GROVETON SURVEY

Upper Ammonoosuc River & Connecticut River

Near Lancaster and Groveton,

New Hampshire

September 1973

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GROVETON SURVEY

During the period September 8 through September 14, 1973, Region I, United States Environmental Protection Agency personnel conducted a survey on the Upper Ammonoosuc River and Connecticut River in the State of New Hampshire near Lancaster and Groveton. The purpose of the survey was to verify a mathematical model of the Upper Ammonoosuc River and Connecticut River below Groveton Paper Company. The model was established to develop discharge limitations for Groveton Paper Company.

This report is not intended to be an interpretation of the results, but rather a summary of the data collected during the study period.

I. Approach

The concept of sampling was to evaluate the changes in a slug of water as it traveled downstream. This allows the evaluation of the effects of a specific mill loading on the mixing and natural purification of the river.

To accomplish this type of evaluation, the sampling at each station was based on the time of travel between stations.

Pursuant of the objectives of this survey, several types of data were collected:

1) Time of Travel and Flow Data - Two time of travel studies were completed, one at high flow done during June 1973 and at a lower flow done during the study period. Flow data was also compiled during the time of travel studies.

2) Analytical Data - At each sampling station, six (6) grab samples were taken at four (4) hour intervals. Section V expands on the method and types of samples collected and composited.

3) Physical Data - During and after the study period, cross-sections of the river were measured and dredge samples taken to determine the type of material forming the river bed.

II. Station Location

The following is a description of the station locations followed by a Table showing river miles from Groveton Paper Company and latitude and longitude. The locations are also pinpointed in the maps in Appendix A.

GA01 - Upper Ammonoosuc River, upstream of the intake dam at Groveton Paper Co.

GA02 - Upper Ammonoosuc River, at the railroad bridge downstream of the dam below Groveton Paper Co.

GA03 - Upper Ammonoosuc River, 300m upstream of the confluence with the Connecticut River.

GA04 - Connecticut River, 300m upstream of the confluence.

GC05 - Connecticut River, approximately 600 m downstream of the confluence.

GC06 - Connecticut River, approximately 10,000 m downstream of Groveton Paper Co. at the Northumberland Dam.

GC07 - Connecticut River, at the Rt. 2 bridge between Lancaster, New Hampshire and Guild Hall, Vermont.

GC08 - Connecticut River at the covered bridge approximately 32,500 m downstream of Groveton Paper Company.

Table I

Location of Sampling Stations

Station #	Kilometers downstream of Groveton Paper Co.	(miles)	Latitude	Longitude
GA01	.32 (upstream)	0.2	44° 36' 05"	71° 30' 20"
GA02	.80	0.5	44° 35' 31"	71° 31' 01"
GA03	4.0	2.5	44° 35' 26"	71° 32' 03"
GC04	4.3 (+.32 mi.upstream in Conn. River)	2.7	44° 35' 17"	71° 32' 23"
GC05	5.6	3.5	44° 34' 55"	71° 32' 23"
GC06	10.5	6.5	44° 33' 53"	71° 33' 31"
GC07	23.3	14.5	44° 29' 44"	71° 35' 39"
GC08	32.2	20.0	44° 27' 35"	71° 39' 10"

III. Flow Data

Table II lists the flow data for the Connecticut and Upper Ammonoosuc Rivers during the time of travel and study periods. The data was compiled from readings taken at the United States Geological Survey Gaging Stations.*

From a report entitled "Seven-Day Low Flow Analysis - New England Stream Gaging Stations" prepared by Systems Analysis Branch, E.P.A., Region I dated April 12, 1973, the 7-day, 10-year flow for the gaging stations in the study area were extracted and are listed in Table III.

IV. Time of Travel

For the study, two time of travel surveys were completed, one at high flow in June and another during the water quality survey at a lower flow. The time of travel surveys are divided into five main reaches. The data is summarized in Table IV, and the reaches are described below and are located in the maps in Appendix A.

Reach #1 - The Upper Ammonoosuc River from the railroad bridge below Groveton Paper Company to the confluence with the Connecticut River.

Reach #2 - The Connecticut River from the confluence with the Upper Ammonoosuc River to the Dam in Northumberland, N.H.

Reach #3 - The Connecticut River from the Dam in Northumberland, to the Rt. 2 Bridge between Lancaster, N.H. and Guildhall, Vt.

*The readings at the gaging stations were made by the people at New England Electric Company and made available to us by the same.

Table II

Flow Data

Time & Date of Reading	North Stratford, N.H. Connecticut River		Dalton, N.H. Connecticut River		Stark, N.H. Upper Ammonoosuc River	
	cms	(cfs)	cms	(cfs)	cms	(cfs)
6-12-73 8am	24.8	876	63.0	2223	12.3	434
4pm	34.3	1212	-	-	19.8	699
6-13-73 8am	64.1	2265	86.1	3040	45.7	1615
4pm	80.8	2852	122.1	4310	47.2	1667
6-14-73 8am	73.5	2596	165.6	5848	57.2	2020
4pm	59.1	2088	-	5658	50.9	1797
6-15-73 8am	56.8	2004	147.1	5194	39.2	1384
4pm	51.2	1808	134.8	4760	33.7	1190
6-16-73 8am	40.9	1444	114.6	4048	26.8	946
4pm	88.5	3124	126.8	4478	48.7	1719
9-9-73 8am	33.2	1173	70.1	2476	7.3	258
4pm	24.2	854	70.1	2476	6.8	241
9-10-73 8am	18.9	665	44.3	1565	6.5	229
4pm	13.7	482	42.8	1510	6.3	222
9-11-73 8am	10.6	375	38.4	1355	6.0	213
4pm	10.1	355	34.4	1214	5.9	210
9-12-73 8am	9.9	351	20.4	720	6.0	213
4pm	9.7	342	22.4	790	5.9	210
9-13-73 8am	9.4	333	24.1	850	5.9	207
4pm	9.2	324	24.1	850	5.8	204
9-14-73 8am	9.3	328	24.1	850	5.6	198
4pm	9.2	324	20.4	720	5.5	195
9-15-73 8am	21.4	755	20.4	720	5.9	210
4pm	27.8	980	20.2	715	6.1	216
9-16-73 8am	28.8	1016	26.9	950	6.2	219
4pm	28.4	1004	44.0	1555	6.2	216

Table III

7-day, 10-year Low Flow Data

Station	Low Flow	
North Stratford, New Hampshire Connecticut River	4.6 cms	(164 cfs)
Dalton, New Hampshire Connecticut River	10.1 cms	(355 cfs)
Stark, New Hampshire Upper Ammonoosuc River	1.4 cms	(48 cfs)

Table 1[illegible]

Time of Travel Summary

		Run #1		Run #2		Run #3	
Reach #1	3.9 km (2.4 mi.)						
	Flow cms (cfs)	34.0	(1200)	6.7	(235)	5.8	(205)
	Time (hrs.)	1.25		7.04		7.33	
	Vel. m/s (fps)	.85	(2.8)	.15	(0.5)	.15	(0.48)
Reach #2	5.5 km (3.4 mi.)						
	Flow cms (cfs)	159	(5600)	68.0	(2400)	48.1	(1700)
	Time (hrs.)	2.75		6.8		7.33	
	Vel. m/s (fps)	.55	(1.8)	.22	(0.73)	.21	(0.68)
Reach #3	13.0 km (8.1 mi.)						
	Flow cms (cfs)	99.1	(3500)	42.5	(1500)	28.3	(1000)
	Time (hrs.)	10.9		15.6		11.64	
	Vel. m/s (fps)	.33	(1.1)	.23	(0.76)	.31	(1.02)
Reach #4	9.3 km (5.8 mi.)						
	Flow cms (cfs)	63.7	(2250)	41.1	(1450)	41.1	(1450)
	Time (hrs.)	10		10.76		13.5	
	Vel. m/s (fps)	.26	(0.85)	.24	(0.79)	.19	(0.63)
Reach #5	5.0 km (3.1 mi.)						
	Flow cms (cfs)	63.7	(2250)	38.2	(1350)	36.8	(1300)
	Time (hrs.)	7.7		10.1		9.3	
	m/s (fps)	.18	(0.59)	.14	(0.45)	.15	(0.49)

Reach #4 - The Connecticut River from the Route 2 Bridge to the Covered Bridge near Lunenberg, Vt.

Reach #5 - The Connecticut River from the Covered Bridge to the Railroad Bridge approximately 5 kilometers downstream.

Detailed summaries of each time of travel survey are included as Appendicies B & C.

V. Analytical Data

Samples were collected at four (4) hour intervals as grab samples for a 20 hr. period, or six (6) grab samples. A portion of the samples were composited in the following manner equal portions of the first and second, third and fourth, and fifth and sixth samples were combined to make three (3) composite samples to reduce the analytical work load. Grab samples were analyzed for temperature, pH, dissolved oxygen and coliform bacteria. In addition, three (3) grab samples at each station were analyzed for chlorophyll-a. The composited samples were analyzed for total suspended solids, total dissolved solids, total phosphorus and biochemical oxygen demand.

In Tables VI through XIII the data from stations one through eight is summarized.

VI. Physical Data

In addition to the water quality sampling that was done on the river, we recorded river cross-sections which are summarized in Table XIV.

