PROTRACTED RECHARGE OF TREATED SEWAGE INTO SAND

Part III: Nutrient Transport Through the Sand

by

Donald B. Aulenbach, Ph.D.
Professor of
Environmental Engineering,
Rensselaer Polytechnic Institute,
Troy, New York 12181.

James J. Ferris, Ph.D.
Research Coordinator
Rensselaer Fresh Water Institute,
Rensselaer Polytechnic Institute,
Troy, New York 12181.

Nicholas L. Clesceri, Ph.D.
Associate Professor,
Bio-Environmental Engineering, and
Director,
Rensselaer Fresh Water Institute,
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 12201.

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ABSTRACT

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Donald B. Aulenbach
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T. James Tofflemire

Upon the information provided by the resistivity survey indicating that the most probable direction of flow of the sewage effluent discharged onto the sand beds at the Lake George Village sewage treatment plant is northerly along Gage Road toward West Brook, a survey was made of the West Brook flood plain, both upstream and downstream from Gage Road. Considerable seepage was found emanating from the base of the sand hill which delineates the West Brook valley. The high dissolved solids of this seepage plus other chemical parameters and the configuration of the land suggested that this seepage represented the effluent applied to the sand beds. Wells were placed in the sand beds and between the beds and West Brook. Measurement of the quality of the groundwater in these wells indicates that phosphates are effectively removed in passing through approximately 2,000 ft (600 m) of sand, that chlorides are essentially unchanged, and that organic and ammonia nitrogen are effectively converted to nitrate which is not removed. Phage particles were also found. Substances not removed exerted an influence on the quality of water in West Brook. An additional source of chloride appears to be salt stored at the nearby highway department garage. This interferes with the use of chloride as a tracer of the sewage treatment plant effluent.

PROTRACTED RECHARGE OF TREATED SEWAGE INTO SAND

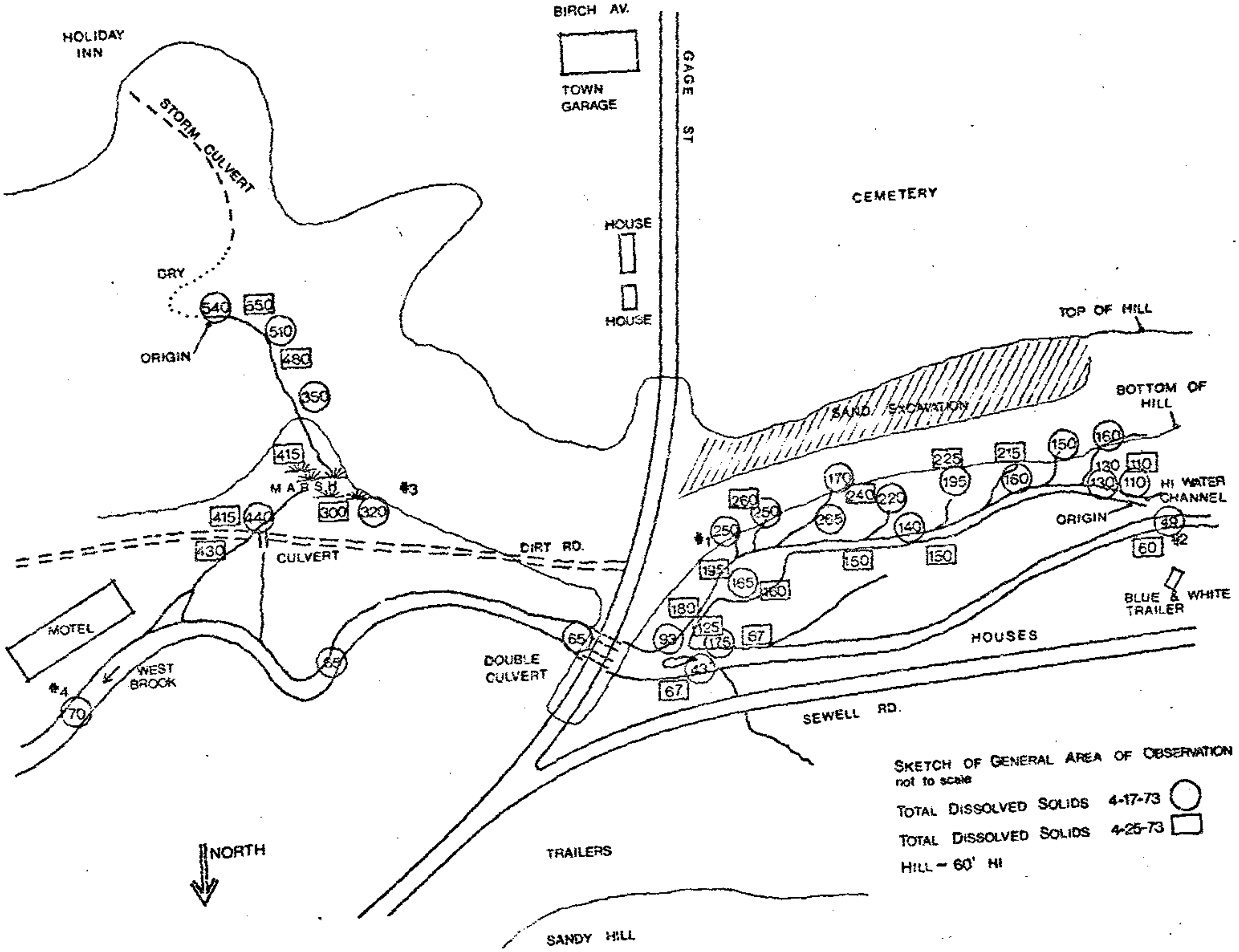
Part III: Nutrient Transport Through the Sand

INTRODUCTION

Part II of this study (Fink and Aulenbach, 1974) indicated that the flow from the Lake George Village sewage treatment plant sand beds apparently flows in a northerly direction generally following Gage Road. Gage Road crosses West Brook approximately 2000 ft (600 m) north of the lower sand beds of the treatment plant. The lower beds, 13 and 14, are 472 ft above mean sea level (amsl), whereas West Brook is at 339 ft amsl where it passes under Gage Road. The level of the surface of Lake George is 319 ft ± 1 ft amsl. There is a steep hill on Gage Road in the immmediate vicinity of West Brook. The hill is approximately 60 ft in height above the surface of West Brook.

On April 17 and 25, 1973, walking surveys were made of the southern banks of West Brook at the base of the steep hill as shown in Figure 1. West Brook flows in an easterly direction reaching Lake George approximately 1/2 mile farther downstream. Immediately west of Gage Road, there is a small tributary which flows into West Brook. The flow from this small stream was estimated to be in the order of one-half million gallons per day. Observation revealed that all of the water which forms this tributary emerges from the ground at the base of the aforementioned hill on the south side of West Brook. The seepage occurs at the base of the sand hill up to a level of approximately 5 ft above the level of West Brook. During these surveys, the conductivity of the water emanating from the ground at the base of the hill was considerably higher than that in West Brook. Also, the conductivity in West Brook was measurably

FIGURE 1



GENERAL AREA OF SEEPAGE NEAR WEST BROOK

greater downstream from the influent of this tributary. Proceeding eastward from Gage Road, slightly farther downstream, additional seepage was noted coming from the base of the hill and flowing into West Brook. A small intermittent stream was followed part way up a small valley which separates a motel from the town highway department garage. The water in this ditch was extremely high in dissolved solids. It was these findings which prompted the more detailed studies which are contained in this report.

