INVESTIGATION OF THE EFFECTS OF THE "PHASE ISOLATION" PROCESS ON THE EFFLUENT FROM THE POLISHING LAGOONS OF CUSHING, OKLAHOMA, WASTE TREATMENT PLANT

By

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CHAPTER I

INTRODUCTION

Waste treatment lagoons or stabilization ponds have been used extensively in the United States to treat domestic waste. It has been estimated that in 1945 only about 45 stabilization ponds were treating domestic wastes (1). Whereas in 1973 it was estimated that approximately 4,500 communities were treating their wastewater by stabilization ponds (1).

The influent to a stabilization pond may be raw, screened, primary settled or secondary treated sewage (2). The type of influent to a treatment pond is just one method of classifying stabilization ponds. Other typical classifications are based on outflow conditions, the method of oxygenation and the type of biological processes utilized in a pond. The different classifications for biological processes are: (1) aerobic ponds (2) anaerobic ponds and (3) facultative ponds.

Aerobic ponds are loaded so that aerobic conditions will exist and the biological processes are mainly bio-oxidation and photosynthesis. These ponds normally employ some type of mechanically induced oxygen to maintain an aerobic environment (3).

Anaerobic ponds are heavily loaded systems where anaerobic conditions exist. The primary biological processes are organic acid and methane formation.

Normally these ponds are followed by aerobic treatment for further BOD reduction (2).

Facultative ponds are the most widely used stabilization ponds. Loading rates and thermal stratification due to greater depths, 3 to 8 feet, create two zones: aerobic surface zone and an araerobic bottom layer. Photosynthesis and surface reaeration provide the needed oxygen for aerobic stabilization in the surface layer, while the sludge in the bottom is anaerobically digested (3).

Stabilization ponds have become popular mainly because of the following advantages:

1. Low operation and maintenance cost.
2. Simplicity of operation.
3. Capacity to withstand shock loadings (Hydraulic or organic).
4. Sludge handling facilities are not required (4, p.5)

The major disadvantage with waste stabilization lagoons is their inconsistency in meeting EPA discharge standards. High quality effluents are usually not obtained due to the discharge of high concentration of algal cells and incomplete stabilization of wastewaters at low temperatures (4). Since the enactment of Public Law 92-500, lagoons have had a hard time complying with the standards as set forth by the Environmental Protection Agency (EPA). These standards are set forth in Table I (5).

Communities served by lagoons are now confronted with meeting these new standards by either replacing their lagoon system with a mechanical treatment process or by upgrading their existing system.

Since approximately 90 per cent of the municipal waste stabilization lagoons are operated in communities of less than 10,000 people and the economic requirements would be hard to meet for the first alternative it is desirable to find an economical way to upgrade the existing lagoons to meet effluent standards (1).

TABLE I

SECONDARY TREATMENT STANDARDS

Parameter	30-Day Mean	7-Day Mean
BOD_5 (arithmetic mean)	30 mg/L and 85% minimum removal	45 mg/L
SS (arithmetic mean) *	30 mg/L and 85% minimum removal	45 mg/L
Fecal Coliform * (geometric mean)	200 per 100ml	400 per 100 mg/L
pH	6.0-9.0	6.0-9.0

* U.S. EPA has adopted SS requirements of 90 mg/L and eliminated the Fecal Coliform Requirements for lagoons with a total wastewater flow not exceeding 2 mgd.

Stabilization waste treatment lagoons may be upgraded by several different methods but to be able to meet the secondary treatment standards at least part of the algal content must be removed (6). The following methods have been used successfully: centrifugation, chemical coagulation, intermittent sand filtration and submerged rock filters, but none are considered to be cost effective.

This study investigated a very economical possibility for algal removal namely " Phase Isolation". Under this study the City of

Cushing, Oklahoma, Waste Treatment Polishing Lagoons were operated by the "Phase Isolation" concept for a period of one year to determine the effectiveness of the process to meet secondary treatment standards.

CHAPTER II

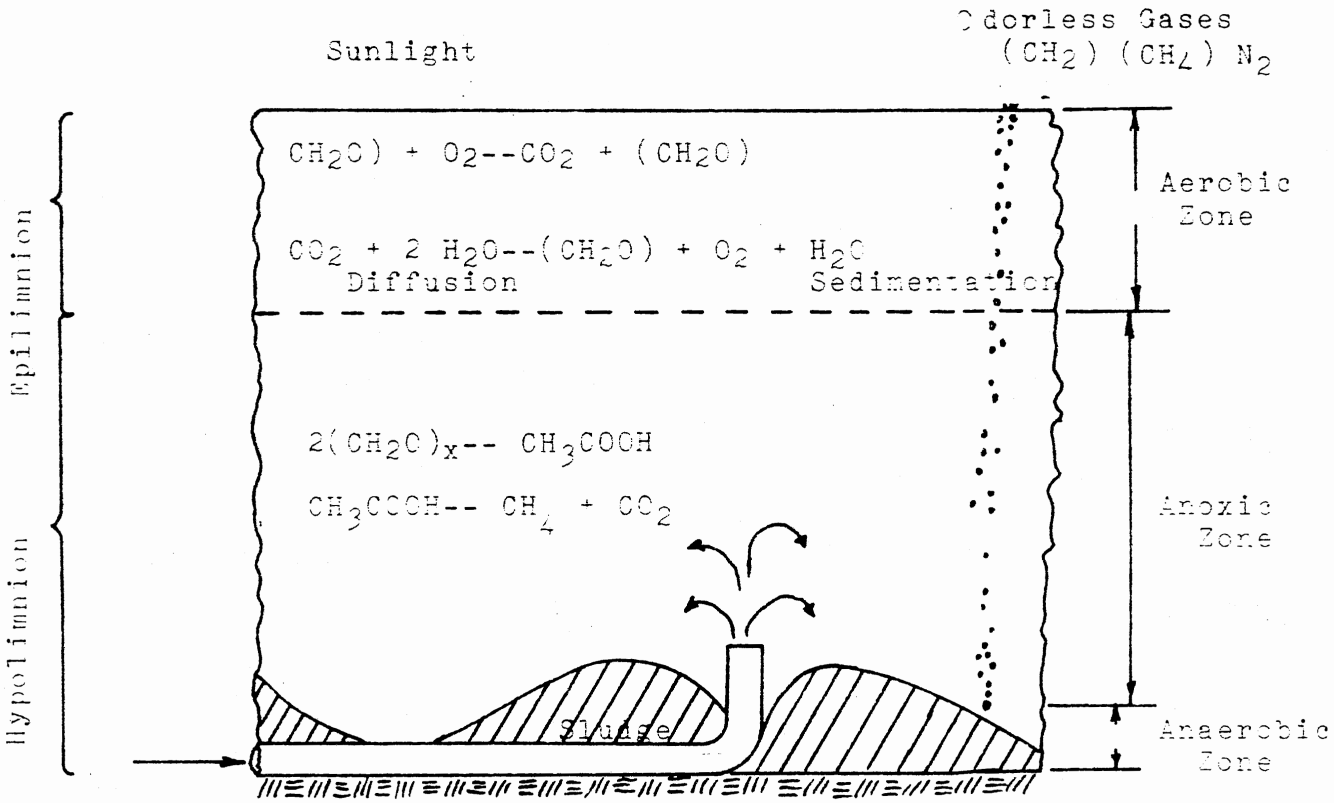
LITERATURE REVIEW

A. General

The idea of treatment of waste in stabilization ponds originated from the concept of natural purification. It was observed when wastewater was introduced in streams, the organic contaminants were purified by the micro-organisms living within the streams within a short time (2). All biological treatment processes utilize natural purification, but they require considerable equipment and close operational controls, whereas, stabilization ponds are less expensive to operate and are easily controlled.

Most waste treatment ponds in this country are of the facultative type (6). The stabilization ponds utilized in this study were of this type; therefore all further discussion will be limited to facultative ponds. The term facultative refers to the tolerance of the bacteria to adopt to varying oxygen levels both spatially and temporal.

Radiation, temperature and thermal gradients, pond geometry, wind, gas exchange, and seedings are just a few of the numerous factors that effect the simultaneous process of growth and decay in facultative ponds. Photosynthesis, respiration, volatile acid fermentation and methane fermentation are the principle reactions within the facultative ponds. Figure 1 illustrates their relationships and interactions.



Source: Koopman (6,p.2), McFauhey (7,p.215).

Figure 1. Schematic Representation of a Waste Stablization Pond

During the daylight hours algal cells by photosynethesis utilize carbon dioxide and ammonia to create new algal cells and oxygen as shown in equation (2.1)

Photosynethsis can occur in either the aerobic or anoxic condition (6).

$$CO_2 + 2H_2O \xrightarrow[\text{algae}]{\text{light}} (CH_2O) + O_2 + H_2O \qquad (2.1)$$

The reaction is reversed and algal respiration occurs during darkness.

$$(CH_2O)_x + O_2 \longrightarrow CO_2 + H_2O + \underset{\text{stable cell matter sludge}}{(CH_2O)} \qquad (2.2)$$

Both pH and the dissolved oxygen concentration are lower during algal respiration, while CO_2 is produced.

Equation 2.3 represents a simplified equation showing the reaction carried out by aerobic bacteria.

$$(CH_2O)_x + xO_2 + xNH_3 \xrightarrow[\text{bacteria}]{\text{aerobic}} xCHNO_2 + x\ CO_2 + xH_2O \qquad (2.3)$$

The oxidation of organic matter provides the energy for cell maintenance as shown in (2.4)

$$CH_2O + O_2 \xrightarrow{\text{bacteria}} CO_2 + H_2O + \text{Energy} \qquad (2.4)$$

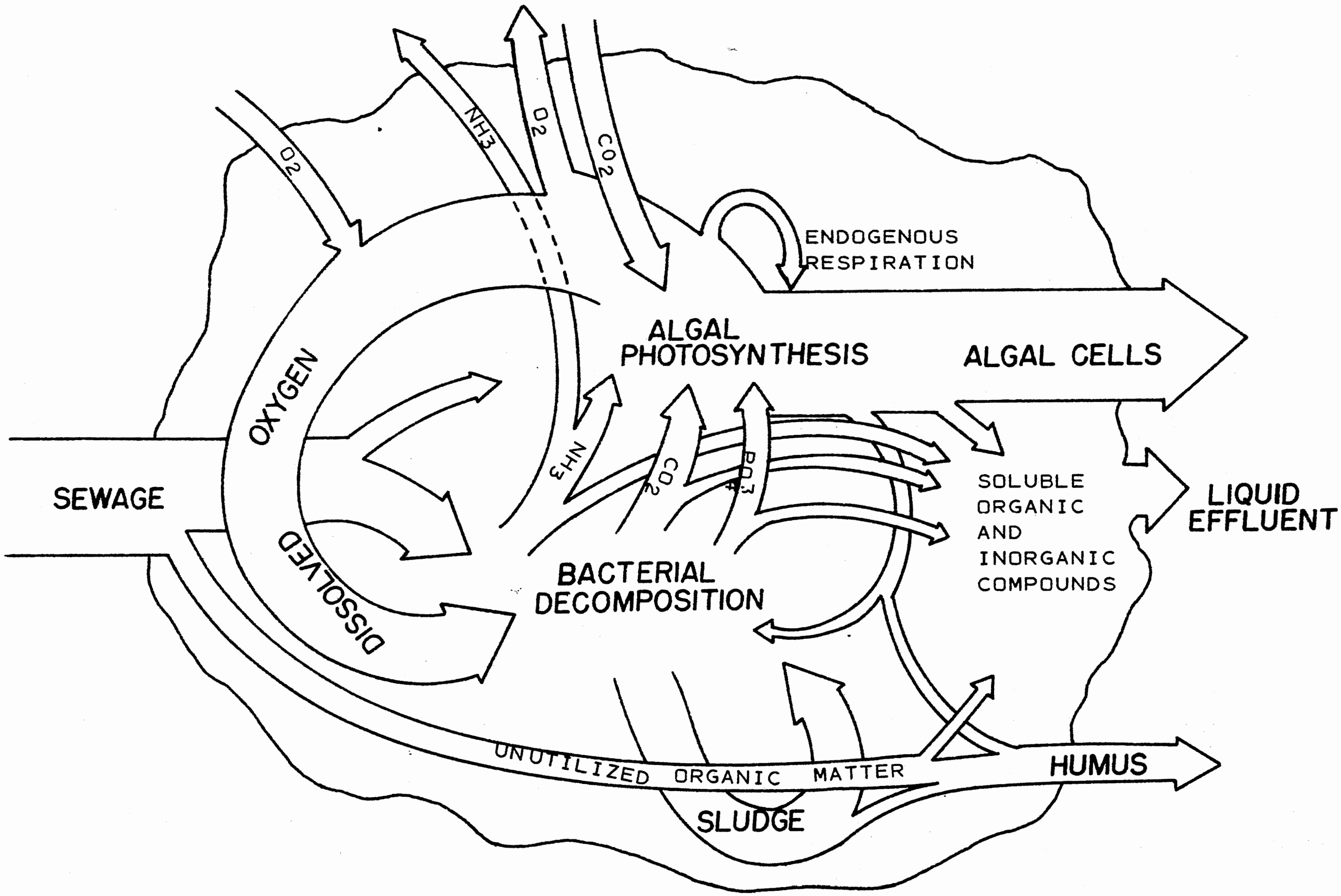
As seen in (2.3) and (2.4) free CO_2 is produced which is available for utilization by algae. Figure 2 shows a schematic representation of the interaction between algae and aerobic bacteria.

Equation 2.5 shows the formation of acetic acid which is the predominate product of acid fermentation.

$$2(CH_2O)x \longrightarrow xCH_3\ COOH \qquad (2.5)$$

This reaction is produced by facultative heterotrophs.

Methane fermentation is represented by the simplified reaction shown in equation 2.6.



Source: Koopman (6,p.5)

Figure 2. Schematic Representation of the Symbiosis Between Algae and Aerobic Bacteria Growing on Sewage.

$$\underset{\substack{\text{settable}\\ \text{solids}}}{CH_3COOH} \xrightarrow[\text{bacteria}]{\text{anaerobic}} CO_2 + CH_4 \tag{2.6}$$

Both fermentation reactions occur in the anaerobic zone. Therefore unless a pond is stably stratified this reaction will only occur in the sludge layer (6). These basic reactions are summarized in Table II (7).

These reactions point out that the pollutants in the wastewater are not removed, but are only converted into an algal biomass which will appear in the effluent. Thus, for stabilization ponds to meet secondary treatment effluent standards the algae must be removed.

B. Phase Isolation

"Phase Isolation" is a term given to an operational technique for oxidation ponds whereby a pond is charged with treated waste from another oxidation pond, with no further inflows being allowed. The pond is held in isolation until the algae in the isolation pond flocculates and settles. After a minimal algal concentration is reached the clarified supernatant is discharged and the process is repeated.

This technique of algae removal was created by Hiatt (8), Director of Public Works, Woodland, California. Hiatt's idea came from the following observations of past experience:

1. When the loading of a normally operated pond was discontinued there was a rapid precipitation of algae and clearing of the pond.
2. The same condition was observed when a new pond was started by filling it with effluent from a normally operated pond.
3. The clearing was temporary but did persist for several days (8,p.42).

TABLE II

SUMMARY OF PRINCIPAL BIOCHEMICAL TRANSFORMATIONS IN PONDS

ZONE	Reaction	Organisms involved	Typical reaction
		Carbon transformations	
Aerobic	Biological Photosynthetic	Aerobic bacteria, fungi, algae: chlorella, scenedesmus, Euglena, and various spp.	$(CH_2O)_x + xO_2 \text{--->} xCO_2 + xH_2O$ $CO_2 + 2H_2O + hv \text{--->} (CH_2O) + O_2 + H_2O$
Anaerobic	Organic acid Methane fermentation	Facultative heterotrophs Methane bacteria	$2(CH_2O)_x \text{--->} xCH_3COOH$ $CH_3COOH \text{--->} CO_2 + CH_4$
		Nitrogen transformations	
Aerated			Organic N-->Ammonia N--->Nitrate N--> Denitrification

TABLE II (Continued)

Aerobic			Organic N--->Ammonia N---> Algae N (removed)
Anoxic			Organic N--->Ammonia N---> Algae N---> Inorganic N(?)
Anaerobic			Organic N--->Ammonia N
Sulfur transformation			
Aerobic			Organic Sulfur---Sulfate
Anaerobic		Photosynthetic bacteria: Thiopedia Chromation	Organic S--->HS + H $\underset{\text{Basic}}{\overset{\text{acid}}{\rightleftharpoons}}$ H_2S $2H_2S + CO_2 + hv \text{--->} (CH_2O) + S_2 + H_2O$
Phosphate transformations			
Aerobic			Organic P--->H_3PO_4-->Calcium Phosphate
Anaerobic	Phosphate Reduction		Organic P---> (?)

Source: McFauley (7, p.216).

Based upon these observations the City of Woodland set up three small pilot ponds to test their ideas. The ponds were filled with treated effluent from the City's facultative pond and set in isolation. The suspended solids and BOD_5 concentrations had dropped well below 30 mg/L in less than three weeks. The pilot ponds were operated through the fall, winter and spring with great success. Suspended solids were recorded as low as 6 mg/L and BOD as low as 3 mg/L (8).