Bottom samples were looked at and it was determined that the river bed was basically hardpan and rock with very few sludge deposits. It was determined in the laboratory that this type of bed had a benthic oxygen demand of approximately 0.9 $gm/d/m^2$ of oxygen in the Upper Ammonoosuc River and approximately 0.6 $gm/d/m^2$ of oxygen in the Connecticut River. Reports relative to sediment composition and benthic oxygen demand are included as Appendicies D and E.

VII. Conclusions

The analysis of the data presented in this report was done by our Systems Analysis Branch within the framework of a mathematical model of the study area. Their report of the interpretations of the data is included as Appendix F.

A conclusion drawn from this work was that with the installation of Best Practical Treatment only, Water Quality Limits would be violated in the Upper Ammonoosuc River.

Table VI

Analysis of Samples from Station GA01

Date/time	9/11 0900	9/11 1300	9/11 1700	9/11 2035	9/11 2330	9/12 0530
Temperature (C°)	14	-	14	14	13	12
pH (su)	7.5	7.0	6.4	6.2	6.1	7.5
Dissolved Oxygen (mg/l)	9.3	-	-	-	-	9.0
Total Coliform/100 ml	1,700	1,100	2,400	800	600	230
Fecal Coliform/100 ml	34	20	25	4	18	30
Chlorophyll -a (ug/l)	-	1.54	-	1.31	-	0.84
Total Suspended Solids (mg/l)	44		25		25	
Total Dissolved Solids (mg/l)	35		19		27	
Total Phosphorus (mg/l)	0.04		0.04		K 0.02	

BOD (mg/l)		9/11 0900 – 1300	9/11 1700 – 2035	9/11 2330 – 9/12 0530
1 day		0	0	1
3 day		1	1	2
5 day		2	2	2
7 day		2	2	3
10 day		3	3	3
12 day	13 day	3	3	4
15 day	16 day	3	3	5
18 day	19 day	4	4	5
22 day	23 day	5	5	5
28 day		6	5	4

K - Less than

Table VII

Analysis of Samples from Station GA02

Date/time	9/11 0800	9/11 1230	9/11 1630	9/11 2115	9/12 0035	9/12 0630
Temperature (C°)	14	16	17	14	14	12.5
pH (su)	6.5	7.1	7.7	6.5	7.4	7.0
Dissolved Oxygen (mg/1)	8.8	5.9	-	-	-	8.4
Total Coliform/100 ml	3,100	29,000	39,000	20,000	25,000	27,000
Fecal Coliform/100 ml	820	880	820	380	570	520
Chlorophyll -a (ug/1)	-	1.9	-	6.2	-	2.4
Total Suspended Solids (mg/1)	241		302		253	
Total Dissolved Solids (mg/1)	173		234		208	
Total Phosphorus (mg/1	0.12		0.10		0.08	
BOD (mg/1) 1 day	12		11		11	
3 day	12		16		46	
5 day	13		27		64	
7 day	14		32		75	
10 day	16		46		82	
12 day / 13 day	25		51		87	
15 day / 16 day	29		56		94	
18 day / 19 day	32		61		101	
22 day / 23 day	34		66		105	
28 day	35		70		118	

Table VIII

Analysis of Samples from Station GA03

Date/time	9/11 1430	9/11 1800	9/11 2330	9/12 0240	9/12 0740	9/12 1030
Temperature (C°	16	17	14	12.5	12.5	17
pH (su)	6.7	6.2	6.2	7.3	6.9	7.1
Dissolved Oxygen (mg/l)	-	-	7.6	6.7	7.0	5.1
Total Coliform/100 ml	1,700	1 100	2,400	800	600	230
Fecal Coliform/100 ml	34	20	25	4	18	30
Chlorophyll -a (ug/l)	-	8.1	-	9.9	-	7.9
Total Suspended Solids (mg/l)	292		292		284	
Total Dissolved Solids (mg/l)	249		250		200	
Total Phosphorus (mg/l)	0.08		0.08		0.08	
BOD (mg/l) 1 day	11		9		8	
3 day	37		12		27	
5 day	59		22		67	
7 day	67		25		76	
10 day	78		34		86	
12 day / 13 day	79		43		91	
15 day / 16 day	88		45		101	
18 day / 19 day	94		47		107	
22 day / 23 day	94		50		114	
28 day	95		61		129	

Table IX

Analysis of Samples from Station GC04

Date/time	9/11 1500	9/11 1830	9/11 2400	9/12 0300	9/12 0800	9 12 1030
Temperature (C°)	14	15	14	13	12.5	16
pH (su)	6.9	6.2	6.4	6.3	6.9	6.8
Dissolved Oxygen (mg/l)	8.9	-	8.6	-	8.8	8.1
Total Coliform/100 ml	1,700	260	2,900	2,700	390	2,200
Fecal Coliform/100 ml	40	44	100	120	20	90
Chlorophyll -a (ug/l)	-	2.2	-	1.70	-	0.85
Total Suspended Solids (mg/l)	63		64		44	
Total Dissolved Solids (mg/l)	35		60		32	
Total Phosphorus (mg/l)	0.04		0.04		0.04	

BOD (mg/l)					
1 day		1	1	0
3 day		1	1	1
5 day		2	2	1
7 day		2	2	2
10 day		3	3	2
12 day	13 day	4	3	2
15 day	16 day	4	4	3
18 day	19 day	5	5	4
22 day	23 day	5	5	5
28 day		6	7	6

Table X

Analysis of Samples from Station GC05

Date/time	9/11 1650	9/11 1845	9/12 0405	9/12 0015	9/12 0800	9/12 1130
Temperature (C°)	15	15	13	14	13	15
pH (su)	6.2	6.2	6.4	6.3	7.0	7.3
Dissolved Oxygen (mg/l)	-	-	7.9	7.6	7.8	7.8
Total Coliform/100 ml	5,700	10,000	20,000	23,000	30,000	41,000
Fecal Coliform/100 ml	66	70	300	690	610	840
Chlorophyll -a (ug/l)	-	3.31	1.76	3.08	-	-
Total Suspended Solids (mg/l)	96		106		86	
Total Dissolved Solids (mg/l)	88		102		60	
Total Phosphorus (mg/l)	0.05		0.05		0.04	

BOD (mg/l)

1 day		2	5	6
3 day		6	8	5
5 day		8	11	10
7 day		10	13	11
10 day		12	14	15
12 day	13 day	13	15	15
15 day	16 day	14	16	14
18 day	19 day	15	18	14
22 day	23 day	16	19	14
28 day		18	22	15

Table XI

Analysis of Samples from Station GC06

Date/time	9/11 2215	9/12 0150	9/12 0710	9/12 0930	9/12 1230	9/12 1530
Temperature (C°)	14	14	12.5	15	16	15
pH (su)	6.2	6.2	6.5	6.8	6.9	6.9
Dissolved Oxygen (mg/l)	-	7.9	7.7	7.3	6.7	6.0
Total Coliform/100 ml	11,000	22,000	21,000	28,000	45,000	49,000
Fecal Coliform/100 ml	620	950	L 150	L 5,000	L 5,000	1,300
Chlorophyll -a (ug/l)	-	4.11	4.32	3.18	-	3.35
Total Suspended Solids (mg/l)	61		80		109	
Total Dissolved Solids (mg/l)	37		60		69	
Total Phosphorus (mg/l)	0.06		0.04		0.06	

BOD (mg/l)

		9/11 2215 – 9/12 0150	9/12 0710 – 9/12 0930	9/12 1230 – 9/12 1530
1 day		3	6	7
3 day		6	8	8
5 day		8	13	13
7 day		9	14	24
10 day		11	15	24
12 day	13 day	12	16	24
15 day	16 day	13	16	24
18 day	19 day	15	17	22
22 day	23 day	17	18	21
28 day		18	19	22

L - Greater than

Table XII

Analysis of Samples from Station GC07

Date/time	9/12 0730	9/12 1400	9/12 1600	9/12 200		
Temperature (C°)	14	15	14	13	13	13.5
pH su)	6.7	6.7	6.1	6.1	6.5	6.6
Dissolved Oxygen (mg/l)	7.3	-	-	-	-	-
Total Coliform/100 ml	17,000	30,000	30,000	12,000	12,000	1 800
Fecal Coliform/100 ml	1,000	410	490	360	910	670
Chlorophyll -a (ug/l)	-	1.33	1.88	3.09	-	2.02
Total Suspended Solids (mg/l)	83		85		- 91	
Total Dissolved Solids (mg/l)	54		75		86	
Total Phosphorus (mg/l)	0.04		L 0.02		L 0.02	
BOD (mg/l) 1 day	2		2		3	
3 day	3		5		5	
5 day	5		7		7	
7 day	5		7		8	
10 day	6		9		9	
12 day	7		10		10	
15 day	7		10		10	
18 day	7		11		11	
22 day	7		12		12	
28 day	8		13		13	

