

Table 4-20—Average surfactant (ABS) concentration as a function of depth at the Rio Hondo Test Basin

Date	Average concentration in milligrams per liter at				
	Surface	2 ft.	4 ft.	6 ft.	8 ft.
January 1963	1.30	0.60	0.50	0.50	0.60
February	1.38	0.77	0.65	0.38	0.35
March	0.88	0.32	0.20	0.15	0.12
April	0.59	0.16	0.08	0.08	0.08
May	1.35	0.20	0.08	0.10	0.10
June	1.46	0.12	0.00	0.00	a
July	2.02	0.23	0.10	0.07	a
August	2.12	0.28	0.10	0.08	a
September	1.26	0.13	0.10	0.10	0.10
October	0.37	0.10	0.10	0.10	a
November	0.46	0.10	0.00	0.03	0.07
December	0.28	0.10	0.10	0.10	0.10
January 1964	0.37	0.12	0.12	0.10	0.10
February	0.28	0.20	0.05	0.10	0.10
March	0.55	0.35	0.05	0.20	0.10
April	a	a	a	a	a
May	1.90	1.50	0.40	0.10	a
June	0.40	0.20	0.10	a	a
July	0.30	0.10	0.10	0.10	a
August	2.00	1.00	0.30	0.10	a
September	1.90	1.10	0.45	0.15	a
October	1.70	0.80	0.30	0.10	a
November	0.40	0.30	0.10	0.10	a
December	0.40	0.25	0.05	0.05	a
January 1965	0.30	0.10	0.05	0.05	a
February	0.40	0.15	0.10	0.10	a
March	0.28	0.10	0.10	0.10	a

a No samples available for analysis.

Table 4-22—Average nitrate concentration as a function of depth at the Rio Hondo Test Basin

Date	Average concentration in milligrams N per liter at				
	Surface	2 ft.	4 ft.	6 ft.	8 ft.
January 1963	a	1.8	1.1	1.1	2.1
February	a	2.7	2.7	>10.6	4.5
March	a	3.0	4.4	4.5	3.3
April	1.2	2.2	2.0	2.5	2.5
May	1.4	7.6	2.0	2.2	1.2
June	2.3	>10.0	0.2	1.5	b
July	5.0	>10.0	6.3	5.0	b
August	5.2	>7.9	7.9	7.6	b
September	4.0	>6.5	6.5	8.7	b
October	1.8	2.5	2.9	3.9	b
November	1.8	3.7	3.1	3.8	0.0
December	0.6	2.1	2.0	3.0	0.9
January 1964	0.9	1.7	1.4	1.8	1.2
February	1.1	6.0	1.2	3.4	3.1
March	1.1	6.0	1.5	3.8	1.7
April	b	b	b	b	b
May	2.9	3.1	4.7	6.2	b
June	0.3	0.3	0.4	b	b
July	2.0	1.7	2.9	3.2	b
August	5.2	6.1	5.2	6.8	b
September	2.2	3.2	3.7	5.5	b
October	0.4	0.6	0.7	3.6	b
November	2.0	1.0	1.3	4.4	b
December	0.7	1.3	1.2	2.2	b
January 1965	0.7	3.2	3.3	3.6	b
February	0.8	5.8	b	3.4	b
March	1.1	1.6	3.8	3.8	b

a No samples taken for analysis.

b No samples available for analysis.

Table 4-21—Average chloride concentration as a function of depth at the Rio Hondo Test Basin

Date	Average concentration in milligrams per liter at				
	Surface	2 ft.	4 ft.	6 ft.	8 ft.
January 1963	63	62	58	93	80
February	54	52	51	55	84
March	84	70	79	78	76
April	64	73	71	88	72
May	90	100	93	94	86
June	94	103	98	110	a
July	100	107	114	121	a
August	119	122	126	128	a
September	62	73	88	134	94
October	51	39	31	68	a
November	43	59	94	87	73
December	86	89	88	73	86
January 1964	69	82	80	88	73
February	87	88	88	81	a
March	68	50	87	101	86
April	a	a	a	a	a
May	111	106	114	111	a

a No samples available for analysis.

Table 4-23—Average nitrite concentration as a function of depth at the Rio Hondo Test Basin

Date	Average concentration in milligrams N per liter at				
	Surface	2 ft.	4 ft.	6 ft.	8 ft.
January 1963	a	0.17	0.02	0.00	0.08
February	a	0.01	0.00	0.02	0.03
March	a	0.00	0.00	0.00	0.03
April	0.54	0.00	0.00	0.01	0.01
May	0.84	0.41	0.18	0.08	0.01
June	0.56	0.04	0.00	0.02	b
July	>1.98	0.28	0.02	>0.42	b
August	2.13	0.35	0.08	0.20	b
September	1.19	0.03	0.01	0.03	b
October	0.07	0.01	0.01	0.04	b
November	0.08	0.01	0.06	0.02	0.00
December	0.32	0.00	0.00	0.01	0.06
January 1964	0.18	0.09	0.03	0.00	0.00
February	0.29	0.00	0.00	0.00	0.00
March	0.06	0.03	0.00	0.00	0.00
April	b	b	b	b	b
May	1.10	0.87	0.58	0.00	b
June	1.74	1.65	0.01	0.00	b
July	0.00	0.00	0.01	0.00	b
August	0.67	0.05	0.01	0.01	b
September	1.04	0.02	0.03	0.02	b
October	0.01	0.01	0.01	0.01	b
November	0.10	0.02	0.01	0.01	b
December	0.20	0.02	0.04	0.01	b
January 1965	0.17	0.18	0.01	0.01	b
February	0.14	0.04	b	0.01	b
March	0.07	0.01	0.01	0.01	b

a No samples taken for analysis.

b No samples available for analysis.

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Table 4-24—Average organic nitrogen and ammonia as a function of depth at the Rio Hondo Test Basin

Date	Average concentration in milligrams N per liter at				
	Surface	2 ft.	4 ft.	6 ft.	8 ft.
January 1963	a	4.6	1.7	1.2	1.2
February	a	1.3	1.6	1.5	1.3
March	a	1.0	1.1	1.3	1.4
April	7.6	1.1	1.1	0.8	0.8
May	>11.2	0.9	1.2	0.8	0.8
June	8.1	1.8	0.8	0.4	b
July	9.0	1.2	1.0	1.0	b
August	2.5	2.0	2.1	2.9	b
September	4.9	4.1	4.0	4.7	b
October	3.3	1.9	3.9	2.4	b
November	5.0	2.8	2.9	2.8	1.9
December	2.7	1.8	2.3	2.1	1.7
January 1964	2.3	1.0	0.8	0.8	0.9
February	3.0	0.9	0.4	0.3	3.3
March	1.1	0.8	0.3	0.4	0.6
April	b	b	b	b	b
May	11.0	8.2	1.0	0.7	b
June	3.0	0.4	0.4	b	b
July	1.4	0.4	0.6	0.4	b
August	3.0	1.0	0.4	0.4	b
September	1.8	1.0	0.7	0.6	b
October	2.4	3.2	1.8	1.1	b
November	2.1	0.4	0.1	0.4	b
December	3.3	0.8	0.6	0.6	b
January 1965	1.4	0.5	0.6	0.5	b
February	3.0	1.2	b	1.0	b
March	1.4	0.6	0.3	0.4	b

a No samples taken for analysis.
b No samples available for analysis.

Table 4-25—Average total nitrogen as a function of depth at the Rio Hondo Test Basin

Date	Average concentration in milligrams N per liter at				
	Surface	2 ft.	4 ft.	6 ft.	8 ft.
January 1963	a	6.6	2.8	2.3	3.4
February	a	3.0	4.3	>12.1	5.8
March	a	4.9	5.5	5.8	4.7
April	9.3	3.3	3.1	3.3	3.3
May	>13.4	8.9	3.4	3.1	2.0
June	11.0	>11.8	1.0	2.0	b
July	>16.0	>11.4	7.3	>7.3	b
August	9.8	>10.2	10.1	10.7	b
September	10.1	>10.6	10.5	13.4	b
October	5.2	4.4	6.8	6.3	b
November	7.0	6.5	6.1	6.6	1.9
December	3.6	3.9	4.3	5.1	2.7
January 1964	3.3	2.8	2.2	2.6	2.1
February	3.3	6.9	1.6	3.7	6.4
March	2.3	6.9	1.8	4.2	2.2
April	b	b	b	b	b
May	15.0	12.2	6.3	6.9	b
June	5.0	2.4	0.8	b	b
July	3.4	2.0	3.5	3.6	b
August	8.9	7.2	5.6	7.2	b
September	5.0	5.0	4.4	6.1	b
October	2.8	3.8	3.1	4.7	b
November	4.2	1.4	1.4	4.8	b
December	4.2	2.1	1.8	2.8	b
January 1965	2.3	3.9	3.9	4.1	b
February	3.9	7.0	b	4.4	b
March	2.6	2.2	4.1	4.2	b

a No samples taken for analysis.
b No samples available for analysis.

Table 4-26—Average turbidity as a function of depth at the Rio Hondo Test Basin

Date	Average concentration in units of turbidity at				
	Surface	2 ft.	4 ft.	6 ft.	8 ft.
January 1963	2.1	0.0	0.6	0.6	1.6
February	2.5	0.8	0.6	0.1	1.2
March	4.8	7.2	0.6	3.6	0.8
April	2.8	1.2	0.8	1.1	1.2
May	2.7	0.7	0.7	0.6	0.6
June	1.3	0.5	0.9	0.7	a
July	1.7	0.7	0.9	0.8	a
August	2.6	0.9	1.2	1.0	a
September	3.4	1.7	1.1	1.1	2.1
October	3.6	1.4	1.6	1.3	a
November	3.0	1.8	2.3	1.7	2.1
December	1.8	1.3	1.8	1.6	1.3
January 1964	3.7	1.4	1.4	1.4	1.7
February	2.2	1.4	1.8	1.8	1.0
March	4.1	2.7	1.3	2.7	7.1
April	a	a	a	a	a
May	2.8	2.2	1.7	1.7	a
June	8.3	2.4	2.1	a	a
July	2.4	1.6	1.0	2.1	a
August	2.1	1.3	1.0	1.0	b
September	2.1	1.3	1.5	1.3	b

a No samples taken for analysis.
b No samples available for analysis.

Table 4-27—Summary of average chemical data at the Whittier Narrows Test Basin

Period I. January–April 1963

	Average concentration in milligrams per liter				
	Surface	2 ft.	4 ft.	6 ft.	8 ft.
Total solids.....	688	959	1,059	1,312	2,206
Fixed solids.....	442	587	654	812	1,634
Volatile solids.....	246	372	405	500	572
Chemical oxygen demand.....	47.6	41.1	44.0	52.2	30.3
Alkylbenzenesulfonate.....	3.23	2.38	1.72	0.84	0.76
Nitrate as N.....	0.2	0.3	>6.8	>16.3	>13.4
Total nitrogen as N.....	21.3	>9.4	>8.7	>18.4	>14.2

Period II. May 1963–January 1964

Total solids.....	667	937	974	965	1,000
Fixed solids.....	462	625	620	609	618
Volatile solids.....	205	312	354	356	382
Chemical oxygen demand.....	33.7	24.5	21.4	79.4	52.9
Alkylbenzenesulfonate.....	1.96	1.08	0.59	0.57	0.45
Nitrate as N.....	6.2	7.6	>15.7	12.2	—
Total nitrogen as N.....	>22.2	>10.3	>17.6	>14.2	16.0

Period III. February–June 1964

Total solids.....	813	1,057	1,021	1,089	1,174
Fixed solids.....	532	618	623	652	670
Volatile solids.....	280	439	398	437	504
Chemical oxygen demand.....	36.7	8.8	9.1	12.6	38.8
Alkylbenzenesulfonate.....	2.07	0.35	0.24	0.18	0.16
Nitrate as N.....	4.7	22.7	24.6	22.7	24.9
Total nitrogen as N.....	25.3	23.7	25.3	23.5	25.8

Period IV. July 1964–March 1965

Total solids.....	798	1,049	1,025	1,035	1,183
Fixed solids.....	526	626	602	627	680
Volatile solids.....	272	423	423	408	503
Chemical oxygen demand.....	39.3	10.4	9.7	17.0	14.6
Alkylbenzenesulfonate.....	2.54	0.34	0.33	0.35	0.29
Nitrate as N.....	4.7	22.5	24.6	20.0	28.7
Total nitrogen as N.....	27.0	25.6	25.4	21.1	29.8

Entire Test. January 1963–March 1965

Total solids.....	740	1,000	1,010	1,065	1,335
Fixed solids.....	494	619	620	655	840
Volatile solids.....	246	381	390	410	495
Chemical oxygen demand.....	37.8	19.4	17.8	40.8	29.9
Alkylbenzenesulfonate.....	2.30	0.89	0.60	0.46	0.28
Nitrate as N.....	5.0	14.4	>19.0	>17.6	>24.2
Total nitrogen as N.....	>21.0	>17.8	>20.3	>19.0	24.8

Table 4-28—Summary of average chemical data at the Rio Hondo Test Basin

Period I. January–April 1963

	Average concentration in milligrams per liter at				
	Surface	2 ft.	4 ft.	6 ft.	8 ft.,
Total solids.....	784	713	739	769	785
Fixed solids.....	490	419	471	542	530
Volatile solids.....	294	294	268	227	255
Chemical oxygen demand.....	27.4	25.4	18.4	15.8	17.0
Alkylbenzenesulfonate.....	1.04	0.46	0.36	0.28	0.29
Nitrate as N.....	1.2	2.7	2.6	>4.7	3.1
Total nitrogen as N.....	9.3	4.5	3.9	5.9	4.3

Period II. May 1963–January 1964

Total solids.....	660	665	737	850	727
Fixed solids.....	455	460	512	571	494
Volatile solids.....	205	205	225	279	233
Chemical oxygen demand.....	34.5	13.5	18.1	12.4	45.5
Alkylbenzenesulfonate.....	1.08	0.15	0.08	0.08	0.09
Nitrate as N.....	2.6	>5.8	3.6	4.3	0.8
Total nitrogen as N.....	>8.8	>7.8	5.7	>6.3	2.2

Period III. February–December 1964

Total solids.....	756	1,018	825	925	878
Fixed solids.....	485	756	560	610	608
Volatile solids.....	271	262	265	315	270
Chemical oxygen demand.....	35.0	16.0	8.9	7.0	7.4
Alkylbenzenesulfonate.....	0.98	0.58	0.19	0.11	0.10
Nitrate as N.....	1.8	2.9	2.3	4.3	2.4
Total nitrogen as N.....	5.4	5.0	3.0	4.9	4.3

Period IV. January–March 1965

Total solids.....	869	884	974	977	—
Fixed solids.....	641	670	666	690	—
Volatile solids.....	228	214	308	287	—
Chemical oxygen demand.....	12.5	7.5	6.6	7.6	—
Alkylbenzenesulfonate.....	0.33	0.12	0.08	0.08	—
Nitrate as N.....	0.9	3.5	3.5	3.6	—
Total nitrogen as N.....	2.9	4.4	4.0	4.2	—

Entire Test. January 1963–March 1965

Total solids.....	740	835	800	880	775
Fixed solids.....	494	592	543	596	529
Volatile solids.....	246	243	257	284	246
Chemical oxygen demand.....	31.4	15.6	13.3	10.7	8.8
Alkylbenzenesulfonate.....	0.99	0.36	0.16	0.12	0.17
Nitrate as N.....	1.9	>3.9	2.9	>4.3	2.0
Total nitrogen as N.....	>6.6	>5.8	4.2	>5.5	3.4

WASTEWATER RECLAMATION AT WHITTIER NARROWS

Table 4-29—Water temperature as a function of depth at the Whittier Narrows Test Basin

Date	Surface water		Percolate at							
			2 ft.		4 ft.		6 ft.		8 ft.	
	Number of observations	Range of temperature, °F	Number of observations	Range of temperature, °F	Number of observations	Range of temperature, °F	Number of observations	Range of temperature, °F	Number of observations	Range of temperature, °F
January 1963	21	56-68	3	54-62	2	54-56	3	53-56	2	56-59
February	18	62-72	4	59-61	4	59-61	3	58-61	1	58
March	15	63-70	2	59-60	1	60	1	57	1	59
April	20	64-77	2	59-60	1	58	2	57	0	--
May	13	63-79	4	63-69	4	63-68	4	62-70	0	--
June	5	69-78	3	65-66	3	65-66	1	65	0	--
July	9	74-80	3	66-68	2	65-66	0	--	0	--
August	10	76-82	3	70-73	0	--	0	--	0	--
September	5	77-81	2	70-72	3	68-72	3	68-72	0	--
October	8	72-79	4	70-75	4	70-75	4	70-75	0	--
November	10	72-77	4	61-68	4	61-70	4	61-70	0	--
December	11	70-75	4	54-59	4	54-59	4	54-59	0	--
January 1964	11	66-70	4	52-55	4	54-57	4	54-57	2	55
February	9	68-72	4	54-61	4	54-61	4	54-61	3	54-61
March	13	68-73	3	59-63	4	59-68	4	59-68	4	59-64
April	13	68-73	5	64-68	5	64-72	5	64-72	4	64-72
May	6	70-75	4	63-72	4	64-72	4	66-73	4	65-68
June	4	75-79	3	72-74	3	72-75	3	73-76	3	72-74
July	12	79-84	3	76-79	3	77-79	3	78-82	3	75-79
August	19	81-82	4	79-81	4	79-82	4	81-82	4	79-81
September	22	79-81	4	72-77	4	73-77	5	73-79	4	73-77
October	20	75-80	5	73-76	5	73-77	4	73-79	5	74-77
November	18	71-75	3	59-68	3	60-70	3	62-68	3	62-70
December	19	66-72	4	58-64	4	60-65	4	61-67	4	60-66
January 1965	19	66-69	4	55-63	4	57-64	4	60-64	4	58-64
February	19	65-69	4	59-62	4	60-62	4	58-62	4	58-64
March	21	67-70	3	59-64	3	59-65	3	62-67	3	59-66

Table 4-30—Water temperature as a function of depth at the Rio Hondo Test Basin

Date	Surface water		Percolate at							
			2 ft.		4 ft.		6 ft.		8 ft.	
	Number of observations	Range of temperature, °F	Number of observations	Range of temperature, °F	Number of observations	Range of temperature, °F	Number of observations	Range of temperature, °F	Number of observations	Range of temperature, °F
January 1963	7	54-60	1	53	1	53	1	54	1	53
February	8	58-69	3	55-59	3	56-58	3	55	1	56
March	26	58-76	4	54-62	3	53-59	3	55-59	3	53-59
April	28	57-75	5	59-64	5	59-64	5	59-63	4	59-63
May	22	63-77	4	63-66	3	63-66	4	64-66	2	62-66
June	6	65-78	5	62-68	1	64	5	62-66	0	--
July	6	74-84	3	65-73	2	67-72	3	66-72	0	--
August	12	77-84	5	70-74	5	69-74	4	72-73	0	--
September	8	75-86	1	74	1	74	1	75	0	--
October	9	65-75	1	65	0	--	0	--	0	--
November	6	62-70	3	59-65	0	--	1	62	1	61
December	9	52-64	3	54-59	3	54-59	3	55-59	3	54-59
January 1964	10	55-60	4	50-55	4	49-54	4	49-54	3	48-54
February	5	59-68	2	54-55	2	54-55	2	53-55	1	55
March	6	56-73	2	54-58	1	57	2	57-59	1	56
April	3	61-68	0	--	0	--	0	--	0	--
May	5	64-76	1	66-68	2	68-72	2	68-72	0	--
June	1	67	1	69	1	69	0	--	0	--
July	2	73-75	2	77-80	2	74-79	2	73-78	0	--
August	4	72-85	1	76	1	76	1	76	0	--
September	1	68	2	70	2	70-72	2	70-73	0	--
October	1	60	1	68	1	68	1	68	0	--
November	1	67	1	60	1	62	1	62	0	--
December	2	57-61	2	59-61	2	57-60	2	57-59	0	--
January 1965	2	59-58	2	51-58	1	52	2	52-56	0	--
February	1	63	1	56	0	--	1	54	0	--
March	0	--	1	64	1	61	1	60	0	--