Woodland then began a full scale 12 acre pilot pond in August 1974. This pond was filled with pond effluent averaging 42 mg/L, BOD_5 and 110 mg/L suspended solids concentration and then isolated. After two weeks the BOD_5 and suspended solids had dropped to 28 mg/L and 30 mg/L respectively. The pond was continued in isolation to see if further reduction would occur. After an unreported time the concentration of the BOD_5 dropped to 13 mg/L and the suspended solids to 8 mg/L.

In December 1975, Woodland reported that for the past four months they were consistently obtaining BOD's in the range of 4 mg/L and suspended solids were averaging 12 mg/L (6).

After three years of operating the phase isolation ponds, Woodland reported that secondary effluent standards were still being met with the phase isolation operation (9).

The following important observations were derived from Woodland's study:

1. During isolation, flow must be absolutely and totally shut off.
2. Inflow and discharge should be accomplished in as short a time as practical to hasten the clearing of the pond and minimize pond area needs.
3. Attached filamenteous algae at times obscurred as much as 85 percent of the surface of the phase isolation pond but caused no difficulty.

4. Filamenteous algae and suspended algae did not appear compatible and generally it was observed that one excluded the other.
5. The algae precipitated out more rapidly on some occasions than on others (4,p.23).

An intensive study of the phase isolation concept was conducted by the Sanitary Engineering Research Laboratory at the University of California, Berkeley under an Environmental Protection Agency grant from March 1977 to August 1978. Hereafter the above stated study will be referred to as the California Study. Under this study they not only monitored the Woodland California ponds, but also studied pilot ponds in Richmond, California which investigated the phase isolation process treating facultative pond effluent and high rate pond effluent.

In the California study it was found that the initial isolation cycles demonstrated a large reduction in volatile suspended solids, averaging 85% removal during the period of April-June 1977, but still exceeded a 30 mg/L average due to wind induced sediments resuspension. Little or no algal reduction was observerd in the summer and fall of 1977. During this period (July-December 1977) of unsatisfactory algal removal, it was observed that there was a predominance of blue-green algae Oscillatora present. The study was continued until August of 1978 to determine if this Oscillatora bloom was a regular seasonal occurence. During the spring and early summer good algal removal, was observed but in late July the process began to show signs of upset and failed in August (6).

Under the California study the phase isolation process, as monitored at Woodland, failed to meet suspended solids standard of 30 mg/L in ten out of sixteen cycles. The major problem reflected was sediments being suspended during windy periods, resulting in discharges of greater than 30 mg/L suspended solids concentration even when algal settling was effective. BOD_5 removal was reported effective with no discharge greater than 15 mg/L and total nitrogen removal was also high averaging 45 per cent.

The pilot pond studies at Richmond and Woodland, performed by the University of California, Berkeley, established that (1) neither nutrient deficiency nor grazer activity affected the overall process efficiency, (2) the process is not unique to Woodland's water or environmental conditions, and (3) the process is more effective for high-rate pond effluents than for facultative pond effluents.

The recomendations from the California study were as follows:

1. The pond isolation process should not be applied to meet a discharge standard for total suspended solids of 30 mg/L (30 day average) at Woodland, California, without a suitable backup system. The backup system must be capable of storing, polishing, or disposing of the effluents from six months of continuous operation extending from summer through fall.
2. The design of any isolation pond should be made to minimize wind-induced resuspension of sediments which result in high total suspended solids discharged even when algal removal is effective.
3. The isolation ponds should be completely drained and the accumulated sediment removed at least once each year.
4. Pond isolation should be recognized as an efficient process for reduction of BOD_5 and total nitrogen in effluents from facultative ponding systems.
5. We recommend that research be conducted into the use of pond isolation to remove algal biomass from effluents of high-rate ponds. Specifically, this research should address:
    a) the effect of high-rate pond mixing and loading on the effectiveness of pond isolaton and its reliability.
    b) the seasonal effects on the performance of this process.
    c) the basic mechanisms for the observed bio-flocculation of algae during the process (6,p.14).

Another major study to evaluate the effectiveness of phase isolation to achieve secondary treatment requirements was conducted by the

Civil Engineering Department of Mississippi State University. The impact of environmental and operational parameters upon phase isolation were also investigated. The study was conducted for eleven months, starting on August 31, 1977, utilizing the lagoon system serving the City of Kilmichael, Mississippi. In this investigation the effects of depth, organic loading and isolation period on the phase isolation operation were evaluated.

The results obtained in the study by Mississippi State University, as in the University of California, Berkeley study, were somewhat erratic and inconsistent. The conclusions as published are as follows:

> 1. Phase isolation as operated in this study could not consistently achieve secondary treatment requirements.
> 2. Operational parameters favorable for phase isolation include:
>   a) 6 foot depth
>   b) cold temperatures
>   c) quiescent conditions must exist in the isolation ponds
>   d) Phase isolation performs best during the winter and early spring when conditions were not favorable for algal growth. Performance was worst during the summer months.
> 3. The length of time necessary for phase isolation to achieve secondary standards was primarily dependent on environmental conditions. Therefore, the time of isolation must be determined by daily monitoring of the isolated ponds (4,p.3).

CHAPTER III

MATERIAL AND METHODS

A. Geography of Study

The City of Cushing, Oklahoma, is a growing community with a population of approximately 8,600 and located in southeastern Payne County, about 70 miles northeast of Oklahoma City, Oklahoma (Figure 3).

The Cimarron River flows northeastward just northwest of Cushing. The area is generally rolling hills with no distinctive physical features such as mountains or large bodies of water, to influence the climate in and around Cushing, Oklahoma.

The Cushing climate is mild and essentially of continental origin, although moist air currents from the Gulf of Mexico have some effect on the climate. Winters are usually short and mild with temperatures averaging about 51° as a high and 29° as a low. The summer season is generally hot and long, which is characteristic of the southwest with temperatures averaging 95° and 70° for highs and lows respectively. During an average summer temperature will exceed 100° around 22 times.

Spring is a season of changeable conditions with the greatest intensity of rainfall occurring. Severe local thunderstorms and tornados normally plague this season. The fall provides the most favorable weather with warm days, cool nights and some light rainfall.

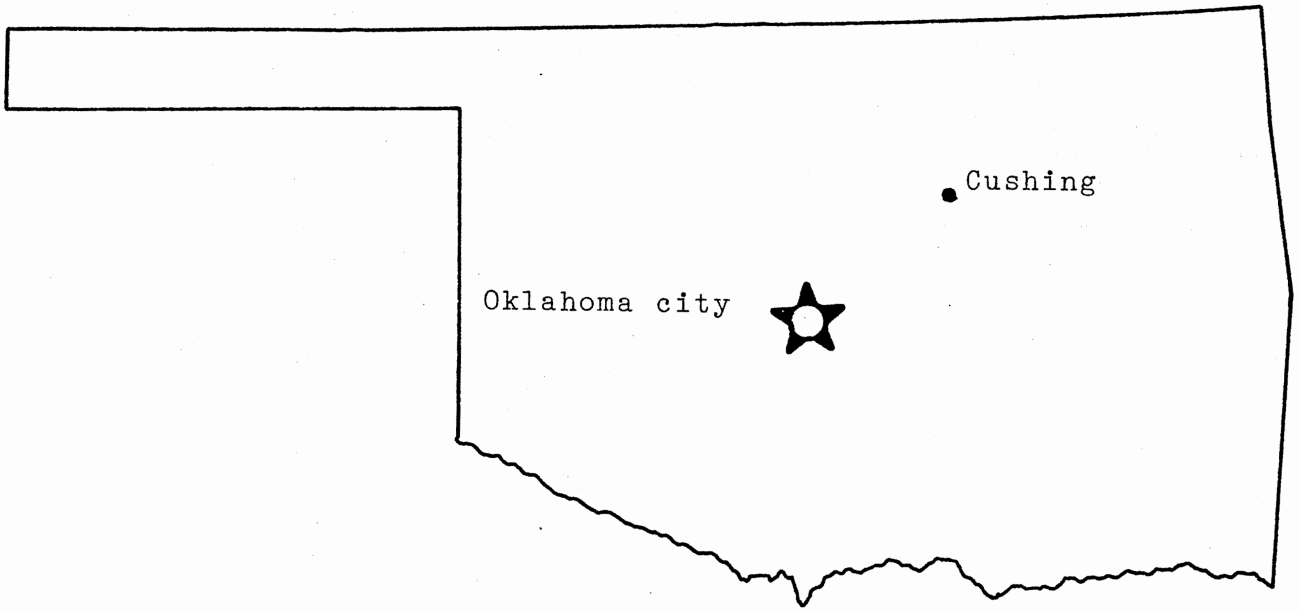


Figure 3. Geograpic Location of Cushing, Oklahoma

Cushing receives an average of 34" of rain annually and approximately 9" of snow. The prevailing winds are southerly, except during the winter they are northerly. The wind speed averages 12 miles per hour.

B. Cushing's Existing Treatment Facility

The City obtains its water from Cushing Lake on Big Creek and is supplemented with 9 deep wells. Typical analyses of the lake water and well water are given in Tables III and IV, respectively. Cushing's wastewater is primarily domestic in origin. Typical analyses of Cushing's wastewater is given in Table V. Two wastewater treatment plants are operated in Cushing, one in the Northwest quarter of Section 13, Township 17 North, Range 5 East of the Indian Meridian known as the south plant and the other (north plant) in the southwest quarter of Section 27, Township 18 North, Range 5 East of the Indian Meridian. The south plant serves the larger collection area and is the newest, constructed in 1958, and the larger of the two. The north plant is scheduled to be abandoned and replaced with a lift station to pump the waste water to the south plant.

The south plant is the facility where this study was conducted. This facility consists of a grit removal tank, comminutor, two primary clarifiers, a single high-rate trickling filter, two final clarifiers, two cell polishing lagoons, two digesters, and sludge drying beds. The flow scheme is shown in Figure 4. The plant, based on 1958 standards was designed for a population equivalent of 16,000 people. Plant effluent is discharged into Cottonwood Creek, Cimarron river basin. The existing hydraulic loading is shown in Table VI. Prior to this study a two year investigation of plant records revealed the BOD of the lagoon effluent was equal to or less than 30 mg/L, 70 per cent of the time and equal to or less than 20 mg/L, 30% of the time with an average of 24 mg/L. During this same two year period, prior to the change of lagoon operations to phase isolation, the lagoons normally proved to have adverse effect on the suspended solids concentration due to the algae production. The suspended solids concentration was 30 mg/L or less only 31 per cent of the time and only 45 mg/L 44 per cent of the time with an average value of 48 mg/L (9).

Each cell of the lagoon system has approximately 10 acres of surface area with a average operation depth of three feet creating a storage of approximately 10 million gallons per cell.

TABLE III

TYPICAL CHEMICAL ANALYSIS, CUSHING TREATED LAKE WATER

pH	7.0
Specific Conductors	240 microhms/cm
Alkalinity	58
Calcium (Ca CO_3) soluble	53
Magnesium (Ca CO_3) soluble	35
Sodium (Ca CO_3)	27
Ammonia (Ca CO_3)	*ND(0.6)
Chloride (Ca CO_3)	58

Table III (Continued)

Sulfate (Ca CO_3)	41
Nitrate (Ca CO_3)	27
Silica (Si O_2) soluble	*ND (1.0)
Iron soluble and insoluble	*ND (0.1)
Fluoride	.9
Total organic Carbon	8.
Alpha Color Number	*ND (0.1)
Turbidity (nephelometric turbidity units)	0.2

TABLE IV

TYPICAL CHEMICAL ANALYSIS CUSHING WATER WELLS

pH	7.7 pH units
Specific Conductance	533 micromhos/cm
Alkalinity	218
Calcium (Ca CO_3)-soluble	140
Magnesium (Ca CO_3)-soluble	46
Sodium (Ca CO_3)	118
Ammonia (Ca CO_3)	*ND (0.6)
Chloride (Ca CO_3)	21
Sulfates (Ca CO_3)	61
Nitrate (Ca CO_3)	*ND (1.0)
Silica (Si O_2)-soluble	17

Table IV (Continued)

Silica ($Si\ O_2$)-soluble	17
Iron - soluble and insoluble	0.2
Total organic carbon	29
Alpha color number (units)	*ND (1.0)
Turbidity (nephelometric turbidity units)	.9
Temperature	66°F

* Not detected (below indicated limit of detection).

TABLE V

TYPICAL ANALYSIS OF CUSHING'S WASTEWATER

Total settleable solids	4.2 ml/L
Total suspended solids	121 mg/L
BOD_5	199 mg/L
Temperature	50°F-81°F
pH	6.8-7.5
Phosphorus	7 mg/L
Nitrogen	19 mg/L

TABLE VI

HYDRAULIC LOADING OF SOUTHSIDE PLANT

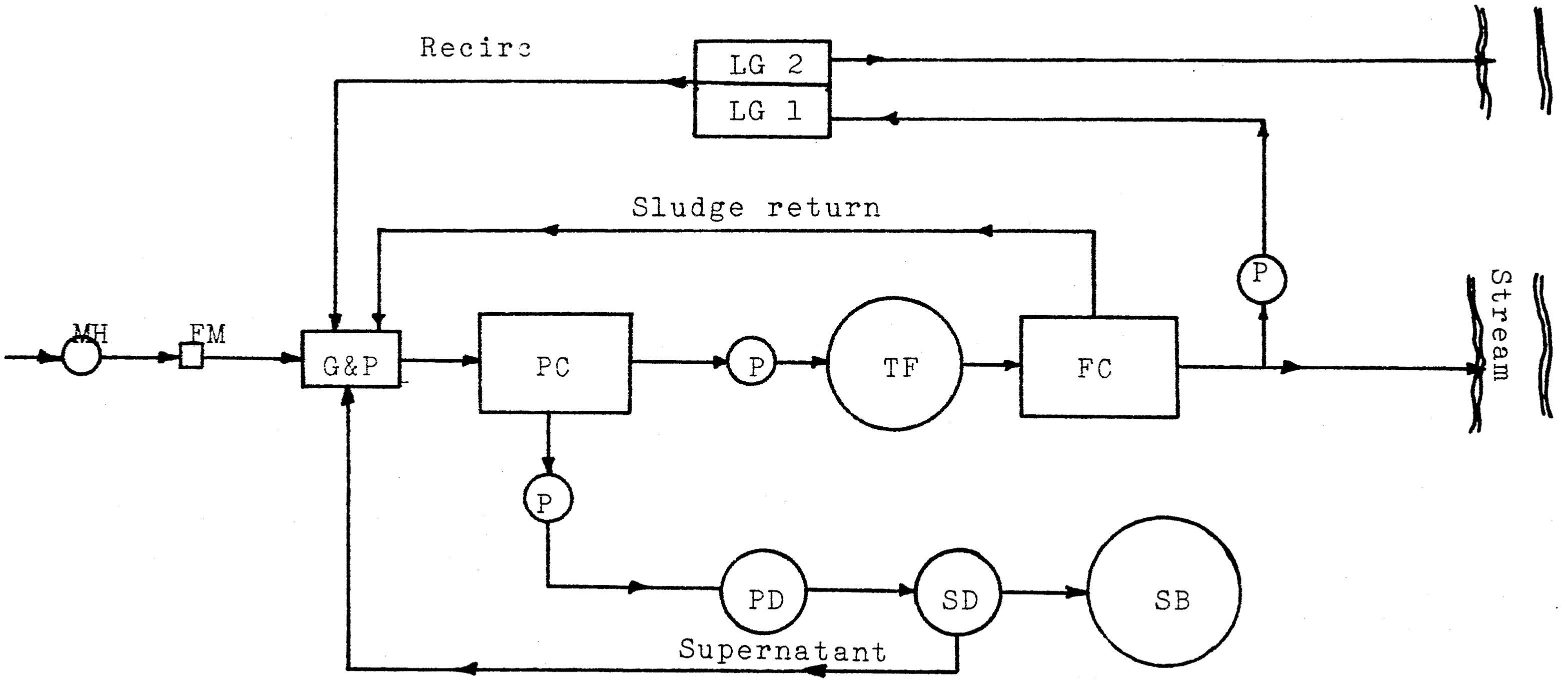
	Gallons per capita per day	Million gallons per day
Minimum (dry)	39	0.27
Average (dry)	71	0.48
Maximum (dry)	83	0.56
Maximum (wet)	196	1.33

C. Plant modifications

The only change in the plant operation was operating the lagoon system. Instead of a continuous discharge from the second cell of the polishing lagoons, a phase isolation operation was initiated.

The process was started by emptying the lower lagoon then refilling it with effluent from the upper polishing lagoon. Then all flow was discontinued to the lower lagoon allowing it to become isolated. Additional baffles were added to the outlet structure of both lagoons to increase the depth to approximately five feet which helped gain storage capacity and decrease the effect of wind. The upper lagoon became a holding basin and polishing lagoon while the lower lagoon remained in isolation allowing the algae to flocculate and settle.

To gain operational experience during the first eight months regardless of the supended solid concentrations, the lower lagoon



LG-1	Lagoon 1st Cell
LG-2	Lagoon 2nd Cell
TF	Trickling Filter
P	Pump
FM	Flow Measurement
G&P	Grit & Preaeration
PC	Primary Clarifier
FC	Final Clarifier
PD	Primary Digester
SD	Secondary Digester
SB	Sludge Bed

Figure 4. Existing Southside Pland Flow Diagram

was held in isolation until the upper lagoon became full and had to be discharged into the second cell. After the lower lagoon was emptied it was then filled again and the process restarted again.

