EVALUATION OF THE EUTROPHICATION PROCESS IN LAKE İZNİK

by

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ABSTRACT

Lake İznik is located in the southern east part of Marmara region within the province of Bursa . Its water is of a big importance to the region with a Mediterranean climate, and an annual rainfall ranging between 500 - 750 mm , falling mainly in the period from October to March . This water is used in dry season for irrigation .

In this thesis , a physical study of the region is conducted . The physical , chemical and biological parameters were examined at several sites in order to determine the eutrophication state and a suitable model was applied to represent the lake

Lake İznik was found to be very near to the eutrophic state and the limiting nutrient in the lake was found to be the phosphorus element

ÖZET

İznik gölü , Marmara bölgesinin kuzey doğusunda , Bursa ilinin sınırları içinde bulunmaktadır . Akdeniz iklimine sahip olan ve genel olarak Ekim ile Mart ayları arasındaki dönemde yoğun olmak üzere , yıllık 500 - 750 mm yağış düşen İznik , çevresi için çok önem taşımaktadır . Bu gölden elde edilen su , yazın sulama amacıyla kullanılmaktadır

Bu tezde , bölgenin fiziksel bir etüdü yapılmıştır Göldeki ötrofikasyon durumunun belirlenmesi için fiziksel , kimyasal ve biyolojik parametreler incelenmiş olup gölü simgeleyen bir model uygulanmıştır

İznik gölünün , ötrofik duruma çok yaklaştığı ve göl sularında sınırlayıcı elementin fosfor olduğu bulunmuştur

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A	Surface area of the lake
C	Concentration of the nutrient within the lake
CO	Initial nutrient concentration
Ci	Input nutrient concentration
E	Direct evaporation from lake surface
Gs	Indirect outflow from lake
Ic	Direct inflow from streams and springs
Ig	Underground water runoff
Io	Runoff from land
K	Sedimentation rate
L	Actual areal load
Lc	Permitted areal load
M	Load of nutrient
P	Direct precipitation on lake surface
Q	Inflow from streams and surface runoff
Qc	Outflow from lake outlet
Qt	Total inflow of water
R	Indirect water return from irrigation
Rn	Nutrient residence time
Rw	Water residence time
TSI	Trophic state index
V	Volume of lake
W	Water used for irrigation and industrial purposes
Z	Lake depth

σ	Sedimentation coefficient
ρ	Hydraulic flushing rate

1. INTRODUCTION

1.1. Importance of Eutrophication Process in Lakes

Many elements are essential for the growth of algae , e.g. , carbon , cobalt , hydrogen , potassium , magnesium , nitrogen , oxygen , phosphorus and sulfur . However , in natural waters compounds of nitrogen and phosphorus are frequently limited supplied so that they tend to control the extent of growth that occurs .

Phosphorus , nitrogen and carbon of the elements , are essential for the growth of phytoplankton and macrophytes which serve as a source of food for fish , however , large growth of these plants have many undesirable effects . Large accumulations of algae can decrease property values as they produce unsightly accumulations on shorelines . They form breeding grounds for flies and insects and the decomposition of algae can lead to unpleasant odors . In addition , they have various effects on impounded waters used for water supplies (Linsley & Franzini,1984) .

At present , lake İznik is the only source of water for Orhangazi and İznik cities and their surroundings. It is the source of water used for irrigation purposes in the region .

In this study , the factors influencing water quality of lake İznik have been determined . The nutrient loadings and the response of the lake to them have been examined and the limiting element in the lake water body has been determined .

A model which reflects the function of the limiting element in the primer productivity has been investigated and applied to lake İznik .

2. EUTROPHICATION PROCESS

2.1. Definition of Eutrophication

The pollution in lakes is measured as the increment in nutrients necessary for growth of plants and algae . Eutrophication is the enrichment of water bodies with nutrients such as NITROGEN and PHOSPHORUS ; Although this process occurs under natural conditions the activities of man in altering the landscape by urbanization and agricultural and industrial development , accompanied by the discharges of wastes , frequently localize and intensify the quantities of nutrients going into lakes , streams and estuaries .

Eutrophication may have beneficial results by increasing productivity in receiving bodies of water , but in many locations throughout the world the effects of eutrophication are undesirable . An excess of nutrients often results in excessive growth of algae and larger aquatic plants , which interfere with the use of water for recreation , increase the cost of filtration of water for domestic and industrial purposes , reduce or fully consume the oxygen resources in the deeper or hypolimnetic waters , adversely affect aesthetic values , and impart tastes and odors to the waters. Furthermore , excessive growth of larger aquatic plants along waterways hinders drainage and enhances the probability of flooding (Whittaker,1975)

2.2. Factors Affecting Productivity of Lakes

There are many factors affecting the nutrient circulation and productivity , and thus eutrophication of lakes . Effects of these factors are interrelated , but the following paragraphs should be understood as statements in the form : if other characteristics of two lakes are closely similar , then the effect on productivity of a difference between them in this factor would be :

(a) Fertility of the drainage basin . Of two lakes , one receiving inflowing water from an area of infertile rocks (quartzite or granite mountains) , the other from an area of fertile soils (as a rich farming area on limestone) , the latter should be more productive .

(b) Lake depth and slope of shore . Comparing two lakes , one deep with steep , rocky shores , the other shallow with sloping shores of mud and sand , the latter should be more productive . In the first most of the bottom is out of reach of sunlight , the plants cannot grow on the bottom and contribute to the lake's production . The steep , rocky shores imply that the growth of plants along the shore are limited .

(c) Form of shore line . Closely related to the preceding is the form of the shore line . Of two lakes with similar size , depth , and slope of the shores , the lake with a long and irregular shore line with many inlets should have greater productivity than one with short shore line . The longer shore line implies a greater area of production by the shore plants relative to the area of the lake .

(d) Temperature . Of two similar lakes the one in the warmer climates has the longer season of biological activity and greater nutrient turnover through the year , and should have the higher productivity .

(e) Water turnover . Climates , humidity and manner of water inflow and outflow indirectly affect productivity . If a lake is virtually a wide part of the river , with inflow and outflow large relative to its volume , plankton productivity may be limited by the short residence time of water in the lake . The manner of water budget in lakes is affected also by climatic humidity . In a humid climate the amount of water leaving the lake by evaporation from the surface is generally small compared with that leaving by stream and underground outflow . In a drier climate , the fraction of loss by evaporation from the surface is larger , and in an arid climate may lakes have no stream outflow , losing their water only by evaporation .

(f) Lake age . Lake age , especially as it affects the filling of the basin , thus influences lake productivity . Most lakes are relatively short-lived ; many were formed by glaciers or changes in river courses and are only a few thousand years old .

Lakes age primarily is affected by the filling of their basins with organic and inorganic deposits . Increasing fertility and productivity of a lake , or development from an oligotrophic toward an eutrophic condition , is termed eutrophication . The aging of a lake may lead to eutrophication , but the two processes need not run in parallel . Productivity of lakes can both increase and decrease with age , particularly as the conditions of their watershed change (Whittaker,1975) .

2.3. Types of Lakes

Lakes are classified according to some criterias as follows :

(a) Oligotrophic lakes : are generally deep and have clear waters but have very low productivity . They are poor of nutrients . Algae blooms are rarely happening with oxygen existing in all seasons and in all depths . Their phytoplankton production level is low such as 0.03 - 0.1 g of carbon per m2.day .

(b) Mesotrophic lakes : this type has specifications between those of oligotrophic and eutrophic ones .

(c) Eutrophic lakes : they are generally shallow and rich of nutrients , plants and organic matters therefore they have high level of productivity . Their surfaces may be covered by grasses . In natural eutrophic lakes phytoplankton production level is between 75 - 250 g of carbon per m2.day whereas in polluted eutrophic lakes this level is much higher . On the other hand , dissolved oxygen concentrations changes with seasons and depths .

(d) Dystrophic lakes : they exist generally in rainy regions and are rich of nutrients . Dissolved oxygen may not exist in deep waters and they become shallow with time to turn to marshes but this occurs not because of eutrophication process but because of the materials entering them .

(e) Mixotrophic lakes : they are very rich of nutrients and organic suspended matters and they are very productive .

2.4. Source of Nutrients

Rivers are the main arteries of transport of nutrients from agricultural , industrial and urban regions to freshwater, lakes and the sea . Although no specific information is available concerning phosphorus , it is estimated (Meybeck,1976) that the total load of rivers is around 90 per cent of the supply of matter (dissolved plus particulate) to water reservoirs . Phosphorus is also known to be the limiting pollutant responsible for the eutrophication of lakes and rivers and a great deal of research has been directed to estimate the loads of phosphorus inputs to lakes where eutrophication already exists or is seen to be a potential problem for the future .

The entry of phosphorus and nitrogen into a lake may either be at a point of discharge , e.g. direct input from rivers , as land runoff, or direct wet and dry precipitation.

(a) Direct Loading from Rivers & Runoff from Land : this was mostly studied in defined experimental watersheds by recording , multiplying and integrating concentrations and flow rates . An important component of these budgets is weathering of minerals and subsoils . Losses of total phosphorus were found to be linearly and directly proportional to percentage of farmland in a watershed (Ryding 1983 , Kauppi,1984) . Losses of dissolved phosphorus are reported to be increasing by application of manure (Brink, 1986) but losses of particulate P from farmland are even more important (Blazka,1989) .

The effect of soil cover is even more evident in forests . Keller (1983) in his review gives TP export rate for nine forested watersheds with less than 10 per cent agricultural area . The annual rates are all less than 0.5 kg TP/ha , with a mean of 0.122 kg TP/ha (Blazka,1989) . The phosphorus export coefficient of Uttormak ,et al. for forested land was thought by Rast and Lee(1983) to be too high for use as an average value , based on their literature review and on the comparison of the value with the export coefficient for mostly forest land reported by the U.S.EPA and Omernik . Rast and Lee (1983) have selected the forest phosphorus and nitrogen export coefficients to be 0.01 g TP / m2.yr and 0.5 g N/m2.yr respectively .

(b) Loading from Animal Farms : with livestock kept indoors , is usually estimated using "cow equivalents ", " sheep equivalents ", and ," poultry equivalents " . One lactating cow is assumed to produce 68.5 g TP and 104 g N per day . Whereas , one sheep is assumed to produce 5.5 g TP and 30 g N per day , one poultry animal is assumed to produce 0.55 g TP and 1.37 g N perday (Uttormak,Chapin & Green,1974).

(c) Sewage from Human Population , Particularly Urban : its magnitude is generally also estimated using population equivalents , its physiological value is about 2.5 g TP per day per individual , but where P detergents are used, the population equivalent is about 4.1 g TP per day with 12 g N per day (Uttormak,Chapin & Grenn,1974). It is evident that urban sewers are major route of P input into waters .

The importance of sewage is further increased when not only cities but also villages are joined to sewer system. With less concentrated country populations without sewerage , some P is retained in the basin and does not reach the watercourses .

(d) Industrial Phosphorus Pollution : will likely be fairly specific from case to case . Fertilizer and foodstuff industries are the most likely contributors .

(e) Aerial Input : in the practical absence of gaseous P compounds in nature and particularly in biochemical cycle , the only important route of aerial transport of P are windblown soil , fertilizers and possibly other P-containing particles and their dry and wet deposition . Broberg and Persson (1984) have estimated range between 0.055 and 0.34 kg TP per ha-yr (Blazka,1989) . On the other hand , Uttormak (1974) has estimated a value of 0.025 g TP per m2.yr and 2.4 g N per m2.yr of the surface area of the lake .

2.5. Parameters Determining Eutrophication Process in Lakes

There are some parameters which determine eutrophication process in a lake such as :

(a) In the epilimnion layer :

- Concentration of phosphorus at the beginning of spring ,
- Suspended organic material and suspended nitrogen ,
- Concentration of chlorophyll-a ,
- Sizes and population of phytoplankton ,
- Mass of phytoplankton ,
- Light intensity through waters ,
- Secchi depth value ,
- Primer productivity level ,
- Activity of P and N and ,
- Growth potential of algae .

(b) In the hypolimnion layer :

- Concentration of dissolved oxygen at the end of stagnation period ,
- Production of dissolved oxygen ,
- BOD5 concentration and ,
- Concentration of phosphorus and nitrogen .

3. LAKE İZNİK

3.1. Geographical Features

Lake İznik is located in the southern east part of Marmara region within the province of Bursa (Figure 3.1.1) . It has a surface area changeable between 303.34 km2 and 304.74 km2 according to water level in it whereas its average surface area is 304.30 km2 (Table 3.1.1) , (Figure 3.1.2) . Lake İznik is approximately 85 m high over sea level and It's mean depth is 40 meters whereas its deepest point is 70m (Mater,1988) . Minimum volume of the lake is 11.28 billions m3 but it has a mean volume of 12.12 billions cubic meters (Figure 3.1.3) (D.S.İ.,1984) .

Drainage area of lake İznik is 626 km2 , whereas its raining area is 936 km2 . Because lake İznik is surrounded by steep mountains , the plains around it are not large . The İznik plain has an area of 76 km2 and is on the east of the lake , the Orhangazi plain has an area of 91 km2 and is on the west of the lake and , the Gemlik plain which has an area of 6 km2 and is on the southern part of the lake . Lake İznik and its drainage area have been formed by a geological depression which happened between the southern part of İznik plain crossing from the south of Orhangazi plain to reach the southern part of Gemlik plain (Mater,1988)

NO	DESCRIPTION
A	DSİ PUMP STATION
B	DSİ METHEOHYDROGICAL ST.
C	KÖYHİZMETLERİ PUMP ST.
D	D. METEOROLOJİ ST.
E	OUT LET
F	INDUSTRIAL PLANTS
G	PETROL ST.
H	SÜMERBANK PUMP ST.
I	DARKA TATİLKÖYÜ
J	DSİ KAMPI
İL	SAMPLE COLLECTION ST.

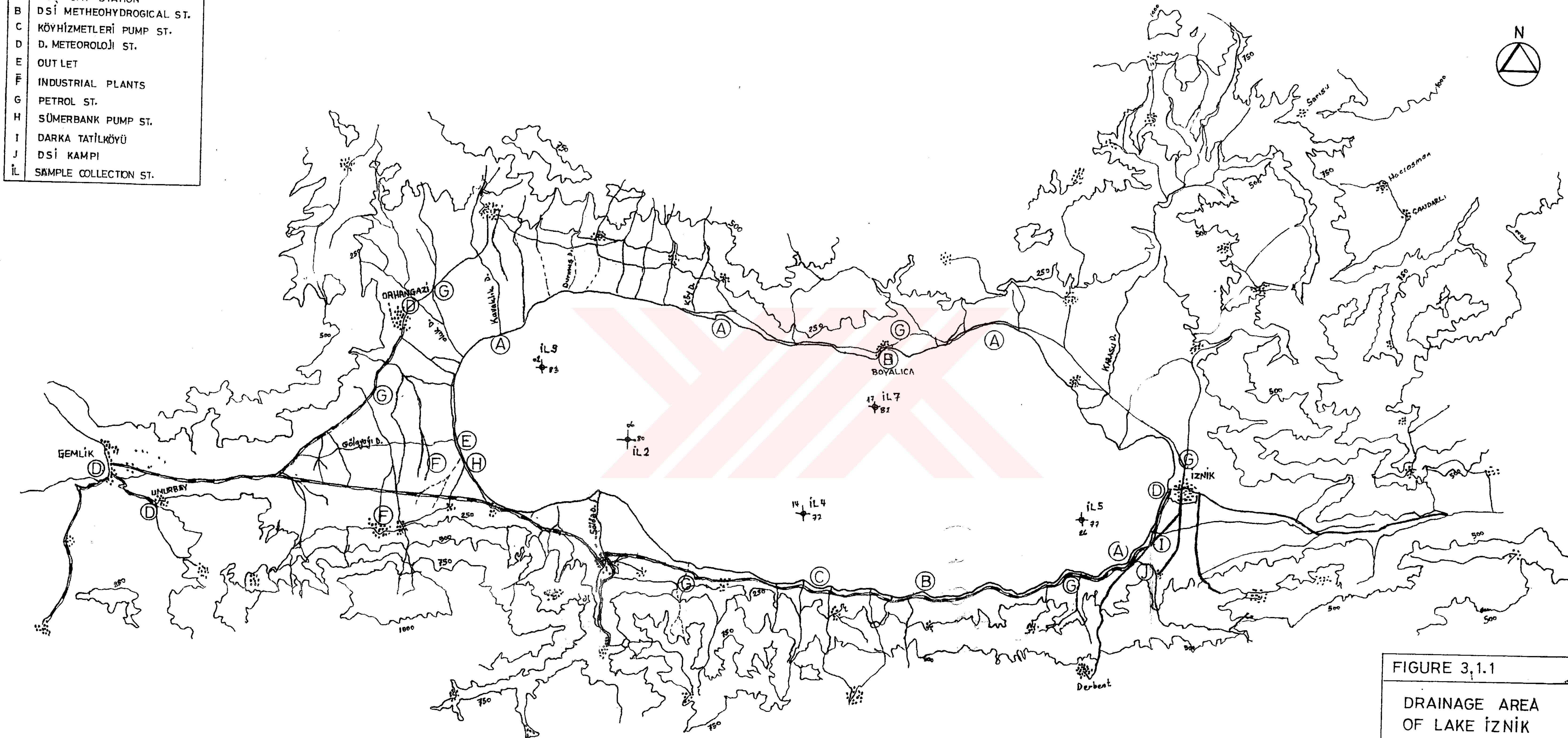


FIGURE 3.1.1

DRAINAGE AREA OF LAKE İZNİK

SCALE: 1/100 000

TABLE 3.1.1. Surface Area and Volume Values versus Lake İznik Water Level

LEVEL (m)	S.AREA E06(m2)	VOLUME E09(m3)
82.00	303.335	11.280
82.50	303.535	11.415
83.00	303.735	11.550
83.50	303.900	11.725
84.00	304.065	11.900
84.50	304.230	12.080
85.00	304.396	12.260
85.50	304.568	12.365
86.00	304.740	12.510