Table 4-31—Dissolved oxygen as a function of depth at the Whittier Narrows Test Basin

Date	Surface water		Percolate at							
			2 ft.		4 ft.		6 ft.		8 ft.	
	Number of observations	Range of D. O., mg/l	Number of observations	Range of D. O., mg/l	Number of observations	Range of D. O., mg/l	Number of observations	Range of D. O., mg/l	Number of observations	Range of D. O., mg/l
January 1963	3	1.9- 6.7	2	1.8-2.2	1	1.7	3	1.8-3.3	4	1.0-3.2
February	3	4.3- 8.3	3	4.2-6.8	1	0.5	2	0.3	2	0.6-0.8
March	0	--	1	5.4	0	--	1	2.4	3	1.1-1.5
April	1	2.6	1	2.6	0	--	1	1.9	0	--
May	2	7.8- 8.4	4	0.8-3.1	3	1.4-4.5	2	1.1-1.4	1	5.1
June	2	8.1- 8.0	3	0 -0.4	2	0 -2.8	1	0	1	0
July	2	5.2- 8.0	2	0	0	--	1	2.8	0	--
August	0	--	3	0 -2.3	0	--	1	1.3	0	--
September	0	--	1	0	0	--	1	2.1	0	--
October	0	--	2	0 -2.5	0	--	1	1.9	0	--
November	1	9.4	4	0.2-3.3	0	--	3	0.2-2.9	0	--
December	0	--	3	0 -2.1	0	--	1	0	0	--
January 1964	1	9.4	3	0.2-1.7	0	--	3	0.3-3.6	0	--
February	3	6.2-11.1	3	0.2-1.2	0	--	4	1.9-6.8	2	0.7-1.7
March	0	--	3	0.5-2.2	0	--	2	0.3-6.3	1	0.3
April	0	--	3	0.5-1.8	0	--	4	1.8-5.5	1	0.7
May	0	--	3	0.6-2.7	0	--	3	0 -7.4	1	0.2
June	0	--	3	0.7-5.2	0	--	3	0 -0.7	3	0.5-1.3
July	5	4.7- 9.5	3	0.3-3.0	0	--	4	0 -2.2	2	0 -0.6
August	4	8.5- 9.8	4	0 -0.8	0	--	4	2.5-4.2	2	0 -0.5
September	5	9.4-10.1	4	0 -1.6	0	--	4	0.4-2.8	4	0 -0.2
October	4	8.4-10.1	5	0 -1.8	1	3.9	5	0 -7.1	5	0 -2.0
November	2	9.0-11.5	2	0 -0.6	0	--	3	0.2-1.5	2	0.1-0.4
December	4	4.1-11.3	4	0.2-2.9	0	--	4	0.7-5.0	4	0.2-0.5
January 1965	4	9.9-11.5	4	1.5-8.6	1	0.4	4	0.1-0.5	3	0.1-0.2
February	3	10.5-12.0	3	0.6-1.8	0	--	3	0.1-2.2	3	0.1-0.3
March	3	10.4-11.8	1	0.9	1	8.0	3	0 -0.1	3	0.1

Table 4-32—Dissolved oxygen as a function of depth at the Rio Hondo Test Basin

Date	Surface water		Percolate at							
			2 ft.		4 ft.		6 ft.		8 ft.	
	Number of observations	Range of D. O., mg/l	Number of observations	Range of D. O., mg/l	Number of observations	Range of D. O., mg/l	Number of observations	Range of D. O., mg/l	Number of observations	Range of D. O., mg/l
January 1963	0	--	1	8.1	1	8.7	1	8.5	1	4.6
February	1	4.5	2	5.0- 5.8	2	7.2- 8.2	3	7.5- 8.4	3	3.8- 7.2
March	1	9.7	1	10.0	0	--	3	7.9- 9.2	2	3.7- 7.6
April	1	9.4	3	4.5- 7.7	2	5.0- 5.5	5	5.0- 9.3	1	5.0
May	1	9.6	4	1.0- 3.6	1	3.4	3	1.1- 2.8	0	--
June	2	7.6- 7.8	4	1.6- 2.6	1	1.9	4	1.2- 3.6	0	--
July	1	8.0	2	1.7- 2.5	1	3.4	2	1.7- 2.6	0	--
August	0	--	5	0.5- 1.8	5	1.3- 3.6	5	1.9- 3.3	0	--
September	0	--	1	1.9	1	4.0	1	3.6	0	--
October	0	--	1	5.9	0	--	0	--	0	--
November	0	--	0	--	0	--	0	--	0	--
December	0	--	3	5.0- 8.2	3	2.2- 4.7	3	3.9- 4.1	4	0.6- 9.1
January 1964	0	--	4	9.0-10.2	3	6.7- 8.4	4	5.0- 8.3	1	8.8
February	0	--	1	5.4	1	9.0	1	9.0	2	8.8-10.8
March	2	6.9-14.2	2	1.4-10.5	2	8.5-10.6	1	10.5	0	--
April	0	--	0	--	0	--	0	--	0	--
May	4	12.0-22.0	1	0	1	7.1	1	6.9	0	--
June	1	4.3	1	3.2	1	8.4	0	--	0	--
July	2	9.8-13.4	2	0 - 3.5	2	0 - 5.5	2	4.9- 5.7	0	--
August	1	24.0	1	1.6	1	6.5	1	5.3	0	--
September	2	9.4-25.2	2	0.9- 3.1	2	6.8- 7.4	2	6.4- 6.8	0	--
October	1	14.2	1	1.5	1	7.7	1	7.2	0	--
November	1	11.0	1	4.2	1	9.5	1	7.9	0	--
December	2	7.5-14.2	2	5.1- 8.2	3	7.5- 9.9	2	6.2- 9.1	0	--
January 1965	1	13.5	1	9.8	1	8.0	2	4.9- 6.8	0	--
February	2	12.3-12.7	1	9.4	0	--	2	7.8- 9.4	0	--
March	1	14.0	0	--	1	10.3	1	8.8	0	--

WASTEWATER RECLAMATION AT WHITTIER NARROWS

Table 4-33—Water quality of percolate at Whittier Narrows Test Basin * (composite samples, 12-21 Aug. 1964)

Constituent	Concentration in milligrams per liter at				
	Surface	2 ft.	4 ft.	6 ft.	8 ft.
Calcium, Ca.....	60.8	132	127	139	158
Magnesium, Mg.....	19.9	20.9	19.4	17.9	30.1
Sodium, Na.....	152	120	142	140	138
Potassium, K.....	14.5	13.0	15.4	12.6	5.1
Ammonium, NH ₄	40	0	0	0	0
Bicarbonate, HCO ₃	385	369	336	395	487
Sulfate, SO ₄	164	180	164	161	168
Chloride, Cl.....	126	134	131	130	126
Nitrate, NO ₃	44.0	44.0	104	84.2	88.0
Phosphate, PO ₄	5.4	0.60	10.0	0.30	0.2
Total dissolved solids (sum)...	1,011	994	1,050	1,080	1,200
Total hardness (as CaCO ₃)...	234	411	398	422	520
pH.....	8.02	7.69	7.87	7.84	7.78
Electrical conductivity (micromhos at 25°C).....	1,230	1,390	1,390	1,410	1,530

* Analyses by Los Angeles County Flood Control District.

Table 4-34—Water quality of percolate at Rio Hondo Test Basin * (composite samples, 12-21 Aug. 1964)

Constituent	Concentration in milligrams per liter at				
	Surface	2 ft.	4 ft.	6 ft.	8 ft.
Calcium, Ca.....	52.8	52.0	65.6	93.6	•
Magnesium, Mg.....	18.7	17.0	18.2	20.9	•
Sodium, Na.....	142	144	142	137	•
Potassium, K.....	15.2	12.5	9.7	9.5	•
Ammonium, NH ₄	0	0	0	0	•
Bicarbonate, HCO ₃	180	174	188	246	•
Sulfate, SO ₄	170	177	170	193	•
Chloride, Cl.....	122	120	126	124	•
Nitrate, NO ₃	38.3	30.0	49.0	52.2	•
Phosphate, PO ₄	6.5	7.0	7.0	3.5	•
Total dissolved solids (sum)...	746	734	776	880	•
Total hardness (as CaCO ₃)...	209	200	239	320	•
pH.....	8.30	8.02	7.84	7.90	•
Electrical conductivity (micromhos at 25°C).....	1,080	1,060	1,140	1,230	•

* Analyses by Los Angeles County Flood Control District.

• No sample available for analysis.

Table 4-35—Phosphate (as PO₄) as a function of depth at the test basins
Whittier Narrows Test Basin

Date	Ortho-phosphate (mg/l)					Total phosphate (mg/l)				
	Surface	2 ft.	4 ft.	6 ft.	8 ft.	Surface	2 ft.	4 ft.	6 ft.	8 ft.
1964 12-30/12-31.....	16.8	5.4	15.7	4.8	0.0	29.1	18.6	29.1	16.1	0.8
1965 1-6/1-7.....	16.9	5.5	17.6	6.5	0.0	18.8	6.4	17.8	7.0	0.9
1-13/1-14.....	15.4	6.3	18.1	14.3	0.2	17.8	7.0	19.9	16.1	0.8
1-20/1-21.....	15.6	7.3	17.7	16.6	1.5	16.2	6.5	17.0	14.3	0.6
1-27/1-28.....	21.5	6.4	18.8	15.7	0.2	--	--	--	--	--
2-3/2-4.....	23.8	6.8	14.5	11.3	0.0	26.4	6.8	14.4	11.3	0.2
2-10/2-11.....	18.4	7.6	15.3	13.6	0.0	19.1	9.2	14.9	14.9	0.2
2-17/2-18.....	23.1	7.6	15.9	17.2	0.4	34.4	7.9	17.6	17.7	0.6
2-24/2-25.....	24.0	8.2	21.1	17.9	0.3	22.4	7.4	22.9	17.2	0.2
3-3/3-4.....	22.2	10.1	19.9	19.9	0.2	29.1	10.3	16.7	18.1	0.3
3-10/3-11.....	22.4	10.6	18.7	16.3	0.0	27.4	12.2	16.4	17.8	0.2
3-17/3-18.....	16.8	11.8	21.6	17.3	0.2	16.8	11.1	21.2	17.1	0.3
3-24/3-25.....	18.1	10.8	20.7	19.8	0.0	17.4	11.1	22.1	21.7	0.3
Totals.....	255.0	104.4	236.6	191.2	3.0	274.9	114.5	230.0	189.3	4.8
Mean.....	19.6	8.0	18.2	14.7	0.2	22.9	9.5	19.2	15.8	0.4
Range.....	15.4-24.0	5.4-11.8	14.5-21.6	4.8-19.9	0.0-1.5	16.2-34.4	6.4-18.6	14.4-29.1	7.0-21.7	0.0-0.9

Rio Hondo Test Basin

Date	Ortho-phosphate (mg/l)					Total phosphate (mg/l)				
	Surface	2 ft.	4 ft.	6 ft.	8 ft.	Surface	2 ft.	4 ft.	6 ft.	8 ft.
1965 1-12.....	1.8	3.4	--	2.2	--	2.4	4.0	--	2.7	--
1-25/1-26.....	2.1	3.6	3.2	2.4	--	2.6	3.7	4.0	2.6	--
2-5/2-9.....	3.5	4.9	3.5	2.3	--	3.6	4.9	--	2.4	--
2-22.....	4.8	2.3	--	4.4	--	7.6	2.2	--	4.5	--
3-5.....	2.6	4.2	3.8	2.4	--	2.4	4.2	4.0	2.6	--
3-22/3-23.....	2.0	3.4	6.1	2.3	--	2.1	2.1	3.1	2.4	--
Totals.....	16.8	21.8	16.6	16.0	--	20.7	21.1	11.1	17.2	--
Mean.....	2.8	3.6	4.2	2.7	--	3.4	3.5	3.7	2.9	--
Range.....	1.8-4.8	2.3-4.9	3.2-6.1	2.2-4.4	--	2.1-7.6	2.1-4.9	3.1-4.0	2.4-4.0	--

