STUDY OF POLLUTION IN ARTHUR KILL

Technical Report 56-3

June 1956

INTERSTATE SANITATION COMMISSION

New York • New Jersey • Connecticut

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The Arthur Kill is one of the busiest waterways in the Interstate Sanitation District. It is only thirteen miles in length and about a half mile in breadth for most of its length. For its entire length, the Kill is the boundary between the Counties of Union and Middlesex of the State of New Jersey and the County of Richmond of the State of New York.

The location of the Arthur Kill within the Interstate Sanitation District is shown on the accompanying map (Figure I). This map also illustrates the position the Kill serves as an alternate exit to the Kill van Kull for the waters of Newark Bay. The Arthur Kill also receives the fresh water runoff of the Elizabeth and Rahway Rivers and of Morses, Piles, Smith, Woodbridge, Old Place, and Benedicts Creeks as well as the fresh waters draining through the Fresh Kills.

The importance of the Arthur Kill as a major waterway lies not in its size but in its phenomenal development as a center of the chemical and petroleum industries in the Metropolitan Area. The problems that developed concomitant with this industrial buildup in the Arthur Kill include water pollution. Because of the growing pollution load on this water area, the Interstate Sanitation Commission has been conducting a series of investigations to determine the nature and

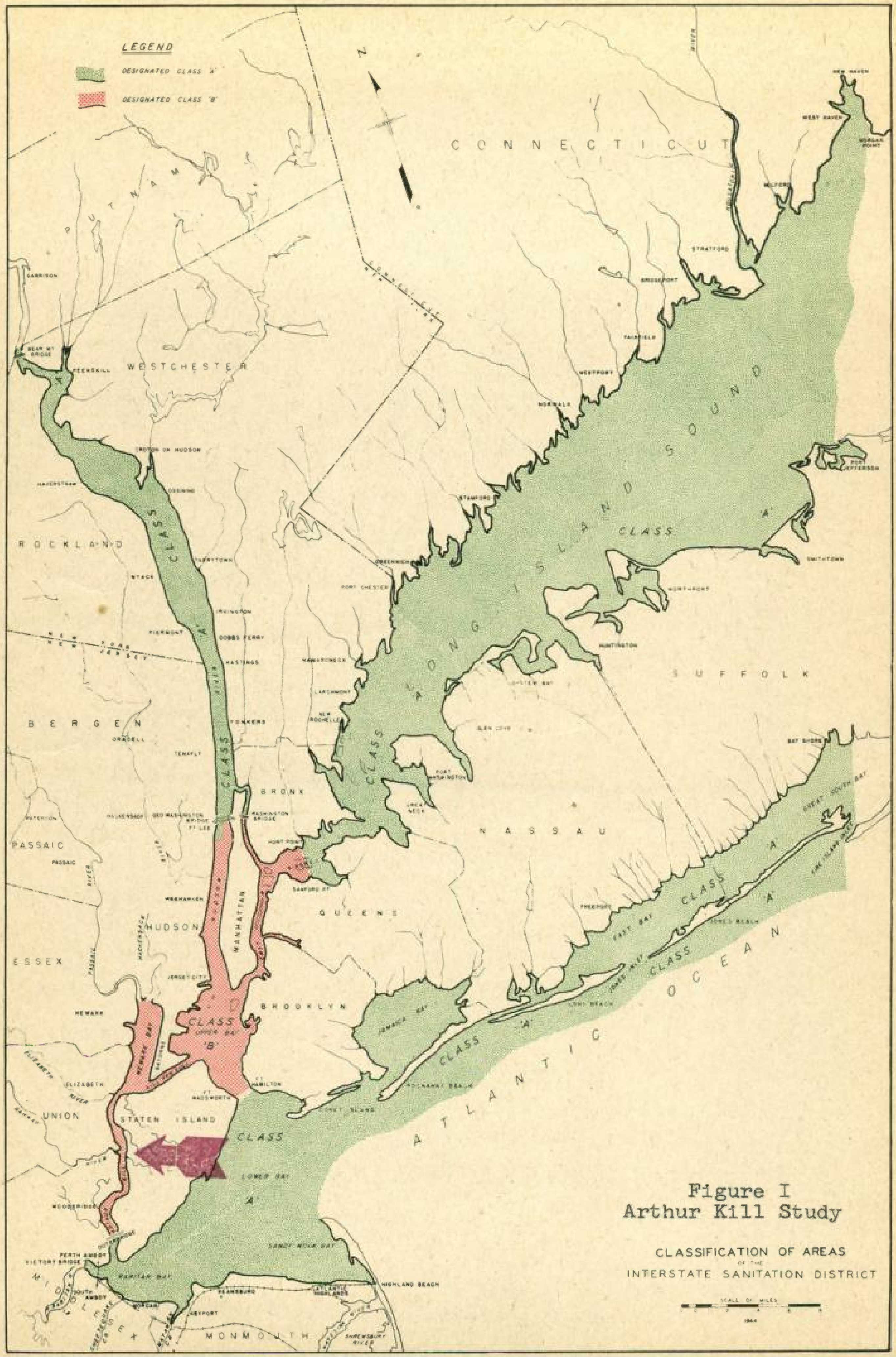


Figure I
Arthur Kill Study

extent of the situation.

In examining all the available previously collected material, much of which was from the survey reports of the New York City Department of Public Works, the pollutional parameters that seemed the most ameniable to further study were those of dissolved oxygen, 5 day 20°C. biological oxygen demand, temperature, salinity, and most probable number of coliform bacteria. There is a sparsity of known available information regarding oil, suspended solids, metals, phenols, cyanides, and others of more complex nature. The scanning of the data pointed up the importance of the dissolved oxygen, biological oxygen demand and the temperature as the parameters for first consideration. Inasmuch as the major portion of the Kill is within Class "B" waters, the coliform data is presently of less relative importance than might be the case for some other area.

