15 percent of that of sea water; this was undoubtedly not the maximum. These channels are not controlled and are connected with networks of canals and ditches, thus making a sizable area vulnerable to salt contamination—an area that is used for farming and where municipal supplies ultimately may be developed.

HOMESTEAD AREA

The marl lands, stretching in an increasingly wide zone along the coast from Cutler to Cape Sable, are generally below an elevation of 4 ft and slope gradually into Biscayne Bay and its extensions to the southwest. The marl overlies very permeable oolitic limestone; water control in this area is difficult where the canals and ditches are excavated into the limestone. Despite the high productivity of the soil, a small to moderate amount of rainfall is required for farming during the winter growing season, which is normally quite dry. Owing to the need generally for a low water table, the area is subject to contamination by salty water, particularly along the large east-west canals.

The Homestead area is much like the main Everglades farming area near Lake Okeechobee in that there is excess water in wet periods and a scarcity of water during droughts.

In the drought years of 1943–45 extensive areas of crop land were rendered useless by salt contamination. Salt concentrations

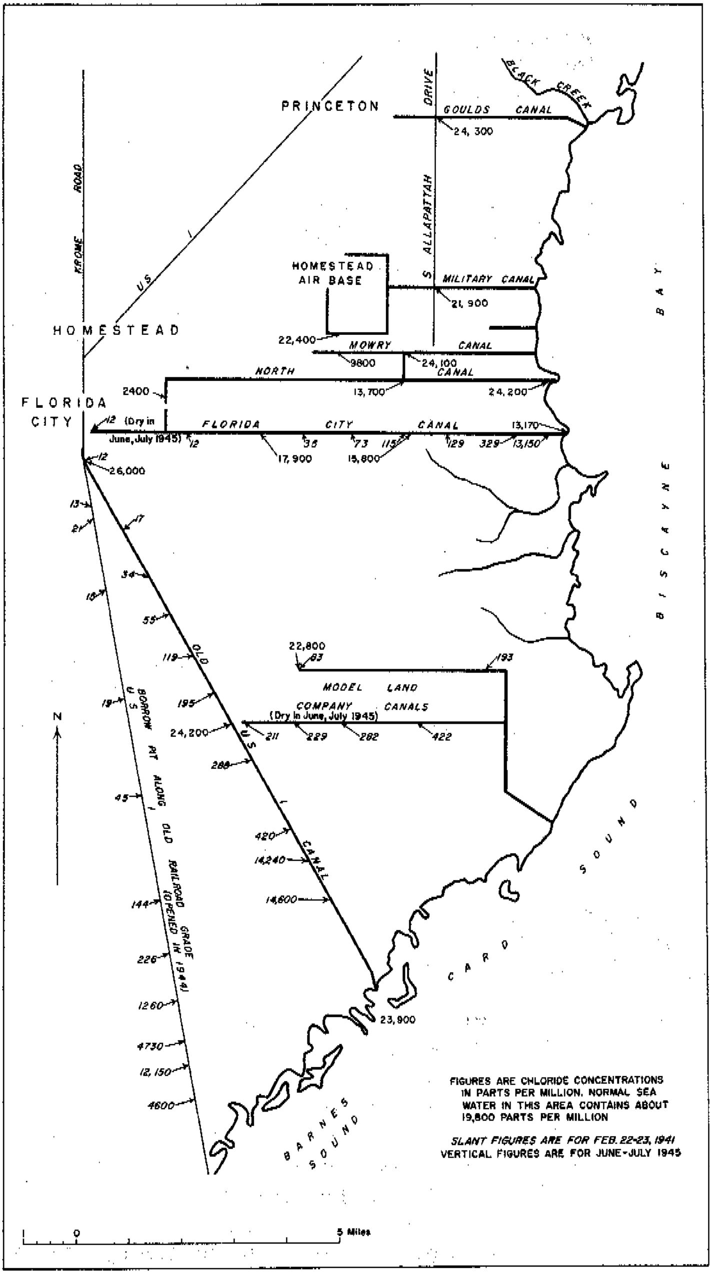


Figure 188. — Map of Homestead area, showing chloride concentrations in canals, February 22, 23, 1941, and June and July 1945.

in the soil exceeded the salt tolerance of many plants, and crop failure was the inevitable result. Salt crystals were found on the leaves of several varieties of plants and even on the fruit of cucumber vines. Where ground water and soil moisture were contaminated, evaporation resulted in the formation of thin surface crusts of highly salty soil. Fortunately, the salty soil condition was dissipated annually in the wet season, but ground-water and canal contamination continued in varying degrees.

Although reconnaissance observations of chloride concentrations in the Homestead area were made in 1945, a regular series of observations was not started until 1946. Therefore, it is not possible to show the variations of chloride contamination with the change of water conditions.

Figure 188 shows the chloride concentrations found in some of the canals in the Homestead area. The general reconnaissance in 1941 was made when there were fairly high water levels for the time of the year. The winter of early 1941 was marked by continued high runoff, following a wet fall. The concentrations less than 20 ppm of chloride represent uncontaminated water of the area, which was found only at the head ends of the canals. Of all the canals identified on the map, only North and Florida City Canals were controlled. The heavy concentrations undoubtedly show contamination directly from the sea. The lesser concentrations may have been a result of direct intrusion, but it is more likely that they indicate contamination from salty ground water that was residual from the intrusion of the previous dry season.

The borrow ditch along the east side of the old railroad embankment in this area (now the alignment of U. S. Highway 1) is deeper to the south and connects with Barnes Sound (see fig. 188) in a shorter distance than the borrow ditch on the west side. Contamination was found to extend 2 miles farther north in the east borrow ditch than it did in the west borrow ditch. The embankment is partially effective in preventing salty surface water in the east borrow ditch from penetrating to the west side. The vegetation suggests that the difference in chloride concentrations is more than a temporary condition. Mangroves, which thrive only in salty and brackish waters, were observed about 2 miles nearer to Florida City on the east side than on the west side of the embankment.

The extent of salt-water encroachment in the Homestead area in the extreme drought of 1945 is also shown in figure 188. All of the canals, whether controlled or not, became contaminated with salt water, which in places exceeded the normal concentration of sea water by about 30 percent. At the time, ground-water levels were very low—below sea level in some areas. As a result, net flow in the canals probably was inland and the canals supplied salt water to the porous formations. Water that was more salty than sea water extended to Florida City and the outskirts of Homestead, more than 9 miles from Biscayne Bay.

Most of the salty water in the canals was flushed out by the late summer rains but contaminated water from the ground continued to seep into the canals. No samples were taken along the new route of U. S. Highway 1 in 1945, but later observations indicated that the shallow borrow ditches along the highway fill probably were strongly contaminated to a point less than 6 miles from Florida City. This location is at the northern end of the continuous ditches and borrow pits and it is possible that ground-water contamination continued even farther inland. It was observed also that chloride concentrations were higher along the east side of the highway fill than on the west side, the same situation that was found when only the railroad embankment was there.

Starting in 1946, series of samples were taken from the borrow canal along Ingraham Highway southwest from Royal Palm Park (formerly Royal Palm State Park and now part of Everglades National Park), which is 11 miles southwest of Homestead. Thirteen miles by road, west-southwest from the ranger station in Royal Palm Park, a concrete bridge crosses the borrow canal and the road changes from an east-west to a northeast-southwest course for a distance of 1 mile, and then to a north-south course for a distance of 5 miles. About 2 miles south on the 5-mile north-south reach, mangroves occur, showing that the soil and water in the area are salty to a considerable degree and for a major part of the time. This essentially continuous contamination is also shown by the sampling program in the canal. The salt front was never found below the lower end of the north-south reach 14½ miles southwest of the ranger station in Royal Palm Park.

In dry periods, strongly salty water moves inland to the end of the canal near the ranger station at Royal Palm Park. The canal is not controlled, and its value for drainage is limited; however, it is an avenue for salt-water encroachment in the area between Whitewater Bay and Homestead.

SALT-WATER CONTAMINATION OF THE AQUIFER FROM TIDAL CANALS

By Gerald G. Parker

The amount of salt water that escapes from a tidal canal into the adjacent rocks is dependent upon several factors: The salinity of the canal water itself; the coefficient of transmissibility of the rocks through which the canal is cut; the presence or absence of a layer of sediment, which, if present, may be relatively impermeable and thus prevent free movement of water from the canal to the adjacent rocks; and the stage of the water table adjacent to the canal compared to the stage of the water surface in the canal.

Rocks of the Biscayne aquifer in the Atlantic coastal ridge, through which the canals are cut, are of very high permeability and transmit water readily. (See p. 269-270.) The amount of sedimentation in the canals is variable in time and in place. In some parts of the canals the bottom appears to be well sealed by deposits of calcareous mud, organic material, and very fine sand. In other parts, sealing material is absent and canal and ground water are freely exchanged. These conditions lead to the salting of some areas along the canals, whereas other areas remain unsalted or receive only a small amount of salty water. A further complication may result from the pumping of wells. Where the effects of the draft on ground water extend to the canal, pumping may induce or increase the movement of canal water into the aquifer.

For an understanding of the process of salt-water contamination of a fresh-water inland aquifer, a study was made in the area of the Miami well field (see figs. 13 and 189), through which the Miami Canal runs. In all respects, except for the pumping, this area is typical of the coastal area in southeastern Florida. The method of salt-water contamination of the aquifer is the same as would be found in any other tidal canal in which salt water has penetrated into an area of fresh ground water. Pumping from the nearby city-supply wells influences the flow of the ground water in the aquifer and thereby distorts the chloride-contamination pattern.

The following generalizations on salt-water contamination are based on ground-water studies made along Miami Canal between NW. 36th and NW. 54th Streets. A part of this area of study is usually intersected by the cone of depression formed in the water table by draft from the Miami well field. Figure 189, a map of the area, shows a pair of typical cones of depression in the water table.

Figure 190*A* is a cross section of this same area, showing ground-water conditions as they were before salt water made its appearance in this segment of the canal in 1939.

When salty water first reached this area in large quantities, it moved through the canal bottom, where it was not too heavily silted, and downward toward the bottom of the Biscayne aquifer. In doing so, it constantly encountered fresh water and was steadily diluted until it finally reached the top of the relatively impermeable Floridan aquiclude. When salt water had remained long enough in the canal, all fresh water directly under the canal disappeared (fig. 190 *B*) and saline water, lessening in chloride concentration as the bottom of the aquifer was approached, completely occupied the former fresh-water zone. An average pumpage of 30 mgd in the nearby Miami well field caused a general southwestward movement of the salted body of water.

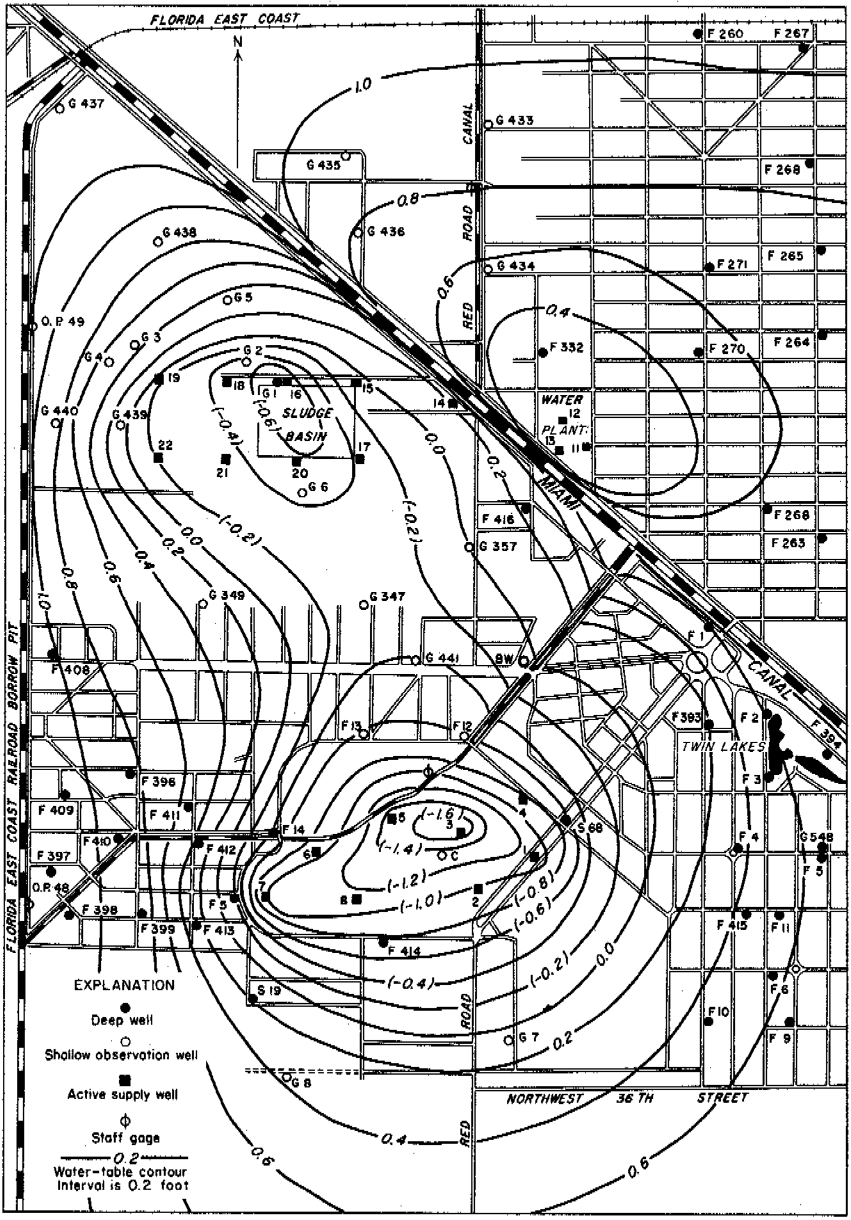
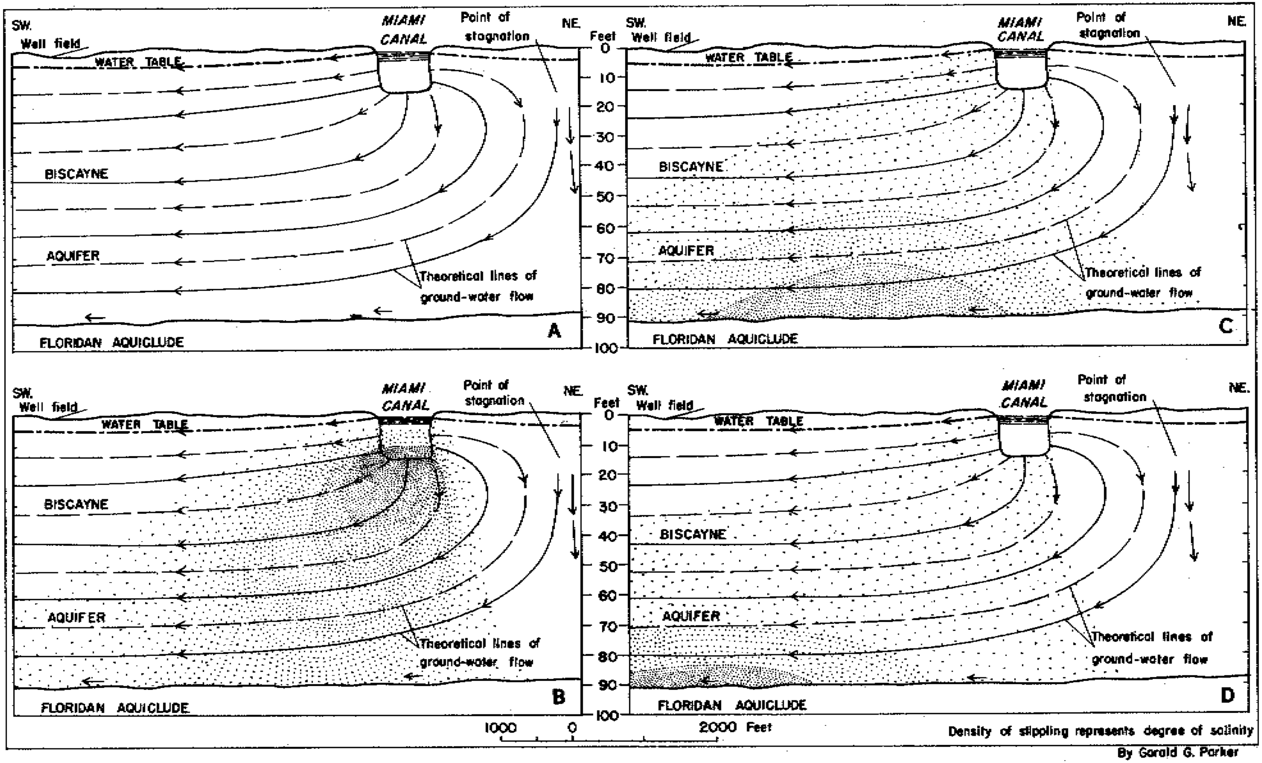


Figure 189. —Map of Miami well-field area showing shape of typical cones of depression in the water table.