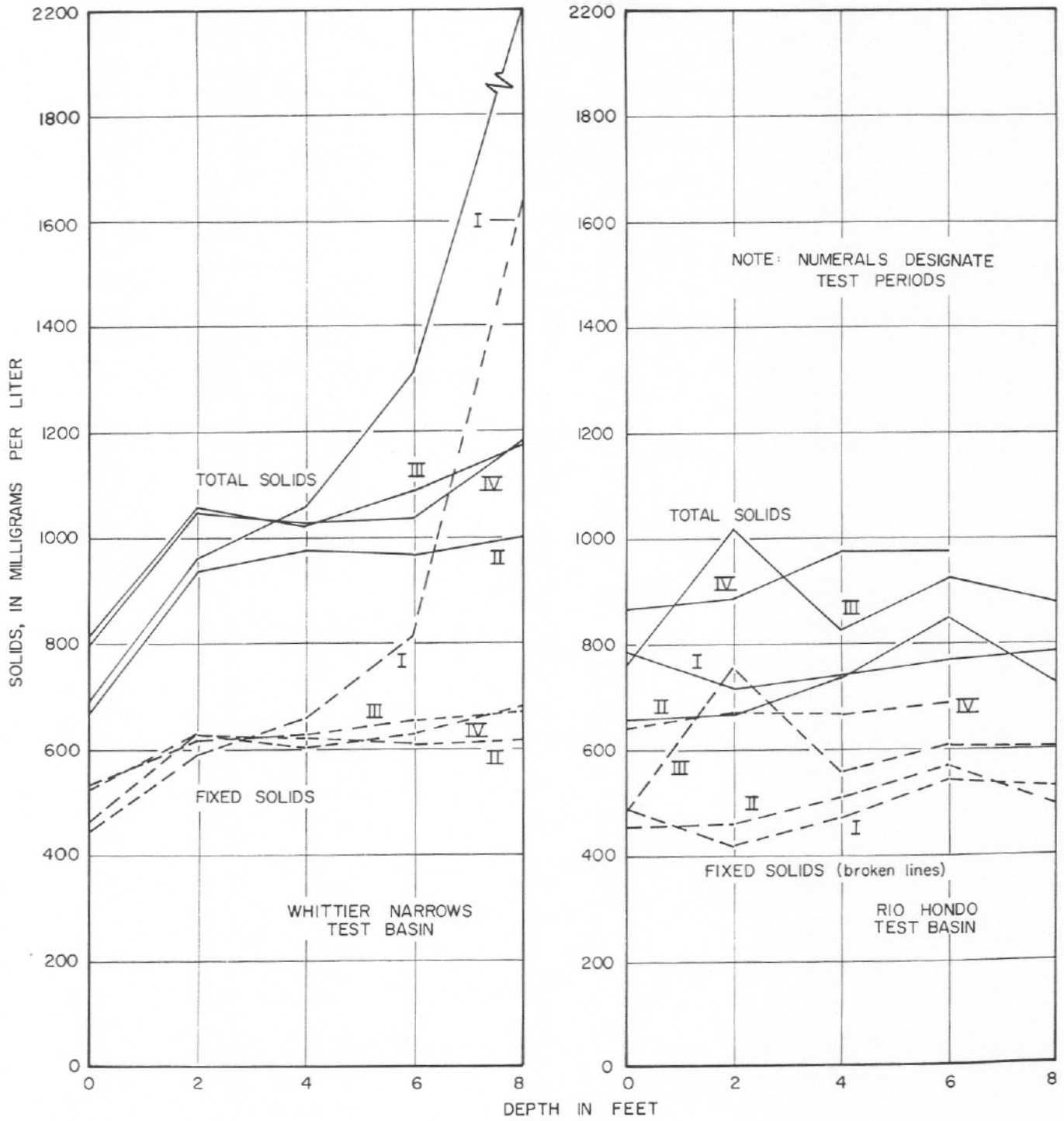


Fig. 4-11—Total Solids and Fixed Solids at Both Test Basins

WASTEWATER RECLAMATION AT WHITTIER NARROWS

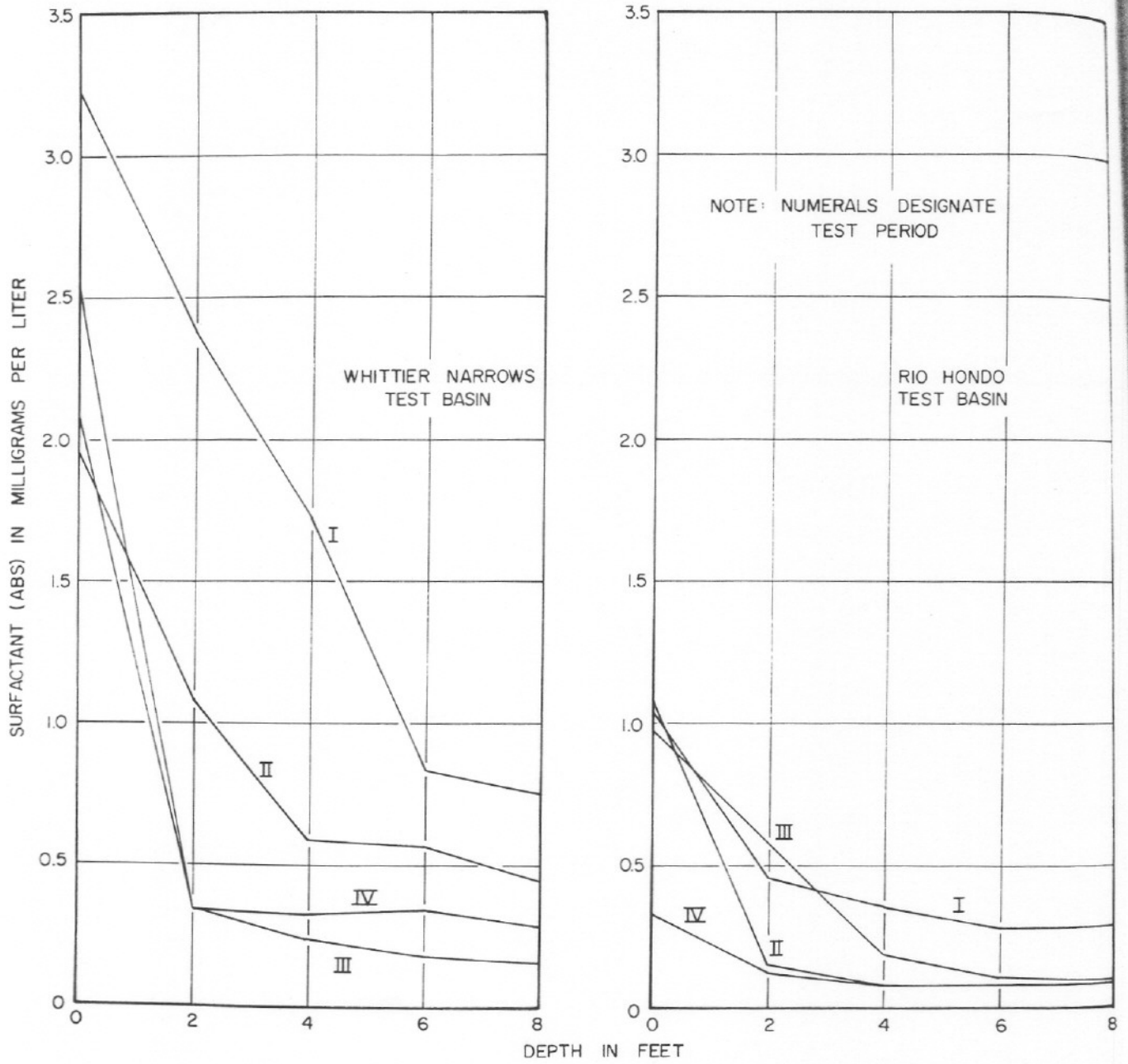


Fig. 4-12—Surfactant (ABS) at Both Test Basins

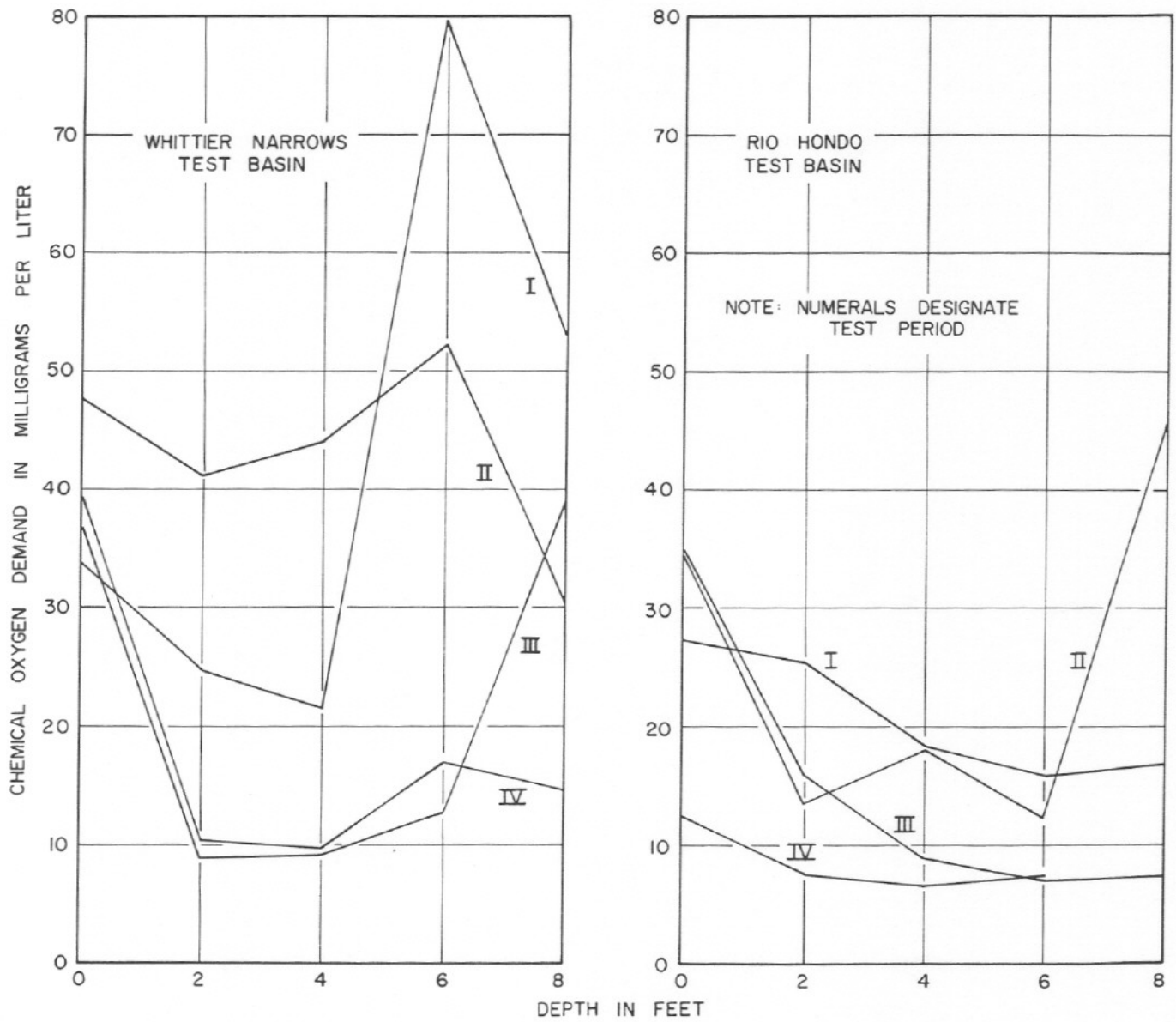


Fig. 4-13—Chemical Oxygen Demand (COD) at Both Test Basins

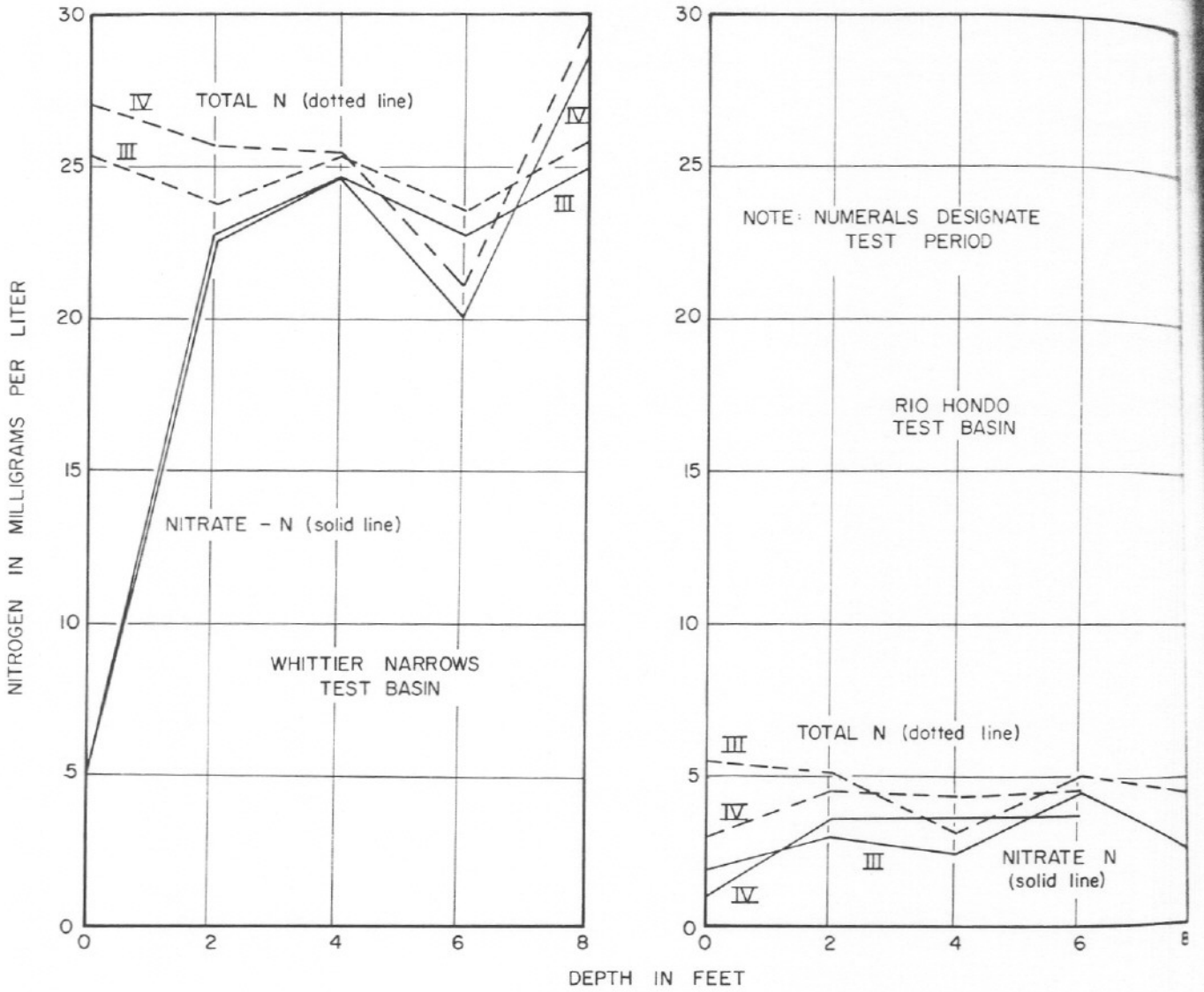


Fig. 4-14—Nitrates and Total Nitrogen at Both Test Basins

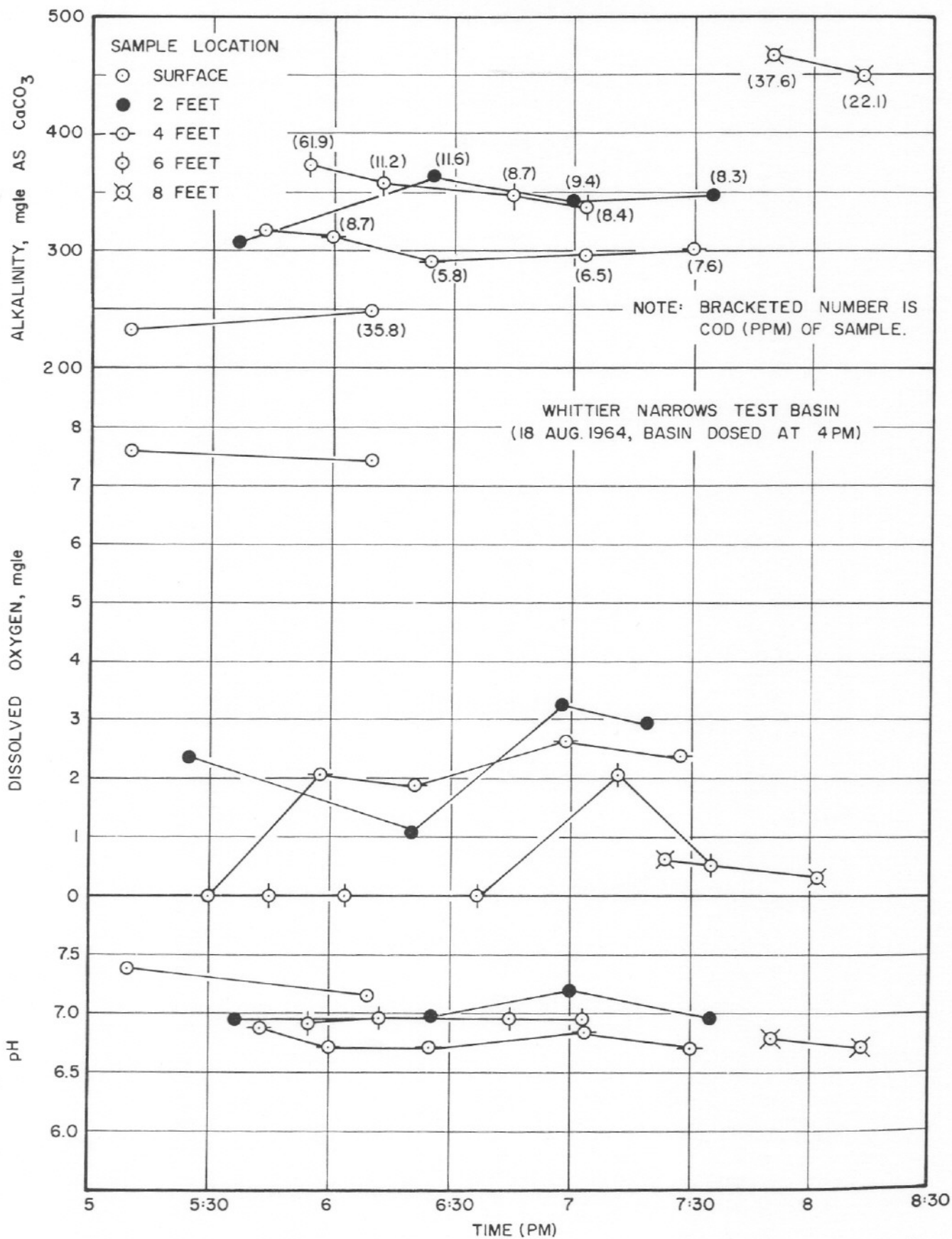


Fig. 4-15—Chemical Analyses of Instantaneous Percolates at Whittier Narrows Test Basin

CHAPTER 5

DATA FROM PROGRAM OF WELL SAMPLING
IN THE MONTEBELLO FOREBAY

5.01 Location of the Wells.

In the spring of 1962, seventeen wells located in the Whittier Narrows area were selected by Caltech and the Los Angeles County Flood Control District (LACFCD) to form the network for a shallow-well sampling program. These wells are shown on the vicinity map designated Figure 4-1, Chapter 4. With funds supplied by this project, an additional well identified by the LACFCD as well No. 1573J was drilled at a site just south of the Rio Hondo Spreading Grounds. The wells were selected because they delineate the area directly influenced by the spreading of the effluent from the Whittier Narrows Water Reclamation Plant. Wells were also selected on the basis of good condition of the well hole, access to the well site, knowledge of the condition of the well casing and depth of perforations, and the well having a diameter large enough to accept the portable, selective-depth pumping unit of the LACFCD.

Table 5-1 is a list of the eighteen wells selected for routine sampling. These wells are classified as shallow wells because they penetrate only the zone of aquifers near the ground surface. These near-surface aquifers constitute the Gaspur zone. In the area of the Rio Hondo Spreading Grounds and to the north of the Montebello forebay, the Gaspur zone is fairly continuous between an elevation of about mean sea level and the ground surface which is approximately 200 feet above mean sea level. About one mile south of the Rio Hondo Spreading Grounds an impervious layer caps the Gaspur strata, changing this zone from an unconfined aquifer to a so-called pressure aquifer. The Gaspur zone is of interest because waters introduced into the ground-water basin from spreading grounds in the Montebello forebay first come in contact with ground water in the Gaspur zone.

Because spreading of reclaimed water was practiced on the San Gabriel River side of the Montebello forebay as well as in the Rio Hondo Spreading Grounds, some wells were selected in 1963 for sampling along the San Gabriel River. These wells are shown in Figure 4-1.

5.02 Method of Sampling.

Each of the shallow wells was sampled on a routine basis with a 3-month to 6-month interval between samplings. The collection of water samples was done by the personnel of the Los Angeles County Flood Control District, and the laboratory analyses were performed by Caltech personnel on the campus.

A special selective-depth pumping unit was fabricated by the Los Angeles County Flood Control District for sampling in the shallow wells. This special unit is portable and permits the collection of a water sample from a particular level in a well. Inflatable balloons or packers are positioned above and below

Table 5-1—Shallow wells chosen for multiple depth sampling

Well number*	Well diameter (inches)	Well reference point elevation† (feet above mean sea level)	Casing depth (feet)
2936A.....	10	216.5	75.9
2936.....	8	210.5	80.6
2937V.....	12	212.0	61.6
2917T.....	8.5	198.2	56
2928N.....	8.5	186.4	50
2928R.....	8.5	188.7	50
2918N.....	12	187.2	118.4
2909N.....	12	177.0	105.4
1600L.....	12	169.9	129.6
1590F.....	10	168.8	71
1590D.....	12	167.4	123.9
1590M.....	12	158.1	89.6
1592A.....	12	156.9	162.8
1592X.....	8	150.0	201
1573J.....	8	141.5	141
1563H.....	12	136.5	243.5
1562.....	12	148.5	260
1561M.....	8	161.0	168.6

* Number based on well grid identification system of the Los Angeles County Flood Control District.
† At or near ground surface elevation.

the pump intake. When inflated, the packers close off the well above and below the pump intake so that water can be pumped from a particular level in a well. This type of operation permits the taking of water samples at multiple depths within a well. Limitations are caused by the spacing of the perforations in a cased well and the location of zones of impervious material.

The Los Angeles County Flood Control District selective-depth pumping unit consists of a Reda pump with a $\frac{3}{4}$ -HP motor. It has an overall length of 56 inches and has a 3.77-inch diameter. The pump is 21 inches long and the pump screen is 2 $\frac{1}{4}$ inches long. The packers are made from 40 durometer natural rubber tubing which has a 5 $\frac{1}{2}$ inch internal diameter and a $\frac{1}{4}$ inch wall thickness. Each packer is about 12 inches long and is held to the pump body with stainless steel clamps. Where the rubber tubing is attached to the pump unit the body has been built up with fiberglass.

After placing the pumping unit at a selected depth, the packers are inflated with nitrogen gas from a portable cylinder to a pressure of 10 psi above the hydrostatic water pressure at that depth. This pressure differential provides a tight seal in the well which prevents the short-circuiting of water around the packers. The pump is operated for a short period of time, generally fifteen minutes, and then a one-gallon sample is taken. The pumping rate is generally 1 to 10 gallons per minute. Measurements of temperature, pH, and dissolved oxygen are made in the field by Flood Control District personnel. Samples are usually taken at 10-foot intervals in a well. However, the sampling pattern varies from well to well, depending on location of the casing perforations and depth of the well.

WASTEWATER RECLAMATION AT WHITTIER NARROWS

Table 5-2—Summary of water analyses on integrated samples for shallow well network

Sample No.	25	31	20	34	22	29	36
Well No.	2936A	2936A	2936	2936	2937V	2937V	2917T
Date—1962	25 June	16 July	21 June	17 July	23 June	16 July	18 July
Temp., field/lab. (°C.)	18/—	16/23	20/—	23/—	17/—	17.5/22	15/22
pH, lab.	7.25	7.51	7.58	7.63	7.40	7.70	7.31
Dissolved oxygen (mg/l O ₂)	1.4	1.4	1.0	—	1.5	—	1.2
Turbidity (units)	2.8	0.2	0.5	0.6	3.0	0.2	0.4
Conductivity (µmho/cm)	788	738	347	521	1110	1345	970
Total dissolved solids (mg/l TDS)	625	627	—	380	824	893	850
Total volatile solids (mg/l TVS)	282	220	—	174	185	272	255
Alkalinity (mg/l CaCO ₃)	258	279	142	167	231	190	197
Calcium (mg/l Ca)	109	112	49	70	148	136	112
Magnesium (mg/l Mg)	36	32	16	12.7	32	30	26
Sodium (mg/l Na)	27.6	28.1	12.1	15.7	32.9	62.0	95.5
Potassium (mg/l K)	1.7	1.4	2.1	2.5	5.0	4.7	4.5
Iron (mg/l Fe)	0.55	0.11	1.54	0.11	0.00	0.01	0.00
Manganese (mg/l Mn)	0.00	0.00	0.05	0.00	0.00	0.01	0.00
Chloride (mg/l Cl)	77.4	25.7	5.4	8.5	88.3	105	79.6
Sulfate (mg/l SO ₄)	210	157	151	71.4	288	247	264
Nitrate (mg/l N)	18.2	20.4	0.16	6.9	—	12.7	4.1
Nitrite (mg/l N)	0.01	0.00	0.00	0.10	0.00	0.04	0.00
Phosphate (mg/l PO ₄)	—	0.11	—	0.32	—	0.05	0.31
Boron (mg/l B)	0.2	0.17	0.0	0.06	0.2	0.14	0.08
Silica (mg/l SiO ₂)	—	19.9	—	15.4	—	15.8	16.6
Alkyl benzene sulfonate (mg/l ABS)	—	—	—	—	—	—	<0.1

Sample No.	37	39	21	24	32	19	30
Well No.	2928N	2928R	2918N	2909N	2909N	1600L	1600L
Date—1962	18 July	18 July	23 June	25 June	17 July	18 June	16 July
Temp., field/laboratory (°C.)	13.5/22	16/22	16.5/—	18/—	20/23	13/—	16.5/22
pH, laboratory	7.44	7.30	7.62	7.40	7.51	7.82	7.49
Dissolved oxygen (mg/l O ₂)	0.06	0.05	0.0	6.6	6.6	8.6	6.0
Turbidity (units)	0.7	1.0	5.3	1.0	0.2	0.25	0.4
Conductivity (µmho/cm)	—	1003	975	930	1137	875	983
Total dissolved solids (mg/l TDS)	770	687	637	613	785	—	791
Total volatile solids (mg/l TVS)	182	184	124	158	180	—	211
Alkalinity (mg/l CaCO ₃)	158	144	145	116	112	117	120
Calcium (mg/l Ca)	99	87	96.4	80.8	90	97	100
Magnesium (mg/l Mg)	30	22	24	28	27	29	23
Sodium (mg/l Na)	94.8	82.8	73.3	101	95.6	72.6	83.3
Potassium (mg/l K)	4.5	4.5	4.2	4.0	4.6	3.8	4.4
Iron (mg/l Fe)	0.00	0.09	0.73	0.48	0.19	0.75	0.57
Manganese (mg/l Mn)	0.00	0.05	0.00	0.00	0.00	0.00	0.00
Chloride (mg/l Cl)	84	82.9	82.2	81.2	89.6	80	89
Sulfate (mg/l SO ₄)	275	243	250	250	289	251	282
Nitrate (mg/l N)	1.7	2.2	—	3.5	2.9	0.27	3.8
Nitrite (mg/l N)	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Phosphate (mg/l PO ₄)	0.10	0.14	—	0.07	0.07	—	0.09
Boron (mg/l B)	0.10	0.07	0.2	0.1	0.12	0.0	0.09
Silica (mg/l SiO ₂)	9.8	13.2	—	—	8.6	—	8.2
Alkyl benzene sulfonate (mg/l ABS)	<0.1	<0.1	—	—	<0.1	—	—

