TERTIARY TREATMENT BY SOIL
AT LAKE GEORGE VILLAGE SEWAGE TREATMENT PLANT

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Lake George, a beautiful recreational lake noted for the clarity of its waters and the beauty of its shoreline, is located in the eastern part of New York State (Figure 1). For many years, the lake has attracted tourists, many of whom come from urban regions to the south. Due to (a) this predominance of tourists from the south, (b) a former rail terminal at Lake George Village and (c) the recent completion of the Adirondack Northway (I-87) through the area in the 1960's, the greatest influx of tourists occurs around the southern edge of the lake, with Lake George Village being the largest center of population.

Residents of the Lake George area have been concerned with the quality of the water of the lake for many years. The Lake George Association was organized ninety years ago and has been primarily responsible for maintaining the high quality of the water of the lake. Due mainly to their efforts, the lake has been given a special AA classification,[2] thus allowing the water to be used as a drinking water supply after treatment with only chlorine[6]. Legislation was enacted prohibiting the discharge of any wastewater, treated or untreated, into the lake or into any waters discharging into the lake[7]. In order to lessen any possible pollution of the lake, the Village of Lake George planned a sewage treatment plant in 1936. The regulation restricting the discharge of wastewater into the drainage basin was interpreted to mean surface

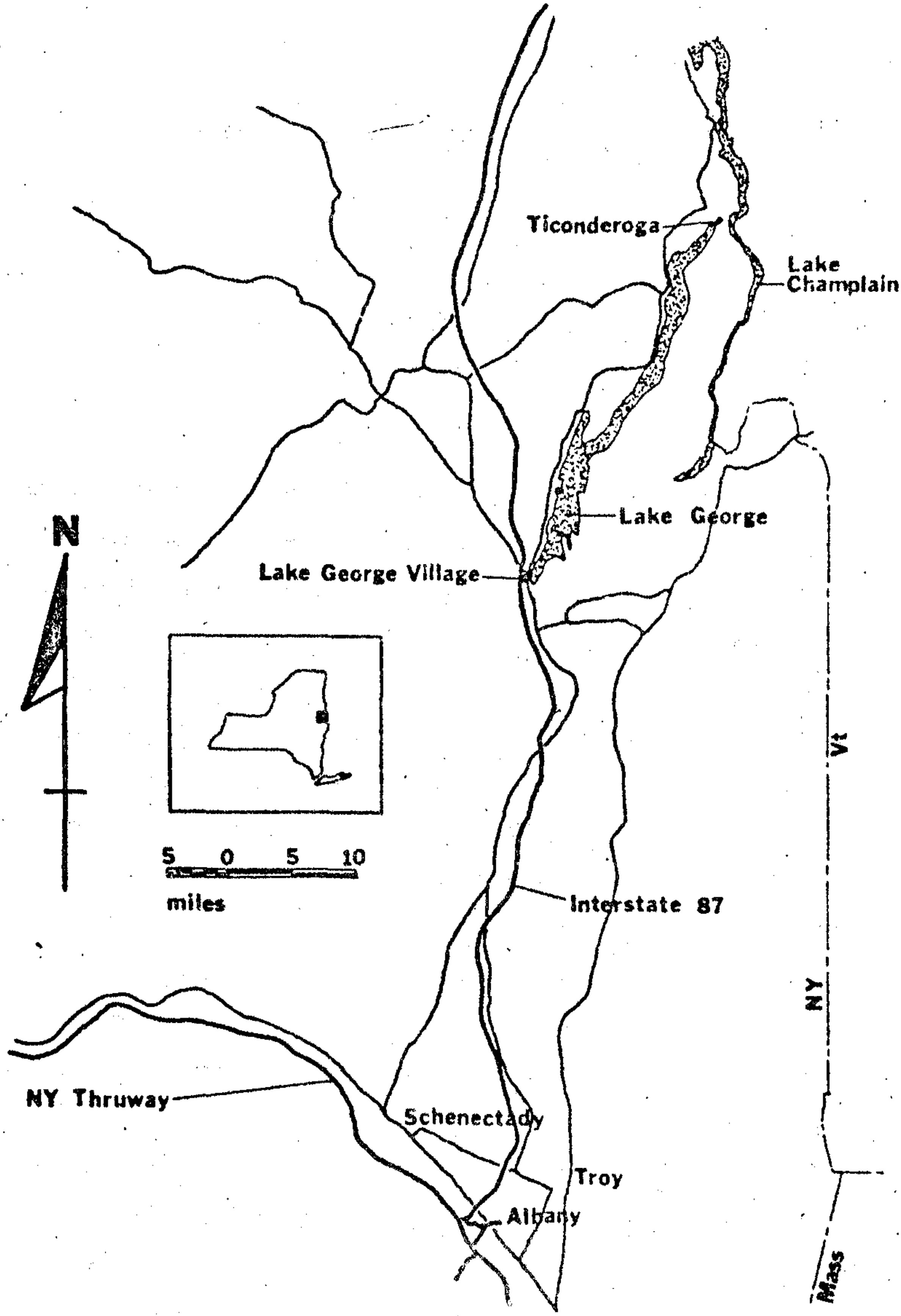
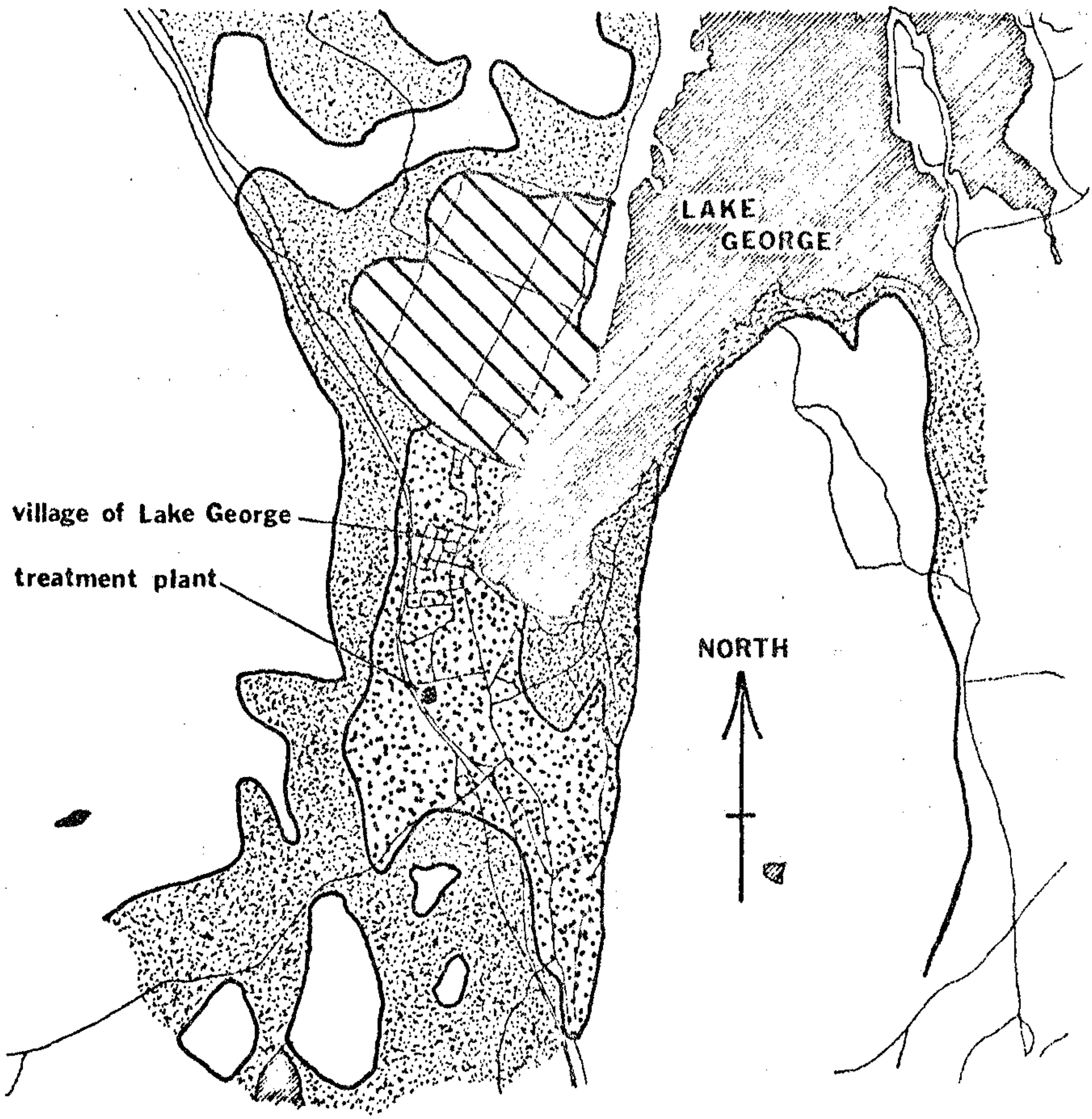


FIGURE 1

NORTHEASTERN NEW YORK AND LAKE GEORGE REGION discharges and did not apply to properly operating septic tank systems. Since septic tank systems were allowed, it was contemplated that discharge into the soil would be a satisfactory means of disposal of the treated effluent from a sewage treatment plant. Although, in general, the Lake George area is underlain by rock consisting of pre-Cambrian gneisses with valleys underlain by lower Paleozoic strata, a small area of delta sand deposits created by the outwash from receding glaciers was found just southwest of the Lake George Village area as shown in Figure 2.[4,5] Advantage was taken of this area of delta sand and the sewage treatment plant was built at this location with the discharge of the final secondary treated effluent into this natural delta sand. The original treatment plant was completed and put into operation in 1939 and has been in continuous operation ever since. The original plant was designed in triplicate with the entire plant being utilized during the summer tourist season, whereas with only one-third of the flow, only one-third of the plant was utilized during the winter period.[9] Although total flows have increased since 1939, the three to one summer to winter flow ratio has remained relatively constant. The sand bed area has been increased several times since the completion of the original treatment plant. The final treatment plant system is shown in Figure 3. The sewage is delivered to the treatment plant through a force main with an auxiliary pumping system and is metered at the plant. Presently, there are two sewer districts served by the treatment system: one from the Village and one from the surrounding Town of Lake George. The combined flows are provided with primary sedimentation with Imhoff type sludge digestion, secondary treatment by trickling filters, and secondary sedimentation. The final effluent from the secondary sedimentation tanks is discharged without chlorination onto any of the 21 sand infiltration beds. Two of the trickling filters have rotary distributors,



LEGEND

- unclassified by Hill
- moraine sand, gravel, & boulders (Newland)
- delta deposits (Newland)
- lakes