(Source : D.S.İ.1.Bölge Müdür. Bursa)

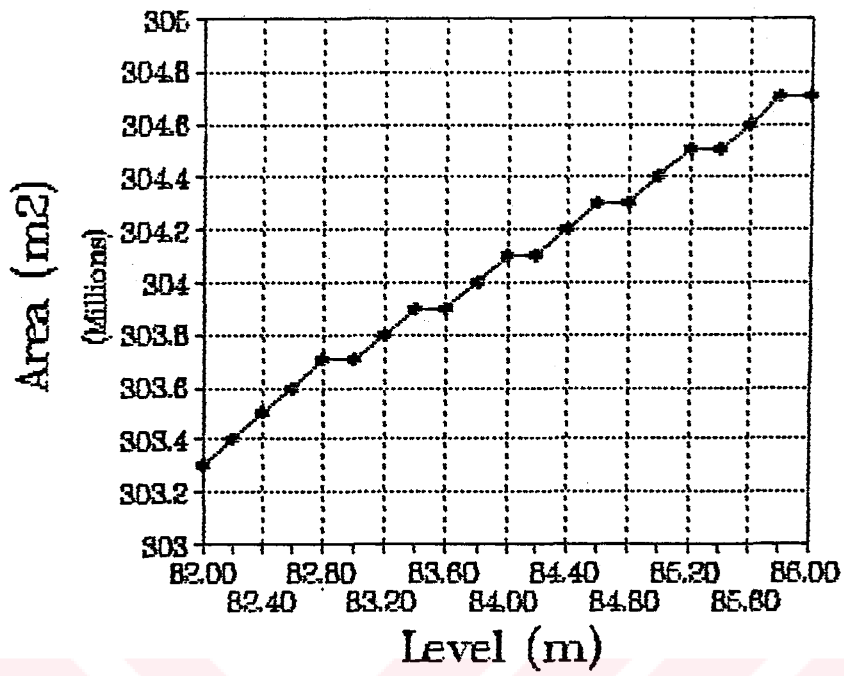


FIGURE 3.1.2. Surface area versus water level in lake İznik

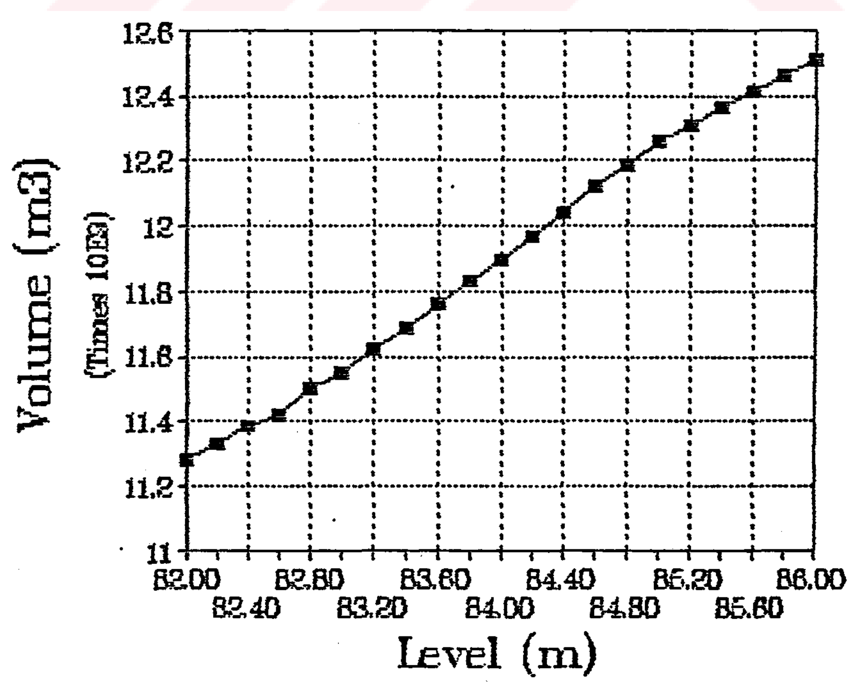


FIGURE 3.1.3. Lake volume versus water level in lake İznik

Beginning from Gemlik gulf and continuing to the east with the cavity of lake İznik there are Samanlı mountains (800 m) on the north whereas there are Katırlı mountains (1250 m) on the south . Lake İznik basin is characterized by existence of vegetation , and soils of deciduous forests but some parts of the lake side are marshes as well as some rural areas (Mater,1988) .

Most parts of west , north and north east areas have been used for agricultural purposes whereas southern and southwestern regions are steep slopes .

3.2. Climatic and Economical Features

3.2.1. The Climate of the Region :

Lake İznik and its environment is under the same climatic conditions as Marmara region . Winters are warm and rainy whereas summers are hot and dry , but because of the mountains circling the region , the climate is more tepid . According to the personal communication with State Directory for Meteorology and D.S.İ.1st Region Directory in Bursa city, the average annual precipitation rates in the region is 558.3 mm, but this value increases to 700 -750 mm/year in the southern regions of the drainage basin (Table 3.2.1),

TABLE 3.2.1 Average Monthly Rain Rates Over The Region (mm) .

	Jan.	Feb.	Mar.	Apr.	May	Jun	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
D.Gazi	98.4	66.4	63.9	49.5	53.6	26.1	30.1	17.5	32.3	71.6	96.4	122.1	734.4
İznik	70.8	39.3	51.9	33.8	37.5	23.0	15.2	9.9	24.4	38.9	49.8	78.9	474.6
Boyalıca	65.3	42.5	45.4	48.8	36.8	27.3	18.6	13.6	27.5	51.5	60.0	79.5	517.8
Göllüce	85.7	36.0	42.4	46.0	41.5	36.4	23.3	7.7	22.5	60.9	92.3	66.2	503.9
Umurbey	88.2	53.2	58.6	47.9	49.8	27.3	25.8	18.9	30.9	68.7	89.3	106.7	560.9

(Source : D.S.İ. 1.Bölge Müdürlüğü and D.Meteoroloji Müdürlüğü)

TABLE 3.2.2 Average Monthly Evaporation Rates From The Region (mm) .

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
D.Gazi	30.8	35.8	50.4	97.8	120.3	249.2	278.5	200.9	153.9	98.1	56.7	23.7	1396.1
İznik	22.8	27.8	45.7	75.1	166.8	189.7	259.4	235.8	157.9	101.5	32.8	27.6	1342.9
Boyalıca	31.2	37.7	62.5	120.1	84.3	250.3	308.1	291.3	201.7	111.0	55.6	39.9	1697.6
Göllüce	24.7	28.5	49.5	84.8	132.6	178.7	203.7	196.3	138.2	75.4	37.3	27.3	1176.9
Umurbey	28.9	26.8	48.9	110.5	115.8	220.6	298.2	229.7	186.9	92.7	45.8	22.9	1427.7

(Source : D.S.İ. 1.Bölge Müdürlüğü and D.Meteoroloji Müdürlüğü)

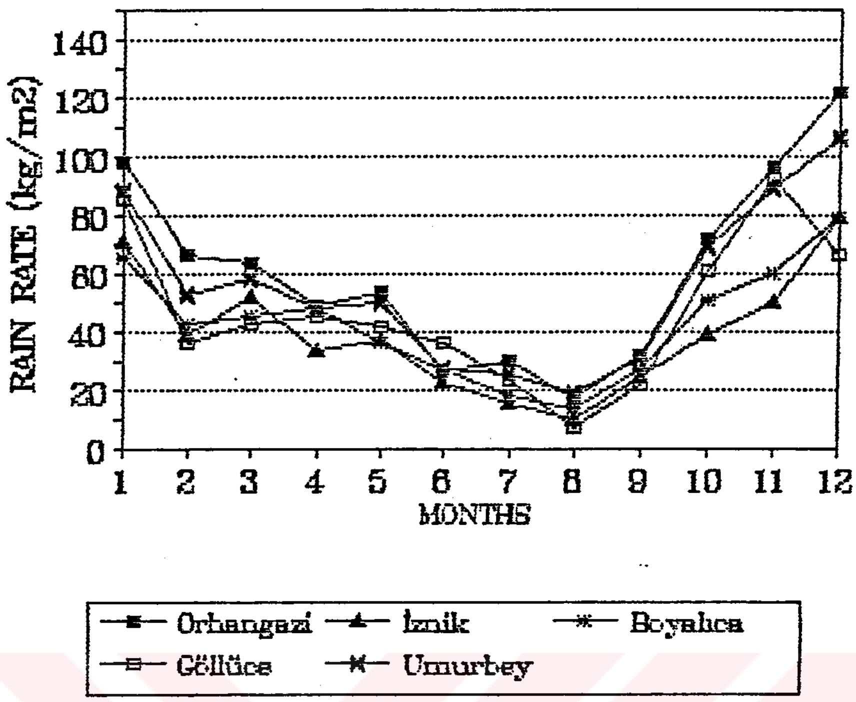


FIGURE 3.2.1. Average monthly rain rates for lake İznik region

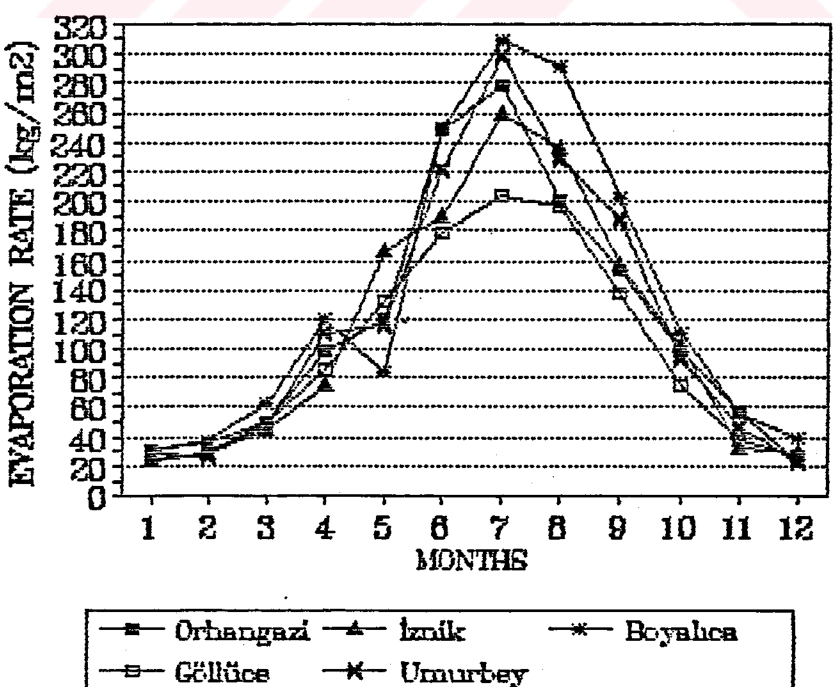


FIGURE 3.2.2. Average monthly evaporation rates for lake İznik region

(Figures (3.2.1)) . Average annual temperature of the region is 14.7 C . The highest value occurs in July whereas the lowest value occurs in January . The average annual evaporation rate in the basin is 1449 mm (Table 3.2.2), (Figure 3.2.2) .

3.2.2. Economical State of the Region :

The economy of the region depends on agriculture . Grape , tobacco , olive , and early vegetables are some of the widely produced agro-products of the region . 13290 hectares are irrigated by the irrigation canals which were built by DSİ . Orhangazi and Gemlik districts are industrially more developed than İznik district . Asil Çelik , Döktaş , Ormo iplik , Orhangazi tuğla industries , Angora tekstil industry and Sümerbank suniipek are the main factories in the lake region . On the other hand , some summer houses are located on the lake side such as Darka holiday village and Gölköy holiday apartments (Figure 3.1.1).

3.3. Streams and Springs Feeding Lake İznik

3.3.1. Streams Feeding the Lake :

There are more than thirty streams and springs feeding lake İznik but generally , they flow during the rain seasons (Mater,1988). In the most rainy months -January , February and March -these streams have their maximum flow rates whereas in summer they are wholly or mostly dry .

The main streams are :

1 - Karadere : it collects the waters from the northeastern regions of the lake having 219.7 km2 area . There is a DSİ station of number 2-31 to measure its flow which has an average annual rate of 2.172 m3/sec

2 - Kırandere : it collects the waters of the southeastern regions having an area of 147 km2 . Its flow rate is not known because no flow measuring station exists .

3 - Kocadere (Sölözdere) : it collects the waters of the south western regions having an area of 76.9 km2 . Its average annual flow is 0.805 m3/sec . DSİ station code is 2-30 .

4 - Kurudere : is on the north of the lake and it has a flow rate of 0.354 m3/sec . It has a drainage area of 38.89 km2. DSİ station code is 2-31 .

5 - Olukdere (Orhangazi deresi) : it collects the waters of northwestern regions of Orhangazi plain which has an area of 74 km2 and has an annual average flow rate of 0.70 m3/sec. The station existing on it is belonging to EİE and its code is 213 .

6 - Nadır deresi : it collects the waters of northwestern regions of lake İznik . Its flow rate is 0.153 m3/sec .

Inflows and drainage areas of the main streams are given in Table (3.3.1) (D.S.İ. 1st Region Directory ,personal communication) .

3.3.2. Springs Feeding the Lake :

1 - Dereköy spring : its flow rate is 0.363 m3/sec .

2 - Gedelek spring : has a flow rate of about 0.067 m3/sec .

3 - Ilıpınar spring : has a flow rate of 0.067 m3/sec .

4 - Ilıcapınar spring : has a flow rate of 0.086 m3/sec . (D.S.İ. 1st Region Directory , personal communication).

TABLE 3.3.1. Average Annual Inflows and Drainage Areas of some of the Streams Feeding Lake İznik

STREAM NAME	Average annual Inflow	Drainage area
	* E06 m3	km2
Karadere	68.50	219.7
Kocadere	25.39	76.9
Kurudere	11.16	38.89
Olukdere	22.08	74.0
Total	127.13 E06 m3	409.49 km2

(Source:D.S.İ. 1st Region Directory)

4. WATER BUDGET AND NUTRIENT LOADINGS ON LAKE İZNİK

4.1. Water Budget of Lake İznik

4.1.1. Introduction :

The entry of water to a lake may be either as direct precipitation, direct inflow such as rivers, or as runoff . Runoff may be further classified as :

(a) Surface runoff which flows over the land surface and enters the lake directly or via drainage ditches or storm sewers ,

(b) Sub-surface runoff or that part of the precipitation which penetrates the upper soil horizons and flows into the lake above the groundwater table and ,

(c) Runoff which percolates through to the groundwater table and enters the lake as spring water or seepage .

The flow out of the lake may be either by direct discharges from the outlets and irrigation canals of the lake , by evaporation from the surface of the lake or , by indirect outflows such as underground discharges through groundwater table .

Water budgets of lakes are generally given by the equation :

$$Ic + Io + Ig + P + R - (E + Gs + Qc + W) = \Delta V \qquad (4.1.1)$$

in which :

Ic = direct inflow from streams and springs (m3/yr) ,

Io = runoff from land (m3/yr) ,

Ig = underground water runoff (m3/yr) ,

P = direct precipitation on lake surface (m3/yr) ,

R = indirect water return from irrigation (m3/yr) ,

E = direct evaporation from lake surface (m3/yr) ,

Gs = indirect outflow from lake (m3/yr) ,

Qc = outflow from lake outlet (m3/yr) ,

W = water used for irrigation and industrial purposes (m3/yr) and ,

ΔV = volume change (m3/yr)

4.1.2. Predicting Values Required for Water Budget of Lake İznik :

1 - Direct inflow from streams and springs : as given in Table (3.3.1) average annual flow rates of some of the streams are known . To estimate the average annual flow rates for the others , the following method is used :

a - Change the average annual flow rates to precipitation rate over the drainage area of the mentioned streams .

b - Multiply the rate found in (a) by the drainage areas of the other streams . i.e.

$$\text{Annual Average Inflow} = \frac{\text{total annual inflow}}{\text{total drainage area}} \qquad (4.1.2.)$$

$$===) \qquad AAI = \frac{127.13 \text{ E06 m3/yr}}{409.49 \text{ E06 m2}} = 0.310 \text{ m/yr} .$$

Drainage area of lake İznik = 626.0 km2

Drainage area of streams which have measured inflows = 409.49 km2

Drainage area of streams which have not measured inflows = 216.51 km2

Total annual inflows of streams which have not measured inflows = 216.51 E06 m2 * 0.310 m/yr = 67.118 E06 m3/yr .