Sample No.	14	33	13	40	15	35	45
Well No.	1590F	1590F	1590D	1590D	1590M	1590M	1592X
Date—1962	16 June	17 July	16 June	17 July	16 June	17 July	20 July
Temp., field/laboratory (°C.)	14/—	23/23	15/—	19.5/22	13.5/—	17/23	19/25
pH, laboratory	7.60	7.53	7.74	7.58	7.59	7.44	7.52
Dissolved oxygen (mg/l O ₂)	10.0	6.7	7.4	5.6	8.7	5.3	11.3
Turbidity (units)	0.15	0.8	0.1	1.0	0.35	1.0	4.1
Conductivity (µmho/cm)	930	1036	975	863	914	1187	1160
Total dissolved solids (mg/l TDS)	669	812	697	767	643	820	623
Total volatile solids (mg/l TVS)	147	216	191	164	158	212	140
Alkalinity (mg/l CaCO ₃)	126	136	125	126	129	143	142
Calcium (mg/l Ca)	92	94	105	98	97	103	104
Magnesium (mg/l Mg)	27	26	36	26	19	24	21
Sodium (mg/l Na)	85.2	87.4	83.9	103	85.5	81	82.6
Potassium (mg/l K)	3.5	4.3	3.5	4.4	3.5	4.2	4.0
Iron (mg/l Fe)	0.19	0.22	0.02	0.09	0.03	0.12	1.2
Manganese (mg/l Mn)	0.00	0.00	0.00	0.02	0.00	0.01	0.02
Chloride (mg/l Cl)	82.8	87.9	87.0	90.5	80.4	88	68.2
Sulfate (mg/l SO ₄)	247	283	250	297	237	285	230
Nitrate (mg/l N)	6.9	5.6	4.1	2.3	4.5	5.6	6.1
Nitrite (mg/l N)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phosphate (mg/l PO ₄)	—	0.10	—	0.12	—	0.07	0.05
Boron (mg/l B)	0.1	0.11	0.1	0.10	0.1	0.18	0.16
Silica (mg/l SiO ₂)	—	8.6	—	11.6	—	7.5	20.0
Alkyl benzene sulfonate (mg/l ABS)	—	<0.1	—	<0.1	—	<0.1	—

Table 5-2—Summary of water analyses on integrated samples for shallow well network—continued

Sample No.	23	44	18	17	41	16	42
Well No.	1592A	1592A	1563H	1562	1562	1561M	1561M
Date—1962	24 June	20 July	18 June	17 June	19 July	17 June	19 July
Temp., field/laboratory (°C)	18/—	18/23	18.5/—	17/—	18.5/23	17.5/—	17.5/23
pH, laboratory	7.07	7.46	7.93	7.56	7.50	7.53	7.41
Dissolved oxygen (mg/l O ₂)	8.2	8.3	7.8	7.4	8.3	9.3	11.2
Turbidity (units)	0.9	1.1	1.0	0.4	1.1	0.45	1.2
Conductivity (μmho/cm)	706	1420	930	794	924	776	937
Total dissolved solids (mg/l TDS)	534	595	--	553	627	546	889
Total volatile solids (mg/l TVS)	201	111	--	183	197	180	225
Alkalinity (mg/l CaCO ₃)	121	137	179	188	192	175	177
Calcium (mg/l Ca)	76.8	92	111	114	122	108	113
Magnesium (mg/l Mg)	22	19	28	25	14	28	22
Sodium (mg/l Na)	61.6	60.0	64.4	39.2	40.9	43.2	45.3
Potassium (mg/l K)	3.3	3.5	3.8	3.0	2.9	3.0	3.5
Iron (mg/l Fe)	0.74	0.07	1.50	0.62	0.00	0.19	0.30
Manganese (mg/l Mn)	0.00	0.00	0.02	0.00	0.01	0.04	0.03
Chloride (mg/l Cl)	50.8	60.7	74.4	62.4	59.5	61.8	66.2
Sulfate (mg/l SO ₄)	178	227	246	150	175	140	201
Nitrate (mg/l N)	8.0	9.3	0.41	6.16	6.6	9.7	7.8
Nitrite (mg/l N)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phosphate (mg/l PO ₄)	--	0.07	--	--	0.11	--	0.09
Boron (mg/l B)	0.0	0.10	0.2	0.1	0.025	0.1	0.15
Silica (mg/l SiO ₂)	--	16.2	--	--	20.8	--	20.1
Alkyl benzene sulfonate (mg/l ABS)	--	--	--	--	--	--	--

Considerable difficulty was encountered with the inflatable packers. While operation was very successful in 8- and 10-inch diameter wells, the packers have burst many times in the 12-inch diameter wells. At present the Los Angeles County Flood Control District is critically reviewing the design of the inflatable packers in order to increase the reliability of the unit in the larger wells.

5.03 Analyses of Integrated Samples.

The selective-depth pumping unit was not fabricated until March 1963. Prior to that time, starting in June and July 1962, integrated samples were collected with a portable pumping unit. They represent the water which enters a well from all depths. Table 5-2 is a summary of the chemical analyses performed on these samples. Rather complete mineral analyses were run in order to provide background information on the water quality. In several instances the methylene-blue assay for the alkyl benzene sulfonates (ABS) was performed, but no concentration of ABS was found in any of the wells. A blank space in the table indicates that no analysis was performed. No sample from well No. 1573J was made at this time because the well was not yet constructed.

5.04 Analyses of Multiple Depth Samples.

The purpose of sampling the shallow well network at multiple depths was twofold: first, to discover any changes in water quality attributable to the spreading of the reclaimed waters, and second, to delineate, if possible, any near-surface patterns in the ground-water movement. Because of the complex nature of the ground-water basin and the lack of any clear-cut tracers in the reclaimed water, the second purpose was not attainable.

Table 5-3 is a summary of the chemical analyses performed on the multiple-depth samples. Complete mineral analyses were not run because many of the components are not suitable tracers. Initially, it was thought that ABS was the most satisfactory tracer

for the reclaimed water; however, on this basis alone there has been no apparent change in water quality in the wells within the spreading grounds or the neighboring area.

Tables 5-3 and 5-4 show the results of analyses performed on multiple-depth samples taken from shallow wells at the downstream base of the Whittier Narrows Dam (see Figure 4-1, Chapter 4). These wells are referred to as "toe-drain" wells because they are used to control the phreatic surface through the earth dam. Three of these wells are shown in Figure 4-1, namely 2917T (TD#29), 2928 (TD#43), and 2928R (TD#64). The other toe-drain wells referred to in Table 5-3 by the notation "TD#" are in the same general location along the southern side of the dam. During the whole period of this investigation, these shallow wells were the only ones to show significant concentrations of apparent ABS. The concentration of ABS in these wells tended to be high in fall and winter season and low in the spring and summer. Concentrations of more than 1.0 mg/l were reached in several of the wells, but they decreased markedly on the next sampling to 0.1 mg/l. A concentration of 0.1-0.2 mg/l by the methylene-blue assay is not felt to be significant when done in our laboratory. It should be emphasized also that although the apparent ABS for some of the samples was more than 1.0 mg/l by the methylene-blue assay, these samples did not foam when shaken vigorously.

Samples from wells, such as the San Gabriel Valley Water Co. Plant W2, immediately south of the toe-drain wells have had no apparent ABS. None of the wells sampled in this study have shown any tendency to foam. It is important to note that no intentional spreading of water is done upstream of the toe-drain wells, with exception of the small quantities spread at the Whittier Narrows Test Basin. Some reclaimed water will seep into the ground through the unlined transport canals north of the dam, but reclaimed waters in the canal in the vicinity of the toe-drain wells have been diluted most of the time with Colo-

WASTEWATER RECLAMATION AT WHITTIER NARROWS

Table 5-3—Summary of multiple depth samples for shallow well network

Sample Number	Well Number	Date 1963	Sample depth (ft)	Sample elevation† (ft)	ABS (mg/l)	Cl (mg/l)	Specific conductance (µmho/cm)	Field temperature (°C)	Field pH
W33	2936	14 Mar.	36	174.5	0.0	12	545	21	7.2
W34	2936	14 Mar.	46	164.5	0.0	12	587	22	7.1
W35	2936	14 Mar.	56	154.5	0.0	12	620	22	7.2
W36	2936	14 Mar.	66	144.5	0.0	12	594	22	7.1
W37	2936	14 Mar.	76	134.5	0.0	12	585	22	7.1
W38	2936	14 Mar.	81	129.5	0.0	12	606	22	7.1
W47	2936	14 Mar.	40	170.5	0.0	14	617	18.5	7.1
W66	2936	19 April	36	174.5	0.0	14	590	23	7.1
W67	2936	19 April	46	164.5	0.0	14	607	22.5	--
W68	2936	19 April	56	154.5	0.0	14	625	22	--
W71	2936	19 April	66	144.5	0.0	14	610	21	--
W69	2936	19 April	76	134.5	0.0	14	620	21	--
W70	2936	19 April	81	129.5	0.0	14	608	21	--
W72	2936	19 April	81	129.5	0.0	14	608	21.5	--
W89	2936	10 July	36	174.5	0.0	8.7	437	22.5	--
W88	2936	10 July	46	164.5	0.0	9.6	457	25	--
W87	2936	10 July	56	154.5	0.0	9.3	441	22.5	--
W85	2936	10 July	66	144.5	0.0	10.0	449	23	--
W86	2936	10 July	76	134.5	0.0	9.5	441	25	--
*W49	2937V	20 Mar.	35	177.0	0.1	61	1,108	18	7.0
W102	2937V	12 July	35	177.0	0.2	47.0	734	20.5	7.2
W21	2917T	8 Mar.	40	158.2	0.1	85	804	21.5	--
W20	2917T	8 Mar.	46	152.2	0.3	78	923	18	7.0
W22	2917T	8 Mar.	46	152.2	0.1	84	809	23	--
W23	2917T	8 Mar.	52	146.2	0.2	82	846	22	--
W60	2917T	18 April	40	158.2	0.1	106	1,215	23.5	--
W61	2917T	18 April	46	152.2	0.1	104	1,230	27	--
W62	2917T	18 April	52	146.2	0.1	106	1,220	25.5	--
W94	2917T	10 July	40	158.2	0.2	79.7	831	22.5	--
W91	2917T	10 July	46	152.2	1.0	90.8	779	22	--
W90	2917T	10 July	52	146.2	1.1	94.5	790	22	--
W127	2917T	6 Aug.	40	158.2	0.4	85.1	791	24	6.9
W121	2917T	6 Aug.	46	152.2	0.9	96.9	756	24.5	6.9
W124	2917T	6 Aug.	52	146.2	1.0	96.0	779	24	6.9
W12	2928N	11 Mar.	34	152.4	0.1	75	947	23.5	--
*W13	2928N	11 Mar.	40	146.4	0.1	69	1,000	19	7.0
W14	2928N	11 Mar.	40	146.4	0.1	73	961	21	--
W15	2928N	11 Mar.	44.5	141.9	0.1	73	951	21.5	--
W52	2928N	18 April	34	152.4	0.3	98	1,040	23.5	7.1
*W53	2928N	18 April	40	146.4	0.2	96	1,100	18.5	--
W54	2928N	18 April	40	146.4	0.1	97	1,115	24	--
W55	2928N	18 April	44.5	141.9	0.3	95	1,140	23	--
W93	2928N	9 July	34	154.4	0.3	81.9	831	25	--
W97	2928N	9 July	40	146.4	0.4	83.7	831	25	--
W98	2928N	9 July	45	141.4	0.3	84.4	845	25.5	--
W9	2928R	8 Mar.	34	154.7	0.5	80	951	21	--
*W8	2928R	8 Mar.	40	148.7	0.5	81	951	19	--
W10	2928R	8 Mar.	40	148.7	0.5	79	951	24	--
W11	2928R	8 Mar.	46	142.7	0.4	80	1,040	23.5	--
W56	2928R	17 April	34	154.7	0.6	94	1,040	--	--
W57	2928R	17 April	40	148.7	0.6	93	1,040	23	--
*W59	2928R	17 April	40	148.7	0.6	93	1,035	19.5	7.2
W58	2928R	17 April	46	142.7	0.6	94	1,040	22.5	--
W92	2928R	9 July	34	154.7	0.8	72.5	734	28.5	--
W96	2928R	9 July	40	148.7	0.8	73.4	734	28	--
W95	2928R	9 July	46	142.7	0.9	74.4	734	24.5	--
W48	2918N	13 Mar.	60	127.2	0.0	74	1,051	18	7.2
W106	2918N	18 July	60	127.2	0.1	80.2	756	22	--
W152	2918N	22 Aug.	110	77.2	0.0	77.1	768	22.5	7.0
W6	2909N	25 Feb.	45	132.0	0.2	33	1,620	20.5	7.2
*W73	2909N	22 April	45	132.0	0.1	95	1,090	15.5	7.5
W142	2909N	16 Aug.	75	102.0	0.1	84.4	851	20	0.9
W143	2909N	16 Aug.	85	92.0	0.1	84.5	860	20	--
W144	2909N	16 Aug.	95	82.0	0.1	83.5	845	19.5	--
*W16	1600L	6 Mar.	90	79.9	0.1	54	1,300	20	7.2
W17	1600L	6 Mar.	93.5	76.4	0.1	53	1,300	--	--
W18	1600L	6 Mar.	104.5	65.4	0.1	53	1,280	21	--
*W19	1600L	6 Mar.	114.5	55.4	0.1	54	1,330	20.5	--
W147	1600L	20 Aug.	95	74.9	0.0	75.8	860	21	6.9
W146	1600L	20 Aug.	105	64.9	0.1	73.7	779	22.5	--
W148	1600L	20 Aug.	115	54.9	0.1	74.5	818	24	--
W7	1590F	21 Feb.	42	126.8	0.3	60	1,050	21	7.2
W76	1590F	22 April	39	129.8	0.0	63	811	22	--
*W29	1590D	7 Mar.	99	68.4	0.2	69	1,025	19.5	7.0
W129	1590D	9 Aug.	80	87.4	0.1	79.7	722	24	--
W128	1590D	9 Aug.	90	77.4	0.1	83.9	722	22.5	--
W1	1590M	15 Feb.	40	118.1	0.2	79	875	--	--
W2	1590M	15 Feb.	50	108.1	0.2	78	880	19.5	--
W3	1590M	15 Feb.	60	98.1	0.1	78	880	20	--
W4	1590M	15 Feb.	70	88.1	0.1	78	875	20.5	--
W5	1590M	15 Feb.	80	78.1	0.1	82	900	19.5	--
W149	1590M	21 Aug.	72	86.1	0.1	92.2	875	22.5	7.0
W150	1590M	21 Aug.	78	80.1	0.1	91.7	875	22	--
*W51	1592A	20 Mar.	75	81.9	0.1	79	1,155	18	6.9
W105	1592A	12 July	80	76.9	0.1	84.4	831	17	7.0
W151	1592A	23 Aug.	85	71.9	0.0	79.3	818	22.5	6.9
W152	1592A	23 Aug.	100	56.9	0.1	79.4	860	21.5	--
W154	1592A	23 Aug.	130	26.9	0.1	80.4	891	22	--

Table 5-3—Summary of multiple depth samples for shallow well network—continued

Sample Number	Well Number	Date 1963	Sample depth (ft)	Sample elevation† (ft)	ABS (mg/l)	Cl (mg/l)	Specific conductance (µmho/cm)	Field temperature (°C)	Field pH
W31	1592X	12 Mar.	169	-19.0	0.1	67	1,090	21	---
W30	1592X	12 Mar.	175	-25.0	0.1	66	1,090	18.5	7.0
W32	1592X	12 Mar.	175	-25.0	0.0	65	1,090	21	---
W63	1592X	18 April	169	-19.0	0.0	93	993	20	---
W64	1592X	18 April	175	-25.0	0.0	89	970	20	---
W65	1592X	18 April	181	-31.0	0.0	83	954	20	---
W101	1592X	11 July	169	-19.0	0.0	90.7	756	22.5	---
W104	1592X	11 July	175	-25.0	0.0	81.3	744	21.5	---
W103	1592X	11 July	181	-31.0	0.0	80.2	744	20.5	---
W24	1573J	11 Mar.	110	31.5	0.0	84	923	18.5	7.0
W25	1573J	11 Mar.	124	17.5	0.1	84	904	21	---
W26	1573J	11 Mar.	130	11.5	0.1	84	924	20.5	---
W27	1573J	11 Mar.	138	3.5	0.1	83	924	20.5	---
W74	1573J	19 April	124	17.5	0.0	101	1,130	20.5	---
W75	1573J	19 April	130	11.5	0.0	101	1,130	20	---
W99	1573J	11 July	124	17.5	0.1	94.2	860	22	---
W100	1573J	11 July	130	11.5	0.0	94.2	860	22.5	---
*W50	1562	20 Mar.	166	-17.5	0.0	66	963	17.5	7.0
W40	1561M	15 Mar.	135	26.0	0.0	68	932	21	---
W41	1561M	15 Mar.	145	16.0	0.0	68	946	21	7.1
W39	1561M	15 Mar.	146	15.0	0.0	67	943	17.5	7.1
W42	1561M	15 Mar.	155	6.0	0.0	66	921	21	7.1
W107	1561M	17 July	138	23.0	0.1	76.3	580	28	---
W109	1561M	17 July	145	16.0	0.1	77.5	702	28.5	---
W108	1561M	17 July	150	11.0	0.1	77.8	791	28	---

† Sample elevation above mean sea level measured relative to reference point in well.

‡ Packer ruptured.

* Integrated sample taken without using packers.

rado River water. If the canals are filled with water for an extended period of time, one can expect the soil beneath the canal to become saturated. North of the dam the ground-water table is close to the ground surface, about 10-12 feet down, and it is quite possible that reclaimed water reached the ground-water table without seeping through a soil zone with a highly developed aerobic culture such as exists in the near surface soil of the test basins. Under anaerobic conditions, ABS is readily transmitted with the water and not removed and degraded. Local geologic conditions associated with a high ground-water table could then cause this water to be short-circuited to the shallow toe-drain wells.

There has been no evidence to date that the spreading of reclaimed water has affected the quality of water in wells in the Montebello forebay. The fact that the reclaimed water and Colorado River water have quite similar chemical characteristics has made difficult the tracing of reclaimed water in the forebay. The most sensitive tracer, which occurs in wastewater but not in natural or Colorado River water, is ABS. From the results of this sampling program it is apparent that the ABS from wastewater has not reached water-supply wells in the Montebello forebay, partly because it has been removed in aerobic percolation and partly because of the high dilution of wastewater by natural waters.

