WATER RENOVATION USING DEEP NATURAL SAND BEDS

By:

Donald B. Aulenbach, Ph.D.
Nicholas L. Clesceri, Ph.D.
Stephen Beyer
Louis Hajas
Rensselaer Polytechnic Institute
Troy, New York 12181

T. James Tofflemire, D. Eng.
Senior Research Scientist
Research Division
New York State Department of
Environmental Conservation
Albany, New York 12233

Presented at
The 30th Annual Purdue Industrial Waste Conference
W. Lafayette, Indiana
May 6, 1975

FWI Report 75-2

Abstract

WATER RENOVATION USING DEEP NATURAL SAND BEDS

by

Donald B. Aulenbach
Nicholas L. Clesceri
T. James Tofflemire
Stephen Beyer
Louis Hajas

Lake George is a beautiful recreational lake in New York whose waters are used for drinking without any treatment by many lake residents. In order to preserve its high quality, no discharges of wastes, treated or not, are permitted to the lake or any tributary streams thereof. To accomplish this goal, "complete" treatment was provided when the Lake George Village sewage treatment plant was constructed, with operation beginning in 1939. The plant consists of conventional primary sedimentation, trickling filters, and secondary sedimentation, but the final effluent is discharged without chlorination onto natural delta sand beds whose depths reach 28 m (92 ft).

Until April 1973, no knowledge was available as to the ultimate residence of the liquid. Investigations at that time revealed a considerable seepage from the banks of the flood plain of West Brook which ultimately flows into Lake George. This has since been identified as the effluent from the sewage treatment plant. Studies have been made of the quality of this seepage and its effects upon West Brook.

Wells have been placed between the sand beds and West Brook to trace the contaminant transport through the sand. Analysis has shown that aerobic conditions persist in the ground water between the sewage treatment plant and West Brook. Coliforms, BOD, ammonia, organic nitrogen, and phosphate are completely removed before the effluent reaches West Brook 600 m (2000 ft) away. Chlorides are not diminished and nitrates are increased. The nitrate increase represents oxidation of ammonia and organic nitrogen, but a nitrogen balance could not be established.

The effects of the seepage upon West Brook were also determined. The dissolved solids, alkalinity, chlorides, and nitrates in West Brook were increased in passing the area where the seepage enters the stream. There was no measurable change in phosphate concentration. The quality of the water in West Brook was not degraded below acceptable drinking water standards. There was little detectable effect upon Lake George with the exception of a measurable increase in nitrate content near the discharge of West Brook.

The natural delta sand filter of the Lake George Village sewage treatment plant appears to be providing adequate purification of the applied effluent to allow reuse of the water for most purposes.

WATER RENOVATION USING DEEP NATURAL SAND BEDS

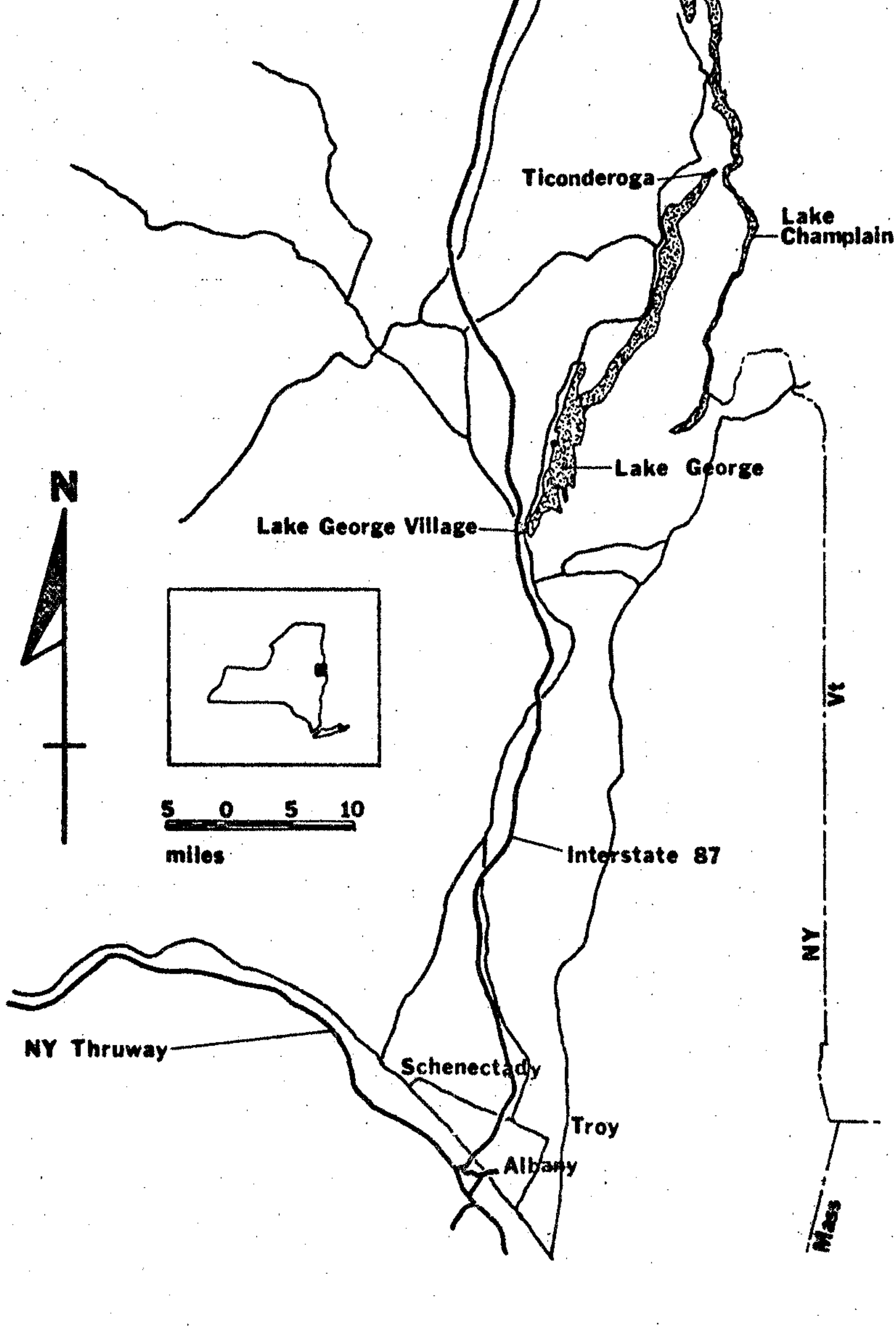
INTRODUCTION

Lake George is a beautiful recreational lake noted for its clear water and tree-lined shores. The lake is located in the southeastern portion of the Adirondack Forest Preserve in the State of New York (Figure 1).

The beauty of Lake George has encouraged tourism to this location. Initially, it attracted people from the south including the New York State Capital District and New York City. Thus, the largest center of population in the drainage basin is Lake George Village at the southern end of the lake (Figure 2). More recently, a large motel population has sprung up along the southern and western shores of the lake with the major concentration from Lake George Village to Bolton Landing. The southeastern shore is more predominantly individual residences and marinas. With the construction of the Adirondack Northway, Interstate 87, during the 1960's, the influx of population to the Lake George area increased markedly.

Concern for the preservation of Lake George has existed for many years with action promulgated by the Lake George Association. Through their efforts the lake was given a special AA classification[3] thus allowing it to be used as a public drinking water supply after treatment with only chlorine[7]. Legislation was enacted prohibiting the discharge of any wastewaters, treated or untreated, into the lake or into any waters discharging into the lake[8].

In order to meet these restrictions, the Village of Lake George initiated a sewage treatment plant in 1936. The regulation restricting the discharge of wastewater into the drainage basin area was interpreted to mean surface discharges. This allowed the use of many septic tanks around the area. It also permitted treated effluent from the treatment plant to be discharged into the