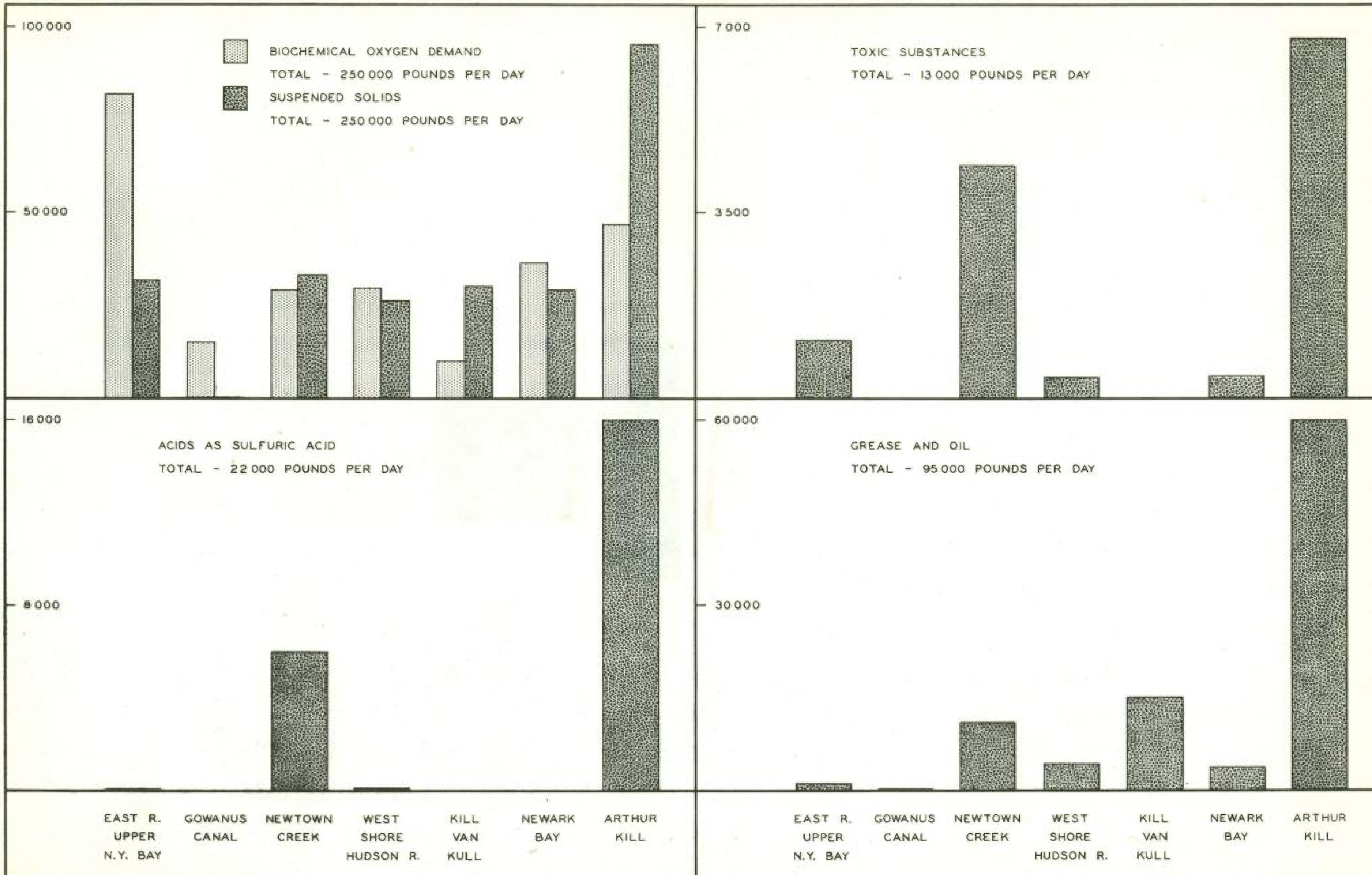
With this in mind, there follows an exposition of the basic elements in the determination whether a problem exists, and if so, a qualitative and quantitative statement of the problem.

The Arthur Kill represents some five square miles of water area or about 0.5% of the total water area within the Interstate Sanitation District. Yet this same small body of water receives an estimated seventy-five (75.) million gallons per day of sewage or approximately 5.% of the total sewage of the District. In addition, there is an industrial waste discharge to this area of an estimated two hundred and nineteen (219.) million gallons per day or 43.% of the total discharged daily to the entire District. There is also approximately one hundred and fifty (150.) million gallons per day of clean discharge usually representing water that has been used for cooling purposes, and therefore raised in temperature. This total discharge of approximately four hundred and fifty (450.) million gallons per day is more than four times the estimated average fresh water flow into the Kill from the adjacent rivers and creeks. The biological oxygen demand load placed in the Kill daily is estimated at a minimum of 122,000 pounds or approximately 12.% of the total discharged to District waters.

The distribution of the industrial waste load in the District is depicted in Figure II, whereas Figure III gives the estimated maximum potential daily industrial waste load on Class "B" waters and illustrates the relatively large load on Arthur Kill. Both of these Figures as well as Table I were abstracted from the Industrial Waste Inventory (1950) of the Interstate

The Arthur Kill represents some five square miles of water area or about 0.5% of the total water area within the Interstate Sanitation District. Yet this same small body of water receives an estimated seventy-five (75.) million gallons per day of sewage or approximately 5.% of the total sewage of the District. In addition, there is an industrial waste discharge to this area of an estimated two hundred and nineteen (219.) million gallons per day or 43.% of the total discharged daily to the entire District. There is also approximately one hundred and fifty (150.) million gallons per day of clean discharge usually representing water that has been used for cooling purposes, and therefore raised in temperature. This total discharge of approximately four hundred and fifty (450.) million gallons per day is more than four times the estimated average fresh water flow into the Kill from the adjacent rivers and creeks. The biological oxygen demand load placed in the Kill daily is estimated at a minimum of 122,000 pounds or approximately 12.% of the total discharged to District waters.

The distribution of the industrial waste load in the District is depicted in Figure II, whereas Figure III gives the estimated maximum potential daily industrial waste load on Class "B" waters and illustrates the relatively large load on Arthur Kill. Both of these Figures as well as Table I were abstracted from the Industrial Waste Inventory (1950) of the Interstate