By Gerald G. Parker

Figure 190. —Geologic cross section near the Miami well field: *A*, prior to salt-water intrusion; *B*, the beginning of the intrusion; *C*, several months later; *D*, a late stage.

At the close of the drought period in 1939, the fresh-water discharge in the canal increased, and salty water in the canal was swept downstream beyond the new zone of contamination. However, the salty water in the ground under the canal was not removed so quickly. It continued to sink toward the bottom of the Biscayne aquifer, to move toward the well field, and to create a salt-water mound on top of the Floridan aquiclude (fig. 190 *B*, *C*, *D*). As it was drawn toward the well field, the mound of salty water was diluted by the overlying fresh water from the canal and the surrounding fresh water. Finally, it was entirely isolated from its original source. Owing to its greater density, the water of greatest chloride content moved to the bottom of the aquifer. This mound is shown as an "island" of salty water on the map, figure 193.

Figure 190*D* shows a still later stage in the history of the salt-water encroachment. The salty water is continually, but slowly, being diluted by fresh ground water and being removed by pumping from the well field. If no further contamination had occurred through the canal, the final stage would have been reached with a return to original conditions, as shown in figure 190 *A*.

However, salty water again gained access to this reach of the canal in 1940, 1943, 1944, and 1945 (see fig. 192). As a result, new patterns of salt-water encroachment were imposed on the altered patterns of preceding encroachments. A more extensive discussion of encroachment in the Miami Springs–Hialeah well field is given in a later section of this report (see p. 691–705).

Encroachment of salt water also takes place in areas along canals that contain salt water continuously. In such areas, however, the manner of encroachment is the same as that which occurs directly from the ocean at depth in the aquifer.

CONTAMINATION OF CANALS BY RESIDUAL SALTY GROUND WATER

Figure 191 shows how residual bodies of salty water may contaminate fresh water in an overlying canal or other stream. The illustration represents a section of North New River Canal in its upper reach, south of Bolles Canal. When the level of North New River Canal is lower than the adjacent water table, ground water flows into the canal, and salty water from the Fort Thompson formation and the Caloosahatchee marl percolates upward into the canal. Water from the land surface and from Lake Okeechobee is relatively low in dissolved minerals, and the amount of chloride in the water, which may be used as a measure of contamination, is generally less than 20 ppm. However, under effluent conditions, as outlined above, it is not unusual for the canal water to contain as much as several hundred parts per million of chloride.

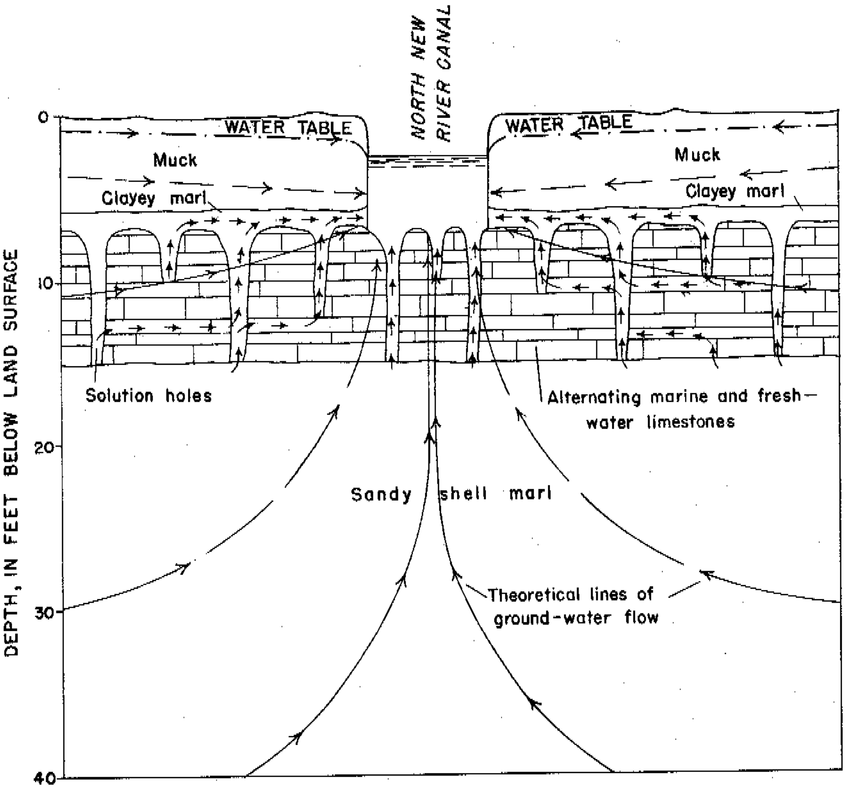


Figure 191. —Geologic cross section under North New River Canal showing residual salty ground water contaminating fresh canal water.

During times when the canal is influent (when the canal level is higher than the adjacent water table, and water is lost to the ground) it often carries water with less than 10 ppm of chloride.

SALT-WATER ENCROACHMENT IN THE MIAMI WELL FIELDS

The development of the water sources used by the city of Miami is described in the section on Ground water (Occurrence), p. 163—165. The abandonment of some of these sources was not because of failure of the wells to yield sufficient quantities of water; it was always because of salt-water encroachment.

SPRING GARDENS WELL FIELD

The Spring Gardens well field occupied the site at NW. 11th Street and 10th Avenue, where the present storage tanks are located (see map, fig. 168). H. H. Hyman and H. D. Wright, of the Florida Power and Light Company, reported that when this field was first put into use, about 1907, it yielded typical hard limestone water with no salty taste. The depths of the wells are from 80 to 90 ft, which is near the base of the Biscayne aquifer. At that time, therefore, salty water was absent from the aquifer of this part of the coastal ridge.

As the city grew and more water was required, additional wells of the same depth were drilled. Then, gradually, the effects of the drainage program began to be felt. The water table declined so much that the wells, which had been flowing into a sunken reservoir, ceased flowing or were so reduced in flow that by about 1918 it was necessary to install pumps. At this time there were about 11 wells.

Shortly after the pumps were installed the water became brackish in the easternmost wells; then, one by one, the other wells became brackish also. It was decided to plug the bottoms of the wells and develop them at shallower depths, where fresh water might be obtained. This was done, and the wells began producing fresh water from about 40 to 45 ft below the land surface. More wells were added, one or two at a time, all located to the north and west. In the latter part of 1918 a total of 24 wells, with average depths of about 40 to 45 ft, constituted the well system (Hyman, 1943). Gradually, however, even these shallow wells were contaminated by salt water, and by January 1919 only 13 were still in service. They were the wells located farthest to the north and west.

At the request of the Florida State Board of Health, Clyde P. Ross (1919) of the U. S. Geological Survey prepared a report on the water supply at Miami (table 78).

The composite sample of ground water reported above is a combination of water from 13 pumping wells and is therefore representative of neither the saltiest nor freshest water from this field. Although the water is hard and contains 269 ppm sodium chloride, it is potable, and most people would not detect the chloride by taste.

After 1919, the salinity continued to increase. Lawsuits were brought against both the Miami Water Company and its manager, H. H. Hyman, for selling salty water (Bellamy, 1946). Nevertheless, by reducing the pumpage from the Spring Gardens field and drilling additional wells elsewhere in the city, the water company continued its service until the new municipally owned well field in the Miami Springs - Hialeah area was developed and put into operation in the spring of 1925. At present, even very shallow wells in the Spring Gardens well field yield only salty water.

Table 78.—*Analyses of ground and surface water at Miami, January 21, 1919*

[Samples collected by C. P. Ross. Analyses, in parts per million, by M. D. Foster and C. M Forman]

Source	Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na +K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Organic matter
Spring Gardens wells[1].......	772	12	0.64	116	18	141	282	56	269	tr.	1.6
Miami Canal[2]................	339	20	.25	85	8	24	278	23	32	tr.	11

[1] Composite sample from 13 pumping wells, average depth about 45 feet.

[2] From middle of stream, under Miami Canal bridge (probably the bridge formerly at NW. 27th Ave.).

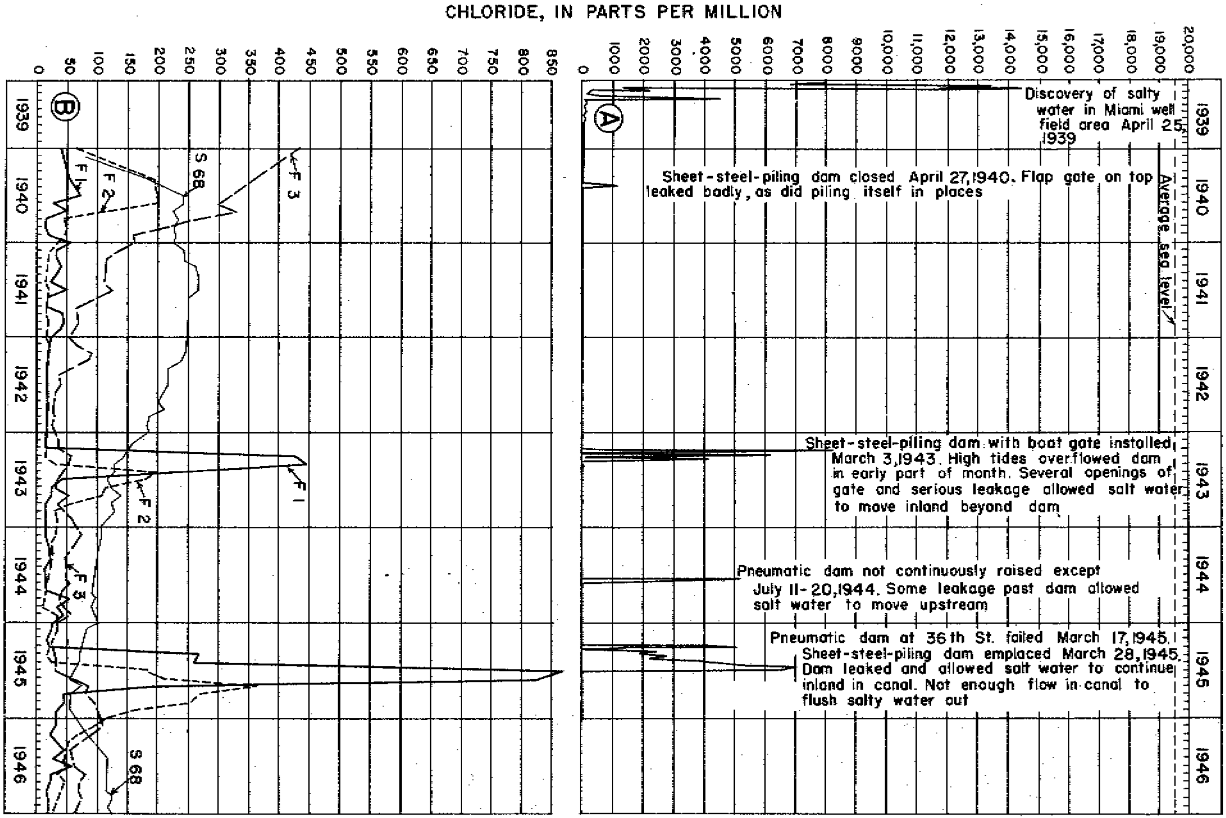


Figure 192.—Graph showing variation of chloride in: *A*, Miami Canal at NW. 54th Street; *B*, wells F1, F2, F3, and S68, Miami well-field area.

MIAMI SPRINGS–HIALEAH WELL FIELD

The salting of the water at Spring Gardens made it necessary to find a new water source. This was found in the Miami Springs–Hialeah area. According to W. L. Black, superintendent of the Miami Water Works, it was developed largely in 1924 and put into service in March 1925. The raw water from the new well field apparently was quite similar to that first obtained in downtown Miami (see p. 163–165) and from the Spring Gardens well field—a hard limestone water containing considerable organic color. It continued to yield water of this quality until April 1939, when certain wells nearest Miami Canal began producing salty water. By mid-May, the chloride concentration of water from some of the wells had increased to 1,900 ppm. Figure 192*A* is a graph based on data furnished by the Miami Department of Water and Sewers. It shows the variation of chloride concentration in water of the Miami Canal at the NW. 54th Street Bridge between Hialeah and Miami Springs. The record begins on April 29, 1939, by which time the chloride content of the canal water had already reached 8,100 ppm; by mid-May it had increased to 14,400 ppm, equivalent to 73.8 percent of sea water.

The U. S. Geological Survey began sampling ground water from the well-field area in December 1939, but it did not achieve adequate areal coverage until April 1940; all critical wells since that time have been sampled at least once a month. In addition to the fire and supply wells already existing in the area, the Survey drilled 12 observation and test wells that penetrated to the base of the Biscayne aquifer at an average depth of about 100 ft. Water from about 45 wells (see map, fig. 189), including the 20 city supply wells, was sampled.

SALT-WATER INTRUSIONS IN THE MIAMI CANAL

Figure 186 shows the approximate position of water in Miami Canal containing 1,000 ppm of chloride. Figure 192*A* shows that the highest recorded chloride concentration in the canal water at the 54th Street bridge sampling station occurred in 1939. The record for 1939 is incomplete, however, for it does not start until April 25, and it is probable that salt water had occupied the canal at that point for a considerable time before discovery and sampling. By October, the salt had retreated downstream and the canal water at the 54th Street Bridge was again normal. (See pages 636–640 for a discussion of salt-water encroachment in Miami Canal from 1940 to 1946.)

CONTAMINATION OF WELLS

As a result of the several incursions of salt water in Miami Canal in the Miami well-field area, salt water contaminated the adjacent ground water. The method of contamination is shown in figures 190 and 192*B*, and in map form in figures 193–198.

Figure 192*B* is a graph showing variation in the chloride content of ground water at four wells situated at increasing distances from Miami Canal (see fig. 189). Well F 1 is about 80 ft from the canal and is about 50 ft deep; F 2 is about 400 ft from the canal and is about 71 ft deep; F 3 is about 900 ft from the canal and is about 46 ft deep; and S 68 is about 2, 900 ft from the canal and is about 61 ft deep. Wells F 1 and F 2 are adjacent to Twin Lakes.

It was not until December 1939 that samples were collected from these wells and the water in Twin Lakes was analyzed for chlorides. Therefore, a direct comparison cannot be made with the Miami Canal record, which begins in April 1939.