After the first eight months the isolation pond was empty when the suspended solid level dropped below 30 mg/L or when the upper lagoon level forced the lower lagoon to be emptied.

It normally took about three days to fill the lower lagoon. During the first nine months of the study it took approximately six days to empty the isolation lagoon to keep from discharging above the plant permit condition of two million gallons per day, but in April of 1979 permission was obtained from the Environmental Protection Agency to exceed the maximum discharge limit, under these conditions it took two days to empty the lagoon.

D. Sampling and Analysis

Grab samples were collected from the isolation pond at four different locations, namely the north, south, east and west side of the lagoon. The samples were taken approximately 2" below the surface not allowing large floating masses of algae to enter the sample. The four samples were mixed to form a representative sample for testing.

The lagoon configurations and sampling locations are given in Figure 5.

All samples were analyzed by the City of Cushing's waste treatment plant operators under the direction of the City Engineer. All analysis were performed as approved in The 14th Edition of Standard methods for The Examination of Water and Wastewater (10). Table VII lists the parameters determined, method of determination and observation frequency of each sample.

Additional climatical data for the study period are given in the appendix .

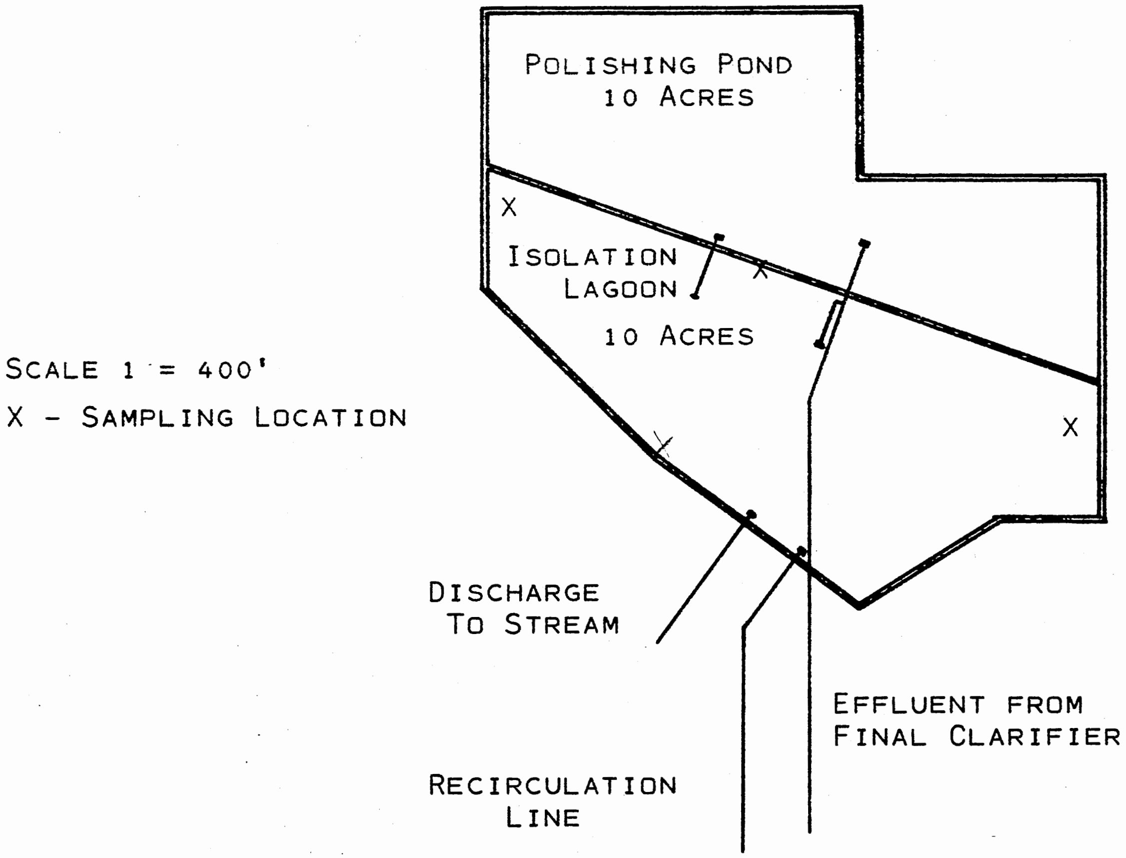


Figure 5. Layout and Sampling Locations in Isolation Pond

TABLE VII

ANALYSIS OF PARAMETERS

Parameters	Method of Analysis	Observation Frequency
BOD_5	5-day incubation @20°C	2 / week
SS	103°C residue	daily
pH	glass electrode pH meter	daily
Phosphorous	Ascorbic acid method	daily

CHAPTER IV

RESULTS

As was previously stated this investigation was primarily conducted to test the effectiveness of the phase isolation process on the City of Cushing's polishing lagoons. Mainly to determine if Environmental Protection Agency discharge requirements could be met.

The initial data point for all parameter studied was taken on the first day the isolation pond was full and set in isolation. The temperature of the isolation pond ranged from a low of 32°F in January to a high of 89°F in August with an average or the days sampled of 61.8°F. Figure 6 shows how the lagoon temperature varied from month to month.

Figure 7 shows how the pH varied from day to day. The maximum pH value was 9.9 on August 10, 1978, with a minimal value of 6.8 being recorded on April 11 and 12, 1978. The greatest variation within an isolation cycle was in cycle 3 with a difference of 1.4 units. Fall and winter cycles showed less variation in pH than the spring or summer cycles. The pH varied with the time of the year, becoming higher in the warm months and lower in the colder months. This phenomenon is shown in Figure 8. The yearly average was 8.2. The allowable secondary effluent limitation of a pH of 9 was exceeded 22 times.

The results of the phosphorus test are given in Figure 9. Like the results of the pH tests the phosphorus tests also showed a large daily variation with a pattern of high-low varations being developed.

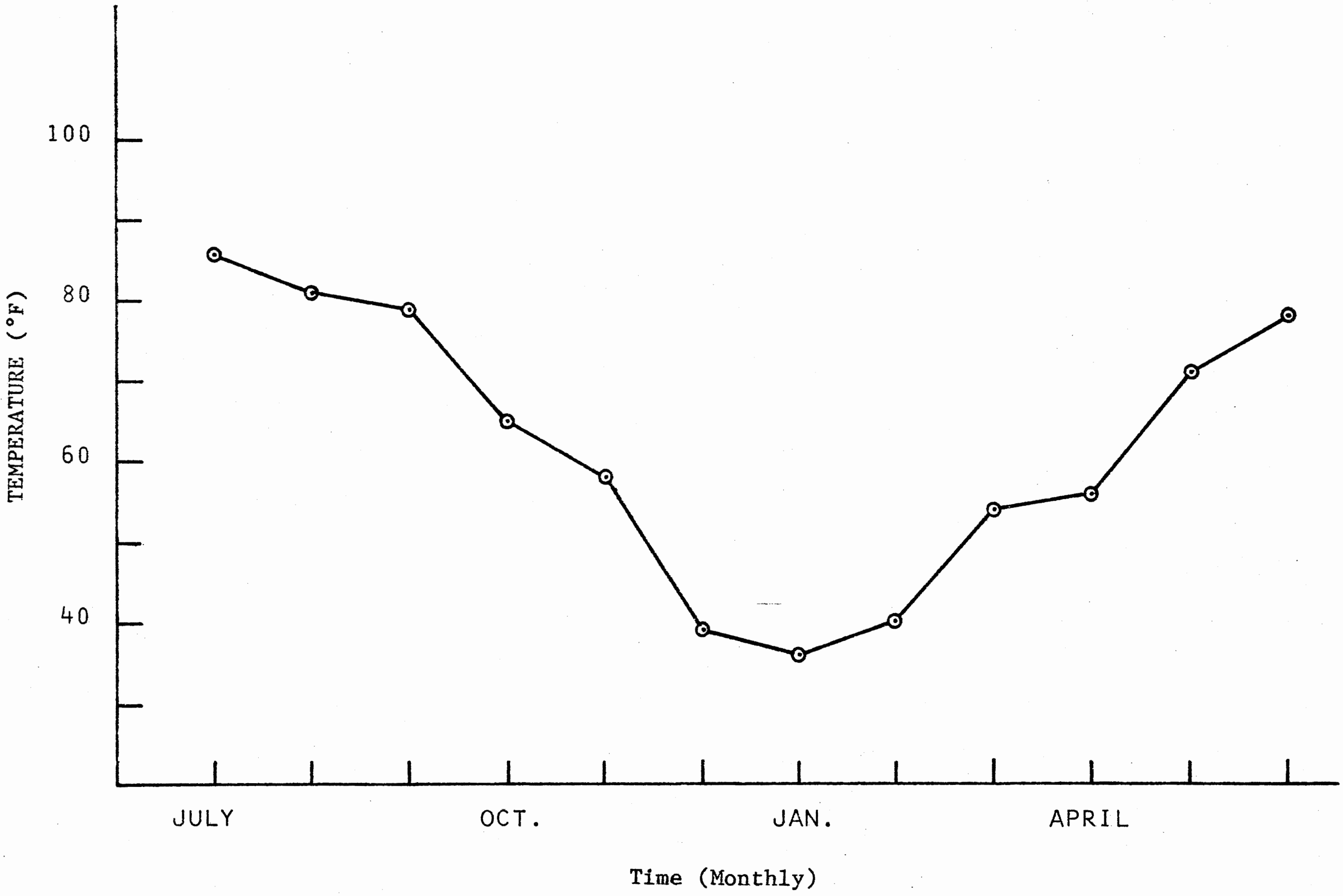


Figure 6. Monthly Variation of Temperature in Isolation Pond.