Total inflow from all streams and springs :

$$Ic + Io = 194.25 \text{ E06 m3/yr} .$$

2 - Underground water runoff : measurements of this part of the water budget is very complex . The best estimation of underground water runoff is to equate it with the indirect

flow from the lake İznik . i.e.

$$Ig = Gs$$

3 - Direct precipitation on lake surface : as shown in Table (3.2.1) , average monthly precipitation rates for İznik , Orhangazi , Umurbey , Göllüce and Boyalıca meteorological stations for long periods are given (State Directory for Meteorology and D.S.İ.1st Region Directory,Bursa city) . The effective real average annual precipitation rates for the lake is found by using Thiessen method ;

$$\text{Average P} = \frac{\text{Product}}{A} \qquad (4.1.3)$$

Where :

Product = average annual precipitation rate multiplied by the area which the station represents (Figure (4.1.1))

TABLE 4.1.1. Precipitation Products

Station Name	Thiessen Area (km2)	Precipitation (mm)	Product (km2*mm)
Orhangazi	52.80	734.4	38776.32
İznik	54.80	474.6	26008.08
Boyalıca	109.55	517.8	56724.99
Göllüce	66.95	503.9	33736.11
Umurbey	20.20	560.9	11330.18

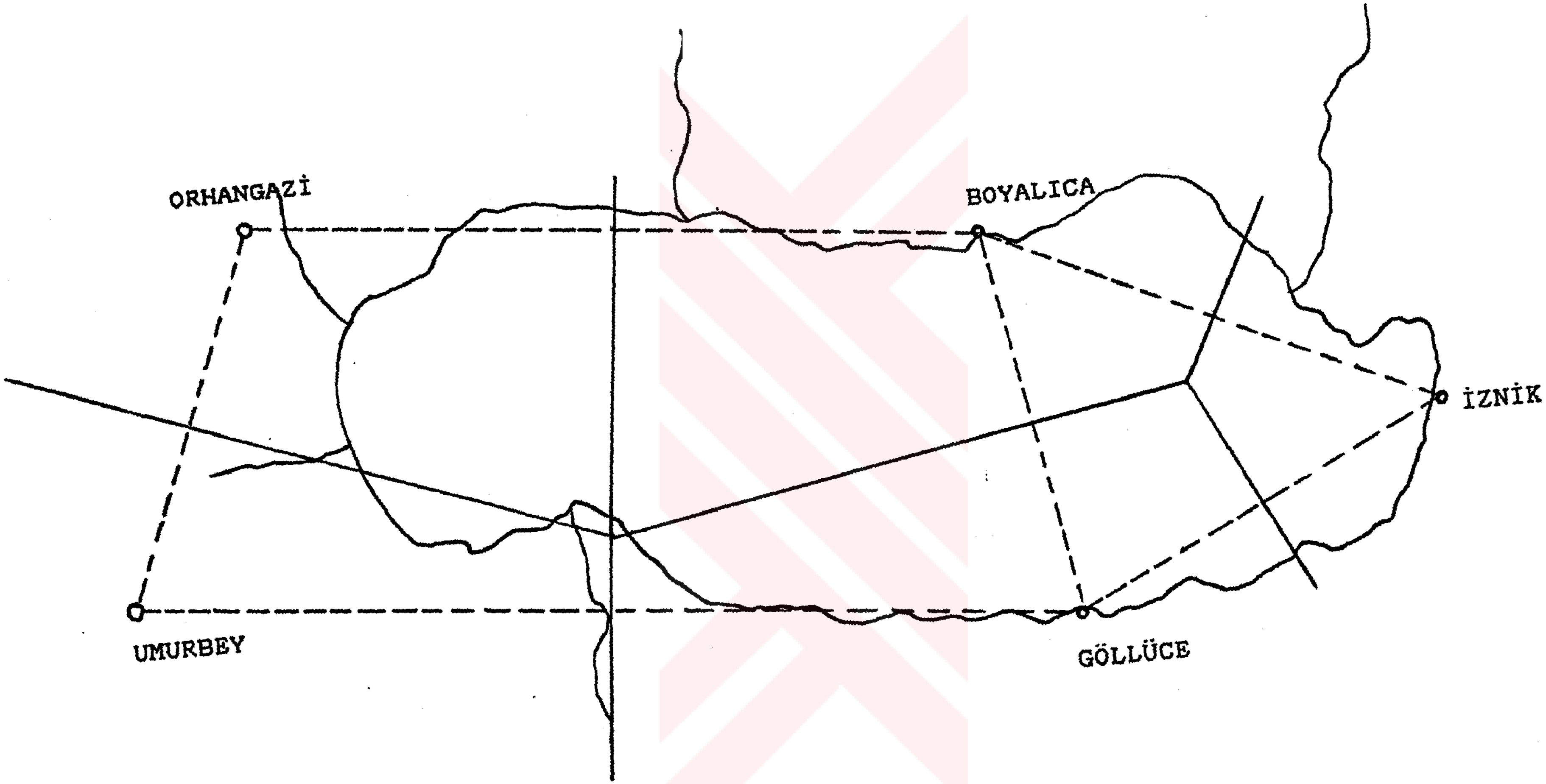


FIGURE 4.1.1. Thiessen areas

i.e.

$$\text{Average } P = \frac{166575.60}{304.30} = 547.41 \text{ mm}$$

Average annual water load due to precipitation to lake İznik :

P = 304.30 E06 * 0.5474 = 166.58 E06 m3 / yr .

4 - Indirect water return from irrigation : this load is the excess of water pumped to irrigation canals and when not used return to the lake . This load may be estimated as a percentage of the water used for irrigation purposes . An accurate value for this percentage may not known but a factor of 10 per cent of the annual irrigation water volume must be a satisfactory estimate (D.S.İ.1st Region Directory) .

R = 37.17 E06 m3/yr * 0.10 = 3.72 E06 m3/yr

5 - Direct evaporation from lake surface : the average monthly evaporation rate from the evaporation pans in Orhangazi , İznik , Boyalıca , Göllüce and Umurbey meteorological stations are given in Table (3.2.2) (State Directory for Meteorology and D.S.İ.1st Region Directory) . The annual average pan coefficient for lake İznik is assumed by hydraulic department of DSİ to be equal to 0.75 .

By using Thiessen method for predicting the real average evaporation load ;

$$\text{Average E} = \frac{\text{Product}}{\text{Area}} \qquad (4.1.4)$$

TABLE 4.1.2 Evaporation Products

Station Name	Thiessen Area (km2)	Evaporation (mm)	Product (km2*mm)
Orhangazi	52.80	1396.1	73714.1
İznik	54.80	1342.9	73590.92
Boyalıca	109.55	1697.6	185972.08
Göllüce	66.95	1176.9	78793.46
Umurbey	20.20	1427.7	28839.54

Therefore ;

$$\text{Average E} = \frac{440910.10}{304.30} = 1448.93 \text{ mm}$$

Average Annual Evaporation Rate from surface of lake İznik is :

$$\text{AER} = 1449 * 0.75 = 1086.75 \text{ mm}$$

therefore ,

$$E = 304.30 \text{ E06 m2} * 1.087 \text{ m/yr} = 330.77 \text{ E06 m3/yr} .$$

6 - Outflow from lake outlet : for lake İznik there is only one controlled outlet to Gölayağı stream and then to Karsak stream and finally to Gemlik bay . This outlet is used only to empty the excess water collected in the lake after heavy rainy days . Because of the reason that this outlet is mostly unused (not opened since 1986 (D.S.İ.)), no significant outflow is known ..

7 - Water used for irrigation and industrial purposes : there are four DSİ pump stations and one Köy hizmetleri pump station withdrawing water from the lake between May and November for irrigation purposes . The annual average irrigation water supplied by DSİ to farms by canals is 35.67 millions cubic meters . The annual average irrigation water supplied by Köy hizmetleri to Mustafalı village by pipes is 0.5 millions cubic meters . There is one pump station for Sümerbank suniipek fabrikası withdrawing water all over the year for industrial purposes . The annual average industrial water withdrawn by Sümerbank is one millions cubic meters . On the other hand , the other factories which are mentioned before are not withdrawing water from the lake and they are not polluting the lake because they are discharging their waste water to Karsak stream .

$$W = 35.67\ E06 + 0.5\ E06 + 1.0\ E06 = 37.17\ E06\ m3/yr\ .$$

By substituting the values obtained above into (4.1.1.)

$$\Delta V = (194.25+166.58+3.72)*E06-(330.77+37.17)*E06$$

$$\Delta V = -3.39 \text{ E06 m3 / yr} .$$

The reasons after the result obtained for the decrement in the volume of lake İznik may be explained as one or more of the following :

(a) because of underestimating of inflowing loads .
(b) because of overestimating of outflowing loads .

4.2. Calculating Nutrient Loads on Lake İznik

An increase in the load of phosphorus and nitrogen in a lake may not lead to a substantial change in the nutrient concentration in the lake water but signs of gradual eutrophication may become evident from chlorophyll-a analyses and gradual sliming of stones near the lake banks .

Excessive eutrophication is one of the most significant causes of water quality deterioration in lakes and reservoirs in many countries in the world . In recent years , a number of investigators have developed models for quantitatively relating nutrient loads to the eutrophication response of a water body resulting from these loads . The effective use of these quantitative nutrient load-eutrophication response models depends not only on the basic structure and predictive capability of the model used , but also on the accuracy of the nutrient loads estimates used as input to the models .

The major inputs to a waterbody generally are waste waters discharges , land runoff , the atmosphere (dry fallout and precipitation) and ground water. The inputs from several of these sources , especially the non-point sources , are usually difficult to quantify reliably . The accuracy of the estimation of the nutrient loads to a water body is dependent upon a number of factors , including the frequency and duration of sampling of the point and non-point sources , analytical methodologies used , percent of tributaries sampled , etc .

The use of nutrient export coefficients for estimating phosphorus and nitrogen loads is based on the knowledge that , for a given climatological regime , specific types of land uses will yield or export characteristic quantities of these nutrients to a downstream waterbody over an annual cycle. This nutrient export is associated primarily with land runoff resulting from precipitation in the watershed and is usually expressed on an areal basis .

Knowing the area of land in a watershed devoted to specific uses and the quantities of nutrients exported per unit area of these uses , it is possible to estimate the annual total phosphorus and nitrogen loads to a waterbody from non-point sources .

In the preparation of this study most of the time data required were available and satisfactory . Estimations were made based on general literature review .

1 - Loading from agricultural area : Excessive quantities of commercial fertilizers are applied annually to agricultural lands throughout the region . The types and quantities of fertilizers used in the drainage area of the lake in year 1990 which were obtained from Directory of Agriculture in Bursa city and the percentages of phosphorus and nitrogen which they contain are given in Table (4.2.1) .

High percentage of phosphorus and nitrogen in the fertilizers are utilized by plants whereas a notable mass of them is held by soil and a remarkable amount is washed from soil by water and finally reach the lake . The fractions of phosphorus and nitrogen which are washed by water depends mainly on the amount of fertilizers used ,the type of plants, amount of water , slope of the land and , type of the soil . According to the amount of fertilizers used , the amount of nutrient washed by water is a characteristic value , these are given in Table (4.2.2) . Ten per cent of this amount is assumed to be reaching the lake (Uttormak,Chapin & Green,1974).

Accordingly , the load of phosphorus and nitrogen which entered lake İznik in 1990 due to fertilizers were estimated to be :

Mp(E) = 624.4 kg P/yr .

Mn(E) = 29.8 E03 kg N/yr .

2 - Loading from farm animal sources : the kinds and amounts of farm animals in the drainage area of lake İznik for the year 1990 which were obtained from Directory of Agriculture in Bursa city and given in Table (4.2.3) . The load of farm animals is estimated by Uttormak and given in Table (4.2.4) . By assuming that ten per cent of the load is reaching the lake waters (Uttormak,Chapin & Green,1974), the amount of the nutrients entering the lake may be found .

The total amount of phosphorus produced by farm animals in 1990 is calculated to be :

a) due to cows :

(5000 + 5150) * 25 kg/yr = 253.75 E03 kg P/yr

TABLE 4.2.1 Amount and Types of Fertilizers Used in İznik and Orhangazi Districts (Year 1990) .

TYPE	İZNİK Ton/Y	O.GAZİ Ton/Y	TOTAL Ton/Y	T.P %	T.N %
Amoniumsulphate	460	1640	2100	-	21
Amoniumnitrate	1850	1900	3750	-	26
Manur	310	915	1225	-	46
Triplesupperphos	73.2	250	323.2	47	-
Diamoniumphospha	488	1095	1583	46	18
20.20.20	330	235	565	20	20
15.15.15	2300	2055	4355	15	15

(Source : Bursa Tarım Müdürlüğü , Destekleme Şube Müdür.)

TABLE 4.2.2 Nutrient Characteristic Values due to the Amount of Fertilizers Used .

	P (kg/ha-yr)	N (kg/ha-yr)
Amount of fertilizers used	29	56
Nutrient characteristic value	0.11	5.5

(Source : Uttormak,Chapin and Green,1974)

TABLE 4.2.3 Amount and Kinds of Farm Animals in İznik and Orhangazi Districts (Year 1990) .

TYPE	İZNİK	ORHANGAZİ
COWS	5000	5150
SHEEP	12500	8150
POULTRY	36000	31000

(Source : Bursa Tarım Müdürlüğü ,Hayvan sağlığı şube müdürlüğü) .

TABLE 4.2.4 Amount of Nutrients Produced by Farm Animals .

TYPE	TP(Kg/yr)	N(Kg/yr)
COWS	25	38
SHEEP	2	11
POULTRY	0.2	0.5

(Source : Uttormak,Chapin and Green,1974) b) due to sheep :

(12500 + 8150) * 2 kg/yr = 41.30 E03 kg P/yr .

c) due to poultry :

(36000 + 31000) * 0.2 kg/yr = 13.40 E03 kg P/yr .

i.e. the total amount of P produced by farm animals and reach the lake is :

$$Mp(A) = 308.5 E03 kg/yr * 0.1 = 30.85 E03 kg P /yr .$$

And the total amount of nitrogen produced by farm animals in 1990 and assumed to reach the lake is :

$$Mn(A) = 64.64 E03 kg/yr .$$

3 - Loading from sewages : the distribution of population of the region as published by State Statistical Institute for the year 1990 is given in Table (4.2.5) . Phosphorus and nitrogen loading from human wastes are assumed as 1.5 kg P and 4.4kg per capita per year (Uttormak,Chapin & Green,1974).

Despite the fact that the sewage of Orhangazi city is given to Karsak stream ,thus the pollution of 31889 person's products are not polluting the lake directly , no sewage system exists in İznik city and the other villages in the region which are still using septic tanks .

There are some summer houses on the lake sides such as Darka holiday village (350 houses) , Gölköy holiday departments and DSİ holiday camp . These summer villages have their own waste water treatment plants and are discharging the treated water to dry streams . All the factories near the lake but Marmara birlik which discharge the treated water to the lake , are discharging their treated waste water to Karsak stream to reach Gemlik bay finally .

In calculating the load of P and N from human resource , ten per cent of the load of villages is assumed to reach the lake (Uttormak,Chapin & Green,1974) whereas all the loads of İznik city and Boyalıca village are assumed to reach the lake because they are on the lake side .

The phosphorus loading produced by man for İznik city and Boyalıca village is :

(17232 + 2227) * 1.5 kg/yr = 29.19 E03 kg P /yr

The phosphorus loading produced by man for villages is :

(24537 + 22483) * 1.5 kg/yr = 70.53 E03 kg P /yr

The total load of phosphorus reaching the lake is :

Mp(S)= 29.19 E03 + (70.53 E03 * 0.1) = 36.24 E03 kg P /yr .

And for nitrogen ;

$$Mn(S) = 85.6\ E03 + (\ 206.9\ E03 * 0.1\ ) = 106.29\ E03\ kg\ N\ /yr\ .$$

4 - Loading from forests : the area of forests in the region is 24.036E07 m2 (Table 4.2.6). As estimated by Rast and Lee (1983), the export coefficients of phosphorus and nitrogen for forested areas are 0.01 g P/ m2-yr and 0.5 g N/ m2-yr respectively .

i.e. $$Mp(F) = A(F) * 0.01 = 24.036\ E07 * 0.01$$

$$Mp(F) = 2.4\ E03\ kg\ P/yr\ .$$

$$Mn(F) = A(F) * 0.5 = 24.036\ E07 * 0.5$$

$$Mn(F) = 120.2\ E03\ kg\ N/yr\ .$$

5 - Aerial loading : the area of the lake surface is 304.3 E06 m2 . The aerial export coefficient is 0.025 for TP and 2.4 for N (Rast and Lee, 1983) .

$$Mp(I) = A(S) * 0.025 = 304.30\ E06 * 0.025$$

$$Mp(I) = 7.61\ E03\ kg\ P/yr$$

and ,

$$Mn(I) = 730.3\ E03\ kg\ N/yr$$

TABLE 4.2.5 Population of İznik and Orhangazi Districts

(Year 1990)

	POPULATION
İznik city	17232
İznik villages	24710
Orhangazi city	31889
O.gazi villages	24537

(Source : Devlet İstatistik Enstitüsü)

TABLE 4.2.6 Area and Types of Land in İznik and Orhangazi Districts .

TYPE	İZNİK km2	O.GAZİ km2	TOTAL km2
Agricultural land	274.88	138.63	413.51
Forests	190.00	50.36	240.36
Heathly land	141.14	100.74	241.88
Pasture land	54.50	7.50	62.00
Inhabited area	5.73	4.01	9.74
Not suitable for Agr	4.58	11.02	15.60
Streams	1.00	0.50	1.50
Lake	237.17	65.00	302.17

(Source : Bursa Tarım Müdürlüğü , İstatistik ve projeler şube müdürlüğü) .

The total annual loading of total phosphorus on lake İznik is

$$Mp = 624.40 + 30.85\ E03 + 36.24\ E03 + 2.4\ E03 + 7.6\ E03$$

$$Mp = 77.71\ E03\ kg\ P\ /\ yr\ .$$

The total annual loading of total nitrogen on lake İznik is

$$Mn = 29.8\ E03 + 64.64\ E03 + 106.29\ E03 + 120.2\ E03 + 730.3\ E03$$

$$Mn = 1.09\ E06\ kg\ N\ /\ yr\ .$$

The ratio of total loading of nitrogen to the total loading of phosphorus is found to be equal to 14.0 , which is higher than seven which emphasize that phosphorus is the limiting element in lake İznik .