ESTIMATED MAXIMUM POTENTIAL DAILY INDUSTRIAL WASTE LOADING ON CLASS "B" WATERS

DOES NOT REFLECT TREATMENT AT SOURCE

FIG. III

TABLE I

Appendix iv

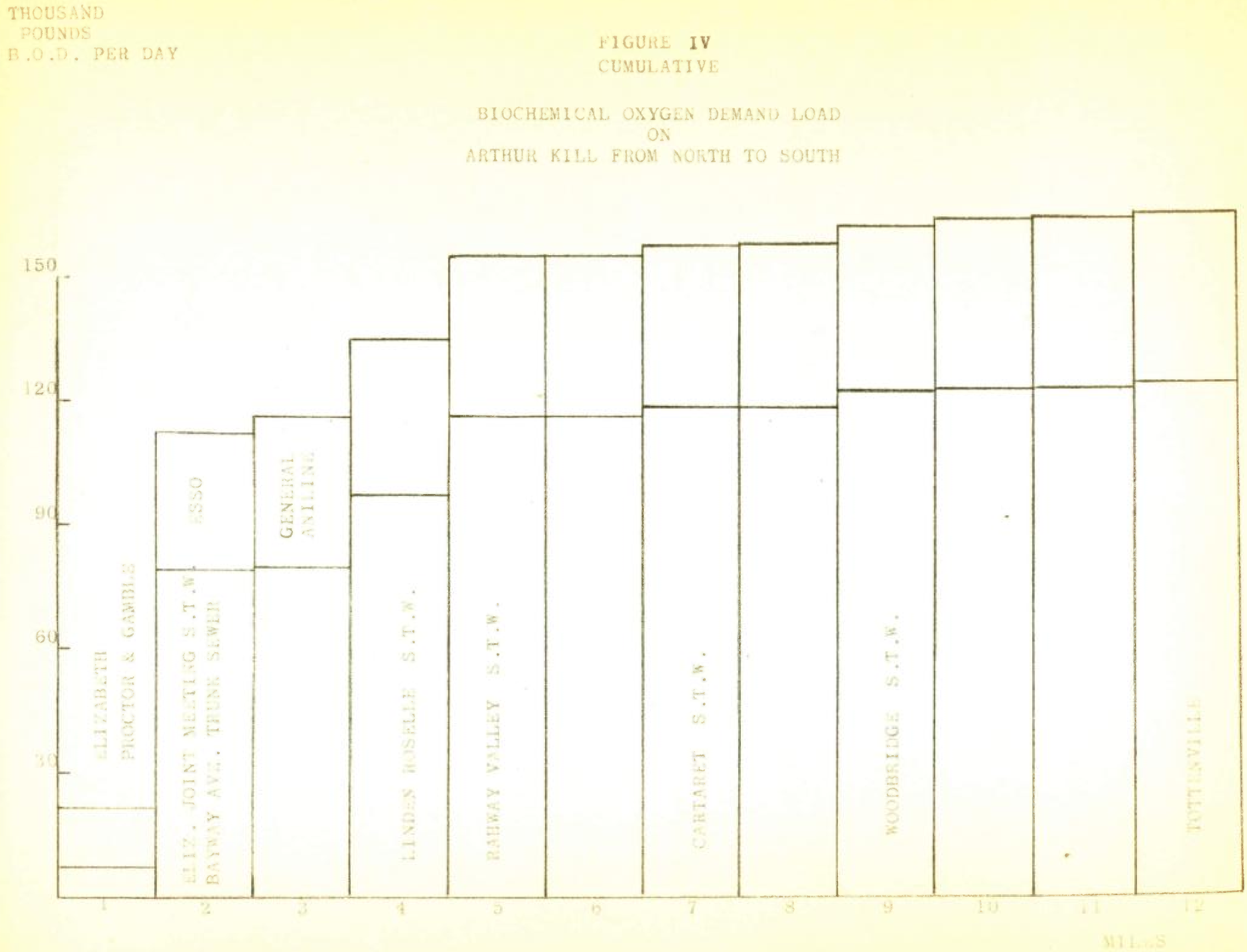
Receiving Waters	Contributing Municipalities	No. of Plants	Production Employees	Discharge MGD Waste	Discharge MGD Clean	Treatment at Source Plants	Treatment at Source Vol. MGD	Estimated Maximum Potential Pounds per day Generated B.O.D.	Suspended Solids	Acids	Metals	Toxic Substances	Grease and Oil
B. CLASS "B" WATERS (cont'd)													
Newark Bay-West Shore													
Newark Coast	Newark	2	200	5.48	1.41	2	5.48	14,000	11,600				1,600
Elizabeth Coast	Elizabeth	2	4,455	.33	.31	1	.32				200	20	
Total		4	4,655	5.81	1.72	3	5.80	14,000	11,600		200	20	1,600
Newark Bay-South Shore	Staten Island	3	1,000	6.19	.24	1	6.18	15,000	14,600				1,000
Total Newark Bay		16	7,355	13.80	6.48	9	13.49	36,875	29,060		201	20	3,850
Kill Van Kull-North Shore	Bayonne	5	4,737	101.64	2.01	3	101.64	9,700	23,000				15,000
Kill Van Kull-South Shore	Staten Island	8	614	2.02	288.03	1	*	300	8,000				50
Total Kill Van Kull		13	5,351	103.66	290.04	4	101.64	10,000	31,000				15,050
Arthur Kill-West Shore													
Elizabeth River	Elizabeth	2	112	.08	4.30	2	.08	1,700	20				100
Elizabeth Coast	Elizabeth	4	2,876	.37	1.24	4	.37	60	20	10,000	6,500		150
Linden Coast	Linden	5	8,039	207.42	52.88	4	204.99	35,000	66,000	5,000		48	33,000
Carteret Coast	Carteret	8	2,334	.95	27.56	3	.18		1,150	800	60		300
Woodbridge Coast	Woodbridge	3	501	.19	1.45	2	.18	40	80			1	100
Perth Amboy Coast	Barber	1	500	8.97	26.48	1	8.97	6,700	16,000			3	26,000
Total		23	14,362	217.98	113.91	16	214.77	43,500	83,270	15,800	6,560	52	60,150
Arthur Kill-East Shore	Staten Island	5	281	.80	31.64	1	.11	3,375	11,500				400
Total Arthur Kill		28	14,643	218.78	145.55	17	214.88	46,875	94,770	15,800	6,560	52	60,450
TOTAL CLASS "B" WATERS		168	66,699	405.19	591.93	69	389.50	248,960	249,640	21,865	10,209	2,797	95,410
TOTAL I.S.D.		306	110,258	515.04	1,160.93	138	432.60	347,725	360,870	95,042	55,510	10,582	101,904

TABLE II

	Outfalls in Order of Appearance	5 day 20°C. B.O.D. pounds/day Sanitary	Industrial	Total
	Elizabeth			
	Trumball St. Sewer	4,700	-	4,700
	Magnolia Ave. Sewer	1,300	-	1,300
	Richmond			
	Proctor and Gamble Company	50	15,000	15,050
	Elizabeth			
Mile 1	Livingston - E.Jersey Street	670	-	670
	Elizabeth Avenue	1,570	-	1,570
	Third Avenue	1,020	-	1,020
	Elizabeth Joint Meeting S.T.W.	53,000	-	53,000
	Elizabeth			
	Bayway Avenue Trunk Sewer	16,500	-	16,500
	Phelps Dodge Company	30	280	310
	Richmond			
	Gulf Oil Company	5	100	105
	Linden			
Mile 2	Esso Refinery	-	18,000	18,000
Mile 3	General Aniline	75	4,200	4,275
	Dupont	30	685	715
Mile 4	Linden Roselle S.T.W.	17,230	-	17,230
	Linden			
	Cities Service	10	610	620
	American Cyanamid	30	835	865
Mile 5	Rahway Valley S.T.W.	19,500	-	19,500
	Richmond			
	Staten Island Edison Company	5	270	275
	Carteret			
	American Oil Company	-	20	20
Mile 6	Westvaco	-	220	220
	American Ag. & Chem. Company	-	235	235
	Benjamin Moore Company	-	70	70
	Armour Company	15	1,900	1,915
	U. S. Metals	-	140	140
	J. Berry Company	-	25	25
Mile 7	Carteret S.T.W.	2,080	-	2,080
	Richmond			
	Rossville Dyestuffs	-	120	120
	Oakland Chemical	-	40	40
Mile 8	Onyx Chemical	-	20	20
Mile 9	Woodbridge S.T.W.	3,750	-	3,750
	Woodbridge			
	Vulcan Detinning Company	5	60	65
	Shell Oil Company	20	85	105
	California Refineries	20	1,670	1,690
Mile 10	Hess Oil Company	5	15	20
	Richmond			
Mile 11	Nassau Smelting & Refining	10	35	45
Mile 12	Tottenville Area	835	-	835
	TOTAL FOR KILL	122,465	44,635	167,100

FIGURE IV
CUMULATIVE

BIOCHEMICAL OXYGEN DEMAND LOAD
ON
ARTHUR KILL FROM NORTH TO SOUTH



Sanitation Commission, and represent conditions as of 1950.

A breakdown of the biological oxygen demand loading for Arthur Kill is presented in Table II. These figures represent the 5 day 20°C. B.O.D. of the effluents discharged to the Kill. The Table as well as Figure IV illustrates the concentrated loading that occurs in the upper or northern section of the Kill. The major contribution of the B.O.D. load are seen to be the Bayway Avenue Outfall; the Esso Standard Oil Refinery; Proctor and Gamble; and the Elizabeth, Linden-Roselle, and Rahway Valley Sewage Treatment Works. More than 80% of the B.O.D. load is contributed to the northern four miles or 31% of the length of the Kill.

At the same time the major users of cooling waters are the Esso Standard Oil Refinery, Proctor and Gamble, Staten Island Edison, General Aniline, American Cyanamid, and U.S. Metals Refining, all located in the northern half of the Kill. The use of the Kill as a source as well as a recipient of these cooling waters tends to increase the temperature of the Kill above that normally encountered in tidal waters in this area.