Figure 192*B* shows that in 1940 the salinity was greatest in well F 3, less in F 2, and still less in F 1. The plate also shows that while F 3 was declining in salinity, the other two were increasing, and the amount of increase was less in F 1 (farthest from F 3) than in F 2. This suggests that a pocket of saline water, probably trapped in the deepest part of West Twin Lake, was slowly seeping downward and outward. Months after the adjacent Miami Canal water had returned to normal, this salty water was further contaminating the ground water immediately adjacent to it. The occurrence of such an isolated pocket of salty water in Twin Lakes is possible because the canal connecting them with Miami Canal is much shallower than either the lakes or Miami Canal. When this salty water entered the lakes it could leave only by relatively slow underground seepage.

Later incursions of saline water in the Miami Canal (1940 and 1943–45) were all of a lower concentration than that in 1939 (fig. 192 *A*). This saline water occupied only the canal bottom and did not spill over the shallow entrance into Twin Lakes (as in 1939). Therefore, it did not create a local source of contamination in the lakes. The truth of this statement is illustrated by the fact that the increase in chloride concentration was not significant in wells F 1 and F 2 after the removal of the contamination in Miami Canal, whereas the increase was significant in 1940 following the incursion of 1939. The incursion of 1943 was moderate, but typical: F 1 responded first and in greatest amount; F 2, next and in lesser amount; and F 3, still later and in least amount. These responses indicate that the salt water seeps downward and outward from Miami Canal, and that it becomes progressively diluted as it moves farther from the canal.

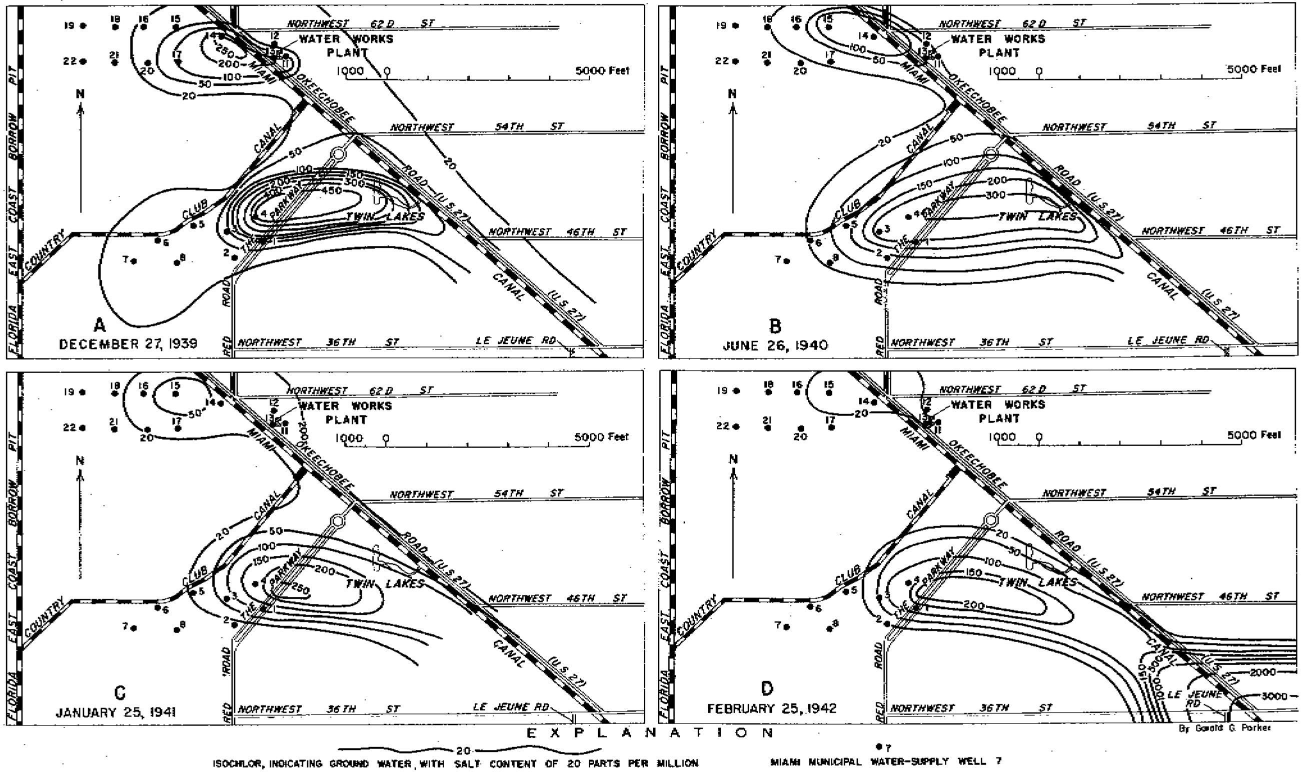


Figure 193. —Isochlor map of the Miami well-field area: *A*, December 1939; *B*, June 1940; *C*, January 1941; and *D*, February 1942.

The response of well S 68, which is 2, 900 ft from the canal, was entirely different from that of F 1, F 2, and F 3, which are nearer the canal. For example, the increase in chloride caused by the 1939 incursion did not reach a maximum in S 68 until May 1940—a lag of about 6 months. Similarly, the incursions of March 1943 and June 1944 caused small increases in chloride in S 68 that did not reach their peaks until August and December, respectively. The extensive incursions that occurred from March to June 1945 resulted in an increase in salinity at S 68 that did not reach its peak until early in 1947. However, most of this increase had taken place by May 1946. A period of about 6 months to a year was thus required for the salt water to move approximately 2, 900 ft, which is at the rate of 8 to 16 ft per day. This variation was chiefly due to changes in the rate of pumping in the well field.

Chloride maps (figs. 193—198) were prepared as a result of regular month-end studies that were made in the well-field area from the time the U. S. Geological Survey began its investigation. These 24 maps (selected from 96 maps) are considered necessary for a full understanding of the history of salt-water encroachment in the well-field area.

As the investigation proceeded, it became apparent that certain critical spots in the salt-front area were not adequately covered. Therefore, additional observation and test wells, penetrating to the bottom of the aquifer, were drilled from time to time. Each month, water levels in these wells were observed and water samples were collected for chloride analysis. These data were then plotted on topographic base maps, which gave month-end information on the shape of the water table, including the extent of the cone of depression and the concentration of salt in the ground water. Only isochlors are plotted in figures 193–198.

Figure 193*A* shows chloride conditions in December 1939, six months after the salt-water incursion in Miami Canal reached the 54th Street bridge. The oval-shaped body, or "island", of salty ground water (maximum chloride content slightly more than 450 ppm), extending from the Twin Lakes area to the lower well field, is notable in the figure. The map indicates the role that Twin Lakes played in the original salting of this area (see p. 692). It shows that the salty water did not come directly from the tongue of salty ground water in the vicinity of NW. 36th Street, as has much of the salty water of later invasions. From its source at Twin Lakes, the salty water, in response to pumping in the lower well field, was drawn in almost a straight line into the well field.

Another island of contamination that is notable in figure 193*A* is in the upper well field. It now has a maximum chloride content of slightly more than 250 ppm; at one time, however, its chloride content was more than 1,000 ppm. This contamination is directly related to pumping in the upper well field.

Figure 193*B* shows chloride conditions in the well-field area in June 1940. A slight incursion of salty water occurred in Miami Canal in May, but it did not greatly change the chloride pattern of December 1939. In the lower field, the pattern widened somewhat and moved much farther into the well field. In the upper field, the pattern became smaller and the salinity decreased considerably.

Figure 193*C* shows conditions in the well-field area in January 1941, 19 months after the extensive salt-water incursion of 1939 had withdrawn and 8 months after the minor incursion of 1940. By this time the upper well field had returned almost to normal, and the lower well field contained only one small area where chloride was in excess of 250 ppm. The entire pattern in this area was greatly reduced, and the axis of the pattern shifted from approximately S. 80° W. (Dec. 27, 1939) to approximately S. 80° E.

Figure 193*D* shows conditions in the well-field area in February 1942. Since May 1940 no new incursions of salt water had occurred in Miami Canal above NW. 36th Street. In the upper well field there remained only one small area of ground water that had a chloride content slightly above 20 ppm. (Chloride of less than 20 ppm is regarded as normal for this area.) In the lower well field the ground water that had contained 250 ppm or more of chloride had disappeared. Now, for the first time, the tongue of salty ground water near NW. 36th Street and Le Jeune Road could be related to the salty water in the well field. This tongue was merely the westernmost extension of the salt-water wedge that extended inland from the western shore of Biscayne Bay along the canal. Similar tongues extended from Biscayne Bay along, and beneath, each of the tidal canals of Dade County (see fig. 200); these tongues were not induced by pumpage in the Miami well field.

Figure 194*A* represents salinity conditions in ground water of the well-field area at the end of January 1943. New incursions of salty water had not taken place in Maimi Canal, and conditions had improved in both the upper and lower well fields, where the highest isochlor was 150 ppm. The NW. 36th Street tongue had advanced only slightly on the south side of NW. 36th Street and west of Le Jeune Road.

Figure 194*B* shows conditions in March 1943 immediately following the second of two salt-water incursions up Miami Canal in March. As a result of these incursions a new center of contamination developed in the upper well field. The lower field was not affected, however, and there the salinity lessened. This continued improvement is credited to dilution, a factor that is quite apparent when the increased extent of the zone of 20- to 50-ppm concentration

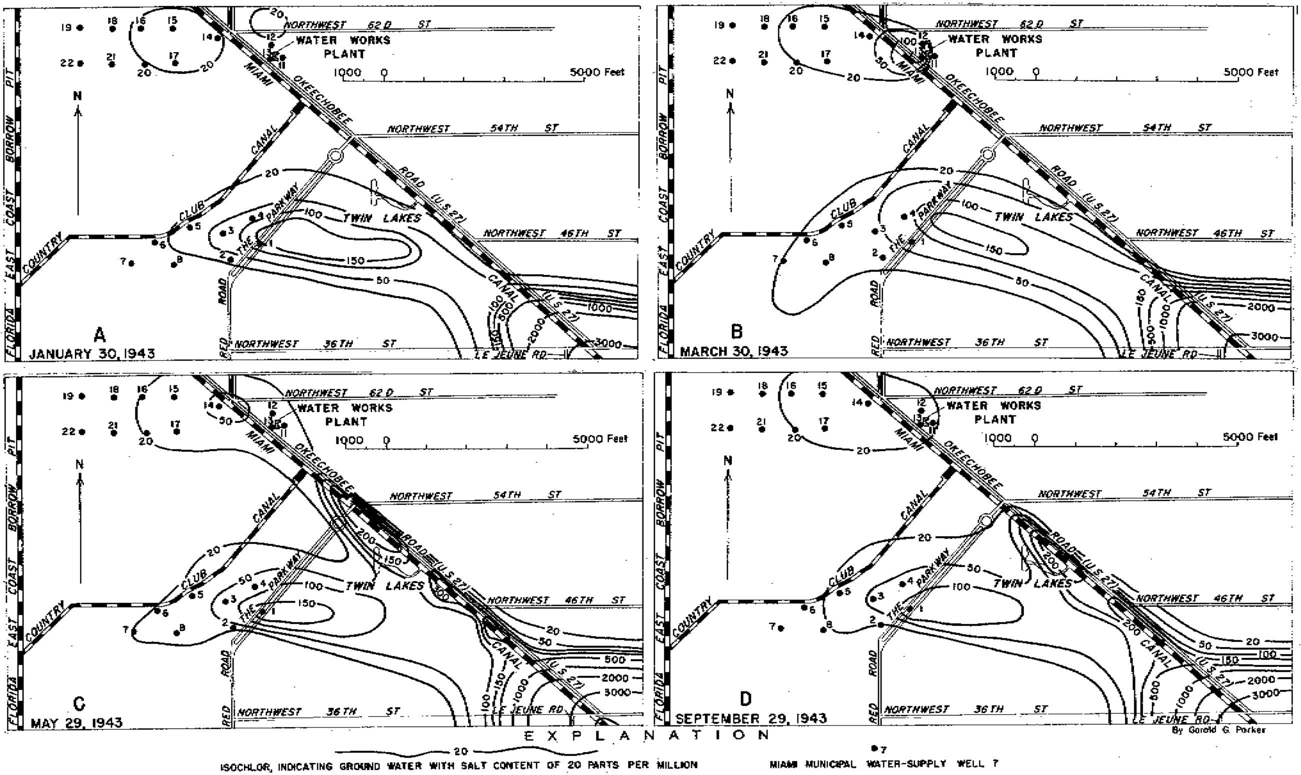


Figure 194. —Isochlor map of the Miami well field area: *A*, January 1943; *B*, March 1943; *C*, May 1943; and *D*, September 1943.

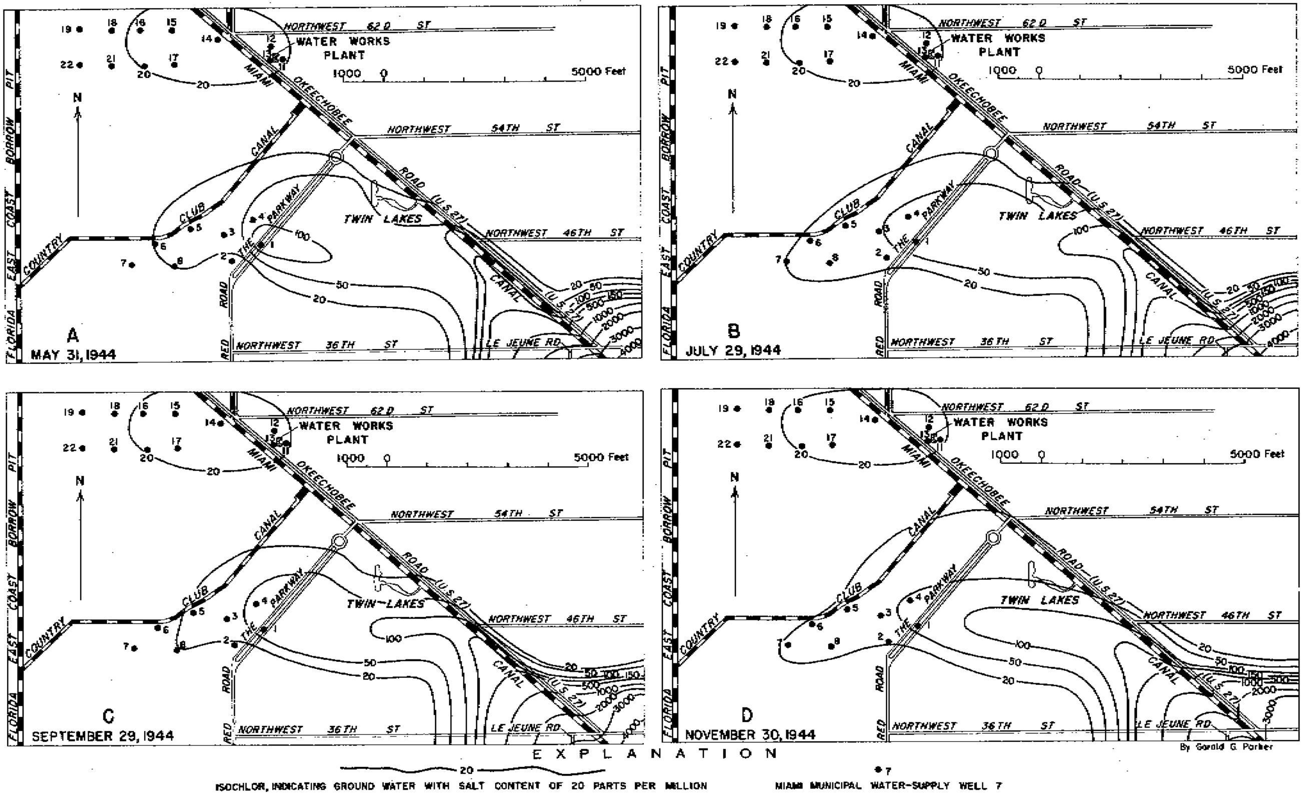


Figure 195. —Isochlor map of the Miami well-field area: *A*, May 1944; *B*, July 1944; *C*, September 1944; and *D*, November 1944.

is considered. Note also the westward advance of the NW. 36th Street tongue south of NW. 36th Street and west of Le Jeune Road.