L - Greater than

Table XIII

Analysis of Samples from Station GC08

Date/time	9/13 0100	9/13 0500	9/12 2045	9/13 0930	9/13 1315	9 13 1700
Temperature (C°)	13	.13	13	14	15	15
pH (su)	6.1	6.2	6.0	6.5	-	6.6
Dissolved Oxygen (mg/l)	7.4	-	-	5.8	-	-
Total Coliform/100 ml	4,500	4,100	4,900	6,100	8,000	8,500
Fecal Coliform/100 ml	610	420	680	350	250	170
Chlorophyll -a (ug/l)	-	2.22	-	1.88	-	2.62
Total Suspended Solids (mg/l)	90		82		- 71	
Total Dissolved Solids (mg/l)	80		80		38	
Total Phosphorus (mg/l)	L 0.02		L 0.02		0.02	

BOD (mg/l)

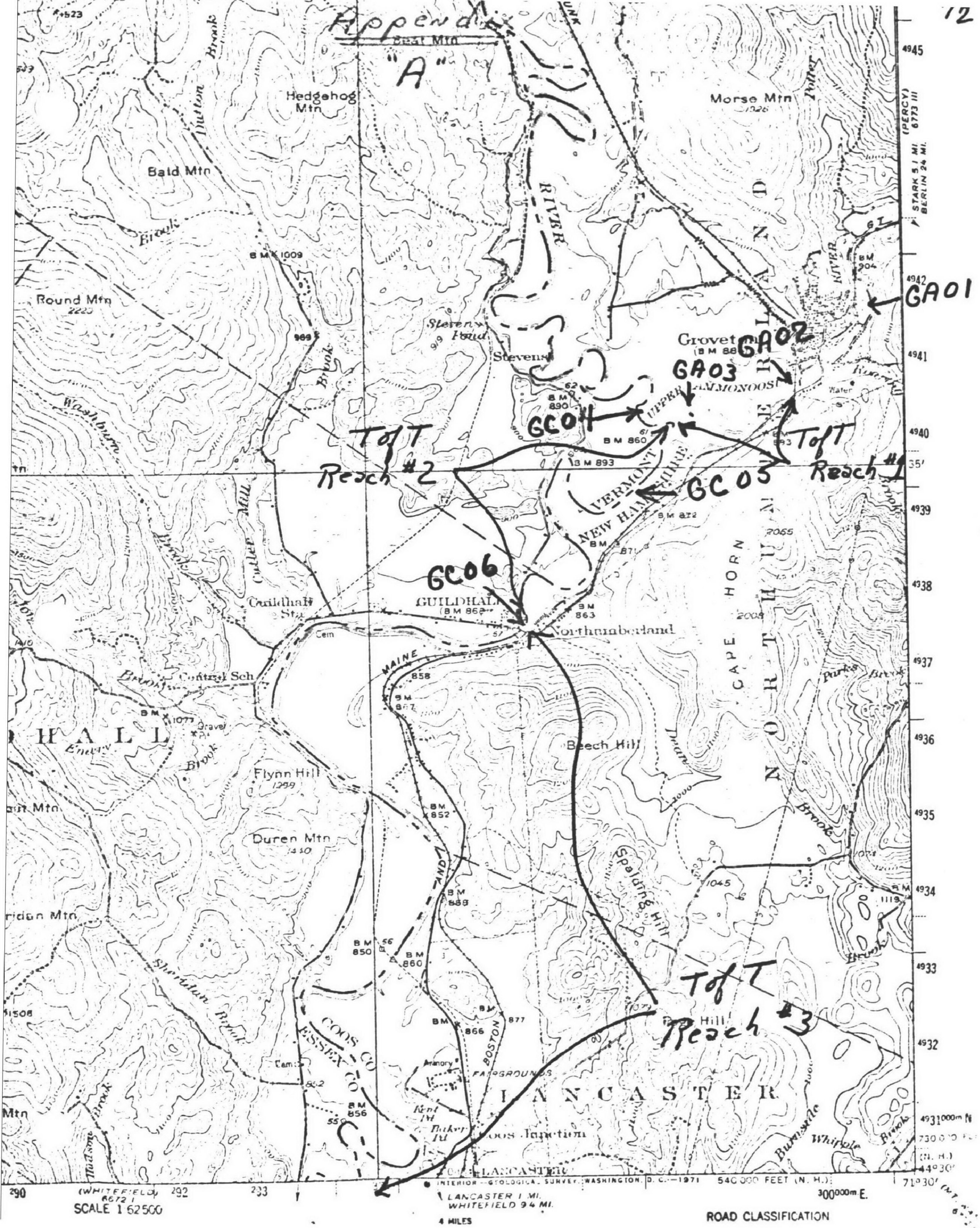
Day	9/13 0100 – 0500	9/12 2045 – 9/13 0930	Day	9/13 1315 – 1700
1 day	1	1		1
3 day	2	3		3
5 day	3	4		5
7 day	4	5		5
10 day	4	6		6
12 day	5	6	14 day	8
15 day	6	7	17 day	6
18 day	6	8	21 day	6
22 day	7	9		-
28 day	8	10		8