SCALE

6000ft

GEOLOGY OF THE SOUTHERN LAKE GEORGE DRAINAGE BASIN

FIGURE 2

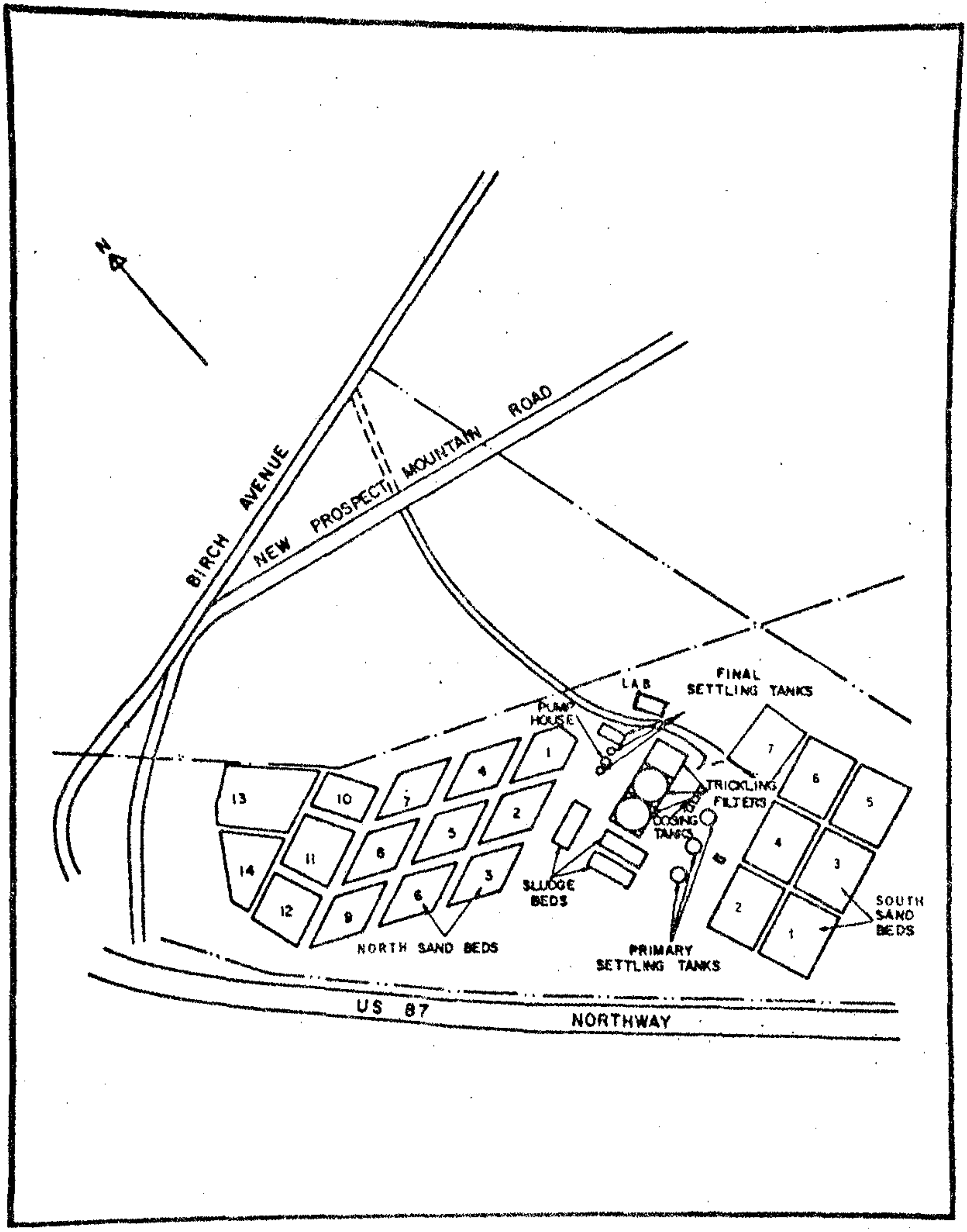


FIGURE 3 LAKE GEORGE VILLAGE SEWAGE TREATMENT PLANT

the third has fixed nozzles. The latter trickling filter is used exclusively in the winter and is covered with boards which prevent icing of the filter. Temperatures in this area reach as low as -40°C.

Normal operation of the sand beds is to flood one of the south beds and one of the north beds during the daytime from approximately 8:00 AM to 3:30 PM. Then the flow is directed to another set of north and south beds for the nighttime flow until the next morning. The beds normally drain dry in one to three days, after which they may be dosed again as needed. Occasionally, as required and as operator time permits, the beds are scraped to remove the dried algae cake which forms on the beds and then raked and re-leveled for further use. A minimum amount of sand is removed in the scraping and this is deposited in the area around the sewage treatment plant. In 1973, approximately one foot of sand was removed from the top of each of the sand beds. With this exception, there have been no significant changes in the operation of the treatment system since it first began operation in 1939.

As part of the Rensselaer Fresh Water Institute's efforts to evaluate the quality of Lake George and to identify any major sources of pollutants or nutrient inputs to the lake, studies were begun at the Lake George Village Sewage treatment plant in 1968. The initial studies(1) indicated that there was almost complete removal of BOD, ammonia nitrogen and organic nitrogen in the top 10 ft of passage through the sand beds. Nitrates were increased slightly but not quantitatively with the removal of organic and ammonia nitrogen. Chlorides were unaffected in passing through the sand beds. Phosphate removal, however, showed an unusual pattern in that a bed which had been in constant use showed considerably less phosphate removal than a bed which had been out of service for approximately a year. The conclusion reached was that the phosphorus removal capacity of the sand had been regenerated by the non-use of this sand bed.

These studies did not provide sufficient information to evaluate the potential contribution of nutrients (nitrogen and phosphorus) to Lake George from the treatment plant.

As a further investigation to identify the direction of flow from the sand beds at the treatment plant, a resistivity study was conducted during 1972. This method involved the placing of four electrodes in the soil at a fixed interval of 50 ft (15.24 m) apart, applying a current to one pair of electrodes, and measuring the current produced on the other pair. The concept is that water of higher conductivity has less resistance and since sewage has a higher content of dissolved solids, it would have a greater conductivity and therefore be identified by an area of lower resistivity. The results of this study,[3] as shown in Figure 4, indicate that the area of lowest resistivity follows a line northward from the treatment plant along Gage Road toward West Brook. Unfortunately, interferences caused by underground water and sewer lines prevented the determination of whether or not the low resistivity profile continued across West Brook or whether it ended at West Brook.

As a result of these resistivity studies, an investigation was made of the south bank of West Brook. The ground surface slopes downward from the area of the treatment plant toward West Brook with a very steep hill immediately adjacent to the south bank of West Brook. The base of this steep hill defines the edge of the flood plain of West Brook. Along the base of this hill, a considerable amount of seepage was observed emerging from the ground both upstream and downstream from the crossing of Gage Road over West Brook. The quality of this seepage water indicated a rather high conductivity suggesting that it could have been related to the effluent from the sewage treatment plant. However, the conductivity of the seepage downstream from Gage Road was considerably higher than that of the sewage treatment plant effluent. An investigation revealed that

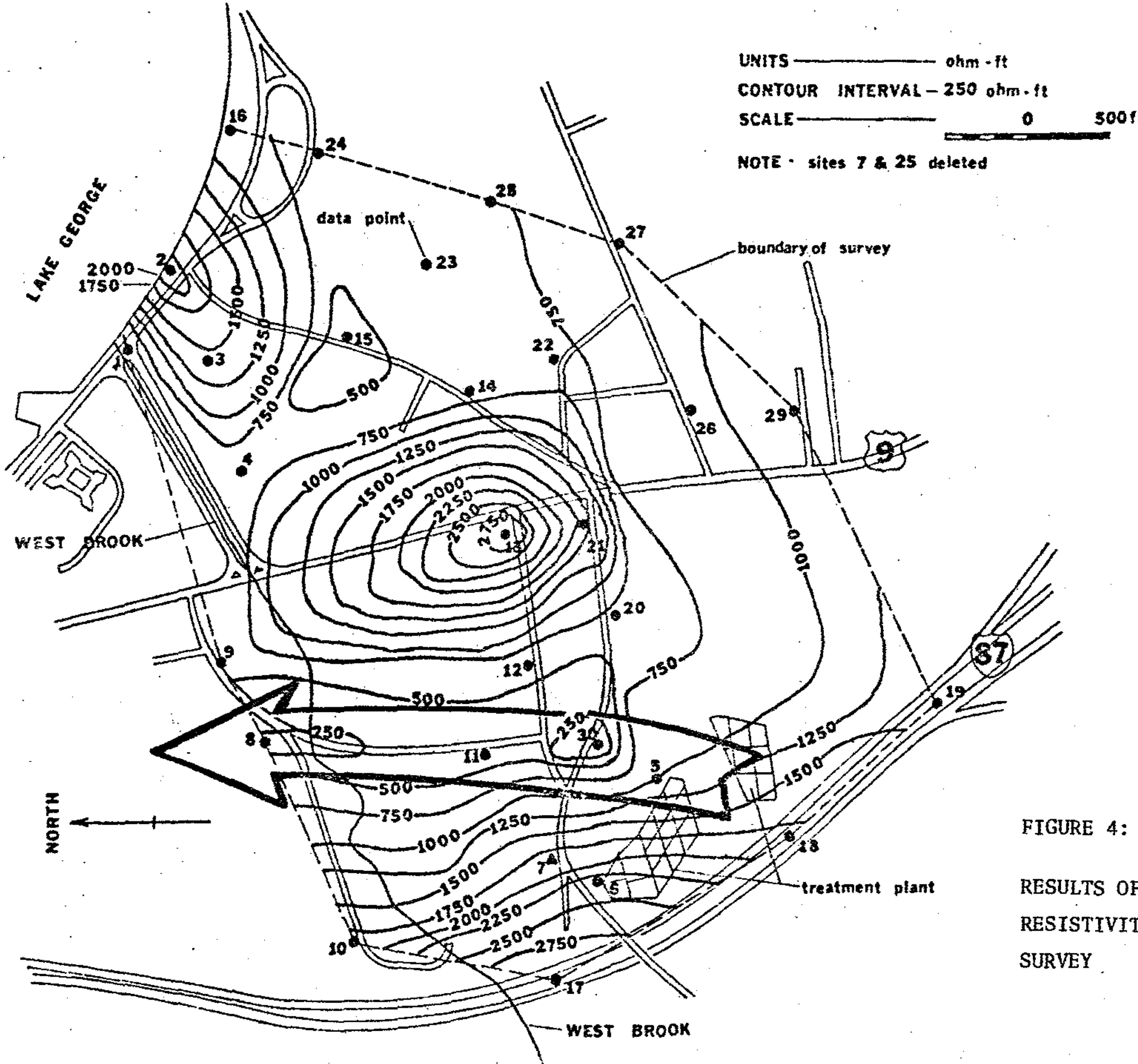


FIGURE 4:

RESULTS OF RESISTIVITY SURVEY

before the present storage shed was built, the highway department had stored road de-icing salt in the open at their garage which is located at the top of the hill above the location of the seepage below Gage Road. Thus, this interference prevented the conclusive decision, based on conductivity or chloride measurements, that the seepage represented the effluent from the treatment plant. The location of the seepage is shown in Figure 5 which indicates the general area of the study. The seepage above Gage Road naturally collects in a separate channel passing through a small pond and entering West Brook just upstream from the Gage Road crossing. The seepage below Gage Road initially flowed through many channels into West Brook. However, with the help of the Village highway department, some ditching was performed to collect all of this seepage into one main channel which could then be monitored for flow as well as water quality. In November of 1974, continuous recording flow gages were installed to measure the flow of the two major seepage streams. There previously has existed a continuous recording flow gage in West Brook just downstream from Route 9. A staff gage has been maintained upstream in West Brook west of the Northway. Some seepage was observed emerging from the north side of West Brook and this was found to flow into West Brook below the downstream sampling point but above the West Brook flow recording gage as is shown in Figure 6.