PROCEDURE

In response to the recommendation of the Village engineer, Rist-Frost Associates, funds were provided by the Village of Lake George and with the aid of manpower from the New York State Department of Environmental Conservation, wells were located in and around the area as shown in Figure 2. Well 1 is in approximately the center of the lower seepage bed No. 4. Well 2 is located approximately halfway down the steep portion of the slope just south of West Brook and west of Gage Road. Well 3 actually consists of three wells, A, B, and C, and just recently, Well 3D has been installed. The three wells secure water from three different depths and are located adjacent to a significant seepage of water from the base of the hill close to West Brook. Well 4, intended to be installed upstream from all potential sources of groundwater contamination, was never installed due to encountering rocks before water level was reached. Well 5 is located near the center of upper sand bed No. 16. Well 6 is located just south of Prospect Mountain Road, slightly west of the entrance road to the sewage treatment plant. There are no wells numbered 7, 8, and 9. Well 10 is located in the field slightly east of the sewage treatment plant and was intended to represent uncontaminated groundwater. The samples designated West Brook upstream were taken where Sewell Street crosses West Brook and the samples designated West Brook downstream were taken sufficiently far downstream in order to insure adequate mixing of the drainage which enters

LOCATION OF WELLS RELATIVE TO THE LAKE GEORGE VILLAGE SEWAGE TREATMENT PLANT

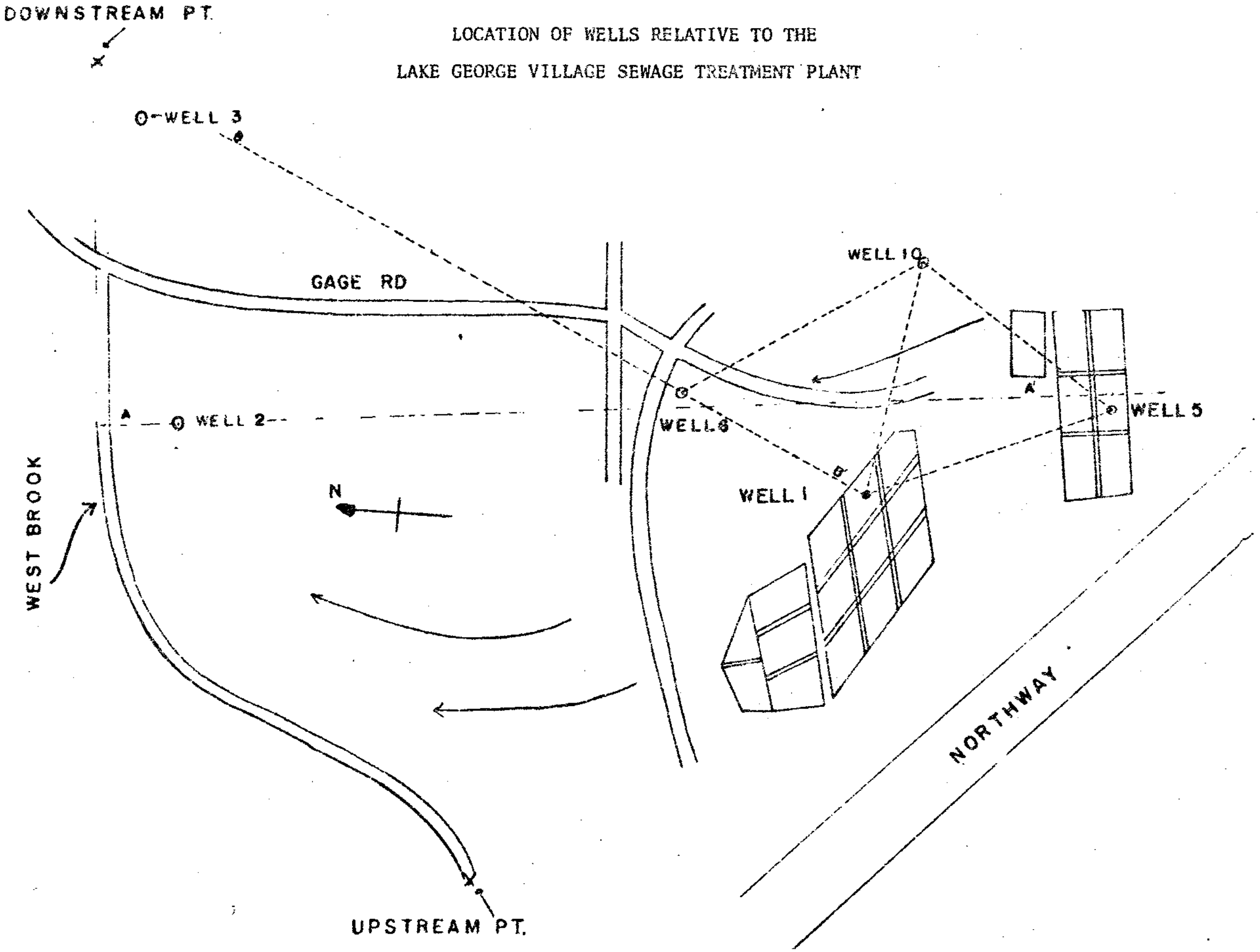


FIGURE 2

West Brook near Wells 3. Specific data for the wells are summarized in Table 1 and Figure 3.

Samples were secured from the various locations in the area during the spring and summer of 1973. In addition, measurements were made of the depth to the water table in each well. Studies of the virus content were made in one set of samples.

RESULTS

The results are separated into four categories: (1) the temperature and DO indicate the condition of the water in the ground, (2) the dissolved solids, pH, alkalinity, and chloride may be used to indicate the relationship to the sewage effluent discharged to the ground, (3) the phosphorus and nitrogen indicate the nutrient transport to that point and/or dilution by the available groundwater and (4) the effect of the emergent water upon West Brook. Representative changes in measured parameters during the sampling period are summarized in Figures 4 - 12. Changes with distance may be represented by the selected wells: Well 1 is within the sand beds, Well 6 is approximately 500 ft (150 m) from Well 1, Well 2 is approximately 2,000 ft (600 m) from Well 1, and Wells 3 are just slightly farther away, but are potentially influenced by the salt from the highway department garage located on the hill above this location.

(1) Groundwater Condition

In general, the temperature of the groundwater decreased with depth and distance from the sand beds. Well 1 had a lower temperature when the bed was dry. This indicates the direct effect of the sewage effluent on the bed. Well 3 decreased in temperature with depth. This indicates the effect of close contact of the water nearer the surface with the warm air during the time