L - Greater than

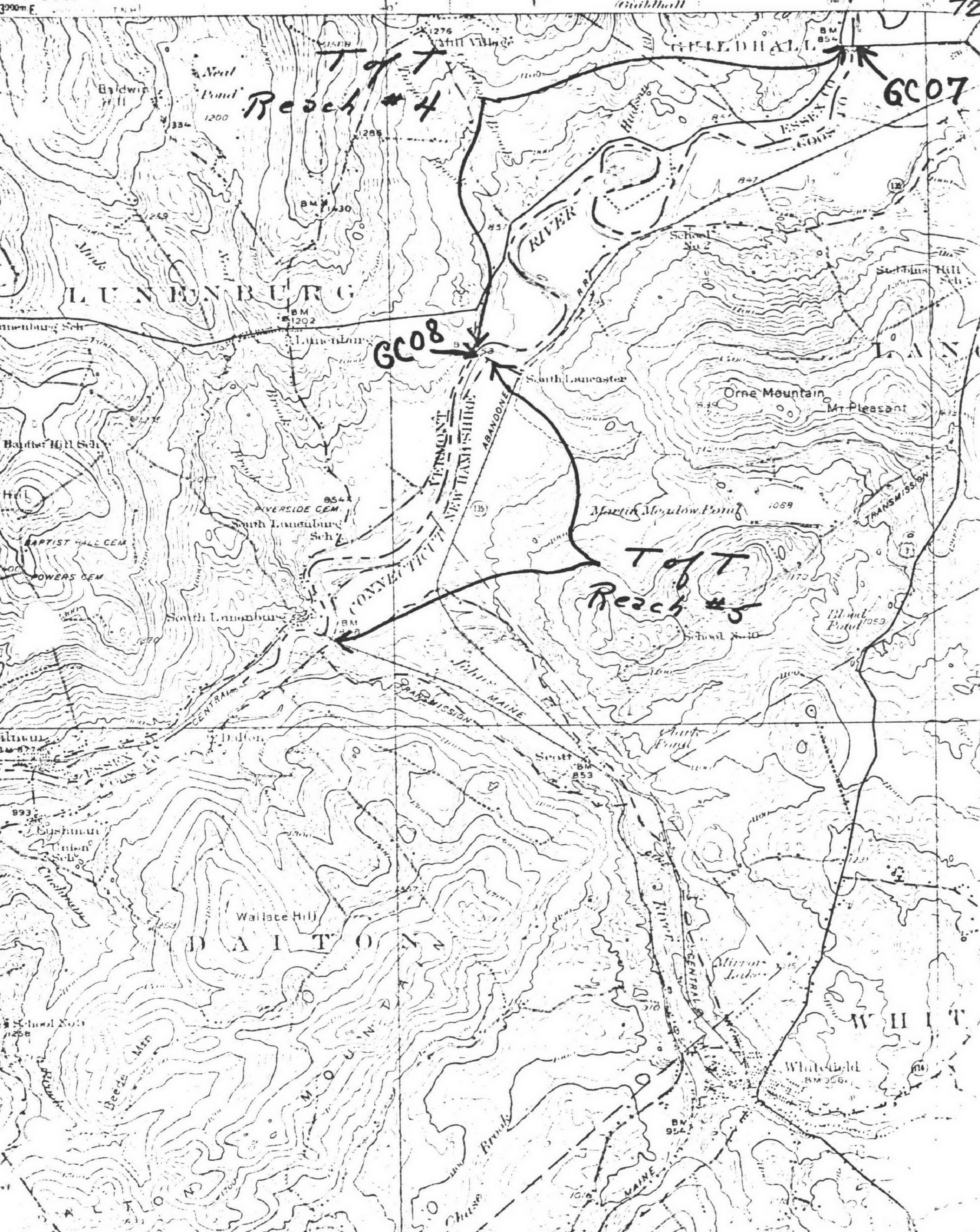
Table XIV

Cross-Section Data
Connecticut River - Groveton Survey

River kilometers downstream from the Confluence	(miles)	River Width m	(ft)	Depth Measurements: 1/3 river width off west bank m	(ft)	mid point m	(ft)	1/3 river width off east bank m	(ft)	Cross Section Area m^2	ft^2
.97 upstr.	(0.6)	30.5	(100')	.49	(1.6)	1.1	(3.5)	.52	(1.7)	15.8	(170)
.32 upstr.	(0.2)	36.6	(120')	3.3	(10.8)	4.0	(13.0	1.0	(3.3)	75.5	(813)
.32	(0.2)	61.0	(200')	3.0	(9.8)	1.9	(6.2)	.8	(2.6)	86.4	(930)
.40	(0.25)	61.0	(200')	.40	(1.3)	1.6	(5.3)	3.0	(10.0)	77.1	(830)
1.20	(0.75)	83.8	(275')	1.5	(4.8)	1.6	(5.4)	1.5	(5.0)	97.1	(1045)
1.77	(1.1)	36.6	(120')	1.1	(3.6)	2.9	(9.7)	5.9	(19.3)	90.9	(978)
2.49	(1.55)	45.7	(150')	3.9	(12.8)	5.2	(17.0)	2.0	(6.7)	127.2	(1369)
3.38	(2.10)	61.0	(200')	3.7	(12.3)	2.5	(8.2)	2.0	(6.6)	125.9	(1355)
3.86	(2.4)	39.6	(130')	1.9	(6.3)	3.8	(12.4)	4.7	(15.4)	102.9	(1108)
4.02	(2.5)	61.0	(200')	1.8	(5.9)	2.3	(7.6)	2.1	(6.8)	94.3	(1015)
5.15	(3.2)	68.6	(225')	2.4	(8.0)	2.6	(8.5)	1.9	(6.2)	118.6	(1277)
5.30	(3.3)	56.4	(185')	1.1	(3.6)	2.9	(9.5)	1.8	(5.8)	81.2	(874)
5.79	(3.6)	53.3	(175')	1.3	(4.4)	1.9	(6.3)	1.7	(5.5)	65.9	(709)
6.68	(4.15)	61.0	(200')	1.0	(3.4)	1.6	(5.3)	2.4	(8.0)	77.6	(835)
7.72	(4.8)	48.8	(160')	2.0	(6.6)	1.4	(4.6)	.7	(2.2)	49.8	(536)
8.69	(5.4)	53.3	(175')	1.3	(4.3)	1.3	(4.4)	1.6	(5.4)	57.3	(617)
9.33	(5.8)	45.7	(150')	4.1	(13.4)	4.6	(15.2)	3.7	(12.3)	142.5	(1534)
11.42	(7.1)	61.0	(200')	0.6	(2.0)	.8	(2.6)	.9	(3.0)	35.3	(380)
13.76	(8.55)	68.6	(225')	1.5	(4.9)	1.5	(4.8)	1.5	(4.9)	80.0	(821)
15.12	(9.40)	51.2	(170')	1.8	(5.9)	2.7	(8.8)	.9	(3.0)	69.9	(752)
15.92	(9.9)	48.8	(160')	7.5	(24.5)	7.9	(25.8)	3.4	(11.1)	228.2	(2456)
16.57	(10.3)	68.6	(225')	2.3	(7.6)	1.4	(4.6)	1.3	(4.4)	86.8	(934)
17.46	(10.85	53.3	(175')	1.2	(4.0)	3.7	(12.0)	5.4	(17.8)	137.4	(1479)
19.15	(11.90	48.8	(160')	3.7	(12.2)	4.5	(14.7)	3.1	(10.3)	138.2	(1488)



Appendix
"A"
Hedgehog Mtn
Bald Mtn
Round Mtn
2223
Morse Mtn
Stevens Pond
Stevens
Groveton
RIVER
UPPER AMMONOOSUC
VERMONT
NEW HAMPSHIRE
GA01
GA02
GA03
GC04
GC05
GC06
T of T
Reach #1
T of T
Reach #2
T of T
Reach #3
GUILDHALL
Guildhall Sta
Northumberland
Central Sch
Flynn Hill
Duren Mtn
Beech Hill
Spaulding Hill
CAPE HORN
MAINE
BOSTON
COOS CO
ESSEX CO
LANCASTER
Coos Junction
Armory
FAIRGROUNDS
Whipple Brook
Sheridan Brook
Washburn
Cutler Mill
Dutton Brook
Potter
Parks Brook
Burnside
Emery Brook
Sheridan Mtn
Hudson Brook
BM 1009
BM 890
BM 860
BM 893
BM 904
BM 863
BM 862
BM 858
BM 852
BM 850
BM 860
BM 866
BM 856
4945
4942
4941
4940
4939
4938
4937
4936
4935
4934
4933
4932
4931000m N
35'
44°30'
71°30'
540 000 FEET (N. H.)
300000m E.
INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—1971
LANCASTER 1 MI.
WHITEFIELD 9.4 MI.
STARK 5.1 MI.
BERLIN 24 MI.
(WHITEFIELD)
6672 I
290
292
293
SCALE 1:62500
4 MILES
ROAD CLASSIFICATION



T of T
Reach #4
GC07
GC08
T of T
Reach #5
GUILDHALL
LUNENBURG
RIVER
CONNECTICUT
VERMONT
NEW HAMPSHIRE
ABANDONED
South Lancaster
Orne Mountain
Mt Pleasant
Martin Meadow Pond
South Lunenburg
RIVERSIDE CEM
BAPTIST HILL CEM
POWERS CEM
TRANSMISSION
MAINE
CENTRAL
Wallace Hill
DALTON
MOUNTAIN
Whitefield
Mirror Lake
Blood Pond
Clark Pond
Scott
School No 2
School No 10
Baldwin Hill
Neal Pond
Mill Village
ESSEX CO

APPENDIX B

HIGH-FLOW TIME OF TRAVEL STUDY

CONNECTICUT AND UPPER AMMONOOSUC RIVERS

June 12 - 15, 1973

A time of travel study was conducted on the Upper Ammonoosuc River from the lower dam in Groveton, New Hampshire to the confluence with the Connecticut River and from the confluence with the Connecticut River 22.6 miles downstream to the dam at Gilman, Vermont.

The study was conducted to provide preliminary time of travel data for a future water quality study and mathematical modeling purposes.

The study area was broken into four primary reaches on the Connecticut River and one on the Upper Ammonoosuc River. The reaches used were as follow:

Reach 1: Gilman, Vermont dam to a covered bridge 5.3 miles upstream.

Reach 2: Covered bridge 5.8 miles upstream to a steel bridge between Lancaster, New Hampshire and Guildhall, Vermont. (This steel bridge will henceforth be referred to as the Guildhall Bridge.)

Reach 3: Guildhall Bridge 8.2 miles upstream to the dam at Northumberland, New Hampshire. This reach was split into two sub-reaches, 4.0 miles long and 4.2 miles long. However, the data for the reach is reported for the full length of 8.2 miles.

Reach 4: Dam at Northumberland, New Hampshire 3.4 miles upstream to the confluence of the Connecticut and Upper Ammonoosuc Rivers.

Reach 5: From the confluence of the Connecticut and Upper Ammonoosuc Rivers 2.4 miles upstream to the first dam on the Upper Ammonoosuc River.

Flow data for the Connecticut River was obtained from the U. S. Geological Survey gaging station at Dalton, New Hampshire. Flows for the Upper Ammonoosuc River were obtained at the gaging station on that river near Groveton, New Hampshire. Flows at the gage on the Upper Ammonoosuc River may not be representative of flows in Reach 5. This is due to Groveton Paper's controlling the flows in the river at three dams between Reach 5 and the gage.

Weather conditions during the study period varied from generally overcast skies to severe thunder storms. Due to these heavy rains, the flow in the Connecticut River increased by 2667 c.f.s. during the study period.

Attachment 1 provides the reaches, their lengths, the time of travel for each reach, the average velocities in feet per seond and flow data at the two gages for the study period.

REACH	DISTANCE/KILOMETERS	(Miles)	TIME OF TRAVEL	VELOCITY m/sec	(ft/s)
Covered Bridge 6/12 To Gilman Dam	8.5	(5.3)	*13 hours	.18	(.59)
Guild Hall Bridge 6/12 to Covered Bridge	9.3	(5.8)	10 hours	.26	(.85)
Northumberland Dam 6/13 to Guild Hall Bridge	13.2	(8.2)	10.9 hours	.34	(1.10)
Confluence Conn. and Upper Ammonoosuc Rivers to Northumberland Dam 6/14	5.5	(3.4)	2.75 hours	.55	(1.8)
RR Bridge in Groveton 6/15 to Confluence	3.86	(2.4)	1.25 hours	.85	(2.80)

FLOWS AT DALTON GAGE

Date	Reading	Time	Flow m^3/s	
6/12	9.17	@ 0810	64.2	(2267 cfs)
6/13	10.07	@ 0950	94.1	(3321 cfs)
6/14	11.87	@ 0920	170.5	(6022 cfs)
6/15	11.29	@ 0830	139.7	(4934 cfs)

FLOWS AT U. AMMONOOSUC GAGE

Date	Reading	Time	Flow m^3/s	
6/14	4.54	@ 1010	50.63	(1788 cfs)
6/15	4.04	in A.M.	35.9	(1266 cfs)

* This is an approximate value.

APPENDIX C

Low Flow Time of Travel Study
Connecticut and Upper Ammonoosuc Rivers
Sept. 9-13, 1973

A second Time of Travel Study was conducted on the Upper Ammonoosuc and Connecticut Rivers. The study area was the same as that during the low flow study,that is, from Groveton Paper Co. on the Upper Ammonoosuc River to a dam at Gilman, Vt. approximately 23 miles downstream in the Connecticut River.