In addition to the sampling and monitoring locations in West Brook and of the seepage, a series of wells was placed in the area between the sewage treatment plant and West Brook as shown in Figure 6. Wells 4, 7, and 10 were located in the areas not expected to be affected by the treatment plant effluent and therefore were designed to serve as controls. Also, well points were placed in north sand bed 4 and in south sand bed 3 to monitor the quality of water in the water table below the actual sand seepage beds. At some locations,

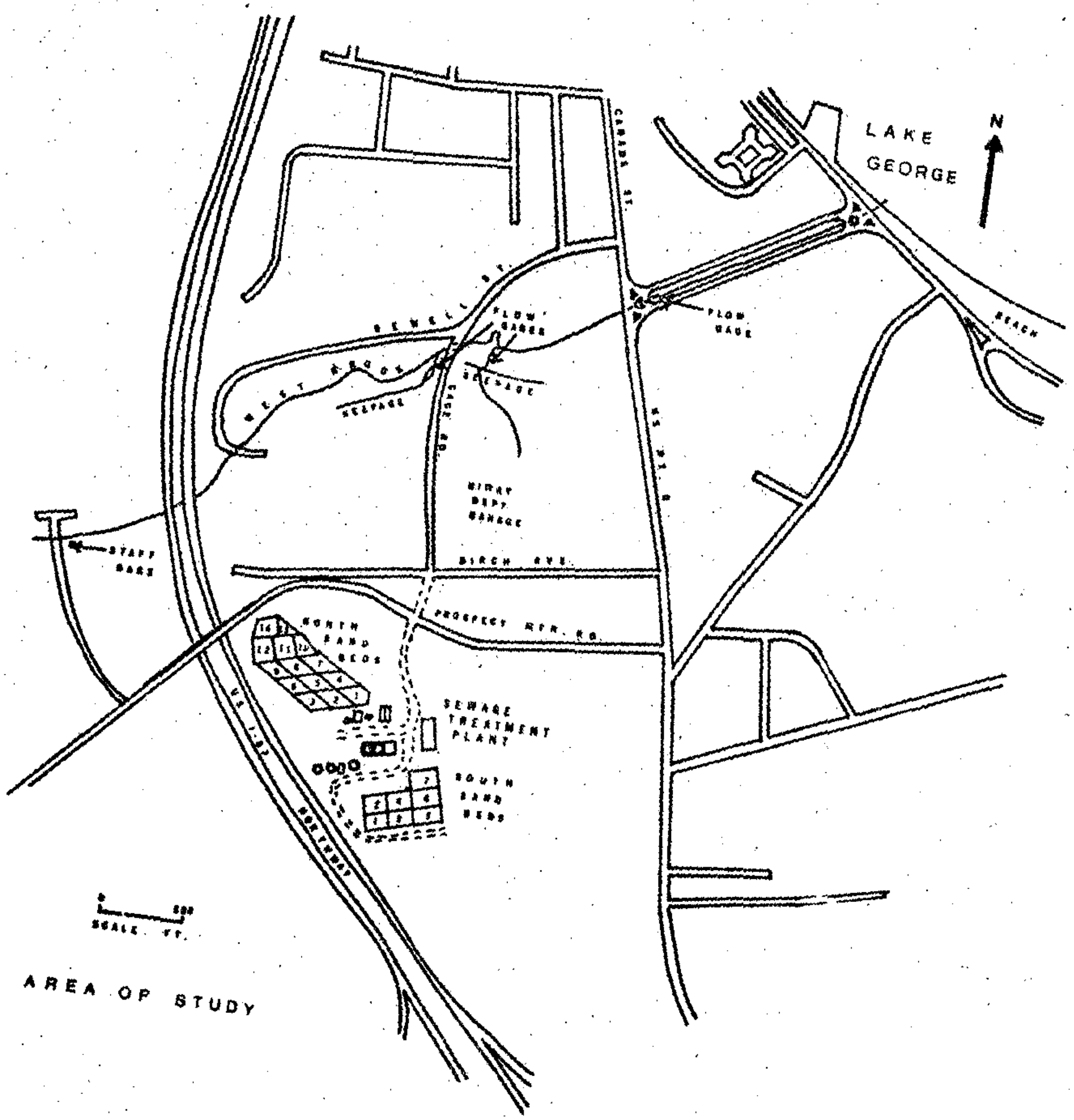

LAKE
GEORGE
N
SEWELL ST.
WEST BROOK
FLOW
GAGES
SEWAGE
SEWAGE
FLOW
GAGE
BEACH
STAFF
GAGE
BIRCH AVE.
PROSPECT MTN. RD.
NORTH
SAND
BEDS
SEWAGE
TREATMENT
PLANT
SOUTH
SAND
BEDS
AREA OF STUDY

FIGURE 5

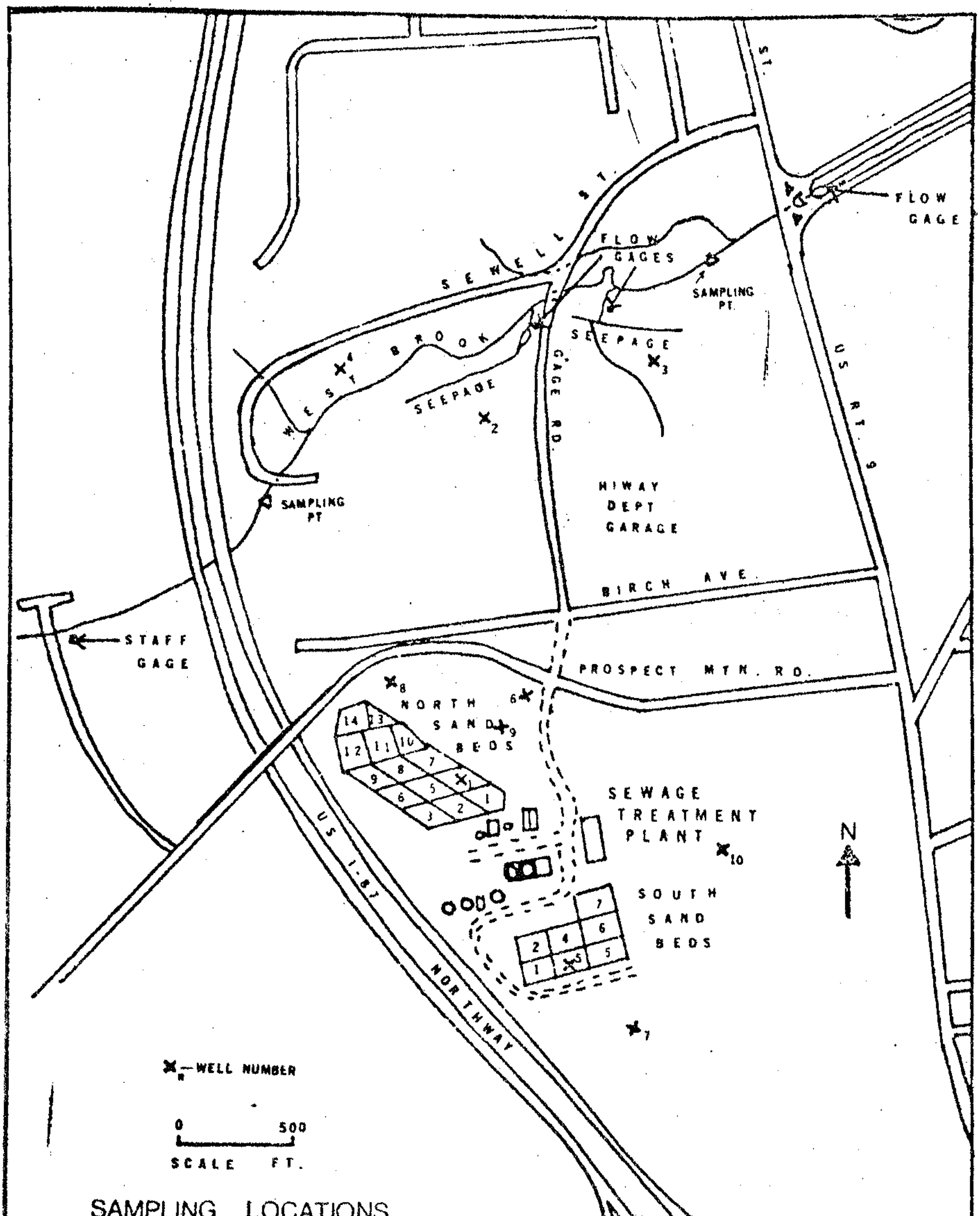

FLOW GAGE
SEWELL ST.
FLOW GAGES
SAMPLING PT.
WEST BROOK
SEEPAGE
SEEPAGE
GAGE RD.
US RT. 9
HIWAY DEPT GARAGE
SAMPLING PT
BIRCH AVE.
STAFF GAGE
PROSPECT MTN. RD.
NORTH SAND BEDS
SEWAGE TREATMENT PLANT
SOUTH SAND BEDS
N
US I-87
NORTHWAY
WELL NUMBER
0 500
SCALE FT.
SAMPLING LOCATIONS

FIGURE 6

well points were placed at several depths within the aquifer in order to monitor the quality of the ground water at the various depths. The depths and elevations of the well points are shown in Figure 7. Also, for comparison, this figure shows the elevation of West Brook opposite well sites 2 and 3.

Not all of the well points were installed at the same time. As the wells were installed, samples were secured from the water in each well. Thus, there is more extensive data from the original wells than from the newer wells.

After samples were secured from well 4, intended to serve as a control well, it was found that there was some apparent influence from the salting of Interstate 87 as shown by the high chloride content of this water. Wells 1 and 5 are located directly in sand beds north 4 and south 3, respectively. The quality of the water recovered from these wells reflected noticeably whether or not the respective bed was flooded at the time of sampling. During times of flooding of the bed, the quality appeared more like that of the sewage effluent, whereas during the time of nonflooding of the bed, the quality appeared more like that of the natural ground water. As of this time, there are insufficient data to separately evaluate each condition of flooding of the bed in these two wells; therefore, all of the data for these wells are combined. Progressing in distance away from the sand beds, the wells appear as sites No. 9, No. 6, and Nos. 2 and 3. Where there is more than one well point at a site, they are lettered progressively with the shallowest well always being indicated by the letter "A".