Table 5-3—Summary of multiple depth samples for shallow well network—continued

Sample Number	Well Number	Date	Sample Depth (feet)	ABS (mg/l)	Cl (mg/l)	Specific Conductance (µmho/cm)	Field Temp. (°C)	Field pH
W235	2936	29 Oct. 63	36	0.0	7.3	399	24	---
W236	2936	29 Oct. 63	46	0.0	6.3	378	24	---
W234	2936	29 Oct. 63	56	0.0	5.6	320	24	---
W238	2936	29 Jan. 64	36	0.0	5.6	321	18.5	7.0
W246	2936	29 Jan. 64	52	0.0	4.3	318	21	7.1
W239	2936	29 Jan. 64	60	0.0	4.5	323	22	7.1
W296	2936	14 Oct. 64	36	0.1	3.8	365	22	---
W294	2936	14 Oct. 64	46	0.0	3.6	359	20.5	---
W299	2936	14 Oct. 64	56	0.0	---	---	23	---
W298	2936	14 Oct. 64	66	0.0	2.5	320	---	---
W334	2936	23 April 65	36	0.0	3.7	339	23	---
W335	2936	23 April 65	46	0.0	3.2	331	24	---
W336	2936	23 April 65	56	0.0	3.2	326	24	---
W337	2936	23 April 65	66	0.0	3.2	326	25	---
W232	1573J	30 Oct. 63	120	0.1	89.5	1,142	23	---
W233	1573J	30 Oct. 63	130	0.1	88.1	1,124	24	---
W251	1573J	31 Jan. 64	120	0.0	90.5	---	20.5	6.9
W252	1573J	31 Jan. 64	130	0.0	85.3	---	20.5	6.9
W356	1573J	30 April 65	125	0.0	79.5	1,030	25	---
W352	1573J	30 April 65	146	0.0	81.4	1,050	23	---
W295	1561M	14 Oct. 64	138	0.1	88.2	967	21	---
W297	1561M	14 Oct. 64	145	0.1	80.7	990	21	---
W292	1561M	14 Oct. 64	150	0.1	82.3	990	20.5	---
W353	1561M	29 April 65	138	0.0	83.4	1,000	25.5	---
W357	1561M	29 April 65	145	0.0	82.0	1,000	25.5	---
W361	1561M	29 April 65	150	0.0	82.7	1,020	24	---
W360	1562	30 April 65	166	0.0	82.3	1,000	17.5	---
W172	2917B	16 Sept. 63	---	0.2	83.4	1,015	---	---
W293	2917B	15 Oct. 64	---	0.1	313	1,400	---	---

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Table 5-3—Summary of multiple depth samples for shallow well network—continued

Sample number	Well number	Date	Sample depth (feet)	ABS (mg/l)	Cl (mg/l)	Specific conductance (µmho/cm)	Field temp. (°C)
W302.....	2917B	9 April 65	--	0.2	183	1,180	--
W327.....	1590D	28 April 65	99	0.0	71.4	891	15
W332.....	1590F	28 April 65	42	0.0	86.5	1,020	14
W179.....	2947V	30 Sept. 63	--	0.1	14.0	378	--
W253.....	2947Z	15 June 64	--	0.0	27.5	576	19.5
W273.....	2947Z	30 Sept. 64	--	0.0	27.9	565	19.5
W167.....	2938D	16 Sept. 63	--	0.1	41.7	800	--
W254.....	2938D	15 June 64	--	0.1	45.5	864	17
W269.....	2938D	30 Sept. 64	--	0.1	47.2	834	19.5
W173.....	2948	25 Sept. 63	--	0.0	33.1	526	--
W262.....	2948	17 June 64	--	0.1	22.4	555	18
W166.....	2939B	16 Sept. 63	--	0.2	66.0	1,015	--
W256.....	2939B	15 June 64	--	0.1	70.4	1,000	17
W274.....	2939B	30 Sept. 64	--	0.2	72.5	1,050	21.5
W174.....	1620GG	16 Sept. 63	--	0.1	83.2	1,050	--
W263.....	1620GG	17 June 64	--	0.1	74.6	990	17.5
W265.....	1620GG	30 Sept. 64	--	0.1	74.8	976	17
W193.....	1620BB	23 Sept. 63	--	0.1	77.9	1,010	--
W164.....	1621SS	16 Sept. 63	--	0.1	65.5	920	--
W257.....	1621SS	15 June 64	--	0.1	57.0	919	17
W267.....	1621SS	30 Sept. 64	--	0.1	70.6	944	17
W165.....	1621S	16 Sept. 63	--	0.1	79.5	1,000	--
W176.....	1613S	16 Sept. 63	--	0.1	16.9	550	--
W261.....	1613S	15 June 64	--	0.1	15.3	569	18.5
W271.....	1613S	30 Sept. 64	--	0.1	16.5	543	19
W177.....	1615R	16 Sept. 63	--	0.1	66.5	1,020	--
W175.....	1596H	16 Sept. 63	--	0.1	41.1	740	--
W260.....	1596H	15 June 64	--	0.1	38.8	745	17
W266.....	1596H	30 Sept. 64	--	0.1	48.0	794	18.5
W188.....	1606	25 Sept. 63	--	0.1	43.7	797	--
W191.....	1606X	25 Sept. 63	--	0.1	46.3	771	--
W169.....	1597BB	16 Sept. 63	--	0.1	46.7	803	--
W259.....	1597BB	15 June 64	--	0.1	50.7	846	--
W264.....	1597BB	30 Sept. 64	--	0.1	53.0	836	17
W170.....	1587Y	16 Sept. 63	--	0.1	30.2	705	--
W255.....	1587Y	15 June 64	--	0.1	31.1	732	18
W268.....	1587Y	30 Sept. 64	--	0.1	16.9	557	20
W333.....	1590M	28 April 65	60	0.0	79.3	976	14
W330.....	1592A	27 April 65	80	0.0	89.2	1,070	18
W171.....	1598K	16 Sept. 63	--	0.1	26.9	671	--
W258.....	1598K	15 June 64	--	0.1	29.5	708	18
W272.....	1598K	30 Sept. 64	--	0.1	31.6	698	17.5
W270.....	1612Q	30 Sept. 64	--	0.1	79.6	965	16.5
W328.....	1600L	28 April 65	90	0.0	86.9	1,070	14
W331.....	2909N	27 April 65	50	0.0	27.8	478	15
W329.....	2918N	27 April 65	60	0.6	87.1	976	18.5

Table 5-4—Summary of analyses for Whittier Narrows dam toe drain wells

Sample No.	Well No.	Date	Sample depth (ft.)	ABS (mg/l)	Cl (mg/l)	Specific conductance (umho/cm)	Sample No.	Well No.	Date	Sample depth (ft.)	ABS (mg/l)	Cl (mg/l)	Specific conductance (umho/cm)
W130	TD#21	9 Aug. 63	34	0.1	56.1	683	W219	2017T	25 Oct. 63	46	0.5	95.5	981
W141	TD#21	9 Aug. 63	40	0.2	52.5	702	W223	2017T	25 Oct. 63	52	0.5	97.5	967
W140	TD#21	9 Aug. 63	46	0.2	53.0	692	W245	2017T	28 Jan. 64	40	0.0	85.0	1,110
W200	TD#21	24 Oct. 63	34	0.4	73.2	871	W243	2017T	28 Jan. 64	46	0.1	85.4	1,060
W204	TD#21	24 Oct. 63	40	0.4	73.6	884	W247	2017T	28 Jan. 64	52	0.1	85.6	1,080
W208	TD#21	24 Oct. 63	46	0.4	75.8	889	W316	TD#21	20 Apr. 65	34	0.1	84.0	1,030
W133	TD#26	9 Aug. 63	34	0.3	60.7	692	W320	TD#21	20 Apr. 65	40	0.0	82.3	1,020
W132	TD#26	9 Aug. 63	40	0.2	60.4	734	W324	TD#21	20 Apr. 65	46	0.0	83.4	1,030
W131	TD#26	9 Aug. 63	46	0.2	60.2	712	W286	TD#26	8 Oct. 64	34	0.5	80.5	945
W220	TD#26	23 Oct. 63	34	0.5	73.8	816	W290	TD#26	8 Oct. 64	40	0.5	84.2	960
W216	TD#26	23 Oct. 63	40	0.5	75.8	806	W279	TD#26	8 Oct. 64	46	0.4	79.9	990
W212	TD#26	23 Oct. 63	46	0.4	72.5	800	W305	TD#26	20 Apr. 65	34	0.0	90.4	1,080
W134	TD#32	8 Aug. 63	34	0.3	86.7	845	W309	TD#26	20 Apr. 65	40	0.0	89.9	1,080
W135	TD#32	8 Aug. 63	40	0.4	88.9	860	W313	TD#26	20 Apr. 65	46	0.0	91.3	1,080
W136	TD#32	8 Aug. 63	46	0.4	89.8	860	W303	TD#32	21 Apr. 65	34	0.4	100	1,180
W214	TD#32	25 Oct. 63	34	0.3	88.8	1,015	W307	TD#32	21 Apr. 65	40	0.4	99.8	1,110
W218	TD#32	25 Oct. 63	40	0.4	89.8	990	W311	TD#32	21 Apr. 65	46	0.2	99.0	1,100
W222	TD#32	25 Oct. 63	46	0.3	88.1	995	W304	TD#35	21 Apr. 65	34	0.4	102	1,210
W118	TD#35	7 Aug. 63	40	0.4	88.5	924	W308	TD#35	21 Apr. 65	40	0.3	98.4	1,280
W117	TD#35	7 Aug. 63	46	0.6	89.6	845	W312	TD#35	21 Apr. 65	46	0.4	101	1,140
W202	TD#35	24 Oct. 63	34	0.4	88.5	1,122	W340	TD#39	22 Apr. 65	34	0.4	102	1,090
W206	TD#35	24 Oct. 63	40	0.3	83.0	1,066	W343	TD#39	22 Apr. 65	40	0.6	101	1,090
W210	TD#35	24 Oct. 63	46	0.4	86.6	1,060	W347	TD#39	22 Apr. 65	46	0.4	99.4	1,090
W120	TD#39	7 Aug. 63	34	0.3	83.1	804	W341	TD#48	22 Apr. 65	34	0.7	102	1,090
W123	TD#39	7 Aug. 63	40	0.2	83.7	818	W342	TD#48	22 Apr. 65	40	0.7	102	1,090
W126	TD#39	7 Aug. 63	46	0.5	85.6	791	W346	TD#48	22 Apr. 65	46	0.6	102	1,090
W201	TD#39	24 Oct. 63	34	0.2	72.5	942	W339	TD#54	23 Apr. 65	34	0.6	97.5	1,070
W205	TD#39	24 Oct. 63	40	0.2	72.0	941	W344	TD#54	23 Apr. 65	40	0.5	98.0	1,080
W209	TD#39	24 Oct. 63	46	0.3	74.4	949	W348	TD#54	23 Apr. 65	46	0.5	97.4	1,070
W116	TD#48	7 Aug. 63	34	0.1	78.4	791	W338	TD#59	23 Apr. 65	34	0.6	98.5	1,080
W119	TD#48	7 Aug. 63	40	0.3	81.1	791	W345	TD#59	23 Apr. 65	40	0.6	97.1	1,070
W122	TD#48	7 Aug. 63	46	0.7	90.0	756	W349	TD#59	23 Apr. 65	46	0.5	97.7	1,080
W213	TD#48	25 Oct. 63	34	0.3	55.8	771	W291	2028R	8 Oct. 64	34	0.5	69.3	904
W217	TD#48	25 Oct. 63	40	0.3	61.4	806	(TD#64)	W283	8 Oct. 64	40	0.5	62.9	865
W221	TD#48	25 Oct. 63	46	0.3	88.1	995	W280	2028R	8 Oct. 64	46	0.5	69.8	888
W125	TD#54	7 Aug. 63	34	0.4	73.3	768	W318	2028R	30 Mar. 65	34	0.8	102	1,080
W115	TD#54	7 Aug. 63	46	0.3	74.9	744	W326	2028R	30 Mar. 65	40	0.6	97.6	1,060
W224	TD#54	28 Oct. 63	34	0.3	51.9	794	W322	2028R	30 Mar. 65	46	0.8	97.2	1,070
W226	TD#54	28 Oct. 63	40	0.3	50.5	782	W289	2028N	9 Oct. 64	34	0.4	96.0	1,123
W229	TD#54	28 Oct. 63	46	0.3	49.8	794	(TD#43)	W275	9 Oct. 64	40	0.4	100	1,075
W139	TD#50	8 Aug. 63	34	0.2	53.6	756	W277	2028N	9 Oct. 64	45	0.3	98.2	1,095
W138	TD#50	8 Aug. 63	40	0.4	69.5	788	W319	2028N	30 Mar. 65	34	0.7	99.6	1,080
W137	TD#50	8 Aug. 63	46	0.6	77.2	906	W323	2028N	30 Mar. 65	40	0.5	99.2	1,060
W155	2028R	8 Oct. 63	34	0.9	79.7	920	W315	2028N	30 Mar. 65	45	0.7	101	1,060
W158	(TD#64)	8 Oct. 63	40	0.8	80.6	920	W281	2017T	9 Oct. 64	46	0.8	107	1,080
W156	2028R	8 Oct. 63	46	1.0	81.6	920	(TD#29)	W284	9 Oct. 64	52	1.1	116	990
W203	2028R	23 Oct. 63	34	0.8	81.0	981	W306	2017T	20 Apr. 65	40	0.1	98.7	1,150
W207	2028R	23 Oct. 63	40	0.6	78.6	981	W310	2017T	20 Apr. 65	46	0.1	97.9	1,170
W211	2028R	23 Oct. 63	46	0.5	80.5	932	W314	2017T	20 Apr. 65	52	0.1	98.7	1,170
W240	2028R	28 Jan. 64	34	0.3	86.4	946	W288	TD#134	13 Oct. 64	34	1.2	99.1	1,015
W241	2028R	28 Jan. 64	40	0.4	86.5	946	W287	TD#134	13 Oct. 64	40	1.1	98.1	1,040
W242	2028R	28 Jan. 64	46	0.4	86.4	970	W285	TD#134	13 Oct. 64	46	1.3	105	1,080
W157	2028N	8 Oct. 63	34	0.3	71.1	920	W358	TD#134	3 May 65	34	0.2	94.0	1,100
W162	(TD#43)	14 Oct. 63	34	0.2	63.0	870	W354	TD#134	3 May 65	40	0.2	93.7	1,110
W160	2028N	14 Oct. 63	40	0.3	63.0	857	W350	TD#134	3 May 65	45	0.1	94.1	1,100
W231	2028N	28 Oct. 63	34	0.2	57.6	821	W282	TD#135	13 Oct. 64	34	1.3	111	1,123
W228	2028N	28 Oct. 63	40	0.2	78.8	852	W276	TD#135	13 Oct. 64	40	1.3	112	1,100
W225	2028N	28 Oct. 63	46	0.3	59.3	782	W278	TD#135	13 Oct. 64	46	1.2	115	1,105
W248	2028N	28 Jan. 64	34	0.1	87.4	970	W359	TD#135	3 May 65	34	0.1	66.3	892
W249	2028N	28 Jan. 64	40	0.1	88.1	970	W355	TD#135	3 May 65	40	0.1	70.6	915
W244	2028N	28 Jan. 64	45	0.2	88.2	970	W351	TD#135	3 May 65	46	0.1	70.9	911
W163	2017T	14 Oct. 63	40	0.6	87.8	958							
W161	(TD#29)	14 Oct. 63	46	0.8	88.1	937							
W159	2017T	14 Oct. 63	52	0.7	90.0	937							
W215	2017T	25 Oct. 63	40	0.4	96.7	972							

LABORATORY SOIL COLUMN INVESTIGATIONS

6.01 The Purpose of the Study.

Experience and information obtained from the field spreading basin study have pointed out the need for the accelerated accumulation of data on the effects of aerobic percolation through a soil system. While the field study is quite valuable, the lack of control over many of the variables of the spreading operation often creates great difficulties in the interpretation of data. Therefore, it was decided to set up in the laboratory multiple columns of media (soil and sand) which could be dosed at higher rates and heavier loads than occur under present conditions in the field. Closer control over this complex biological system is a primary consideration. It is advantageous to develop a laboratory setup in which special attention can be given to the optimization of the necessary parameters for the degradation of refractory compounds, in this case a highly aerobic soil system for rapid removal of synthetic detergents.

6.02 The Intermittent Laboratory Sand Filter.

A new design for a laboratory soil column incorporated the features necessary to permit operation of the column as a respirometer as well as a lysimeter. The column is shown schematically in Figure 6-1. It consists basically of sections of four-inch diameter, anodized aluminum tubing. Each column is a combination of two types of modules, a filter section and a sampling section. No section is more than eighteen inches long; hence the entire section can be placed in the laboratory autoclave to be sterilized if desired.

The filter section is a straight piece of tubing with an aluminum screen of about 8 mesh mounted near one end. Sand or other filter media are retained in this section. A sampling section is made from a connector piece used to join sections of four-inch aluminum irrigation pipe. One end of the sampling section is closed, so that the unit looks simply like a small coffee can. Mounted in the aluminum end plate of the sampling section are two $\frac{3}{8}$ -inch aluminum tubes. One tube is U-shaped and is a siphon which causes water collected in the sampling section to be emptied automatically and discharged out the bottom when the level of the water reaches some specific height. The second tube is a straight pipe which permits gas to flow through the sampling section even though it may be partially filled with water causing the siphon tube to be sealed off. A third tube is mounted through the side of the sampling section. This is a port which permits emptying of the water from the sampling section by not letting the water level rise to the height necessary to prime the siphon.

A complete laboratory column consists of alternate sampling and filter sections. A whole unit can be constructed of sand beds of arbitrary depths. Each sampling section permits the sampling of the percolate after it has passed through a given depth of sand without disturbing the sand bed or the pattern of

flow through the bed. The columns can be modified at will by simply removing a section without disturbing the rest of the column.

In order to operate the columns as respirometers, it is necessary to make them airtight. This is accomplished by using O-ring seals at the joints between the modules and taping the joint on the outside with a plastic tape. Preliminary studies have shown that it is possible to run the columns with a co-current forced flow of air and water. However, the experiments discussed in this chapter were run with a natural ventilation only, that is, the air is drawn into the columns as a result of the intermittent dosing with the liquid feed.

Each time a sampling section discharges its liquid feed, a natural draft is produced drawing air into the column. Because of the multiple sampling sections in each column, a given volume of liquid causes the column to be "aerated" several times as it passes down the column.

6.03 Design of Columns Used in Study.

Five sand columns were fabricated and set for a preliminary laboratory experiment. These columns each consist of four filter sections alternated with sampling sections between. The uppermost sand bed is two inches deep, the second four inches, the third eight inches, and the bottom section is twelve inches for a total sand depth of 26 inches for each of the columns. The material used in the columns is a coarse sand having a mean size of about 1.3 mm and a geometric standard deviation of 1.21. This is a foundry grade sand and was quite clean when purchased. The table below summarizes the distribution of sand in the columns.

Nominal Sand Depth (inches)	Weight of Sand in Section	
	(lbs.)	(kg.)
2	1.36	0.62
4	2.76	1.25
8	5.28	1.76
12	8.19	3.72

To keep the sand from passing through the support screens a thin layer of pea gravel was placed on top of each filter support screen.