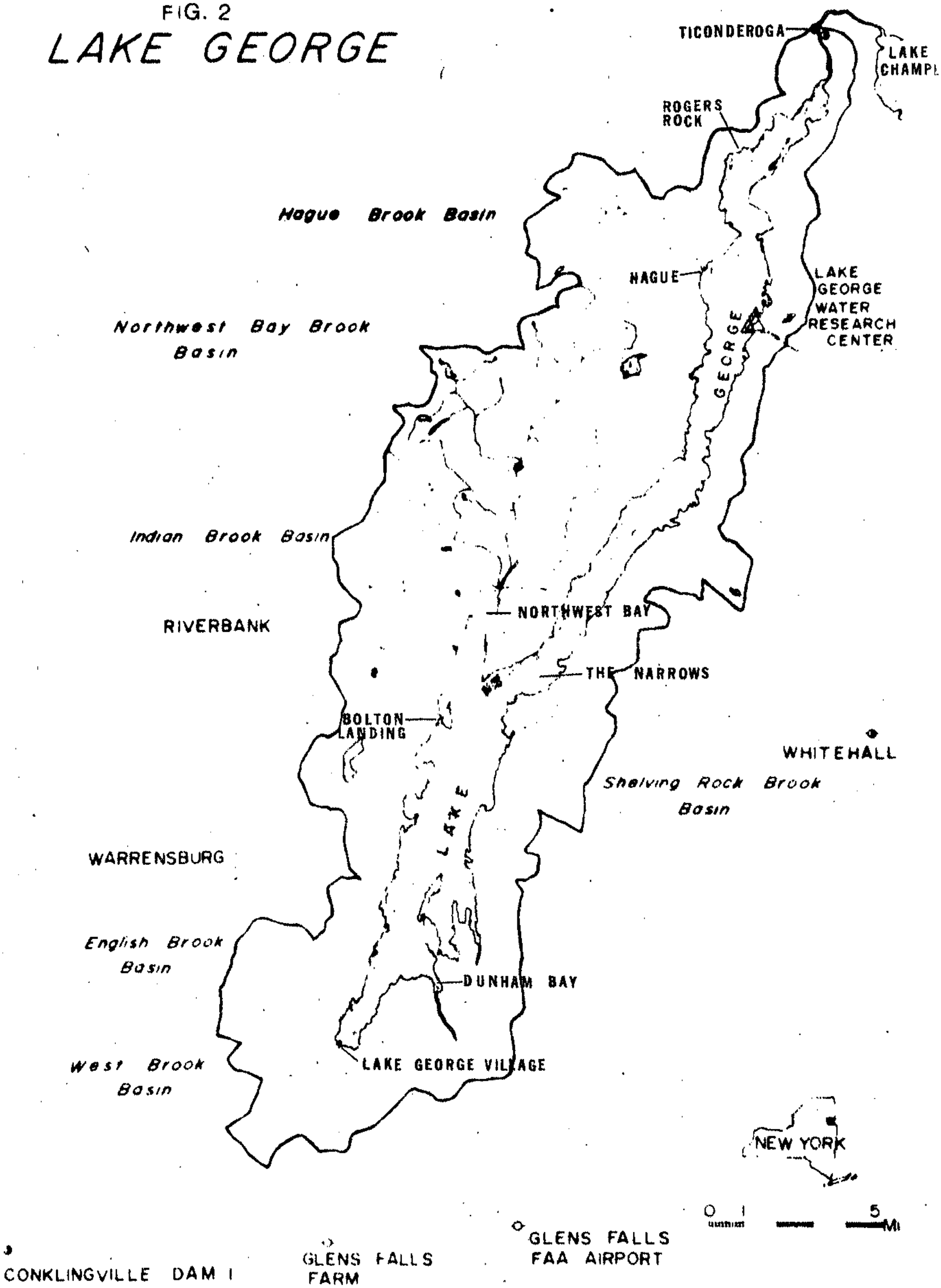


LOCATION OF LAKE GEORGE, N. Y.

FIGURE 1

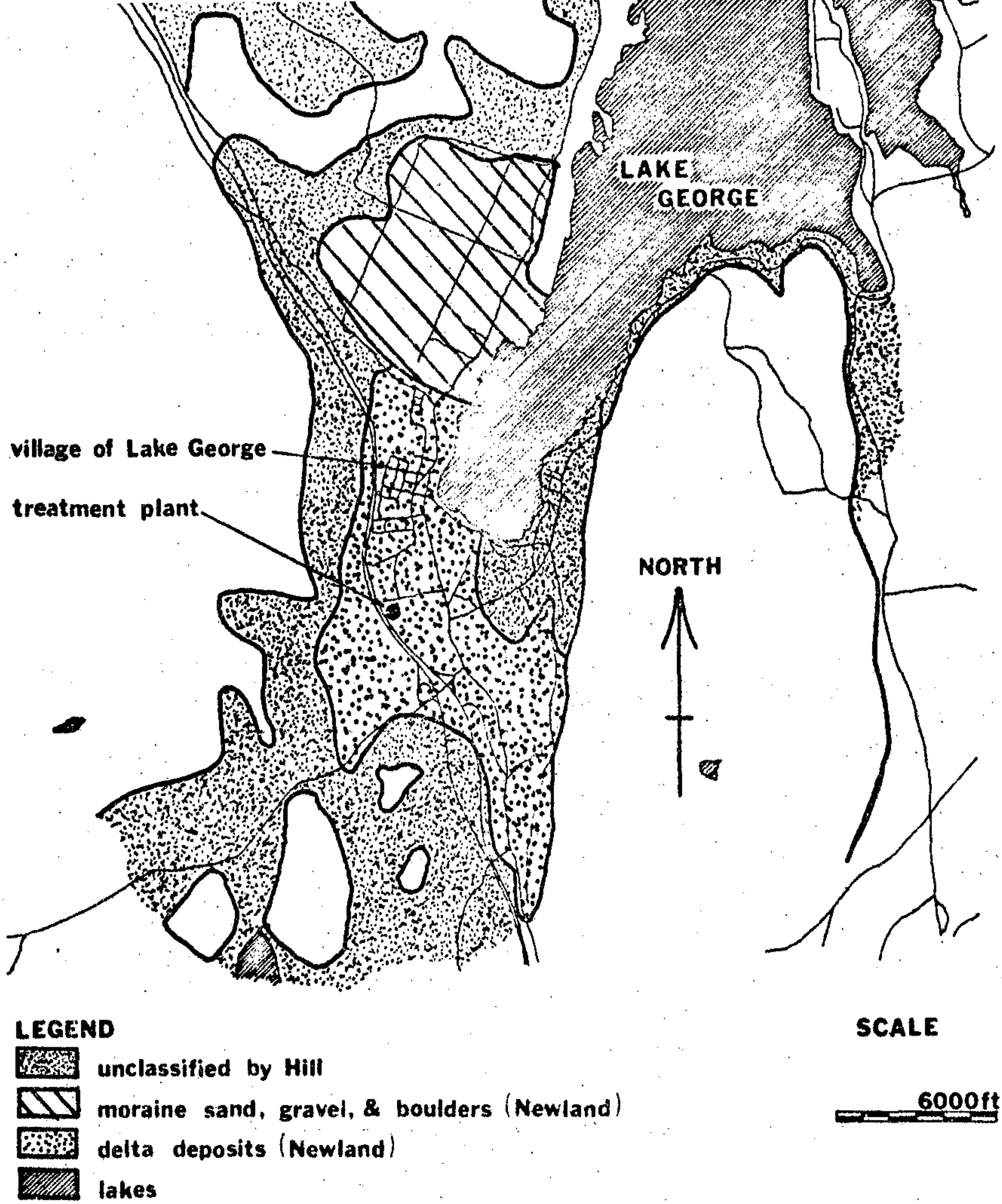
FIG. 2

LAKE GEORGE



ground. In general, the Lake George watershed is underlain by rock consisting of pre-Cambrian gneisses with valleys underlain by lower Paleozoic strata[5]. However, in a few areas there are some natural delta sand deposits created by outwash from the receding glaciers. One such delta sand deposit is located at the southwest corner of Lake George as shown in Figure 3[5,6] and the treatment plant was constructed here to utilize this sand as an infiltration area for the treated effluent. The sewage is collected at a central pumping station along the shore of the lake and is pumped through a force main with an intermediate pumping station to the sewage treatment plant. This force main is approximately 1.6 km (1 mile) long with a vertical rise of approximately 55 m (180 ft). More recently, an additional sewer district was created to serve the wider area of the Town (township) of Lake George. This is collected in what is known as the Caldwell Sewer District and is conveyed to the plant via another force main.

The treatment plant shown in Figure 4 was initially comprised of units built in triplicate. The basis for this design was that the flow during the summer tourist season was approximately three times the winter flow. Although the flows have increased from the original design, the ratio of summer to winter flow has remained approximately the same. The flows from the two force mains are measured through individual Parshall flumes, after which the flows are combined with the recycle from the trickling filter effluent. The flow is divided into three settling tanks, and the settled effluent is passed through one of three trickling filters. One trickling filter is a fixed nozzle type which is covered and used exclusively in the winter, whereas the other two are standard high rate rotary arm trickling filters. After secondary sedimentation, the unchlorinated effluent is passed onto the natural delta sand beds for infiltration into the soil. Originally, there were six sand beds in what is now called the north sand bed area. These have been expanded with one bed being added in 1947,