Figure 194C represents conditions in May 1943, 1½ months after the withdrawal of the salt water in Miami Canal. The upper well field now shows considerable improvement, and the lower well field continues to improve. However, several local pockets of salty ground water have developed, principally along the southwest bank of Miami Canal. Twin Lakes did not act as a focal point of contamination this time, as they apparently did in 1939–40. Note the initial appearance of a 4,000-ppm isochlor in the NW. 36th Street tongue downstream from the NW. 36th Street dam.

Figure 194*D* shows conditions at the end of September 1943, 4 months later. Miami Canal had been free of salt water in the well-field area since March; therefore, conditions in both the upper and lower fields continued to improve. The areas of contamination along the southwest bank of Miami Canal have tended to coalesce and move slightly toward the lower well field.

Figure 195*A* represents conditions in the well-field area 8 months later, at the end of May 1944. New incursions had not occurred in Miami Canal in this area, and conditions had generally improved. For water-supply purposes the upper well field was back to normal. In the lower well field the water of highest chloride content was now enclosed in a relatively small area bounded by the 100-ppm isochlor. The contamination that occurred on the southwest side of the canal 1 year before (May 1943) had since been greatly reduced; however, part of this reduction was at the expense of an enlargement of the areas bounded by the 20- and 50-ppm isochlors. Slightly west of Le Jeune Road, the NW. 36th Street tongue had widened, and it was now being diluted by fresh canal water.

Figure 195*B* shows conditions only 2 months later (July 1944). At this time an offshoot of salty ground water was beginning to move directly toward the lower well field from the NW. 36th Street tongue. This offshoot was a remnant of the contamination that was initiated in March 1943 on the southwest side of the canal. It was drawn toward the well field in consequence of the extension of the cone of depression from the field. In the lower well field no trace remained of chlorides in excess of 100 ppm; the isochlor of highest value was now only 50 ppm. Note that the NW. 36th Street tongue was still being diluted, and that it was moving west from Le Jeune Road.

Figure 195C represents chloride conditions in the well-field area in September 1944. The continued westward movement of the offshoot from the NW. 36th Street tongue is of interest. In 2 months it had advanced approximately 950 ft (475 ft per month or 5,700 ft per year), an extremely rapid rate. However, this tongue had not moved in the area west of Le Jeune Road.

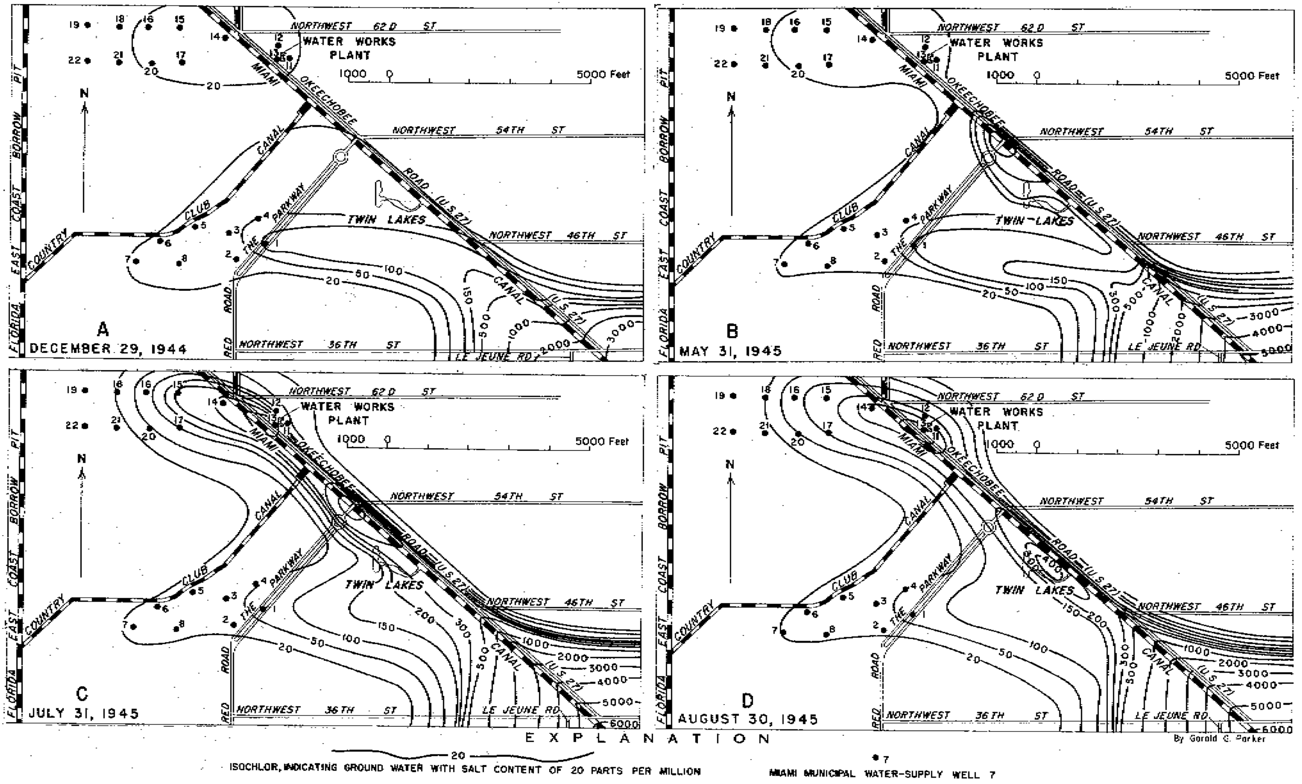


Figure 196.—Isochlor map of the Miami well-field area: *A*, December 1944; *B*, May 1945; *C*, July 1945; and *D*, August 1945.

Figure 195*D* shows conditions in November 1944. The NW. 36th Street offshoot was moving more rapidly than before. During the 2 months between September 29 and November 30, the offshoot had moved westward 1,030 ft, which is at the rate of 515 ft per month or 6,180 ft per year.

Figure 196*A* represents conditions in December 1944. The offshoot of the NW. 36th Street tongue had now moved another 1,400 ft into the well field at the very high rate of 16,800 ft per year. This was more than twice the velocity of the previous month. The increased velocity is explained by the fact that the velocity of ground-water flow increases as flow lines converge toward the center of a well-field cone of depression. The gradient along which the movement took place is approximately 0.6 foot per thousand feet (measured on the mapped water table for December 29, 1944). The average daily pumpage from the well field at that time was about 35 mgd.

Figure 196*B* shows chloride conditions in the well-field area May 1945, 5 months later. On March 17, salty water had gained access to Miami Canal in this area because of the failure of the pneumatically controlled tidal dam. It was not until March 28 that a sheet-steel piling dam replaced this loss. In the meantime, the water levels had continued to decline until the highest altitude of the water table between the well field and the dam was 0.2 ft above the U. S. Coast and Geodetic Survey's mean sea level. Average sea level in Biscayne Bay was about 0.4 ft higher than this datum plane; therefore, the highest level of the water table referred to above was at least 0.2 ft below the actual observed average sea level. These conditions prevented the flushing out of the salt water from the canal above the dam, and, by the creation of a strong negative hydraulic head at times of flood tide, they caused additional salty water to leak through the dam and into the underlying permeable limestone. The result was a major incursion of salty water in Miami Canal that lasted until July (see fig. 192 *A*).

Figure 196*B* shows conditions 2½ months after the pneumatic dam had failed. The NW. 36th Street tongue now showed a 5,000-ppm isochlor. All isochlors were elongated upstream, showing a strong contamination effect on the ground water. In addition, a new offshoot (150 ppm) had made a rapid thrust westward, following the path of the previously traced 100-ppm offshoot. Since December 29, 1944, the 150-ppm offshoot had traveled 2,750 ft, which is at the rate of 550 ft per month or 6,600 ft per year. The 100-ppm offshoot traveled at the rate of 5,700 to 6,180 ft per year when it was in the same position. It is noted also that the NW. 36th Street tongue showed a strong westward movement beyond Le Jeune Road. A new contamination pattern, similar to that of 1943 (see fig. 194 *B*), had developed in the Twin Lakes area. As before, the lakes appear to have had no effect on the encroachment pattern. A new "island" of salty water was just beginning to develop in the upper well field.

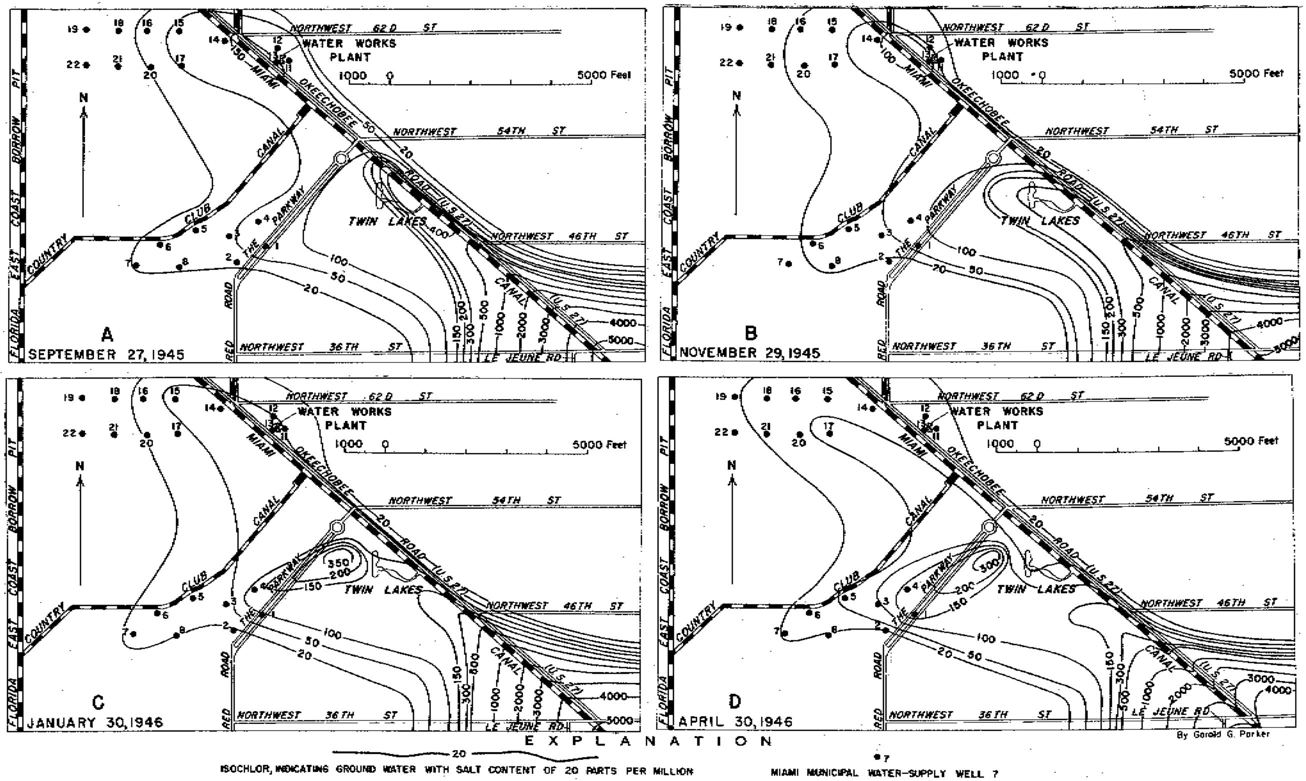


Figure 197. —Isochlor map of the Miami well-field area: *A*, September 1945; *B*, November 1945; *C*, January 1946; and *D*, April 1946.

Figure 196*C* represents conditions in July 1945, 1 month after Miami Canal in this area had been flushed of its salty water. A 6,000-ppm isochlor had pushed into the NW. 36th Street tongue, and the entire pattern in that area had moved upstream and laterally. Pockets of salty water, in excess of 800 ppm and 450 ppm, had developed near Twin Lakes and in the upper well-field, respectively, and the 150-ppm offshoot had merged with the pattern of contamination on the southwest side of the canal.

Figure 196*D* shows conditions in August 1945, just 1 month later. No further incursions of salty water had occurred in Miami Canal. The diluting effect of ground-water movement is apparent from the figure, especially in the Twin Lakes and upper well-field areas. The 6,000 ppm isochlor had moved downstream, but no other notable change had taken place in the NW. 36th Street tongue.

Figure 197*A* illustrates conditions in September 1945. Still further improvement is shown, especially in the upper well-field area where the 20-ppm isochlor had widened in response to dilution, and where the 400-ppm area of the previous month had been reduced to a smaller area of only 150 ppm. The local 300-ppm isochlor near Twin Lakes and the 300-ppm isochlor of the NW. 36th Street tongue, which had been separated during the previous month, had now joined. The resulting offshoot of 300 ppm or more enclosed an "island" of 400 ppm or more.

Figure 197*B* indicates changes in the chloride pattern that took place during October and November 1945. Continued dilution of the higher concentrations is evident by the wider spread of the 20- and 50-ppm isochlors, especially in the Miami Springs area. Near Twin Lakes the 400-ppm isochlor had disappeared as a result of the enlargement and southwestward movement (toward the lower well field) of the 300-ppm area.

Figure 197*C* represents conditions in January 1946, 2 months later. Most notable in the figure is the pinching off of the western end of the 300-ppm offshoot from the NW. 36th Street tongue. An elongated "island" of salty ground water west of Twin Lakes, oriented approximately S. 70° W. (toward the lower well field), was thus formed. The upper well field had become cleared of the 100-ppm zone of 2 months before, largely through dilution. Consequently, the 50-ppm area expanded widely.