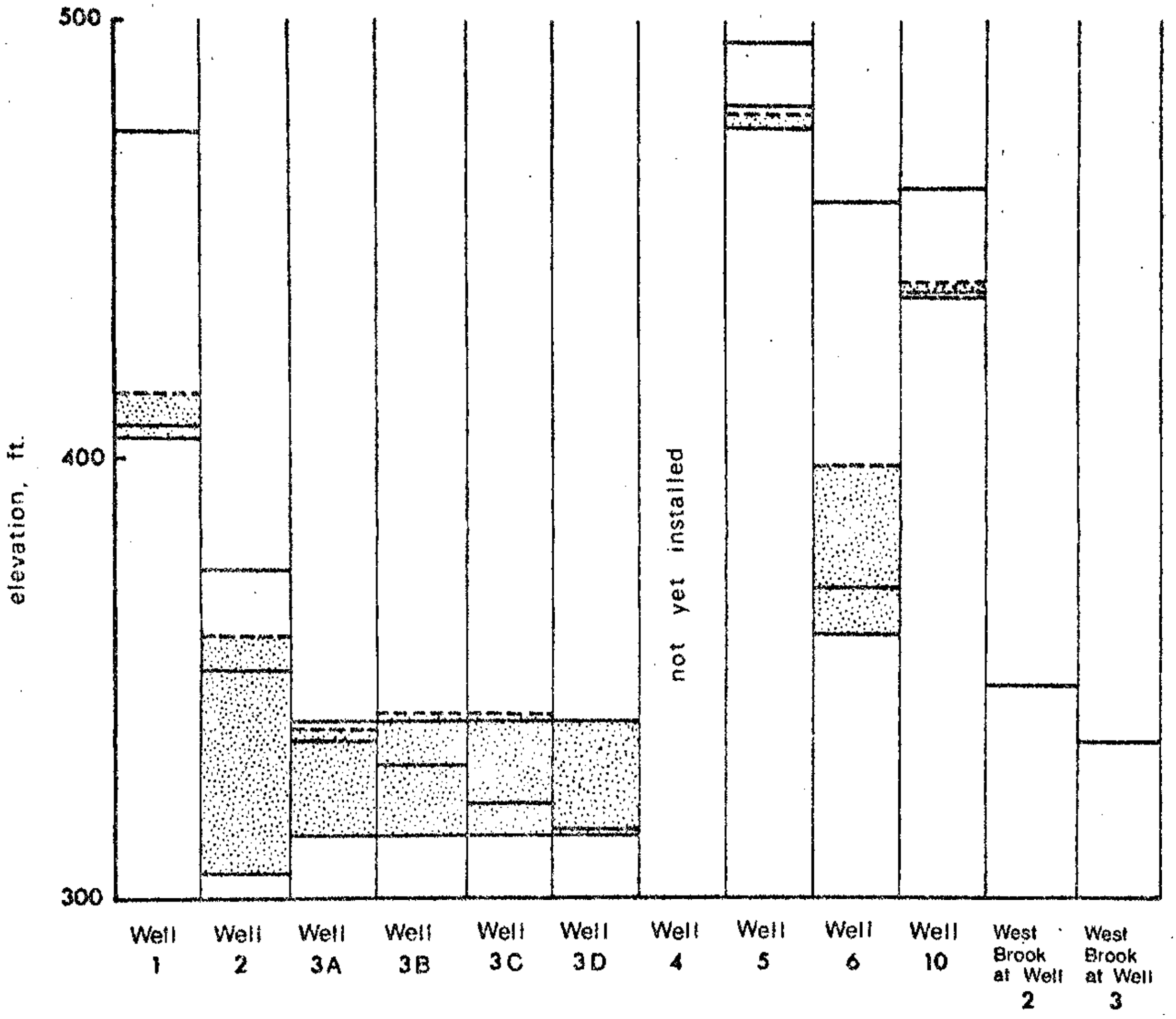
TABLE 1

WELL DATA

	Surface Elevation	Groundwater Elevation	Bottom of Point	Bedrock Elevation
Well 1	475.0	415.66	407.80	405.0
Well 2	375.40	359.22	352.13	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	314	314
Well 4	-	-	-	-
Well 5	495.37	480.98	479.40	477.40
Well 6	458.7	397.6	370.68	360.0
Well 10	462.73	441.7	438.91	438.91
West Brook at Well 2	348.0	-	-	-
West Brook at Well 3	334.9	-	-	-

FIGURE 3

WELL DATA



Upper solid line is ground surface level

Upper broken line is ground water level

Next solid line is bottom of well point

Bottom solid line is bedrock level

Shaded area represents ground water saturation of sampling and/or the possibility that the warmer sewage effluent remained nearer the surface of the groundwater. The one anomaly is a high temperature (23.4°C) in Well 10 on July 25 which may be an error in recording the data.

The presence of dissolved oxygen (DO) is considered desirable for the efficient treatment of sewage effluent discharged into the ground. Figure 4 shows the DO generally increased with distance from the sand beds to Well 6 to Well 2 which always had a high DO. Well 3C always had a lower DO than 3A. There was no consistent change in DO with time during the period of this study.

(2) Similarities to Treated Sewage Effluent

The dissolved solids in the representative wells are shown in Figure 5. In general, the wells in the sand beds (Wells 1 and 5) exhibited noticeable increases in dissolved solids when the beds were flooded. On the other hand, the wells not located in sand beds had a relatively constant dissolved solids content throughout the period of the sampling. Wells 3 were consistently higher in dissolved solids than the other wells.

The highest alkalinities (Figure 6) were found in Well 3A with noticeably lower values in Well 3B and slightly lower values in Well 3C. This obviously represents the depth profile and indicates that the high alkalinity liquid is coming in near the surface, and at the deeper location there is probably more dilution due to lower alkalinity groundwater. Wells 1, 2, and 6 were consistently lower in alkalinity. The lowest alkalinities were found in Well 10 consistently and in Well 5 when it was dry. This latter would indicate that the alkalinity is being flushed away by fresh groundwater after the treated sewage has percolated through upper bed 16.