GEOLOGY OF THE SOUTHERN LAKE GEORGE DRAINAGE BASIN

FIGURE 3

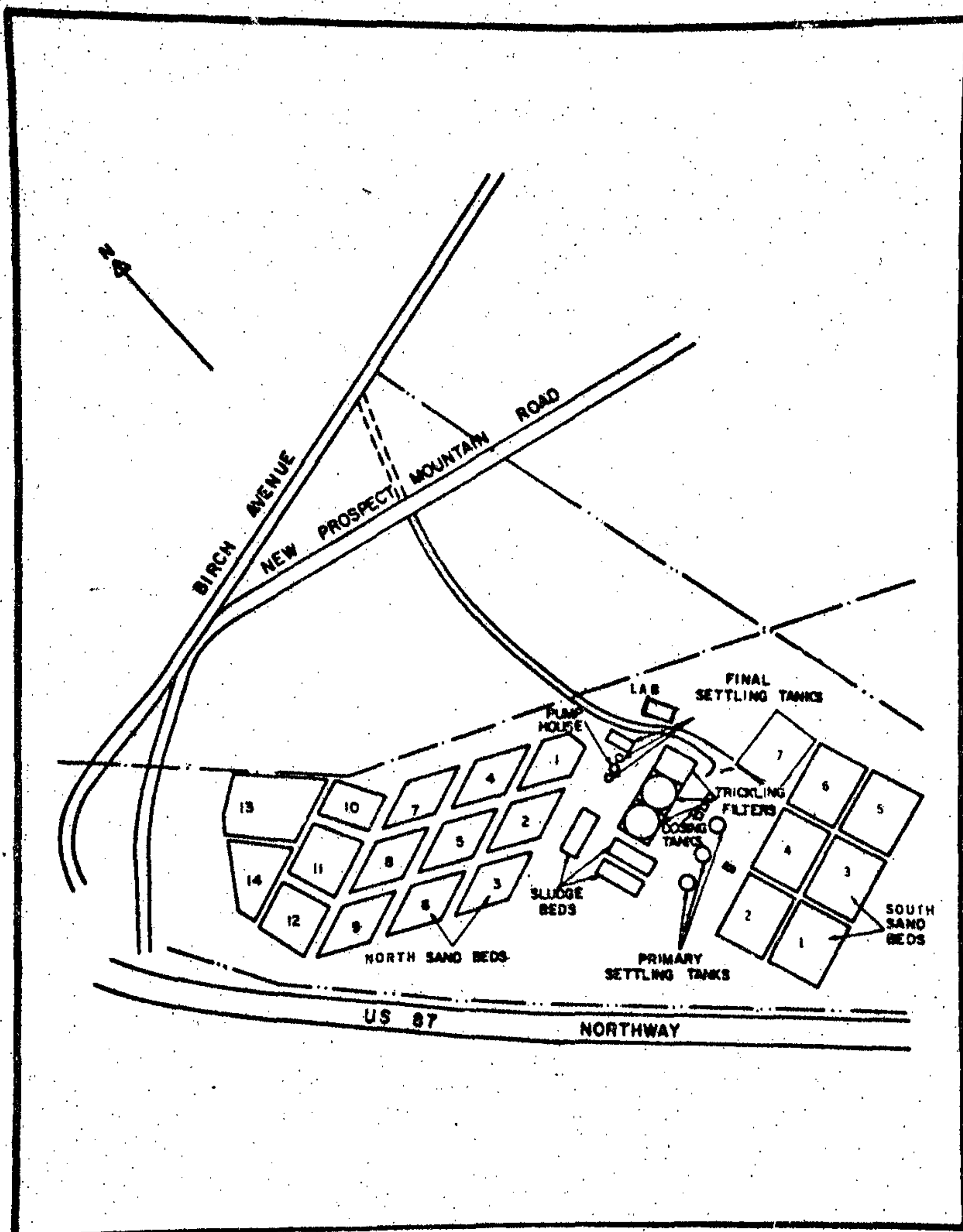


FIGURE 4

LAKE GEORGE VILLAGE SEWAGE TREATMENT PLANT two in 1950, three in 1956, and the last two in this area in 1965, bringing the total in this area to the present 14 beds. The first six beds in the southern section were added in 1965 and the last bed in this area was added in 1970. The combined area of the sand beds is presently 2.6 ha (6.4 acres).

Present flows reach slightly over 3,800 m^3/day (1 mgd) during the summer tourist season, whereas the winter flows are in the order of 1,100 m^3/day (0.3 mgd). Normal operation of the sand beds is to dose one north and one south bed during the day and to direct the flow to another similar pair of beds at night. Most beds drain to dryness in 0.5 to 2 days. Depending upon the need for the beds, they may be flooded several times before they are allowed to dry more thoroughly for reconditioning which involves removing the surface mat by scraping or raking followed by releveling.

The engineer who designed the treatment system described it as "complete treatment..... for a small community. The final effluent becomes ground water which in all probability seeps eventually to some water course as a highly purified liquid which cannot be identified as a sewage effluent."(9) The studies reported herein were conducted in order to determine if effluent polishing using infiltration beds can achieve this degree of purification.

PREVIOUS STUDIES

Rensselaer Polytechnic Institute (RPI) became involved in studies at Lake George during 1967. This resulted in the creation of the Rensselaer Fresh Water Institute at Lake George. One of the concerns of the research being conducted at Lake George included the sources of nutrients being discharged into the lake. Potentially, the effluent from a treatment plant could represent a large point source of nutrients which could be controlled. Thus, studies were begun by RPI in 1968 to evaluate the ability of the Lake George Village sewage treatment plant system to renovate the wastewater with particular concern for nutrients which could ultimately reach the lake. Initial efforts to identify or trace the flow of the treated effluent through the ground were thwarted by the fact that the ground water was in excess of 17 m (56 ft) below the surface of the ground, which is approximately the limit for a hand-driven well point. Instead, well points were driven at intervals of 5 ft (1.5 m) down to 25 ft (7.6 m) in three of the sand beds. Samples secured at the 5 ft (1.5 m) and 10 ft (3.0m) depths in north beds 11 and 13 indicated[1] that BOD, coliforms, and ammonia and organic nitrogen were almost completely removed in the top 10 ft of the sand beds, but that chlorides were not removed and that nitrates were increased, apparently due to the oxidation of the organic and ammonia nitrogen. Phosphorus removal appeared to be a function of previous use of the beds. Bed 11 had been in almost constant use and exhibited little phosphorus removal, whereas bed 13 had not been used for a period of nearly one year and exhibited significant phosphorus removal in the top 10 ft.

A further study was conducted[4] to determine the direction of the flow of the effluent in the ground by means of a resistivity survey. This method is based on the fact that sewage effluent containing more disssolved material would have a lower resistiviy (or greater conductivity) than the natural ground water. The results of this study are summarized in Figure 5. The arrow drawn on this map indicates the zone of lowest resistivity and the estimated direction of flow of the ground water from the treatment plant. It may be seen that the flow appears to be in a generally northerly direction from the treatment plant toward West Brook. Unfortunately, other complications prevented the determination of whether or not the low resistivity profile continued across West Brook or whether it ended at West Brook.