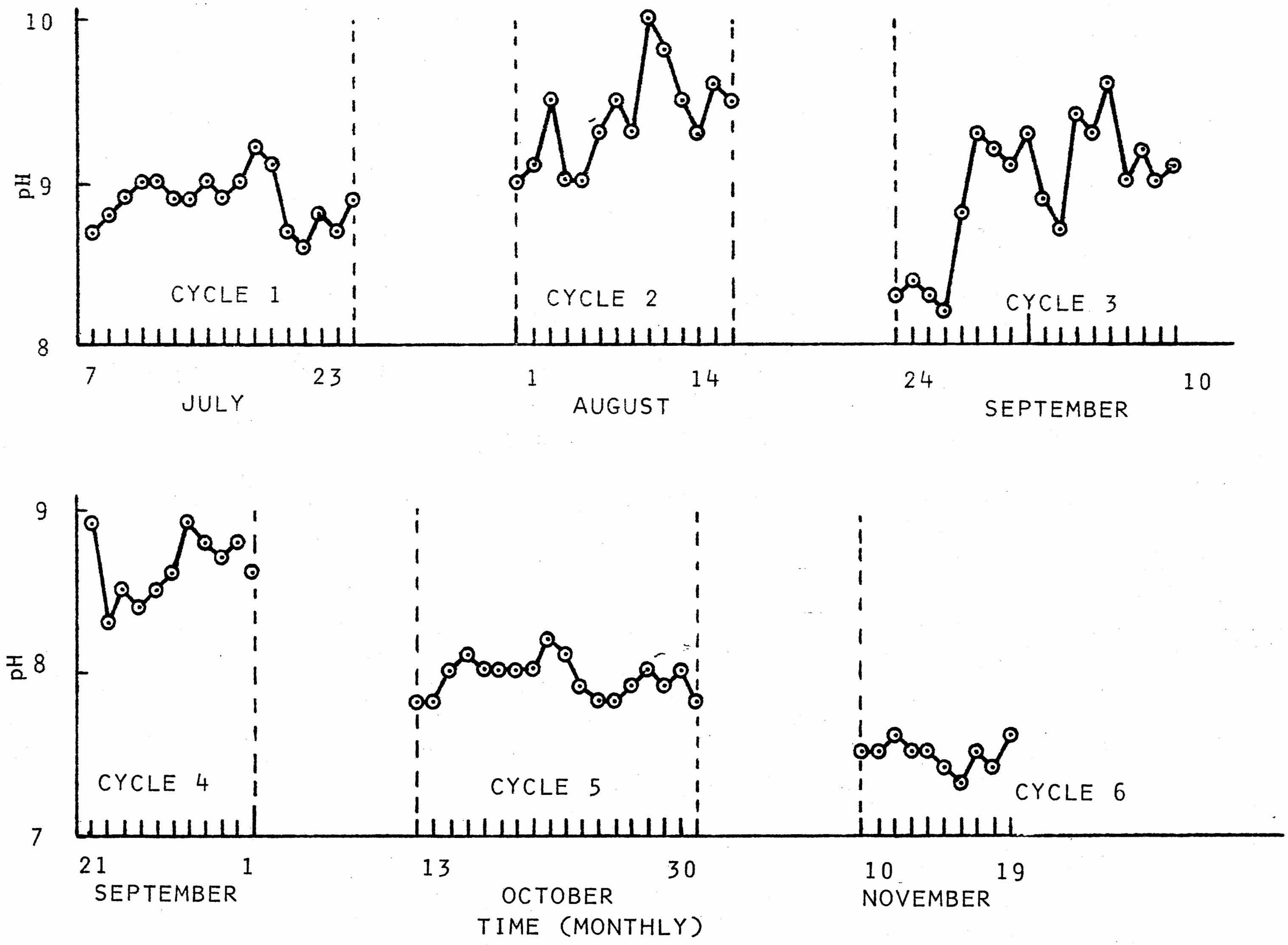


Figure 7. Daily Variation of pH in Isolation Pond

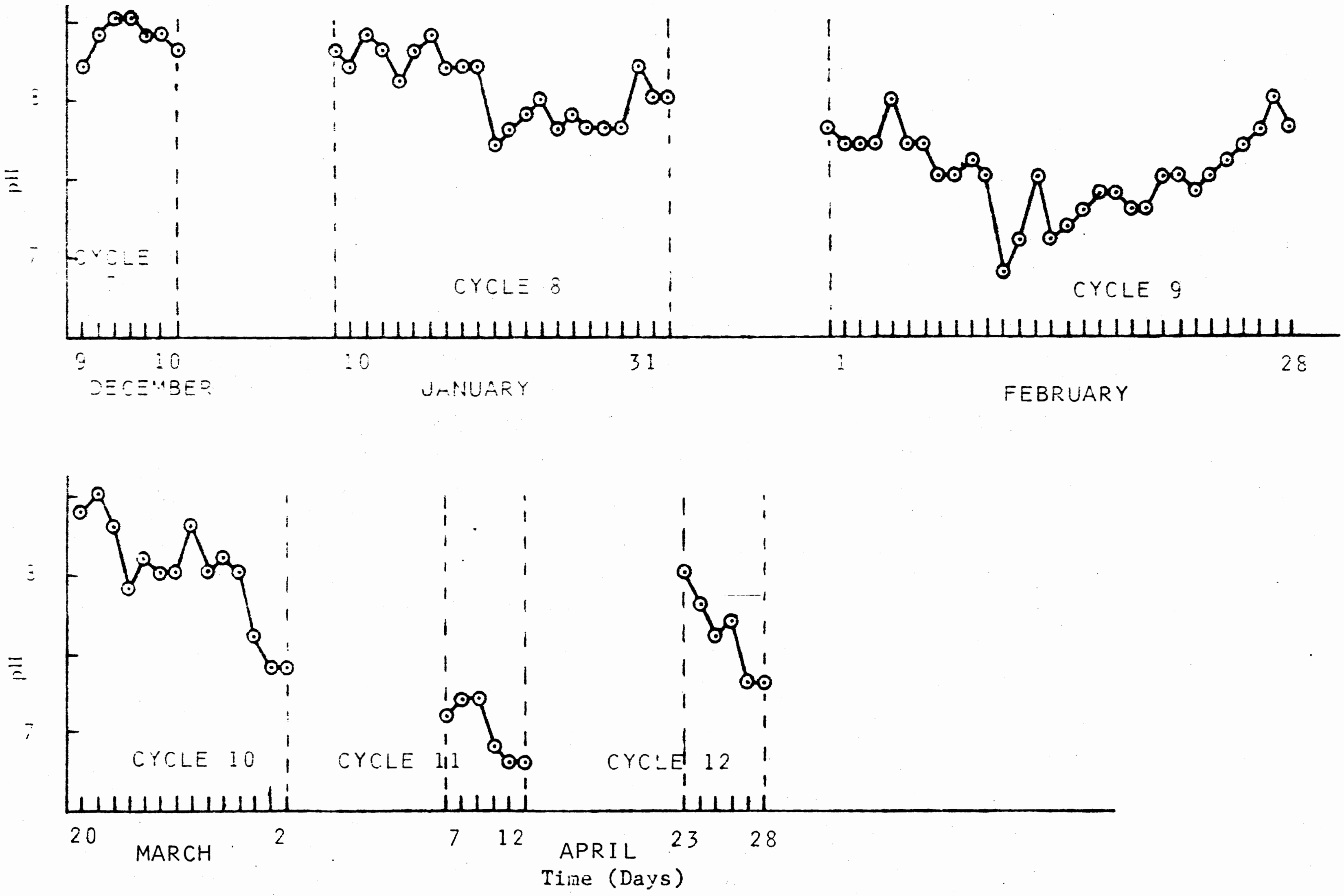
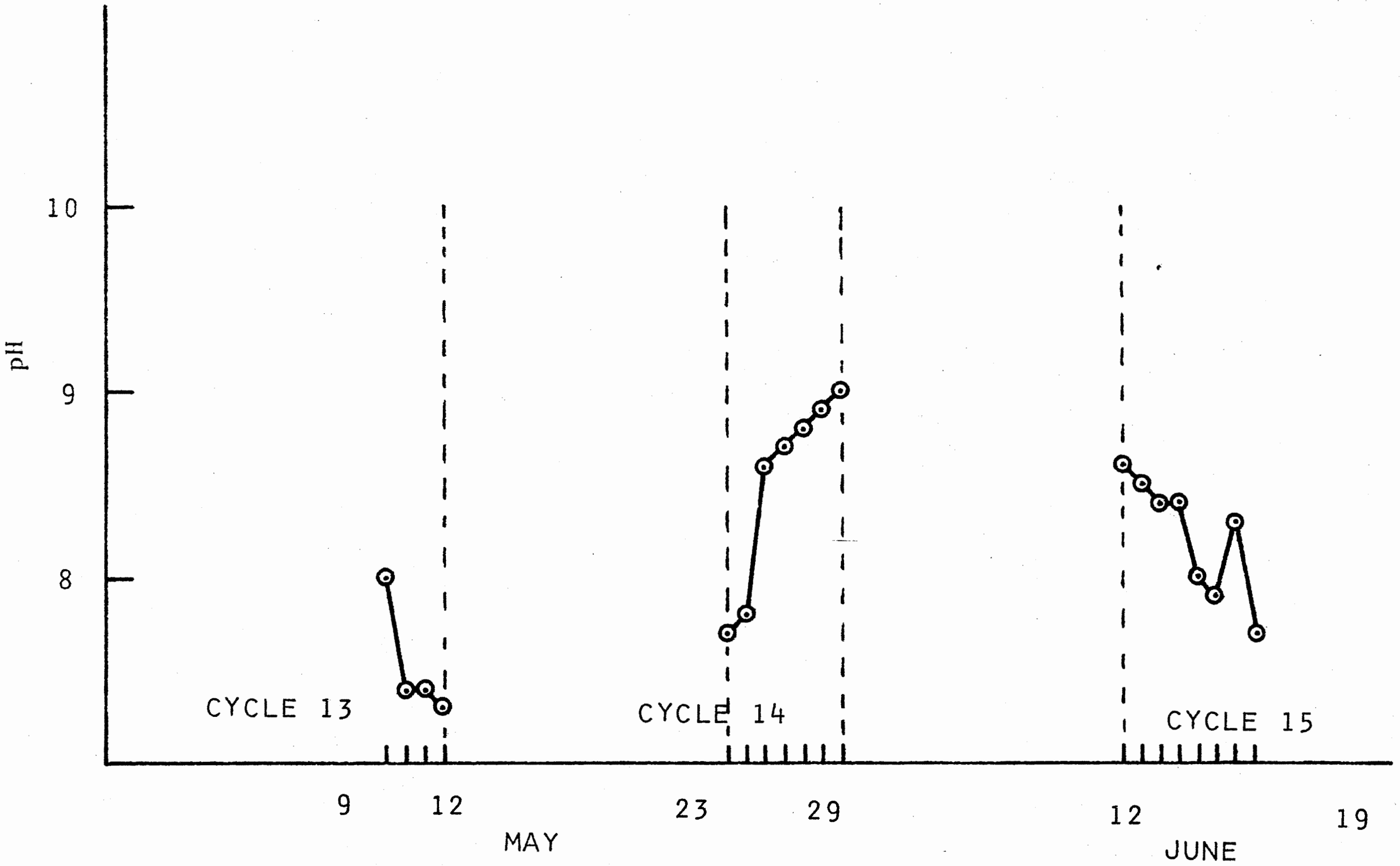


Figure 7. (Continued)



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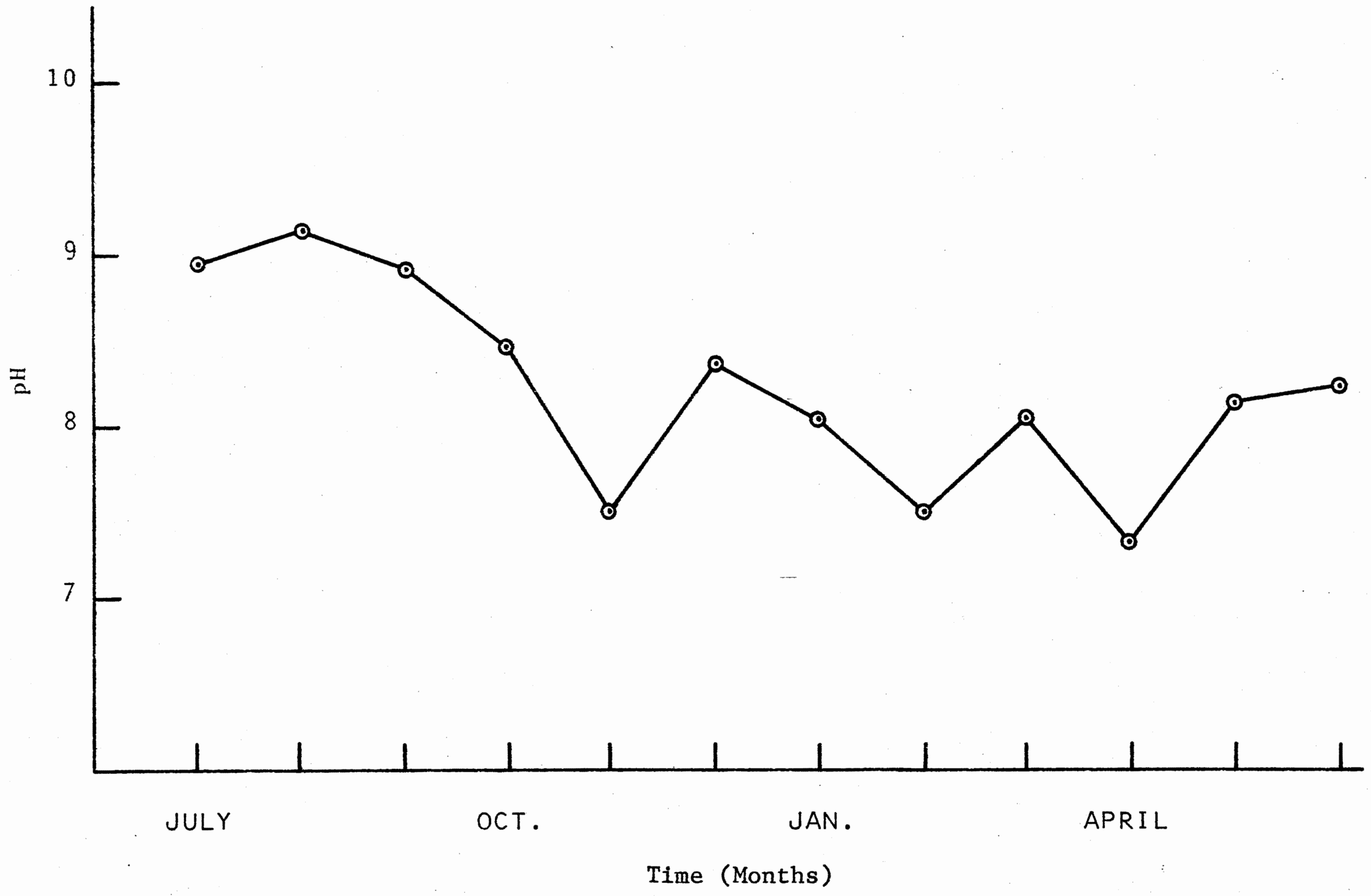

Figure 8. Monthly Variation of pH in Isolation Pond.

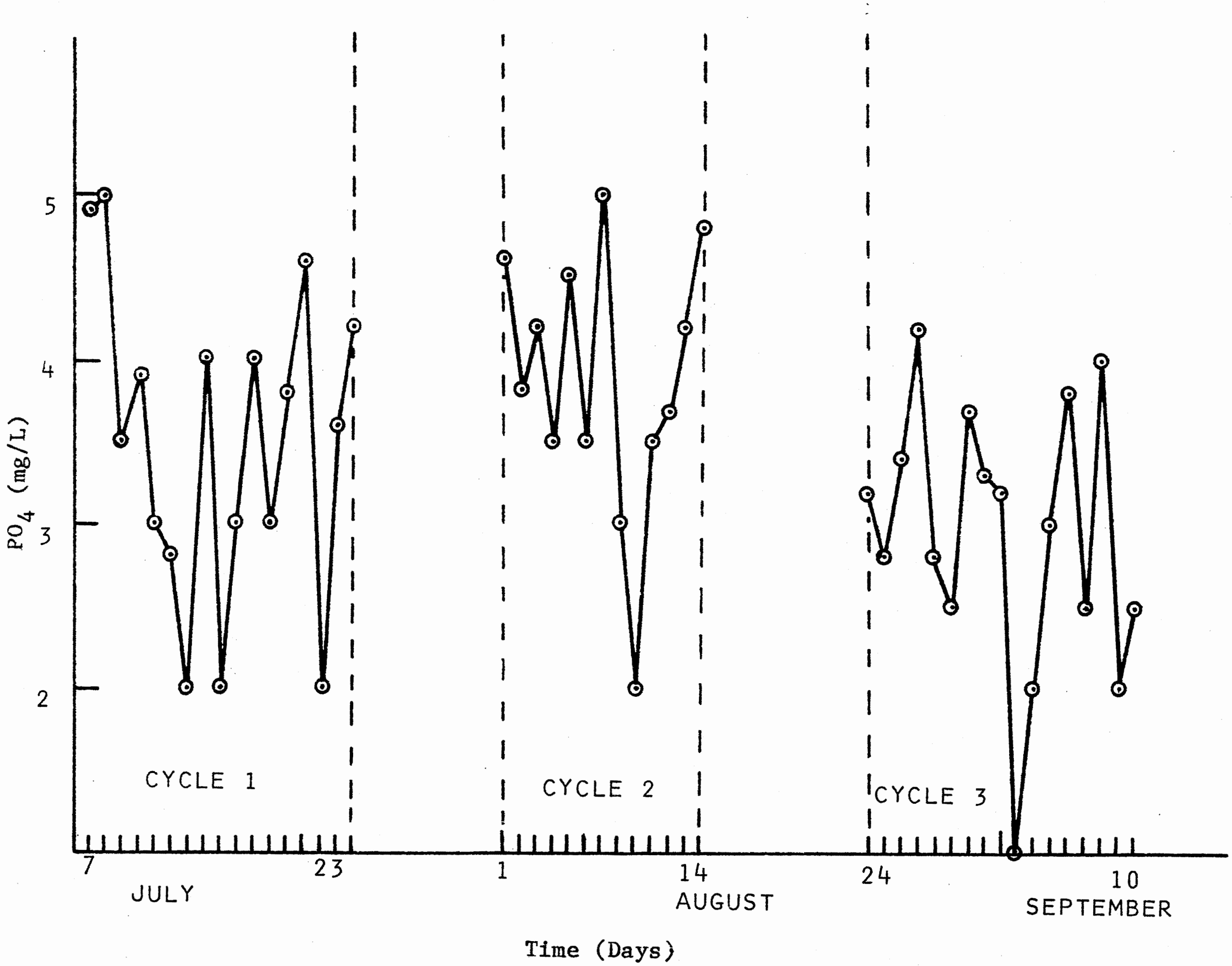

Figure 9. Daily Variation of PO_4 in Isolation Pond

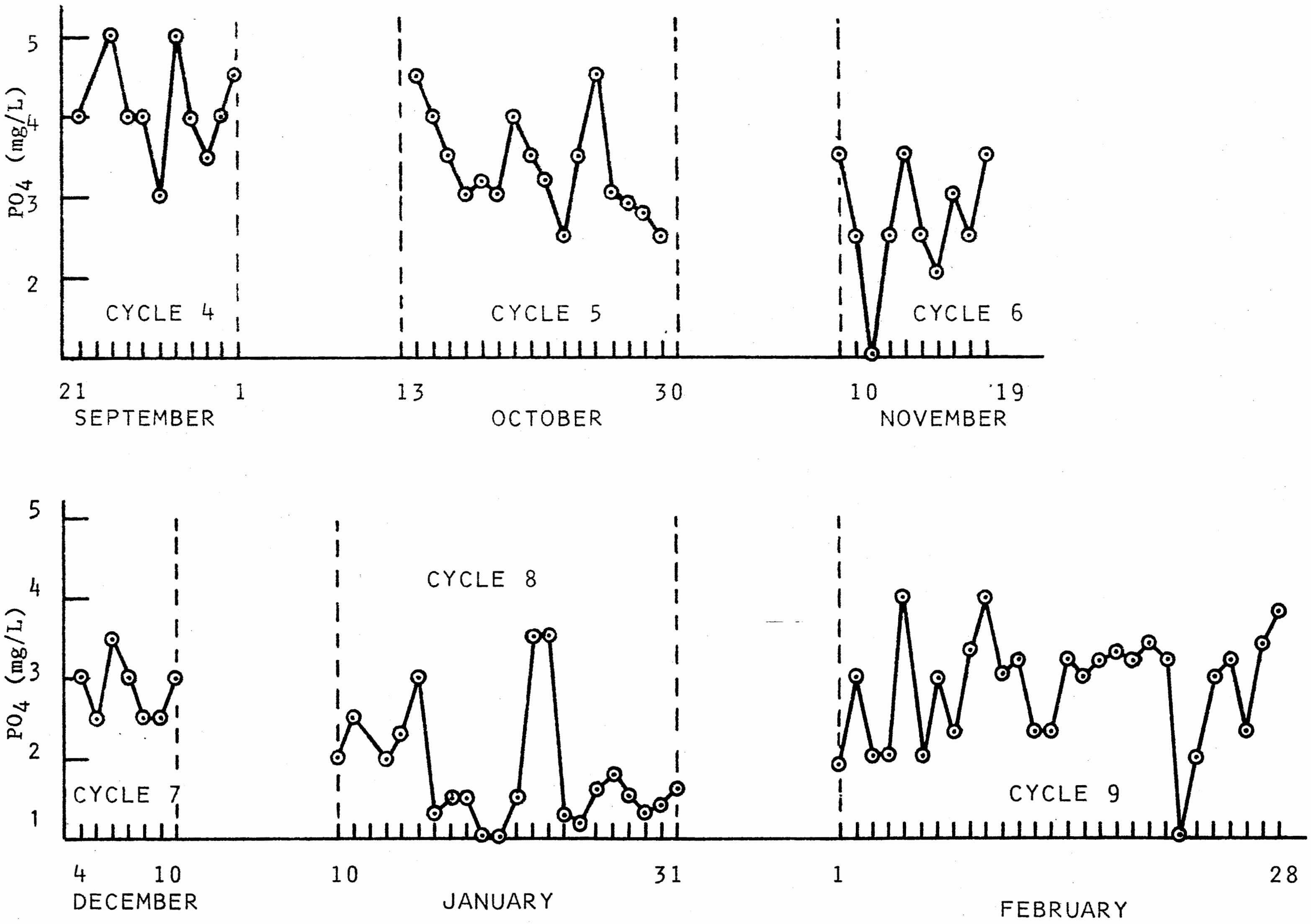

Figure 9. (Continued)

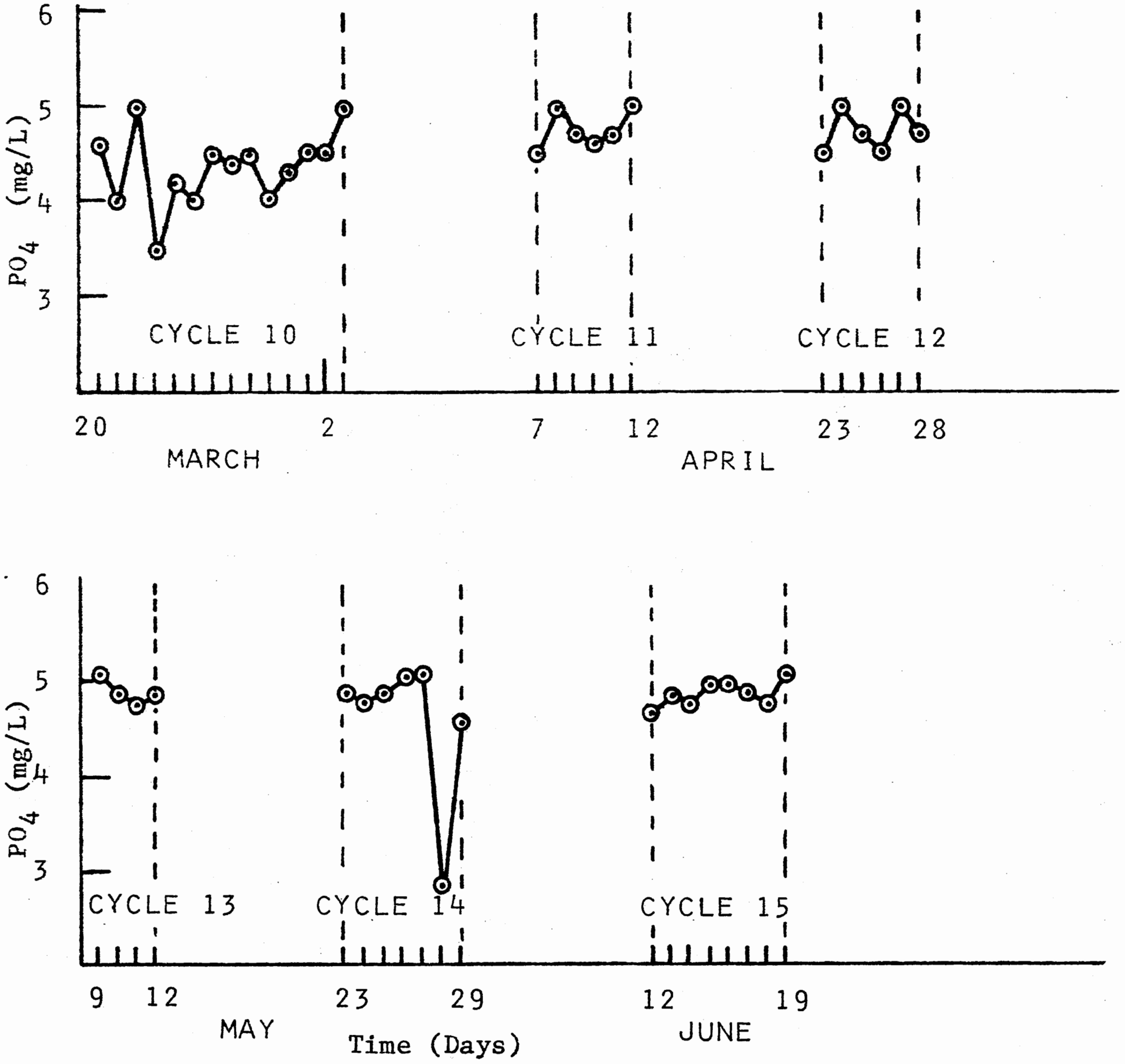

Figure 9. (Continued)

The average value for phosphorus, during a given cycle, was lower during colder weather. Within a given isolation cycle, the maximum difference between low and high phosphorus levels was 3.2 mg/L. Although there was a decrease-increase cycle being demonstrated almost all cycles started with a decrease in phosphorus.