Measurements at each well normally include the water level, temperature, DO, total dissolved solids, pH, alkalinity, chlorides, total soluble phosphorus, nitrate, ammonia and total Kjeldahl nitrogen. Space does not permit presenting all the data here. The sampling locations illustrated in Figures 9-13 were chosen to give a representative picture of the quality of the water as it passes

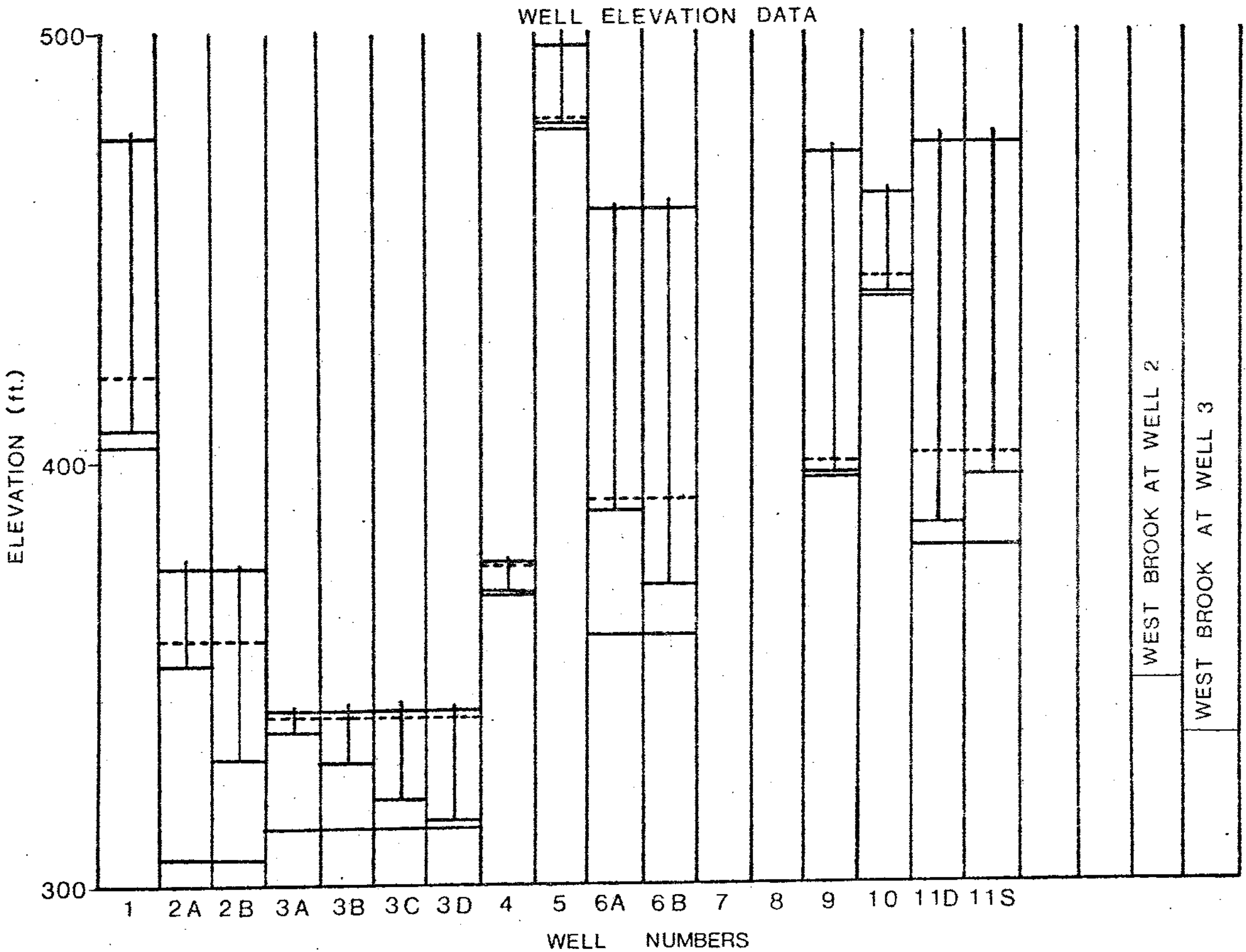

WELL ELEVATION DATA
ELEVATION (ft.)
500
400
300
1
2A
2B
3A
3B
3C
3D
4
5
6A
6B
7
8
9
10
11D
11S
WEST BROOK AT WELL 2
WEST BROOK AT WELL 3
WELL NUMBERS

FIGURE 7

through the system. The influent and the effluent of the treatment plant are compared; however, it must be pointed out that the results are the average of a series of grab samples and do not necessarily represent the same slug of water influent and effluent at the treatment plant. Well 10 represents the control well. Well 1 is located in a sand bed and is influenced most directly by the sewage effluent applied to that sand bed. Well site 6 is approximately 500 ft (150 m) from the sand beds. Well site 2 is approximately 1,600 ft (490 m) away and is close to West Brook. The seepage above and below Gage Road represents the major portion of the ground water seepage. The samples above and below the influence of the seepage in West Brook indicate how this seepage affects the quality of the water within West Brook. The data are summarized according to season, as this reflects the most significant variations in overall conditions and flow at the treatment plant (Figure 8). Winter represents the period of lowest sewage flow (population) and subfreezing temperatures. Spring is the time of snowmelt, with highest streamflow and ground-water conditions. Summer is the period of maximum tourist population, causing maximum sewage flow, as well as the warmest period. Fall represents lower sewage flow, lowest ground-water levels, and normally lower stream flows, although occasional heavy rains may increase the stream flows significantly.

Figure 9 shows that the largest seasonal temperature fluctuations occurred in the sewage treatment plant influent and effluent and there was little significant difference between the influent and the effluent. The most constant temperatures were found in the two deeper wells, 6B and 2B. Well 2A and both of the seepage samples had relatively constant temperatures. West Brook is a cold water stream; no sample was measured to have a temperature greater than 15°C.

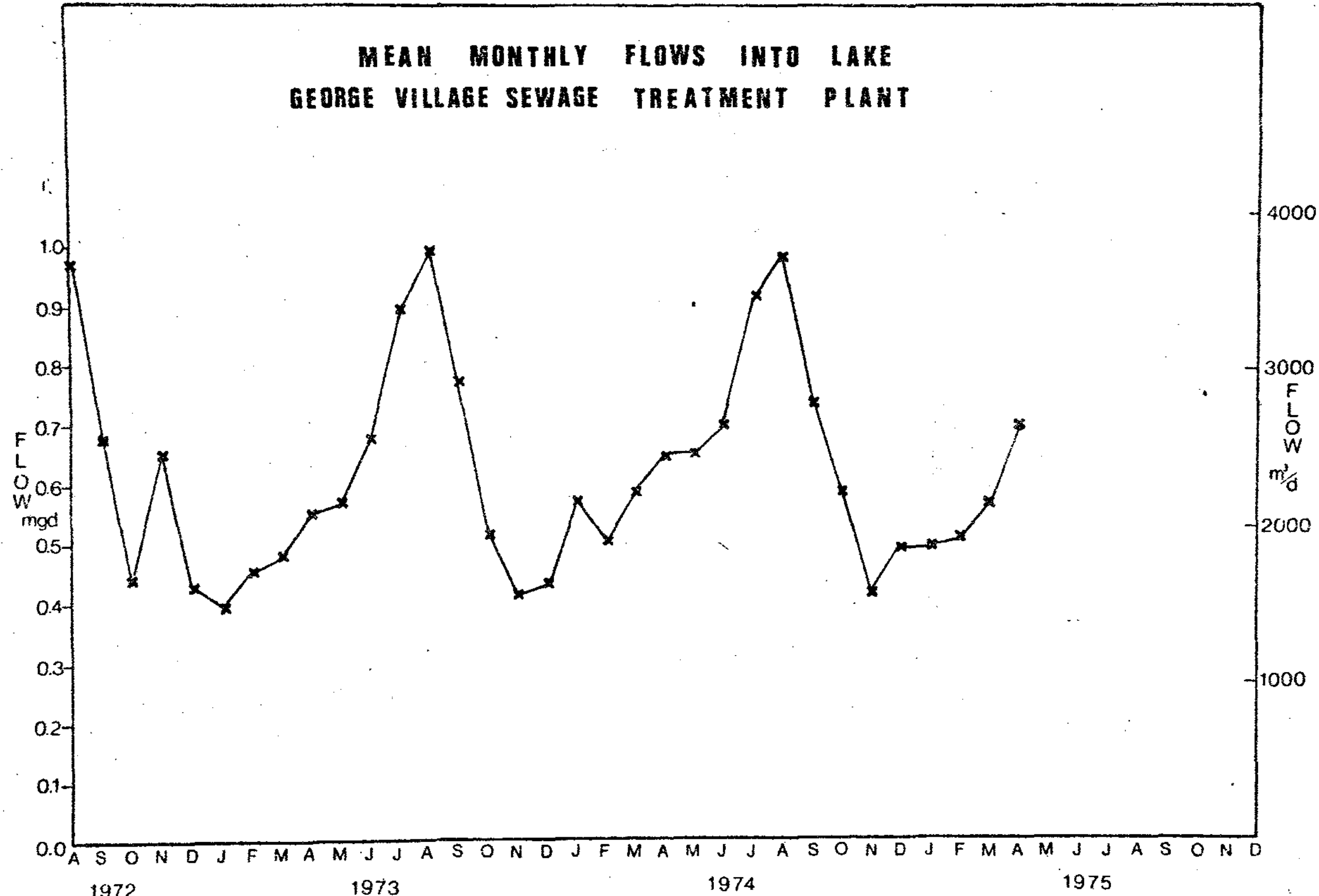
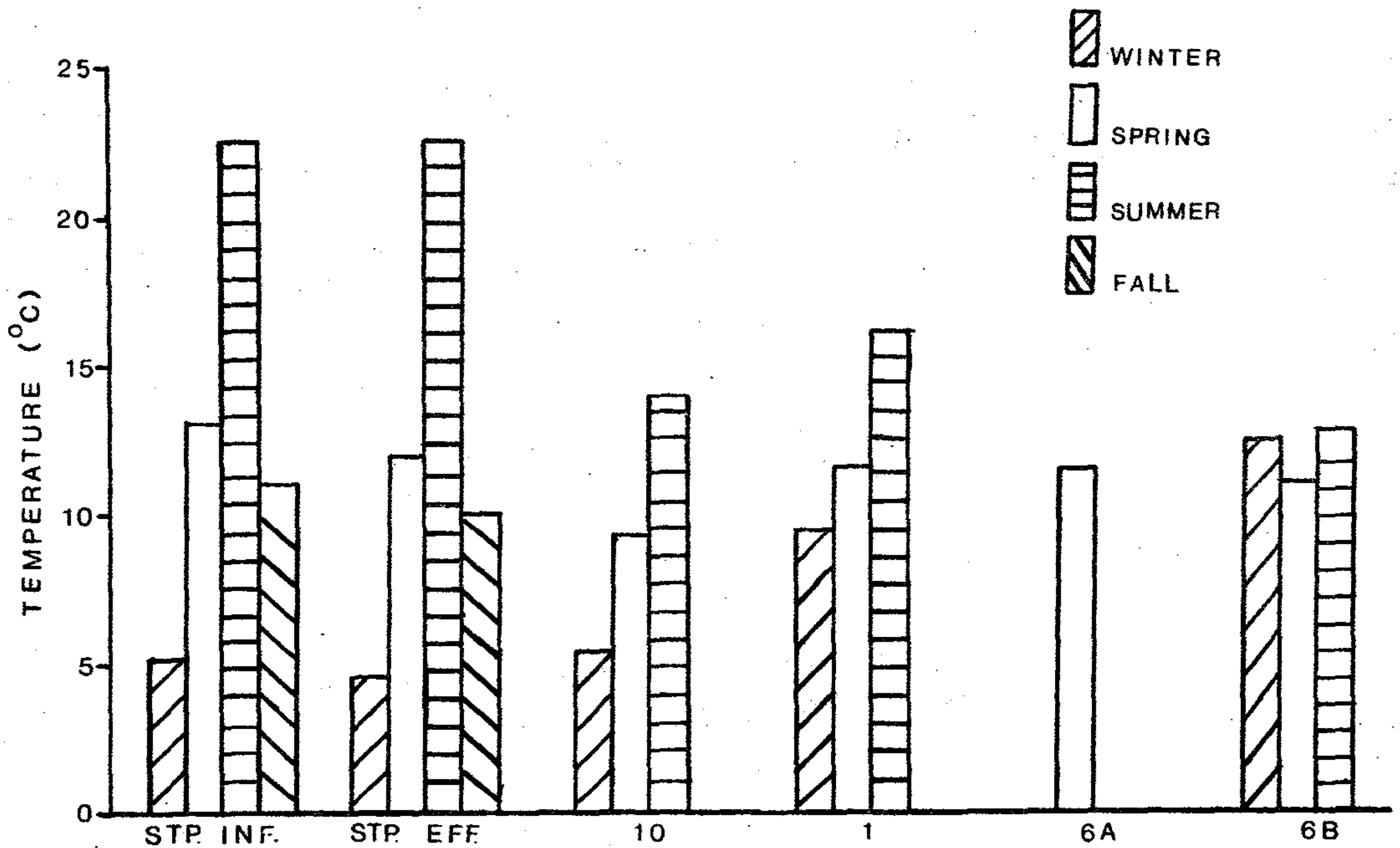