4.3. Comparison Between Permitted Load and Existent Load

The permitted areal loading of phosphorus on lakes is given by the following equation (Vollenweider,1971)

$$Lc(P) = 100 + (10 (Z / Rw)) \text{ (mg P /m2-yr)} \quad (4.3.1)$$

$$= 100 + (10 (40/326))$$

$$Lc(P) = 101.2 \text{ mg P / m2-yr}$$

Whereas $L(P) = Mp / A = 77.71 \text{ E09(mg/yr)} / 304.30 \text{ E06 (m2)}$

$$= 255 \text{ mg P / m2-yr}$$

The areal loading of phosphorus on lake İznik exceeds the permitted loading by more than two times which will affect the concentration of phosphorus in the lake water and will result in accelerating the eutrophication process in lake İznik .

5. INVESTIGATION OF THE TROPHIC STATE OF LAKE İZNİK

5.1. Physical and Chemical Parameters

5.1.1. Introduction :

In order to have a sufficient study about lakes , the critical parameters must be controlled for a long period of time . For this reason , the measurements which were performed by the 1st Region Directory of D.S.İ. in lake İznik , although they are not adequate enough, were used in this study . The results of the measurements are given in Appendix B . On the other hand , as done by Soyupak,S.,et al (1993) , the arithmetic averages of the data were calculated based on the dates , sample collection points , and the water levels in order to observe the trend of the parameters and are given in Table (5.1.1) .

5.1.2. Temperature :

Even water bodies warm and cool very slowly , water surface temperatures change instantly due to the changes in the air temperatures . In spring , when air temperatures begin to rise , the temperatures of the water surface begin to rise accordingly but temperature of deeper parts of the

TABLE 5.1.1. Some Critical Parameters of Lake Iznik .

DATE	SS mg/l	PH	NH3-N mg/l	NO2-N mg/l	NO3-N mg/l	Σ N mg/l	D-PO4 mg/l	TP mg/l	CHL-A mg/m3	N/P
22/09/86	5.9	-	0.246	0.0033	0.126	0.3753	0.0081	-	4.960	-
20/11/86	38.7	9.06	0.211	0.0031	0.238	0.4521	0.0133	-	1.233	-
09/06/87	5.1	8.67	0.221	0.0021	0.094	0.3171	0.0150	0.027	2.998	11.7
30/09/87	27.3	-	0.289	0.0021	0.239	0.5301	0.0128	0.030	4.633	17.7
26/10/87	24.3	9.00	0.290	0.0000	0.200	0.4900	0.0123	0.039	5.949	12.6
04/05/88	20.0	8.47	0.208	0.0034	0.171	0.3824	0.0128	0.021	1.207	18.2
07/07/88	-	8.72	0.064	0.0037	0.165	0.2327	0.0018	0.009	1.860	25.8
20/09/88	-	8.73	0.060	0.0032	0.109	0.1722	0.0147	0.020	0.750	8.6
24/04/89	-	8.60	0.038	0.0092	0.179	0.2262	0.0028	0.076	9.960	3.0
20/12/89	25.1	8.87	0.067	0.0031	0.159	0.2291	0.0123	0.029	1.310	7.9
30/05/90	39.8	8.51	0.461	0.0017	0.130	0.5927	0.0145	0.026	3.890	22.8
16/07/92	54.1	-	0.029	0.0032	0.318	0.3502	0.0158	0.058	3.913	6.0
09/09/93a	-	-	0.551	0.0098	0.404	0.9684	0.0112	0.087	17.030	11.1

(Source : D.S.İ. 1. Bölge Müdürlüğü , Bursa)
(a : Samples collected in this research and measured by D.S.İ. 1.Bölge Müdür.)

water body does not rise at the same rate . In fall , temperatures begin to fall down and accordingly temperatures of water begin to fall down too but at a slightly slower rate .

Water temperatures for different dates and water depths of lake İznik between years 1986 - 1990 were measured by D.S.İ. The data collected from D.S.İ have been summarized and given in Table (5.1.2) .

In Figure (5.1.1) temperatures of water due to two different dates versus water depth for station İL5 in lake İznik are shown . Important changes in water temperature with water depths are noticed in the summer period which emphasize the presence of thermocline whereas in winter no such case is noticed .

5.1.3. Dissolved oxygen :

The rate of dissolving of oxygen in water has a direct relationship with the temperature of water . The distribution of oxygen in water is the result of Eddy diffusion . In the epilimnion layer oxygen is found as a result of the atmospherical interaction and photosynthesis process .

In summer , as a result of thermocline which prevent full mixing of water body , dissolved oxygen in the hypolimnion layer does not exist in the same concentration as in the epilimnion .

In eutrophic lakes , dissolved oxygen concentration in summer may exceed the saturation value because of the excessive production of algae existing which results in excessive release of oxygen due to photosynthesis process.

Dissolved oxygen concentrations for different water depths for years 1986 -1990 were measured by D.S.İ. and are given in Appendix B , but those for station İL5 are given in Tables (5.1.3) and (5.1.5) . In Table (5.1.4) solubility values of oxygen in water are given .

Figure (5.1.2) shows dissolved oxygen concentrations and temperature of water for station İL5 with respect to depth . The two diagrams agree with each other which explain the relation between dissolved oxygen concentration and temperature in lakes .

Figure (5.1.3) shows the concentration of dissolved oxygen in two different dates for station İL5 with respect to depth of water. The increment of oxygen concentration between 5 - 20 m depth in summer may be explained as a result of the excessive production of algae in the thermocline layer

TABLE 5.1.2 Water Temperatures (Oc) versus Depth ,(Station : İL 5) .

Depth (m)	22/09/86	20/11/86	11/06/87	05/05/88	07/07/88	20/09/88	24/04/89	20/12/89	30/05/90
0.5	23.0	13.6	23.2	9.9	28.4	23.1	17.9	9.9	21.6
2.0	23.0	13.6	22.6	10.1	27.8	23.1	17.0	9.6	21.3
4.0	22.8	13.6	19.5	10.1	26.2	22.9	16.5	9.5	21.0
6.0	22.7	13.6	17.5	10.3	25.7	22.8	16.2	9.4	20.8
8.0	22.7	13.6	16.0	10.3	22.4	22.8	14.3	9.4	20.6
10.0	17.7	13.6	16.0	10.6	18.5	22.8	13.9	9.4	19.2
15.0	12.6	13.6	16.0	10.4	12.8	21.9	10.4	9.3	13.7
20.0	9.6	9.3	16.0	9.6	11.0	11.9	8.5	9.2	10.6
25.0	8.6	8.4	16.0	9.8	9.8	10.1	8.1	9.2	9.4
30.0	8.2	8.1	16.0		9.1	9.3	7.9	9.1	8.4
35.0	8.0	8.0	16.0		8.7	8.8	7.9	9.1	7.7
40.0	8.2	8.0			8.4				
45.0		8.0			8.4				

(Source : D.S.İ. 1. Bölge Müdürlüğü, Bursa)

TABLE 5.1.3. Dissolved Oxygen Saturations (%) versus Lake Depth , (Station : İL 5) .

Depth(m)	22/09/86	19/11/86	09/06/87	05/05/88	07/07/88	20/09/88	24/04/89	20/12/89	30/05/90
0.5	113.9	93.9	111.1	115.1	139.4	102.9	139.9	107.8	152.2
2.0	113.5	93.5	107.7	112.0	138.6	104.0	141.5	103.7	150.2
4.0	113.0	93.5	103.8	111.8	135.7	103.7	137.3	101.0	149.5
6.0	112.1	92.9	99.5	110.3	135.9	102.2	132.7	95.9	150.0
8.0	110.5	93.2	92.8	109.3	172.1	101.5	127.2	94.7	148.7
10.0	105.7	93.1	88.3	106.0	184.4	101.7	123.2	92.8	150.4
15.0	58.6	92.9	78.0	101.8	130.6	100.3	112.4	88.8	131.0
20.0	56.9	44.9	68.2	101.5	103.6	87.0	101.4	86.5	112.4
25.0	57.5	48.4	63.9		104.1	58.9	97.0	85.9	102.7
30.0	66.8	56.0	60.4		103.9	63.0	92.2	83.7	99.3
35.0	32.1	13.1			102.0	56.8	86.9	79.5	84.6
40.0	0.3	9.3			102.0			78.3	
45.0		7.7			64.8				

(Source : D.S.İ. 1. Bölge Müdürlüğü , Bursa)

TABLE 5.1.4 Solubility of Oxygen in Water

Temperature (Oc)	D.O. (mg/l)	Temperature (Oc)	D.O. (mg/l)
0	14.6	20	9.2
2	13.8	22	8.8
4	13.1	24	8.5
6	12.5	26	8.2
8	11.9	28	7.9
10	11.3	30	7.6
12	10.8	32	7.4
14	10.4	34	7.2
16	10.0	36	7.0
18	9.5	38	6.8

TABLE 5.1.5 Conversion of D.O.% to D.O.(mg/l) .

Date	07/07/1988			20/12/1989		
Depth (m)	Temp. (Oc)	D.O. %	D.O. (mg/l)	Temp. (Oc)	D.O. %	D.O. (mg/l)
0.5	28.4	139.4	11.0	9.7	107.8	12.2
2.0	27.8	138.6	11.1	9.6	103.7	11.7
4.0	26.2	135.7	11.1	9.5	101.0	11.6
6.0	25.7	135.9	11.2	9.4	95.9	10.9
8.0	22.4	172.1	15.1	9.4	94.7	10.8
10.0	18.5	184.4	17.4	9.4	92.8	10.6
15.0	12.8	130.6	13.8	9.3	88.8	10.3
20.0	11.0	103.6	11.4	9.2	86.5	10.0
25.0	9.8	104.1	11.8	9.2	85.9	9.9
30.0	9.1	103.9	11.9	9.1	83.7	9.7
35.0	8.7	102.0	11.7	9.1	79.5	9.2
40.0	8.4	102.0	12.1		78.3	
45.0	8.4	64.8	7.7			

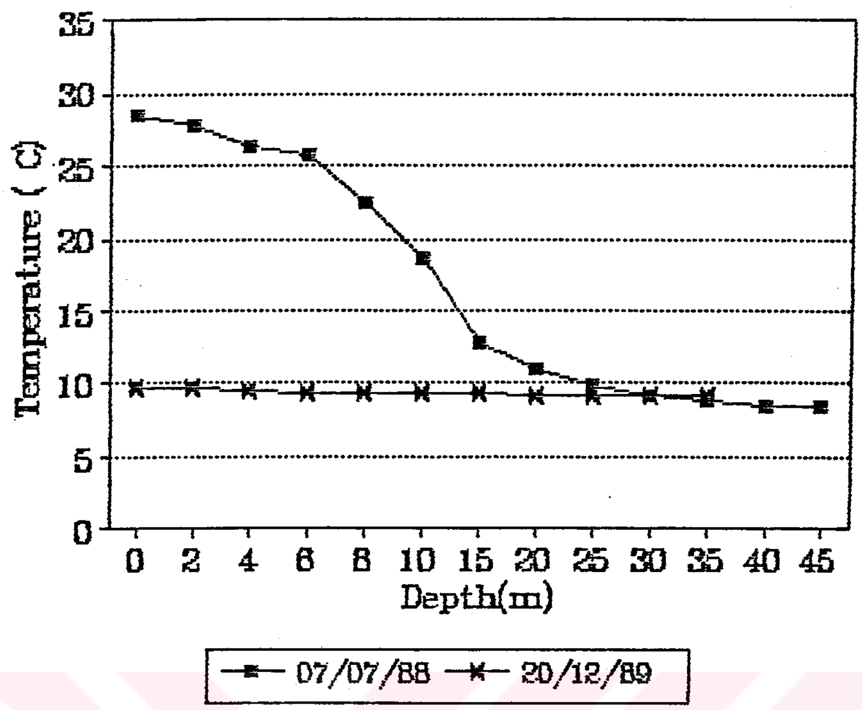


FIGURE 5.1.1. Temperature of water versus depth

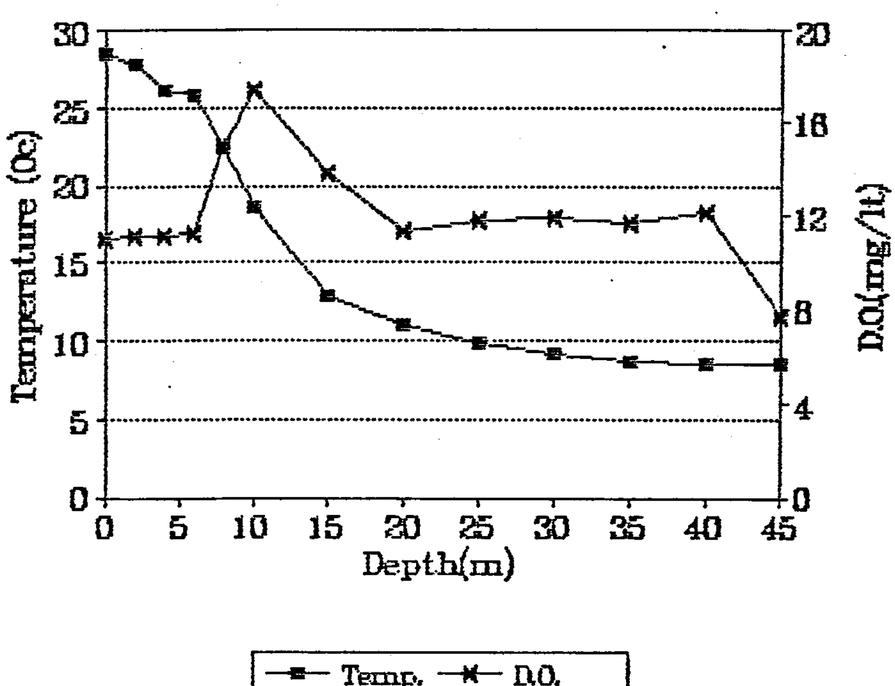


FIGURE 5.1.2. Temperature and D.O. con. versus depth (date 07/07/1988)

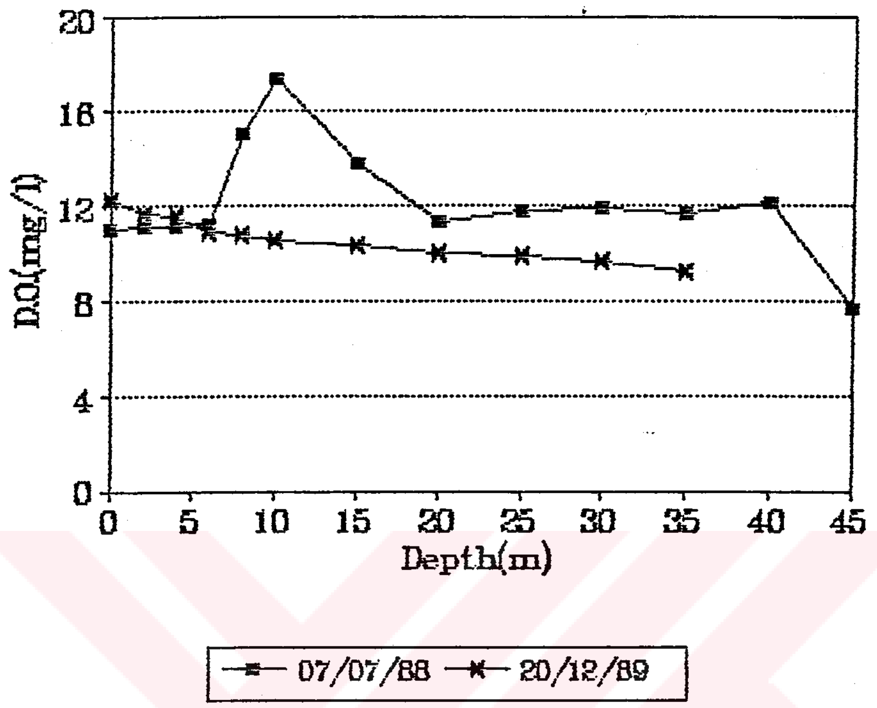


FIGURE 5.1.3. Dissolved oxygen conc. versus depth

5.1.4. PH level :

The average PH levels in lake İznik which were measured by D.S.İ. are given in Table (5.1.1) and shown in Figure (5.1.4) . As noticed from the mentioned Figure , PH level in lake İznik has inconsiderable changes and generally the lake water is slightly basic .

5.1.5. Phosphorus :

It is usually classified according to the analytical procedure used in its determination rather than its precise chemical formulation . The fractions most commonly referred to in the literature for phosphorus are as follows :

(a) Soluble reactive phosphorus (SRP) . This is usually determined by filtering the water sample through a 0.45 μm filter and determination of phosphate by colorimetric analysis . A more accurate description of this fraction is "filterable reactive phosphorus" because the arbitrary choice of 0.45 μm filter means that this fraction phosphorus associated with particles smaller than 0.45 μm in size . SRP is mainly $PO4^{3-}$ + $HPO4^{2-}$ + $H2PO4^{-}$ (inorganic phosphorus abbreviated ,IP) but may include condensed phosphates and organic phosphorus which are hydrolysed or oxidized dúring the determination .