FIGURE 4

DISSOLVED OXYGEN IN SELECTED WELLS

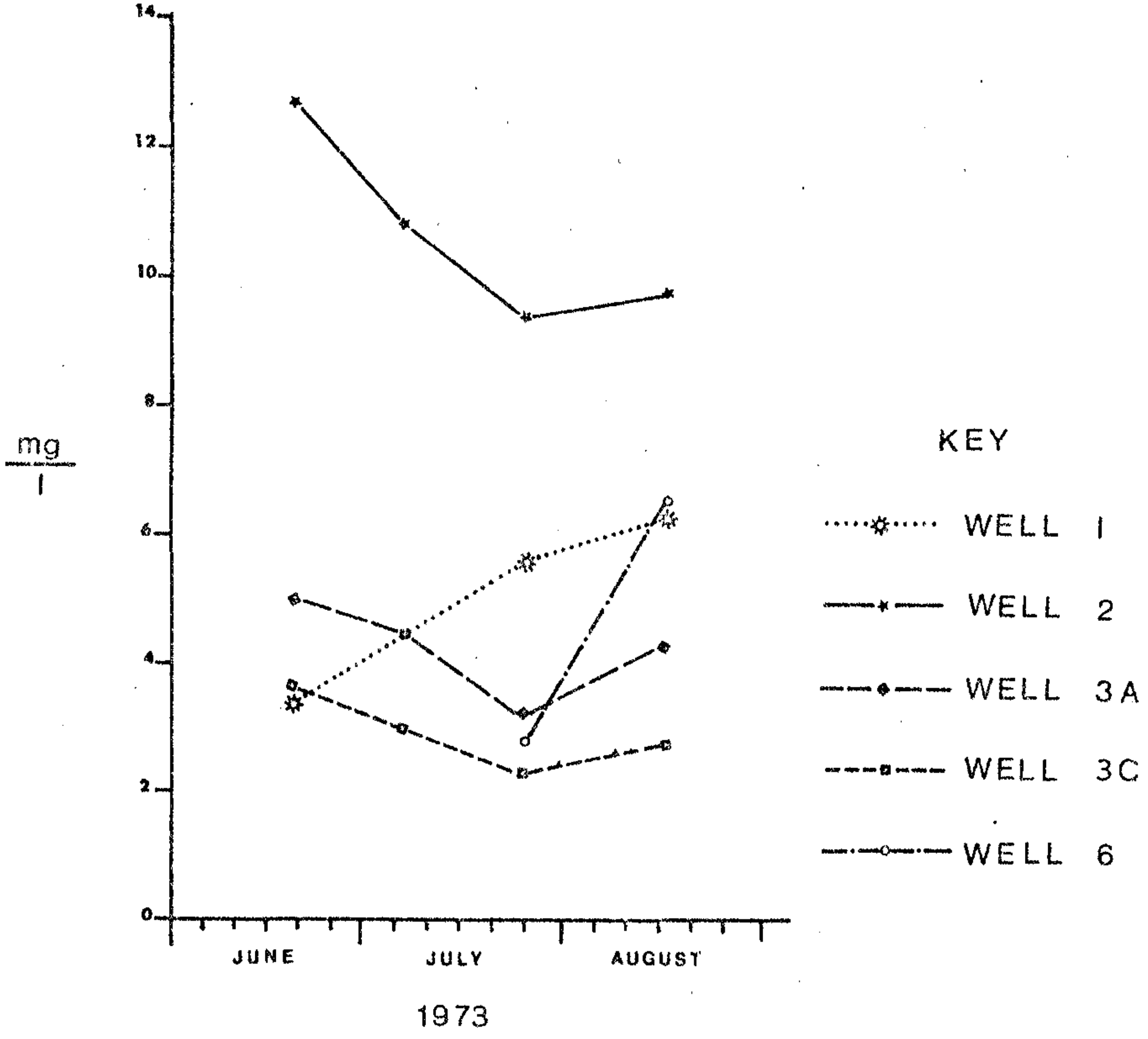


FIGURE 5

DISSOLVED SOLIDS IN SELECTED WELLS

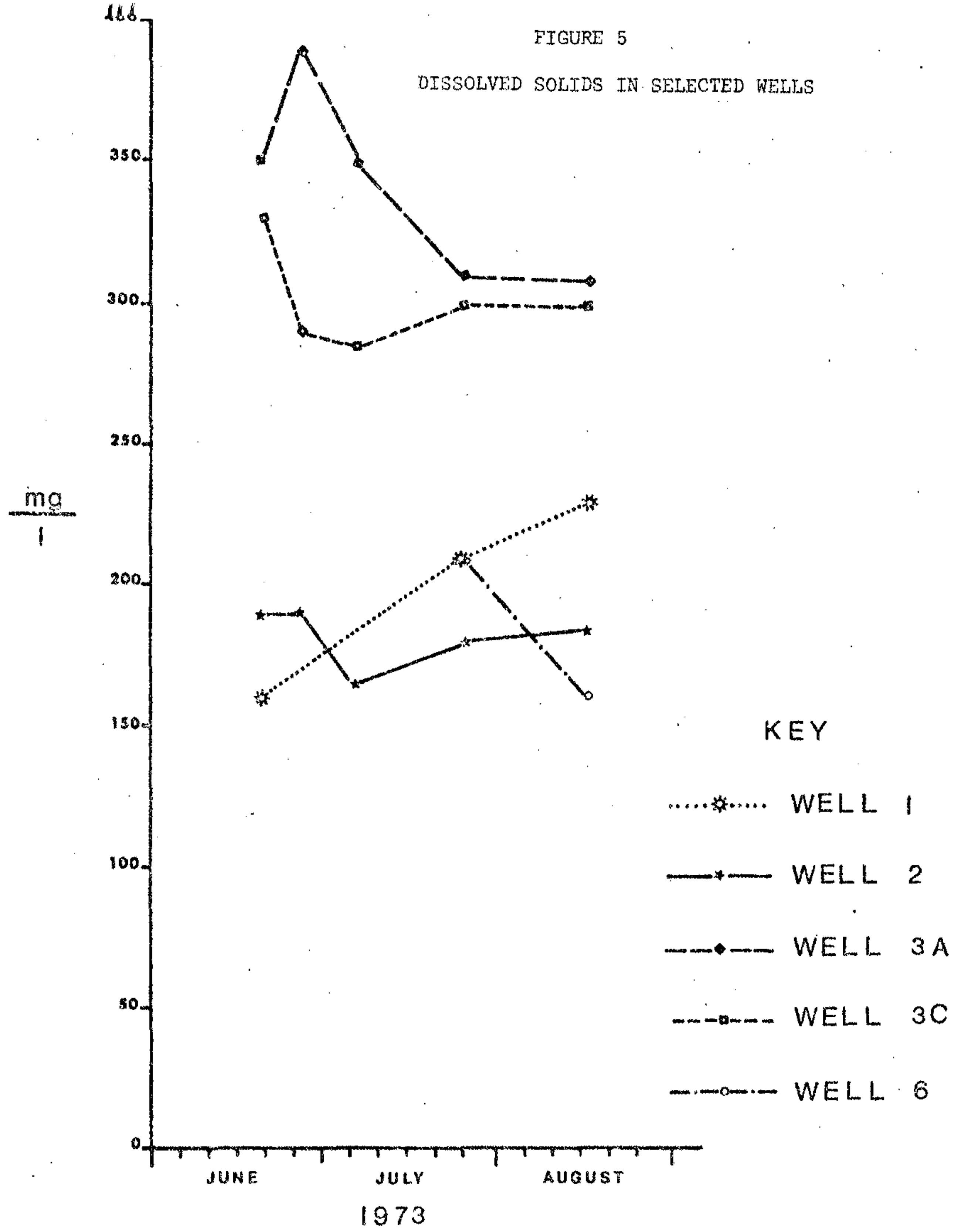
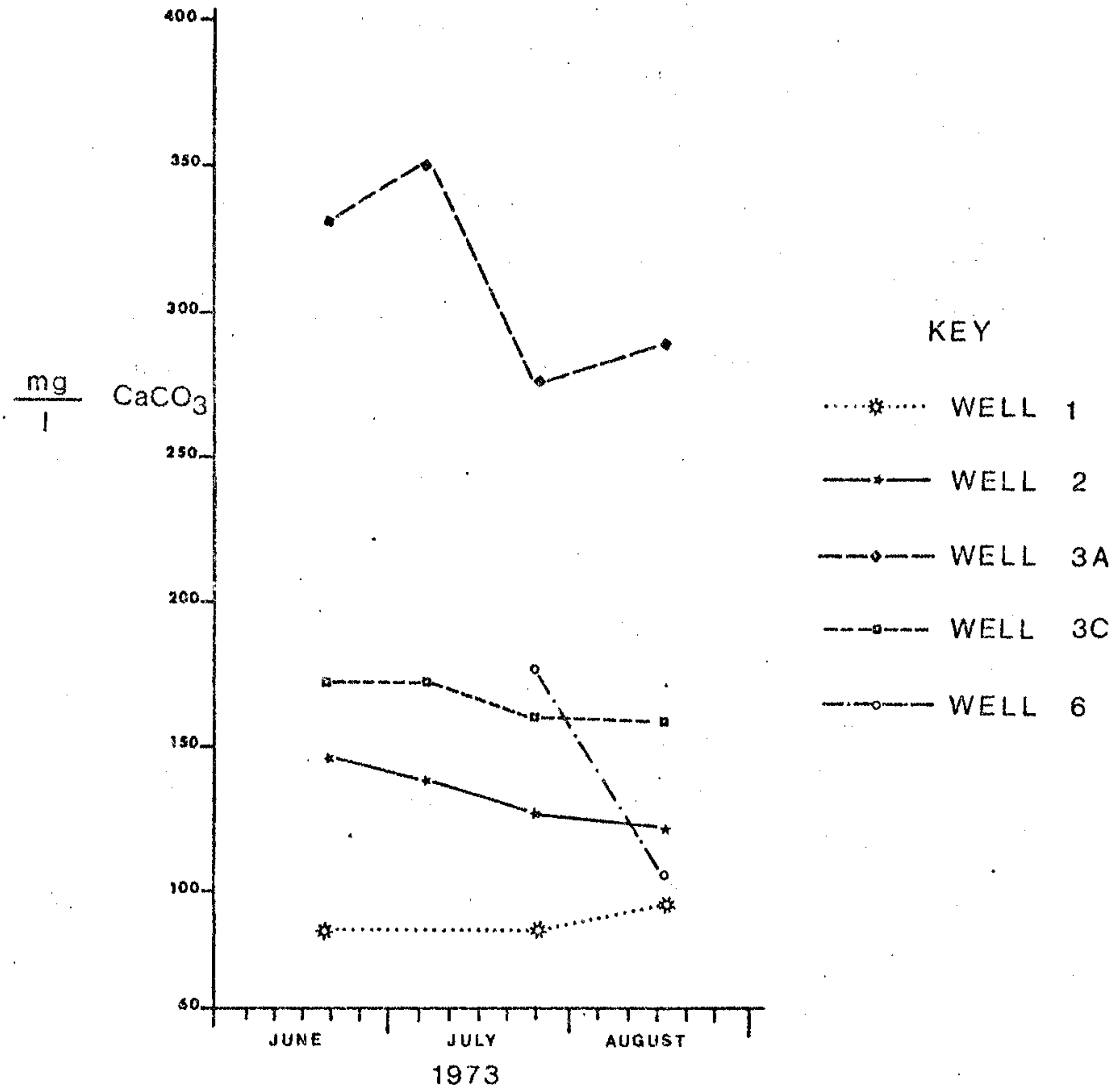


FIGURE 6

ALKALINITY IN SELECTED WELLS



The chloride concentration of the sewage treatment plant effluent varied between 30 and 35 mg/l during this sampling period. Normally, the chloride concentration may be used as a tracer in groundwater due to the fact that there is little adsorption of chloride by the soil. Figure 7 shows that Wells 6 and 2 had chloride concentrations similar to that of the sewage effluent. Well 5 had a concentration similar to the sewage effluent during the period that the bed was flooded but when the bed was dry, the concentration was only 8 mg/l, probably representing the chloride content of the natural groundwater in the area. Wells 3, however, were consistently higher in chloride content than the sewage effluent discharged onto the sand beds, and the chloride content of Well 3B was consistently higher than that of Wells 3A and 3C. In one instance, the chloride content of the seepage in the small drainage ditch behind the highway department garage (Figure 1) reached a maximum of 153 mg/l. Since this is much greater than the sewage effluent, this raises some doubt as to the validity of using chloride as a tracer in this particular case. It must be restated that the town highway garage is located atop the hill very close to this location. The highway department stores salt on this property for use on the roads during the winter. It is probable that this salt has leached into the ground and is thereby interfering with the use of chloride as a tracer for the treated sewage effluent.