MEAN MONTHLY FLOWS INTO LAKE
GEORGE VILLAGE SEWAGE TREATMENT PLANT
FLOW mgd
FLOW m³/d
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1000
2000
3000
4000
A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1972
1973
1974
1975

FIGURE 8

TEMPERATURE



FIGURE

TEMPERATURE

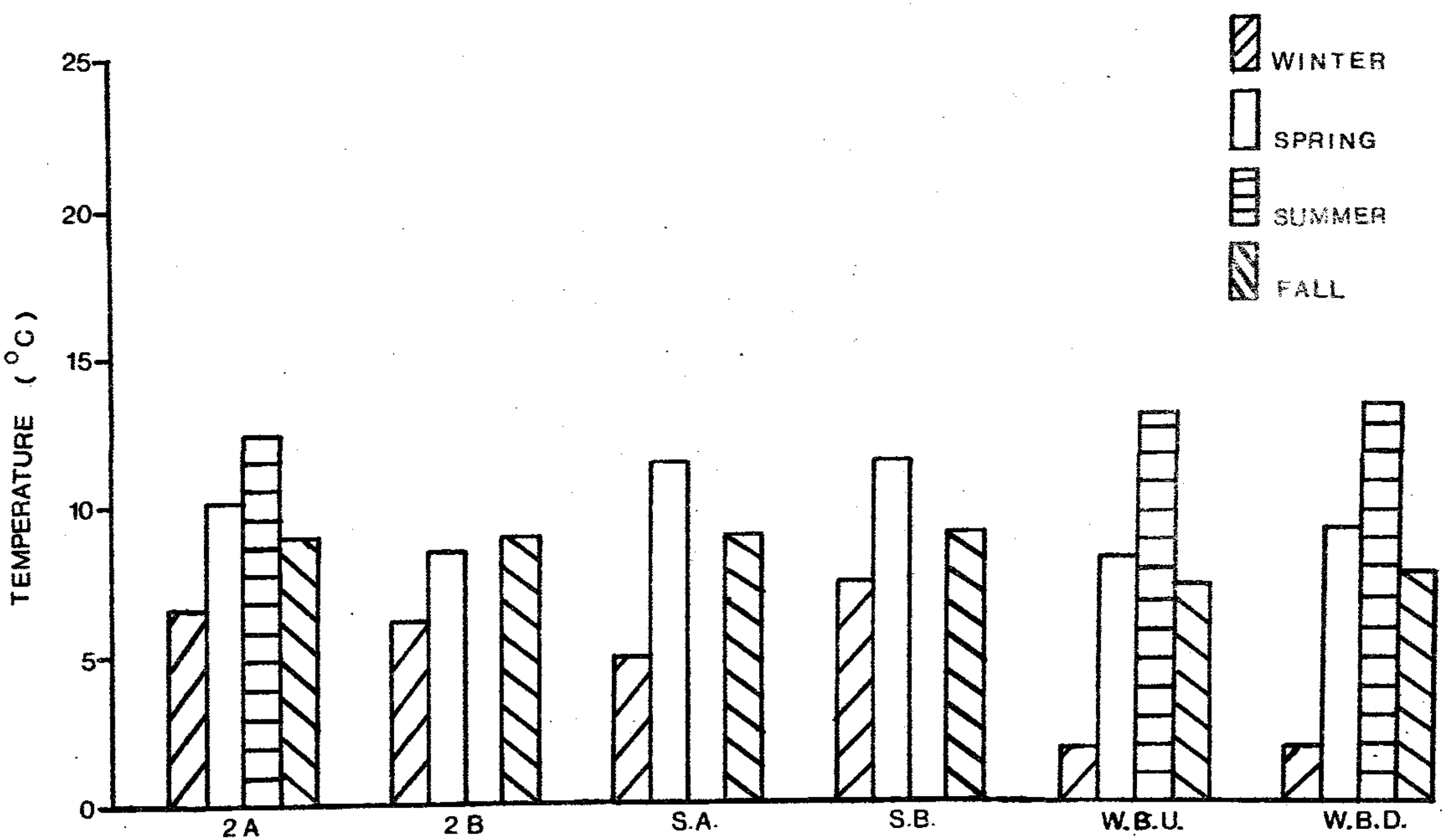


FIGURE 9b

The total dissolved solids as shown in Figure 10 indicate relatively constant values in the sewage treatment plant influent and effluent with little significant change between the influent and the effluent. The dissolved solids in the control well 10 were considerably lower than that in any other well and are similar to the quality of West Brook upstream. The total dissolved solids in well 1 were approximately the same as in the treatment plant effluent. There was a lower dissolved solids content in the deeper point at location 2. The dissolved solids in the seepage above Gage Road were similar to that of the sewage treatment plant effluent, but in the seepage below Gage Road were considerably higher. This is attributed to the salt which gained access to this seepage location. West Brook definitely shows the influence of the seepage by the increase in the dissolved solids as the stream passes this area.

The seasonal chloride concentrations (Figure 11) were fairly constant with little differences between the treatment plant influent and effluent and the water in well 1. The control well 10 was low in chloride content. With the exception of a low value for spring in well 6A, both the shallow and the deep well points at location 6 showed chloride contents similar to those of the sewage effluent. At well site 2, the shallower well point 2A had a lower chloride content than the deeper point, 2B. The seepage above Gage Road had a chloride content not unlike that of the sewage treatment plant effluent; whereas the seepage below Gage Road was high, again reflecting the contamination from the stored road salt. The chloride content in West Brook above the influence of the seepage was generally low and there was a definite increase in the chloride content after the stream picked up the seepage.

The seasonal nitrate concentrations as shown in Figure 12 indicate the oxidation of reduced nitrogen compounds to nitrate. There was a marked increase

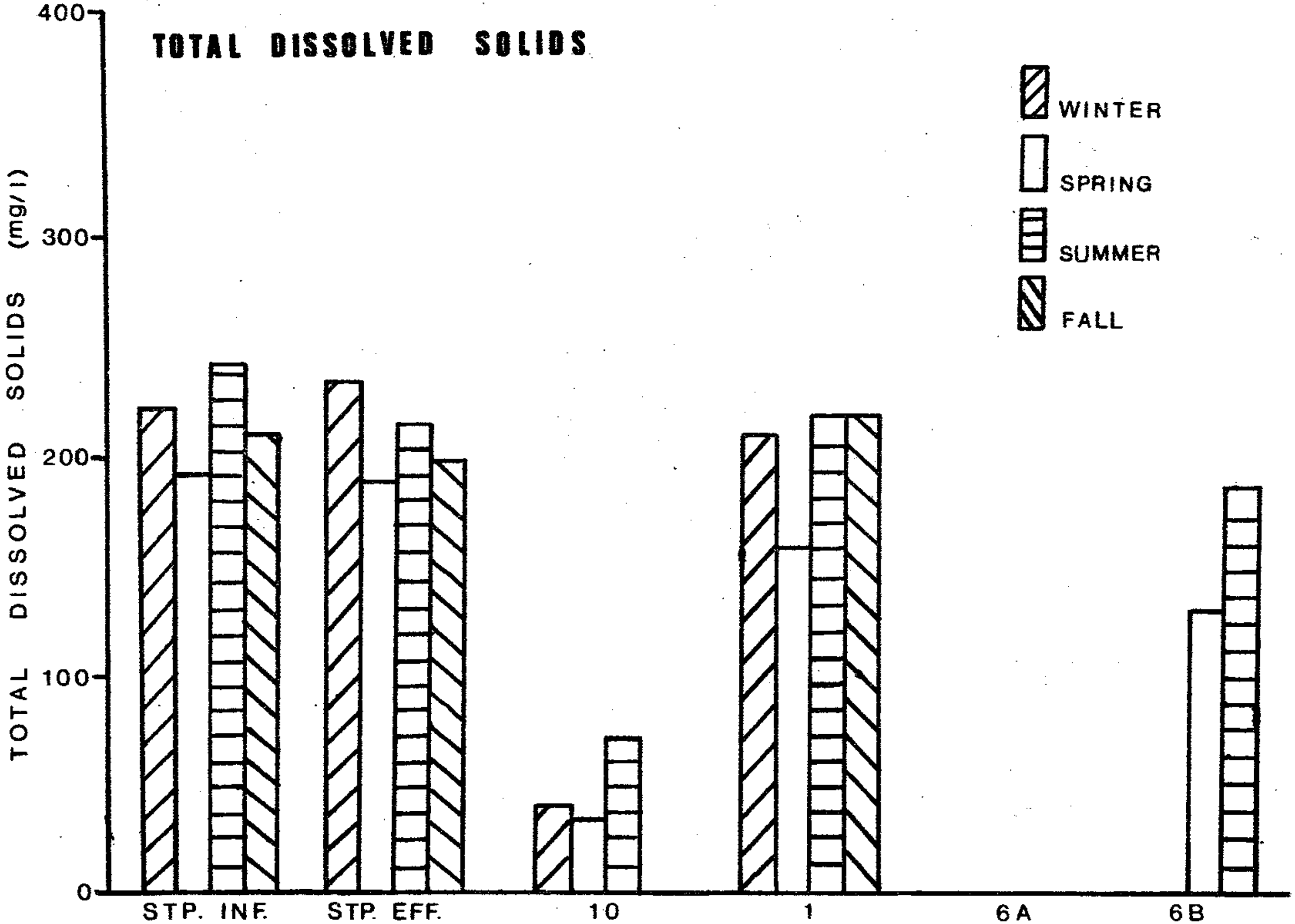

TOTAL DISSOLVED SOLIDS
TOTAL DISSOLVED SOLIDS (mg/l)
400
300
200
100
0
WINTER
SPRING
SUMMER
FALL
STP. INF.
STP. EFF.
10
1
6A
6B