The effect of this heavy B.O.D. loading and increased temperatures in a tidal strait of limited circulation such as the Kill would only serve to lower the dissolved oxygen content of the Kill. The extent of this lowering of D.O. is observable both seasonably as

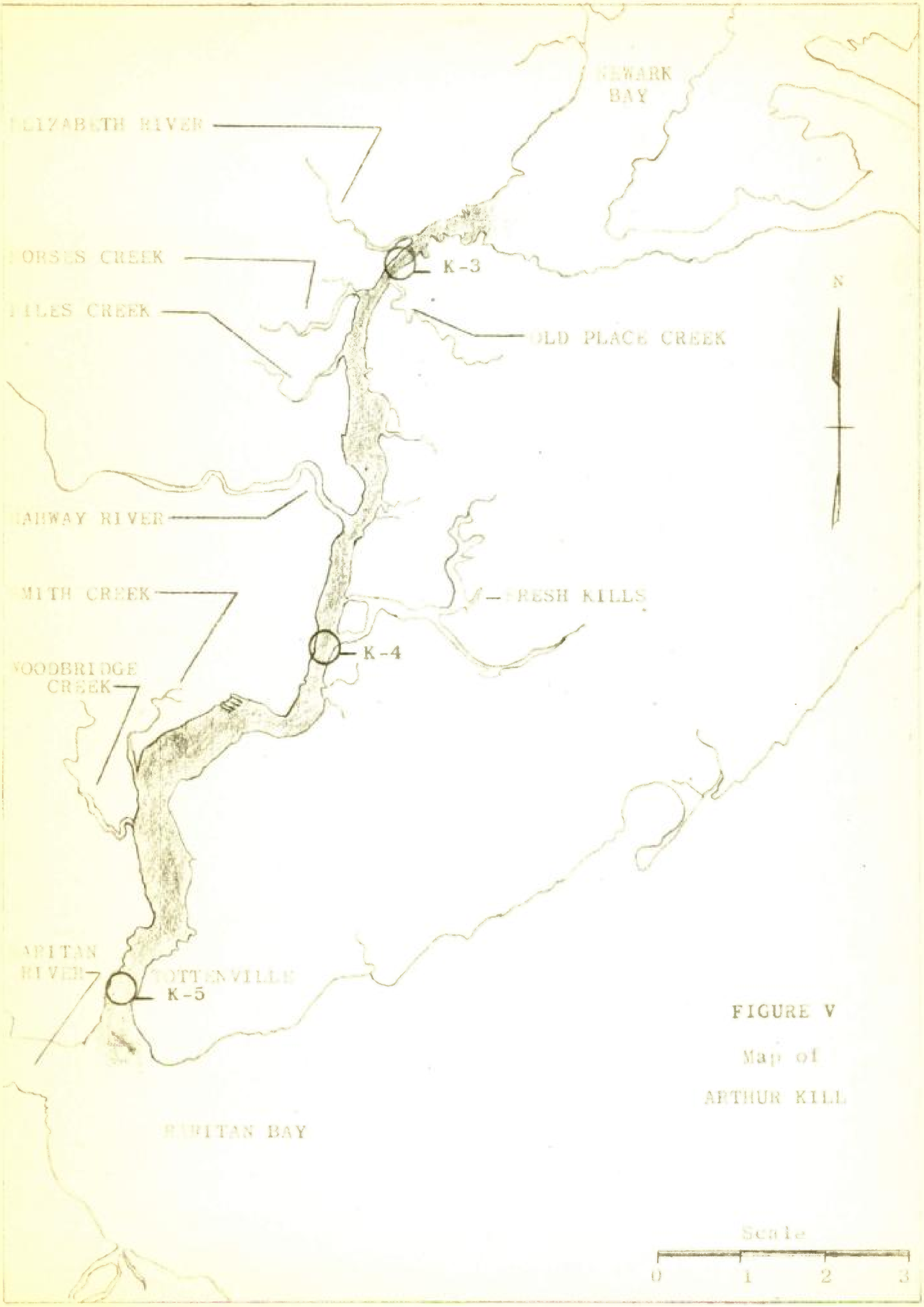


FIGURE V

Map of

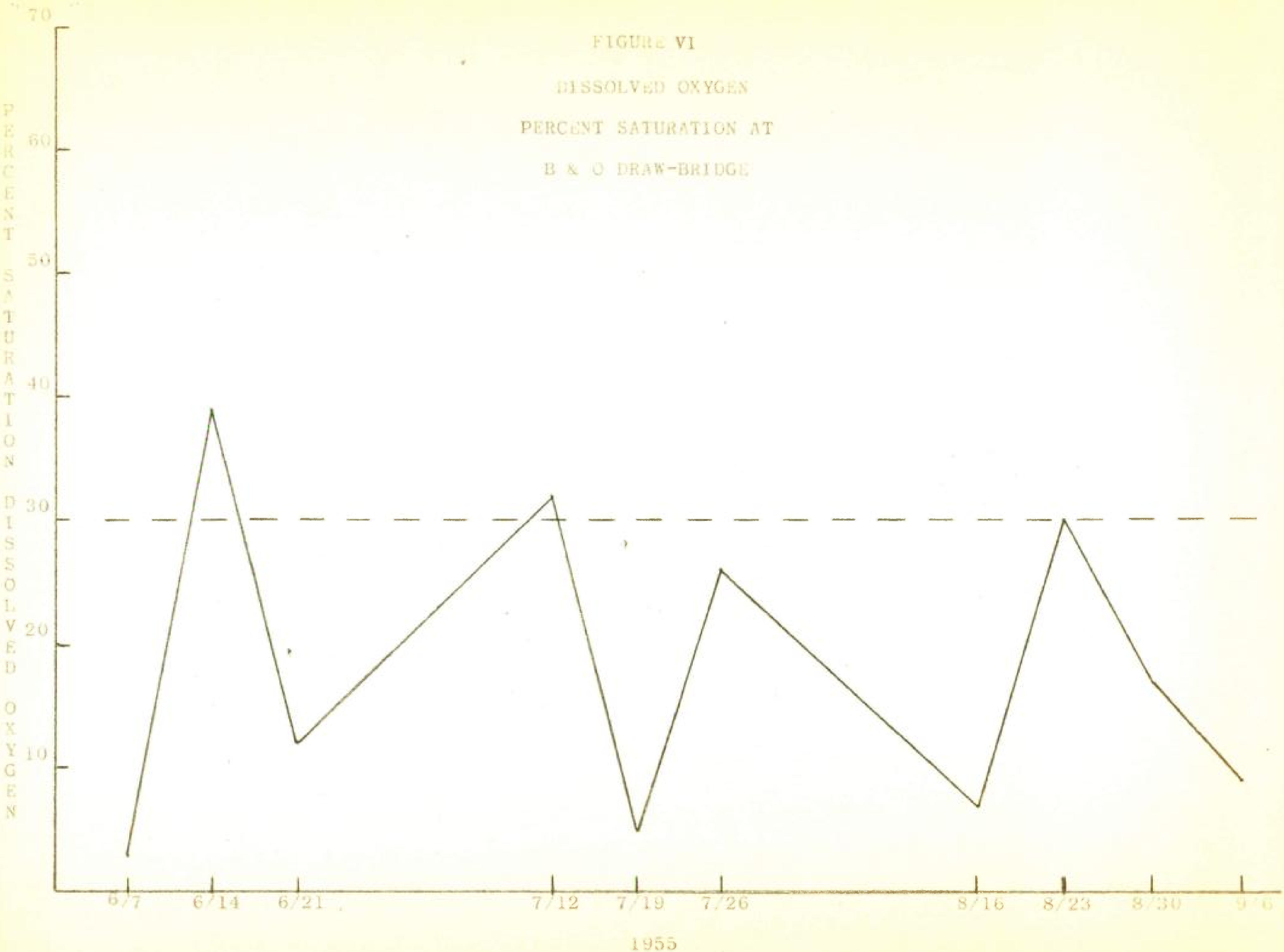
ARTHUR KILL

FIGURE VI