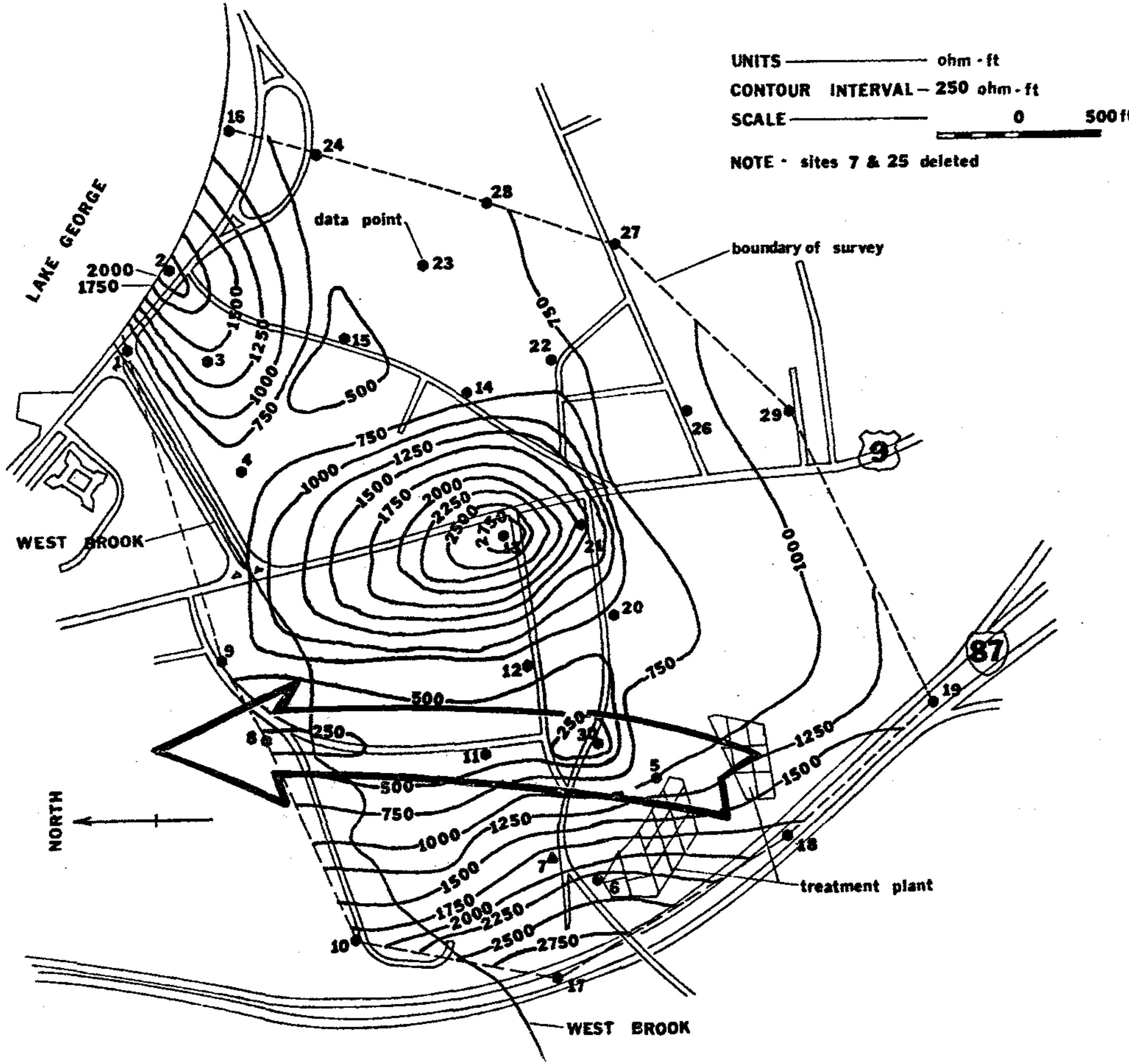


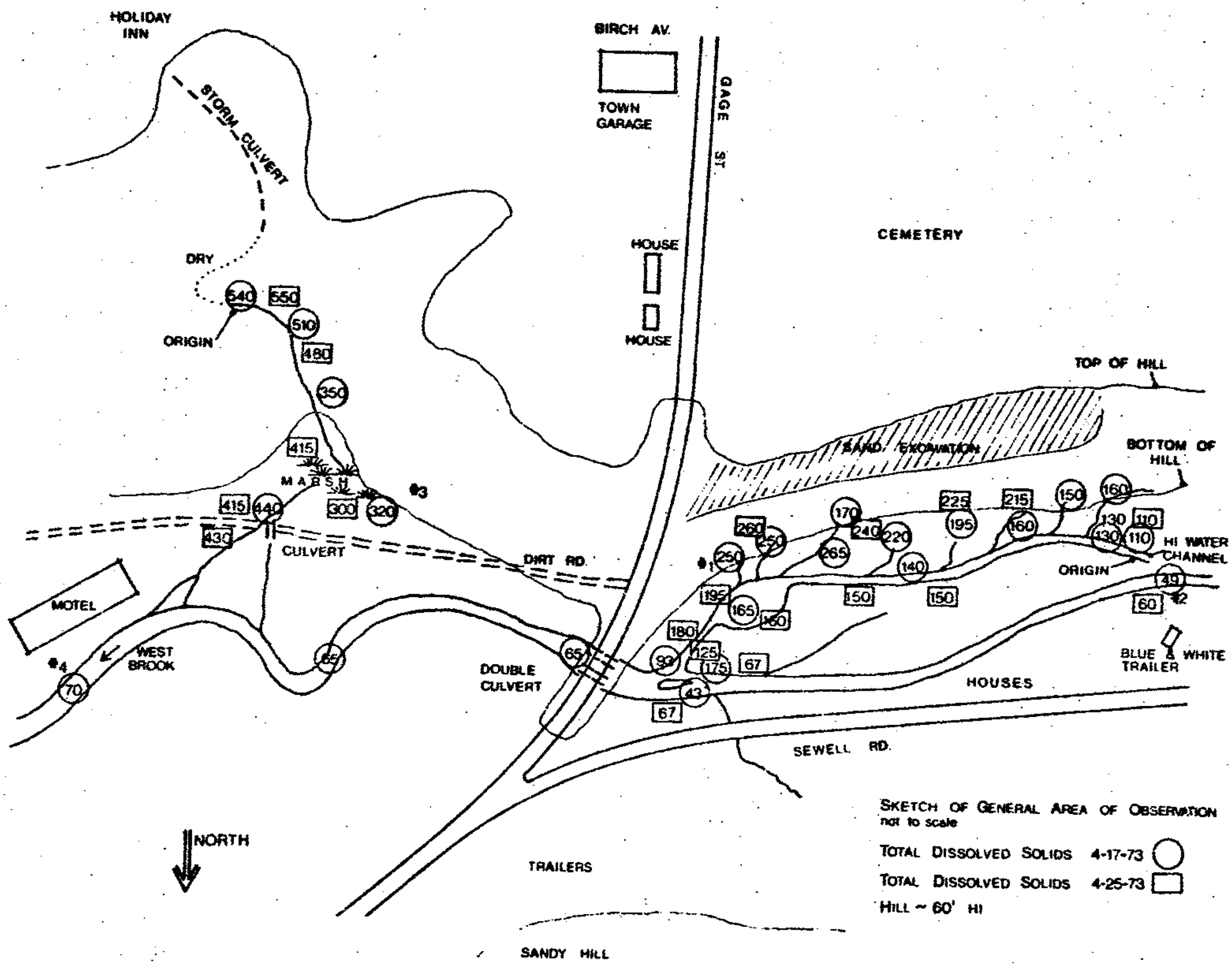
FIGURE 5

FLOW OF GROUND WATER BY RESISTIVITY STUDIES

The results of this study suggested a more thorough investigation of the area in and around West Brook as shown in Figure 6[2]. In the area west (upstream) from Gage Road, a significant amount of seepage was observed coming out of the bottom of the steep hill onto the flood plain of West Brook. Nearly all of this seepage is collected in a smaller stream which flows into West Brook just above the culvert under Gage Road. Conductivity measurements were made on two occasions as indicated in Figure 6 and were found to be high near Gage Road, tapering off to lower values proceeding west from Gage Road. East (downstream) of Gage Road, additional seepage was observed coming out of the base of the steep portion of the slope onto the flood plain of West Brook. Here, however, the seepage flowed through several small tributary channels into West Brook rather than through one main channel. Conductivity measurements showed high values east of Gage Road but extremely high values in the small drainage ditch from a side valley from the south. It was later discovered that the extremely high conductivity values found in the side valley could be attributed to the Town highway department garage which at one time stored highway salt in an open pile immediately above this drainage channel. Measurements in West Brook above and below the influence of both of these seepage areas indicated that there was a definite increase in the conductivity of the stream as it flowed past this area.

These results give a strong indication that the sewage effluent applied to the sand beds reappears as surface water along the south bank of West Brook and then flows into West Brook and ultimately back into Lake George. The Village of Lake George and many individual homes around the lake utilize Lake George for a water supply with no treatment except for chlorination of public supplies. Discovery of this complete recycle prompted studies to determine if the effluent at this point met drinking water standards.

FIGURE 6 OBSERVATION OF SEEPAGE ALONG WEST BROOK



PRESENT STUDIES

Figure 7 is a map showing the field study site and the overall relationship of the treatment plant to West Brook and Lake George. Since 1970, a continuous recording flow gage has been maintained in West Brook just east of Rt. 9, and a staff gage has been located west of the Northway. For approximately the same time, a weather station has been maintained at the Lake George Village sewage treatment plant, with an additional rainfall gage adjacent to the upstream staff gage. In November of 1974, recording flow gages were installed to measure the seepage above and below Gage Road. The seepage above was monitored just before it enters West Brook (Figure 8). Below Gage Road, some ditching was performed by the Town of Lake George to divert all of the seepage into one main channel which is then monitored for flow before it discharges into West Brook. Some additional seepage has been identified farther east of this location and some of this is collected in the drainage ditch below Gage Road. In addition, there is some seepage from the north bank of West Brook. A significant drainage channel crosses Sewell Street approximately opposite the seepage stream gage above Gage Road. This channel, however, passes under Gage Road and parallel to West Brook for a considerable distance until it enters West Brook just downstream from the downstream sampling station. Thus this seepage does not influence the quality of West Brook as measured in this area, but it does contribute to the flow as measured at the gaging station east of Rt. 9

In addition to the stream flow and seepage sampling locations, with the aid of New York State Dept. of Environmental Conservation, wells have been located in the area primarily between the sand beds and West Brook. These are identified in Figure 8. Wells 4, 7, and 10 are located outside of the projected influence of the treatment plant and were intended to serve as controls or measurements of the natural ground water in the area. Well 1 is located in