FIGURE 10a

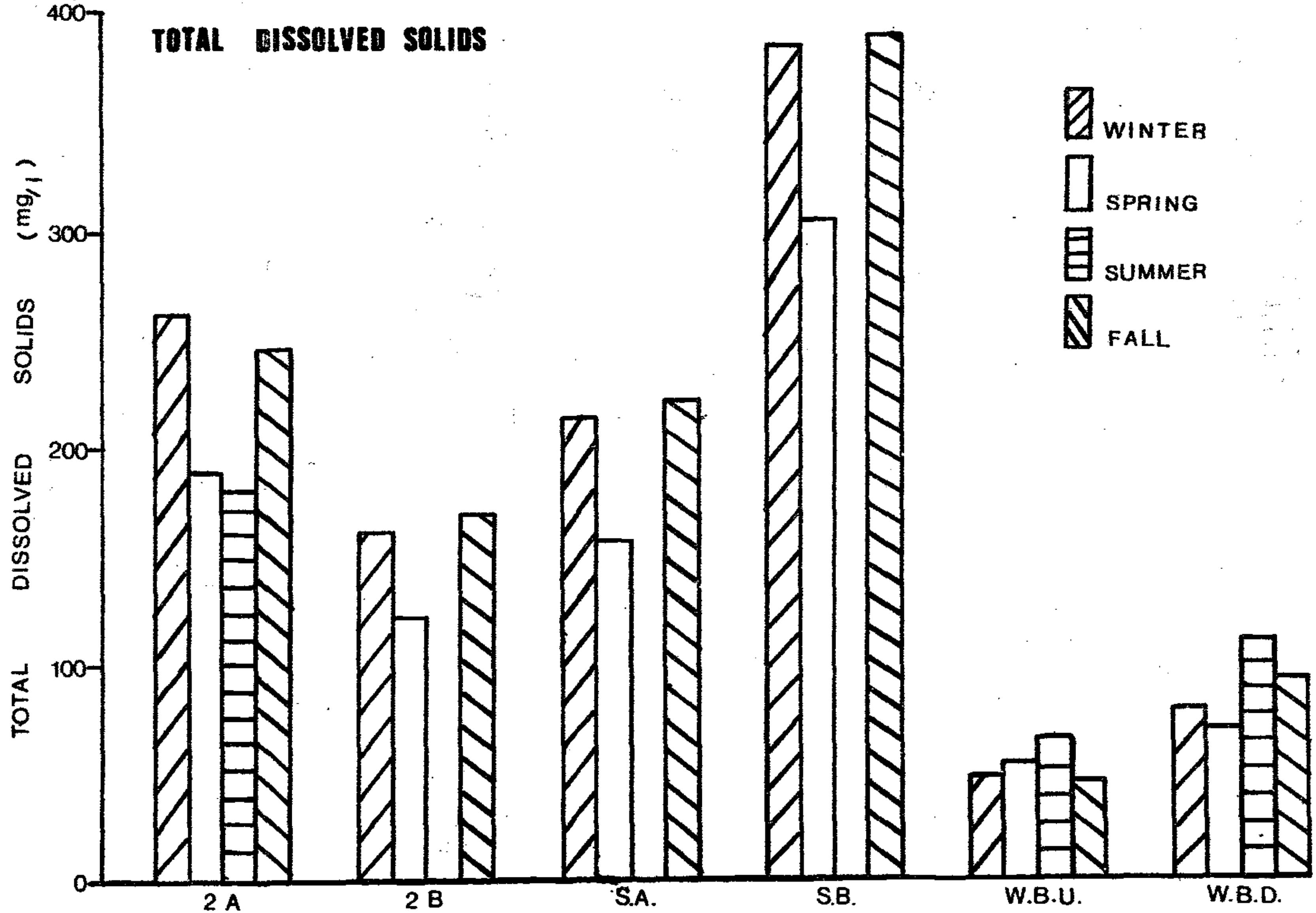

TOTAL DISSOLVED SOLIDS
TOTAL DISSOLVED SOLIDS (mg/l)
400
300
200
100
0
WINTER
SPRING
SUMMER
FALL
2 A
2 B
S.A.
S.B.
W.B.U.
W.B.D.