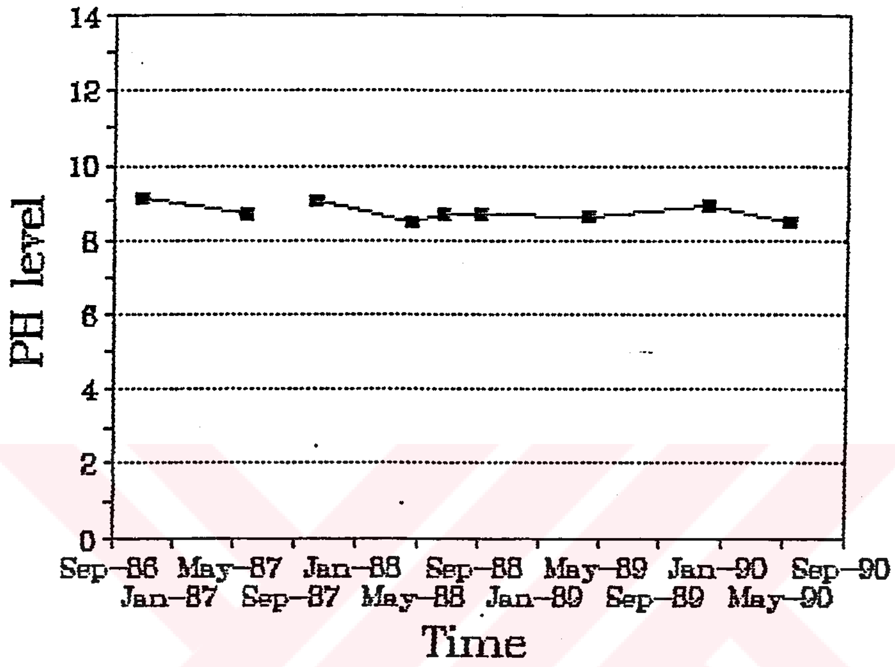


FIGURE 5.1.4. Changes in average PH w.r.t. time

(b) Total phosphorus (TP) . This includes all forms of phosphorus both dissolved and particulate matter in suspension . It is usually determined by acid digestion and oxidation using the persulfate digestion method . TP has also been determined by photo-oxidation using ultraviolet light but found to give values of about 20 per cent lower than those determined using acid digestion procedures

(c) Total dissolved phosphorus (TDP or simply soluble phosphorus , SP) . This is the fraction determined after filtration by using a 0.45 μm filter and acid digestion . It includes both SRP and dissolved organic phosphorus (DOP)

(d) Particulate phosphorus (PP) . This is the difference between TP and TDP .

(e) Dissolved organic phosphorus (DOP) . This may be defined as the TDP minus the acid-hydrolyzable phosphorus (mild acid hydrolysis to degrade condensed phosphates and may include easily hydrolysed organophosphorus compounds) . If condensed phosphates are known to be absent then DOP = TDP - SRP .

The majority of studies have limited the measurement of phosphorus to TP and SRP . However , it is important to consider the more precise speciation of phosphorus when considering heterogeneous reactions such as precipitation of solid phases , coprecipitation and sorption interactions with particulate materials (House and Casey ,1989) .

For lake İznik , D.S.İ. , had decided to hold measurements of TP and O-PO4 concentrations . The list of the average of these measurements are given in Table (5.1.1) . By plotting annual average TP and O-PO4 concentration values , it can be noticed that TP has an increasing tendency which means that phosphorus loading on lake İznik is increasing (Figures (5.1.5) , (5.1.6)) .

5.1.6. Nitrogen :

The continuous cyclic exchange between combined nitrogen in the soil and molecular nitrogen in the atmosphere is called nitrogen cycle . Soil nitrogen occurs naturally in organic forms not utilizable by higher plants but made available as ammonia through the activities of soil microorganisms . The ammonia may be used by microorganisms directly or after oxidation to nitrate-nitrogen . Most of the nitrogen quantity entering lakes is in soluble forms . In the lake water interchanges between nitrogen forms happen by nitrification , denitrification and fixation processes .

DSİ had decided to measure nitrogen concentrations in lake İznik as NH3-N , NO2-N ,and NO3-N . An averages of these measurement is given in Table (5.1.1) and plotted in Figures (5.1.7),(5.1.8) and (5.1.9) . As can be noticed from mentioned figures , nitrogen concentrations have increasing tendency . This may be explained as that nitrogen influx to the lake is increasing with time .

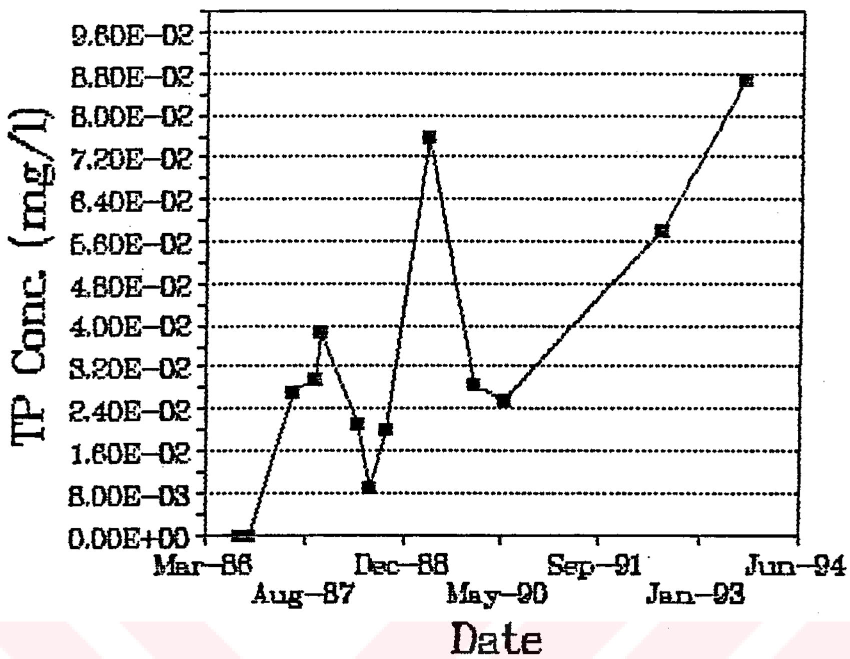


FIGURE 5.1.5. Changes in average TP conc. with time

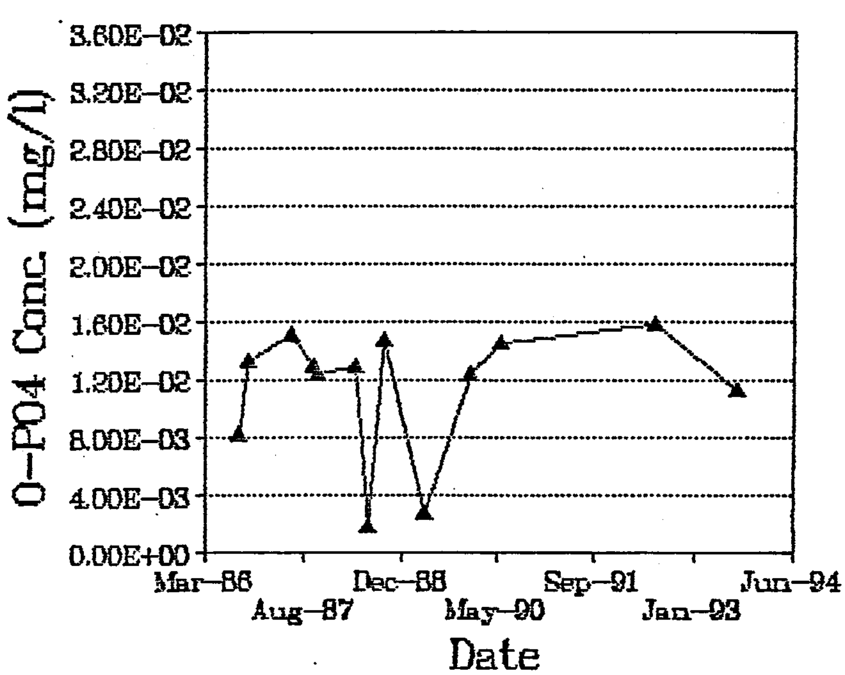


FIGURE 5.1.6. Changes in average O-PO4 conc. with time

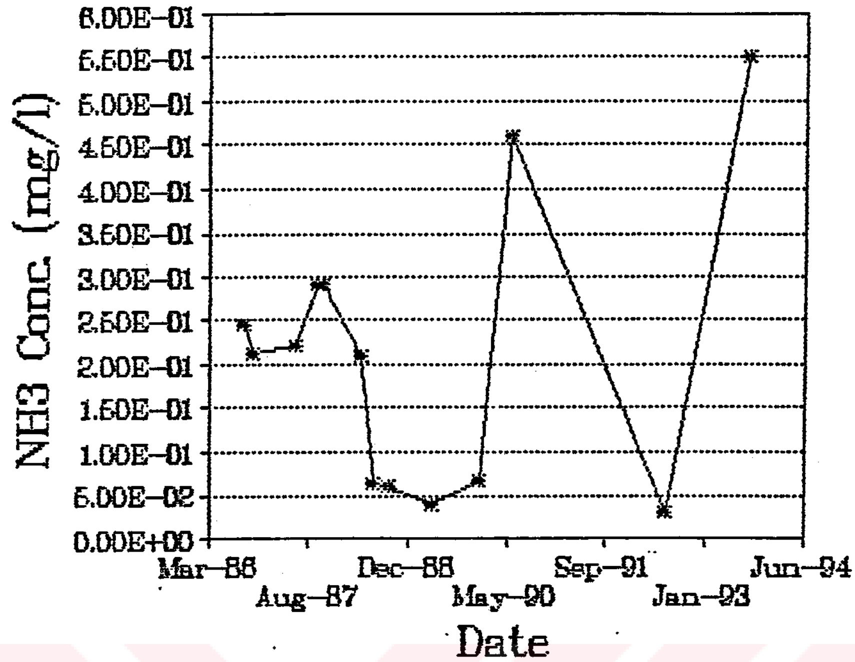


FIGURE 5.1.7. Changes in average NH3-N conc. with time

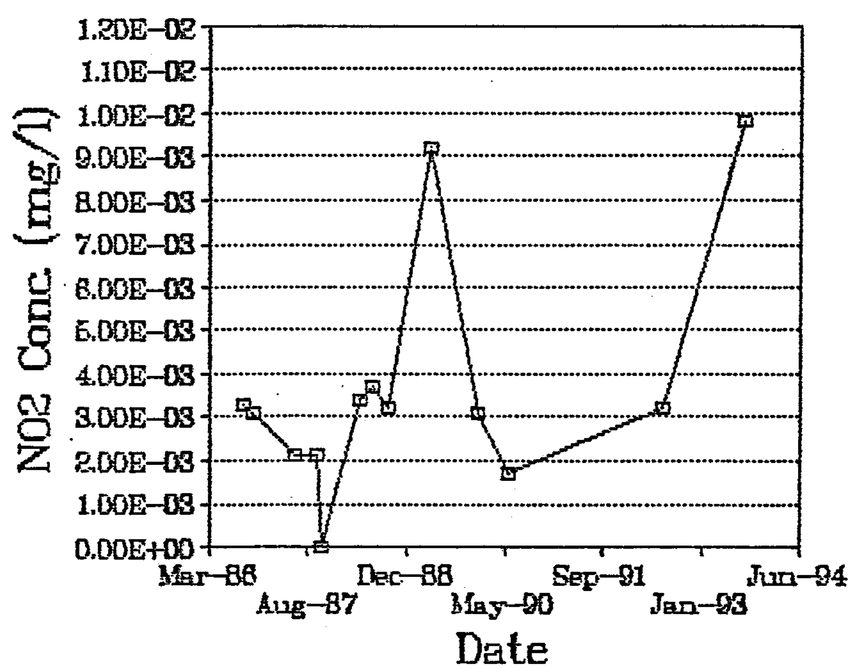


FIGURE 5.1.8. Changes in average NO2-N conc. with time

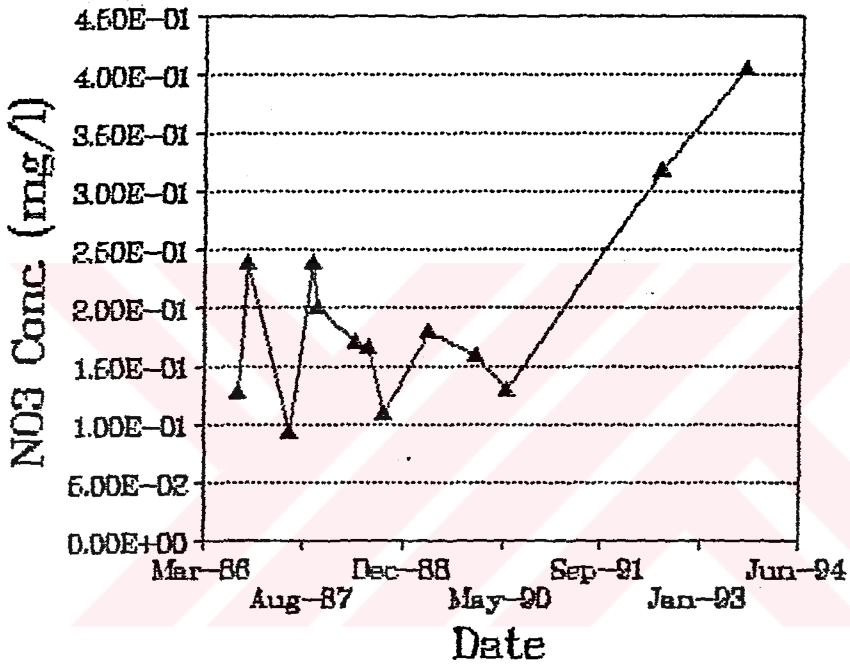


FIGURE 5.1.9. Changes in average NO3-N conc. with time

5.2. Determining the Limiting Element in Lake İznik

5.2.1. Introduction :

The stoichiometric ratio for algal cells is known to be 106 C:16 N:1 P which means that in the presence of enough light and heat , one mole of phosphorus and 16 mole of nitrogen with 106 mole of carbon is the optimum requirement for algae growth .

Although the values of P and N concentrations in a water body is important , the forms of these elements which are consumed by plants and algae are more important . These forms are phosphorus with ammonia , nitrate and nitrite for nitrogen . The ratio of inorganic nitrogen (nitrate + nitrite + ammonia) to total phosphorus is 7 / 1 by weight . If this ratio is more than seven then the limiting element is phosphorus (Stumm and Morgan,1970) .

5.2.2. Calculating N / P ratio :

In Table (5.1.1) the ratio´s of the average concentrations of TP and inorganic nitrogen for 1986-1990 years are given . As may be noticed, the N/P values are all over seven except the value measured in April 1989 and July

1992 which are less than seven . Therefore , the limiting element in lake İznik is found to be the phosphorus.

5.3. The Relation Between Plankton Growth and P Concentration

Increasing evidence indicates that algal levels in lakes are controlled by the external input of plant nutrients . Vollenweider showed how the trophic states of a group of lakes could be related to the annual loading of phosphorus and the lake depth . Dillon related phosphorus loading and flushing rate to trophic state for a group of Ontario lakes . Bachmann and Jones(1976) demonstrated a simple model relating phosphorus input to algal levels for a group of lakes with the expression

$$\text{LOG CHL-}\underline{a} = 1.46 \text{ LOG TP} - 1.09 \qquad (5.3.1)$$

Measurements of total phosphorus and chlorophyll a concentrations were made in the lake İznik by DSİ, Directory of 1st Region (Bursa) beginning in 1986 . The average of these measurements are given in Table (5.1.1) .

By plotting the concentrations of total phosphorus versus chlorophyll a concentrations on log-log paper , Figure

(5.3.1) , a correlation (r =0.76) was found between chlorophyll *a* concentrations and the measured concentrations of total phosphorus . The relation found for lake İznik is

$$\text{LOG CHL-A} = 1.35995 \text{ LOG TP} - 1.52303 \qquad (5.3.2)$$

In view of the insufficient data used , it is surprising to find such a strong relationship between algae and a single nutrient element . A much greater scatter was expected because of :

(a) the effect of other limiting nutrients ,

(b) the utilization of phosphorus by other parts of the food chain ,

(c) the complexity of the phosphorus cycle and the fact that the total phosphorus measurement lumps together the many different phosphorus components found in the open waters of lakes .

The implication of this finding is that phosphorus is the element controlling algal biomass in a broad range of lakes . The slope of the log-log regression line is greater than one, indicating that the algal chlorophyll *a* increases at a faster rate than does the phosphorus concentration . The ratio of chlorophyll *a* to phosphorus is greater at high concentrations of P than at low concentrations . This might be because of changes in the species composition of the algal populations .