(3) Nutrients

Having reasonably well established that the water recovered from Wells 2, 3, and 6 and the seepage as it emerges from the ground near West Brook is the same water which was applied to the sand beds at the sewage treatment plant, the transport of the nutrients phosphorus and nitrogen through the soil may be observed. Figure 8 shows that at Well 6, approximately 500 ft (150 m) downstream from the percolation beds, the phosphorus

FIGURE 7

CHLORIDE IN SELECTED WELLS

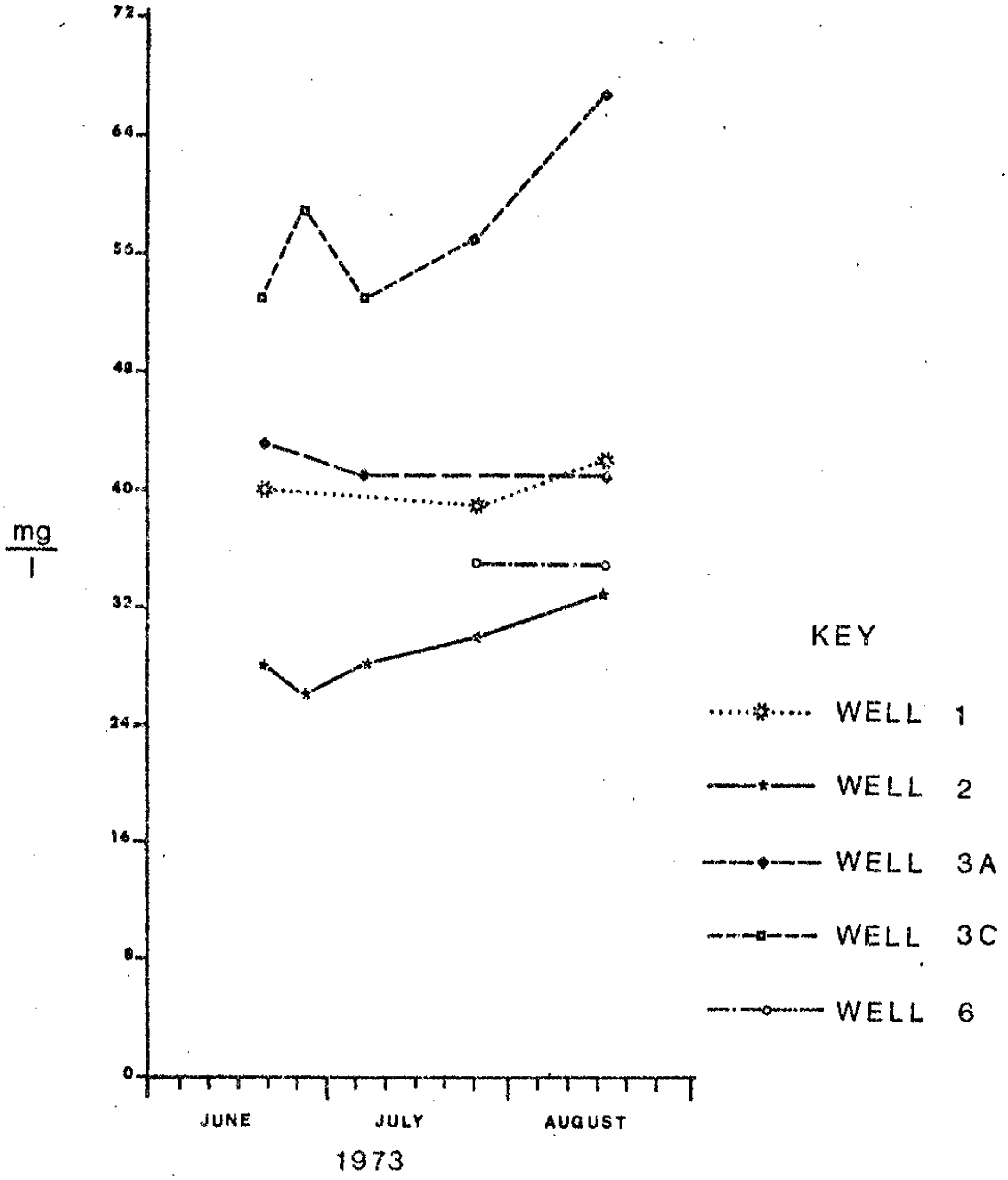
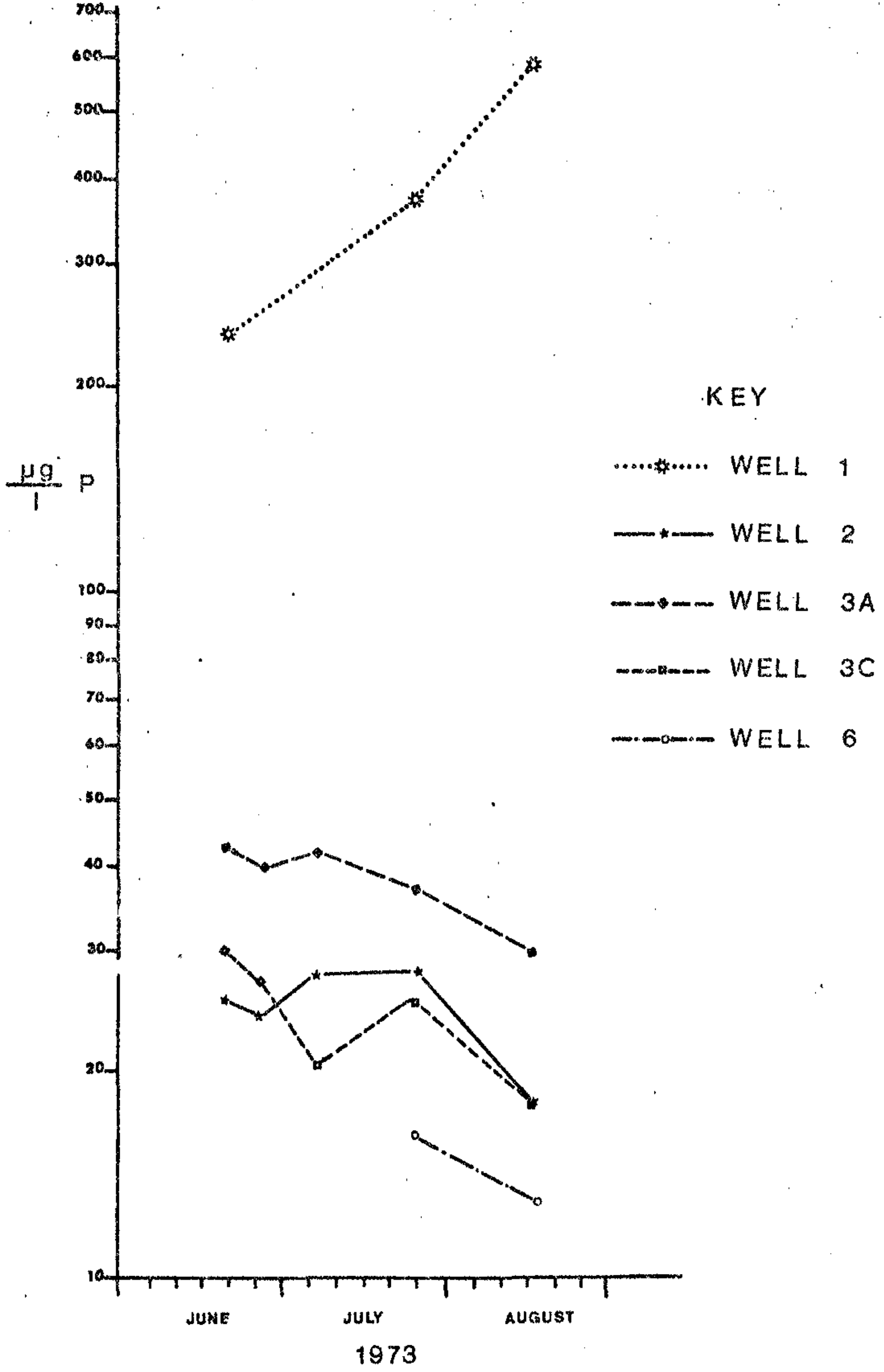


FIGURE 8

TOTAL SOLUBLE PHOSPHORUS IN SELECTED WELLS



content was less than 1% of that found in the sewage effluent applied to the beds. Similar low results were found in Wells 2 and 3 with generally higher phosphorus content being found nearer the surface at Well 3A than at the deeper Wells 3B and 3C. With the exception of the one high value of 92 µg/l of soluble phosphorus on April 17 at the seepage area above Gage Road, all of the results showed that the soluble phosphorus content in the seepage from the south bank of West Brook was less than 50 µg/l.