Because the Time of Travel Study immediately preceded the water quality sampling, the dye was injected at Groveton Paper Co. and reinjected as needed on the way downstream. During the survey, two dye patches were followed, the second having a 12-15 hour lag time from the first. Table 1 describes major points of interest, the miles downstream from Groveton Paper Co., and the locations for each run when the dye was located; therefore forming the sub-reaches for which is reported the date, the length of reach, and the time it took the dye peak to travel between those points.

The summary also includes the high flow time of travel.

Flow data for the low flow time of travel survey is summarized in Table 2.

Table 1

Summary of Low Flow
Time of Travel Study
Groveton Survey

ription of Location	Miles From G.P.C.	High Flow	Low Flow Run #1	Low Flow Run #2	Low Flow Run #3
	0			Date: 9/9 L= 1.3 km. T= 3.0 hrs.	Date: 9/13 L= 4.5 km. T= 8.7 hrs.
foot bridge	.5				
R.R. Bridge	.8	Date: 6/15 L= 3.9 km. T= 1.3 hrs.		Date: 9/10 L= 5.8 km. T= 10.6 hrs.	
	4.0				
Confluence	4.7	Date: 6/14 L= 5.5 km. T= 2.7 hrs.	Date: 9/9 L= 5.5 km. T= 6.8 hrs.		Date: 9/13 L= 5.0 km. T= 9.1 hrs.
	8.2			Date: 9/10 L=15.6 km. T=13.9 hrs.	
Northumberland Dam →	9.0				*
	10.1	Date: 6/13 L= 13.0 km. T= 10.8 hrs.	Date: 9/10 L= 10.8 km. T= 13.5 hrs.		*Date: 9/13 L= 10.3 km. T= 7.2 hrs.
			Date: 9/10 L= 8.7 km. T= 8.7 hrs.		
Guildhall or →	23.2				
Lancaster Bridge	23.8	Date: 6/12 L= 9.3 km. T=10.0 hrs.		Date: 9/11 L= 8.7 km. T=12.8 hrs.	
	29.6				
Covered Bridge	32.5	Date: 6/12 L= 8.5 km. T=13.2 hrs.	Date: 9/11 L= 6.9 km. T=14.0 hrs.	Date: 9/11 L= 5.3 km. T= 9.9 hrs.	
	36.5				
[illegible]. Bridge	37.5				
	37.8				
Gilman Dam	41.0				

Scale (miles / km): 0 / 0, 3 / 1, 2, 6 / 3, 4, 9 / 5, 6, 12 / 7, 8, 15 / 9, 10, 18 / 11, 12, 21 / 13, 14, 24 / 15, 27 / 16, 17, 30 / 18, 19, 33 / 20, 21, 36 / 22, 23, 39 / 24, 25

Table 2

Low Flow Time of Travel

Flow Data

Time & Date of Reading	North Stratford, N.H. Connecticut River		Dalton, N.H. Connecticut River		Stark, N.H. Upper Ammonoosuc River	
	cms	(cfs)	cms	(cfs)	cms	(cfs)
9-9-73 8am	33.2	1173	70.1	2476	7.3	258
4pm	24.1	854	70.1	2476	6.8	241
9-10-73 8am	18.8	665	44.3	1565	6.5	229
4pm	13.7	482	42.8	1510	6.3	222
9-11-73 8am	10.6	375	38.4	1355	6.0	213
4pm	10.1	355	34.4	1214	5.9	210
9-12-73 8am	9.9	351	20.4	720	6.0	213
4pm	9.7	342	22.4	790	5.9	210
9-13-73 8am	9.4	333	24.1	850	5.9	207
4pm	9.2	324	24.1	850	5.8	204

APPENDIX D

Sediment Composition of Upper Ammonoosuc and Connecticut Rivers From Groveton to Gilman, N.H. Sept. 19-20, 1973

Bottom samples were taken with a Petersen Dredge on the Upper Ammonoosuc and Connecticut Rivers between Groveton and Gilman, New Hampshire, approximately 48 river kilometers, to determine depth and area of any paper waste sludge deposits downstream of Groveton Paper Mills.

Sediment samples for COD and volatile solid analysis were obtained at the following stations:

GA01 - Upper Ammonoosuc River control station, Groveton, N.H.

GA03 - Upper Ammonoosuc River, Groveton, N.H.

GC06 - Conn. River, upstream Northumberland Dam, Guildhall, Vt.

GC6.3 - Conn. River, between Guildhall and Lancaster Bridge

GC6.5 - Conn. River, between Guildhall and Lancaster Bridge

GC7.5 - Conn. River, between Lancaster Bridge and Covered Bridge

GC09 - Conn. River, upstream Gilman Power Station Dam

Four bottom samples were collected for studies of oxygen uptake rates at the Needham Laboratory from the following stations:

GA01 - Upper Ammonoosuc River control station, impoundment upstream of Groveton, N.H.

GA03 - Upper Ammonoosuc River, north side, Groveton, N.H.

GA03 - Upper Ammonoosuc River, south side, Groveton, N.H.

GC06 - Conn. River, west side, Guildhall, Vt.

On Sept. 19, 1973, the Upper Ammonoosuc River was full bank to bank, averaged 30.5 m wide and 2-4 m deep. Approximately 30 sediment samples for field analysis were dredged between the mouth of the Upper Ammonoosuc River to 450 meters downstream of the Railroad Bridge in Groveton where fast shallow water prevented further progress upstream. Small to large stones covered the bottom in this area that was scoured by fast water.

Throughout its length, except for small back-eddy areas and areas of heavy vegetation along the banks, the bottom was composed of clean mud, sand, sand and gravel, and small and large stones.

Foul paper waste sludge filled the Petersen Dredge in a few small back-eddy areas and under heavy vegetation growing along the river banks. These areas, however, comprised only a small percent of the total bottom area.

A transect of three sediment samples at Station GA03 in the Upper Ammonoosuc River contained fine sand on the south side and middle of the River, but paper waste sludge was present in the fine sand from the north side that had vegetation along the bank.

On the Connecticut River, from the mouth of the Upper Ammonoosuc River, Groveton, N. H. to the Gilman Power Station Dam, 28 bottom samples were dredged for field analysis of sediment composition.

The river ranged from 75 - 90 meters wide and 2.5-3 meters deep. Bottom sediment consisted mostly of fine sand with a few small areas of paper waste in back-eddies and submergent vegetation along the banks.

Sediment Composition
(Field Analysis)
Upper Ammonoosuc and Connecticut Rivers
Sept. 19-20, 1973

Stations	North	Middle	South
Upper Ammonoosuc River			
GA01 (Control)		Mud, Sand	
Transect 1	Stone	Stone	Stone
2	Stone	Stone	Stone
3	Stone	Sand	Stone
4	Sand	Gravel	Sand
5	Gravel, Sand	Sand	Sand
6	Sand	Hard Mud	Sand
7	Sand	Sand	Gravel, Sand
8	Sand	Hard Mud	Sand
9	Sand	Sand	Sand
GA03	Sand, Sludge, Paper	Sand	Sand
Connecticut River	Vermont Side	Middle	N. H. Side
Transect 1	Sand	Sand	Sand
2	Sand	Sand	Sand
3	Sand	Sand	Sand
4	Rock, Sand	Sand	Paper, Sludge
GC06	Silty, Sand	Sand	Silty Sand
GC6.3	Sand	Sand	Sand
GC6.5	Sand	Sand	Sand
GC7.5	Sand	Sand	Sand
Transect 5	Sand	Stone	Boulders
GC09		Silty Sand	

APPENDIX E

Benthic Oxygen Demand
Groveton, N. H.

Benthic Oxygen Demand determinations were performed on four sediment samples collected from the Upper Ammonoosuc River and the Connecticut River.

The SOD results listed in Table I are calculated from the following equation:

$$SOD\ (g\ O^2/d/m^2) = \frac{(O_i - O_f)\ (V)}{(t)\ \ (SA)}$$

O_i= D.O. initial (mg/l)

O_f= D.O. final (mg/l)

V= Volume confined H_2O m^3 (.05192)

t= Time in days

SA= Surface area of confined sediment m^2 (.1858)

Figure I gives the linear description for the change in dissolved oxygen for a specified period of time for each of the four sample stations.