The results from daily monitoring of the suspended solids concentration are given in Figure 10. The same cyclic behavior that the other parameters showed is also seen in the suspended solids data.

The lowest suspended solids concentration recorded was 4 mg/L on April 3, 1979. The suspended solids were found to drop below 30 mg/L in twelve of the fifteen isolation cycles observed, but due to great daily variations only seven cycles were below 30 mg/L on the day discharge was occurring. A closer examination of the data shows only 34 days out of 184 days where the suspended solids were below the 30 mg/L limitation. Only isolation cycles 7, 9, 10, 11 and 12 showed a consistent reduction of suspended solids with increasing isolation time.

The results of the BOD_5 tests are given in Figures 11. As seen in these figures the BOD_5 also appeared to cycle with a maximum variation, within a cycle of 59 mg/L occurring in cycle 5. The highest recorded BOD_5, 79 mg/L, was also during this cycle. The lowest BOD_5 was 8 mg/L during cycles 11 and 12. The BOD_5 was below the required 30 mg/L, eleven of the fifteen cycles on the day of discharge. Forty-three out of the sixty-one BOD_5 test taken were below or equal to 30 mg/L. The average BOD_5 throughout the study period was 29.2 mg/L. The best BOD_5 reductions occurred in cycles 9-15.

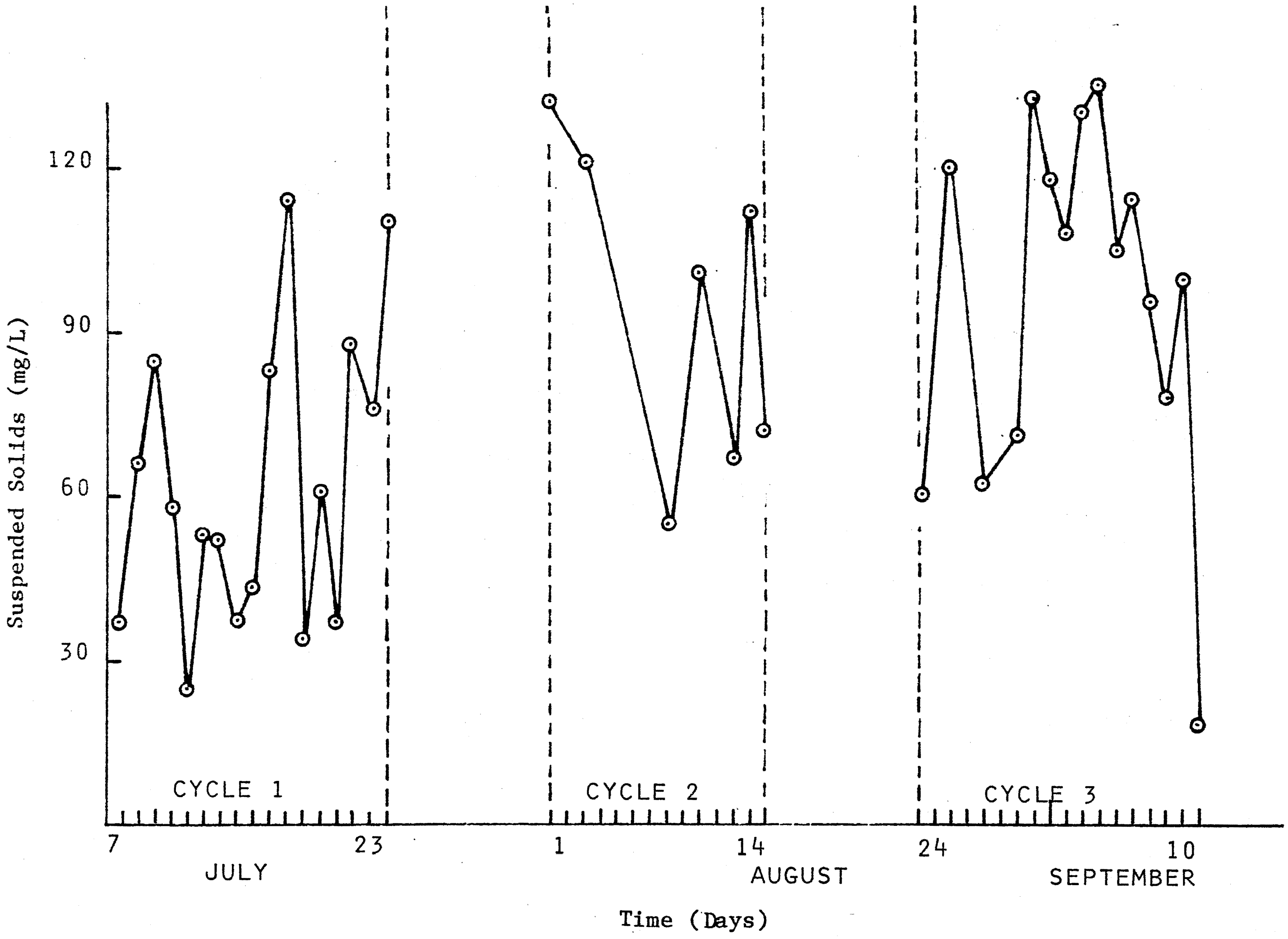

Figure 10. Daily Variation of Suspended Solids in Isolation Pond

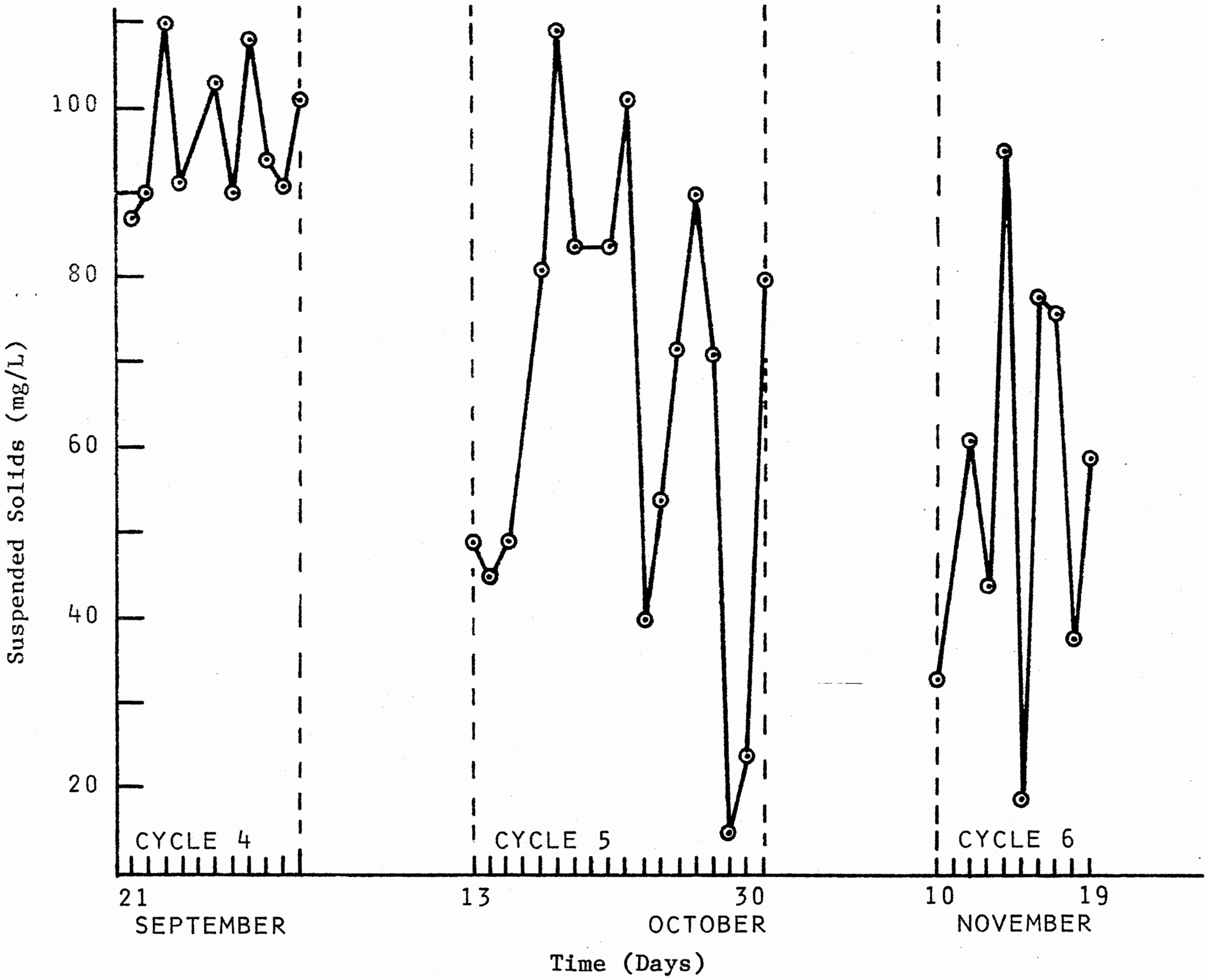

Figure 10. (Continued)

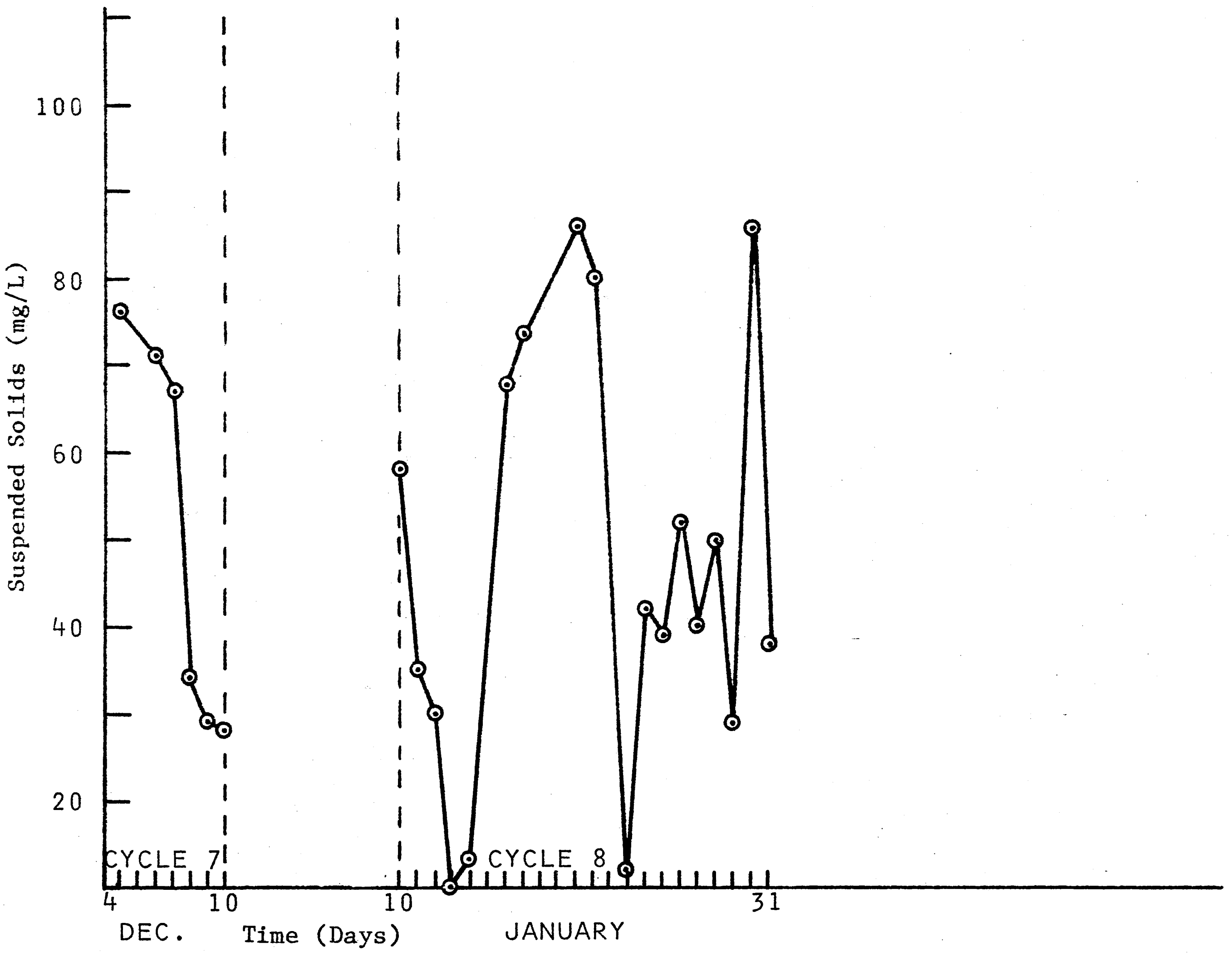

Figure 10. (Continued)

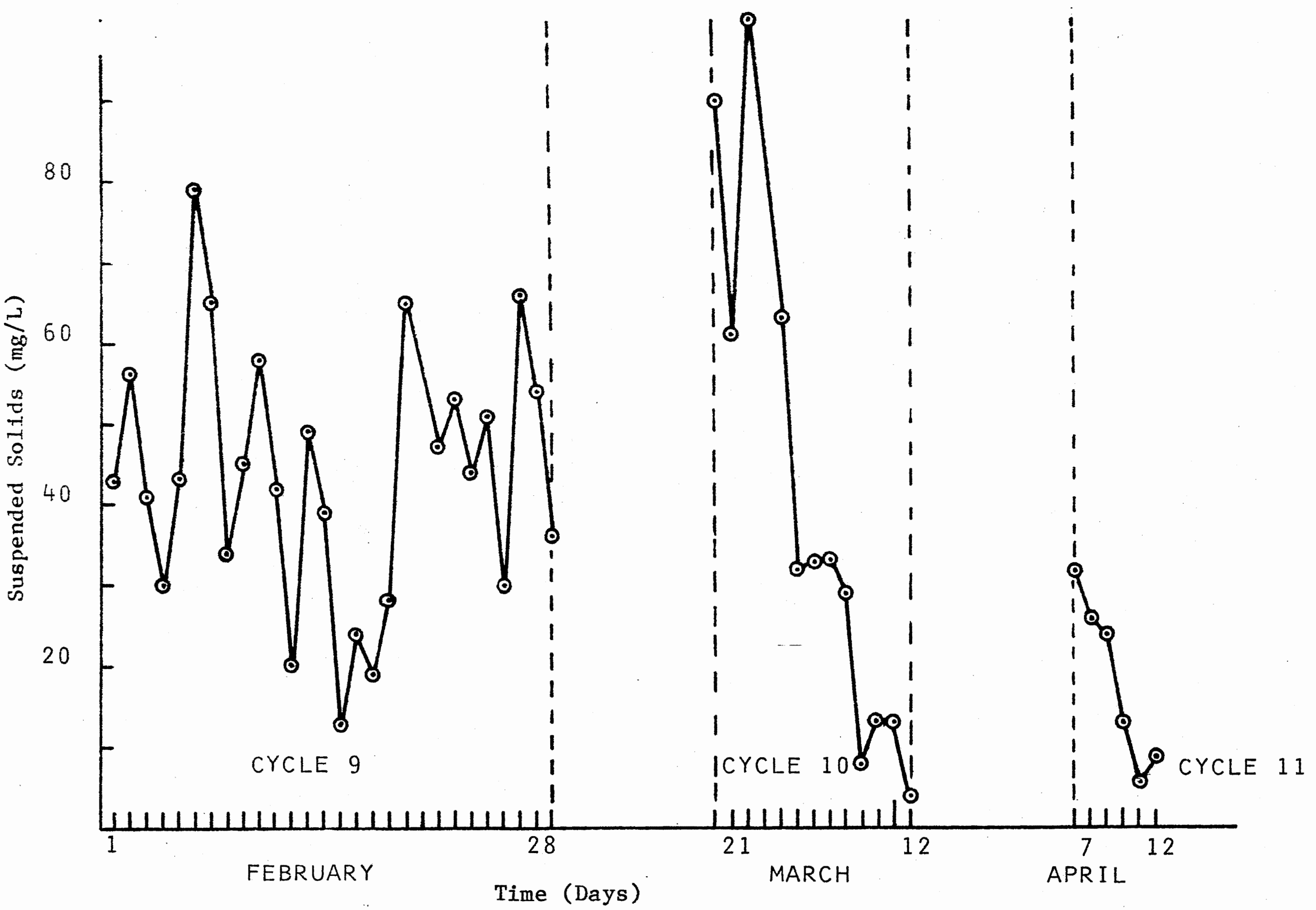

Figure 10. (Continued)