6.04 Method of Seeding the Columns.

In order to develop a rich biological flora in the sand beds each of the columns was fed with heavy doses of settled sewage from the Whittier Narrows Treatment Plant. A single column was erected initially and fed for about 25 days with settled sewage at hydraulic loads from 1 to 3 meters per day. After 20 days of operation of the first columns, four more columns were started and fed raw settled sewage at similar loads. These columns were operated for about 5 days and then all five columns were changed to a daily load of an artificial feed consisting of about 100

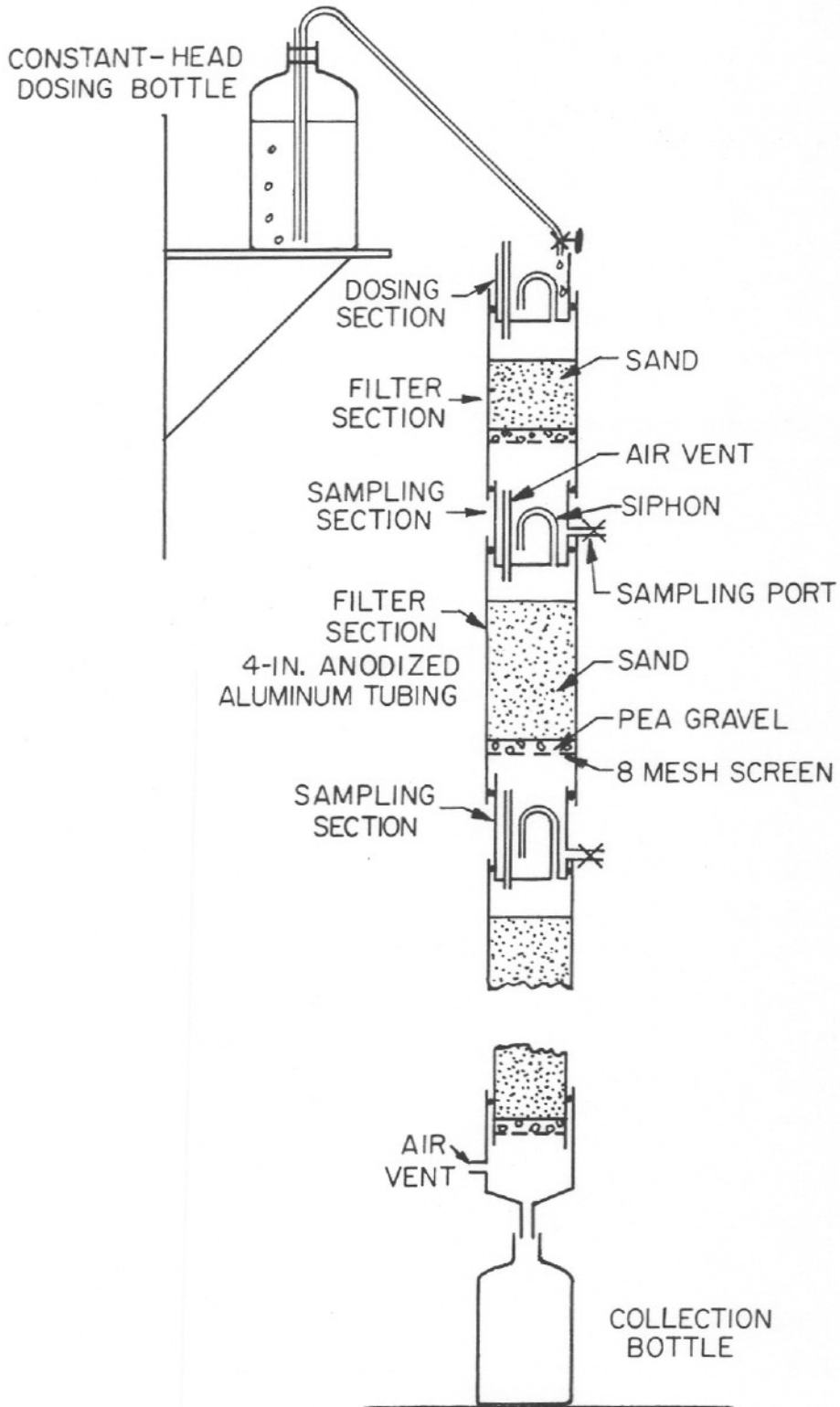


Fig. 6-1—Schematic of Laboratory Soil Column

ml of nutrient broth in 24 liters of Pasadena tap water. A loading of 24 liters per day on a diameter of 4 inches corresponds to a hydraulic load of about 3 meters per day. After 5 days of loading, the synthetic feed was changed to about 100 ml of nutrient broth plus a liter of settled sewage in 24 liters of tap water. The columns were loaded for 15 days with this feed and then the composition was changed to about 200 ml of nutrient broth plus 2 liters of settled sewage in 24 liters of tap water which was fed to the columns for about 9 days. Next the columns were dosed with a sterile feed consisting of about 300 ml of nutrient broth in 24 liters of tap water. This feed was applied for about 25 days. At the end of this seeding period, the first controlled experiments were started. The unusually long seeding period, about 80 days, was partially due to the need for developing loading procedures and sampling techniques and also waiting for an adequate supply of the new blend of synthetic detergent, the linear alkylate sulfonate (LAS).

The study described in this chapter was concerned principally with the comparative behavior of the synthetic detergents linear alkylate sulfonate (LAS) and the conventional alkylbenzenesulfonate (ABS) in an aerobic intermittent sand filter of special design. A careful study of the effects of multiple loadings at different detergent concentrations was carried out. Moreover, the effects of high oxygen demands attributable to ammonia and the influences of pH change on the quality of the percolate were observed. The ABS used in this study was supplied by the Soap and Detergent Association and is identified as CALRESEARCH 61R-8008 (55.3% ABS). Mr. George Cook of the California Chemical Company very kindly supplied the LAS, namely Soap and Detergent Association Blend No. 2, CALRESEARCH 64R-5808 (47.7% LAS).

6.05 Method of Operation

The LAS and ABS were added to artificial feeds consisting of nutrient broth, ammonium chloride or sodium nitrate, and tap water. The major criterion for the feed was to make it similar organically to a highly treated activated-sludge effluent with the exception that the feed would not be seeded with bacteria or other organisms.

The columns were divided into three groups. Two columns were fed LAS and two received ABS. The fifth column received the same basic feed but no synthetic detergent. It acted as the control. An arbitrary hydraulic loading of 1 gallon per day per column was chosen strictly on the basis of the convenience of using bottles that happened to be on hand in the laboratory. This is approximately a dosage of 0.49 meter per day (1.6 ft per day). The characteristics of the feed solutions are given in Table 6-1. The nutrient-broth stock solution has a COD of about 5.8 mg per ml and an organic nitrogen concentration of about 0.7 mg N per ml. The total COD of the feed solutions was not due to nutrient broth only, for there is an appreciable COD from the synthetic detergents. Measured COD concentrations of the ABS and LAS solutions indicate

Table 6-1—Characteristics of feed solutions
Ingredients added to one gallon of tap water

Period (days)	Column	ABS (mg)	LAS (mg)	Nutrient broth* (ml)	NH ₄ Cl (mg)	NaNO ₃ (mg)
0 to 129†	A1	20	--	25	500	--
0 to 129†	A2	40	--	50	1,000	--
0 to 129†	L1	--	20	25	500	--
0 to 129†	L2	--	40	50	1,000	--
0 to 129†	Control	--	--	25	500	--
130 to 353†	A1	20	--	25	--	750
130 to 353†	A2	40	--	50	--	1,500
130 to 353†	L1	--	20	25	--	750
130 to 353†	L2	--	40	50	--	1,500
130 to 353†	Control	--	--	25	--	750

† Days 72 to 140: 5 ml of about 1N Na₂CO₃ was added per gallon daily to buffer feed solutions.

* Stock nutrient broth solution containing 3 g. beef extract and 5 g. peptone in 1 liter of distilled water.

Ingredients of feed solutions on a concentration basis

Period (days)	Column	ABS (mg/l)	LAS (mg/l)	COD (mg/l)	Org. N + NH ₃ (mg N/l)	NO ₃ -N (mg N/l)
0 to 129	A1	5.3	--	49.5	39.3	--
0 to 129	A2	10.6	--	99.0	78.7	--
0 to 129	L1	--	5.3	51.6	39.3	--
0 to 129	L2	--	10.6	103.3	78.7	--
0 to 129	Control	--	--	38.4	39.3	--
130 to 353	A1	5.3	--	49.5	4.6	32.7
130 to 353	A2	10.6	--	99.0	9.2	65.4
130 to 353	L1	--	5.3	51.6	4.6	32.7
130 to 353	L2	--	10.6	103.3	9.2	65.4
130 to 353	Control	--	--	38.4	4.6	32.7

that there are 2.1 mg COD per mg ABS and 2.5 mg COD per mg LAS.

The feeds described in Table 6-1 were continuously applied to each of the columns on a daily basis. Table 6-2 contains a chronological history of unusual events, namely, days the columns were not fed, breakdowns, errors in loading, etc. Initially the feed was delivered to the columns by a peristaltic pump, but continuing breakdowns of the pump caused a changeover to constant-head bottles for the feed solutions. This method proved to be a much more reliable and more easily maintained feeding system.

The columns were loaded hydraulically by continuously applying the feed into a sample section at the top of each column by a pump or constant-head bottle. A volume of about 500 ml was necessary to activate the siphon. The rate of flow into the top of the column was such that it required about 14 to 18 hours to apply one gallon of feed. The siphon tubes discharge about 8 times in this period, sending about 500 ml through the column per discharge. For the clean columns the residence time was less than four minutes. Nearly all of this time could be accounted for in time required to fill and empty the various sampling sections down the column. The residence time in the coarse sand was negligible. After the development of a biological flora in the sands, the residence time increased to about 10 minutes. Because of the slight differences in the volume of the sampling sections, the residence time could vary, that is, a sampling section midway down the column may fill up just to a level slightly less than the height necessary to activate the siphon. This condition means that this section will not discharge until much later when the next load is fed into the top of the column.

6.06 Types of Experiments and Their Durations.

The experiment was monitored by collecting the entire effluent from each column and performing chemical analyses on these samples. The results reported in this section are primarily for the water that passed through the entire 26 inches of sand. The data have been broken down into periods described below.

Experiment I: This experiment covered the first 71 days of the column operation during which time the columns were loaded each day with two exceptions, Day 50 when none were fed and Day 55 when neither L1 nor A2 was loaded. For the first 15 days of this experiment surfactant concentration was measured in the effluent from each column by the methylene-blue assay. Ammonia and organic nitrogen analyses were also run daily for the first 15 days to assess the degree of nitrification taking place in the columns. Determinations of COD, nitrite, nitrate, pH, temperature, TDS, and TVS were run arbitrarily during the first 15 days. Subsequently, measurements of surfactants, COD, nitrogen components, and pH were monitored on a weekly basis.

Experiment II: Because the measured pH of the column effluents showed values below pH 6, it was decided to see if the performance of the sand filters could be improved by attempting to buffer the feeds. Days 72 to 140 were characterized by the addition of about 5 ml of about 1N Na_2CO_3 to the one-gallon feed for the columns. In all other respects, the feed

solutions were identical to those used during the initial 71 days of operation until Day 130 when the ammonium chloride in the feed solutions was replaced by sodium nitrate. This change in the oxidation state of the main source of the nitrogen in the column feed was part of the attempt to delineate the principal cause of the large drop in pH of the feed solutions resulting from passage through the filters.

Experiment IIa: During the interval covered by Days 108 to 129, the column effluents from the daily loading were recycled once more through the columns. This change caused each column to receive twice the hydraulic load normally applied to it.

Experiment III: This was the terminal experiment performed in the sand filters. The addition of the sodium carbonate buffer was stopped on Day 140. For the period Days 141 to 353, the original hydraulic loading pattern of one gallon per day of feed to each column was followed with the nitrogen in the feed solutions being principally in the form of nitrate. During the interval covered by Days 289 to 293, the columns were re-seeded with micro-organisms by feeding each one gallon of a mixture of one-half primary effluent (settled sewage) and one-half tap water. Normal feeding of the sterile solutions began again on Day 294. An error in preparing the stock solution of the ABS resulted in columns A1 and A2 receiving only one-half the expected concentration of ABS after Day 336 until the end of the experiment.

Table 6-2—CHRONOLOGY OF LABORATORY COLUMNS

Day	Date	Remarks
0	11 May 1964	Comparative Detergent Study began using artificial feed (see Table 6-2) under schedule of daily loading of columns.
50	30 June 1964	Columns not loaded.
55	5 July 1964	Columns L1 and A2 not loaded.
64	14 July 1964	Tube pump used to feed columns replaced with constant-head bottles.
72	22 July 1964	Feeds to columns buffered by adding 5 ml of approximately 1N Na_2CO_3 .
84	3 August 1964	Column A2 received feed for column L2 and vice versa.
108	27 August 1964	New loading pattern initiated. Effluent from columns recycled so that a given feed passes through a column twice in 24 hour period.
116	4 September 1964	Columns not loaded.
128	16 September 1964	Top section of Column L2 (2-in sand bed) scarified and loosened up.
130	18 September 1964	Stopped recycling feeds. Replaced NH_4Cl with NaNO_3 in all feeds. Returned to hydraulic load of 1 gallon per 24 hour period.
141	1 October 1964	Discontinued addition of Na_2CO_3 to feeds.
211	8 December 1964	Each column loaded twice for sampling purposes.
218	15 December 1964	Each column loaded twice for sampling purposes.
229	26 December 1964	Each column loaded twice for sampling purposes.
232	29 December 1964	Each column loaded twice for sampling purposes.
282	17 January 1965	Columns not loaded.
280	24 February 1965	Primary effluent diluted 1:1 with tap water fed to all columns. One gallon mixture each day for 5 days.
294	1 March 1965	Resumed feeding columns with artificial feeds.
302	9 March 1965	Columns not loaded.
304	11 March 1965	Columns not loaded.
324	31 March 1965	Columns not loaded.
327	3 April 1965	Columns not loaded.
336	12 April 1965	Stock solution for ABS made at one-half strength by error so that Columns A1 and A2 received only 2.6 mg/l and 5.3 mg/l respectively.
354-360	30 April-6 May 1965	Columns not loaded.
361-364	7-10 May 1965	Columns loaded again for purposes of measuring moisture content of sands.
365	11 May 1965	Columns disassembled.

6.07 Results of Analyses.

The results of the experiments described in the previous section are presented in tabular form in this section. Tables 6-3 to 6-9 show the results of measured values of pH, nitrogen components, COD, chlorides, surfactants LAS and ABS by methylene-blue assay, and total alkalinity for each of the filters. For each experimental period, as well as the entire period of the study, the mean value of the parameters are given along with the number of samples measured and the range, that is the high and low value of each parameter. The quality of the final effluents after the 26

inches of percolation can be compared with the quality of the feed solutions for each period described in Table 6-1.

For comparison with the calculated concentrations of the constituents in the feed solutions presented in Table 6-1, the measured values of the feed quality are given for two feeds, Day 51 and Day 338, in Table 6-10. Tables 6-11 and 6-12 show the quality of the percolate as a function of depth for each of the columns. These samples were taken over nearly a monthly interval. Each value represents the composite of a one-gallon feed solution passing through the depth

Table 6-3—Chemical quality of effluents from laboratory sand columns

Period: 0 to 71 days

	pH value	Concentrations in milligrams per liter					
		NO ₂ -N	NO ₃ -N	NH ₂ -N	COD	Surfactant	Alk (as CaCO ₃)
Column A-1							
Mean.....	6.2	0.14	19.71	22.89	20.5	4.3	28.4
High.....	7.6	0.65	28.00	71.60	28.2	5.8	----
Low.....	5.4	0.00	13.00	10.50	12.7	0.8	----
Number of samples.....	7	14	7	22	14	24	1
Column A-2							
Mean.....	6.7	0.11	18.43	49.43	26.1	5.6	13.6
High.....	7.4	0.41	31.00	61.00	34.8	8.8	----
Low.....	6.1	0.00	0.00	20.10	16.7	0.5	----
Number of samples.....	7	14	7	21	15	25	1
Column L-1							
Mean.....	6.0	0.12	22.00	19.30	14.2	1.0	5.6
High.....	7.5	1.05	25.00	24.80	21.7	1.8	----
Low.....	4.9	0.01	18.00	10.50	7.3	0.4	----
Number of samples.....	7	14	7	22	15	25	1
Column L-2							
Mean.....	6.3	0.32	19.38	50.37	27.0	2.5	24.4
High.....	7.4	0.94	23.00	64.00	32.8	4.5	----
Low.....	5.4	0.02	12.00	12.50	18.3	0.3	----
Number of samples.....	8	15	8	22	15	26	1
Control							
Mean.....	6.3	0.15	17.29	16.37	12.0	0.2	14.8
High.....	7.5	1.04	21.00	27.60	19.7	0.2	----
Low.....	5.8	0.01	11.00	2.80	6.2	0.1	----
Number of samples.....	7	13	7	21	9	22	1

Table 6-4—Chemical quality of effluents from laboratory sand columns

Period: 72 to 140 days

	pH value	Concentrations in milligrams per liter						
		NO ₂ -N	NO ₃ -N	NH ₂ -N	COD	Cl ⁻	Surfactant	Alk (as CaCO ₃)
Column A-1								
Mean.....	5.6	.25	26.00	12.82	20.8	149.5	5.1	45
High.....	7.1	1.51	41.00	26.40	39.5	166	7.7	107
Low.....	4.2	0.00	9.00	2.80	9.2	133	3.3	2.1
Number of samples.....	11	9	11	10	11	2	11	7
Column A-2								
Mean.....	6.6	0.30	27.27	40.60	29.0	237.5	7.9	52
High.....	7.3	1.07	34.00	54.50	42.2	255	9.8	98.5
Low.....	5.1	0.03	13.00	8.50	20.9	220	5.9	9.4
Number of samples.....	11	9	11	10	11	2	11	7
Column L-1								
Mean.....	6.2	0.25	25.82	13.80	16.2	133	0.7	45.1
High.....	7.4	0.59	38.00	23.00	26.3	--	1.2	80.3
Low.....	4.4	0.00	12.00	2.20	7.5	--	0.5	4.3
Number of samples.....	11	9	11	10	11	1	11	7
Column L-2								
Mean.....	6.1	0.55	27.27	46.75	30.5	245.5	2.6	54.9
High.....	7.0	1.82	72.00	60.00	48.0	249	4.6	136
Low.....	4.0	0.00	9.00	10.00	22.8	242	1.6	1.1
Number of samples.....	11	9	11	10	11	2	11	7
Control								
Mean.....	6.0	0.27	25.73	12.04	11.0	144	0.2	48
High.....	7.4	0.74	38.00	19.60	22.1	--	0.2	126
Low.....	4.5	0.00	13.00	4.00	2.0	--	0.1	5.3
Number of samples.....	11	9	11	10	11	1	5	7

of sand filter indicated and then having the analyses run on the entire one-gallon composite.

6.08 Discussion of the Results.

This section will deal with a discussion of the performance of the filters during each of the experimental periods described in Section 6.06, followed by general statements on the overall comparative behavior of the two synthetic detergents relative to each other and to the control.