Figure 197*D* illustrates chloride conditions in the well-field area at the end of April 1946. Concentration of contaminated water in the upper well field had lessened considerably, especially the smaller area enclosed by the 50-ppm isochlor. The elongated "island" of salty water in the Twin Lakes area had moved considerably to the southwest and had expanded as the higher chloride concentrations were diluted. The NW. 36th Street tongue also

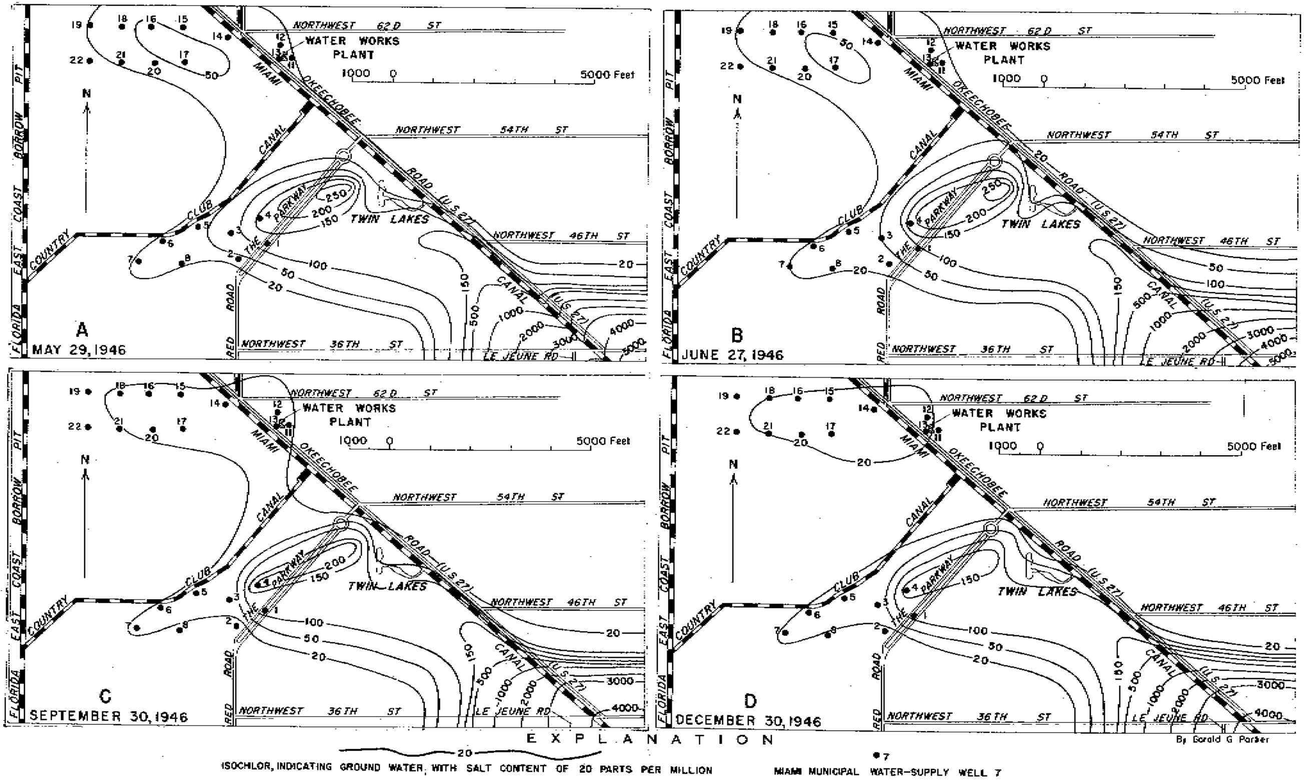


Figure 198. —Isochlor map of Miami well-field area: *A*, May 1946; *B*, June 1946; *C*, September 1946; and *D*, December 1946.

shows dilution effect, particularly where the isochlors approach the canal.

Figure 198*A* shows conditions on May 29, 1946. In the upper well field the area enclosed by the 50-ppm isochlor had been greatly reduced and was now isolated. The Twin Lakes "island" of salty ground water was reduced both in size and concentration. No notable change occurred in the NW. 36th Street tongue.

Figure 198*B* illustrates conditions at the end of June 1946. In both the upper and lower well-field areas the contamination zones continued to diminish in size and concentration. Partial opening of the NW. 36th Street dam during this month allowed minor amounts of salty water to creep a short distance upstream in Miami Canal, resulting in the filling-out of the NW. 36th Street tongue once more. Note the change in shape of isochlors near the canal, as compared with the previous month.

Figure 198*C* shows conditions at the end of September 1946, 3 months later. The continued decrease of chloride is apparent in both upper and lower well-field areas. The "island" of salty ground water west of Twin Lakes had now become extremely elongated, and the 150-ppm offshoot from the NW. 36th Street tongue had retreated seaward about 850 feet.

Figure 198*D* shows conditions in the well-field area at the end of December 1946. Note the improvement in the upper and lower well-field areas. The 20-ppm isochlor has separated the two fields, leaving the upper field entirely isolated from the contamination pattern of the lower field and the NW. 36th Street tongue. The area of salty ground water near Twin Lakes had been reduced in size and was now surrounded by the 150-ppm isochlor. The NW. 36th Street tongue shows little change.

A comparison of the last map (December 1946) with the one for February 1942, when the contamination pattern of the whole area was first drawn, reveals that the patterns are remarkably similar. The principal difference is in the NW. 36th Street tongue south of NW. 36th Street and west of Le Jeune Road. In this area the pattern has made a steady westward advance. Using the 500-ppm isochlor as a measure of movement, it is found that north from the canal, measured along the eastern side of the map, this isochlor occupied approximately the same position in 1946 as in 1942; also, if measured northwestward to its apex, the position of the isochlor is the same for both years. However, if measured due west from the 36th Street Bridge the isochlor is found to have advanced approximately 1,380 ft. Thus, a westward advance has been made on a broad front south of NW. 36th Street rather than along the canal.

The advance of 1,380 ft was made in 4 years and 10 months, which is an average of nearly 24 ft per month or about 290 ft per year. If this rate continues, the NW. 36th Street tongue will reach the lower well field in about 20 years. However, as pointed out earlier (p. 700), as a salt-water tongue approaches a well field, it travels faster; therefore, the time required may be less than 20 years.

Another factor to be considered is that this advance of 1,380 ft has been made during a relatively dry period, when salt water was always free to advance at least as far inland as the NW. 36th Street dam in Miami Canal; up the Tamiami Canal to, and beyond, Red Road; and into the several rock pits between Miami and Tamiami Canals east of Red Road. Thus, salt water has always been available for encroachment into the well-field area.

When the proposed lock and dam in Miami Canal below the confluence of Miami and Tamiami Canals is installed, salt water will no longer gain access to this area by way of the canals; instead, it will be held at some point downstream from NW. 20th Street (proposed site of the control). As a result, the ground-water conditions in this area will change favorably, and the life of the Miami well field will be prolonged indefinitely. The NW. 36th Street salt-water tongue will then be cut off from its source and will probably disappear, as have other high-chloride tongues that have been present in the well field.

COCONUT GROVE WELL FIELD

The Coconut Grove well field was developed in 1925 near Loquat Avenue east of Le Jeune Road (see fig. 199). The site is about 2,200 ft east of Coral Gables Canal and 1 mile from Biscayne Bay. Two wells (S 171 and S 172), 10 in. in diameter and 46 ft deep, with 1,000-gpm pumps, served until 1933. In that year, Charles Morgan, Miami City chemist, noted that the chloride content of the water, which had normally been 13 ppm (Collins and Howard, 1928, p. 210-211), suddenly began to increase. It was decided that a shallower source west of the two original wells would alleviate the situation. Accordingly, three wells (grouped as S 378), 3 in. in diameter and about 35 ft deep, were drilled and coupled by a manifold so that they were operated with a single pump. At first, this new source, pumped at 1,000 gpm, produced water with a chloride content of about 16 ppm. However, the salinity soon began to rise and by 1937 the chloride content was 500 ppm.

In an attempt to get better water, a pit 20 ft square and 16 ft deep was dug. Inasmuch as the land surface at the site is approximately 12 ft above mean sea level, the bottom of the pit was about 4 ft below mean sea level (U. S. Coast and Geodetic Survey datum).

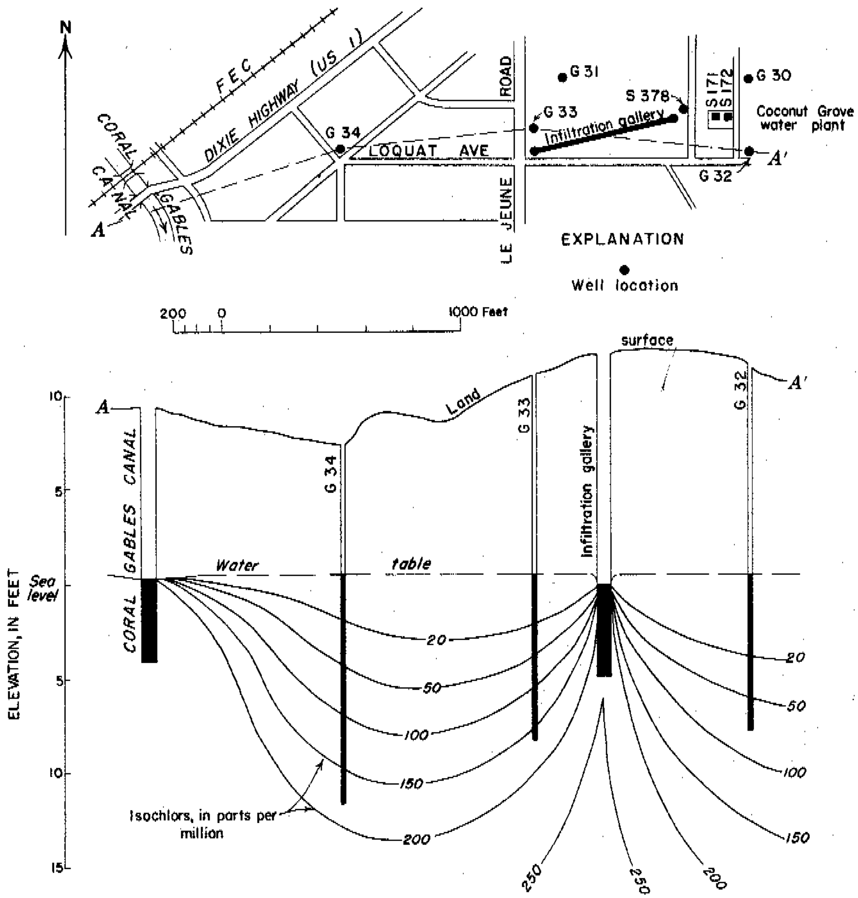


Figure 199.—Map and cross section of the Coconut Grove well-field area showing location and depth of wells and infiltration gallery, isochlor pattern, and water-table profile for June 20, 1940.

According to A. B. DeWolf (1941), water from this shallow source was excellent at first, but it, too, soon began to produce salty water. With increasing demand the pit would not yield the required amount of water, so additional water had to be pumped from the old wells. By January 1939 the salinity of this mixed water was 700 ppm.

It was known that the water of lowest salinity occurs at, or near, the water table. Therefore, an infiltration gallery, or horizontal well, was dug so as to skim the water just below the water table. It was 650 ft long, 4 ft wide, and 17 ft deep—a size sufficient to yield about 600,000 gpd. This well was put into service April 4, 1939.

Analysis of the water first obtained from this gallery shows that it fluctuated in salinity from 112 to 170 ppm, probably in accordance with intermittent recharge from rainfall and with change in pumping rates. On December 10, 1939, shortly after the U. S. Geological Survey opened the Miami district office, a sample of the water was analyzed for most of the common minerals. Later, samples were taken from several shallow wells in the vicinity. Some of these data are given in table 79.

Table 79.—*Analyses of water from infiltration gallery and shallow wells in the Coconut Grove well field*

[Analyses in parts per million, except as indicated]

Well no.	Depth (feet)	Date	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Total hardness as $CaCO_3$
Infiltration gallery	17	12/10/39	0.09	118	5.5	106	245	31	223	317
G 30	19	6/20/40	......	......	....	....	....	....	17	....
G 31	18	6/20/40	......	......	....	....	....	....	167	....
G 32	19	6/20/40	......	......	....	....	....	....	91	....
G 33	18.2	6/20/40	......	......	....	....	....	....	155	....
G 34	19.5	6/20/40	......	......	....	....	....	....	164	....

Figure 199 shows a cross section (*A–A'*) extending in a general east-west direction from Coral Gables Canal through the Coconut Grove well field. Depths of the canal, the infiltration gallery, and wells intersected by the plane of the section are plotted with reference to mean sea level (U. S. Coast and Geodetic Survey, datum of 1929). The water-table profile and isochlors for June 20, 1940 are also shown. The water-table profile is based on measurements made in the wells and gallery, and the isochlors are based on values of chloride in samples of ground water pumped from the wells and gallery.

It is important to note the effect of pumping from the gallery (which obtains water just below the water table) on the chloride pattern. Obviously, Coral Gables Canal is the principal contributing source of salt water, and if it were not for the pumping from the gallery the isochlors would slope gently outward and downward away from the canal. Pumping, however, induces an upward movement of ground water into the gallery, with a resultant upward deflection of the isochlor pattern. The highest isochlor shown in this section for June 20, 1940, is 250 ppm; it does not quite reach the bottom of the gallery. On later dates, chloride values of 260 to 270 ppm were observed in the gallery water. These values, in excess of U. S. Public Health Service standards for public supplies (250 ppm), caused the final abandonment of the Coconut Grove well field in August 1941.

SALT-WATER ENCROACHMENT ALONG THE DADE COUNTY SHORELINE OTHER THAN AT SILVER BLUFF

The Silver Bluff area (see p. 593–607) was believed to be typical of the coastal area of Dade County, and extensive studies of salt- and fresh-water relationships have been made there. These studies, in brief, show the following: (1) A blunt-nosed wedge of salt water is encroaching inland because of an upset equilibrium between salt and fresh water, which is caused by the lowering of the average height of the water table in that part of the coastal area; (2) Inland for a distance of about 2,500 ft the salt-water wedge appears to be approaching equilibrium with the overlying fresh water; (3) In the nose of the salt-water wedge the isochlor pattern dips down rather abruptly; (4) The thickness of the zone of diffusion between the 50-ppm and 16,000-ppm isochlors, measured at a distance of about 3,000 ft from the shore, is about 60 ft whereas in the nose of the wedge, the width, measured parallel to the base of the aquifer, was about 3,500 ft in 1940 and about 5,200 ft in 1946; (5) Only a small amount of movement has been shown by the isochlors representing high salinity (the 16,000- and 18,000-ppm isochlors), whereas there has been a comparatively large inland movement of the isochlors representing lesser salinity (the 50- to 1,000-ppm isochlors).

In December 1946 it was decided to investigate the salt- and fresh-water relationship in one of the coastal areas that had a comparatively narrow encroachment zone (see fig. 200). The Cutler area was selected because it is relatively undeveloped and lies seaward from an area that the city of Miami was considering as a potential new well field (pumping tests in this area are described on p. 249–270). Several test and observation wells were drilled, the most important of which are shown in figure 201. In the Cutler area the isochlor pattern is much different from that at Silver Bluff; a blunt-nosed wedge of encroaching salt water exists, but it extends inland from the shore only about 1,200 ft (measured to the 1,000-ppm isochlor). The vertical thickness of the zone of diffusion, measured between the 100- and 15,000-ppm isochlors, is only about 35 ft at a point about 250 ft inland from the shore. The horizontal width between these isochlors, as measured along the line of 120-ft depth, is about 525 ft.

The pattern in the Cutler area appears to be little affected by a drainage-upset equilibrium, and it is probably quite similar to that which existed in the Silver Bluff area prior to drainage. The fact that it has not expanded inland, as it has at Silver Bluff, is probably due to a locally higher water table. The nearest drainage canal, Snapper Creek, which empties into Biscayne Bay about 4 miles to the northeast, has relatively little effect on the ground water of the Cutler area.