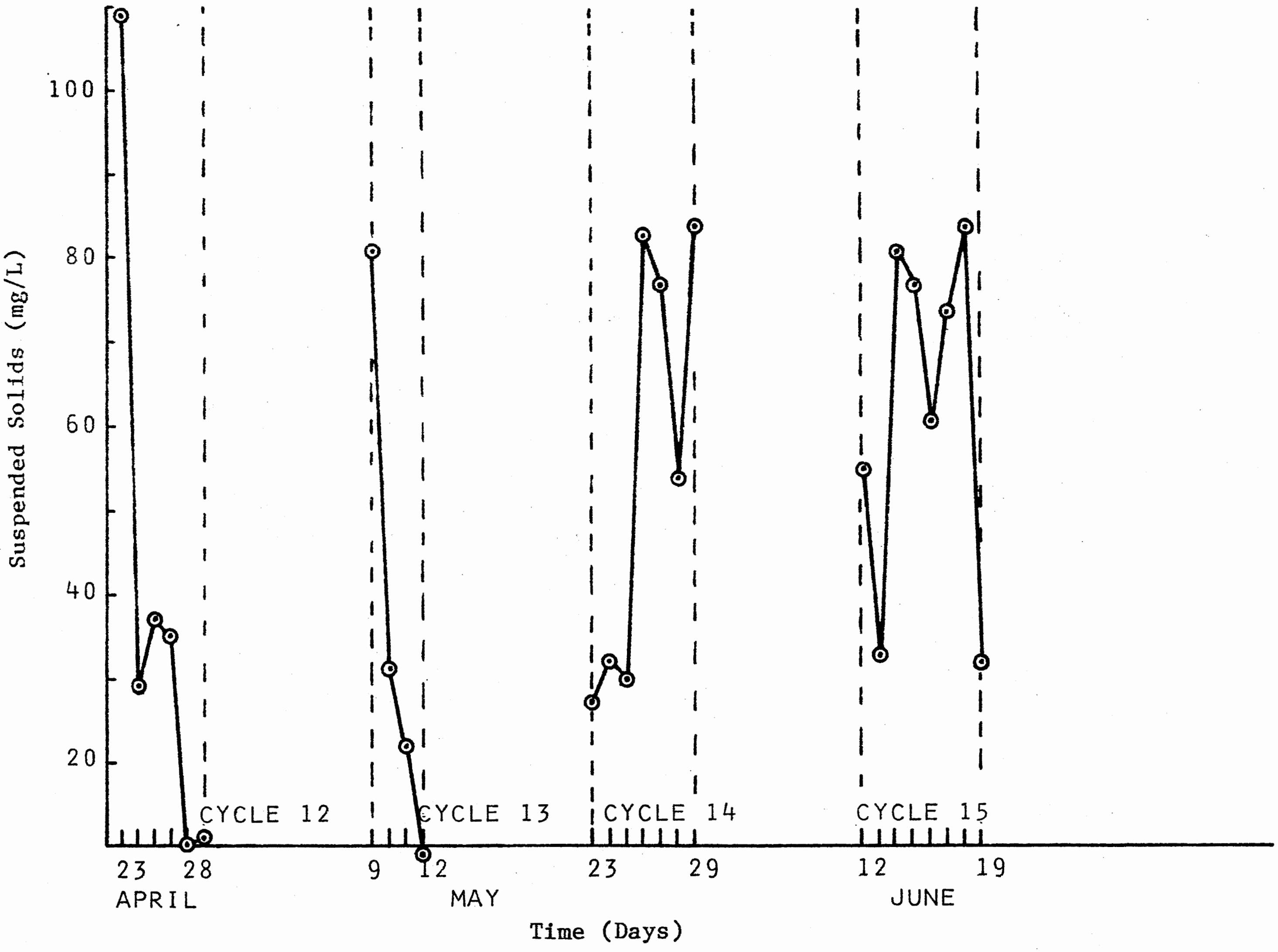

Figure 10. (Continued)

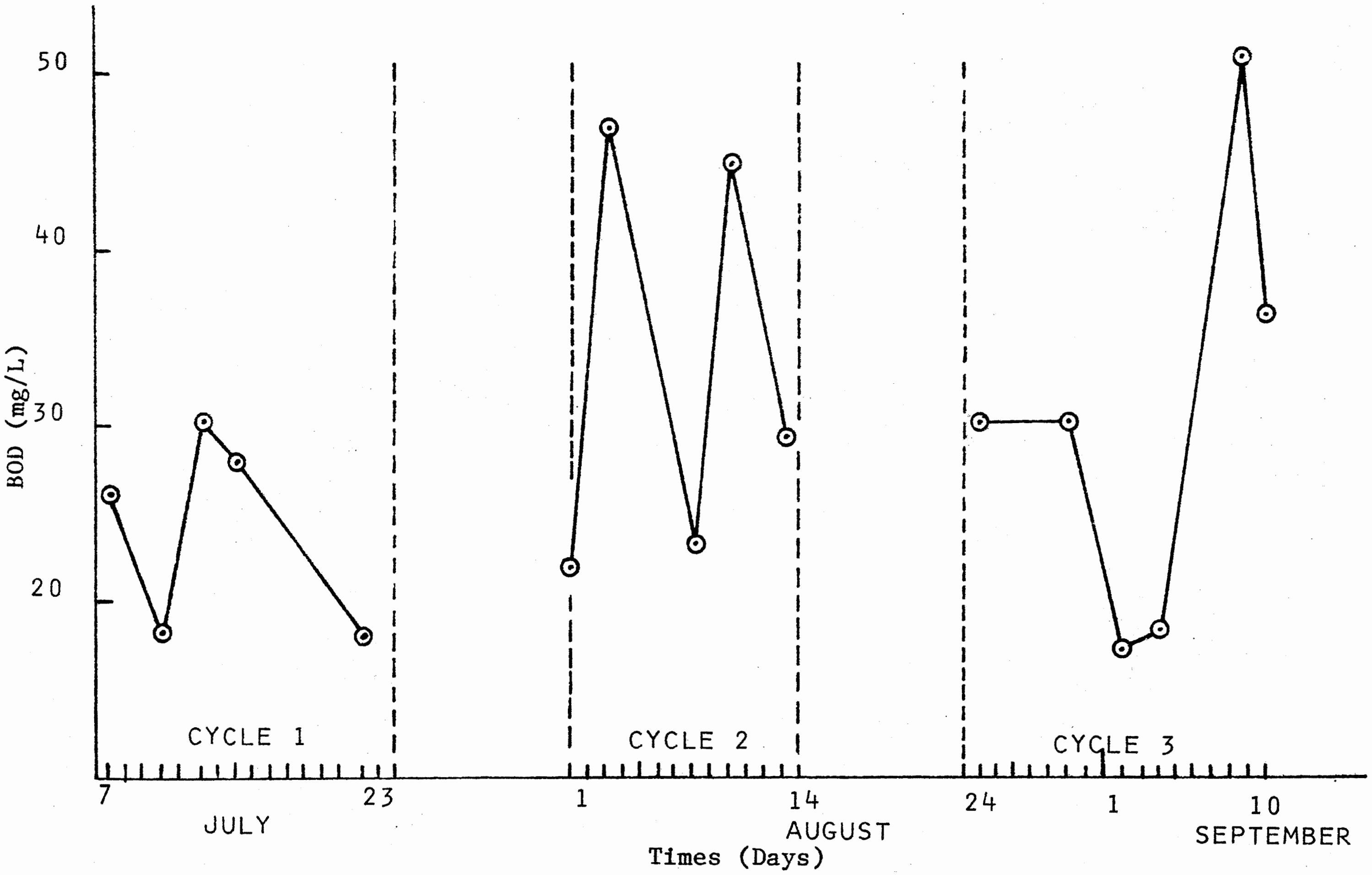

Figure 11. Daily Variation of BOD_5 in Isolation Pond

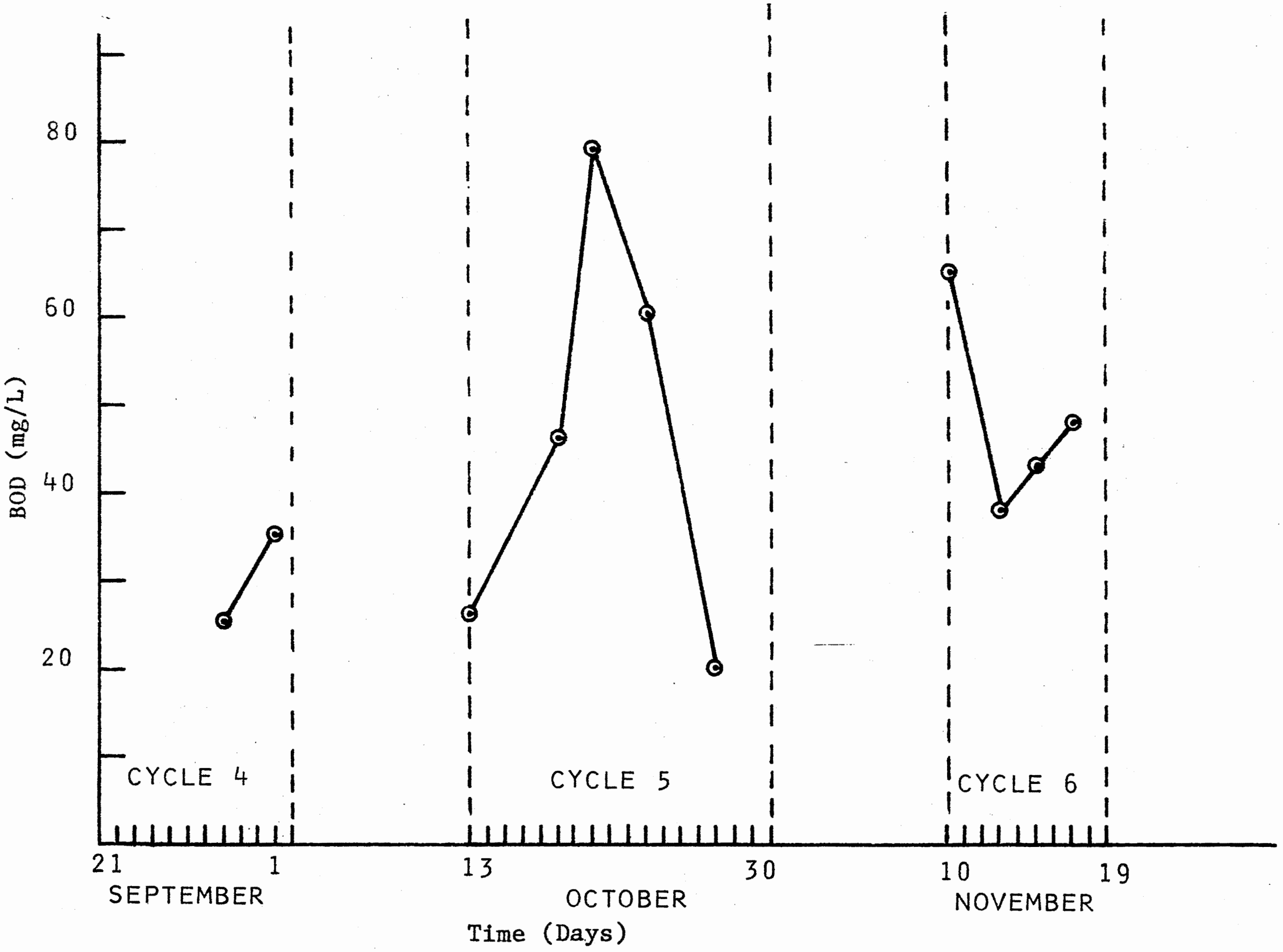

Figure 11. (Continued)

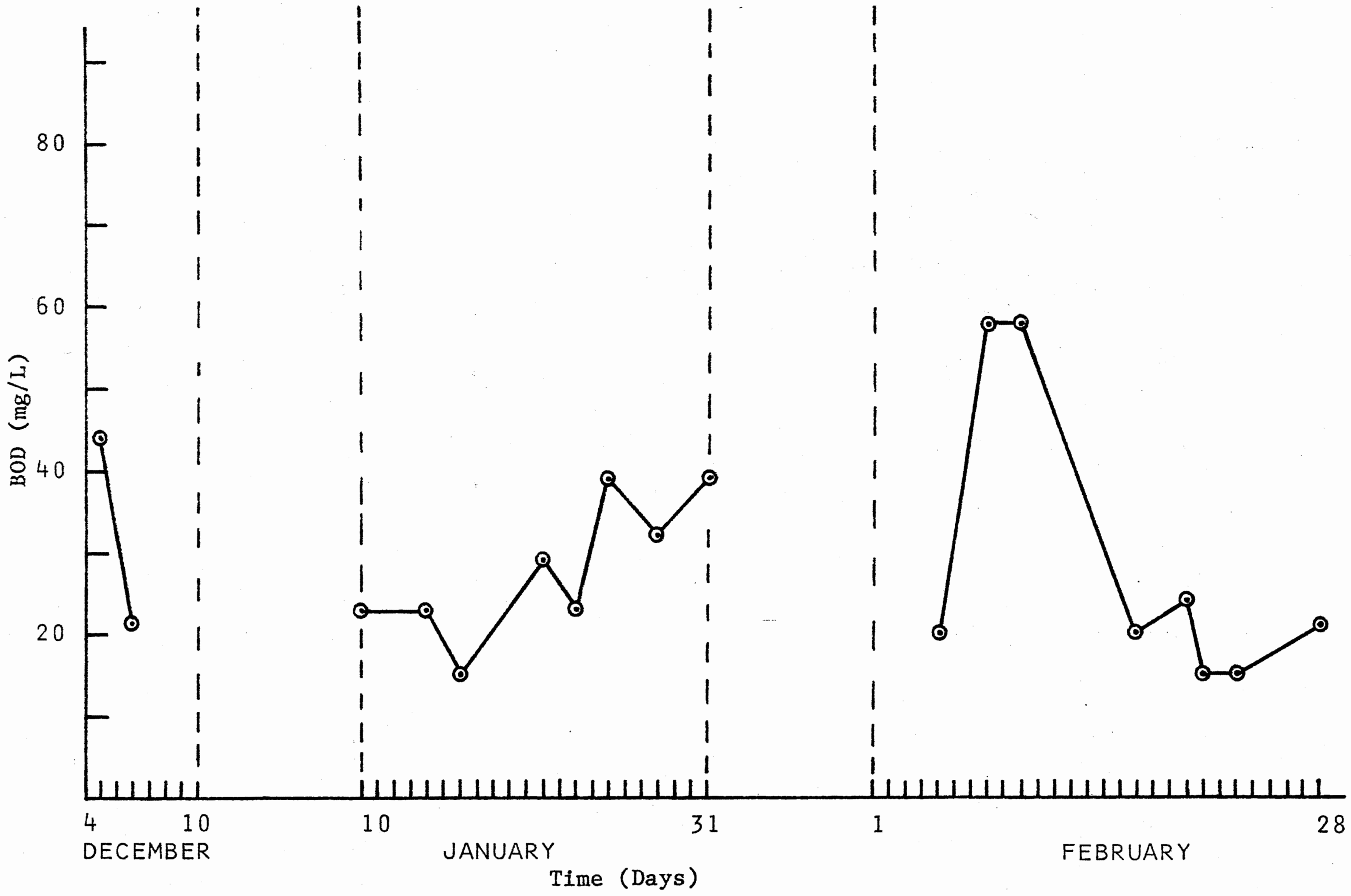

Figure 11. (Continued)