For the first 71 days of operation, Experiment I, the data presented in Tables 6-1, 6-3, and 6-10 show

that all the columns had effluents with mean values of pH ranging from 6.2 to 6.7 after being dosed with feed solutions with pH ranging from 7.2 to 7.6. The final nitrite-nitrogen concentration of the effluents of four of the filters was about the same with the heavily-loaded LAS column showing a slightly higher value than the others. The nitrate-nitrogen concentrations of the column effluents are very nearly equal for all the filters irrespective of the fact that columns A2 and L2 received double the ammonia-nitrogen concentration in their feeds, compared to the other three columns. Perhaps this measure of the degree of nitrifica-

Table 6-5—Chemical quality of effluents from laboratory sand columns

Period: 108 to 130 days

	pH value	Concentrations in milligrams per liter						
		NO ₂ -N	NO ₃ -N	NH ₃ -N	COD	Cl ⁻	Surfactant	Alk (as CaCO ₃)
Column A-1								
Mean.....	4.7	0.01	30.20	7.00	14.8	133	4.4	2.2
High.....	5.8	0.04	35.00	7.80	19.3	--	5.6	2.3
Low.....	4.2	0.00	23.00	5.60	9.2	--	3.3	2.1
Number of samples.....	5	3	5	4	5	1	5	2
Column A-2								
Mean.....	6.3	0.12	24.60	40.88	27.3	220	7.6	22.6
High.....	7.0	0.14	34.00	49.00	30.0	--	8.2	36.4
Low.....	5.1	0.09	19.00	32.00	20.9	--	7.2	9.4
Number of samples.....	5	3	5	4	5	1	5	2
Column L-1								
Mean.....	5.8	0.02	28.60	9.60	11.5	133	0.6	7.4
High.....	6.8	0.05	32.00	10.00	14.2	--	0.6	10.4
Low.....	4.4	0.00	21.00	8.80	7.5	--	0.5	4.3
Number of samples.....	5	3	5	4	5	1	5	2
Column L-2								
Mean.....	5.6	0.03	25.80	45.88	24.3	242	2.2	1.6
High.....	6.9	0.05	37.00	52.00	26.2	--	2.8	2.1
Low.....	4.0	0.00	16.00	40.50	22.8	--	1.8	1.1
Number of samples.....	5	3	5	4	5	1	5	2
Control								
Mean.....	5.2	0.02	29.40	7.60	6.9	144	--	5.8
High.....	6.4	0.05	34.00	11.80	10.6	--	--	6.4
Low.....	4.5	0.00	21.00	5.60	2.0	--	--	5.3
Number of samples.....	5	3	5	4	5	1	--	2

Table 6-6—Chemical quality of effluents from laboratory sand columns

Period: 141 to 353 days

	pH Value	Concentrations in milligrams per liter							
		NO ₂ -N	NO ₃ -N	NH ₃ -N	COD	Surfactant	Alk (as CaCO ₃)	TS	TVS
Column A-1									
Mean.....	7.0	0.13	38.83	1.74	16.2	2.3	106	790	327
High.....	7.3	0.30	44.00	10.30	27.0	3.3	123	934	447
Low.....	6.7	0.08	34.00	0.30	11.2	1.1	83	701	225
No. of samples.....	13	12	12	14	12	15	11	3	--
Column A-2									
Mean.....	7.2	0.37	61.33	1.40	20.9	4.3	134	1338	554
High.....	7.5	0.74	72.00	5.40	31.0	8.4	150	1383	606
Low.....	6.8	0.10	44.00	0.15	17.2	1.4	111	1294	562
No. of samples.....	13	12	12	14	13	14	11	2	2
Column L-1									
Mean.....	7.3	0.23	36.92	1.28	14.1	0.5	110	939	433
High.....	7.5	0.81	40.00	6.60	25.9	0.8	118	1167	451
Low.....	7.0	0.08	34.00	0.30	8.6	0.3	100	711	415
No. of samples.....	13	12	12	14	13	15	11	2	2
Column L-2									
Mean.....	6.9	0.69	63.75	1.79	23.5	1.2	107	1145	530
High.....	7.4	1.65	72.00	6.90	28.6	1.9	118	1323	603
Low.....	6.7	0.28	49.00	0.40	15.3	0.8	94	967	455
No. of samples.....	13	12	12	14	13	15	12	4	4
Control									
Mean.....	7.3	0.15	37.25	0.88	10.3	0.6	110	933	407
High.....	7.5	0.24	40.00	4.60	25.5	1.8	124	1137	427
Low.....	6.9	0.00	32.00	0.30	3.8	0.2	97	693	392
No. of samples.....	13	12	12	14	14	4	11	4	4

tion being independent of the initial loading is not surprising. Each of the columns, the lightly loaded ones, as well as the heavily loaded, showed an appreciable ammonia-nitrogen concentration in the final effluent, that is, nitrification of the feed solutions was by no means complete for any of the columns. Since the columns were of identical construction and were operated the same hydraulically, one might conclude that the degree of nitrification was limited by the amount of oxygen supplied to each column and the duration of the percolate within the column. All these factors were presumably the same for all five columns.

The COD data show about a 75-percent reduction for columns A2, L2, and the Control, whereas column A1 has only about a 66-percent removal and column L1 excels with about an 88-percent removal of COD. However, the main difference in the quality of the effluents is apparent with respect to the much greater removals of the surfactant LAS. On the average for the 71-day study, the lightly loaded LAS column showed an 80-percent removal while the heavily loaded filter showed a 60-percent removal. By comparison, the two columns fed ABS at the same feed concentrations as the LAS columns, had an average removal of

Table 6-7—Chemical quality of effluents from laboratory sand columns

Period: 141 to 289 days

	pH Value	Concentrations in milligrams per liter							
		NO ₂ -N	NO ₃ -N	NH ₃ -N	COD	Surfactant	Alk (as CaCO ₃)	TS	TVS
Column A-1									
Mean.....	7.0	0.12	38.91	1.06	15.5	2.5	105	790	327
High.....	7.3	0.30	44.00	2.45	19.2	3.3	123	934	447
Low.....	6.7	0.08	34.00	0.30	11.9	1.6	83	701	228
No. of samples.....	11	11	11	11	9	12	10	3	3
Column A-2									
Mean.....	7.1	0.37	61.27	1.11	21.1	3.8	134	1338	584
High.....	7.5	0.74	72.00	2.10	31.0	8.4	150	1383	906
Low.....	6.8	0.10	44.00	0.15	17.2	2.5	111	1294	562
No. of samples.....	11	11	11	11	11	11	10	2	2
Column L-1									
Mean.....	7.3	0.23	36.63	0.93	12.8	0.6	109	939	433
High.....	7.5	0.81	39.00	2.20	18.1	0.8	118	1167	451
Low.....	7.0	0.08	34.00	0.30	8.6	0.3	100	711	415
No. of samples.....	11	11	11	11	10	12	10	2	2
Column L-2									
Mean.....	6.9	0.71	63.55	1.11	22.1	1.2	108	1145	530
High.....	7.4	1.65	72.00	2.45	26.1	1.7	118	1323	603
Low.....	6.8	0.28	49.00	0.40	15.3	0.8	94	967	455
No. of samples.....	11	11	11	11	10	12	10	4	4
Control									
Mean.....	7.3	0.14	37.18	0.56	9.2	0.3	109	933	407
High.....	7.5	0.24	40.00	1.15	15.4	0.3	124	1137	427
Low.....	6.9	0.00	32.00	0.30	3.8	0.2	97	693	392
No. of samples.....	11	11	11	11	11	3	10	4	4

Table 6-8—Chemical quality of effluents from laboratory sand columns

Period: 290 to 353 days

	pH value	Concentrations in milligrams per liter					
		NO ₂ -N	NO ₃ -N	NH ₃ -N	COD	Surfactant	Alk (as CaCO ₃)
Column A-1							
Mean.....	7.1	0.17	38.00	4.20	18.1	1.5	114
High.....	7.2	--	--	10.30	27.0	2.1	--
Low.....	7.0	--	--	0.45	11.2	1.1	--
No. of samples.....	2	1	1	3	3	3	1
Column A-2							
Mean.....	7.2	0.42	62.00	2.47	18.8	1.8	136
High.....	--	--	--	5.30	22.5	2.1	--
Low.....	--	--	--	0.70	17.2	1.4	--
No. of samples.....	2	1	1	3	2	3	1
Column L-1							
Mean.....	7.3	0.20	40.00	2.55	18.2	0.8	116
High.....	--	--	--	6.60	25.9	1.3	--
Low.....	--	--	--	0.45	13.1	0.5	--
No. of samples.....	2	1	1	3	3	3	1
Column L-2							
Mean.....	6.8	0.45	66.00	4.12	28.0	1.4	107
High.....	7.0	--	--	6.90	29.3	1.9	--
Low.....	6.7	--	--	2.30	26.2	1.0	--
No. of samples.....	2	1	1	3	3	3	1
Control							
Mean.....	7.3	0.14	38.00	2.07	14.1	1.8	120
High.....	7.4	--	--	4.60	25.5	--	--
Low.....	7.2	--	--	0.30	6.2	--	--
No. of samples.....	2	1	1	3	3	1	1

Table 6-9—Chemical quality of effluents from laboratory sand columns

Period: 0 to 353 days

	pH value	Concentrations in milligrams per liter								
		NO ₂ -N	NO ₃ -N	NH ₃ -N	COD	Cl ⁻	Surfactant	Alk (as CaCO ₃)	TS	TVS
Column A-1										
Mean	6.3	0.16	29.66	14.26	19.2	147	3.0	101	790	227
High	7.6	1.51	44.00	71.60	39.5	166	7.7	123	934	447
Low	4.2	0.00	9.00	0.30	9.2	133	0.8	2.1	701	228
Number of samples	31	35	30	46	37	3	50	18	3	3
Column A-2										
Mean	6.9	0.25	38.83	32.52	25.2	200	5.7	98	1,338	564
High	7.5	1.07	72.00	61.00	42.2	255	9.8	150	1,383	606
Low	5.1	0.00	0.00	0.15	16.7	126	0.5	94	1,294	562
Number of samples	31	35	30	45	39	3	50	19	2	2
Column L-1										
Mean	6.6	0.19	29.37	12.62	14.7	148	0.8	81	939	433
High	7.5	1.05	40.00	24.80	26.3	162	1.8	118	1,167	451
Low	4.4	0.00	12.00	0.30	7.3	133	0.3	53	711	415
Number of samples	31	35	30	46	39	2	51	19	2	2
Column L-2										
Mean	6.5	0.50	39.36	34.36	26.8	233	2.1	85	1,145	536
High	7.4	1.82	72.00	64.00	48.0	249	4.6	141	1,323	663
Low	4.0	0.00	9.00	0.40	15.3	209	0.8	1.1	967	455
Number of samples	32	36	31	46	39	3	52	20	4	4
Control										
Mean	6.6	0.18	28.37	10.51	11.0	118	0.3	82	933	407
High	7.5	1.04	40.00	27.60	25.5	144	1.8	126	1,137	427
Low	4.5	0.00	11.00	0.30	2.0	93	0.1	5.3	693	392
Number of samples	31	34	30	45	34	2	31	19	4	4

Table 6-10—Measured quality of feed solutions to laboratory sand columns *

	Day 51				
	A1	A2	L1	L2	Control
pH	7.6	7.2	7.6	7.4	7.3
NO ₂ -N	0.00	0.01	0.00	0.01	0.04
NO ₃ -N	1.80	1.30	2.00	2.30	1.80
NH ₃ -N	42.0	88.0	44.0	100.0	47.0
COD	59.7	109.0	59.4	112.0	48.8
Alkalinity (as CaCO ₃)	112	128	113	111	123
TS	818	753	730	678	--
TVS	310	292	255	292	--
Surfactant (not measured)	--	--	--	--	--

	Day 338				
	A1	A2	L1	L2	Control
pH	7.9	7.6	7.9	7.7	7.9
NO ₂ -N	0.00	0.06	0.01	0.05	0.00
NO ₃ -N	38.0	70.0	36.0	68.0	38.0
NH ₃ -N	7.70	13.60	8.15	13.30	5.15
COD	54.9	98.0	61.2	114.0	47.0
Alkalinity (as CaCO ₃)	119	125	118	125	119
Surfactant	3.3	5.9	6.2	11.4	--

* Concentrations in milligrams per liter.

23 percent for the lightly loaded column and 47 percent for the heavily loaded column. No reason is available for the relatively better removal of surfactant for the heavily loaded ABS column.

Figure 6-2 graphically shows the relative surfactant concentrations for each of the columns. The concentration of surfactant reported for the Control column which was fed no surfactant indicates the reliability of the methylene-blue assay as performed in our laboratory for detecting surfactant. Over the first 71 days, the mean of the surfactant measurements on the Control effluent was 0.2 mg per liter. From Figure 6-2, covering the initial 50 days of the study, one can see that the LAS columns became adapted to the removal of LAS after about 22 days of feeding. The ABS

columns showed very little removal of surfactant during the first 50 days.

Experiment II covers the time interval from Day 72 to Day 140 and the measured data on filter operation are summarized in Tables 6-1, 6-4, and 6-5. It was observed that there was a significant reduction in pH during the first 71 days of column operation. In order to control the pH, about 5 ml of 1 N sodium carbonate was added to each one gallon of feed solution. After addition of the sodium carbonate, the feed solutions had a pH of about 8.5. From Tables 6-4 and 6-5 it can be seen that the mean values of the pH of the column effluents ranged from 5.6 to 6.6 over the entire period and from 4.7 to 6.3 over the interval Day 108 to 130 (Experiment IIa) when the column effluents after the first pass through the filters were recycled back down the sand columns a second time in each 24-hour interval.

For the entire period of Experiment II all column effluents had about the same amount of nitrite-nitrogen and nitrate-nitrogen without regard to the initial ammonia-nitrogen concentration of the feed solutions. In the interval of recycling, the total amount of nitrate-nitrogen in the effluent after the second pass through the filter increased, but the final concentration was slightly less than double the concentration of the effluent after a single pass. For the interval Day 72 to 140, percent nitrification (based on the reduction of ammonia-nitrogen) averaged 65 to 70 percent for columns A1, L1, and the Control, while for A2 it was about 48 percent and L2, 41 percent. This was a slightly better performance than for the unbuffered, but younger, system in Experiment I.

The average reduction of COD during Experiment II was about 70 percent for columns A2, L1, L2, and the Control; but column A1 continued to show poorer performance with only about a 52-percent COD re-

moval. With respect to surfactant removal, the LAS columns excelled with a removal of 94 percent for L1 and 75 percent for L2, whereas column A1 showed nearly no removal (only 4 percent) of ABS while A2 indicated a 25-percent removal.

After 142 days of operating the sand filters under controlled conditions with the sterile feeds, the be-

havior of the columns indicated a much superior capability for removing LAS compared to ABS. With respect to the total amount of ammonia-nitrogen converted to nitrate, the surfactant columns performed quite similarly to the Control column. Also, with respect to COD reduction with the exception of column A1 all columns showed the same percent reduction

Table 6-11—Quality of effluents as function of depth
(sampling period: days 205 to 232)

Depth of percolation (inches)		pH	NO ₂ -N (mg/l)	NO ₃ -N (mg/l)	NH ₃ -N (mg/l)	Alkalinity (mg CaCO ₃ /l)	Surfactant (mg/l)	COD (mg/l)	TS (mg/l)	TVS (mg/l)
A1	2	7.1	0.09	34.00	6.60	116	4.8	49.3	884	417
	6	6.8	0.11	37.00	4.50	97	4.0	35.4	---	---
	14	7.0	0.17	37.00	1.38	96	2.8	20.0	721	415
	26	--	0.09	41.00	2.30	--	1.8	--	--	--
A2	2	7.3	0.75	59.00	10.65	149	10.0	67.9	911	324
	6	7.1	0.97	61.00	8.40	133	7.4	43.9	---	---
	14	7.0	0.60	65.00	3.62	121	5.4	35.5	921	547
	26	---	0.47	67.00	1.15	---	2.6	20.9	---	---
L1	2	7.1	0.13	34.00	5.60	117	3.1	42.5	795	367
	6	7.1	0.13	34.00	4.05	101	0.8	27.2	---	---
	14	7.3	0.14	37.50	1.25	97	0.8	20.4	709	404
	26	--	0.17	39.00	2.20	--	0.3	10.9	--	--
L2	2	7.0	0.45	57.00	9.25	141	6.4	65.5	969	347
	6	6.9	0.62	51.00	7.85	116	1.9	50.9	---	---
	14	6.8	0.96	60.00	1.10	108	2.4	26.4	902	527
	26	--	0.54	72.00	1.55	111	0.8	16.5	--	--
Control	2	7.1	0.43	34.00	1.40	125	0.4	25.0	866	406
	6	6.9	0.17	36.00	0.55	106	0.3	13.6	---	---
	14	7.1	0.18	38.00	1.95	98	0.2	9.8	548	268
	26	--	0.15	39.00	1.15	--	0.3	8.6	--	--
Feed*	A1	---	---	32.7	4.6	---	5.3	49.5	---	---
	A2	---	---	65.4	9.2	---	10.6	99.0	---	---
	L1	---	---	32.7	4.6	---	5.3	51.6	---	---
	L2	---	---	65.4	9.2	---	10.6	103.3	---	---
	Control	---	---	32.7	4.6	---	--	32.7	---	---

* Calculated from added ingredients.

Table 6-12—Quality of effluents as function of depth
(sampling period: days 338 to 353)

Depth of percolation (inches)		pH	NO ₂ -N (mg/l)	NO ₃ -N (mg/l)	NH ₃ -N (mg/l)	Alkalinity (mg CaCO ₃ /l)	Surfactant (mg/l)	COD (mg/l)
A1	0	7.9	0.00	38.00	7.70	119	3.3	54.9
	2	7.4	0.15	38.00	2.00	130	1.9	52.1
	6	7.1	0.39	35.00	0.40	121	1.7	21.2
	14	7.0	0.15	45.00	0.85	110	1.4	14.7
	26	7.2	0.17	38.00	0.45	114	1.1	11.2
A2	0	7.6	0.06	70.00	13.60	125	5.9	48.0
	2	7.3	1.11	60.00	6.45	160	4.4	51.4
	6	7.3	0.99	68.00	0.85	151	2.7	34.9
	14	7.1	0.52	70.00	0.30	131	2.1	24.4
	26	7.2	0.42	62.00	0.70	136	1.8	15.8
L1	0	7.9	0.01	38.00	8.15	118	6.2	61.2
	2	7.4	0.51	35.00	5.30	133	0.5	35.7
	6	7.3	0.21	39.00	4.00	124	0.6	27.8
	14	7.2	0.11	41.00	0.00	115	0.5	21.7
	26	7.3	0.20	40.00	0.45	116	0.5	13.1
L2	0	7.7	0.05	68.00	13.30	125	11.4	114.0
	2	7.1	0.31	57.00	11.15	148	4.2	69.8
	6	7.1	1.52	68.00	8.70	147	2.9	53.7
	14	6.9	0.45	73.00	5.60	115	1.5	39.1
	26	7.0	0.45	66.00	3.15	107	1.0	26.2
Control	0	7.9	0.00	38.00	5.15	119	--	47.0
	2	7.4	0.69	35.00	0.30	134	--	17.6
	6	7.2	0.35	35.00	0.15	130	--	14.9
	14	7.2	0.13	43.00	3.00	118	--	15.5
	26	7.4	0.14	38.00	0.30	120	--	6.2
Feed*	A1	---	---	32.7	4.6	---	2.6	49.5
	A2	---	---	65.4	9.2	---	5.2	99.0
	L1	---	---	32.7	4.6	---	5.3	51.6
	L2	---	---	65.4	9.2	---	10.6	103.3
	Control	---	---	32.7	4.6	---	--	38.4

* Calculated from added ingredients.

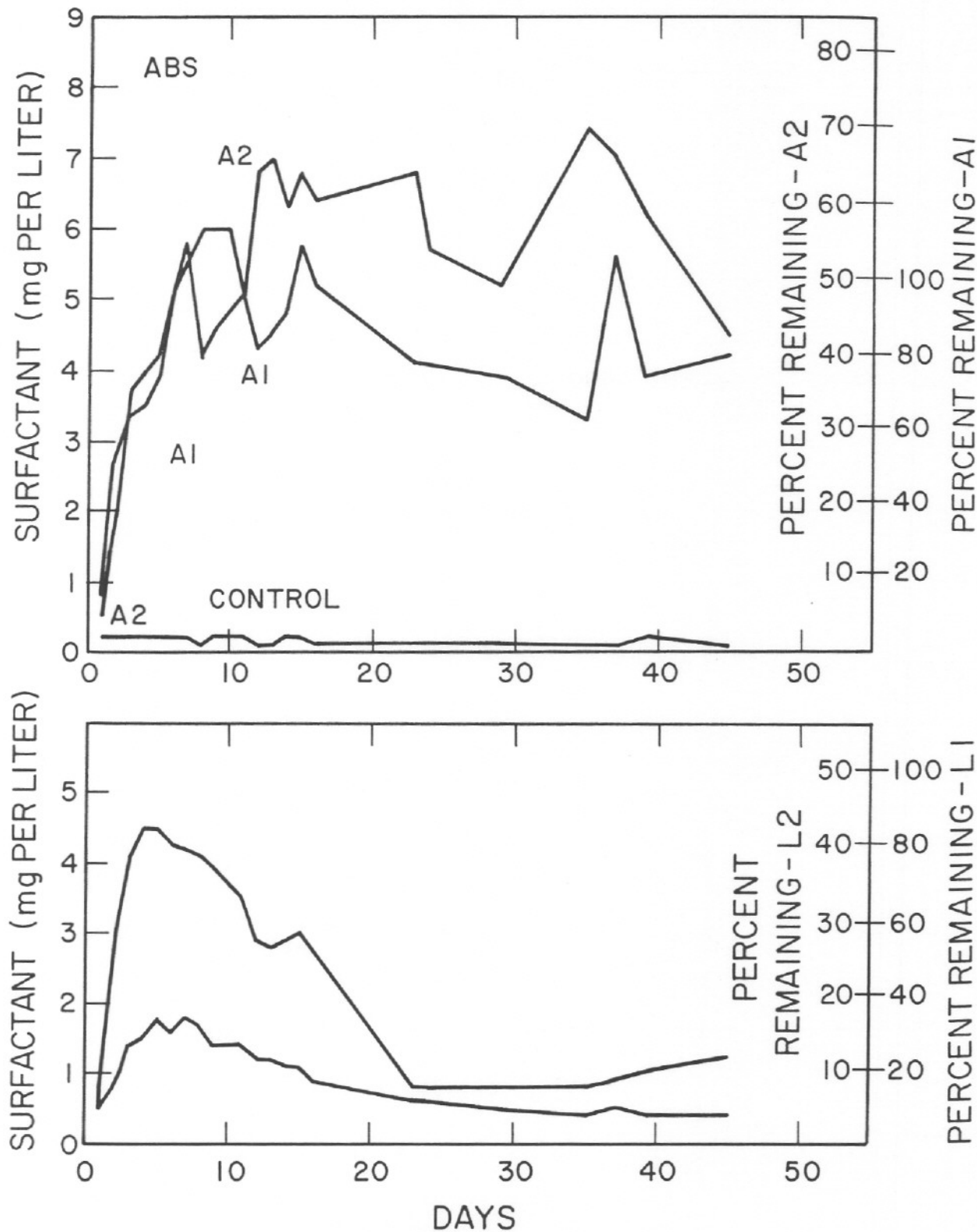


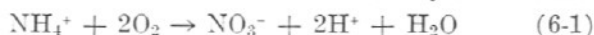
Fig. 6-2—ABS and LAS in Column Effluents as a Function of Time—Experiment I.

after passage through 26 inches of sand. It is concluded that column A1 did not develop any of the proper organisms during the initial seeding of the filters to remove surfactant ABS from the feed solutions.