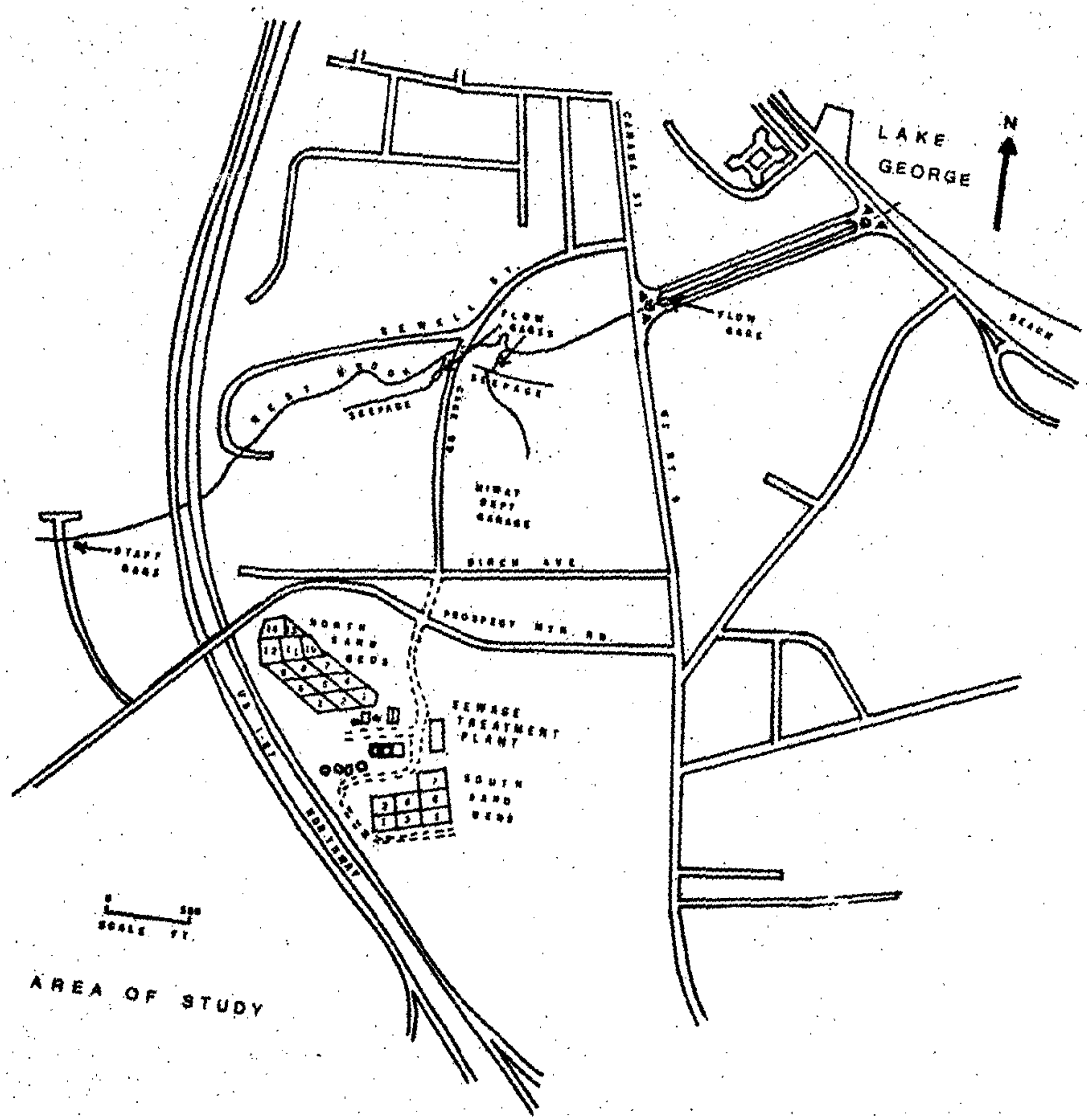
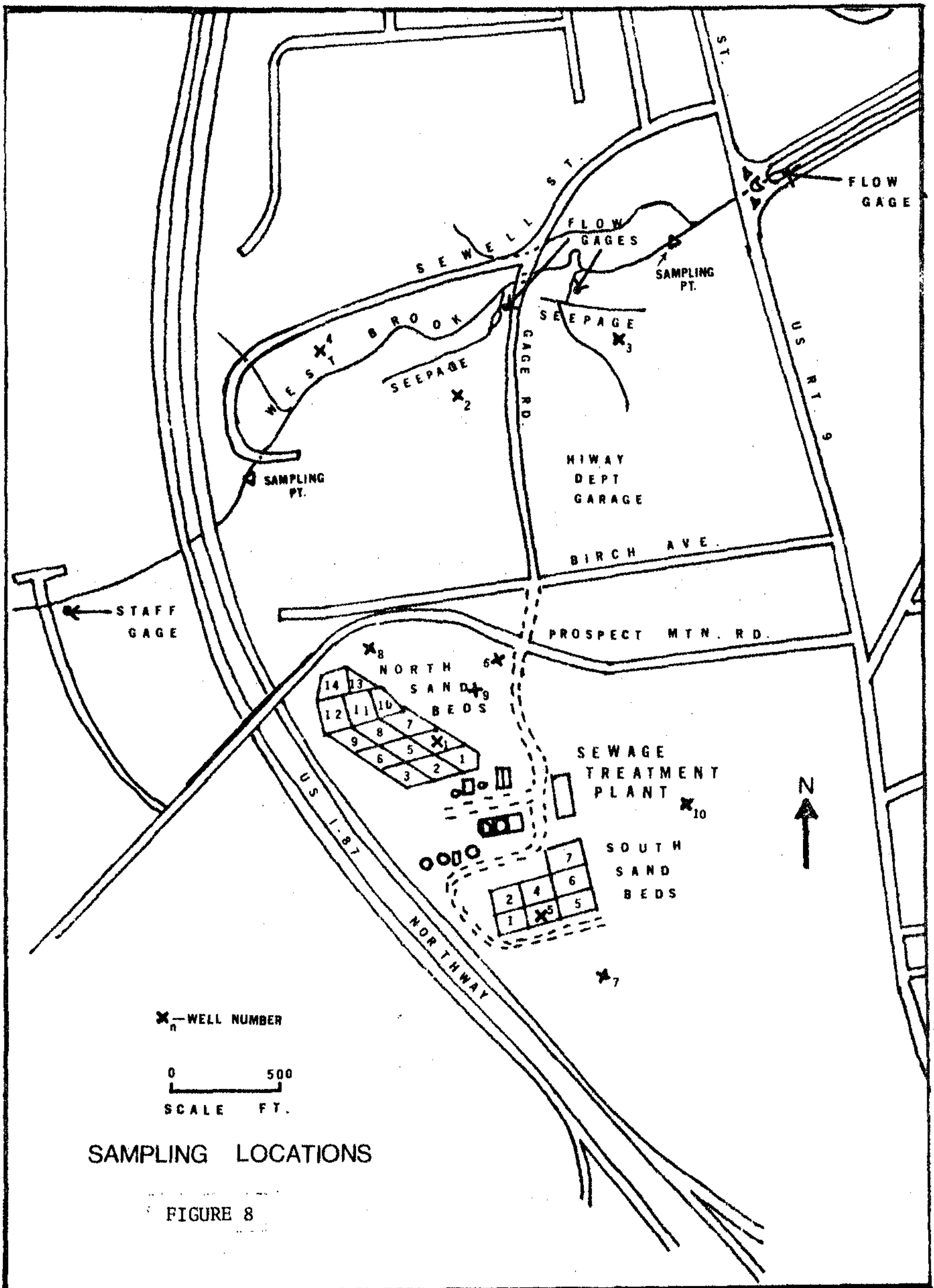

LAKE GEORGE
N
AREA OF STUDY
SEWAGE TREATMENT PLANT
NORTH SAND BEDS
SOUTH SAND BEDS
BIRCH AVE.
PROSPECT MTN. RD.
SEWELL ST.
WEST BROOK
SEEPAGE
FLOW GAGE
STAFF GAGE
HIWAY DEPT GARAGE

FIGURE 7



SAMPLING LOCATIONS

FIGURE 8

approximately the center of north sand bed 4. Well 2 is near West Brook. Well 3 is adjacent to West Brook. Well 5 is located in the approximate center of south sand bed 3. Well 6 is located approximately halfway between well 1 and wells 2 and 3, and well 9 is located approximately halfway between wells 1 and 6. At the present time, well 8 is under construction with further progress in doubt due to rocky soil at a depth of approximately 17 m (55 ft).

Some of the well locations indicated in Figure 8 have points and screens at various depths in the aquifer. The data for each well is shown in Table 1 and depicted in Figure 9.

Extensive water quality sampling began in April of 1973. Stream, seepage, and sewage treatment plant samples were secured and as wells were completed, samples were also secured from these. In order to condense the data obtained, averages were taken over a season. It was felt that actual seasonal dates represented most nearly the various conditions during the period of the year. The spring season represents the time of low population density but encompasses practically all of the heavy spring runoff from snow melt. The summer tourist season runs from approximately the middle of June through the middle of September. The fall season represents a period of fewer tourists in the area and normal dry weather conditions. The winter period represents extreme cold weather conditions with few tourists present with the exception of weekends during the February Winter Carnival.