DISSOLVED OXYGEN

PERCENT SATURATION AT

B & O DRAW-BRIDGE



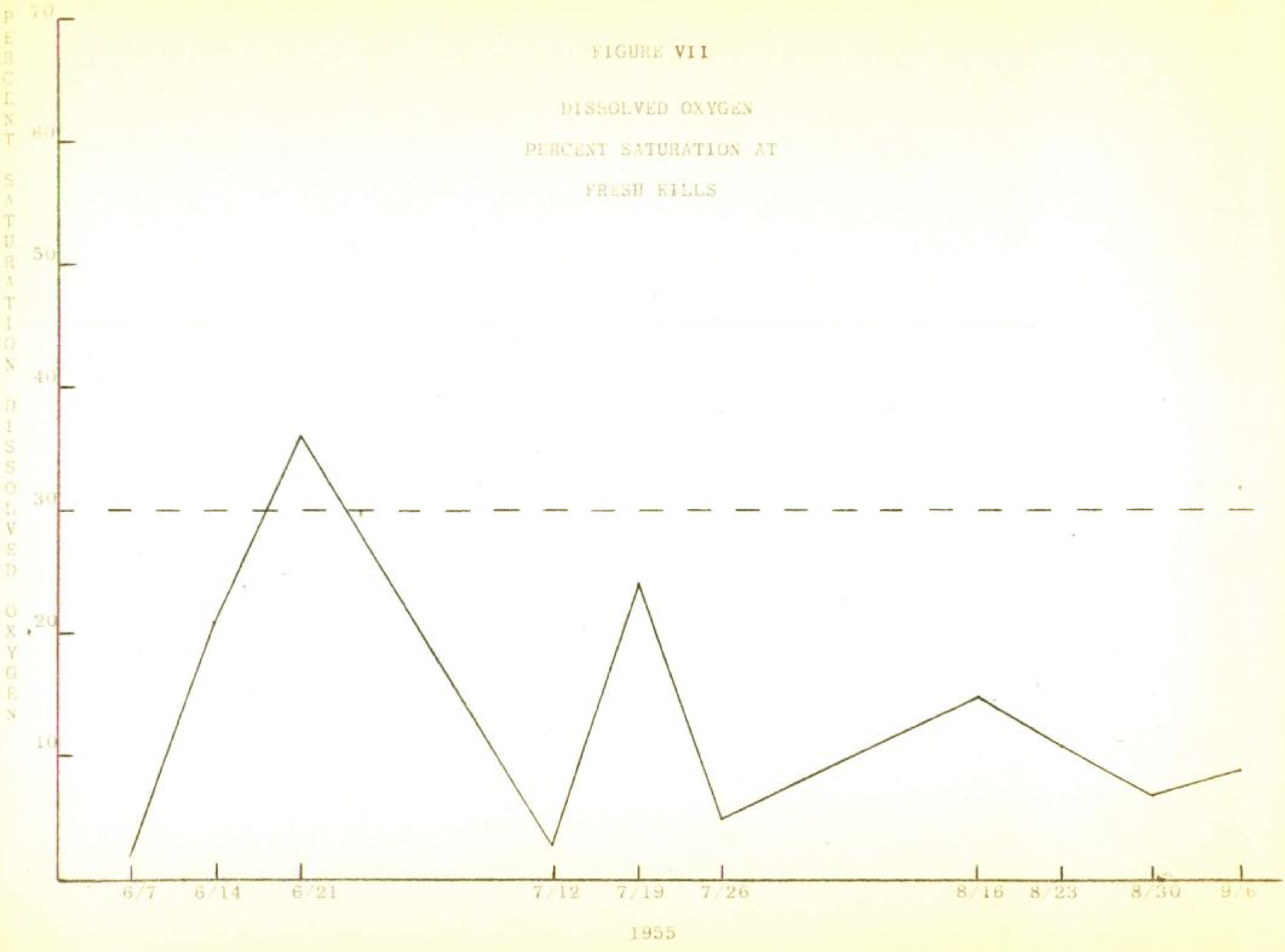


FIGURE VII
DISSOLVED OXYGEN
PERCENT SATURATION AT
FRESH KILLS
PERCENT SATURATION DISSOLVED OXYGEN
70
60
50
40
30
20
10
6/7
6/14
6/21
7/12
7/19
7/26
8/16
8/23
8/30
9/6
1955

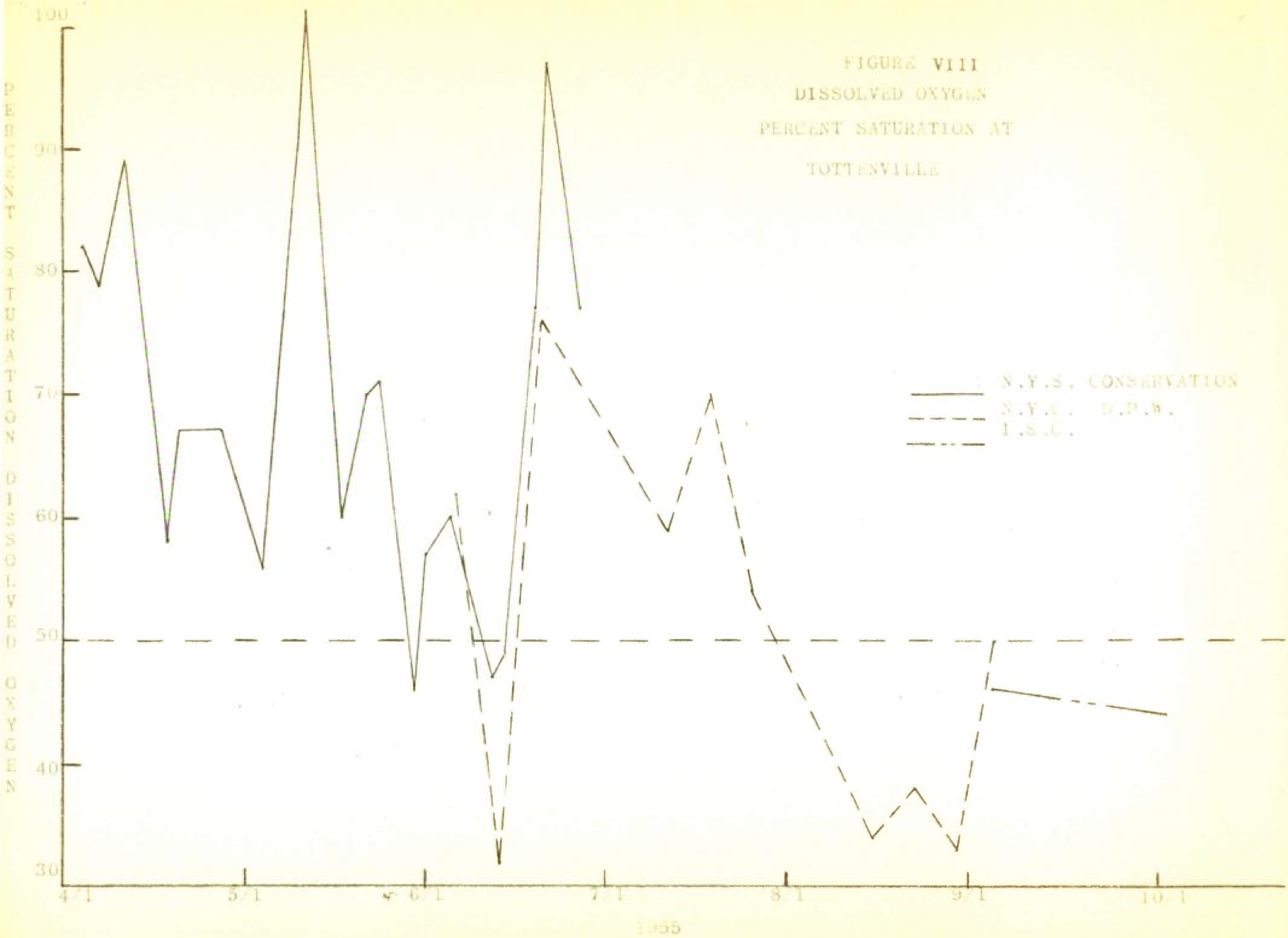


FIGURE VIII
DISSOLVED OXYGEN
PERCENT SATURATION AT
TOTTENSVILLE

well as secularly.