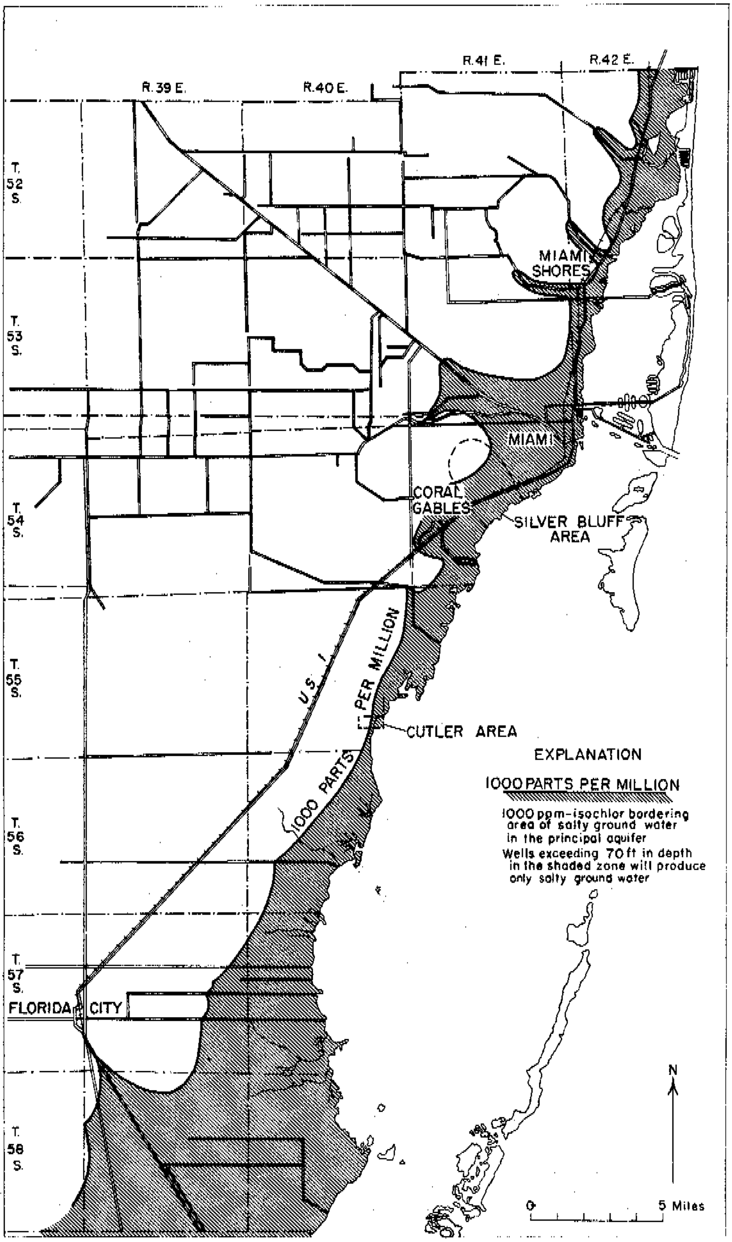


Figure 200. —Map of eastern Dade County showing the area bounded by the 1,000-ppm isochlor of ground water in the Biscayne aquifer. Wells exceeding 70 feet in depth in the shaded zone will produce only salty water.

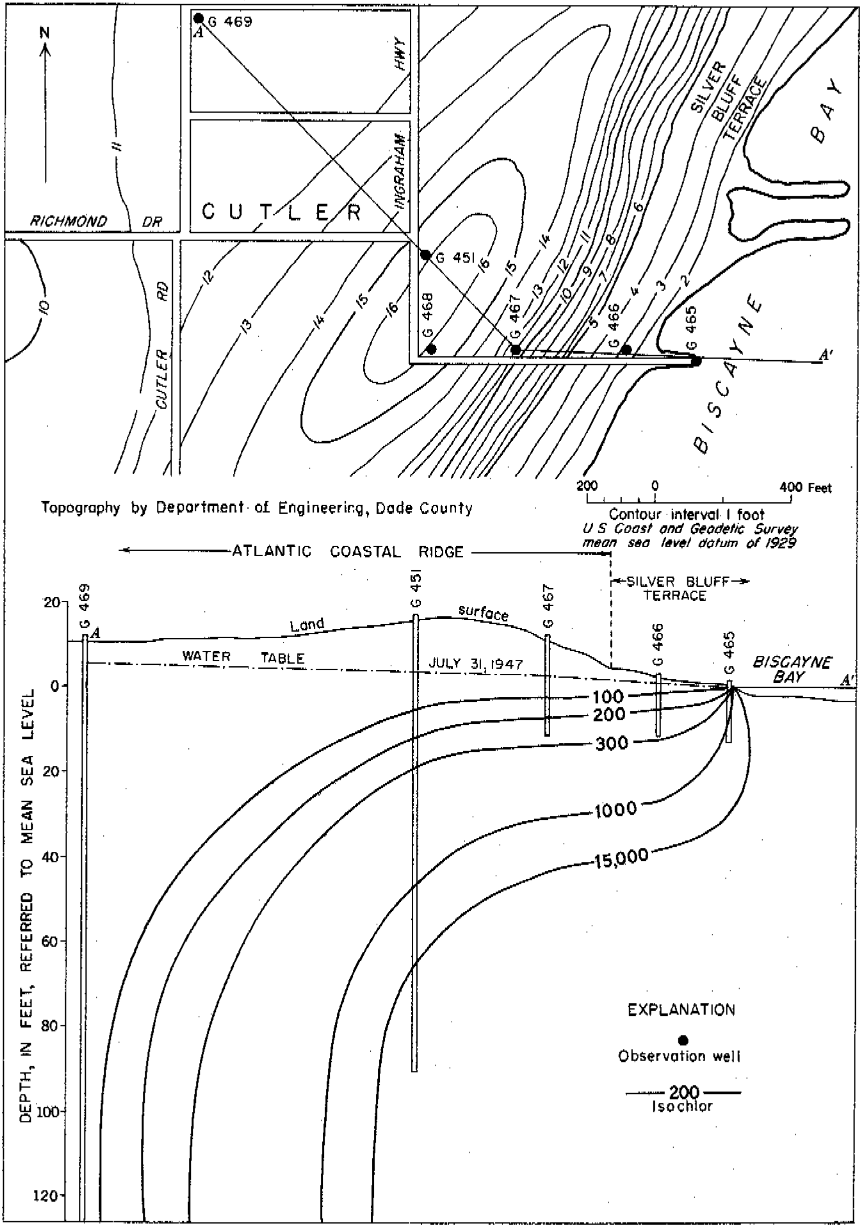


Figure 201. — Topographic map and cross section of the Cutler area, , Dade County, showing locations and depths of wells, , isochlor pattern, and water-table profile.

The widest zone of salt-water encroachment occurs in the marl flats along the southeastern Dade County coast line where a maze of drainage canals has lowered the water table. During times of drought, each canal has acted as an artery for inland movement of salt water. Samples of canal water, taken during the drought of 1945 at the inland limits of tidal canals near Florida City and Homestead, contained chloride in excess of 26,000 ppm (as compared to about 19,800 ppm for normal sea water). This unusual chloride content is due to a high rate of evaporation of the water in the canals, which is replenished by ocean water at each high tide and again evaporated and concentrated. The concentrated salt water, which seeps outward and downward from the sides and bottoms of each canal (see p. 682–686), was the cause of the disastrous crop failure in this area during the 1945 drought. M. H. Gallatin,[2] of the U. S. Department of Agriculture, estimated that salt-water encroachment had ruined more than 18,000 acres of winter-growing vegetable land in southern Dade County by the end of 1945.

Encroachment in many shallow soils need not be permanent, however, because seasonal rains will flush the salted water to depths where it will not affect the growth of most vegetable crops. Dams, placed at the coastal limits of the canals to prevent salt water from again gaining access to the upper reaches, would aid in preserving the soils for farming. However, in the areas most damaged by salt-water encroachment it may never again be possible to utilize wells as a source of water for irrigation during droughts.

Elsewhere along the shoreline in Dade County, the inland encroachment zone is narrower than at Silver Bluff or in the marl flats discussed above. Inland along each of the principal tidal canals, tongues of salty ground water extend for several miles (see fig. 200). These tongues are a result of the dredging of the canals, which have become saline arms of Biscayne Bay. The tongues are in no way related to pumping. In 1939 and 1945, when, owing to the drought, the inland limits of such canals as Biscayne and Little River became dry, salty ocean water from Biscayne Bay flowed inland at each high tide and soaked downward into the rocks of the canal bottoms in the vicinity of Red Road. This process of contamination was taking place along the entire length of these canals, but it was visible only at the inland limits where, at high tide, salt water moved in over the dry canal bottoms.

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[2] Oral communication.

ELECTRICAL-RESISTIVITY STUDIES

By H. Cecil Spicer

INTRODUCTION

During the study of salt-water encroachment in southeastern Florida, an effort was made to utilize as many techniques as possible. Consequently, a series of electrical-resistivity studies were made to evaluate the usefulness of a geophysical method in mapping the position of the underground fresh- and salt-water contact.

ELECTRIC CONDUCTION

Nearly all dry rocks and rock-forming minerals are poor conductors, and thus, they are good insulators. The conductivity of a rock is dependent upon the following factors: (1) porosity or pore space; (2) arrangement of pores or grain packing; (3) amount of pore space filled with electrolytes; and (4) conductivity of the electrolyte, both native and acquired.

An equation was given by Maxwell (1904) for spherical grains in a regular packing arrangement. Hummel (1935) has shown that if the material is completely filled with an electrolyte and if the porosity is 50 percent, then the conductivity of the material increases almost in direct proportion to the conductivity of the electrolyte. For the work in Florida it was decided that if the porosity of the rocks was assumed to be 50 percent, it would be justifiable to disregard the conductivity of the rock grains and to consider only the conductivity of the electrolyte filling the pores.

Chloride determinations and measurements of specific conductance of some Florida waters are given by Collins and others (1941—44) and by Howard and Love (1945) for some canals, creeks, and rivers. Values for the preparation of figure 202 were selected at random from the above papers and include the low range of values with chloride content less than 160 ppm. Figure 203 was prepared in a manner similar to that for figure 202, except that the maximum chloride content shown was 20,000 ppm. It is apparent from these graphs that the relation between conductivity and chloride content is linear except for the very high and very low concentrations of chloride. No attempt has been made to separate the interference produced on the chart by sulfate or bicarbonate, these being the other cations of highest conductivity in solutions, and thus it is possible that they may be the cause for the nonlinearity.

A more detailed study, perhaps by localities, of the relation of conductivity and chloride concentration would also assist in the final interpretation of the electrical resistivity data.

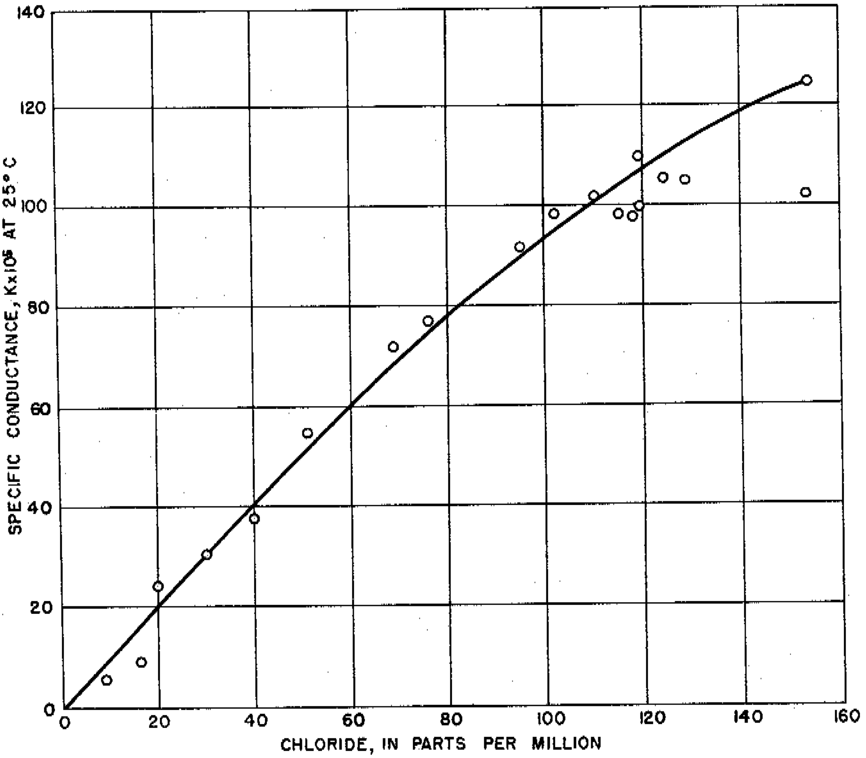

Figure 202. —Specific conductance of salty water for low ranges of chloride content.

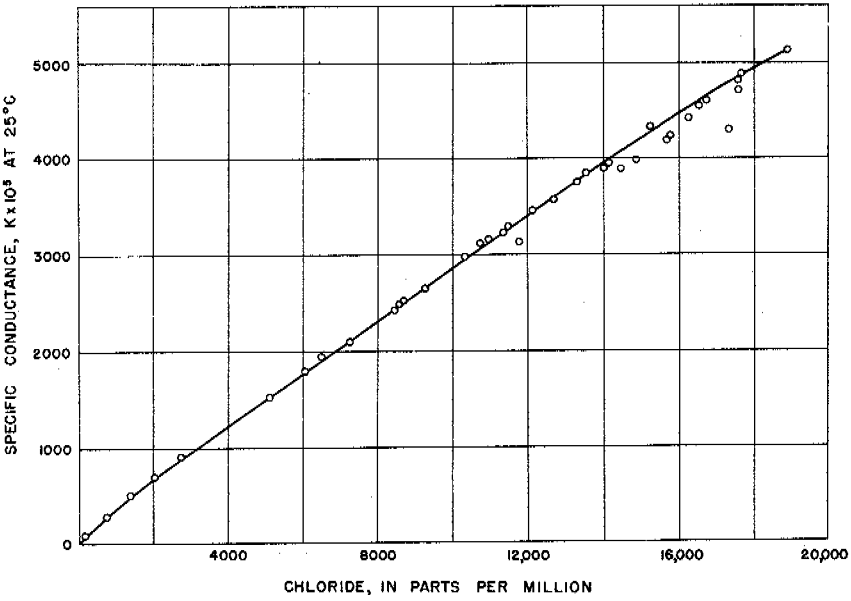

Figure 203. —Specific conductance of salty water for high and low ranges of chloride content.

FIELD MEASUREMENTS

The Gish-Rooney Earth Resistivity Apparatus, as modified by the writer, was used to make the measurements. The electrodes were copper-clad steel rods with steel driving heads that were pushed or driven into the earth to make contact for the potential and current connections to the instrument. The earth around the electrodes was wetted and tamped when better contact was needed.

The character of the formations and the presence of salt water were most important considerations in this problem; therefore depth profiling was used throughout. A modification of the Lee variation of the Wenner electrode configuration was used, and the electrode intervals were expanded outward from the central station. With this method, three apparent resistivity curves were obtained at each station, one in each direction from the center and one over the full interval. These are termed the "P-1", "P-2", and "full" curves. Bearings for the line directions (see Appendix) are referred to P-1. Power for driving the instrument was supplied by the battery on the truck used to transport the equipment, and current to pass through the earth was provided by a bank of

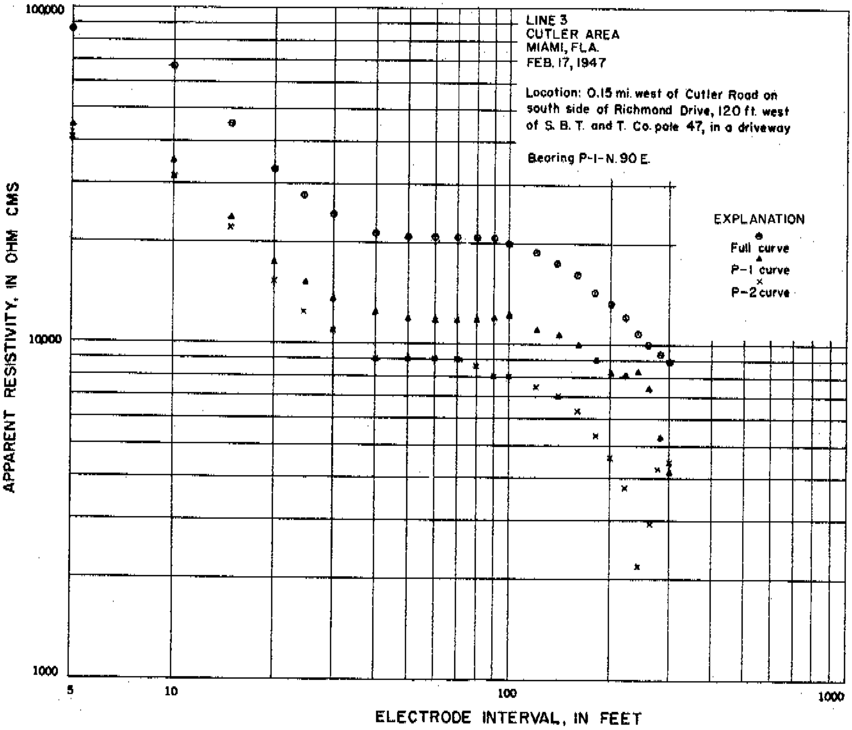

Figure 204.—Resistivity curves obtained in the Cutler area.

super "B" batteries. The fundamental technique of operation is described by the maker of the apparatus and by other authors (such as Heiland, 1940, p. 619–824). A set of curves obtained at one station in the Cutler area is illustrated in figure 204.