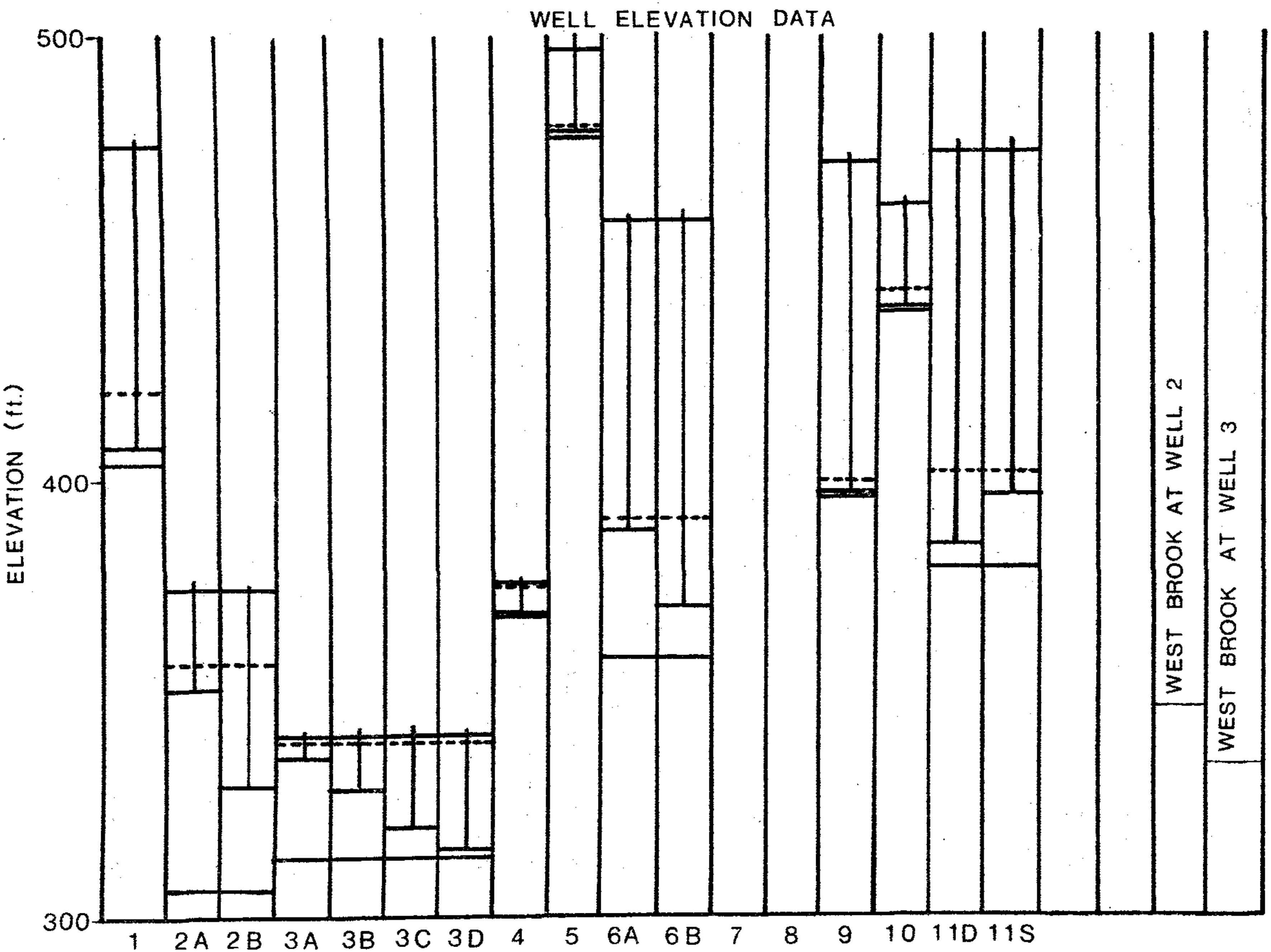
In order to correlate the results with the flows at the treatment plant, the mean "monthly" flows were determined from the totalizing meters at the treatment plant. In order to correspond with the seasons, the "monthly" flow was determined from the 21st of the previous month to the 20th of the month stated. It was felt that this gave more representative results with less deviation than plotting on the calendar monthly basis. For example, the flows increased rapidly during the month of June and decreased similarly during the

TABLE 1

WELL DATA

Elevations in ft. above mean sea level

Location	Surface	Approx. Ground Water	Bottom of Point	Bedrock
Well 1	475.0	415.66	407.80	405.0
Well 2A	375.40	359.22	352.13	306
Well 2B	375.40	359.2	330.35	306
Well 3A	339.90	339.74	336.44	314
Well 3B	339.90	340.01	329.06	314
Well 3C	339.90	340.08	321.23	314
Well 3D	339.90	340.0	315.64	314
Well 4	375.63	375.62	369.48	369.48
Well 5	495.37	480.98	479.40	477.40
Well 6A	458.7	397.6	388.13	360.0
Well 6B	458.7	397.6	370.68	360.0
Well 7	-	-	-	-
Well 8	-	-	-	-
Well 9	467.02	403.14	395.51	395.51
Well 10	462.73	441.7	438.91	438.91
Pumped Well 11 (Deep)	472.10	400	384.60	379.60
Pumped Well 11 (Shallow)	472.23	400	397.73	379.60
West Brook At Well 2	348.0	-	-	-
West Brook At Well 3	334.9	-	-	-


WELL ELEVATION DATA
ELEVATION (ft.)
500
400
300
1
2A
2B
3A
3B
3C
3D
4
5
6A
6B
7
8
9
10
11D
11S
WEST BROOK AT WELL 2
WEST BROOK AT WELL 3

month of September. By starting the average on the 21st of the previous month, less deviation in results is obtained. These "monthly" flows at the treatment plant are summarized in Figure 10. Besides showing the variations in "monthly" flows, this figure shows a gradual increase in total sewage flow throughout this period of display. In general, the seasonal flows on this "monthly" basis fall fairly well into the categories as described in the seasonal averaging of all of the other sampling locations.

Some estimates were made of the actual bed loading. These were based upon a maximum daily flow of 1 mgd (4,000 m^3/day). During a normal day, 4 beds are dosed. Although the beds are somewhat different in size, the average area of the 21 beds comes to 0.3 acres (0.124 ha). Dosing 4 beds per day utilizes 1.2 acres (0.5 ha). At the indicated flow, this is a bed dosing rate of 0.83 mgd/acre or 19 gpd/ft^2 (8,000 m^3/ha-day). However, it must be recalled that this is not a true loading for the beds because the beds must remain idle for a period of time for the sewage effluent to seep into the soil. Thus a more realistic application rate would be to divide the total sewage flow over the entire sand bed area. At the maximum daily rate of 1 mgd (4,000 m^3), this results in a dosing rate of 0.15 mgd/acre or 3.6 gpd/ft^2 (1,500 m^3/ha-day).

The quality analyses measured during the period of the study are summarized on a seasonal basis in Table 2. It must be pointed out that wells 1 and 5, which are located in sand beds N4 and S3, respectively, are highly subject to variations as a function of whether or not the bed was flooded at the time of the sampling. Unfortunately, at the present time, insufficient data are available to warrant separating the results into the two bed dosing conditions.

In all cases the temperature data reflect the season, with the highest temperatures being present in the summer and coldest in the winter. In the wells at location 3, well 3A, closest to the surface, showed the greatest