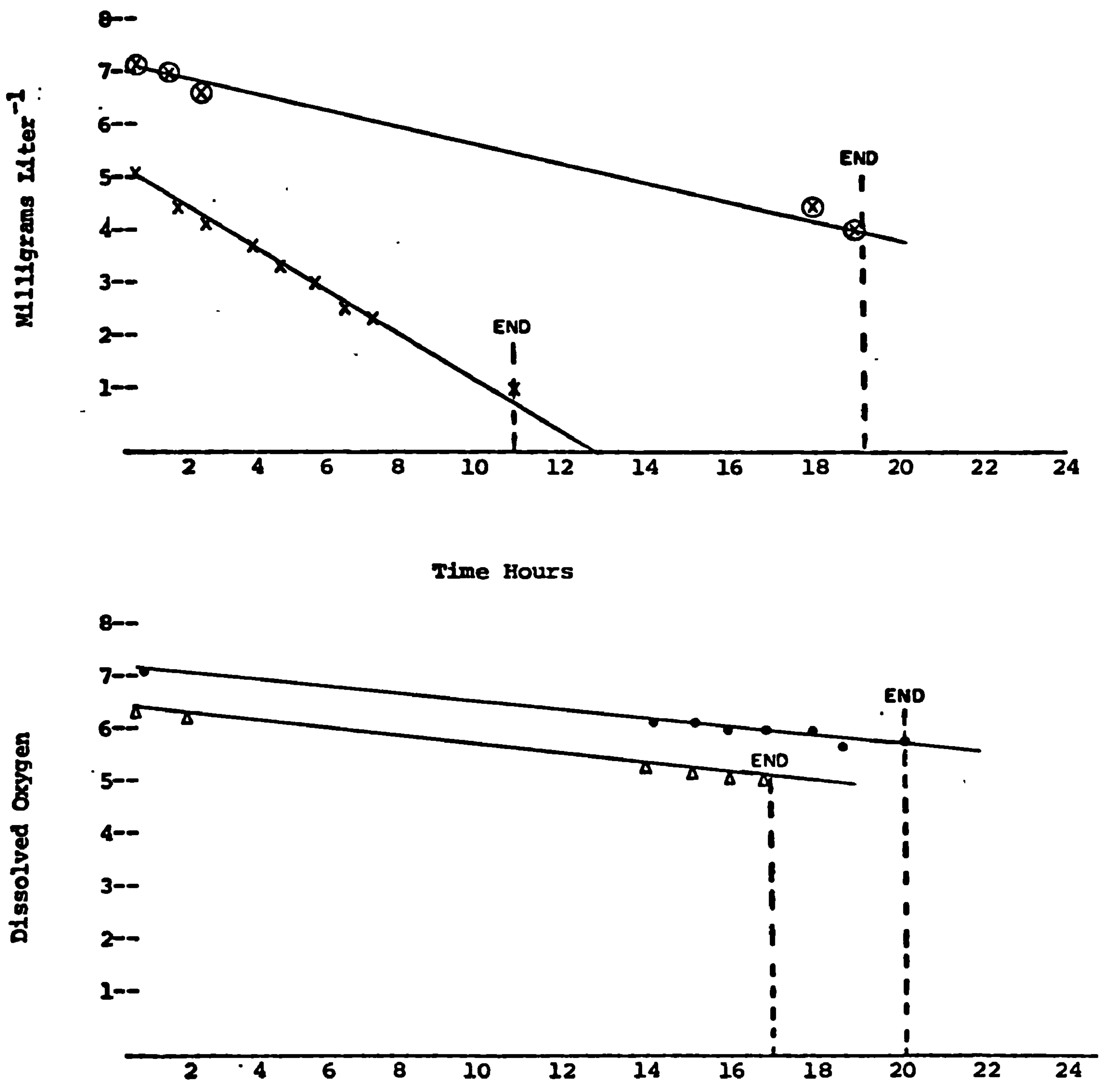
Table I

Sediment Oxygen Demand (SOD)

Station Number	Lab Number	Substrate Type	SOD g $0^2/d/m^2$
GA-01 Control	36861	Muddy Sand	0.5
GA-03 S. Bank	36866	Fine Sand	0.9
GA-03 N. Bank	36867	Sludge Mixed with Sand	2.6
GC-06 Conn. R.	36860	Silty Sand	0.6

Figure I

D.O. Change Per Period Time



LEGEND

- x—x GA-03 N. BANK
- ⊗—⊗ GA-03 S. BANK
- Δ—Δ GC-06 CONN. R.
- •—• GA-01 CONTROL

APPENDIX F

GROVETON PAPER COMPANY

CONNECTICUT RIVER

I Introduction

In September of 1973 a water quality survey of the Upper Ammonoosuc and Connecticut Rivers was carried out in the vicinity of Groveton, New Hampshire in support of the process of the permits branch for granting a discharge permit to Groveton Paper Co. A report covering the details and results of the sampling program is being written by the Technical Studies Section, Surveillance and Analysis Division. This report centers on the mathematical model which was developed utilizing the data from the survey, in a Streeter-Phelps BOD/D.O. analysis.

II Location data

River mile	Point of Interest
325.4	Groveton Paper Co.
322.8	Confluence of U. Ammonoosuc & Connecticut River
319.4	Dam at N. Umberland
311.3	Bridge at Guildhall
305.5	Covered Bridge
300.2	Gilman Dam

III Time of travel estimates

Two dye studies were conducted, one at flows ranging from 2200-6000 cfs at Dalton in July, 1973, and one at flows ranging from 720-1500 cfs at Dalton in September, 1973.

Velocity was assumed to be related to flow rate by the following equation: $V = AQ^B$

Where: V = velocity, miles per day (mpd)

A = Constant

B = Constant

Q = Flow cubic feet per second (cfs)

Necessary conversion factors are used in determining "A" to change units from ft/sec to miles/day

A & B were determined by substituting the survey values for V and Q and solving simultaneously. Table I contains the calculated constants.

IV Reaeration Coeficients

$$K_2 = \frac{(D_L U)^{1/2}}{H^{3/2}}$$

D_L = diffusivity = $.81*10^{-4}$ ft/hr

U = velocity (ft/hr)

H = depth (ft)

Cross-sections provided depths which were assumed constant at the low flow regime due to dam backwaters Table 1 contains low flow coefficients. Dam reaeration used short reaches and high rates to provide a specified D.O. uptake.

V Decay coefficients

Long term BOD samples were used to determine the deoxygenation coefficients. Thomas has proposed a simple approximation for the constants of the BOD curve based on the similarity of two functions $(1-e^{-kt})$ and $kt(1 + \frac{kt}{6})^{-3}$ which are the same for their expansion through the first 3 terms (See Water Supply and Waste-water Disposal, Fair & Geyer, pg. 524). Therefore the BOD equation $y = L\ (1-e^{-kt})$ can be approximated by $Y = L\,kt\,\left(1 + \frac{kt}{6}\right)^{-3}$ which takes the straight line form

$$\left(\frac{t}{y}\right)^{\frac{1}{3}} = (KL)^{-\frac{1}{3}} + \left(K^{2/3}/6L^{1/3}\right)t.$$

We can now use the classical regression line of Y on X of

$$Y = a + bx$$

where $Y_i = \left(\frac{t}{y}\right)_i^{1/3}$ $i = i^{th}$ observation in N observations

$$X_i = t_i$$

so that we can calculate from Laboratory data

$$b = \frac{N\sum_i X_i Y_i - \sum_i X_i \sum_i Y_i}{N\sum_i X_i^2 - \left(\sum_i X_i\right)^2}$$

$$a = \frac{\sum Y_i - b\sum X_i}{N}$$

Now again from the BOD equation

$$a = (KL)^{-1/3}$$

$$b = \left(\frac{K^{2/3}}{6L^{1/3}}\right)$$

we can solve for K (still to the base "e") so that

$$K = \frac{6b}{a}$$

and the ultimate BOD

$$L = \frac{1}{Ka^3}$$

Table 1 contains a list of decay rates used at low flow.

VI Loads and Flows

(a) Groveton Paper Co., Flow = 12.5 MGD, BOD_5 = 1000 #/day - 8000 #/day in increments of 1000 #/day, D.O. = 5.0 mg/l

(b) Georgia Pacific Paper Co., Flow = 2.5 MGD, BOD_5 = 1100 #/day, D.O. = 5.0 mg/l

(c) Background Water:

(1) Upper Ammonoosuc above Groveton Paper Co., 7-day - 10-yr Low Flow = 41 cfs, D.O. = 8.65 mg/l

(2) Connecticut River above the Upper Ammonoosuc River, 7-day, 10-yr Low Flow = 243 cfs, D.O. = 8.05 mg/l

(3) Connecticut River tributary waters, Q = 24. cfs, BOD_5 = 1324 #/day, D.O. = 8.0
24. cfs added at mile points 319.4, 311.3, 305.5, and 300.2

(4) Connecticut River at Dalton, Q = 7-day, 10-yr Low Flow = 370 cfs, BOD, and D.O. determined by the model.

EPA biologists found little or no sludge deposits, so the analysis thus far uses no sludge demand.

VII Results

Two alternative discharge locations were studied, one at the present location, river mile 325.4, and the second at the confluence of the Connecticut River and the Upper Ammonoosuc River, river mile 322.8. Because of a higher amount of dilution water available, the confluence discharge had a much lower local impact on dissolved oxygen, and the important points of consideration became the N. Umberland dam and the Gilman dam. Figure 3 shows predicted dissolved oxygen profiles for three different loads (2000, 4000, and 6 000 #/day) discharged at mile 325.4, at the present discharge point. Figure 1 shows a plot of D.O. vs load at the three critical points for D.O., confluence, N. Umberland dam, and the Gilman dam. The load at the point where the plot crosses the 75% D.O. saturation line, is the predicted allowable load. A load greater than 1000 #/day would violate D.O. criteria at the confluence. A load greater than 4400 #/day would violate D.O. criteria at the N. Umberland dam. A load of more than 5000 #/day would violate D.O. criteria at the Gilman dam.