The nitrogen results are not quite so conclusive due to the lack of some data, particularly the nitrate content in the sewage effluent. It must be pointed out that the total Kjeldahl nitrogen includes both the ammonia nitrogen and the organic nitrogen. In general, where the total Kjeldahl nitrogen (Figure 9) was high, the nitrate (Figure 10) was low and when the nitrate was high, the total Kjeldahl nitrogen was low. At Well 6, the nitrate content was about the same as the total Kjeldahl nitrogen content. However, by the time the water reached Wells 2 and 3, nearly all of the nitrogen was recovered as nitrate. No exact balance of the nitrogen content was made due to the fact that there was a large fluctuation in the nitrogen content of the sewage influent and the effluent discharged onto the sand beds. Obviously, daily fluctuations in the nitrogen content would not be reflected in the content in the wells on the same day.

One set of samples (July 25, 1973) from the influent, effluent, West Brook (upstream and downstream) and several wells was examined for the occurrence of coliphage as a preliminary indication of the possible presence of other such infectious agents. As seen in Table 2, infectious coliphage were present in all samples examined. Of the well samples analyzed, only that sample from Well 6 possessed an average titer below 30 phage ml^{-1}. The average titer for this well sample was 5 phage ml^{-1}. The greatest number of viral

FIGURE 9

TOTAL KJELDAHL NITROGEN IN SELECTED WELLS

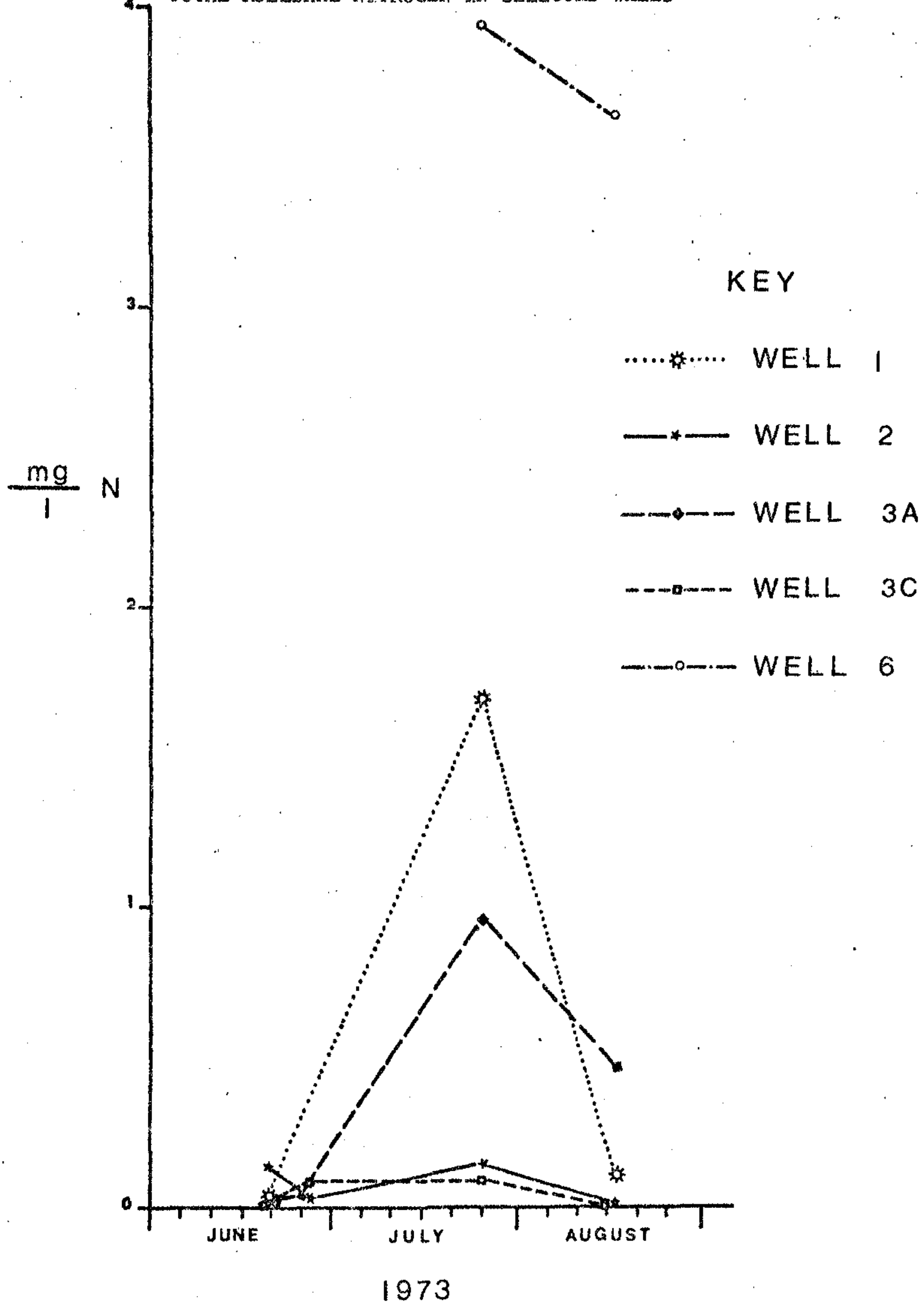


FIGURE 10

NITRATE IN SELECTED WELLS

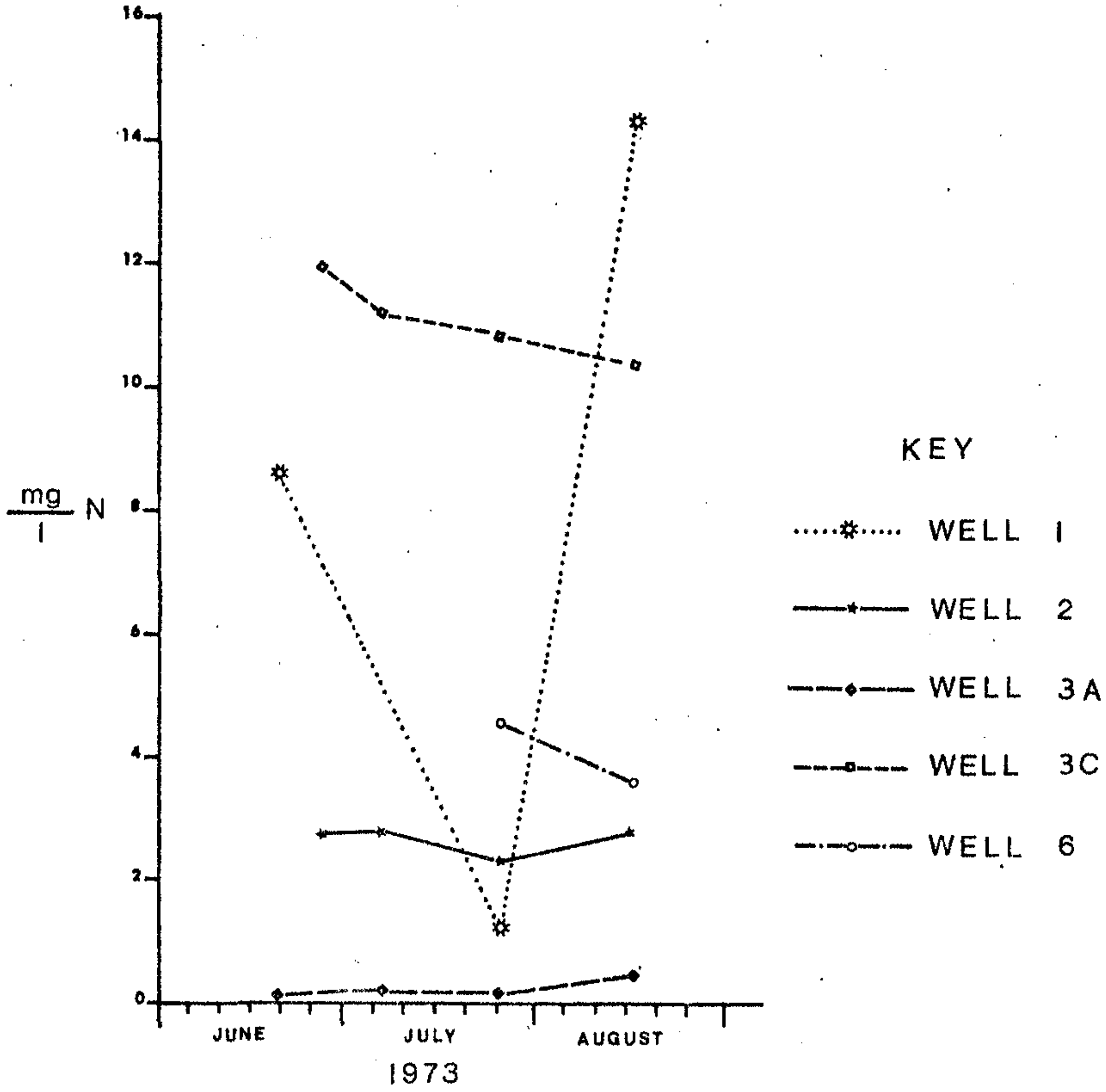


TABLE 2

COLIPHAGE (ml^{-1}) FROM LAKE GEORGE SEWAGE TREATMENT PLANT WELL SAMPLES (7/25/73)