FIGURE 10b

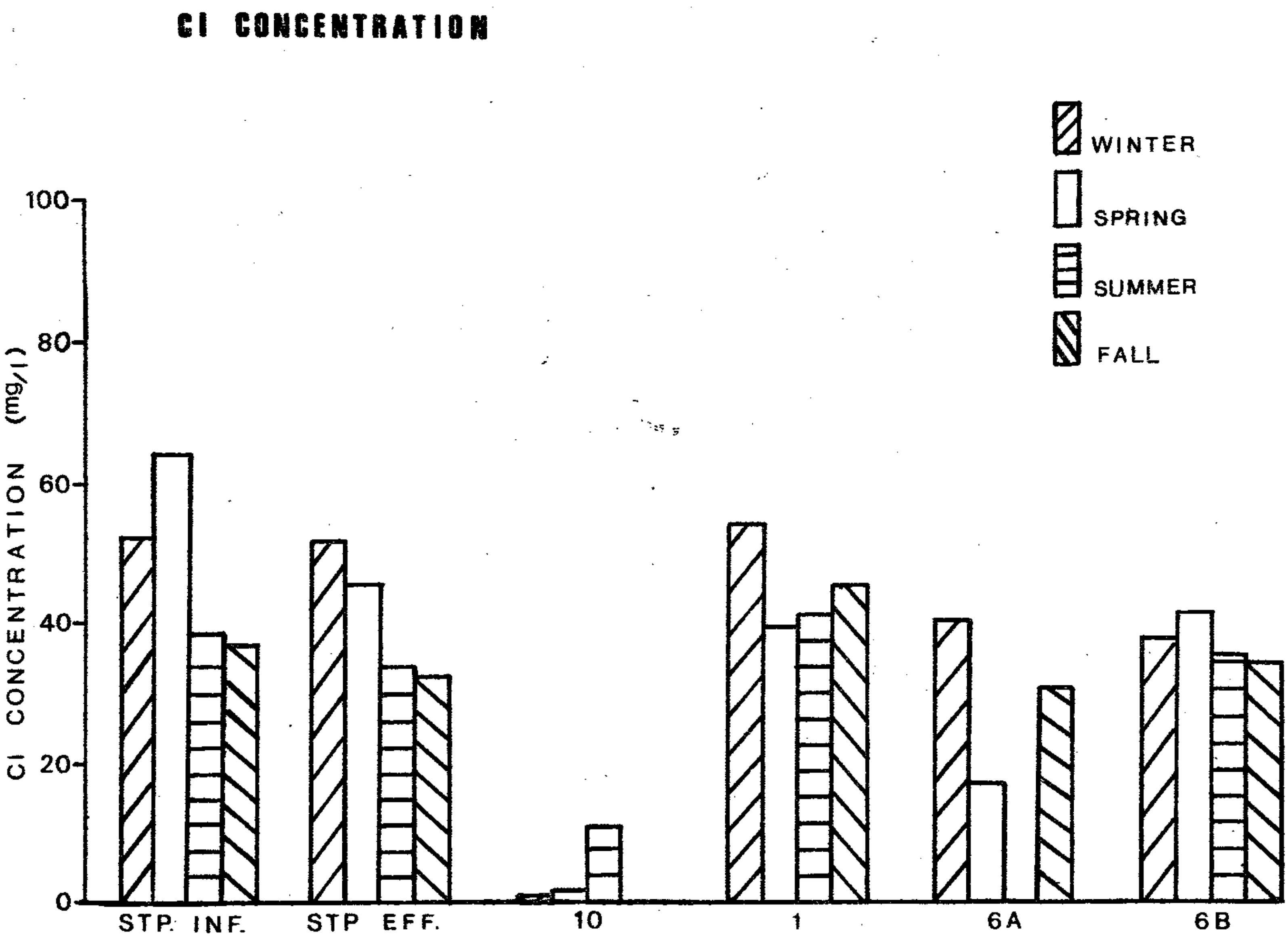

Cl CONCENTRATION
WINTER
SPRING
SUMMER
FALL
100
80
60
40
20
0
Cl CONCENTRATION (mg/l)
STP. INF.
STP EFF.
10
1
6A
6B

FIGURE 11a

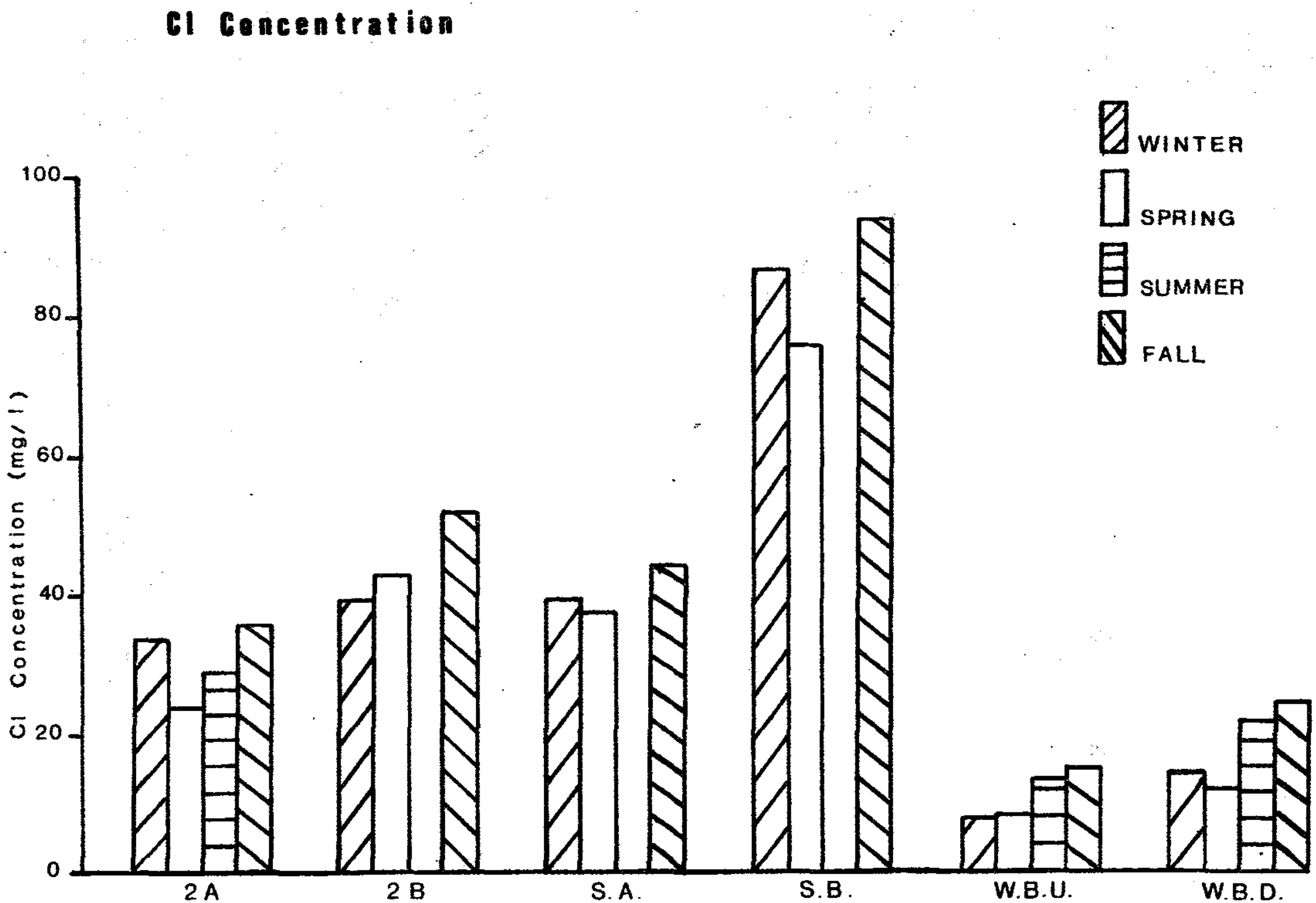
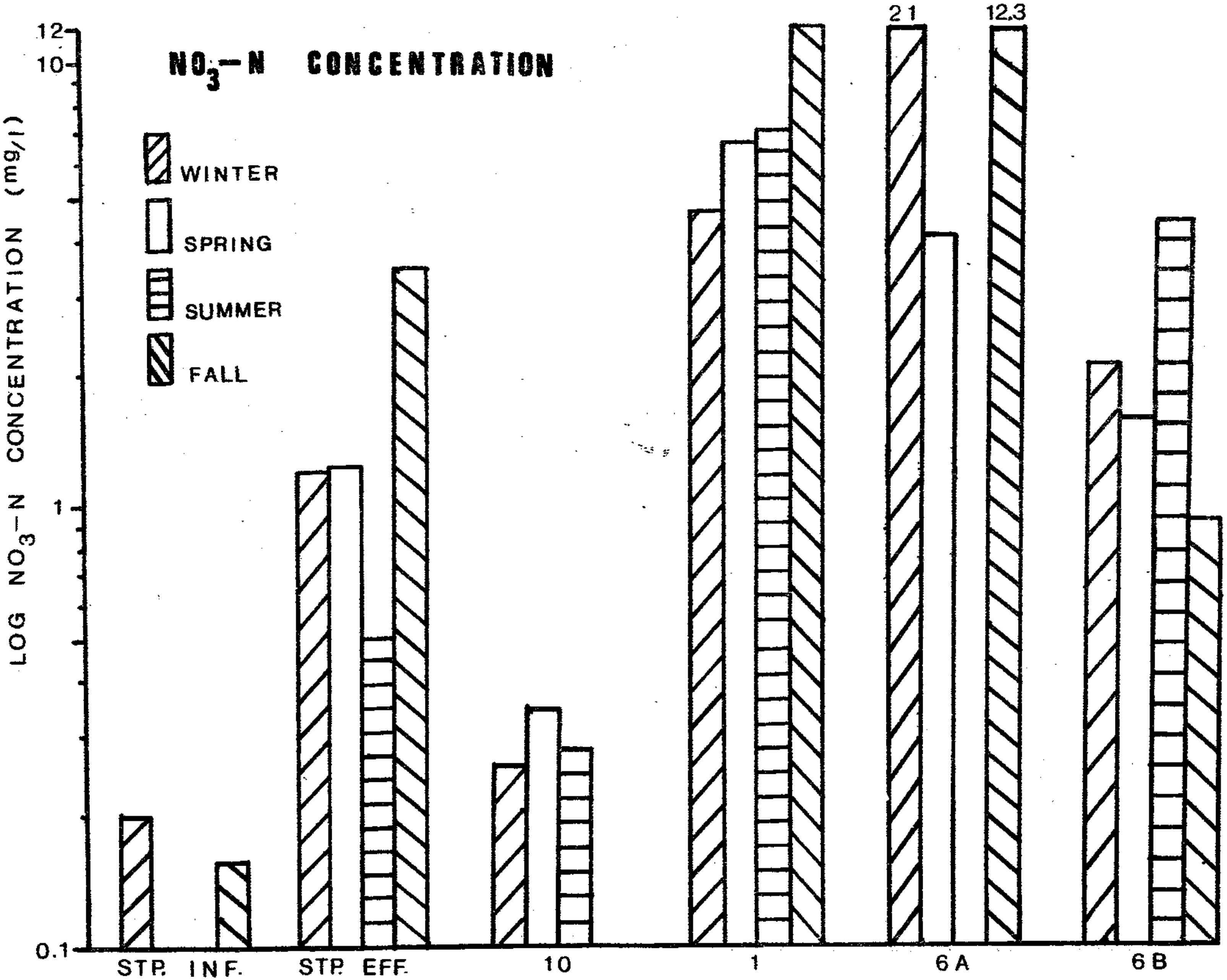

Cl Concentration
WINTER
SPRING
SUMMER
FALL
100
80
60
40
20
0
Cl Concentration (mg/l)
2 A
2 B
S. A.
S. B.
W.B.U.
W.B.D.

FIGURE 11b


NO3—N CONCENTRATION
WINTER
SPRING
SUMMER
FALL
LOG NO3—N CONCENTRATION (mg/l)
12
10
1
0.1
21
12.3
STP. INF.
STP. EFF.
10
1
6 A
6 B

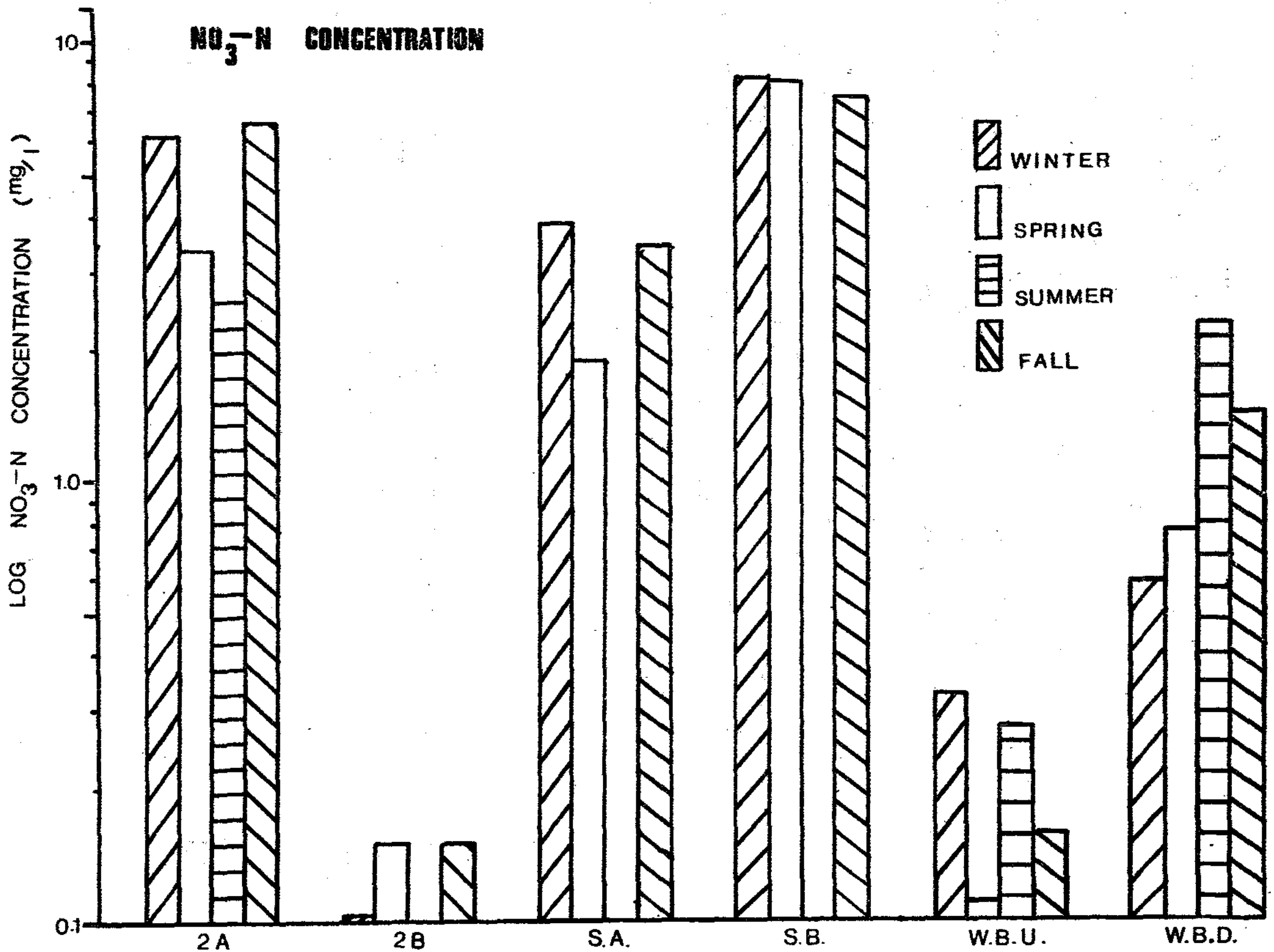
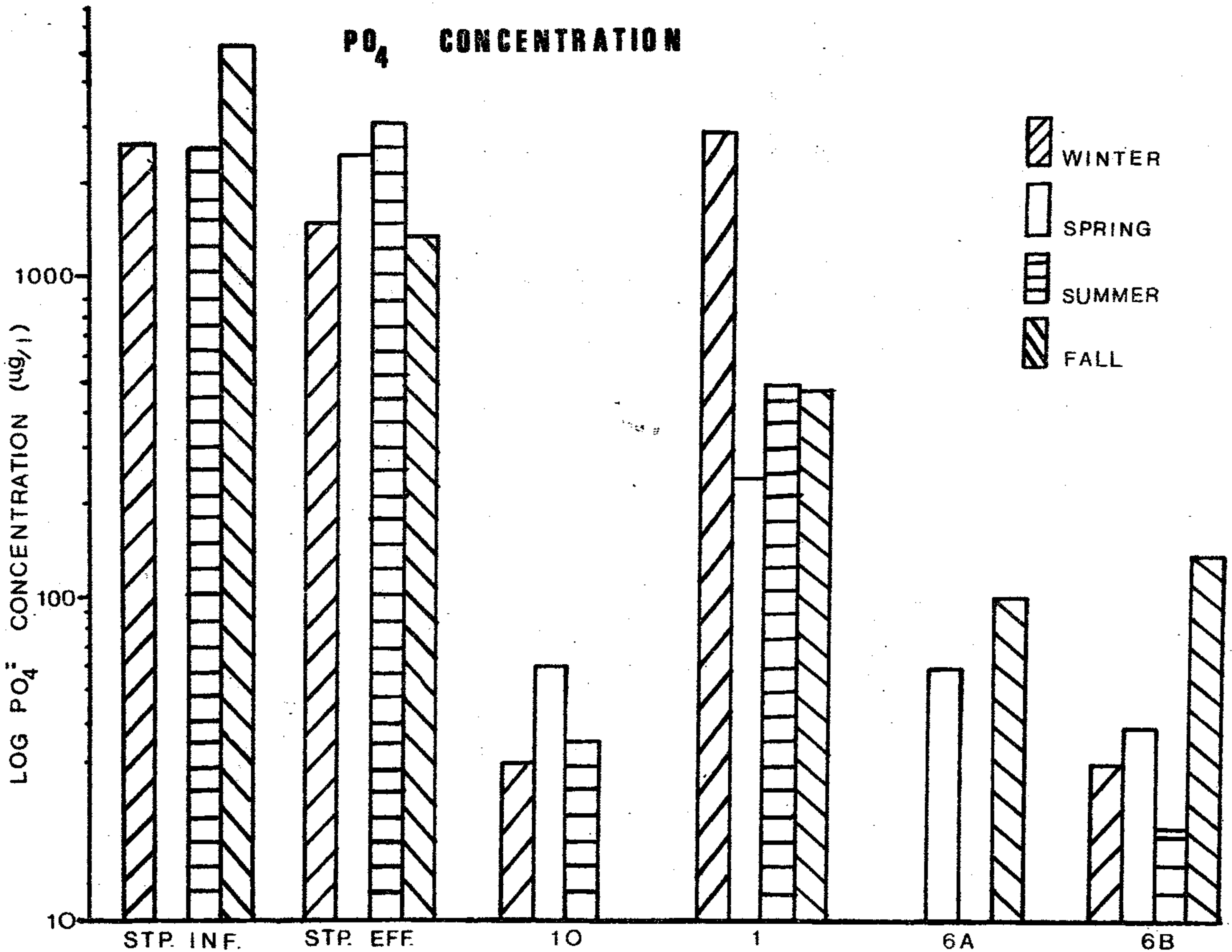