INTERPRETATION OF THE RESISTIVITY CURVES

The resistivity curves were interpreted in part by procedures explained by Hummel (1931), Roman (1931, 1934, 1941), Tagg (1937), and Watson (1934, 1938). The methods described in these references are based upon theoretical and mathematical considerations; in most respects they have been found to be more reliable than any other methods proposed. Furthermore, all the above methods are based upon the theory of images (Jeans, 1925) and apply to two or more layers.

MEASUREMENTS AT MIAMI

The electrical resistivity work at Miami was carried out at Silver Bluff and Cutler (fig. 200). At Silver Bluff, the area extending from Biscayne Bay northward through Coconut Grove, Coral Gables, and Miami proper. At Cutler, these were two areas—one north of Cutler, extending northwestward from Biscayne Bay toward the intersection of Ludlum Road and Coral Reef Drive, and the other at Cutler, extending from Biscayne Bay northwestward toward the intersection of Ingraham Highway and Richmond Drive. These areas were chosen for the initial measurements because of the large amount of subsurface control that was available. This control consisted of well logs and chloride data concerning strategically located points throughout the area.

Because of the proximity of city improvements in the first area, such as water pipes and mains, sewers, gas pipes and mains, sprinkling systems, and buried telephone cables, considerable difficulty was experienced in the location of places to make measurements. A few lines that were started had to be abandoned because of interference on the apparent resistivity curves. Some other curves may contain interference from unknown conductors, which is attributed in the interpretations to subsurface geologic conditions. Experience has shown that electrical resistivity measurements obtained in and near cities are usually of questionable value because of the interference from power distribution networks and buried\conductors.

SILVER BLUFF AREA

Of the six depth profiles begun in the Silver Bluff area, only one was abandoned because of interference from buried conductors.

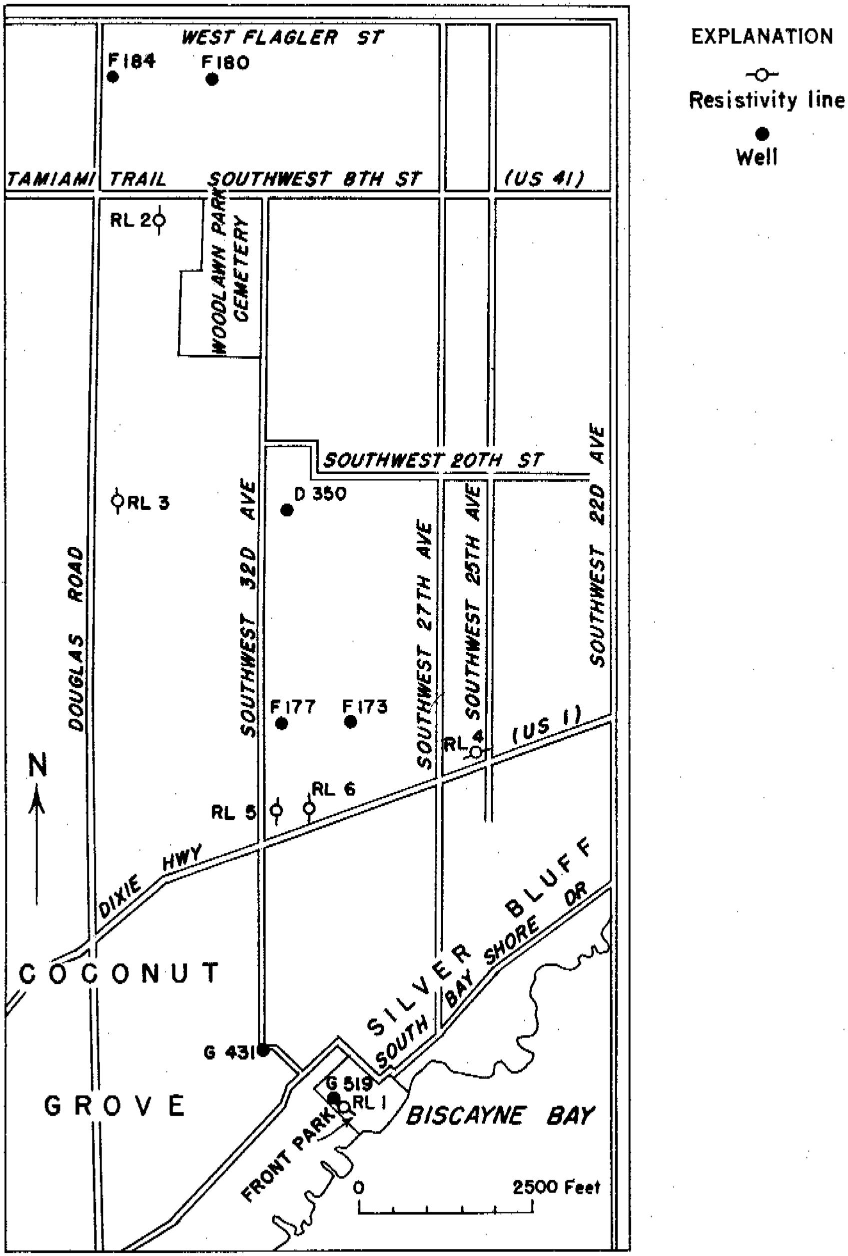

Figure 205.—Location of resistivity lines and related wells, Silver Bluff area, Miami.

All of the apparent resistivity curves of this area were interpreted as three-layer curves.

The position of the resistivity line centers (RL1, RL2, etc.) in the Silver Bluff area are shown in figure 205. The locations of the wells used in correlating the resistivity results are also included in this figure. Well logs and chloride logs are given in the Appendix.

A comparison of the well logs and chloride logs for wells G 519 and D 350 with the interpretation of resistivity lines 1 and 3 is given in figure 206. It appears that the electrical properties of the Miami oolite, the sands, and the calcareous sandstones are essentially the same if wet. The values of resistivity computed for the different layers, as given in table 80, reveals that the controlling factor in the variation of the resistivity is the chloride content of the contained water. In this table, the resistivity lines are arranged in the order of their distance (farthest to nearest) from Biscayne Bay.

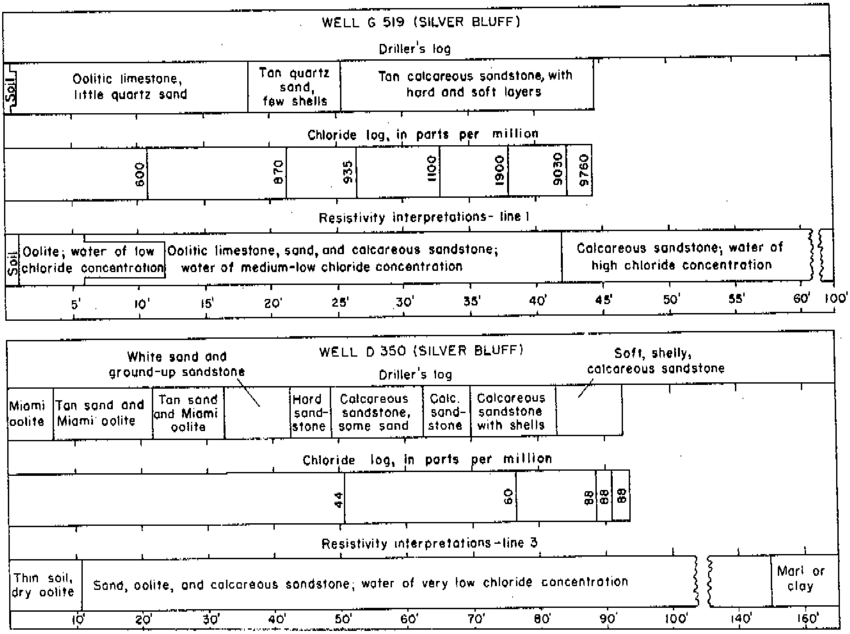

Figure 206.—Comparison of driller's logs and chloride logs with resistivity interpretations, Silver Bluff area, Miami.

It is apparent that the salty water has diffused to the surface and has caused a variation in the resistivities of the upper layers. The seemingly low resistivity value for the salt-water layer of

Table 80.—*Resistivities of layers in the Silver Bluff area, Miami*

[Resistivities in ohm cms; depths are from interpretations of resistivity curves]

Resistivity line no.	Surface layer, 0-10 feet	Intermediate layer[1], 10-42 feet	Bottom layer, 42 feet	Salt-water layer[2]
2	241,000	8,740	486	8,740
3	122,000	15,850	616	15,850
4	89,000	113,300	....	....
	....	2,020	2,020	2,020
6	47,200	141,600	....	....
		980	980	980
1	24,500	1,420	42	42

[1] Resistivity showing that salt water is at bottom of layer.

[2] Top of salt-water layer is about 42 feet below ground surface.

line no. 2, as compared to the value for line no. 3, probably indicates a more permeable layer or perhaps a localized infiltration of salt water. The values of resistivity given for the bottom layer have no particular relation to the salt-water encroachment problem because of the wide range of depth from which they were taken.

CUTLER AREA

Thirteen resistivity lines were completed in the Cutler area; seven were completed in the immediate vicinity of Cutler; five about 1 mile north of Cutler; and one near Goulds. Only one line, no. 8, was abandoned because of interference. On most of the resistivity curves in the Cutler area another layer is present; therefore, they are interpreted as four-layer curves.

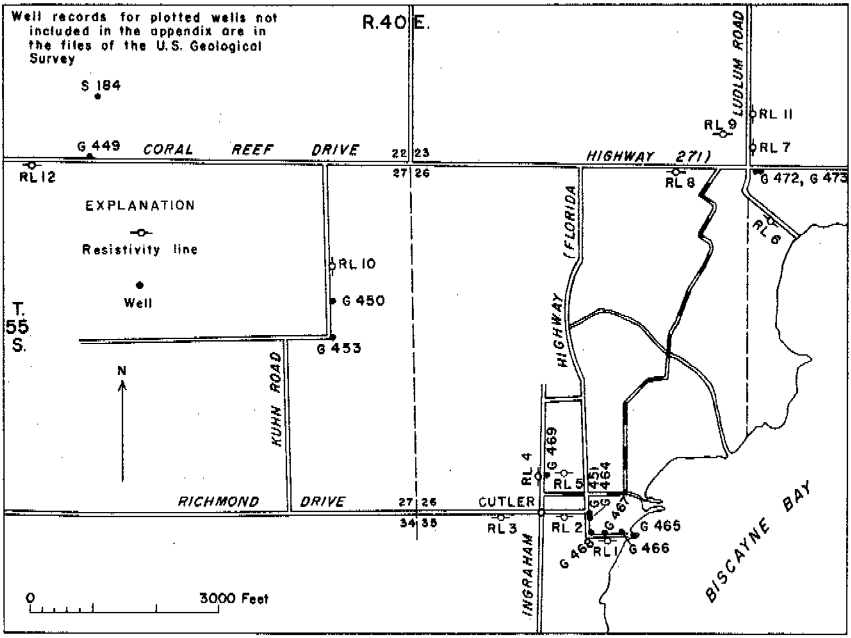

Figure 207.—Location of resistivity lines and related wells, Cutler area.

Figure 207 shows the locations of the resistivity lines (RL1, RL2, etc.) in the Cutler area. The resistivity line near Goulds is not included because it is more than 6 miles southwest of the Cutler area. Locations of the wells that were used for correlation purposes are also shown in the figure. Copies of the well logs and chloride logs are in the Appendix or in the files of the U. S. Geological Survey.

Some of the interpretations from the resistivity curves made near wells in the Cutler area are compared with well logs and chloride logs in figures 208–210.

In the Cutler area, as in the Silver Bluff area, the oolite and calcareous sandstone are very similar in electrical properties near the surface. A layer or bed that probably is rather impermeable and hard, and that is considered to contain some fresh water, appears on nearly all the curves. Salt water, where present in the formations, controls the resistivity and may even eliminate the inherent electrical properties of the beds. This control is shown more clearly in table 81, which gives the values of resistivity computed for the different layers. These values are separated into related areas—Cutler, north of Cutler, and Goulds—and are arranged in order of their distance from Biscayne Bay, those farthest from the bay being listed first.

A study of table 81 reveals the extent of salt-water infiltration in the different layers of each area. At Cutler there is little or no

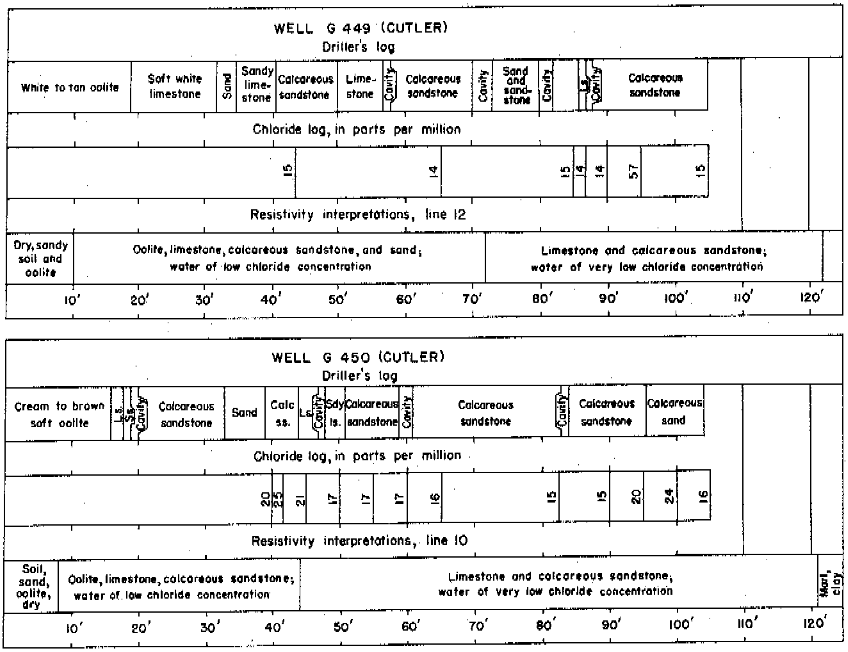

Figure 208. —Comparison of driller's logs and chloride logs with resistivity interpretations, Cutler area.