Reviewing the analytical data available for 1955 from the records of the Interstate Sanitation Commission, the New York City Department of Public Works, and the New York State Conservation Department; Figures VI, VII, VIII were prepared. These Figures represent plots of the percent saturation of the dissolved oxygen for the summer of 1955 at the following points:

K-3 - B. & O. Drawbridge
K-4 - Fresh Kills
K-5 - Tottenville

These points are located on the detailed map of Arthur Kill in Figure V.

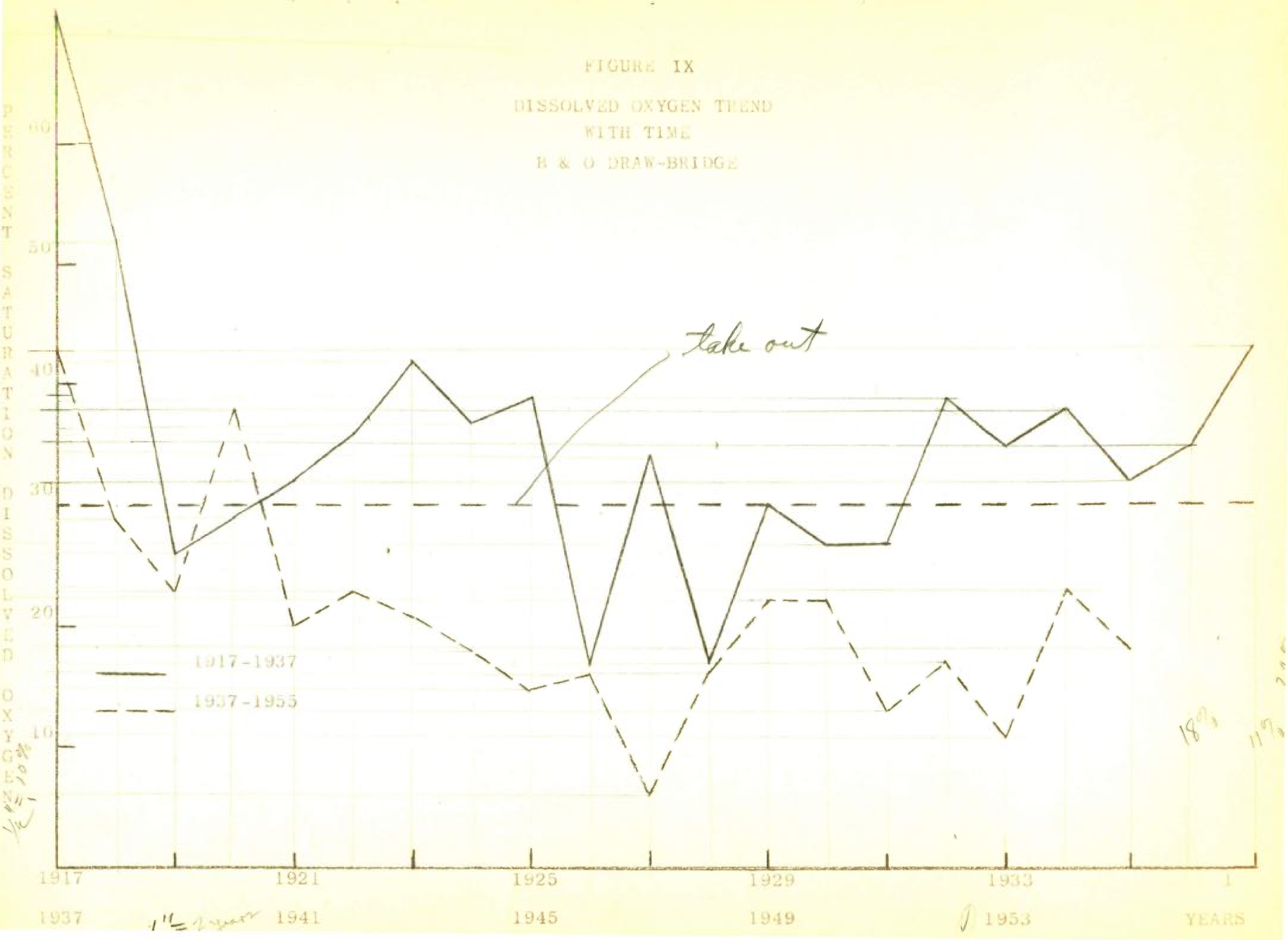
At the B. & O. Drawbrudge, it can be observed that the percentage saturation of the dissolved oxygen was below the thirty percent (30%) level for eight out of the ten samples taken. It should be observed here that the Commission's minimum standard for these waters is 30%. This area failed to observe this standard in eighty percent (80%) of the samples taken.

At the Fresh Kills area, failure to comply with the Compact standard occurred nine in ten times. This represents a failure to meet the Commission's standards ninety percent (90%) of the time.

At the Tottenville end of the Kill, the situation was a little less critical. Failure to comply in this Class "A" area with the fifty percent (50%) saturation standard occurred thirty percent (30%) of the time,