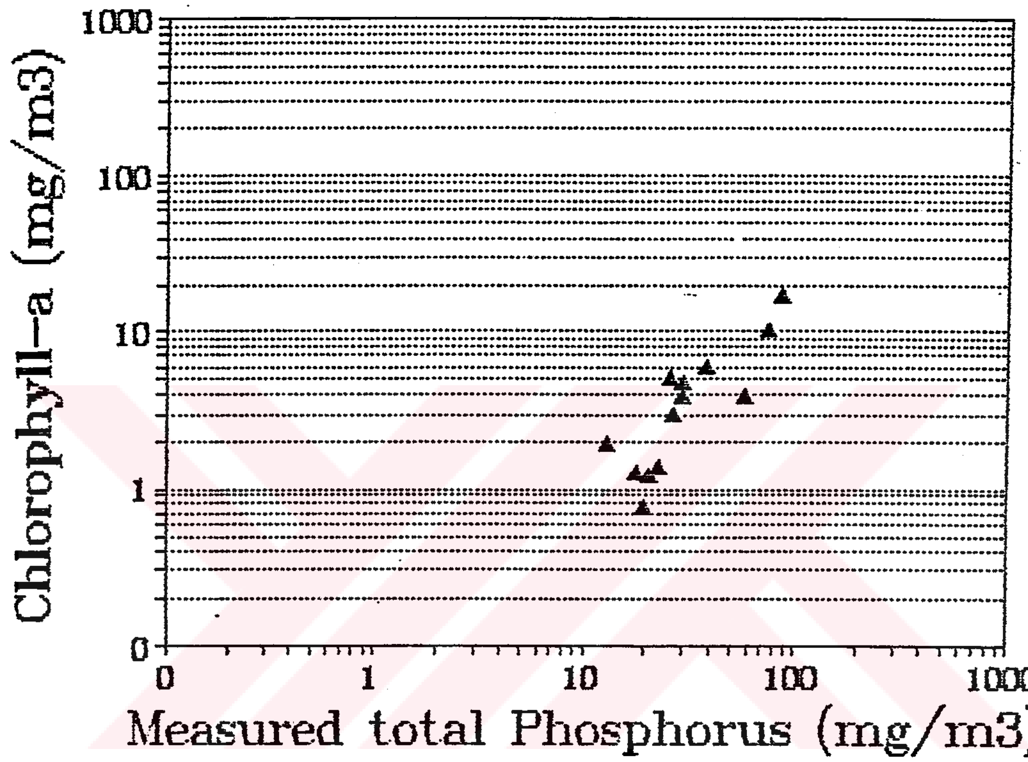


FIGURE 5.3.1. Relationship between annual measured Chl-a and TP conc.

Regression Output:

Constant		-1.58299
Std Err of Y Est		0.240751
R Squared		0.668196
No. of Observations		13
Degrees of Freedom		11
X Coefficient(s)	1.359949	
Std Err of Coef.	0.388311	

5.4. Applying Trophic State Index to Lake İznik :

A numerical trophic state index for lakes has been developed by R.E.Carlson (1977) that incorporates most lakes in a range of 0 to 100 . Each major division (10,20,30,etc.) represents a doubling in algal biomass . The index number can be calculated from any of several parameters , including Secchi disk transparency , chlorophyll-a , and total phosphorus .

In fact , all trophic classification is based on the division of the trophic continuum , however this is divided , into a series of classes termed trophic states . Traditional systems divide the continuum into three classes : oligotrophic , mesotrophic , and eutrophic . There is often no clear delineation of these divisions . Determinations of trophic state are made from examination of several diverse criteria , such as shape of the oxygen curve , species composition of the bottom fauna or of the phytoplankton , concentrations of nutrients , and various measures of biomass or production .

Although each changes from oligotrophy to eutrophy , the changes do not occur at sharply defined places , nor do they all occur at the same place or at the same rate . Some lakes may be considered oligotrophic by one criterion and eutrophic by another ; this problem is sometimes circumvented by classifying lakes that show characteristics of both oligotrophy and eutrophy as mesotrophic .

The large number of criteria that have been used to determine trophic status has contributed to the contention that the trophic concept is multidimensional , involving aspects of nutrient loading , nutrient concentration , productivity , and even lake morphometry . As such , trophic status could not be evaluated by examining one or two parameters (Carlson,1977) .

The trophic state index (TSI) can be computed from Secchi disk transparency value , chlorophyll a concentration , or total phosphorus concentration (equations (5.4.1) , (5.4.2),(5.4.3) respectively) (Carlson,1977) .

$$TSI(SD) = 10*(6 - \frac{\ln SD}{\ln 2}) \quad , \qquad (5.4.1)$$

$$TSI(Chl) = 10*(6 - \frac{2.04 - 0.68*\ln Chl}{\ln 2}) \quad , \qquad (5.4.2)$$

$$TSI(TP) = 10*(6 - \frac{\ln \frac{48}{TP}}{\ln 2}) \quad . \qquad (5.4.3)$$

The completed scale and its associated parameters are shown in Table (5.4.1) .

To use the index for classifying lakes requires that a single number be generated that adequately reflects the trophic status of the lake . It should be emphasized that the number generated is only an index of the trophic status of the lake and does not define the trophic status . The index can be used as a predictive tool in lake-management programs . If the mean total phosphorus after nutrient abatement can be predicted with loading rate equations such as of Vollenweider (1969,1976) , then a new TSI can easily be calculated and the biological conditions of the lake estimated .

The changes in lake İznik eutrophic status with time is given in Figure (5.4.1) .

TABLE 5.4.1. Complete Trophic State Index and its Associated Parameters .

TSI	SECCHI DISC (m)	TP (mg/m3)	Chl-a (mg/m3)
0	64	0.75	0.04
10	32	1.5	0.12
20	16	3.0	0.34
30	8	6.0	0.94
40	4	12	2.6
50	2	24	6.4
60	1	48	20
70	0.5	96	56
80	0.25	192	154
100	0.062	768	1183

(Source: Carlson,1977)

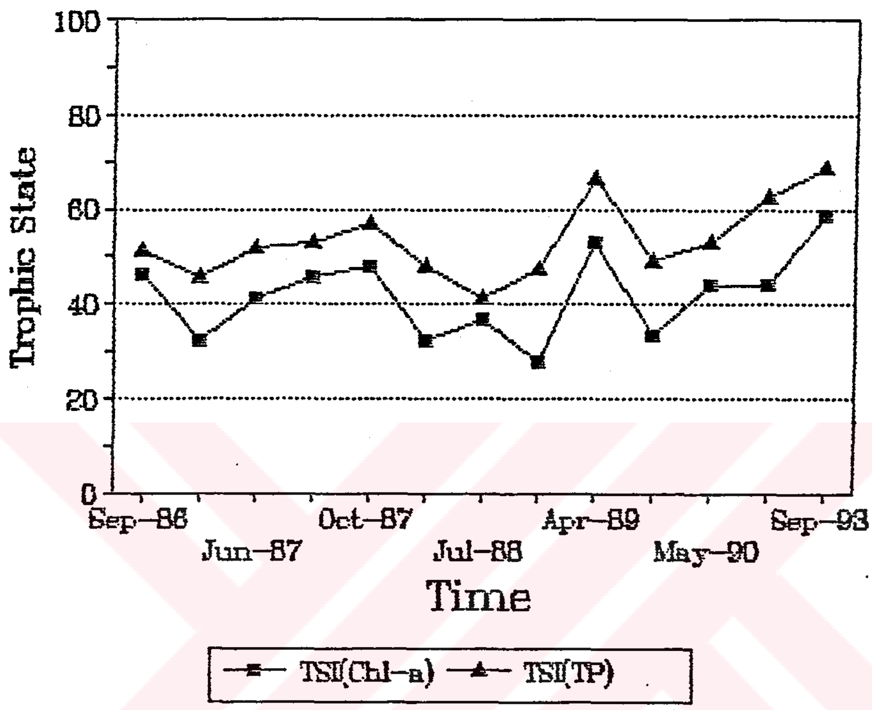


FIGURE 5.4.1. Changes in average TSI level due to Chl-a and TP conc.

6. MODEL INVESTIGATION AND APPLICATION

6.1. Introduction

Mathematical models are used in so many branches of science as in ecological ones . They represent the chemical , physical and , biological relations of the organisms and give direction to water quality management studies . For understanding the events of dynamics , structures and , functions of organisms , limnological , biological and engineering aiming models have been developed .

Models are useful in :

1- Studying relationships between compounds of ecosystems ,
2- Studying dynamics and structure of ecosystems ,
3- Determining and defining changes in environment ,
4- Developing ways for changes in environment ,
5- Examining relations between socio-economics process and ecosystems ,
6- Studying and developing suitable global researches,
7- Developing simulations for environmental practice and ,
8- Developing environmental education (Karpuzcu,1982 and Jeffers,1973) .

The first water quality management model was developed for studying the impacts of organic matters in water bodies on accumulative dissolved oxygen levels . Accordingly mathematical models were developed for predicting future effects of polluting materials on water bodies .

6.2. Models Applied to Lakes

Lakes ecosystems consist of many different bio-chemical events . Models are developed for controlling the experimental and observed studies and then using these in forming hypothesis . Parameters are given in regression state as functions of each others .

Mathematical models are classified into two groups ;

1 - Experimental models which are developed upon given analysis correlations .

2 - Theoretical models which are developed upon data collected from studies and researches .

6.2.1. Experimental Models

It contains the models which explain the relations between loading of nutrients entering a lake , nutrient level in the lake and , primary production parameters .

$$[P] = (L(P) / qs)(1 / (1 + z/qs)) \qquad (6.2.1)$$

where :

[P] : the concentration of phosphorus in lake

L(P): loading of phosphorus per unit area

qs : hydraulic loading

z : mean depth of the lake .

6.2.2. Theoretical Models

They are the models which examine the relations between different systems compounds such as the model applied to lakes which have no effects of sedimentation .

$$V * dc/dt = Q * Ci - Q * C \qquad (6.2.2)$$

where ;

V : volume of the lake

C : concentration of nutrient in water

Ci: concentration of nutrient in inflow

Q : inflow rate

6.3. Selecting a Suitable Model for Lake İznik

There are many factors affecting the biochemical processes in lakes ecosystems . The models which contain all the factors and all the components of a lake ecosystem must be very complex and need wide range of data . The important factors in selecting a model are :

(a) selecting the model according to the aim of modelling ,

(b) simplicity of the model in practice ,

(c) value of the cause-result phenomena and ,

(d) having the basic principles suitable with the conditions of the lake (Karpuzcu,1982 and Jeffers,1973) .

Even simple models take notice of only one variable , but they are accurate indicators of the levels of nutrients of a lake . These simple models are useful in the understanding of the response of a lake toward any changes in the surrounding conditions and give a good idea for the purposes of planning of the area . For this reason , it was seen that the best model fitting the conditions given above is the " nutrient residence time model " which is used to be applied to lakes in which one element is known to be the limiting nutrient .

Five major phases are usually entailed in the evaluation of waste assimilation capacity of a lake . These phases must be sighted :

(a) determination of waste loading ,

(b) definition of hydraulic and climatologist factors ,

(c) adoption and verification of self-purification factors ,

(d) forecasts of expected lake conditions and ,

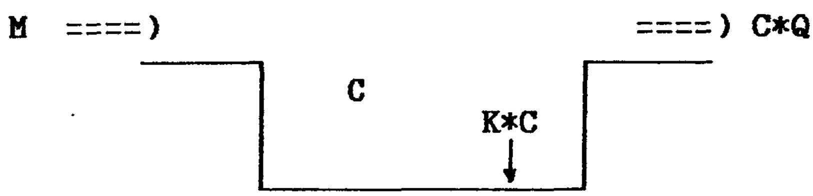
(e) evaluation of the impact of lake developments .

6.4. Nutrient Residence Time Model

Chemical residence time has been used as a basis for modeling the chemical content of the ocean for some time (barth,1972) . Next , Vollenweider (1969) and other workers have used chemical residence time approach to model the rate of recovery of several lakes following pollution abatement . The purpose of this model is to relate the theoretical basis for the chemical residence time model , as it applies to phosphorus and nitrogen , discuss the limits , capabilities and application of the model on lake İznik .

The amount of nutrient in a lake is a function of both : the usage of nutrient by organisms and the losses of it in the lake. The losses of nutrient in a lake may be by either to sedimentation or direct outflow through the outlets of the lakes . Studies have shown that sediments of lakes act as sinks or traps for nutrients . Although there is some release of nutrients from sediments , the net flux of nutrients over an annual cycle is to the sediments . This follows from the fact that a significant portion of the organisms that settle onto the bottom are refractory so that regeneration of the phosphorus and nitrogen upon mineralization is less than 100 per cent (Sonzogni,Uttormak & Lee,1976) .

Assuming that long term effects can be approximated by average annual values in mixed lake , a mass balance can be written on the nutrient of interest . A diagrammatic representation of this case is shown below .



$$M = Q * C * S + K * C * A + dc/dt * V \qquad (6.4.1)$$

where ,

M = mass of nutrient loading over the lake .

Q = annual outflow rate .

C = nutrient concentration at outlet .

S = dimensionless proportionality factor that relates the mean annual outwash or surface water concentration over the whole lake .

K = sedimentation rate .

A = Surface area of the lake .

dc/dt= variety in nutrient concentration .

V = lake volume .

Consequently , it is assumed that the average annual outwash concentration is directly related to the annual concentration over the whole lake by a constant factor . Since the total phosphorus concentration in the epilimnion of most lakes is less than the hypolimnion concentration , S will generally be less than one . For the lake Mendota , Madison , Wisconsin , the total phosphorus in the surface waters was about 70 per cent of the average concentration for the entire lake . Thus, S would have a value of about 0.7 for lake Mendota . For lakes which do not stratify , S would be equal to unity . Although the model was derived based on the mean annual phosphorus content obtained from the average of systematic measurements over the whole year , the mean content at spring turnover might be used as the basis for the annual total phosphorus content . During these periods , lakes are generally well mixed and biological productivity is often at an annual minimum . Therefore , when using the mean content at spring turnover as a basis , S would be equal to unity (Sonzogni,Uttormak & Lee,1976) .

By rearranging equation (6.4.1) and substituting

$$V * \frac{dc}{dt} = M - (Q + K * A) * C \qquad (6.4.2)$$

$$\frac{dc}{dt} = \frac{M}{V} - \left(\frac{(Q + K * A)}{V}\right) * C \qquad (6.4.3)$$

in which

$$Rn = \frac{V}{Q + K * A} \qquad (6.4.4)$$

which is the nutrient residence time for the lake .

Integration of equation (6.4.3) from C0 at time zero to C at time t yields

$$C = \frac{M}{Q+K*A} \left(1- e^{-\frac{Q+K*A}{V} *t}\right) + C0 * e^{-\frac{Q+K*A}{V} *t} \qquad (6.4.5)$$

The steady state concentration in the lake , Ceq , is not identical to the input concentration , but differs by a factor which is the ratio of the phosphorus and hydraulic residence times .

$$Ceq = \frac{M}{Q + K*A} \qquad (6.4.6)$$

From initial concentration C0 to ten per cent within the equilibrium concentration , t10 time must pass . This time is given by the equation

$$t10 = \frac{V}{Q + K*A} \left(2.3 + Ln \left(\frac{(Q+K*A)}{M} * C0 - 1 \right)\right) \qquad (6.4.7)$$

These equations can be used to estimate the gross response of a lake to a step reduction in any nutrient influx . If the lake was at steady state prior to the input reduction , the mean content of the lake will be reduced in direct proportion to the change in the influx . On the other hand , the new steady state concentration will be approached exponentially as a function of the nutrient residence time .

For the case of lake İznik , the average value of the total phosphorus concentrations measured in the lake on 20 of December,1989 was accepted to be the initial concentration of total phosphorus used in the model . In Figures (6.4.1) through (6.4.4) , three different recovery rates are shown . If a reduction of 50 per cent of the present loading is assumed , an equilibrium phosphorus concentration of

$$Ceq = \frac{0.50 * 77.71\ E06}{37.17\ E06 + 8.60 * 304.30\ E06}$$

$$Ceq = 1.47\ E\text{-}02\ mg\ P\ /l$$

is expected .