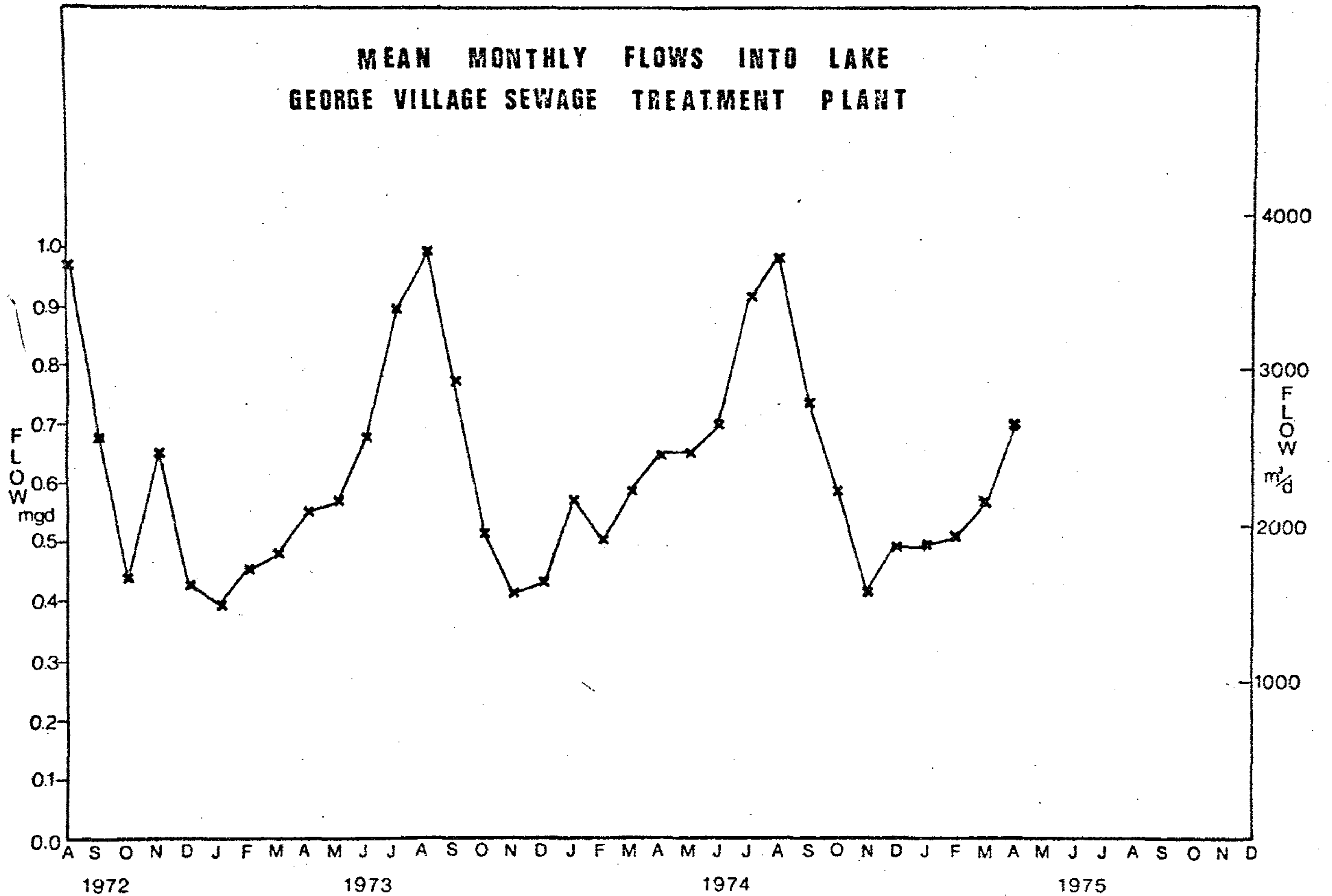

MEAN MONTHLY FLOWS INTO LAKE
GEORGE VILLAGE SEWAGE TREATMENT PLANT
FLOW mgd
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
FLOW m³/d
4000
3000
2000
1000
A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1972
1973
1974
1975

TABLE 2

SEASONAL AVERAGES

Sampling Station	Temp. °C	D.O. mg/l	Diss.Sol. mg/l	pH	Alk. mg/l	Cl. mg/l	Tot. Sol.P. ug/l	NO_3-N mg/l	NH_3-N mg/l	TK-N mg/l
WELL 1:										
Spring	11.8	3.4	160	6.4	100.7	39	237	6.6	0.36	
Summer	16.2	6.0	220	6.6	82.0	41	467	7.0		0.9
Fall		7.5	220	6.7		45	445	12.0	0.32	
Winter	9.5	7.8	210	6.65	86.0	54	2870	4.6	1.2	
WELL 2A:										
Spring	10.1	9.8	190	7.5	147	23.8	27	3.3	0.05	
Summer	12.5	10.0	180	7.65	129	29.0	24.5	2.6	0.15	0.064
Fall	9.0	8.5	248	7.65		35.0	133.3	6.6	0.08	
Winter	6.7	6.3	263	7.9	167.3	32.8	95.5	6.1	0.024	
WELL 2B:										
Spring		1.1		8.7		43	30	0.15	0.61	
Summer		1.6								
Fall		2.7	167.5	9.0	43	52.3	167	0.15	0.30	
Winter	6.3	2.0	160.0	8.9	62.3	39.4	45.5	0.058	0.05	
WELL 3A:										
Spring	16.4	4.7	350	7.1	266	44.5	41.1	0.79	0.015	0.033
Summer	19.6	3.9	340	7.2	306	41.0	37.3	0.27	0.41	0.497
Fall	7.75	5.5	300	7.4		42.5	75.0	0.15	0.34	
Winter	4.2	1.3	335	7.2	264	47.0		1.35	0.043	
WELL 3B:										
Spring	15.1	3.8	360	6.9	205	55.8	31.0	7.48	0.083	
Summer	17.5	4.2	333	7.13	176	65.8	23.4	9.69	0.16	0.182
Fall	8.0	3.6	307	7.21		40.0	75.0			
Winter	5.1	1.7	347	7.1	150	78.5	20.0	7.70	0.014	
WELL 3C:										
Spring	14.3	3.3	330	6.7	177	58.1	46.7	9.7	0.04	
Summer	14.6	3.0	294	7.0	164	59.0	24.3	11.1	0.05	0.052
Fall	8.75	3.7	305	7.5		56.7	85.0	7.5	0.04	
Winter	5.2	2.2	335	7.1	148	69.3	20.0	8.0	0.04	
WELL 3D:										
Spring		0.83		8.5	87	30.8	40	0.5	1.55	
Summer		2.0	280	8.0	184	100.0	20	0.66	0.66	
Fall		2.55	245	9.3	47	52.0	85	0.35	3.3	
Winter	5.1	0.85	158	9.2	64	41.4	28	0.38	1.8	

TABLE 2 (Continued)

SEASONAL AVERAGES

Sampling Station	Temp. °C	D.O. mg/l	Diss.Sol. mg/l	pH	Alk. mg/l	Cl. mg/l	Tot. Sol.P. ug/l	NO_3-N mg/l	NH_3-N mg/l	TK-N mg/l
WELL 4: (New Well)										
Spring				7.7	386	56.0				
Summer										
Fall										
Winter										
WELL 5:										
Spring		7.15		6.4	46	41.0	920	8.0	0.26	
Summer	21.8	3.8	110	6.4	53	22.0	1293	11.9	0.13	0.623
Fall	11.3	5.1	210	6.3	71	32.0		9.5	1.81	
Winter	3.0	4.1	183	6.3	47	34.8	1470	9.8	1.16	
WELL 6A:										
Spring		2.45		8.5		17.5	50	4.1	0.84	
Summer										
Fall		2.5		6.9	135	30.7	100	12.3	0.34	
Winter		4.3		7.7		41.0		21.0		
WELL 6B:										
Spring		3.4		8.3	137	40.3	30	1.6	2.0	
Summer	12.9	4.2	186	8.8	142	35.3	15	4.4	1.3	3.8
Fall		1.8		8.9		34.3	133	0.93	5.5	
Winter	12.75	1.6		7.9	77	37.8	20	2.04	2.5	
WELL 9: (New Well)										
Spring				6.8	80	58.5				
Summer										
Fall										
Winter										
WELL 10:										
Spring		6.65		6.9	29	2.2	50	0.335	0.12	
Summer	14.0	5.5	71	6.5	43	11.0	27	0.279	0.1	0.559
Fall										
Winter	5.6	6.1	41	7.05	34	1.0	20	0.26	0.047	
BED #11 (Shallow Pumping Well)										
Spring				7.0	59	37.0				
Summer										
Fall										
Winter				6.5	68	40.5				

TABLE 2(Continued)

SEASONAL AVERAGES

Sampling Station	Temp. °C	D.O. mg/1	Diss.Sol. mg/1	pH	Alk. mg/1	Cl. mg/1	Tot. Sol.P. ug/1	NO_3-N mg/1	NH_3-N mg/1	TK-N mg/1
BED #11:(Deep Pumping Well)										
Spring				7.1	46	28.4				
Summer										
Fall										
Winter				6.5	43	24.0				
SEEPAGE ABOVE GAGE RD.:										
Spring				7.4	117	36.5				
Summer										
Fall	8.9	10.1	220	7.75	112	44.0		3.5	0.107	
Winter	4.8	11.5	211	7.8	118	39.2	9	3.9	0.01	
SEEPAGE BELOW GAGE RD.:										
Spring				7.5	189	75.5				
Summer										
Fall	9.0	9.0	390	7.9	177	94.3	12	7.7	0.045	
Winter	7.2	10.5	383	7.8	179	86.5	134	8.4	0.012	
WEST BROOK UPSTREAM:										
Spring		12.8	55	7.1	13	8.1	21	0.11	0.024	0.063
Summer	13.0	10.5	66	7.6	40	13.3	50	0.27	0.060	0.069
Fall	7.4	12.3	45	7.4	33	14.6	95	0.15	0.050	
Winter	2.0	13.1	47	7.0	23	8.0		0.33	0.016	
WEST BROOK DOWNSTREAM:										
Spring		12.2	70	7.1	21	12.6	24	0.775	0.062	0.191
Summer	13.4	10.1	107	7.6	70	21.7	35	2.35	0.225	0.066
Fall	8.0	11.5	93	7.5	56	24.5	95	1.47	0.015	
Winter	2.0	13.0	79	7.3	39	14.1	120	0.589	0.011	
SEWAGE PLANT INFLUENT:										
Spring					98	64.0				
Summer	22.5	2.3	243	7.2	163	38.5	4471			13.01
Fall	11.0	2.4	210	7.0	163	36.7	2650	0.15	8.79	
Winter	5.2	5.8	222	7.2	110	52.0	2845	0.20	8.64	
SEWAGE PLANT EFFLUENT:										
Spring			190	7.3	110	44.7	2390	1.23	3.0	8.25
Summer	22.5	2.1	217	6.6	136	33.7	3552	0.50		7.15
Fall	10.0	4.5	198	7.1	94	32.0	1325	3.5	2.95	12.0
Winter	4.5	6.8	234	7.0	109	51.7	1423	1.2	5.6	26.0

variation, reflecting the influence of the air temperature, whereas well 3B showed less temperature variation. The greatest variation in temperature was shown by the sewage which had a high temperature of 22.5°C. West Brook is generally a cold water stream: at no time did a sample have a temperature of greater than 15°C.