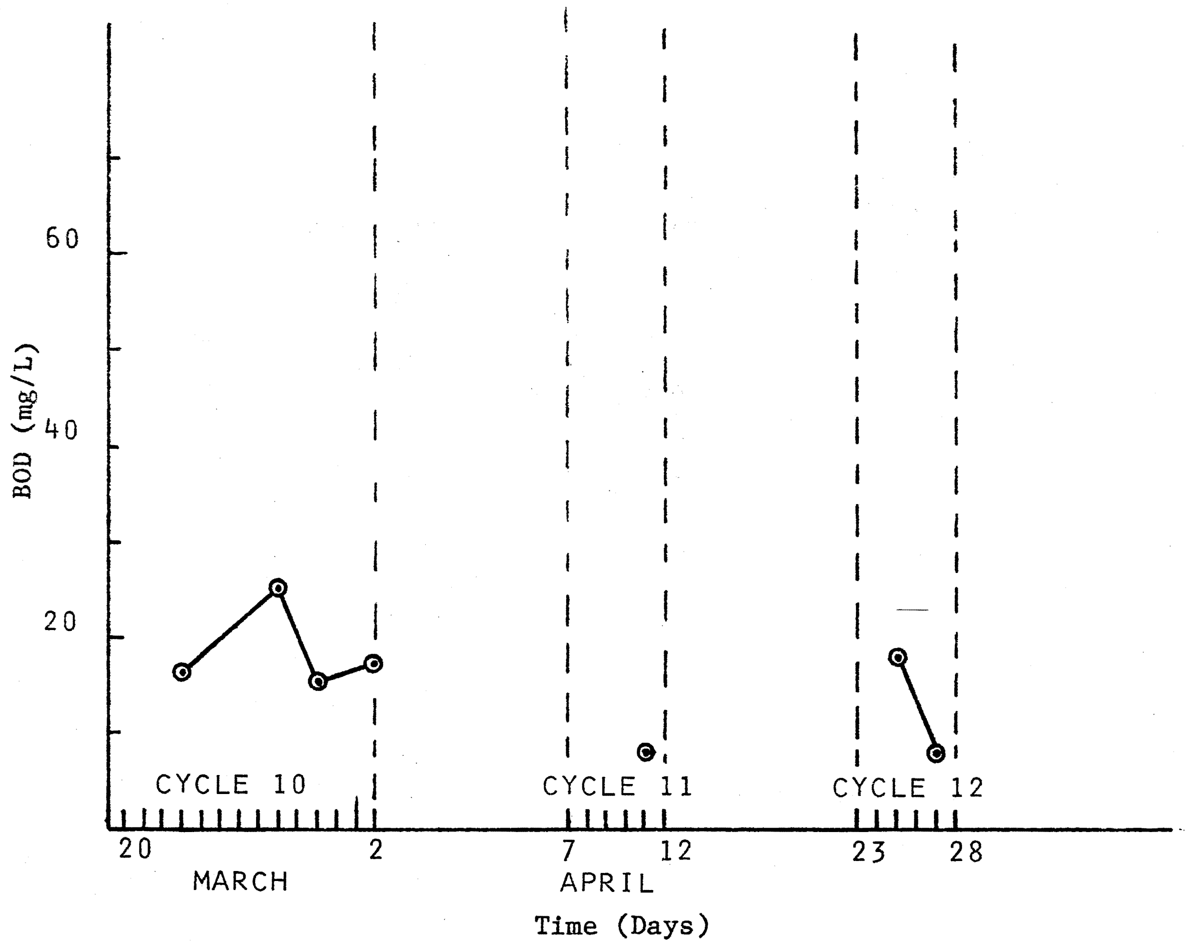

Figure 11. (Continued)

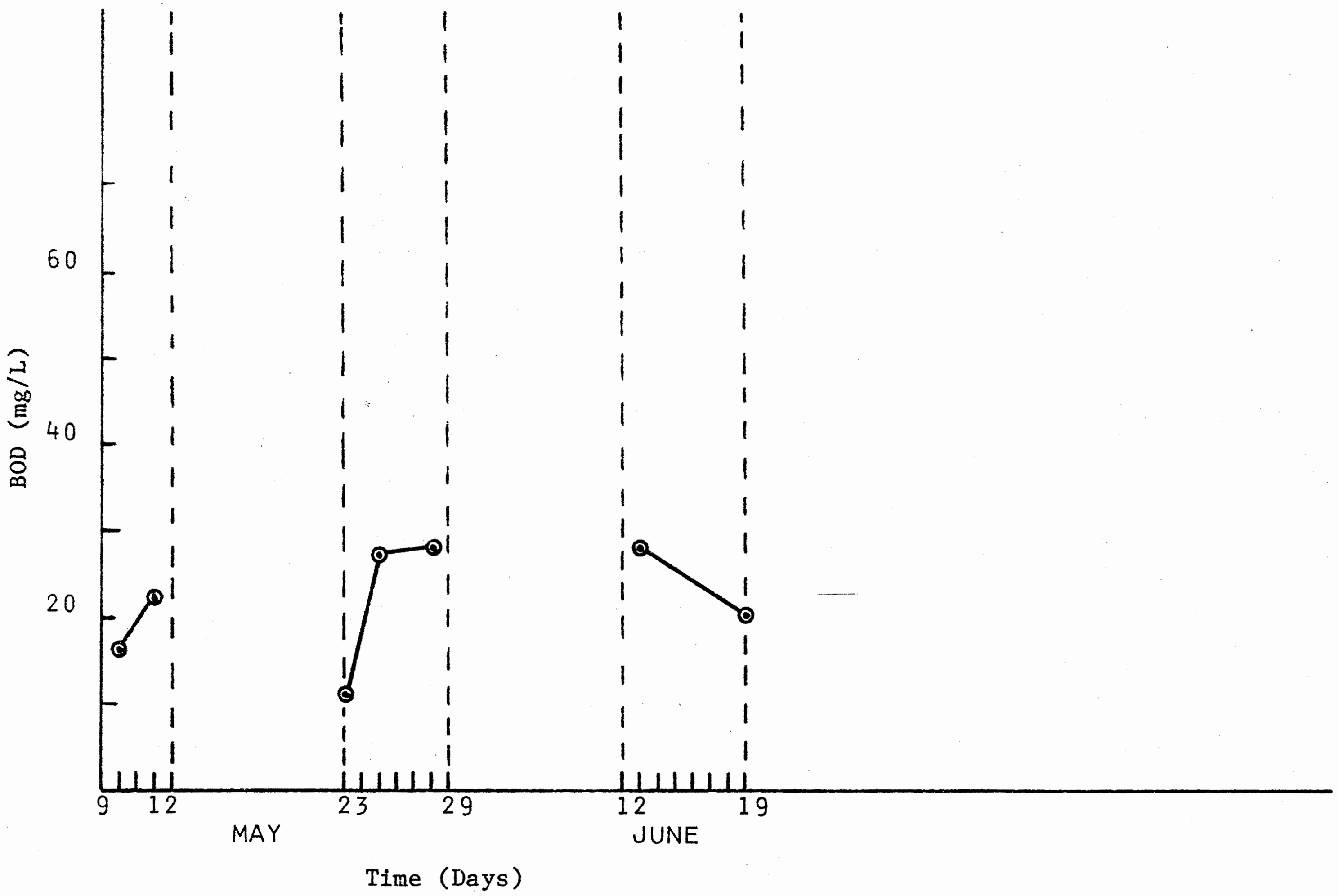

Figure 11. (Continued)

Figure 12 shows the relationship between pH, phosphorous, suspended solids and BOD_5 for cycle 1-summer of 78, cycle 8-winter 79, and cycle 12-short cycle respectively. The cycle 12-short cycle refers to a discharge made as soon as the suspended solids concentration dropped below 30 mg/L.

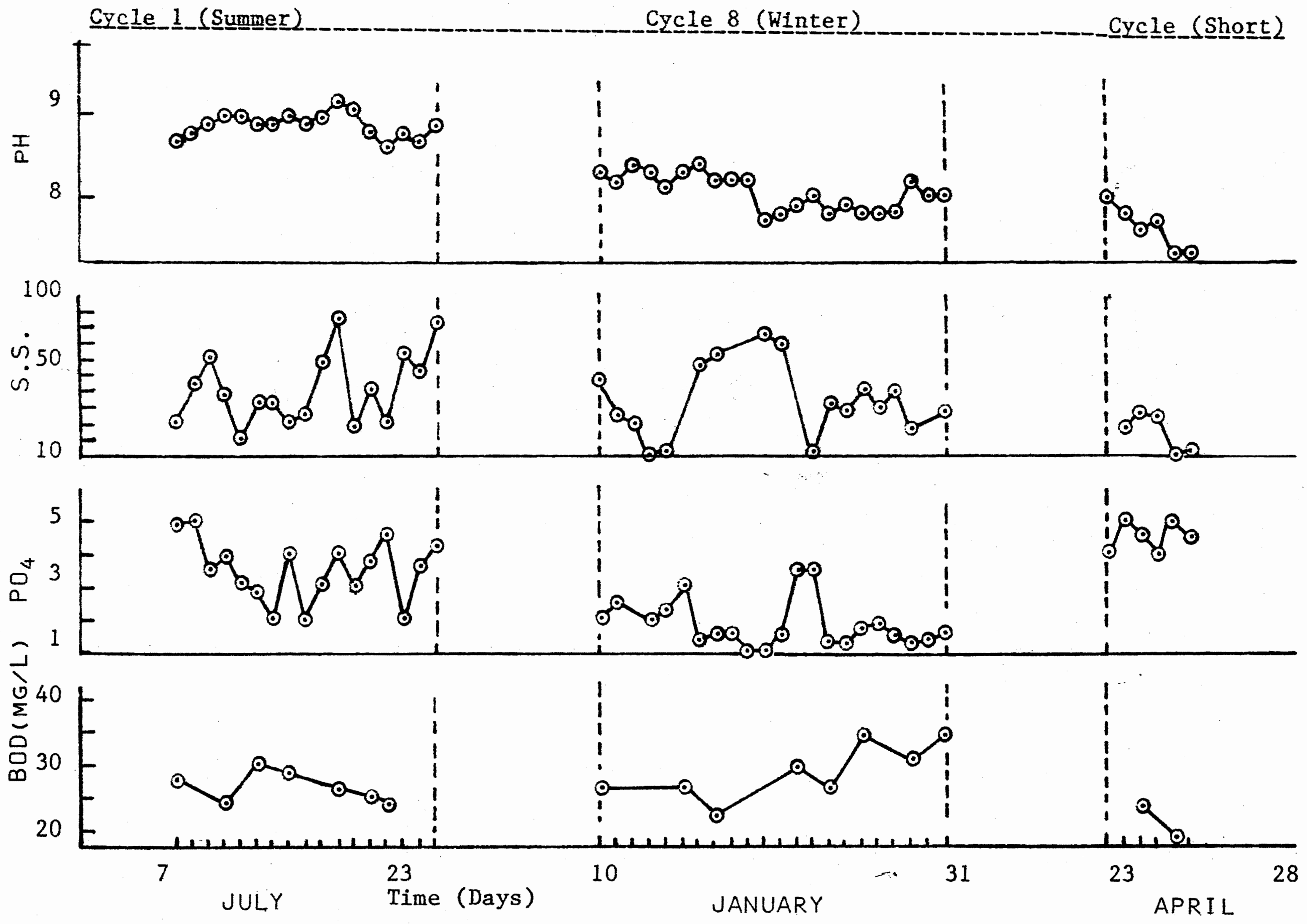

Figure 12. Relationships Between Parameters

CHAPTER V

DISCUSSION

This investigation was conducted to determine the feasibility of utilizing the phase isolation lagoon operation technique to obtain secondary treated effluent meeting the City of Cushing's permit conditions. The process was studied on a full scale basis using the second cell of the City of Cushing's effluent polishing lagoon as the isolation pond. The most notable observation was the developement of high-low patterns in daily variation occurring in all the parameters monitored. During most of the isolation cycles the parameters such as suspended solids and BOD_5 did not show a consistent decline, but a high-low daily cycling. Due to this daily inconsistancy during the first eight months of this study, regardless of the parameter's value at the time of discharge, it was impossible to be confident that permit conditions were not being exceeded during the 6-7 days required to empty the isolation lagoon. After the two million gallon per day maximum discharge limitation was removed, it took only 2-3 days to empty the isolation lagoon which increased the possibility of keeping below permit conditions during the discharge period.

It was obvious for the phase isolation operation to be effective this inconsistancy, high-low parameter cycling, must be controlled.

Trying to combat this high-low daily variation during the last four months of the study, the isolation pond was emptied as soon as the suspended solids fell below 30 mg/L creating "short" cycles.

By emptying the isolation pond before the high-low variation pattern could get started, the phase isolation technique showed the greatest possibilities, further proving if the process is going to work this daily cycling must be controlled. However these short cycle experiments occured during late winter and spring which according to other studies has proved to be the most effective season of the year for the phase isolation process (4) and (6). As in the other studies the results also proved that seasonal changes that effect algal growth also effect phase isolation.

This up and down fluctuation of the suspended solid concentrations was less noticeable in cycles 7, 8, 10, 11, 12, and 13, winter and spring spring months. Also cycles 10, 11, 12, and 13 were "short cycles". These cycles represented the best results to support the success of the phase isolation operation.

The BOD_5 of these isolation cycles, except cycle 8, was below 30 mg/L and pH less than the permit condition of 9 at the time of discharge.

Since the studies have indicated the winter isolation cycles to obtain the best results to support the phase isolation concept, it should be noted that a period during the winter from December 12, 1978 to January 9, 1979, was not considered in this study. This period was omitted due to intermittent discharges from the isolation lagoon due to a down stream oil spill in Cottonwood Creek.

Since the daily inconsistency of the data resulting in a pattern of high-low variation was determental to the process it is important to determine why the daily variation effect occurred. It should be pointed out that this high-low variation was not due to inflow since the pond was in total isolation.

The author feels there are two possible reasons the high-low variation patterns occurred. One explanation is based upon environmental factors effecting the phase isolation performance. As is reported in literature, wind has a determental effect on the process. As observed on many occasions the wind caused turbulance in the lagoon which resulted in the resuspension of nutrient rich sediments and also inhabited algal settling. The availability of substrate from the sediments could increase biological activity on certain days, thus increasing the BOD_5 on some days and decreasing the BOD_5 on other days. The non-ability of the algal settling on certain days could also explain the fluctuation of suspended solids. This same type of reasoning can be applied to explain the inconsistency in pH and PO_4. Other environmental factors such as sunlight intensity and duration are reported to to influence the phase isolation operations.

A second theory that would explain the cycling phenomena is that lysis was occurring in the algae. Lysis is a process of disintegration or dissolution of the cell (11). When the cell wall ruptures nutrients are released and utilized, thus increasing the BOD_5. This would explain the fluctuation in suspended solids and BOD_5. The suspended solids would increase while the algae and bacteria died and then decrease when it settled. When more algae and bacteria died the cycle would start all over again. The BOD_5 would increase when the nutrients were released then drop off when they were utilized or died. Since pH and the PO_4 content is related to the algal growth the same phenomena would explain their high-low. This explanation is also suppported in that the high-low peaks for BOD_5 and suspended solids do not occur on the same day, in fact normally as the BOD_5 showed an increase the suspended solids began to decrease and as the BOD_5 decreased the suspended solids increased. This can be seen in a comparison of the BOD_5 and suspended solids results as showed in Figure 12. Again as shown in Figure 12, when the process is working this pattern of high - low variations does not occur. This problem of daily variation is also seen in the data published in the Mississippi State study.

A comparison of the data published in the Mississippi study as shown in Figure 13 and 14 also reflects an inverse relationship between maximum and minimum BOD_5 and suspended concentrations, especially in cycle 1, also supporting the possibility of lysis occurring (4,p.113 & 114).

The results of this experience indicate that the phase isolation operational technique cannot, on a consistent basis produce effluent to meet the City of Cushing's Environmental Protection Agency, NDPS, permit conditions.