Description	pH	Assay* No. 1	Assay* No. 2	Average Titer
Well 1	6.66	75	70	73
Well 2	7.80	38	57	48
Well 3B	7.43	30	36	33
Well 3C	7.05	42	40	41
Well 5	6.63	35	30	33
Well 6	8.88	6	4	5
West Brook (upstream)	7.63	10	2	6
West Brook (downstream)	7.71	6	2	4
LGSTP Influent	7.30	10	8	9
LGSTP Effluent	6.63	1	3	2
Control		-	-	-

* According to Hershey _et al._ (1943)

particles (73 phage ml^{-1}) was found in Well 1 during the time when this sand bed was flooded.

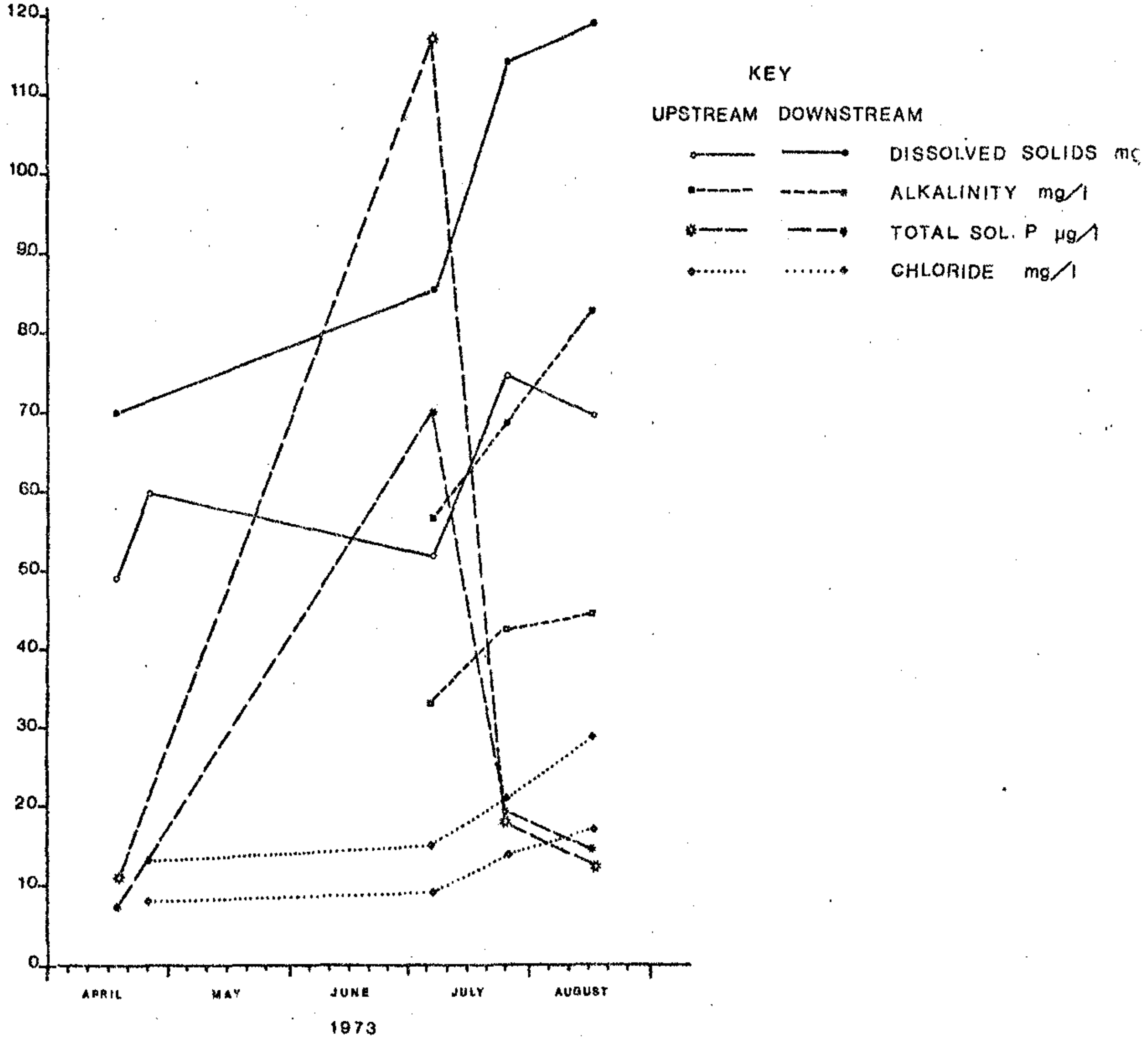
(4) Effect Upon West Brook

The seepage which occurs at the base of the hill along the south bank of the flood plain of West Brook occurs both upstream and downstream from where Gage Road crosses West Brook. Nearly all of the seepage which occurs west (upstream) of Gage Road combines to form a separate small stream which enters West Brook just upstream from the culvert under Gage Road (see Figure 1). Downstream from Gage Road, the seepage accumulates in a marshy area and several channels drain this marshy area into West Brook. A rough estimate of the flow in the tributary above Gage Road was approximately 0.5 million gallons per day, whereas the flow below Gage Road was estimated to be in the order of 0.1 mgd. During the period of the study, the average flow in West Brook was in the order of 5 mgd. Thus it may be seen that the seepage is in the order of 10 percent of the flow of West Brook. In view of the quality of the water, particularly as measured in Wells 2 and 3, it is likely that this seepage will have a measurable influence upon West Brook. Therefore, samples of West Brook were taken routinely upstream where Sewell Street crosses West Brook and downstream behind the motel indicated as Station 4 in Figure 1. The upstream location is free from any observable seepage whereas the downstream location is considered to include all of the observed seepage and to be sufficiently far downstream to provide adequate mixing with this turbulent stream to provide a representative sample. The comparison of the upstream and downstream samples is shown in Figures 11 and 12.

The dissolved solids (Figure 11) were consistently 20 to 35 mg/l higher at the downstream location than at the upstream site. There was a

FIGURE 11

EFFECT OF VARIOUS SEEPAGE COMPONENTS IN WEST BROOK



slight trend of increasing dissolved solids concentration during the summer and a greater divergence between the upstream and downstream locations toward the end of the summer.

Although alkalinity measurements were taken on only three occasions, it may be seen from Figure 11 that the values at the downstream location were 25 to 40 mg/l higher than at the upstream location. All of the values increased during the period from July through August with a greater rate of increase at the downstream location.