The D.O. in the wells at various depths generally decreased with depth. With the exception of well 3D, the D.O. of the ground water was greater than 1 mg/l at all times. Thus in general, it may be stated that the ground water in the area contains dissolved oxygen and that oxidizing conditions prevail. Even the sewage influent and effluent contain dissolved oxygen. The influent probably contains D.O. due to the splashing as it enters the Parshall flume. The effluent contains D.O. as a result of its passage over the trickling filter. There appeared to be a slight decrease in D.O. in West Brook as it passed the area where the seepage enters the stream. However, even at the downstream point in the summer and fall, the D.O. in West Brook exceeded saturation. This is attributed mostly to the reaeration as the stream flows over the rocky bottom.

With the exception of the wells at location 3, the dissolved solids can be used as an indicator of the presence of the sewage effluent. The dissolved solids were lower in the deeper well 2B than in well 2A, and were much lower in the control well 10. The dissolved solids in the seepage above Gage Road were very similar to the sewage plant effluent, whereas in the seepage below Gage Road they were considerably higher. This higher value coupled with the extremely high values in all of wells 3 is attributed to the salt which had been stored at the Town highway department garage immediately above this area. Lower dissolved solids were present in the deepest well 3D. There was a noticeable increase in the dissolved solids in West Brook as it flowed past the location where the seepage enters the stream.

In all cases the pH of the water at the deeper depth at any well location was higher than that at the shallower depth. The pH in wells 2B, 3D, and 6B ranged about 9 whereas the pH in all other well samples seldom exceeded 7.5. The pH of the sewage was near neutral and there was no significant effect of the seepage upon the pH in West Brook.

Alkalinity can also be used as an indicator of the presence of the sewage effluent. The average alkalinity in the sewage effluent ranged between 95 and 135 mg/l. Well 2A generally exhibited higher alkalinity values, whereas well 2B had significantly lower alkalinity. The alkalinity of well 3D was lower than any of the shallower wells at this location with the exception of the summer average. The alkalinity in wells 3A, B, and C consistently exceeded those of the sewage effluent. The alkalinity in both wells 6A and 6B were similar to that of the sewage effluent. The control well 10 showed a very low alkalinity whereas the supposed control well 4 had an exceedingly high alkalinity. The seepage above Gage Road was similar to that of the sewage effluent whereas the seepage below Gage Road was somewhat higher. There was a measurable increase in the alkalinity in West Brook as it flowed past the area of the seepage influent.

Normally, the chlorides could be used as an indicator of the presence of sewage. However, with the interferences to the salt from the highway department garage, the results from well 3 and the seepage below Gage Road cannot be used as indicators of the presence of the sewage. The average chloride content of the sewage effluent varied between 32 and 52 mg/l. Wells 1 and 5 in the sand beds exhibited similar chloride contents. Well 2A was similar to the sewage effluent but well 2B was significantly higher in chloride content. All of the samples from wells 3 exhibited high chloride contents with the highest average value being 100 mg/l during the summer in well 3D. During the spring and fall, the chloride content of well 6B was greater than that of well 6A. Control well

10 had a very low chloride content, whereas control well 4 contained a significant amount of chloride. It is possible that runoff from the Northway containing highway ice-melting salt reaches the area of well 4 which is close to the Northway. This number represents one sample secured from this well during or soon after a snowstorm. The chloride content of the seepage above Gage Road is similar to that of the sewage effluent, whereas that below Gage Road is considerably higher. There is definitely an increase in the chloride content of West Brook as it passes this area.

Comparing the phosphorus content of the influent and the effluent of the sewage treatment plant indicates a measurable reduction in this parameter due to the treatment. The effluent contains between 1 and 4 mg/l of phosphorus. Wells 1 and 5 in the sand beds exhibited extreme variations in phosphorus content due to the loading of the beds. In all other instances, the phosphorus content of the wells was in the μg/l range. There were no consistent trends of phosphate concentration with depth in any of the well locations with points at different depths within the aquifer. In general, higher phosphorus results were obtained in wells 6 which are relatively close to the sand beds, with lower values occurring in wells 2 and 3, greater distances from the sand beds. Small amounts of phosphorus were found in the control well 10. The phosphorus content of the seepage was generally low with somewhat higher values being found in the few samples secured during the winter in the seepage below Gage Road. There was no consistent increase or decrease in phosphorus content in West Brook as the stream flowed past the seepage area; however, the highest phosphorus contents were found during the fall and winter.

The increase in the nitrate content of the treatment plant effluent corresponds to the decrease in ammonia and Kjeldahl nitrogen during treatment, although not quantitatively. Significant amounts of ammonia nitrogen were found in wells 3D and 6B. At all other sampling locations including both seepage samples, the ammonia and Kjeldahl nitrogen contents are low. Higher nitrate values were found in the shallower wells 2A and 6A, but the highest values at well location 3 were found in wells 3B and 3C. The nitrate values were higher in the seepage below Gage Road than above Gage Road. West Brook definitely shows an increase in nitrate content as it picks up the seepage in this area.

In general, there are two classes of components in this system. The soluble unreactive substances such as dissolved solids, alkalinity, and chloride are conveyed to West Brook where they exhibit a noticeable influence on the stream. On the other hand are the substances which are reactive and are either removed or changed within the soil system. The phosphorus appears to be completely removed before the liquid emerges in the seepage and gets into West Brook. The ammonia and Kjeldahl nitrogen are essentially completely removed but the soluble nitrates pass on through the soil and appear in the seepage at a higher concentration than in the applied sewage effluent. However, at no time was the nitrate content of the seepage greater than the 10 mg/l recommended as satisfactory for a drinking water supply. Of greater concern, however, is the potential contribution of nutrients, primarily nitrogen and phosphorus, to Lake George. It may be concluded that no significant amounts of phosphorus reach Lake George due to the Lake George Town and Village sewage disposal system. However, significant amounts of nitrate do reach West Brook and most likely could be measured in Lake George near the outlet of West Brook. In most instances, the nitrate content of West Brook exceeded the recommended limits of .3 mg/l as nitrogen for the control of excess algal growth. However, due to the cold water of the stream and the low phosphorus content of the stream, no problems of excessive algal growth have occurred in West Brook itself.

In general, it may be concluded that the Lake George Village sewage treatment plant is doing an adequate job of purifying the wastewater, providing an effluent which is safe for drinking, satisfactorily removing essentially all of the phosphorus from the wastewater and providing a nitrified effluent which at the present time appears to have no obvious deleterious effects upon the quality of Lake George.

ACKNOWLEDGEMENT

This study was partially supported by funds made available from the Rensselaer Fresh Water Institute, the New York State Department of Environmental Conservation, the United States Environmental Protection Agency under Grant No. R803452-01 and the Corps of Engineers, Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire, under Contract No. DACA89-74-1637.

REFERENCES

1. Aulenbach, D. B., Glavin, T. P., and Romero Rojas, J. A., "Protracted Recharge of Treated Sewage into Sand: Part I - Quality Changes in Vertical Transport Through the Sand." Ground Water 12, 3, 161 (1974).

2. Aulenbach, D. B., Ferris, J. J., Clesceri, N. L., and Tofflemire, T. J., "Protracted Recharge of Treated Sewage into Sand: Part III - Nutrient Transport Through the Sand." Ground Water 12, 5, 301 (1974).

3. "Classifications and Standards Governing the Quality and Purity of Waters of New York State." Part 702.

4. Fink, W. B., and Aulenbach, D. B., "Protracted Recharge of Treated Sewage into Sand: Part II - Tracing the Flow of Contaminated Ground Water with a Resistivity Survey." Ground Water 12, 4, 219 (1974).

5. Hill, F. A., The Precambrian Geology of the Glens Falls and Fort Ann Quadrangles, Southeastern Adirondack Mountains, New York, Ph.D. Thesis, Yale Univ. (1965).

6. Newland, D. H., and Vaughan, H., Guide to the Geology of the Lake George Region, New York State Museum Handbook #19, University of the State of New York (1942).

7. "Official Code Rules and Regulations of the State of New York", Part 830 Title 6, Item 430, Water Index No. C-101-T367, Class AA.

8. "The Environmental Conservation Law", Chap. 664, Sec. 17, Title 17, Art. 1709.

9. Vrooman, M., "Complete Sewage Disposal for a Small Community." Water Works and Sewerage, 87, 130 (March 1940).