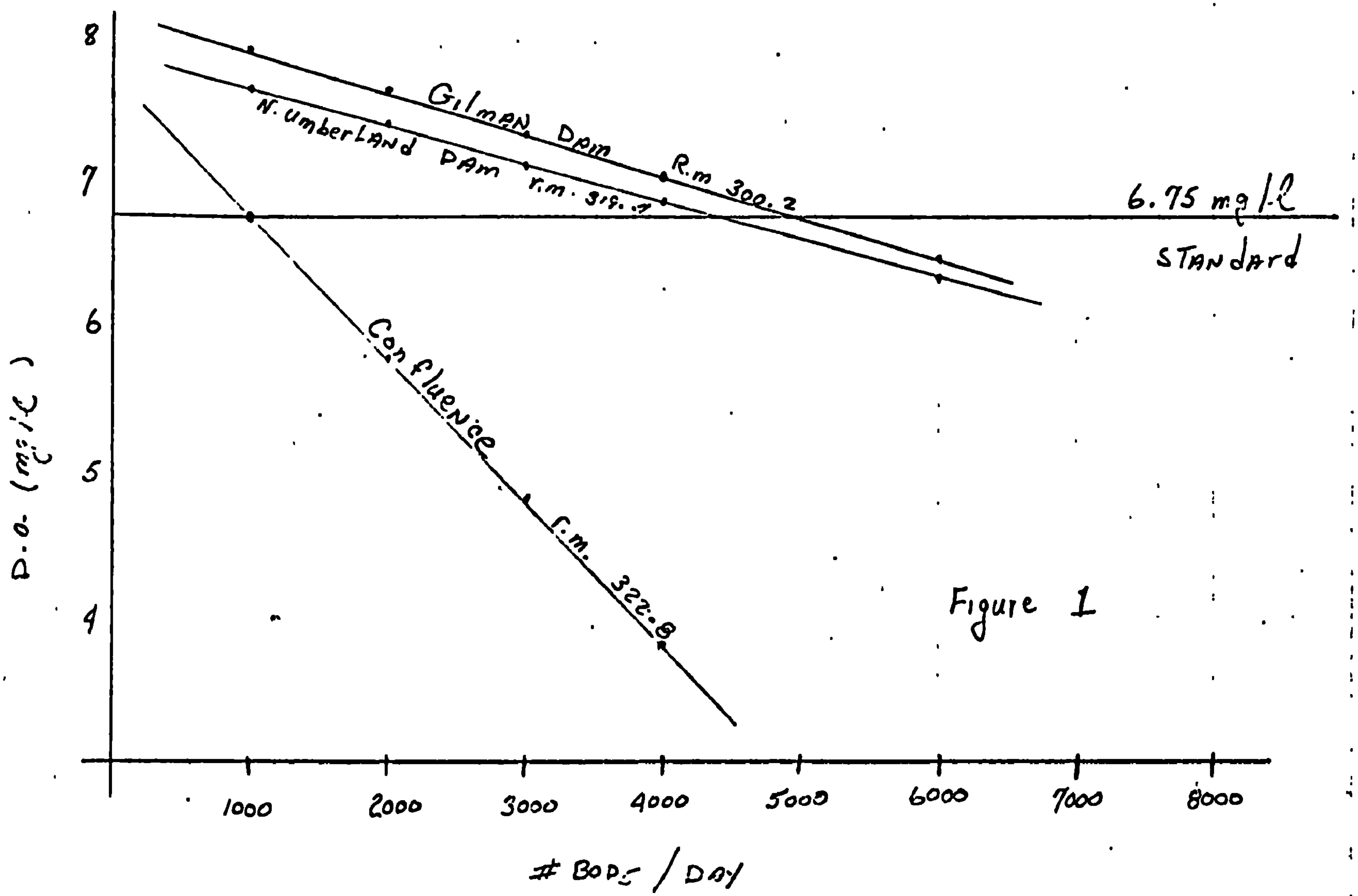
Figure 2 shows the D.O. profile for a discharge at the confluence, river mile 322.8, with figure 4 showing plots of load vs D.O. for the N. Umberland dam and the Gilman dam. A load greater than 5800 #/day would violate D.O. criteria at Gilman dam, while a load greater than 9000 #/day would violate D.O. criteria at both N. Umberland dam and Gilman dam.

The allowable load for a discharge at Groveton required to meet stream standards at the North Umberland Dam is 4400 #/day, BOD_5, while if the discharge was located at the confluence, the allowable load would be 9000 #/day BOD_5. The reason for this large difference is that stream standards require a minimum D.O. of 6.75 mg/l at 20°C and saturation is 9.02 mg/l. This allows the utilization of 2.27 mg/l D.O. for assimilation of wastes. By the time a discharge from Groveton reaches the confluence, and mixes, 1.69 mg/l of the usable D.O. deficit has been utilized, allowing only 0.58 mg/l additional deficit for decay. If the discharge is located at the confluence, after mixing, the D.O. deficit is only 1.11 mg/l, leaving 1.16 mg/l deficit for additional assimilation above N. Umberland Dam. The key to meeting standards at the N. Umberland Dam is the amount of D.O. deficit available between the confluence and the dam. For a discharge at Groveton, only 0.58 mg/l deficit is available, while for a discharge at the confluence, 1.16 mg/l deficit is available, exactly twice as much as for the Groveton discharge. Thus, the allowable load is almost exactly double for the confluence discharge.

Mile	Veolcity Coef. A(mpd)	B	Decay Rate Ki(e)	Re-oxygenation K2(e)	Temp oC	Flow cfs
340	.0473	.96	.110	.10	20.	41.
325.4	.0473	.96	.110	.85	20.	41.
322.8	.0336	.873	.150	.30	20.	284.
319.4	1.26	.323	.160	69.	20.	308.
319.3	1.26	.323	.160	.46	20.	308.
311.3	.0745	.678	.150	.38	20.	332.
305.5	.394	.414	.120	.20	20.	356.
300.2	.785	.460	.25	69.	20.	370.
300.1	.785	.460	.25	.30	20.	370.

Basic River Parameters Used at Low Flow

Table 1



D.O. (mg/l)
8
7
6
5
4
Gilman Dam R.m 300.2
N. Umberland Dam r.m. 319.1
6.75 mg/l standard
Confluence r.m. 322.8
1000
2000
3000
4000
5000
6000
7000
8000
BOD5 / DAY