FIGURE IX

DISSOLVED OXYGEN TREND
WITH TIME
B & O DRAW-BRIDGE



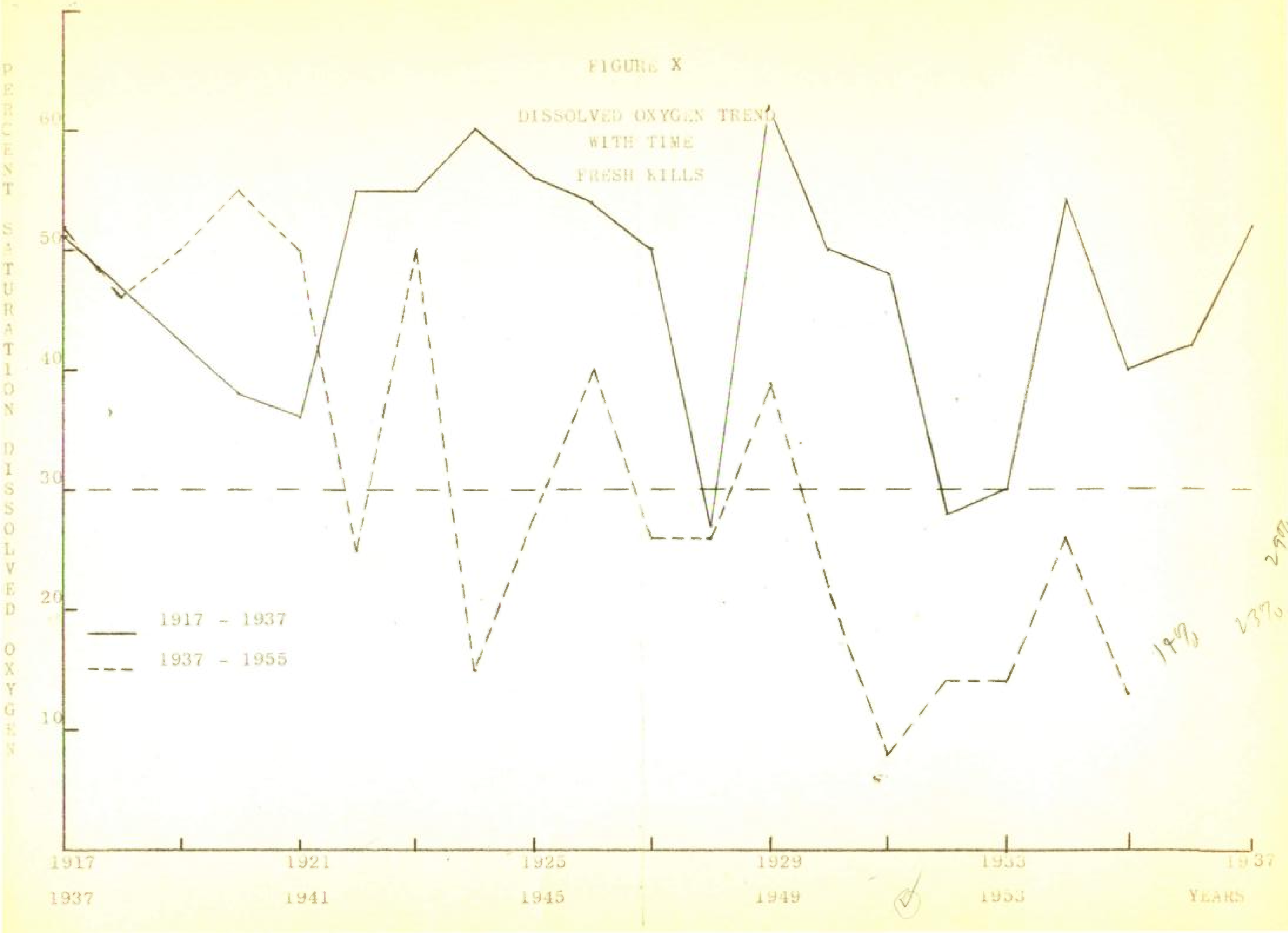


FIGURE X
DISSOLVED OXYGEN TREND
WITH TIME
FRESH KILLS
PERCENT SATURATION DISSOLVED OXYGEN
60
50
40
30
20
10
1917 - 1937
1937 - 1955
1917
1921
1925
1929
1933
1937
1937
1941
1945
1949
1953
YEARS
1949
23%
29%

FIGURE XI

DISSOLVED OXYGEN TREND
WITH TIME
TOTTENVILLE

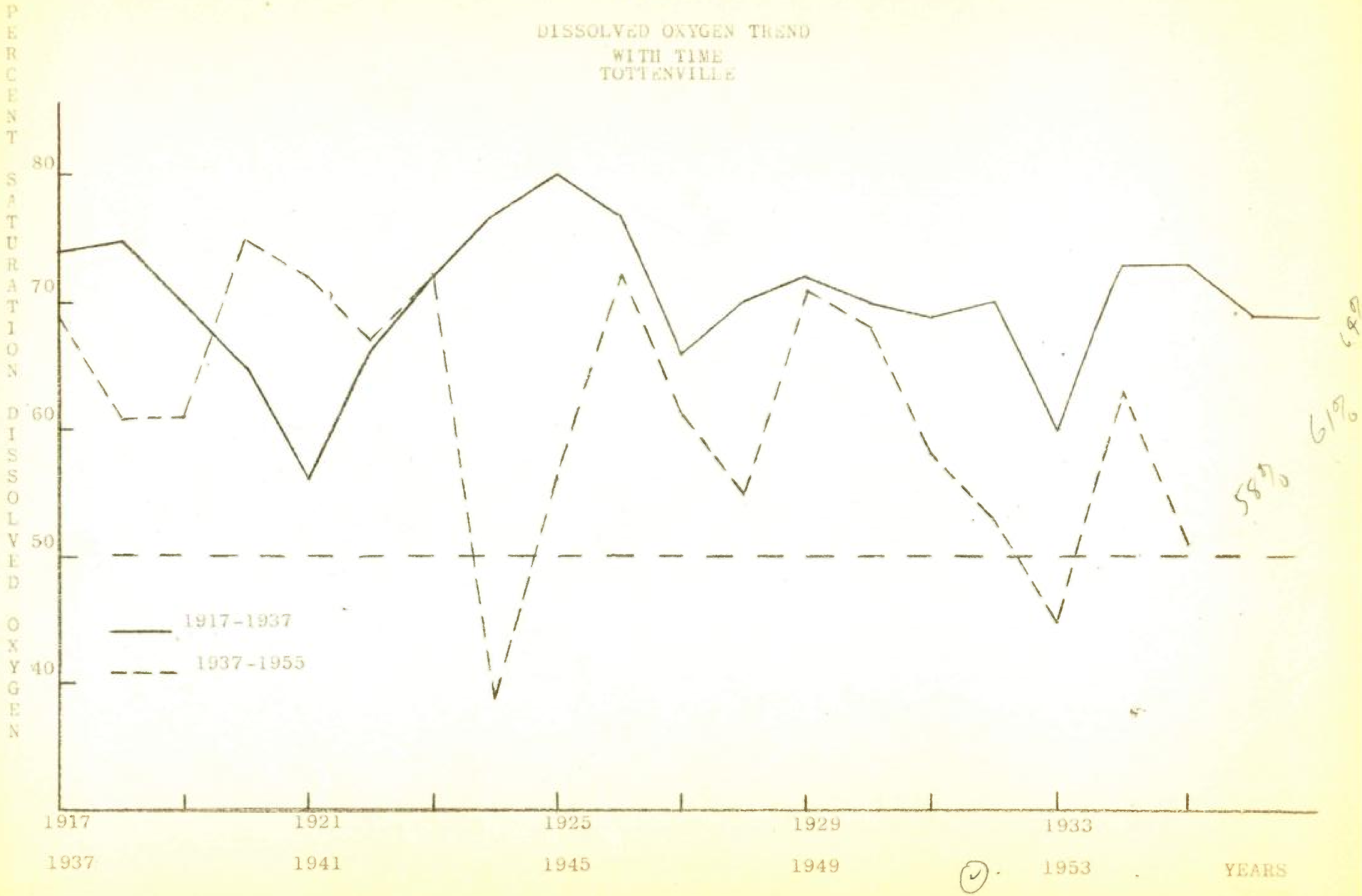


TABLE III

B. & O. DRAW-BRIDGE

CORRELATIONAL ANALYSES

		1917 - 1955			1937 - 1955		
		x=a y=b	x=a y=c	x=c y=b	x=a y=b	x=a y=c	x=c y=b
1	n	39.	39.	39.	19.	19.	19.
2	Σx	741.	741.	2359.	171.	171.	1162.
3	Σx^2	19019.	19019.	144705.	2109.	2109.	72080.
4	Σy	1088.	2359.	1088.	393.	1162.	393.
5	Σy^2	36240.	144705.	36240.	9473.	72080.	9473.
6	Σxy	16996.	45583.	65688.	3013.	10600.	23927.
7	$(\Sigma x)^2$	549081.	549081.	5564881.	29241.	29241.	1350244.
8	$(\Sigma x)^2/n$	14079.	14079.	142689.	1539.	1539.	71065.
9	$(\Sigma y)2$	1183744.	5564881.	1183744.	154449.	1350244.	154449.
10	$(\Sigma y)2/n$	30352.	142689.	30352.	8129.	71065.	8129.
11	$\Sigma x \Sigma y$	806208.	1748019.	2566592.	67203.	198702.	456666.
12	$\Sigma x \Sigma y/n$	20672.	44821.	65810.	3537.	10458.	24035.
13	$\Sigma y/n$	27.897	60.487	27.897	20.684	61.158	20.684
14	$\Sigma x/n$	19.	19.	60.487	9.	9.	61.158
	$P= \frac{6-12}{3-8}=$	$\frac{-3676}{+4940}$	$\frac{+762}{+4940}$	$\frac{-122}{+2016}$	$\frac{-524}{+570}$	$\frac{+142}{+570}$	$\frac{-108}{+1015}$
	P=	-0.74413	+0.15425	-0.06516	-0.91930	+0.24912	-0.10640
	14(p)=	-14.13847	+2.93075	-3.94133	-8.27370	+2.24208	-6.50721
	q=13-14(p)=	42.035	57.556	31.838	28.958	58.916	27.191
	$r= \frac{6-12}{\sqrt{(3-8)\ (5-10)}}$	$\frac{-3676}{\sqrt{29,086,720}}$	$\frac{+762}{\sqrt{9,959,040}}$	$\frac{-122}{\sqrt{11,870,208}}$	$\frac{-524}{\sqrt{766,080}}$	$\frac{+142}{\sqrt{578,550}}$	$\frac{-108}{\sqrt{1,364,160}}$
	r=	-0.68	+0.24	-0.04	-0.60	+0.19	-0.09
	P=	.001 better	-	-	.001	-	-