$$C10 = 1.61\ E\text{-}02\ mg\ P/l$$

will take place after

$$t10 = 11.21\ years\ .$$

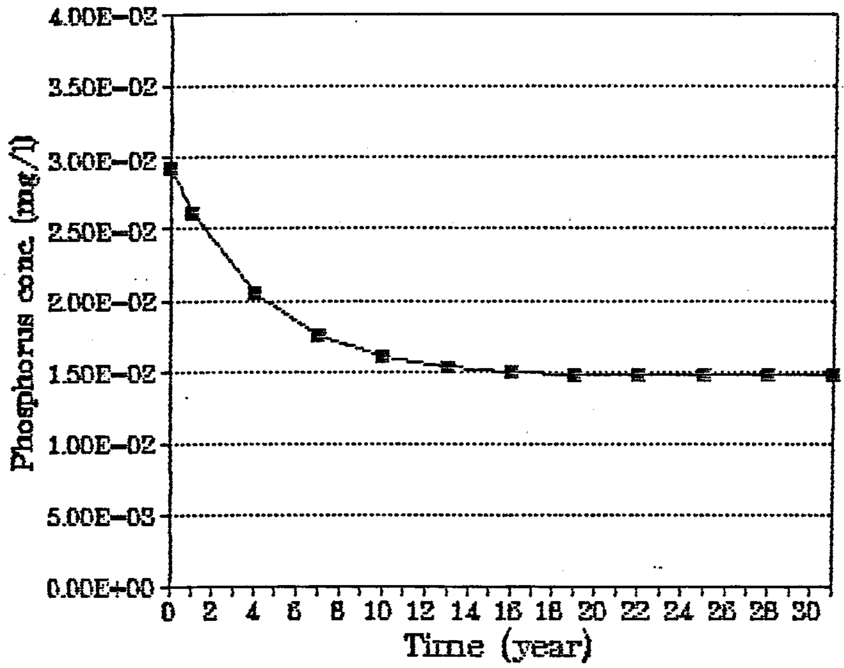


FIGURE 6.4.1. Recovery rate following %50 reduction of P influx

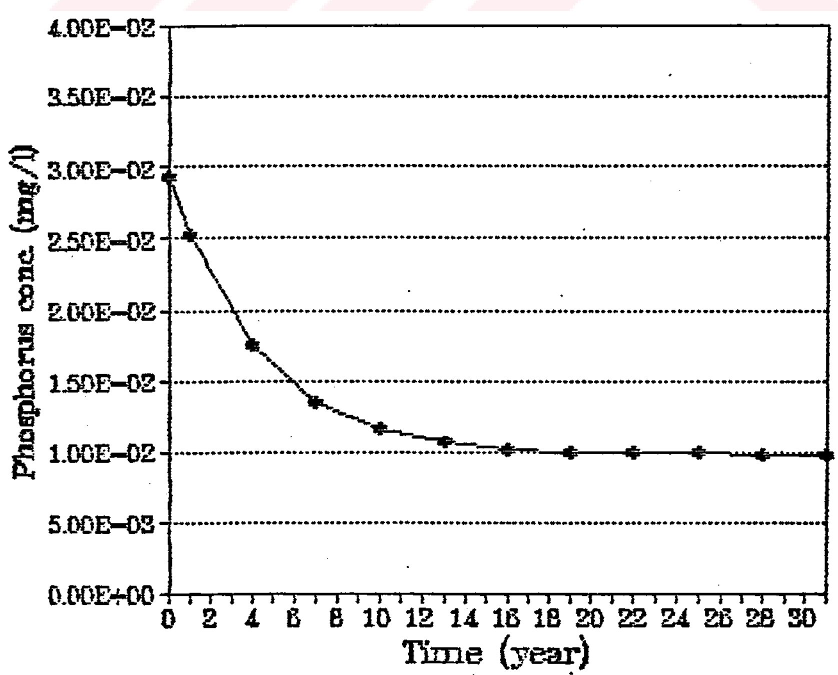


FIGURE 6.4.2. Recovery rate following %67 reduction of P influx

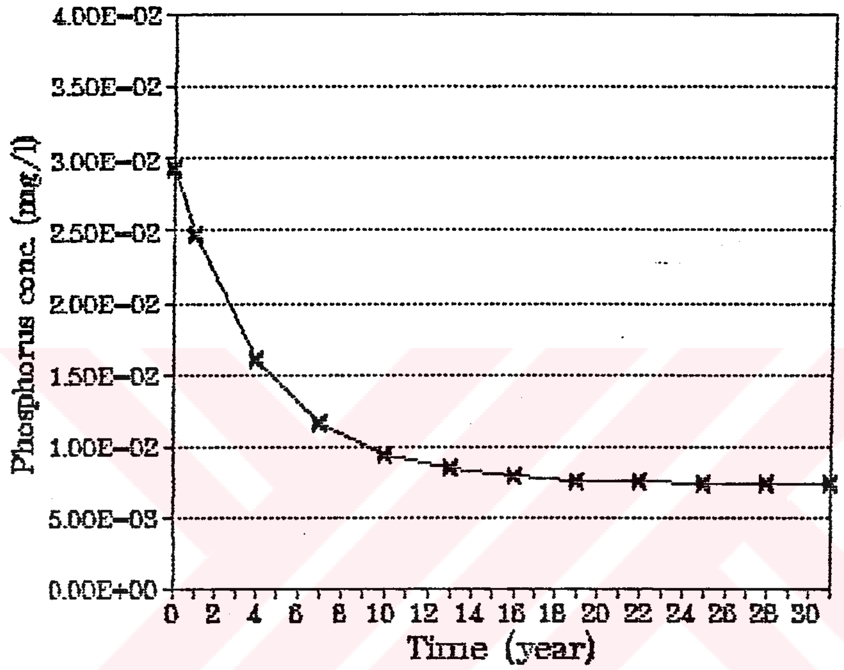


FIGURE 6.4.3. Recovery rate following %75 reduction of P influx

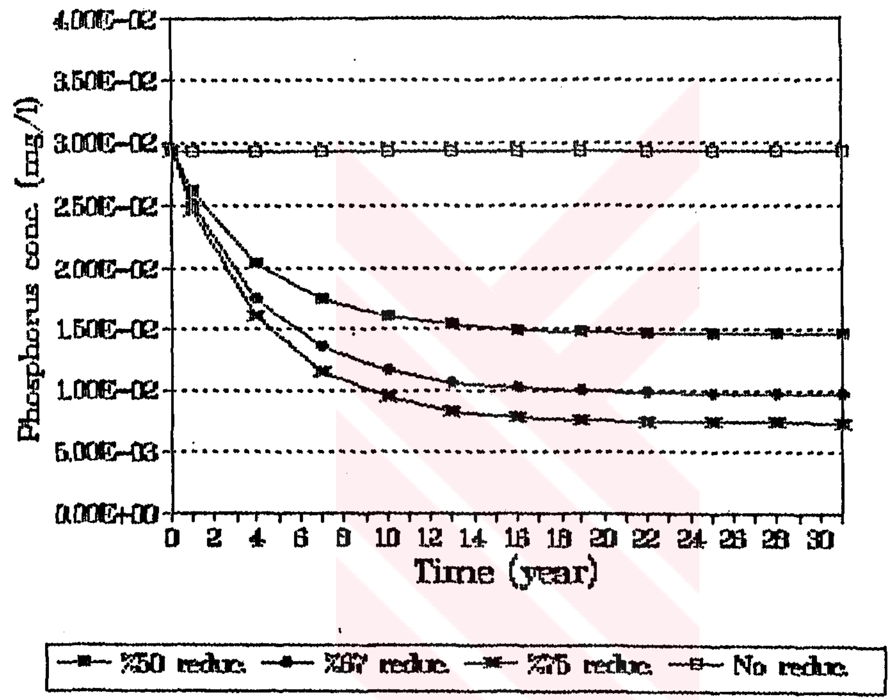


FIGURE 6.4.4 Existing and expected rates of recovery of lake İznik

Fifty per cent within ten percent of the equilibrium value C50= 2.20 E-02 mg P/l will occurs after only 3.7 years beginning from reduction date .

The second reduction rate was chosen as 2/3 of the present loading . In this case , a steady state concentration of Ceq = 0.98 E-02 mg P/l will result from this reduction . In a 14.64 years time , ten per cent within the equilibrium concentration , C10 = 1.08 E-02 mg P/l will be arrived .

The third rate of reduction was taken as 75 per cent of the present phosphorus loading . In a 16.6 years interval, ten per cent within the equilibrium concentration C10 = 8.06 E-03 mg P/l will be reached despite the fact that equilibrium value would be Ceq = 7.33 E-03 mg P/l .

A simple computer program has been developed to predict the steady state concentration with the time required to reach ninety per cent of the recovery concentration . The same program predict the concentrations of the limiting element with respect to time beginning from reduction date .

This program has been written in Basic language and listed in Appendix A .

6.5. Computing Sedimentation Coefficient

6.5.1. Theory :

Many studies have been proposed to provide such information . These have been reviewed recently by Dillon . It has been chosen to follow the approach of Vollenweider who developed a differential equation based on the following assumptions :

1 - The rate of supply of phosphorus , the flushing rate , and the sedimentation rate are constant through time .

2 - The lake is considered as a continuously stirred reactor system (CSRS) defined as a single-compartment , open system .

3 - The concentration of phosphorus in the outflow is the same as the concentration in the lake .

4 - Sedimentation of nutrient is proportional to the nutrient concentration in the lake (Lorenzen,1973) .

The steady-state solution is given by :

$$C = \frac{L}{Z\ (\sigma + \rho\ )} \qquad (6.5.1)$$

where :

C = concentration of nutrient in the lake water , mg/m3 ,

L = annual nutrient loading per unit ares of lake surface, mg/m2 ,

Z = mean depth of the lake , m ,

σ = sedimentation coefficient , yr -1 , and

ρ = hydraulic flushing rate , yr -1 .

In developing this equation , Vollenweider concluded that the concentration of nutrient in lakes is determined largely by rate of supply , but is modified by losses through the outlet and the sediments (Jones & Bachmann,1976) .

The inclusion of the sedimentation term allows the model to be used for nonconcervative substances , but potentially limits its usefulness because directly measuring sedimentation in the field requires more effort than would be involved in measuring the phosphorus , nitrogen and chlorophyll values rather than predicting them .

The sedimentation coefficient can be estimated from the data by rearranging the terms in equation (6.5.1)

$$\sigma = \frac{L / Z}{C} - \rho \qquad (6.5.2)$$

Vollenweider (1969) has listed values for the sedimentation coefficient for phosphorus from 0.1 to 1.0 . Often some other value may be estimated . All that errors involved in estimating loading , mean depth , total nutrient , and the flushing rate are incorporated into the sedimentation coefficient . Negative values might indicate a lake in which steady state does not exist and more nutrient is being lost from the lake than is entering , or from the combined effects of the errors of estimation . No correlation could be found between the estimated sedimentation coefficient and the mean depth , loading rate , or total nutrient concentration of the lake . A slight positive correlation was found with the flushing rate (Jones and Bachmann,1976) .

6.5.2. Calculations Of K :

For lake İznik , the parameters required to predict the sedimentation coefficient of phosphorus are

$$L = 77.71\ E09 \ / \ 304.30\ E06 = 255.37\ mg/m2$$

$$Z = V \ / \ A = 12.12\ E09 \ / \ 304.30\ E06 = 39.83\ m$$

$$TP = 29.3\ mg\ P \ / \ m3$$

$$\rho = Q \ / \ V = 37.17\ E06 \ / \ 12.12\ E09 = 0.0031\ yr^{-1}$$

though ,

$$\sigma = 0.216\ yr^{-1} .$$

Therefore ,

$$K = \sigma * Z = 0.216 * 39.83 = 8.60 \text{ m / yr}.$$

6.6. Calculations Of Rp and Rw

Since Rp is a function only of V , Q , k , and A , Rp is not influenced by changes in the input concentration . Once the phosphorus residence time is known , the rate of response to phosphorus abatement (or pollution) can be predicted from the model .

For lake İznik , the above mentioned parameters are :

V = 12.12 E09 m3

Q = 37.17 E06 m3 / yr

K = 9.24 m / yr

A = 304.30 E06 m2

therefore :

Rp = 4.25 years .

and Rw = V / Q = 326.1 years .

The phosphorus residence time was found to be less than water residence time which means that lake İznik is acting as a sink for phosphorus . It should be noted that although the chemical content of lakes may be determined with reasonable realibity , the rate of phosphorus influx is often much less precisely known , especially when the influx is estimated from land use patterns and generalizations from literature . Nevertheless , the fact that all phosphorus residence times calculated for many lakes in the world are less than the hydraulic residence times (Sonzongi,Uttormak & Lee,1976), gives strong evidence that the response of a lake to phosphorus abatement will be more rapid than that predicted from the hydraulic residence time .

7. SUMMARY OF FINDINGS

In this study , the basic parameters which give sufficient knowledge of the nutrient condition in lake İznik have been investigated . The summation of this application may be given briefly as follows .

1 - Lake İznik is in general not homogeneous and not fully mixed . It has a surface area of 304.30 km2 and a volume of 12.12 millions cubic meters whereas Its mean depth is 40 m .

2 - Average total phosphorus concentration in the beginning of 1990 is 29.30 mg P/m3 , whereas the average chlorophyll-a concentration for the same time is 1.314 mg/m3 . These two values indicate that lake İznik did not reach the eutrophic state yet . Trophic state index was calculated and seen to be commonly of the range 40 - 60 (mesotrophic -eutrophic state) .

3 - From the ratios of inorganic nitrogen concentration to phosphorus concentration which are found to be bigger than seven , and also from the ratio of the total loading of nitrogen to the total loading of phosphorus which was found to be equal to 14.0 , phosphorus was found to be the limiting element in lake İznik .

4 - Because of the existence of a controlled outlet of lake İznik , volume of the lake is almost constant . The biggest water input to the lake is from streams whereas the biggest flow out is by evaporation .

5 - The areal phosphorus loading over lake İznik was found to be more than two times of the permitted one . The most polluting phosphorus load is that one which is produced by human activities (47 per cent) .

6 - Nutrient residence time model has been applied to lake İznik . Phosphorus residence time (4.25 years) was found to be less than water residence time (326.1 years) which means that lake İznik acts as a sink for phosphorus. For the loading of that estimated for 1990 , an equilibrium concentration of Ceq = 2.93 E-02 mg P/l is expected. For 50 per cent reduction in P loading , an equilibrium of Ceq = 1.47 E-02 mg P/l . For 67 per cent reduction in P loading , an equilibrium of Ceq = 0.98 E-02 mg P/l was calculated . And for 75 per cent reduction in P loading will result in recovery of the lake and the equilibrium concentration will be Ceq = 7.33 E-03 mg P/l .

7 - In present , lake İznik is in mesotrophic-eutrophic state but if nutrient loading wouldn't be reduced , lake İznik will reach eutrophic state soonly .

APPENDIX A

Computer Program for "Phosphorus Residence Time" Model Applied to Lake İznik

```
100 CLEAR
110 KEY OFF
120 REM this program calculates the nutrients loads on lakes .
130 DIM T(32).Y(32).C(32)
140 PRINT"Print initial conc. of P in lake İznik (gr/m3)":INPUT C0
150 PRINT"Print sedimentation rate (m/year)":INPUT K
160 PRINT"Print surface area of lake İznik (m2)":INPUT A2
170 PRINT"Print forests area (m2)":INPUT A1
180 PRINT"Print number of cow equivalent":INPUT BBH
190 PRINT"Print number of sheep equivalent":INPUT KBH
200 PRINT"Print number of poultry equivalent":INPT KH
210 PRINT"Print İznik city population":INPUT INS
220 PRINT"Print İznik district villages population":INPUT IINS
230 PRINT"Print Orhangazi city population":INPUT ONS
240 PRINT"Print Orhangazi district villages population":INPUT OONS
250 PRINT"Print average annual inflow (m3/year)":INPUT Q
260 PRINT"Print volume of lake İznik (m3)":INPUT V
270 PRINT"Print weight of Amonium sulfate used annually (kg)":INPUT F(1)
280 PRINT"Print weight of Amonium nitrate used annually (kg)":INPUT F(2)
290 PRINT"Print weight of Manure used annually (kg)":INPUT F(3)
300 PRINT"Print weight of Triple super fosfate used annually(kg)":INPUT F(4)
310 PRINT"Print weight of Diamonium fosfate used annually (kg)":INPUT F(5)
320 PRINT"Print weight of 20.20.20 fertilizer used annually (kg)":INPUT F(6)
330 PRINT"Print weight of 15.15.15 fertilizer used annually (kg)":INPUT F(7)
340 MT=(F(4)*.47+F(5)*.46+F(6)*.2+F(7)*.15)*1000
350 MP(1)=MT*.00379*.1
360 MS=(F(1)*.21+F(2)*.26+F(3)*.46+F(5)*.18+F(6)*.2+F(7)*.15)*1000
370 MN(1)=MS*.0982*.1
380 MP(2)=A1*.01
390 MN(2)=A1*.5
400 MP(3)=(BBH*25+KBH*2+KH*.2)*1000*.1
410 MN(3)=(BBH*38+KBH*11+KH*.5)*1000*.1
420 MP(4)=IINS*1500*.1+INS*1500+OONS*1500*.1
430 MN(4)=IINS*6500*.1+INS*6500+OONS*6500*.1
440 MP(5)=A2*.025
450 MN(5)=A2*2.4
460 FOR I=1 TO 5
470 PRINT"Mp(";I;")=";MP(I),"Mn(";I;")=";MN(I)
480 MP=MP+MP(I)
490 MN=MN+MN(I)
500 NEXT I
```

```
510 PRINT"Mp=";MP,"Mn=";MN
520 FOR I=1 TO 4
530 MP=MP/I
540 PRINT"Mp=";MP
550 FOR T=1 TO 31 STEP 3
560 Y(T)=EXP(-((Q+K*A2)/V)*T)
570 C(T)=(MP/(Q+K*A2))*(1-Y(T))+C0*Y(T)
580 PRINT"t=";T,"C=";C(T)
590 NEXT T
600 CEQ(P)=MP/(Q+K*A2)
610 X=(((Q+K*A2)*C0)/MP)-1
620 ZZ=LOG (X)
630 T10=V*(2.3+ZZ)/(Q+K*A2)
640 PRINT"T10=";T10
650 PRINT"Ceq(p)=";CEQ(P)
660 NEXT I
670 KEY ON
```

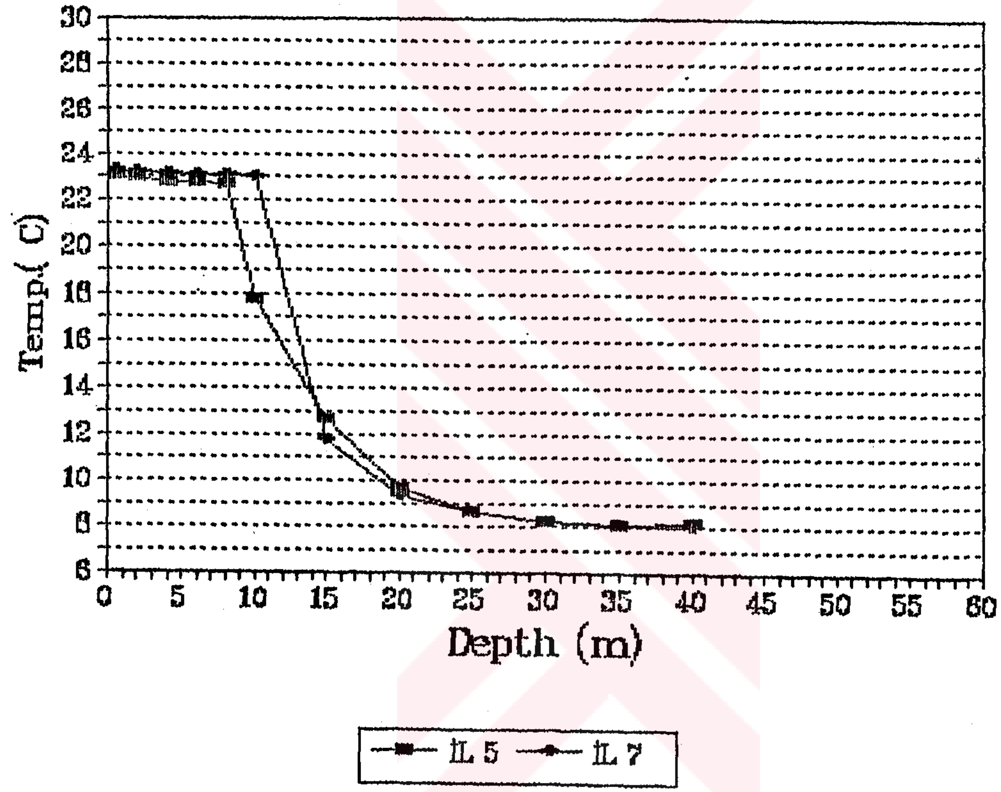
APPENDIX B

DATA COLLECTED FOR LAKE İZNİK (D.S.İ.)