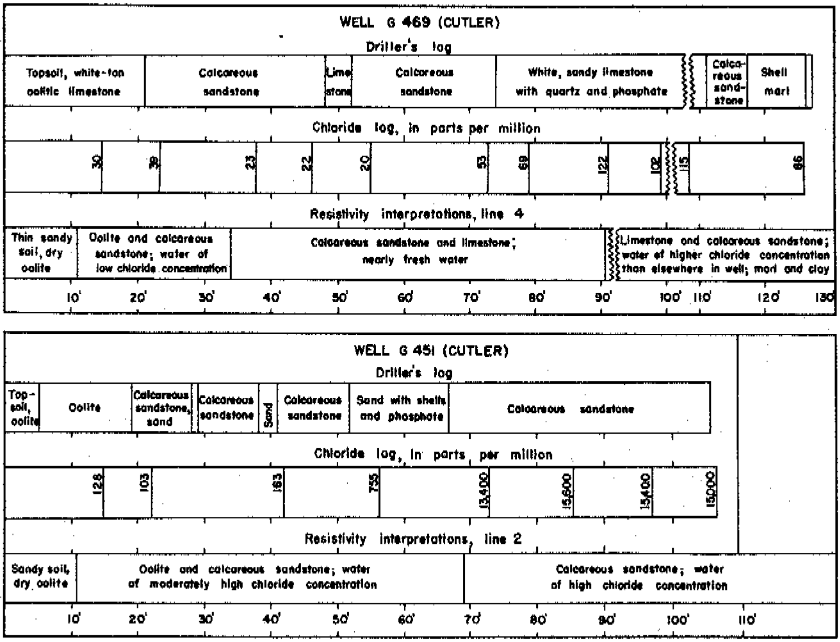

Figure 209.—Comparison of driller's logs and chloride logs with resistivity interpretations, Cutler area.

indication of salt water in the surface materials. The upper intermediate layer may be slightly contaminated westward from Biscayne Bay up to, and including, line no. 4. This is indicated by the lower resistivity, approximately 8,000 ohm cms. The

Table 81.—*Resistivities of layers in the Cutler area*

[Resistivities, in ohms cms; depths, in feet, are from interpretations of resistivity curves]

Resistivity line no.	Surface layer, 0–10 feet	Upper intermediate layer, depth variable	Lower intermediate layer, depth variable	Bottom layer, 39–122 feet
Cutler				
12	126,000	14,000	41,620	6,360
10	131,000	10,620	51,180	2,720
3	91,000	13,000	51,180	4,760
4	67,500	7,500	49,630	3,670
5	103,000	8,320	50,340	4,990
2	112,000	7,780	(1)	285
1	79,000	7,600	(1)	86
North of Cutler				
9	179,000	16,630	(1)	50
11	120,000	360,000	12,080	750
7	120,000	360,000	12,080	16
6	2,260	6,780	3,110	53
Goulds				
13	7,350	41,650	(1)	6,540

[1] This layer is not apparent on the resistivity curve.

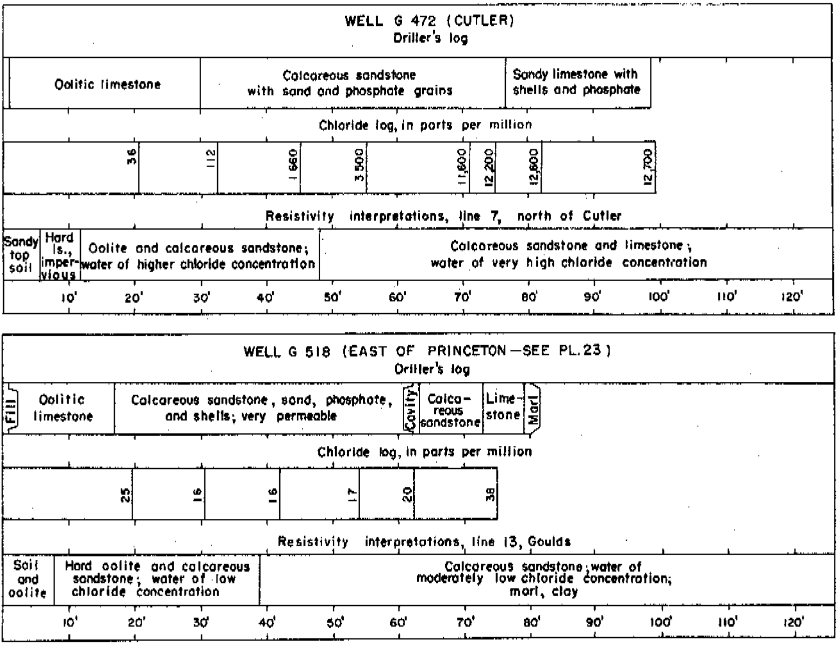

Figure 210.—Comparison of driller's logs and chloride logs with resistivity interpretations, Cutler area and near Goulds.

lower intermediate bed appears to be rather hard and impervious; near Biscayne Bay, its electrical identity is missing. The bottom layer shows that the sea water has infiltrated to a point somewhere between lines no. 2 and no. 5, and that the limestone and sandstone beds saturated with salt water are lower in resistivity than are the marl and clay lying beneath them.

The situation north of Cutler is the same, except that here the sea-water invasion has extended to the surface materials as far inland as line no. 6. This is apparent from the low resistivity values for all of the layers in this line.

The resistivity line at Goulds was taken just across the road from Goulds Canal near well G 518 east of Princeton (see pl. 23). The low resistivity of the surface materials indicates the presence of chlorides, although no samples were taken in this section for the chloride log. It appears that some contamination from the canal may have caused the low resistivity in the upper layer. The resistivity of the intermediate layer indicates that the chloride content of the water there is relatively low. The resistivity of the deeper materials is about the same as is found in the adjacent areas.

MEASUREMENTS AT FORT LAUDERDALE

The electrical resistivity measurements at Fort Lauderdale were made near the Fort Lauderdale water plant, well field, and golf course, located a short distance west of the city. Some control, in the form of well logs and chloride logs, was available, but it was not always possible to obtain resistivity measurements close to the drill holes because of nearby buried conductors or grounded power lines.

Thirteen resistivity profile measurements were begun in this area. One profile was abandoned because it was impossible to get sufficient current into the earth through the very dry sand cover. Another measurement was temporarily abandoned because of instrument failure, but it was made later with a different instrument. A third measurement was of no value beyond the 15-ft interval because negative potentials appeared with a corresponding inequality of the P-1 and P-2 readings. The apparent resistivity curves obtained in this small area are widely variable, both as to the number of layers and the resisitivities of the layers.

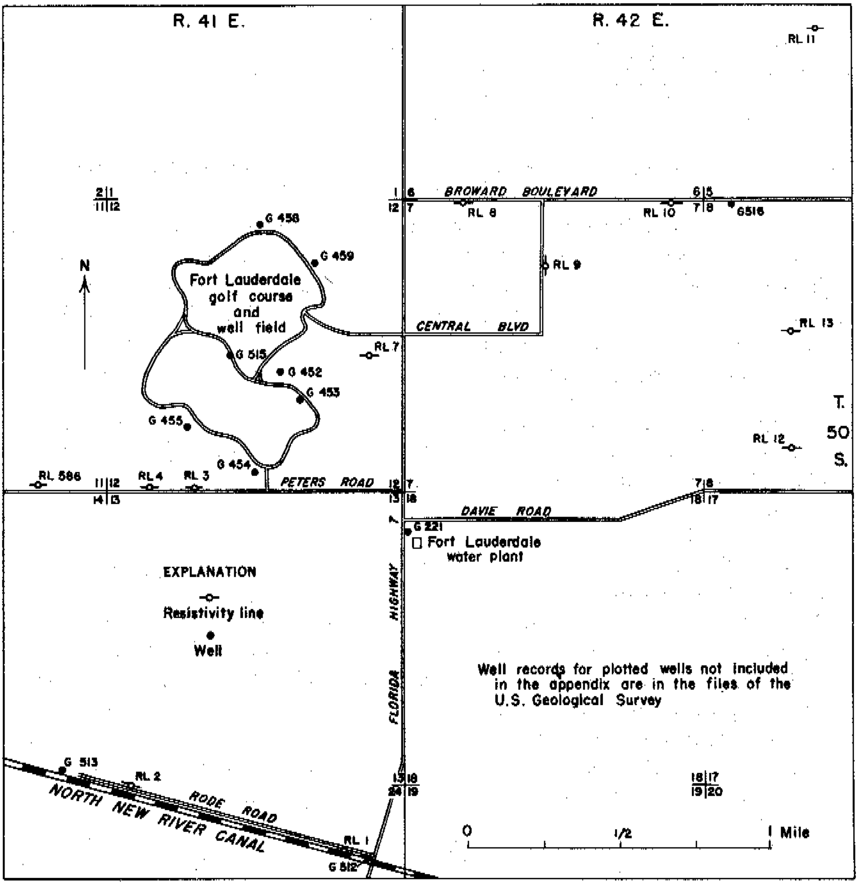

Figure 211.—Location of resistivity lines and related wells, Fort Lauderdale area.

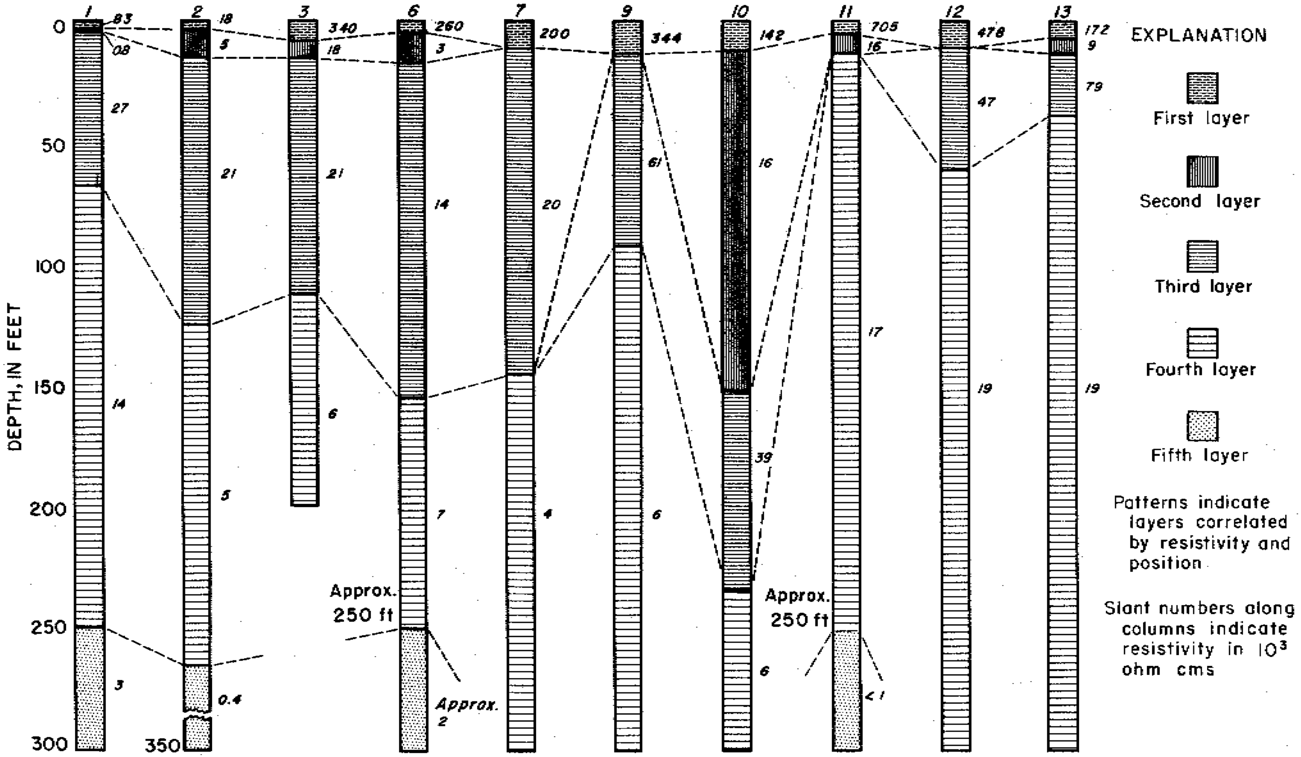

Figure 212.—Correlation of resistivity layers near Fort Lauderdale.

The locations of the resistivity lines in the Fort Lauderdale area are given in figure 211. The wells used in the correlation of the resistivity measurements are also shown in this figure. Copies of the well logs and chloride logs are in the Appendix and in the files of the U. S. Geological Survey.

On plate 18 the interpretations of the apparent resistivity curves are compared graphically with the well logs and chloride logs of the nearest wells. It is apparent from the interpretations that the numerous beds described in the well logs do not have uniquely distinguishing electrical characteristics. Furthermore, the well logs and the analysis of the apparent resistivity curves indicate that the beds may not be continuous throughout the small area in which the resistivity measurements were made.

The resistivity of the surface material varies between 18,200 and 478,000 ohm cms; of the intermediate materials, 14,100 to 60,700 ohm cms; of the deepest materials within the range of observations, 400 to 7,100 ohm cms.

A layer-correlation chart, based upon the computed apparent resistivities of the layers, is presented in numerical sequence from left to right in figure 212. The layer just below the surface layer varies greatly in thickness; however, it is missing at locations 7, 9, and 12, and appears greatly thickened at location 10. The next deeper layer, the third from the surface, changes electrical characteristics at locations 9 and 10, becoming respectively about three times and two times as resistant; however, this layer is missing at location 11.

The three uppermost layers probably contain water of very low chloride concentration, but the next deeper layer, the fourth, is considered to contain water of moderately low chloride concentration. The latter zone is variable both in the amount of chlorides present and the depth to which it extends. According to the interpretations of the resistivity curves, the bottom of this zone was not reached at locations 3, 7, 9, 10, 12, and 13. A very low resistivity was determined for the bottom layer at locations 1, 2, 6, and 11. Any water that is present in this layer would be expected to contain a high concentration of chlorides, perhaps nearly as much as sea water.

Locations 1, 2, 3, and 6 probably contain more chlorides in the water near the surface than any of the others.

Vorhis (1948) states that well G 512 contained salt water at 42 ft and that well G 513 contained salt water at 10 and 52 ft. The concentrations of chlorides are rather low, 180 ppm in the first well and 59 and 52 ppm, respectively, in the other. Resistivity line no. 1 was completed a short distance west of well G 512. The only possible salt-water contamination zone indicated by the resistivity interpretations is the one between 2.7 and 3.1 ft. Resistivity line no. 2 was centered about 700 ft east of well G 513. Resistivity interpretations indicate that a possible zone of salt-water infiltration is between 2.5 and 14 ft. There is, however, no indication of salt-water contamination corresponding to the measured depth of 52 ft. The bed of black muck near the surface probably masks the interpretation of the salt-water zone to a certain extent.

The resistivity interpretations indicate that the zone of near-surface infiltration of salt water has not extended as far west as resistivity line nos. 11, 13, and 12.

EVALUATION OF THE METHOD

It has been demonstrated that salty ground water can be located in the coastal area near Miami by a very careful selection of sites for resistivity lines. The brief study near Fort Lauderdale clearly shows the possibility of carrying out resistivity surveys to trace salt-water encroachment in that area also. To keep a record of the advance and retreat of the salt water, a series of resistivity line centers would have to be laid out and observations would have to be taken at regular intervals. The apparent resistivity curves could be interpreted, a chart of the resistivity prepared, and the entire problem then followed graphically. Furthermore, with more field measurements it should be possible to correlate the formations and determine the geology in the areas between the drill holes. Some difficulties would be encountered, such as interference from power lines, buried mains, pipes, and cables. The very dry mantle of sand would also give trouble. However, with more time and careful planning, these difficulties could be overcome.