NO3-N CONCENTRATION
LOG NO3-N CONCENTRATION (mg/l)
10
1.0
0.1
WINTER
SPRING
SUMMER
FALL
2 A
2 B
S.A.
S.B.
W.B.U.
W.B.D.

FIGURE 12b

in the nitrate content in the sewage treatment plant effluent, indicating a fairly satisfactory treatemnt system. There was very little nitrate in the control well 10. Well 1 immediately indicates an increase in the nitrate content by the time the sewage passes vertically 60 ft (18 m) through the soil to the location of this well point. Well 6A showed rather high nitrate content, particularly during the fall and winter; whereas the deeper point 6B showed relatively low nitrate content. At well site 2, the shallower well indicated nitrate concentrations higher than that of the sewage treatment plant effluent, whereas the deeper well 2B showed very low nitrate content. Both seepage locations indicated a higher nitrate content than in the applied sewage effluent with somewhat higher values located in the samples from the seepage below Gage Road. The nitrate content of West Brook above the influence of the seepage was very low and there was definitely an increase in the nitrate content in the stream as it passed the seepage location. However, the nitrate content of West Brook was well below the recommended standard of 10 mg/l as N, recommended by U.S. Public Health Service Drinking Water Standards.[8]

The mean seasonal phosphate concentrations are shown in Figure 13. The sewage treatment plant seems to reduce the phosphate content by approximately fifty percent with the highest concentrations occurring during the summer. The total soluble phosphate content of the control well 10 was consistently low. There was only a slight reduction in the phosphate content of well 1 as opposed to the treatment plant effluent. The phosphorus content at well site 6 showed somewhat erratic results, but did indicate a significant reduction in the phosphate content as opposed to that in the treatment plant effluent. There was a slight further reduction in phosphate content by the time well site 2 was reached. There was no significant difference between the shallow and the deep well points; however, both wells 6 and wells 2 indicated higher phosphate



PO_4 CONCENTRATION
LOG $PO_4^{=}$ CONCENTRATION (ug/l)
1000
100
10
STP. INF.
STP. EFF.
10
1
6A
6B
WINTER
SPRING
SUMMER
FALL

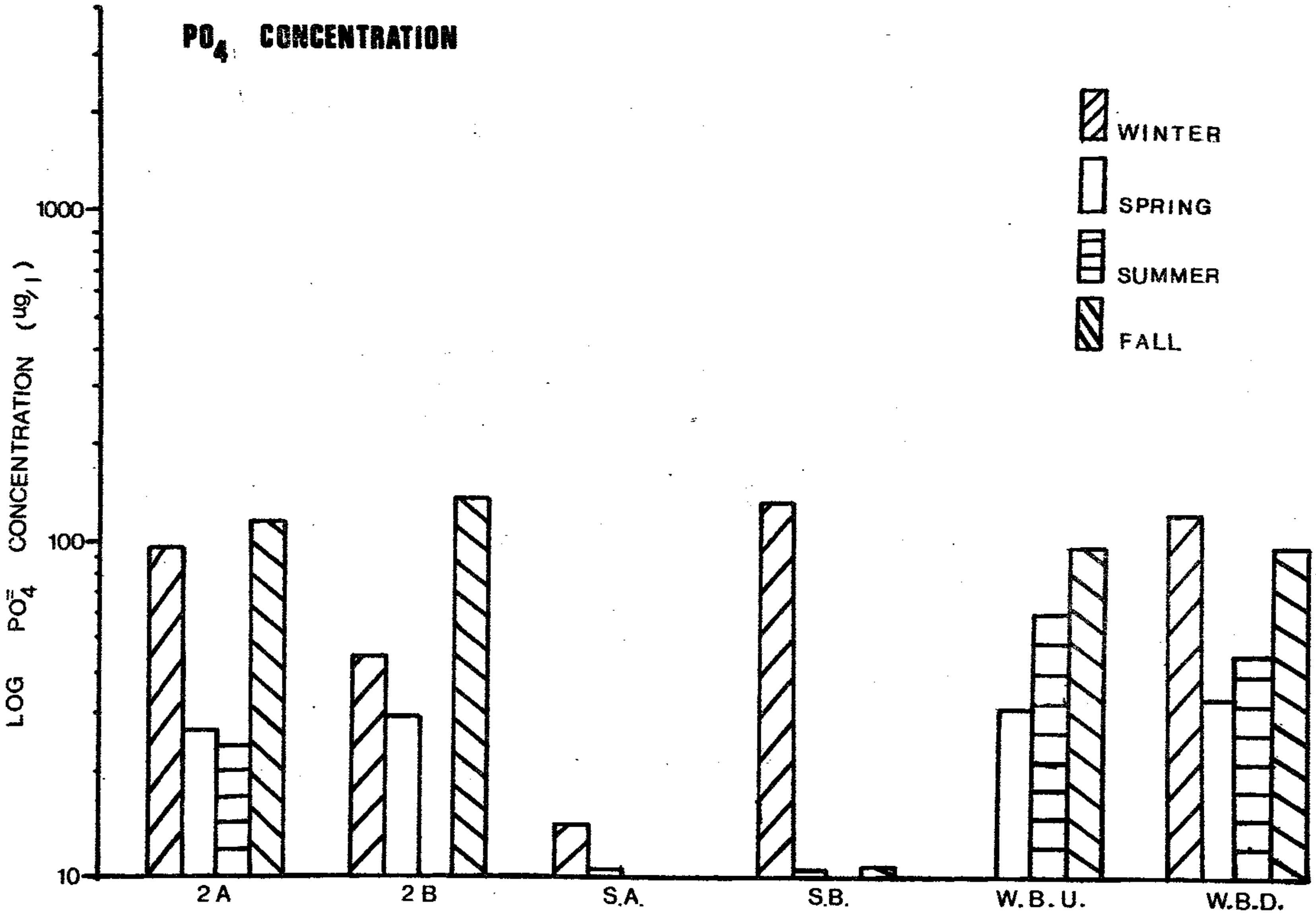

PO4 CONCENTRATION
WINTER
SPRING
SUMMER
FALL
LOG PO4 CONCENTRATION (ug/l)
1000
100
10
2 A
2 B
S.A.
S.B.
W.B.U.
W.B.D.

FIGURE 13b

contents in the fall. With the exception of the winter average for the seepage below Gage Road, the phosphate content of both seepages was generally very low. The higher phosphate content in the seepage below Gage Road during the winter is not yet fully understood. There was no significant change in the phosphate content of West Brook as it flowed past the areas of seepage studied in this report.

In general, the constituents in the treatment plant effluent may be classified into three main categories. The first category includes those substances which are totally soluble and nonreactive in the soil system. This includes the chlorides, the total dissolved solids and the alkalinity. The second category includes the materials which undergo reaction within the soil. This includes specifically the ammonia and organic nitrogen which are oxidized to nitrate in the soil system. The nitrate then may be considered in the first category of materials which are little or nonreactive in the soil, and is carried through the soil system into the seepage and into West Brook. The third category includes those materials which are completely removed by some process within the soil system. This includes the BOD, the coliforms, and the phosphate. The coliforms are removed or destroyed; the BOD is oxidized; and the phosphate is removed in some manner which has not been established by the studies herein described. It is assumed that the phosphate removal reaction involves a precipitation but the exact mode of precipitation has not yet been established.

It may be seen that the disposal of the secondary effluent onto the sand at the Lake George Village sewage treatment plant is achieving the equivalent of tertiary treatment. The BOD and coliforms are completely removed; the ammonia and organic nitrogen are oxidized to nitrate and the phosphate is completely removed. The cost of this system is minimal since it involves only (a) the initial cost of the land which was purchased many years ago before the rapid rise in land costs in the area, and (b) some maintenance performed on the sand beds, keeping them scraped and open so that infiltration may proceed at the most rapid rate possible. Furthermore, it appears that after 36 years of continuous use of this sand system, it is still capable of producing an effluent of drinking water quality. It appears that the system will continue to provide adequate treatment for a long period of time and possibly indefinitely.

Consideration is presently being made for the inclusion of the Lake George Village sewage treatment plant in the Warren County Regional Sewer System. This would collect sewage from around the Lake George area and convey it through a force main to a treatment plant on the Hudson River at approximately Hudson Falls. That treatment plant would provide only secondary treatment. Thus, the present system is providing more complete treatment at a lower cost and without the problems involved in a large series of force mains. If any additional capacity is required at the Lake George Village sewage treatment plant, it is recommended that: (a) purchase the present fallow land adjacent to the treatment plant for additional sand bed capacity; and (b) spray some of the effluent onto the wooded areas adjacent to the present sand beds. Spraying sewage treatment plant effluent onto wooded land increases the nitrate removal of the system. Thus, spraying onto the wooded areas would combine the existing phosphorus removal with the additional nitrate removal due to the forest area. This would provide the ultimate in treatment at a minimum cost which would be far less than joining the county sewer system. It would provide a water balance within the watershed and provide a water of such a quality that it may be returned to Lake George without increasing the nutrient load to the lake. Inasmuch as possible, additional areas should be sewered with treatment provided at this or a similar facility.

The soil system at the Lake George Village sewage treatment plant is providing adequate tertiary treatment for the protection of the quality of the water of Lake George.

ACKNOWLEDGEMENT

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