Experiment III was conducted to demonstrate the importance of nitrification in the reduction of pH of a buffered and unbuffered percolate. In Experiments I and II, a significant reduction of pH resulted during the passage of the feed solutions through the filter columns with the largest pH reduction occurring during Experiment IIa when the effluents from a single pass were recycled for a second pass through the columns in a 24-hour period. In Experiment III, the ammonium chloride in the feed solutions was replaced by sodium nitrate. The only nitrogen in the minus three oxidation state (ammonia) came from the nutrient broth, but this was small compared to the ammonia-nitrogen dose in the previous experiments.

The data presented in Tables 6-6, 6-7, and 6-8 show that the unbuffered feed solutions produced effluents with a pH in the range 6.1 to 7.3. In addition, alkalinities of the final effluents showed means from 104 to 134 mg/l (as CaCO₃) by comparison to alkalinities of effluents during Experiment IIa that were as low as 2.0 mg/l (as CaCO₃).

It is reasonable to suppose that the reduction in pH and drop in alkalinity during Experiments I and II resulted from the oxidation of the ammonia to nitrate. This biochemical reaction may be written as:



The above equation shows a net production of free oxygen ions where 2 mols of hydrogen ions are produced for each mol of nitrogen (N) that is oxidized to nitrate. The alkalinity of the feed solutions is principally in the form of bicarbonate, so that the reduction of alkalinity can be expressed by



Equations 6-1 and 6-2 indicate that each mol of ammonia-nitrogen oxidized to nitrate-nitrogen is capable of neutralizing 2 mols of bicarbonate alkalinity, that is, the oxidation of 14 mg of ammonia as N can reduce the alkalinity by 100 mg (as CaCO₃). These numbers compare very favorably with the alkalinity reductions and ammonia oxidation reported for Experiments I and II.

During the latter part of Experiment III, the filter columns were reseeded with a mixture of settled sewage and tap water. This reseeded was done primarily to see if an improvement in the removal of ABS would result. Because of an error in the preparation of the ABS feed solutions and the short duration of the column experiments after the seeding, no definite conclusions from this rejuvenation are merited.

Table 6-6 summarizes the data for the entire period of Experiment III. The nitrite-nitrogen concentrations

average higher than any of the previous experiments suggesting that some of the nitrate-nitrogen may have been reduced. Enough information is not available to elaborate on this point other than it may well be possible to control the oxidation-reduction potential of the percolate in the sand columns by attempting to supply oxygen to the micro-organisms in the combined form as nitrate. More will be made of this point in the final chapter of this report.

Using the measured values of the ammonia-nitrogen reported in Table 6-10 (Day 338) for the influents and the mean values of the effluents in Table 6-6, the columns show an 80- to 90-percent reduction in ammonia-nitrogen. Columns A1, L1, and the Control have about the same amount of nitrate-nitrogen in the influent and effluents, while columns A2 and L2 have mean values in the effluents slightly less than influents. However, the differences are really not significant.

With respect to COD reduction, on a calculated basis using the influent concentrations from Table 6-1, the columns show 70- to 80-percent reduction. The more heavily loaded surfactant columns, A2 and L2, show the better removal.

6.09 Results of the Full Study.

The average of measured parameters describing effluent quality are summarized in Table 6-9. With respect to oxidation of ammonia-nitrogen and overall removal of COD, the columns receiving the surfactants behaved similarly to the column receiving no surfactant. With respect to surfactant, it is quite apparent that LAS is much more readily removed than ABS. To demonstrate the relative removal on a quantitative basis a material balance was calculated for the four surfactant columns.

Table 6-13 is a summary of the analyses of sand cores that form each of the sand sections making up the filter columns. For each analysis a composite sample was made by using a thin-walled brass tube ($\frac{1}{2}$ -inch I.D., 3 inches long) as a coring device. Several cores were taken from the top of each sand section. Hence, the entire depth of sand was sampled for the 2-inch sand beds, nearly the full depth for the 4-inch beds, and only the upper part for the 8 and 12-inch sections.

To make a material balance of the surfactants, it is necessary to know the total amount of surfactant applied to each column, the relative concentrations of the influent and effluent, and the amount of surfactant adsorbed to the sand and organic matter composing the filter media. Using the data in Tables 6-1 and 6-2 for the full 353 days of the study, one can calculate that columns A1, L2, and the Control were given 350 doses and columns A2 and L1, 349 doses of their respective feed solutions. These numbers result from the failure to load the columns on several days, the addition of settled sewage for five days, and a multiple loading of the columns several

WASTEWATER RECLAMATION AT WHITTIER NARROWS

times for sampling purposes. From the number of doses to each column, and the amount of surfactant in each dose, one can calculate the total load over 353 days.

Total Weight of Surfactant Added (gm)

A1	A2	L1	L2
6.83	13.62	7.98	14.00

Taking the data from section 6.03 for the weight of sand in each filter bed and the apparent weight of surfactant (methylene-blue assay) desorbed from the sand beds after the 353 days of column operation, the following calculations result:

Table 6-13—Results of analyses of sand cores taken from the laboratory filter at the end of the study

Sand section	Moisture content ¹	Volatile solids ²	Organic N + NH ₃ -N ³	COD ⁴	Surfactant ⁵
A1 2.....	0.085	5.6	0.21	1.8	5.2
4.....	0.056	5.1	0.20	2.2	9.3
8.....	0.024	3.7	0.12	0.86	2.4
12.....	0.024	3.8	0.034	0.48	1.7
A2 2.....	0.13	9.1	0.32	4.4	25.8
4.....	0.073	7.1	0.52	4.0	5.1
8.....	0.042	5.5	0.13	2.0	6.5
12.....	0.032	4.9	0.092	1.1	5.3
L1 2.....	0.30	13.0	0.21	1.8	5.4
4.....	0.061	5.1	0.16	1.4	2.2
8.....	0.024	4.1	0.073	0.92	1.6
12.....	0.024	3.3	0.042	0.80	0.77
L2 2.....	0.11	6.6	0.31	3.7	9.8
4.....	0.071	6.8	0.34	3.5	5.2
8.....	--	4.2	0.15	1.9	2.5
12.....	0.025	4.1	0.045	0.63	0.80
Control 2.....	0.15	7.3	0.25	2.8	5.0
4.....	0.050	5.1	0.13	1.1	1.7
8.....	0.029	4.4	0.079	0.86	1.0
12.....	0.027	4.0	0.035	0.55	1.2
New sand.....	--	3.0	--	0.14	0.80

¹ Weight loss at 105°C., gm. water per gm. dry sand.

² Weight loss at 600°C., gm. volatile solids per kg. dry sand.

³ Organic nitrogen + ammonia-nitrogen, gm. N per kg. dry sand.

⁴ Chemical oxygen demand, gm. COD per kg. dry sand.

⁵ Surfactant by methylene-blue assay, mg. surfactant per kg. dry soil.

Total Weight of Adsorbed Surfactant (mg)

Sand Section	A1	A2	L1	L2	Control
2 in.	3.2	16.0	3.4	6.1	3.1
4 in.	10.6	6.4	2.8	6.5	2.1
8 in.	4.2	11.4	2.8	4.5	1.8
12 in.	6.3	19.7	2.9	3.0	4.5
Total.....	24.3	53.5	11.9	20.1	11.5

Using a sample of clean sand from the supply used to pack the columns, an extraction for surfactant was performed. This clean sand had an apparent surfactant content of 0.80 mg ABS per kg dry soil, so that for a column containing 7.35 kg of sand the background apparent surfactant is about 5.9 mg. The numbers for the total weight of adsorbed surfactant for each of the columns given above should have 5.9 mg subtracted from them in order to arrive at the true apparent amounts of adsorbed surfactant.

Corrected Weights of Adsorbed Surfactant (mg)

A1	A2	L1	L2	Control
18.4	47.6	6.0	14.2	5.6

The weight of adsorbed surfactant is practically negligible compared to the total amount of surfactant applied to the columns. Therefore the behavior of the columns with respect to removal and degradation is adequately described by the changes in the concentration between the influent and effluent concentrations since the quantity adsorbed to the sand is so small.

As shown in Table 6-9, the overall performance of the columns resulted in a removal of 26 percent of the ABS from the lightly loaded filter and 46 percent of the ABS from the more heavily loaded filter. For the columns receiving LAS, the lightly loaded filter showed an 85 percent removal while the heavier dosed column removed 80 percent. Table 6-6 shows that the percentage removals were higher in the last days of the study, being about 57 to 60 percent for the ABS columns and reaching 89 to 91 percent for the LAS columns.

REMOVAL AND BIODEGRADATION OF ABS AND LAS IN SOIL SYSTEMS (FIELD AND LABORATORY)

7.01 *The Problem.*

In the light of the decisions by the detergent manufacturers to convert production from the biologically resistant alkyl benzene sulfonates (ABS) to the biologically "soft" linear alkylate sulfonates (LAS) by the end of 1965, some of the problems discussed in this chapter may seem passé and academic. Nevertheless, the knowledge gained by this detailed investigation of ABS will assist in a better understanding of the principles and mechanisms involved in the adsorption and degradation of other exotic organic compounds. Although ABS may soon be of historical interest only, it has served to alert water-quality-control engineers and scientists to problems associated with all types of biologically resistant compounds.

This chapter describes the results of field investigations relative to ABS at the Whittier Narrows and Rio Hondo Test Basins. In addition, the reader is referred to Chapter 6, where the removal of ABS and LAS in laboratory sand columns is discussed.

Prior to the inception of the investigations described in this report, it was evident that the surface-active substances categorized as alkyl benzene sulfonates (ABS) would be critical parameters of pollution. It was recognized that ABS occurred in well-stabilized wastewater effluents in the general magnitude of 3 to 5 mg/l, that the USPHS Drinking Water Standards of 1962 placed on ABS a recommended (i.e., non-mandatory) limit of 0.5 mg/l, and that ABS persisted in some ground waters interminably, traveling many miles with no apparent diminution in concentration or foaming potential. For these reasons, ABS was likely to be the most-critical constituent of treated wastewater with respect to the quality of ground water downstream from the spreading basins.

The fact that ABS had been reported to persist in some ground-water regimes for months and years did not mean necessarily that ABS would be a problem in the Whittier Narrows Water Reclamation project. Indeed, there was some evidence and considerable hope that ABS could be removed effectively by soil under optimum conditions during spreading operations. It was advisable, however, to assess the factors controlling ABS removal and to determine the optimum conditions for the Whittier Narrows project.

Specifically, it was the intent of this phase of the investigation to attempt to answer the following questions:

a. Will the ABS that has survived treatment by the activated-sludge process and foam fractionation be removed during percolation through the upper 2 to 8 feet of soil in conventional spreading operations?

b. Will this removal be permanent, or will a chromatographic effect occur, whereby the ABS will be desorbed and leached to greater depths or longer distances?

c. Is the removal achieved by physical adsorption alone or does biochemical degradation occur, either initially or subsequently?

d. What rate mechanisms are involved and how are they affected by methods of basin operation, soil characteristics, temperature, and other natural variables?

e. If biodegradation does take place, what organisms are involved and what are the pathways of decomposition?

f. How can a spreading basin best be operated to achieve maximum permanent removal of ABS and to prevent ABS pollution of deep or distant ground waters?

These are important but perplexing questions. Quite obviously, they cannot all be answered on the basis of this investigation. Nevertheless, the data gathered to date provide some very interesting opportunities for hypotheses and lead to some provocative observations. Before reporting these results, however, it is well to reflect on some of the work done by others in relation to this problem.

7.02 *A Critical Review of Current Knowledge on the Behavior of ABS and LAS in Ground Water.*

Literature on the occurrence and behavior of ABS in raw wastewaters, during treatment processes, and in surface and subsurface waters is prodigious. An exhaustive review of such literature is far beyond the scope of this report. It should be pointed out, however, that a comprehensive bibliography on synthetic detergents in water and wastes (5) was printed in October 1962. Furthermore, summaries of the general problem have been presented by Ward (6), the Soap and Detergent Association (7), Coughlin, et al. (8), Walton (9), Patton (10) and others. With respect to the fate of ABS in ground water, however, the literature is not voluminous and certainly not very definitive.

There are, to be sure, frequent references to the detection of ABS in ground-water supplies, with computations or conjecture as to the origin of the ABS, the distance traveled, and the elapsed time or duration of ABS persistence. It has been reported, for example, that ABS has traveled two or more miles underground, that it has penetrated to depths of 100 feet or more, and that it has persisted in ground water for three years or longer. Literature describing these situations has been cited by Coughlin, et al. (8), Walton (9), Patton (10), Ewing, et al. (11), a survey by LA Section ASCE (18), a report to the California State Legislature (19), and others.

Published reports on fundamental studies dealing with the mechanisms and rates of ABS removal by soil are relatively sparse. Within the United States, they are confined largely to the work done by the USPHS at Cincinnati (12, 13, 14), by Klein et al. at

Berkeley (15, 16), and by Ewing et al. in Illinois (11).

The Cincinnati group has demonstrated rather convincingly that the ABS in septic-tank effluent can be removed from levels of 5-35 mg/l down to less than 0.5 mg/l by intermittent aerobic filtration through unsaturated soils. By using ABS tagged with sulfur-35, they found that there was apparent degradation as well as adsorption of the ABS, i.e., the tagged sulfur appeared as sulfate in the effluent. Soil columns were dosed once a day with pre-selected volumes of anaerobic septic-tank effluent at the following rates and loadings:

Number of Columns Used	Hydraulic Loading m/day	BOD Loading g/m ² /day*	ABS Loading g/m ² /day*	Duration of Ponding, Minutes†
4	0.122	16.35	1.34	10-24
5	0.203	27.2	2.24	30-46
1	0.406	54.4	4.47	44

* Calculated at 134 mg/l of BOD and 11 mg/l of ABS.

† After one month of sewage dosing.

In practice, conventional intermittent sand filters are dosed at hydraulic rates of 0.15 m/day or less, and at BOD loadings of 20 to 40 g/m²/day. The high rates of loading for these USPHS tests, and the short duration of ponding, were made possible by the fact that Ottawa silica sand was used as the test soil. The effective sizes varied from 0.1 to 0.3 mm in various columns, with uniformity coefficients of about 1.7 in all cases.

The ABS removal was high (80-90 percent) at the start of the test, dropped to as low as 20 percent at the 0.3 meter depth of percolation after 10 to 15 days of operation, and then recovered to 70-80 percent after 2 to 5 months. The initial high rate of removal was attributed to adsorption by the sand itself. The poor removal at 10 to 15 days was undoubtedly due to the saturation of the adsorptive capacity of the sand prior to the development of adequate biological growths. The improved removal in the period from one to five months of operation resulted from a buildup of organisms capable of adsorbing and degrading ABS. The variation in effective size of the sand had no apparent influence on removal efficiencies; nor did the differences in hydraulic or organic loadings. The deeper filters gave better total removal of ABS, but most of the removal came in the first meter of depth.

It is essential to note that these USPHS experiments were performed under highly aerobic conditions. Although the septic-tank effluent used for dosing was anaerobic, the columns were ponded with effluent for brief periods only, and they were exposed to the open air for more than 23 hours out of each day. Since they drained freely, there was ample opportunity for air (and oxygen) to penetrate downward from the surface through the soil interstices.

The Berkeley studies were considerably different and cannot be compared directly with the Cincinnati experiments, as explained below. The first annual report of the Berkeley investigations (15) describes tests with sterile saturated soil columns and with biologically seeded columns, both saturated and unsaturated. All columns during all tests received a

sterilized feed solution containing BOD dilution water plus nutrient broth to give 20 mg/l of BOD. The feed solution also contained 1.0 mg/l of ABS and a very small amount of ABS tagged with sulfur-35.

The sterile saturated columns (indicative of ground-water flow in confined aquifers) revealed that the adsorptive capacity of the five soils tested (based on desorption from the soil at the end of the test) ranged from 1.64 mg/kg for a sandy soil (Oakley) to 13.0 mg/kg for a fine sandy loam (Hanford). All soils exhibited an early breakthrough of ABS, the more permeable and least adsorptive soils requiring the least period of time.

For the biologically active but saturated columns, Oakley sand was used. Prior to the test, the columns were deaerated with CO₂ gas, saturated with water, and then dosed with water containing one or ten percent sewage. The saturated anaerobic seeded columns were allowed to rest for 16 to 64 hours before receiving sterile feed solution with ABS. There was no opportunity for aerobic cultures to develop. In the first test of 48 hours duration (but only 6 hours of actual percolation time) the average hydraulic loading was 3.45 m/day based on the full 48-hour period or 27.5 m/day during the actual time of filtration. These are very rapid rates for most ground-water movement in confined aquifers. A second test with a heavier pre-dose of seed material ran steadily for 52 hours at a hydraulic loading of 6.47 m/day. Neither of these tests gave any indication that ABS adsorption was increased by the presence of bacteria in an anaerobic environment, nor was there any evidence of ABS degradation.

A biologically active unsaturated column (B) was compared with a similar saturated one (A), both using Oakley sand and identical sterile feed solutions. The saturated column was flushed with CO₂ and soaked overnight with a 10-percent sewage mixture containing nutrient broth equivalent to 20 mg/l of BOD. The unsaturated column was similarly soaked with dilute sewage but drained immediately to allow air to be entrapped in the soil. Column A was operated for 20 days with an actual percolation time of 53 hours. The hydraulic loading, based on 20 days, was 1.31 m/day. Column B was operated for 50 days with only 43 hours of percolation time and 1151.5 hours of holding or resting time. The hydraulic loading based on 50 days was 0.46 m/day, a rate comparable to the highest one used by the USPHS but much higher than that employed in practice. The corresponding BOD loading was 9.19 g/m²/day, and the ABS loading was only 0.459 g/m²/day. These organic parameters are much lower than the USPHS loadings reported above. No evidence of biodegradation of ABS was found in saturated column A, based on sulfur-35 assay; but in column B some biodegradation of adsorbed ABS occurred during the holding or resting periods when the column was drained to entrain more air. The percentage of ABS biodegraded, however, was infinitesimal compared with the total amount dosed onto or drained from the column. Most degradation appeared to be confined to the upper 2 or 3 cm of soil.