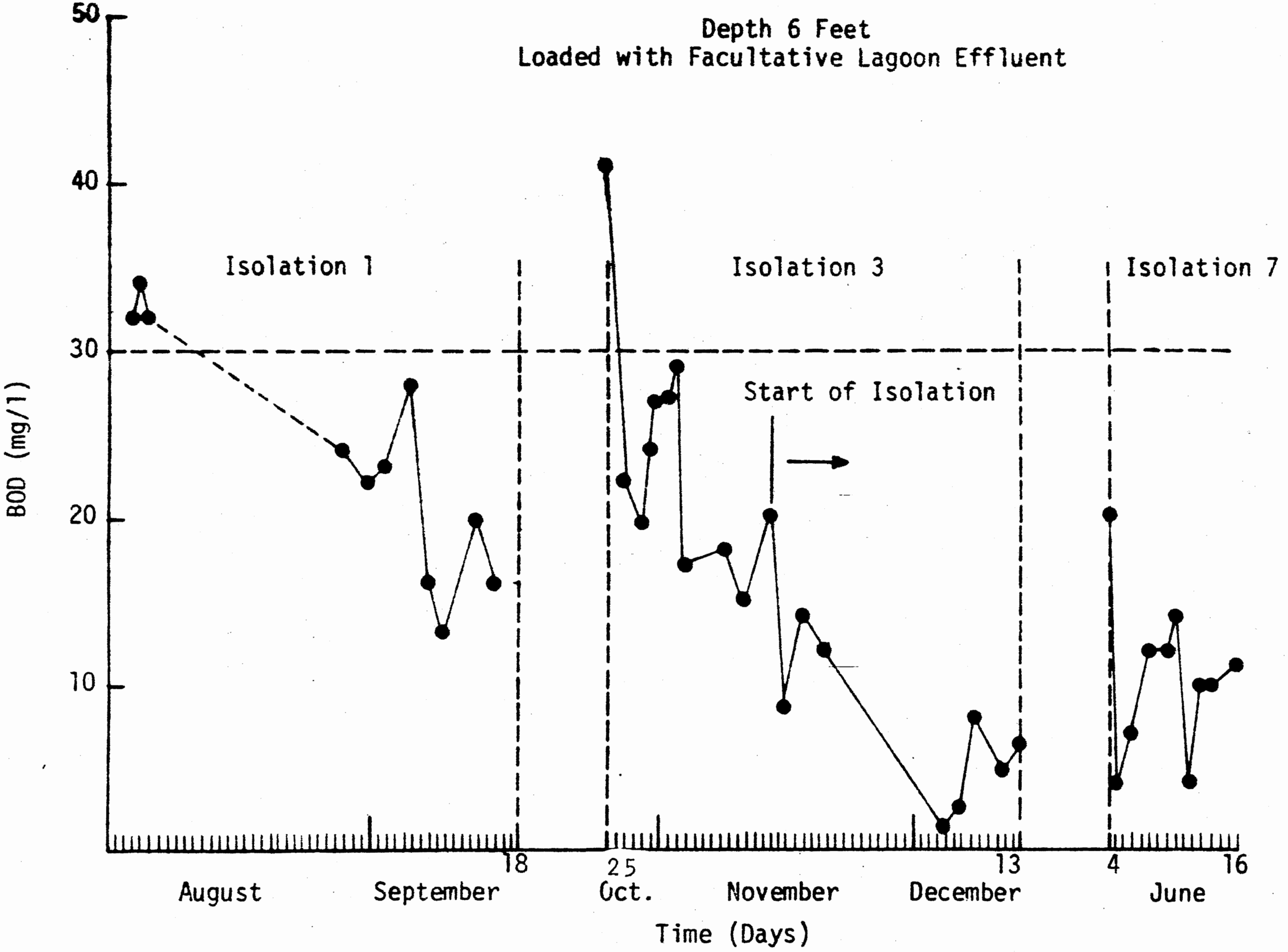

Figure 13. Seasonal Variation of BOD_5

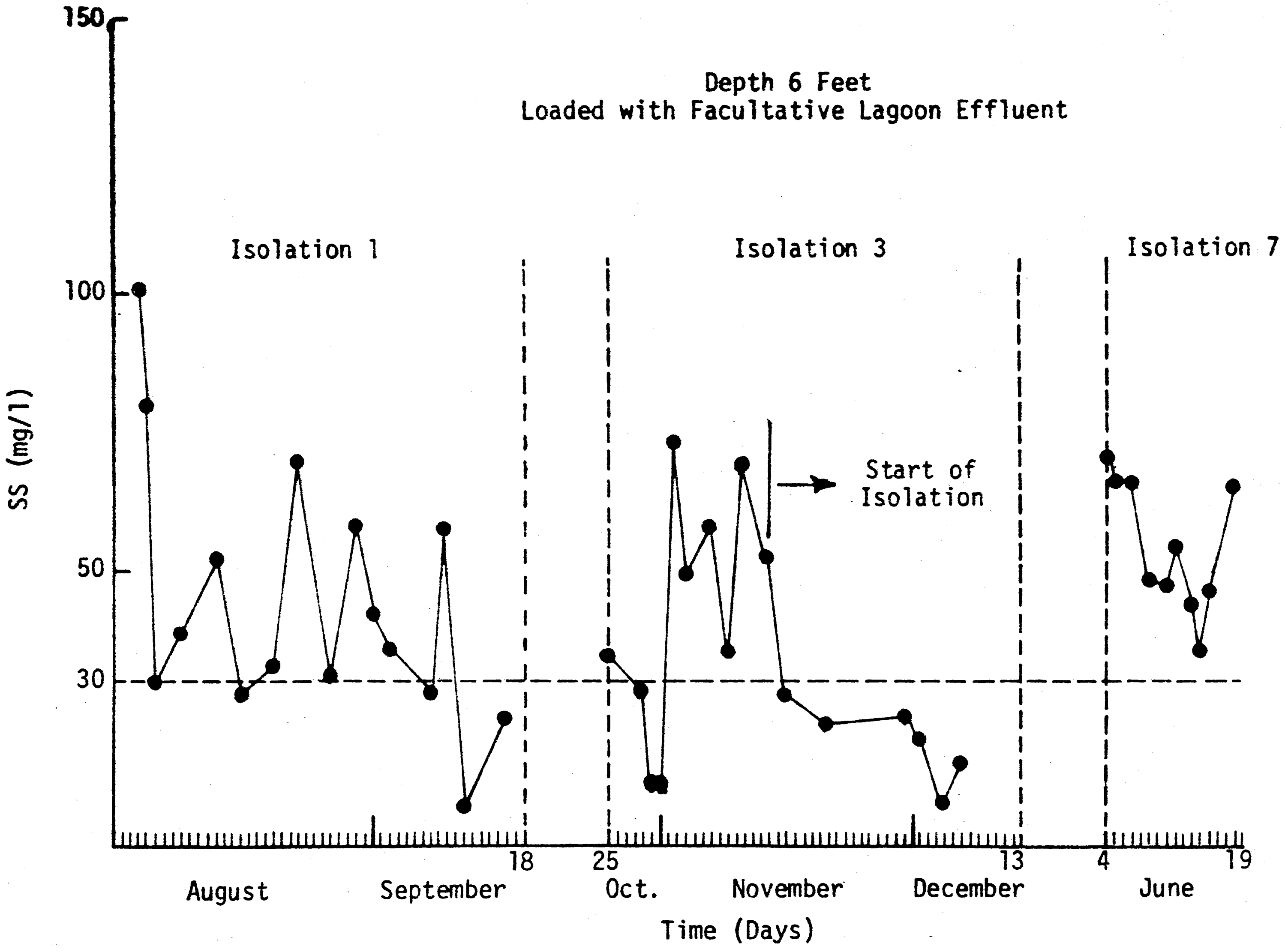

Figure 14. Seasonal Variation of Suspended Solids

CHAPTER VI

CONCLUSIONS

The results of this study support the following conclusions:

(1) The phase isolation process as operated in this study could not consistently achieve Environmental Protection Agency's required effluent standards.

(2) Phase isolation performed best in the winter and spring when conditions were not as favorable for algal growth and high-low concentration variations were not prevalent.

(3) Phase isolation was not effective when the parameter valves varied high and low, ie.- inconsistent daily changes.

(4) Environmental factors and or lysis caused the daily inconsistent and erratic results obtained in some of the isolation cycles.

CHAPTER VII

SUGGESTIONS FOR FUTURE STUDY

Based on the findings of this study, the following suggestions are made for future study of the phase isolation process:

(1) Investigate what causes the results during some isolation cycles to be erratic and inconsistent and others to consistently show improvement in effluent quality.

(2) Investigate if lysis is the cause of the high-low variation patterns developed in the parameters monitored in this study.

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APPENDIXES

TABLE VIII

METEOROLOGICAL DATA

July, 1978				
	Air Temp. (°F)			
Day	Max.	Min.	Precipitation (inches)	Evaporation (inches)
1	96	73		.51
2	97	74		.48
3	96	75		.29
4	99	74		.30
5	99	75		.40
6	99	82		.51
7	99	73		.43
8	98	75		.33
9	102	76		.45
10	104	75		.47
11	101	74		.41
12	101	77		.41
13	100	77		.39
1$	102	70	.63	.59
15	102	76	.03	.45
16	96	71		.36
17	96	72		.37
18	98	72		.44
19	101	77		.51
20	102	75		.46
21	98	76		.20
22	97	73		.67
23	93	68	.76	.19
24	83	66	.10	.30
25	91	67		.25
26	97	72		.32
27	100	66	.08	.32
28	95	67		.45
29	98	71		.38
30	101	77		.45
31	97	77		.55

TABLE VIII (Continued)

August, 1978				
	Air Temp. (°F.)			
Day	Max.	Min.	Precipitation (inches)	Evaporation (inches)
1	96	68		.28
2	92	71	.14	.49
3	92	68		.29
4	86	64	.72	.10
5	69	63	.06	.08
6	84	64		.26
7	88	65		.16
8	91	64		.26
9	93	69		.22
10	93	68		.23
11	91	71	.03	.34
12	100	71		.46
13	100	73		.57
14	102	74		.29
15	100	80		.52
16	90	70		.45
17	100	70		.53
18	102	79		.66
19	101	63		.21
20	80	61		.13
21	95	61		.17
22	100	71		.37
23	97	72		.53
24	100	72		.39
25	99	73		.47
26	100	73		.47
27	100	75		.45
28	98	67		.35
29	90	67		.26
30	88	59		.32
31	89	60		.25

TABLE VIII (Continued)

	September, 1978			
	Air Temp. (°F.)			
Day	Max.	Min.	Precipitation (inches)	Evaporation (inches)
1	90	58		.23
2	89	66		.43
3	94	67		.35
4	99	70		.36
5	101	74		.28
6	83	69	.05	.12
7	98	67		.33
8	95	68		.40
9	92	68	.10	.27
10	85	68	.06	.19
11	92	68		.19
12	87	72		.26
13	88	77		.28
14	95	67		.28
15	88	67		.28
16	98	72		.37
17	99	73		.25
18	93	76		.68
19	95	75		.50
20	92	67		.30
21	85	53	.23	.25
22	74	53		.23
23	74	53		.18
24	85	65		.15
25	86	69		.06
26	78	64		.10
27	80	61		.10
28	85	59		.19
29	89	58		.16
30	89	59		.41

TABLE VIII (Continued)

October, 1978				
	Air Temp. (°F.)			
Day	Max.	Min.	Precipitation (inches)	Evaporation (inches)
1	80	52		.28
2	86	55		.24
3	93	61	T	.36
4	79	52		.36
5	85	52		.28
6	75	45		.27
7	72	44		.28
8	79	49		.19
9	64	54	1.05	.15
10	79	55		.15
11	83	60		.28
12	88	59		.08
13	92	54		.44
14	67	41		.31
15	73	41		.18
16	81	45		.21
17	67	45		.31
18	73	44		.19
19	82	49		.24
20	76	48		.22
21	89	47		.22
22	79	46	.10	.34
23	61	40		.23
24	71	42		.11
25	75	40		.13
26				.05
27	64	39		.08
28	75	41		.25
29	76	41		.19
30	75	46		.17
31	79	46	T	.14

TABLE VIII (Continued)

	November, 1978			
	Air Temp. (°F.)			
Day	Max.	Min.	Precipitation (inches)	Evaporation (inches)
1	80	45		
2	71	45		
3	84	50		
4	83	60		
5	82	58		
6	79	44	.33	
7	33	46		
8	60	34		
9	69	34		
10	70	52		
11	70	40		
12	55	39		
13	65	42	.14	
14	66	42	.29	
15	44	35	.72	
16	42	36	.56	
17	42	33	.50	
18	45	32		
19	66	41		
20	55	33	.01	
21	43	30		
22	40	30	.15	
23	56	38	.06	
24	62	45		
25	67	40	.04	
26	66	51	.44	
27	58	33		
28	45	30		
29	55	30		
30	59	39		

TABLE VIII (Continued)

December, 1979

Day	Air Temp. (°F.) Max.	Air Temp. (°F.) Min.	Precipitation (inches)	Evaporation (inches)
1	58	39		
2	59	39	T	
3	67	19		
4	29	19		
5	52	24		
6	66	29		
7	41	21		
8	25	14	T	
9	28	10		
10	36	10		
11	50	22		
12	52	26		
13	61	31		
14	46	22		
15	52	22		
16	56	29		
17	52	22		
18	50	24		
19	66	45		
20	67	37		
21	43	25		
22	54	26		
23	57	29		
24	59	19		
25	42	19		
26	60	25		
27	47	23		
28	47	19		
29	51	41		
30	49	18		
31	20	15		

TABLE VIII (Continued)

January, 1979

Day	Air Temp. (°F.) Max.	Air Temp. (°F.) Min.	Precipitation (inches)	Evaporation (inches)
1	18	7	.03	
2	14	2		
3	28	4		
4	39	13		
5	16	12		
6	31	12	T	
7	21	12	.14	
8	23	3		
9	31	2		
10	42	20		
11	29	18	.05	
12	32	19	.01	
13	41	13	.15	
14	15	-1		
15	19	-1		
16	38	19		
17	45	30		
18	43	32		
19	52	30		
20	46	29		
21	42	31	T	
22	41	28		
23	40	21		
24	25	9	.03	
25	33	10		
26	38	29	.30	
27	33	13	.08	
28	22	7		
29	24	5		
30	23	10	.14	
31	22	-2		

TABLE VIII (Continued)

	February, 1979			
Day	Air Temp. (°F.) Max.	Min.	Precipitation (inches)	Evaporation (inches)
1	23	2		
2	36	4		
3				
4	25	10		
5	32	7		
6	29	7	.08	
7	32	9	.29	
8	30	29		
9	33	1		
10	27	1		
11	46	18		
12	50	27		
13	31	22		
14	38	24	T	
15	69	34		
16	38	6		
17	13	5	T	
18	16	11	.01	
19	44	18		
20	55	23		
21	41	27	.01	
22	54	27		
23	74	33		
24	49	28		
25	36	24		
26	50	24		
27	55	24		
28	61	36	.02	

TABLE VIII (Continued)

March, 1979				
	Air Temp (°F.)			
Day	Max.	Min.	Precipitation (inches)	Evaporation (inches)
1	45	38		
2	62	38		
3	62	48	.54	
4	50	26		
5	47	25		
6	58	26		
7	65	38		
8	58	29		
9	60	30		
10	52	35		
11	52	34		
12	73	40		
13	73	37		
14	69	33		
15	60	33		
16	58	36		
17	58	35	.22	
18	63	45	1.07	
19	78	32	.31	
20	54	45	.12	
21	65	46		
22	79	48	.75	
23	72	38	.20	
24	49	31	.02	
25	50	29		
26	65	30		
27	70	33		
28	65	34		
29	74	63		
30	81	58		
31	72	40		

TABLE VIII (Continued)

April, 1979				
	Air Temp. (°F.)			
Day	Max.	Min.	Precipitation (inches)	Evaporation (inches)
1	67	41	.54	
2	54	35		
3	54	35		
4	42	34	.22	
5	56	35		
6	74	34		
7	73	36		
8	79	57		
9	70	36		
10	65	38		
11	64	51	1.53	
12	72	47		
13	67	46		
14	69	46		
15	80	47		
16	85	59		
17	82	61		
18	83	55	.03	
19	67	63	.04	
20	76	55		
21	69	51	.41	
22	72	52		
23	74	54		
24	74	54		
25	83	54		
26	84	44		
27	71	46		
28	60	45		
29	63	42	.28	
30	70	42		

TABLE VIII (Continued)

May, 1979				
	Air Temp (°F.)			
Day	Max.	Min.	Precipitation (inches)	Evaporation (inches)
1	75	49		
2	63	54		.07
3	70	50		2.32
4	52	44		2.39
5	63	43		.10
6	53	47	.24	
7	83	63	.32	
8	85	58	.39	
9	84	66	.25	
10	83	68	.30	
11	75	42	.09	.31
12	57	42	.20	
13	72	44	.28	
14	88	49	.15	
15	87	61	.21	
16	86	61	.44	
17	84	61	.34	
18	84	63	.17	.06
19	85	65	.38	
20	82	63	.24	.50
21			.32	
22	65	57	.08	1.00
23	64	51	.04	.05
24	77	48	.31	
25	73	48	.23	
26	70	49	.31	.04
27	75	57	.16	.10
28	86	62	.26	
29	81	58	.15	
30	84	61	.23	
31	82	58	.19	

TABLE VIII (Continued)

June, 1979				
	Air Temp. (°F.)			
Day	Max.	Min.	Precipitation (inches)	Evaporation (inches)
1	74	57		
2	78	57	T	
3	71	55	.05	
4	80	56		
5	88	62		
6	78	63	.04	
7	84	63	.63	
8	92	68		
9	89	64	2.10	
10	86	53	.46	
11	77	54		
12	82	59		
13	84	61		
14	89	63		
15	93	68		
16	91	65		
17				
18	91	67		
19	87	70		
20	86	73		
21	95	68	.13	
22	92	71	.05	
23	90	68	.71	
24	88	66	.99	
25	77	63	.07	
26	80	63		
27	85	64		
28	88	69		
29	93	71	.40	
30	94	69		

* Air temperature and Precipitation were recorded by Cushing Police Department.

* Evaporation data obtained from Oklahoma Climactical Data, Stillwater 2 W. Station.

VITA

Stephen Roger Spears

Candidate for the Degree of

Master of Science

Thesis: INVESTIGATION OF THE EFFECTS OF THE "PHASE ISOLATION" PROCESS ON THE EFFLUENT FROM THE POLISHING LAGOONS OF CUSHING, OKLAHOMA, WASTE TREATMENT PLANT

Major Field: Civil Engineering

Biographical:

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