a = time   b = D.O. % Saturation   c = Salinity % Seawater

TABLE IV

FRESH KILLS

CORRELATIONAL ANALYSES

		1917-1955			1936-1955		
		x=a y=b	x=a y=c	x=c y=b	x=a y=b	x=a y=c	x=c y=b
1	n	37.	37.	37.	20.	20.	20.
2	Σx	738.	738.	2380.	190.	190.	1298.
3	Σx^2	19014.	19014.	154838.	2470.	2470.	85268.
4	Σy	1435.	2380.	1435.	641.	1298.	641.
5	Σy^2	64121.	154838.	64121.	25001.	85268.	25001.
6	Σxy	24543.	47946.	92655.	4746.	12437.	41636.
7	$(\Sigma x)^2$	544644.	544644.	5664400.	36100.	36100.	1684804.
8	$(\Sigma x)^2/n$	14720.	14720.	153092.	1805.	1805.	84240.
9	$(\Sigma y)^2$	2059225.	5664400.	2059225.	410881.	1684804.	410881.
10	$(\Sigma y)^2/n$	55655.	153092.	55655.	20544.	84240.	20544.
11	$\Sigma x \Sigma y$	1059030.	1756440.	3415300.	121790.	246620.	832018.
12	$\Sigma x \Sigma y/n$	28622.	47471.	92305.	6090.	12331.	41601.
13	$\Sigma y/n$	38.784	64.324	38.784	32.050	64.900	32.050
14	$\Sigma x/n$	19.946	19.946	64.324	9.500	9.500	64.900
	$P= \frac{6-12}{3-8}$	$\frac{-4079}{+4294}$	$\frac{+475}{+4294}$	$\frac{+350}{+1746}$	$\frac{-1344}{+665}$	$\frac{+106}{+665}$	$\frac{+35}{+1028}$
	P=	-0.94930	+0.11062	+0.20046	-2.02105	+0.15940	+0.03405
	14(p)	-18.93474	+2.20643	+12.89439	-19.19995	+ 1.51430	+2.20985
	q=13-14(p)	57.7719	62.118	25.890	51.250	63.386	29.840
	$r= \frac{6-12}{\sqrt{(3-8)\ (5-10)}}$	$\frac{-4.079}{\sqrt{36,353,004}}$	$\frac{+475}{\sqrt{7,497,324}}$	$\frac{+350}{\sqrt{14,781,636}}$	$\frac{-1344}{\sqrt{2,963,905}}$	$\frac{+106}{\sqrt{683,620}}$	$\frac{+35}{\sqrt{4,581,796}}$
	r=	-0.68	+ 0.17	+ 0.09	-0.78	+ 0.13	+ 0.02
	P=	.001 better	-	-	.001 better	-	-

TABLE V

TOTTENVILLE

		1917- 1955			1936- 1955		
		x=a y=b	x=a y=c	x=c y=b	x=a y=b	x=a y=c	x=c y=b
1	n	38.	38.	38.	20.	20.	20.
2	Σx	739.	739.	2688.	190.	190.	1422.
3	Σx^2	19015.	19015.	191500.	2470.	2470.	101892.
4	Σy	2503.	2688.	2503.	1238.	1422.	1238.
5	Σy^2	167985.	191500.	167985.	78466.	101892.	78466.
6	Σxy	46653.	57253.	177242.	11268.	13750.	88025.
7	$(\Sigma x)^2$	546121.	546121.	7225344.	36100.	36100.	2022084.
8	$(\Sigma x)^2/n$	14372.	14372.	190141.	1805.	1805.	101104.
9	$(\Sigma y)^2$	6265009.	7225344.	6265009.	1532644.	2022084.	1532644.
10	$(\Sigma y)^2/n$	164869.	190141.	164869.	76632.	101104.	76632.
11	$\Sigma x \Sigma y$	1849717.	1986432.	6728064.	235220.	270180.	1760436.
12	$\Sigma x \Sigma y/n$	48677.	52275.	177054.	11761.	13509.	88022.
13	$\Sigma y/n$	65.868	70.737	65.868	61.900	71.100	61.900
14	$\Sigma x/n$	19.447	19.447	70.737	9.500	9.500	71.100
	6-12	- 2024	+ 478	+ 188	- 493	+ 241	+ 3
	3-8	+ 4643	+4643	+1359	+ 665	+ 665	+ 788
	$p = \frac{6-12}{3-8}$	-0.43593	+0.10295	+0.13834	-0.74135	+0.36241	+0.00381
	14(p)	-8.47753	+2.00207	+9.78576	-7.04283	+3.44290	+0.27089
	q=13-14(p)	57.391	68.735	56.082	54.857	67.657	61.629
	$r = \frac{6-12}{\sqrt{(3-8)\ (5-10)}}$	$\frac{-2.024}{\sqrt{14,467,588}}$	$\frac{+478}{\sqrt{6,309,837}}$	$\frac{+188}{\sqrt{4,234,644}}$	$\frac{-493}{\sqrt{1,219,610}}$	$\frac{+241}{\sqrt{524,020}}$	$\frac{+3}{\sqrt{1,445,192}}$
	r=	-0.53214	+0.19029	+0.09136	-0.44644	+0.33292	+0.00250
	P	.001 better	-	-	.05	-	-

although it should be noted that even in this area there was a tendency for the waters to be below standard for a long period of time (August and September).

Figures IX, X, XI are intended to show the long term trend of the Kill waters at the above three stations. The solid line represents the condition of the waters for the period 1917-1937 whereas the dotted line represents the period 1937 to date. Here again all three points show a constant degradation of the quality of the waters. The dashed line in most instances is below the solid line. These figures represent average data for each of the years plotted.

Linear correlations, a frequent statistical technique, was used on the data in Figures IX, X, XI and the results are shown in Tables III, IV, V. The purpose of using these techniques was to demonstrate whether or not a relationship existed between dissolved oxygen percent saturation and time. At the same time an attempt was made to determine the influence of rainfall or runoff as measured by a change in the salinity of the Kill. The rainfall or runoff appeared to be of no significance whereas the time versus percent saturation appeared to be highly significant.

The correlation was developed for the overall period 1917-1955 as well as for the 1937-1955 period. Both periods appear highly significant. But what was of even greater importance was the increased degradation shown for the 1937-1955 period as compared to the overall period. The small p in the tables represents the slope of the line of the downward trend of dissolved oxygen percent saturation. For the B. & O. Drawbridge area, this slope has changed from 0.744% drop per year for the overall period to an accelerated fall of 0.919% per year in the 1937-1955 period.

The data for the Fresh Kills area shown an even greater overall decline and a much more serious acceleration of this decline in the 1937-1955 period. The overall decline was .949% per year and this has jumped to 2.021% per year in the last two decades. The situation in this area appears rather serious.

The Tottenville area although showing much smaller declines is also accelerating its rate of decline from 0.436% to 0.741% per year. This may be due in part to upkill influence although this is difficult to state at this time.

There seems to be little doubt that the situation calls for prompt consideration. These presentations tend to point out the critical nature of the present conditions in the Kill. It has been shown that at present the requirements of the Tri-State Compact with regard to dissolved oxygen saturation are not being met in most areas of the Kill for long periods of time and furthermore that these conditions are not improving but rather deteriorating. The tremendous industrial and residential growth that appears to be the immediate prospect for this area of the District makes the situation one of utmost concern.

The Commission is conducting further investigations in this area to widen the base of our knowledge of the Kill.

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