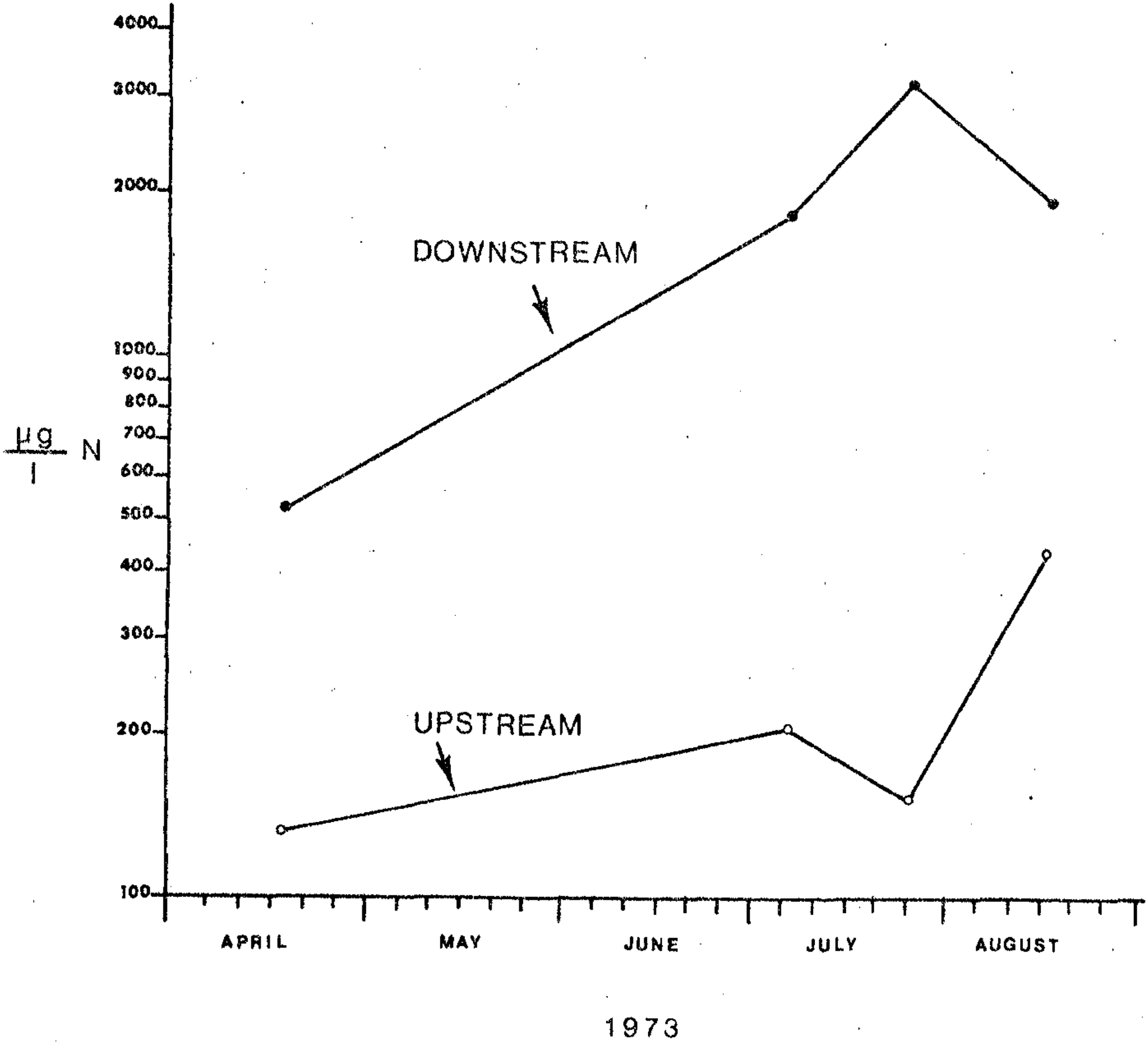
The total soluble phosphorus gave some variable results. On two occasions the concentrations as shown in Figure 11 were higher at the upstream location and on two other occasions, they were slightly higher at the downstream location. However, the values for the July 6 sampling are questioned inasmuch as they are very much out of line with all of the other results for total phosphorus. Analytical error or contamination is suspected, particularly for the upstream sample, and possibly also for the downstream sample. Ignoring the questionable value on the July 6 date, there appeared to be only a slight increase in total soluble phosphorus over the period of the study.

The chloride content (Figure 11) was 5 to 10 mg/l higher at the downstream location than at the upstream location during the period of the study. There was a slight indication of an increase during the period of the study with a very slightly greater increase at the downstream location.

The increase in the nitrate content was most striking as shown in Figure 12. There was an increase of between 400 and 3,000 μg/l of nitrogen between the upstream and downstream locations. In both cases there was an increasing trend of concentration during the summer of the sampling. Vollenweider (1970) suggests 300 μg/l of nitrogen as the critical concentration above which excessive algal growth may be encountered. At all times at the

FIGURE 12

EFFECT OF NITRATE FROM SEEPAGE IN WEST BROOK



downstream location, the concentration exceeded 300 µg/l and on the August 16 sampling, the upstream location exhibited a concentration greater than 300 µg/l.

It may be seen that the effect of the seepage on West Brook was very noticeable. In all cases there was a trend toward increasing concentration of the measured parameters with time during the period of this summer sampling. It must be pointed out that during this time the total flow in West Brook also decreased according to the normal pattern of stream flows during the summer in the northeast. Thus, if the same total amount of nutrients is contributed to a smaller stream flow, the concentration will be increased. Mention must be made of an unusual rainstorm during the period of June 30 - July 2, 1973, during which time over 2 inches of rain fell. The effects of the runoff from this storm could still be felt in the July 6 sampling. It is possible that this could explain the excessive high concentration of total phosphorus on that day. However, none of the other parameters measured showed any significant variation on that day compared with any of the other days during this sampling period. Therefore, it is not considered that this increased runoff is the most logical explanation for the high phosphorus results observed on July 6.

Seepage was also observed on the north bank of West Brook on the opposite side of the stream from the treatment plant. This seepage was not nearly so great as that found on the south bank, but it was significant. Only one sample was secured of this seepage from a small stream which drains into West Brook just upstream from Gage Road. The results indicated low concentrations of dissolved solids, alkalinity, chloride, phosphorus and nitrogen in this water. Although this is not positive proof, it does support the theory that the warmer sewage discharge floats or remains near the top of the colder groundwater during the summer period and this is the water which seeps out of the south banks of West Brook. Little or no sewage effluent appears to flow under West Brook to emerge as seepage on the northern bank. This seepage is attributed to groundwater which originates north of West Brook in the hill which contains the valley of West Brook.

CONCLUSIONS

It appears that the sewage effluent applied to the sand beds at the Lake George Village sewage treatment plant enters the groundwater and flows in a generally northerly direction and emerges with an improved quality from the ground near West Brook, following which it flows into West Brook and ultimately into Lake George. The sandy soil involved in this area appears to be adequate for the conventional treatment of the applied effluent. The dissolved solids, alkalinity, and chloride of the water which emerges from the ground in the area of West Brook are considerably higher than the natural groundwater in the area, reflecting the quality of the sewage effluent applied to the sand beds. These parameters are increased in West Brook as the stream flows past this area. Although insufficient data are available to make a positive statement concerning the nitrogen contributions from the sewage effluent, it does appear that the initially added nitrogen is completely oxidized to nitrate prior to its emergence from the ground where the nitrate content is quite high. This does have a significant effect of increasing the nitrate content of the water of West Brook.

It appears that the total phosphorus content of the applied sewage effluent has been reduced by greater than 99% in its passage through approximately 2000 ft (600 m) of sand from the treatment plant to West Brook. There is no significant increase in the phosphate content of West Brook in passing through this area. The analyses in one sample of spring water secured across West Brook indicate that the quality of this water is quite high and not representative of the sewage effluent applied to the sand beds.

Although the presence of phage particles in the samples necessitates further and more extensive investigations, the discharge of infectious coliphage into West Brook does seem to occur, with wastewater effluent from the sewage treatment plant as one likely source. It is not possible at this time to state conclusively whether or not infectious enteroviruses also are present in these wastewater effluents and eventually reach West Brook. Nevertheless, sufficient coliphage is present in those wells examined to warrant the introduction of labeled attenuated viruses into the influent and subsequently assay for these tagged particles in the effluent and well samples to obtain more conclusive data regarding the source of these particles and their adsorption and/or desorption kinetics within the surrounding soils.

Additional studies are being planned to measure the flows of the various seepage areas including those on the north side of West Brook. Additional wells will be placed between the sand beds and the existing wells, and well points will be placed at various depths within the groundwater. Tracer studies will then be performed to verify the direction of the flow and ascertain the level of the applied sewage effluent in the groundwater and determine the time of transit from the sand bed to West Brook. With this additional information, a more quantitative evaluation of the capability of natural sand beds to purify a secondary treated effluent applied over a protracted period of time can be made.

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