Figure 1

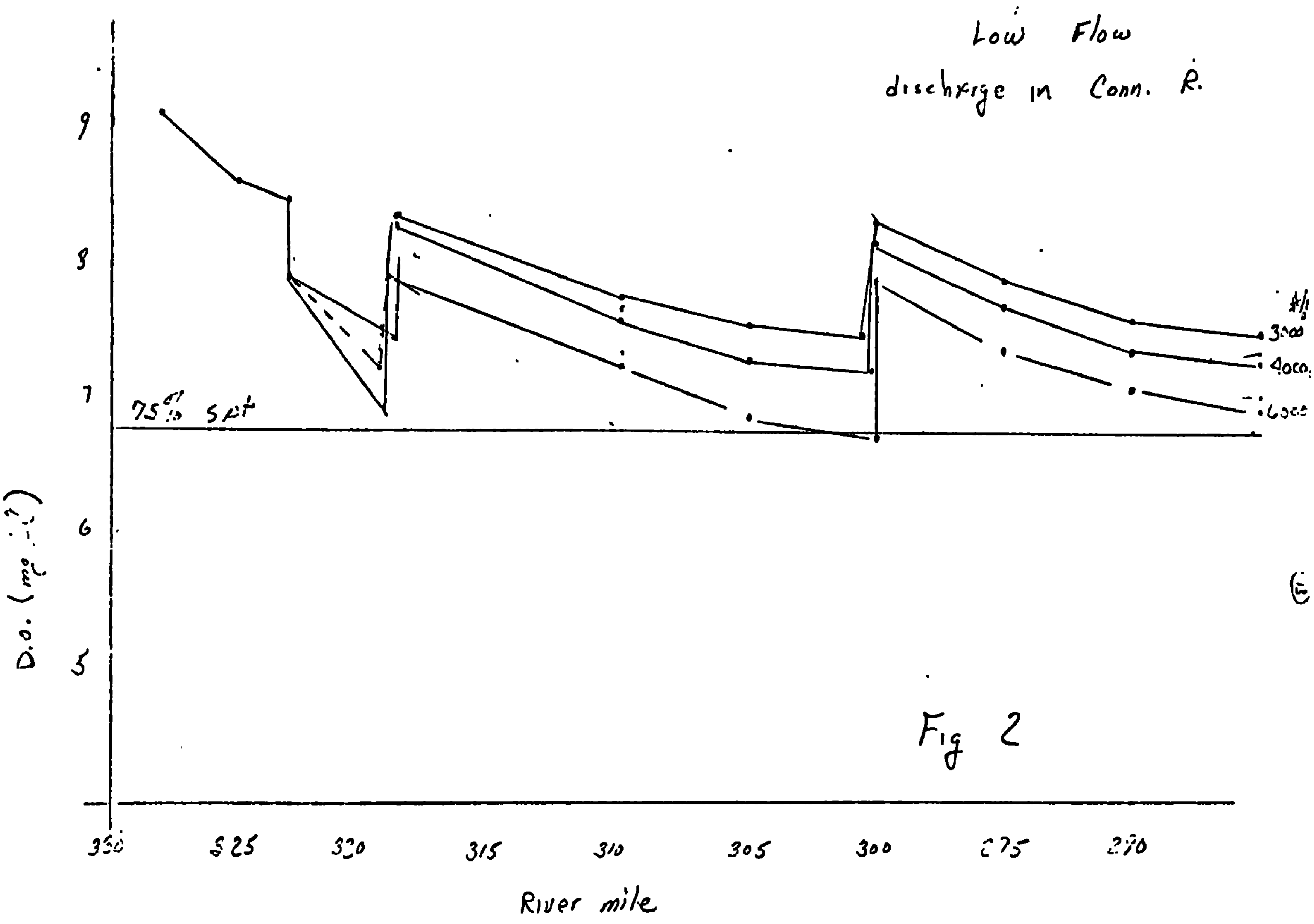
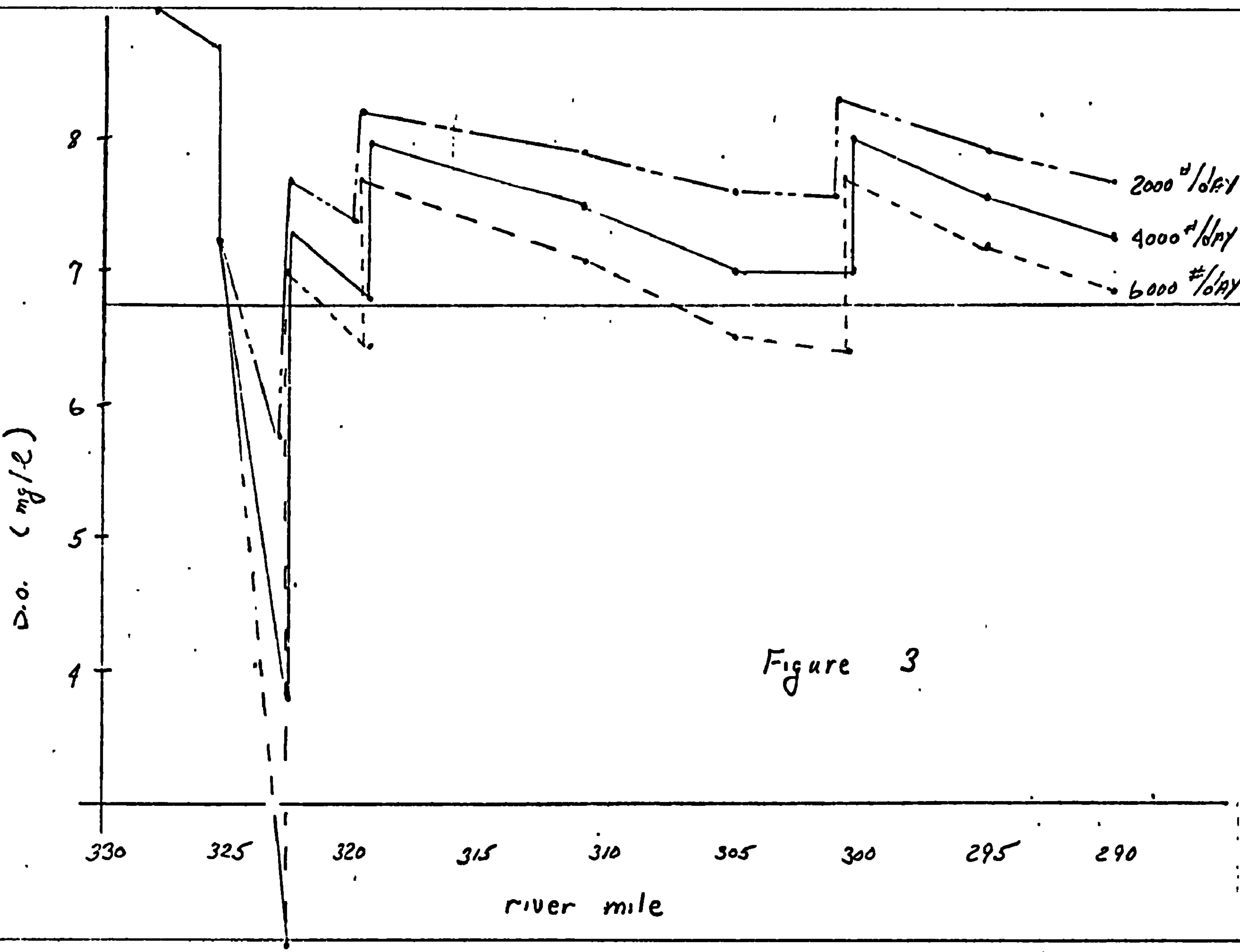
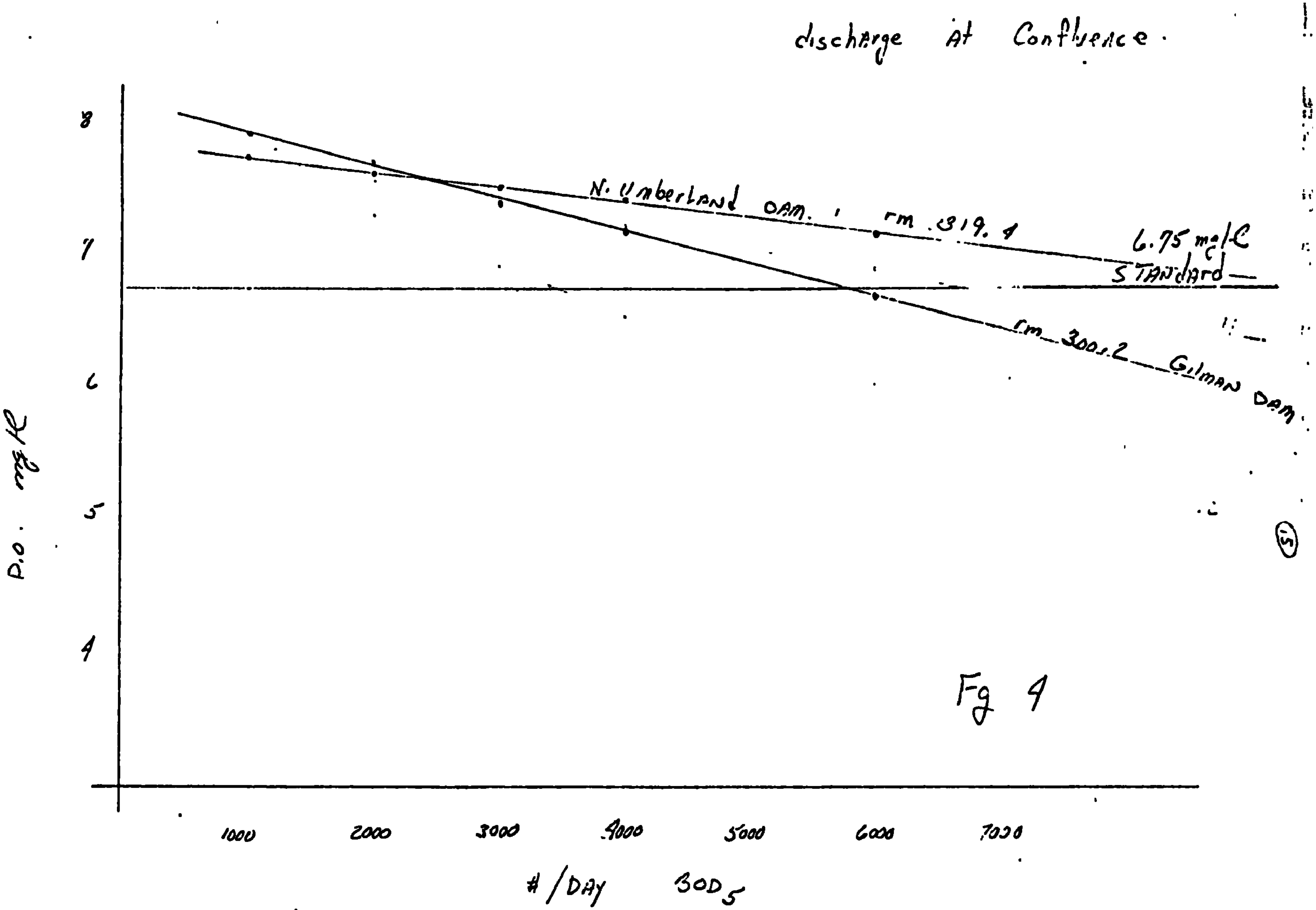

Low Flow
discharge in Conn. R.
9
8
7
6
5
D.O. (mg/l)
75% sat
3000
4000
6000
325
320
315
310
305
300
River mile

Fig 2



8
7
6
5
4
D.O. (mg/l)
330
325
320
315
310
305
300
295
290
river mile
2000 #/day
4000 #/day
6000 #/day

Figure 3


discharge at Confluence
8
7
6
5
4
D.O. Mg/l
N. Umberland DAM. , rm 319.4
6.75 mg/l
STANdard
rm 300.2 Gilman DAM
1000
2000
3000
4000
5000
6000
7000
#/DAY BOD5

Fg 4