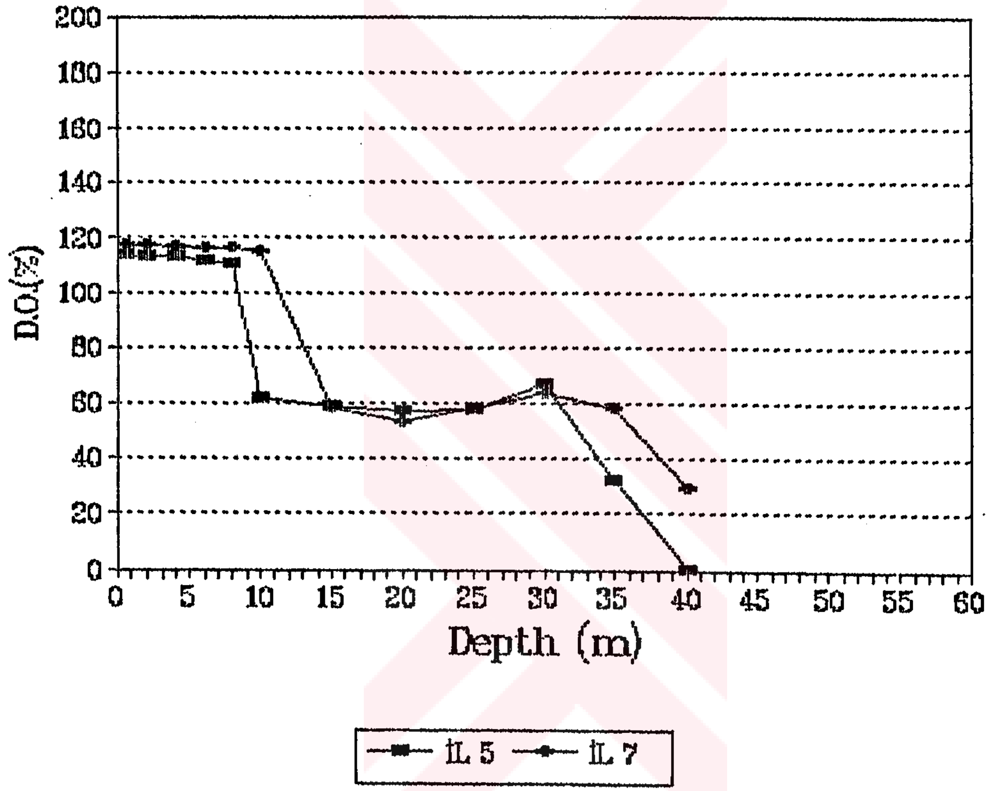
Temperature and D.O. Saturation Values Measured for Different Stations in Lake İznik .

22/09 /1986

	İL2	İL2	İL4	İL4	İL5	İL5	İL7	İL7	İL9	İL9
m	T	DO%	T	DO%	T	DO%	T	DO%	T	DO%
0.5					23	113.9	23.28	117.5		
2					22.98	113.5	23.24	117.3		
4					22.75	113	23.14	116.7		
6					22.71	112.1	23.09	115.9		
8					22.66	110.5	23.07	116	22.75	104.6
10					17.72	61.43	23.01	115.2		
15					12.64	58.64	11.74	58.27		
20					9.62	56.93	9.28	52.85	9.43	52.59
25					8.61	57.5	8.6	58.38		
30					8.2	66.77	8.18	63.38	7.02	56.53
35					8.04	32.09	8.07	58.23		
40					8.17	0.32	8.01	29.08	6.61	16.61
45										
50										
55										
60										



Temperature profiles for different stations .
22/09/1986

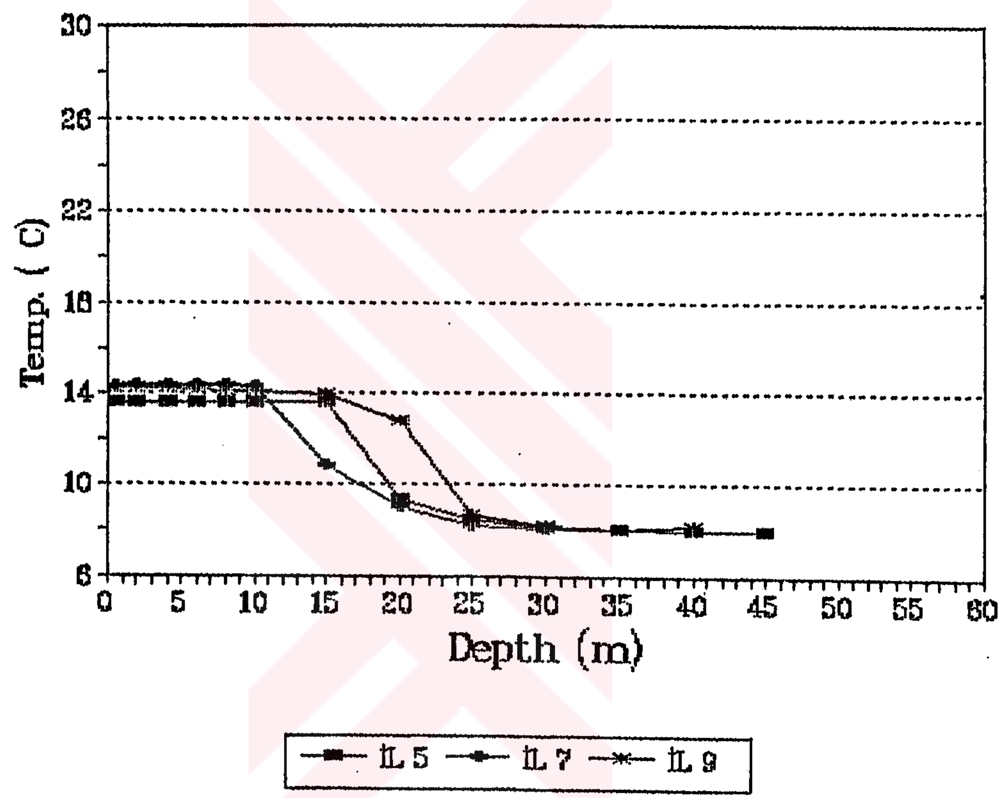


Dissolved oxygen saturation profiles .
22/09/1986

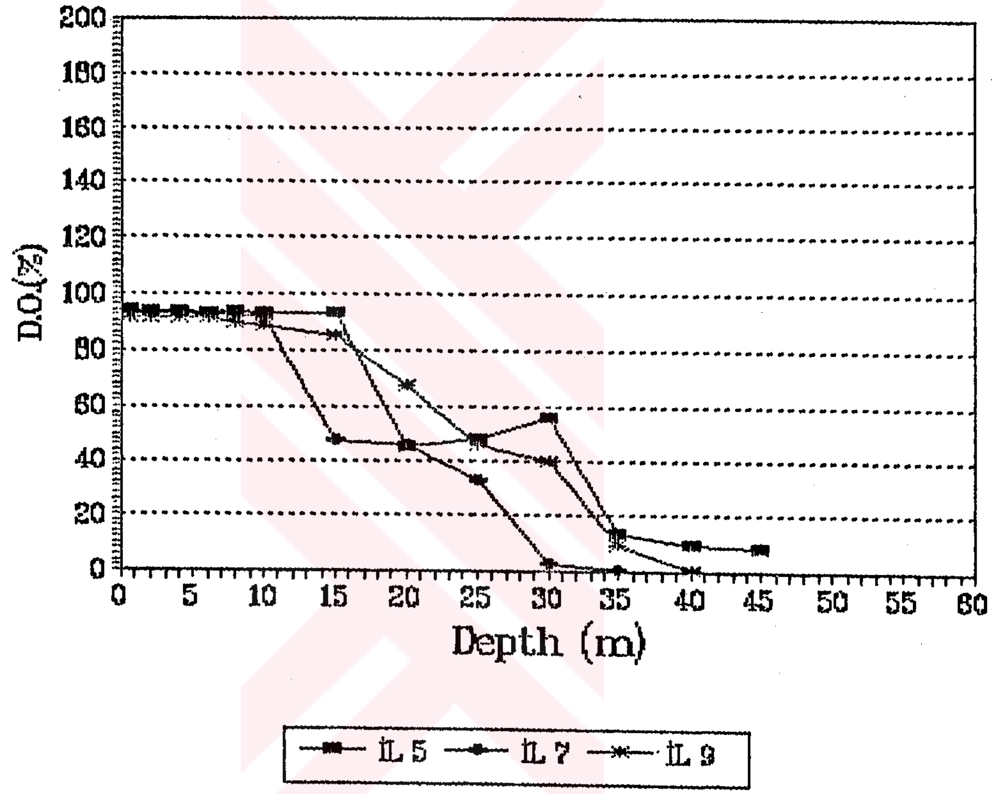
Temperature and D.O. Saturation Values Measured for Different Stations in Lake İznik .

20/11/1986

	İL2	İL2	İL4	İL4	İL5	İL5	İL7	İL7	İL9	İL9
m	T	DO%	T	DO%	T	DO%	T	DO%	T	DO%
0.5					13.56	93.95	14.31	93.44	14.18	91.34
2					13.57	93.53	14.35	93.1	14.18	90.97
4					13.57	93.48	14.37	93.02	14.19	90.99
6					13.58	92.87	14.36	92.69	14.17	90.83
8					13.58	93.18	14.36	92.21	14.11	89.37
10					13.58	93.06	14.25	91.39	14.06	88.2
15					13.56	92.88	10.78	47.33	13.94	84.99
20					9.31	44.87	8.96	45.79	12.78	67.35
25					8.42	48.38	8.15	32.54	8.61	45.93
30					8.08	56	8.01	2.23	8.14	39.6
35					8.01	13.1	8.01	0.15	7.99	9.02
40					7.97	9.26			8.12	0.31
45					7.95	7.73				
50										
55										
60										



Temperature profiles for different stations .
20/11/1986

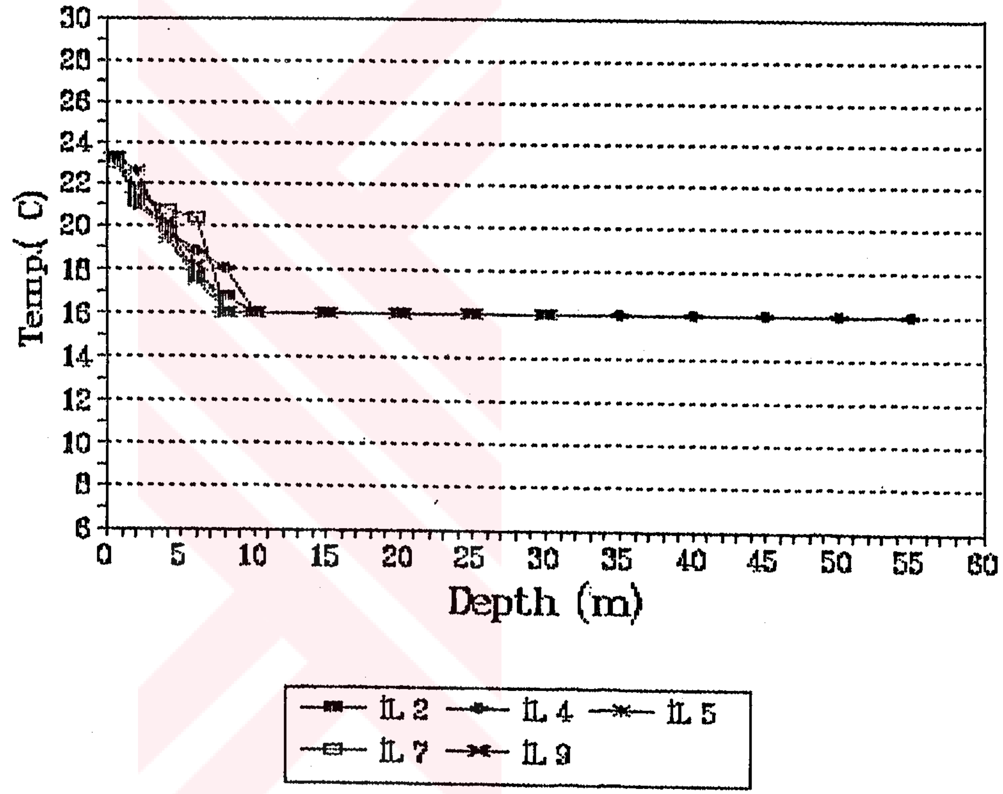


Dissolved oxygen saturation profiles .
20/11/1986

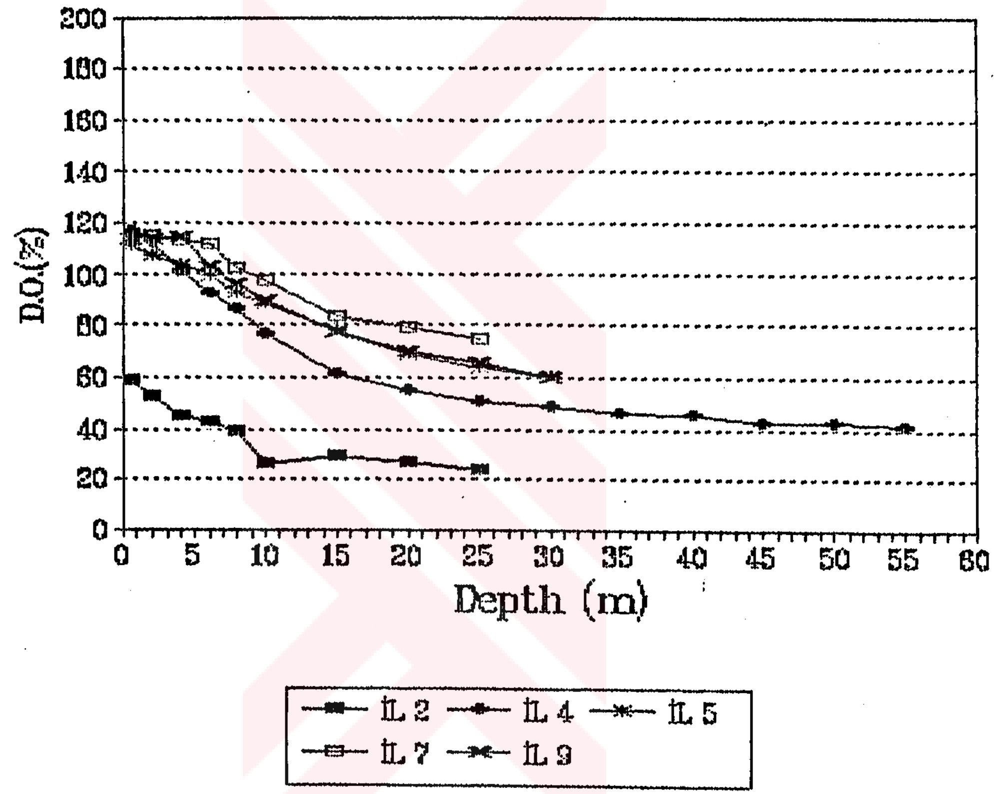
Temperature and D.O. Saturation Values Measured for Different Stations in Lake İznik .

09/06/1987

	İL2	İL2	İL4	İL4	İL5	İL5	İL7	İL7	İL9	İL9
m	T	DO%	T	DO%	T	DO%	T	DO%	T	DO%
0.5	23.17	58.83	23.25	116.2	23.22	111.1	22.97	114.6	23.2	113.9
2	21.19	52.74	20.97	112.5	22.59	107.7	21.51	115.2	21.81	113.8
4	19.89	45.31	19.8	101	19.45	103.8	20.75	113.1	20.2	114.3
6	17.62	42.66	18.79	92.62	17.45	99.54	20.38	111.7	18.13	103.1
8	16.72	39.02	18.02	86.67	16	92.78	16	102.4	16	96.36
10	16	25.79	16	76.52	16	88.27	16	97.39	16	89.94
15	16	28.83	16	61.16	16	78	16	83.64	16	77.42
20	16	26.69	16	54.79	16	68.24	16	79.42	16	70.29
25	16	23.31	16	50.82	16	63.93	16	74.48	16	65.37
30			16	48.79	16	60.42			16	60.21
35			16	46.56						
40			16	45.7						
45			16	43.09						
50			16	42.5						
55			16	41.06						
60										



Temperature profiles for different stations .
09/06/1987

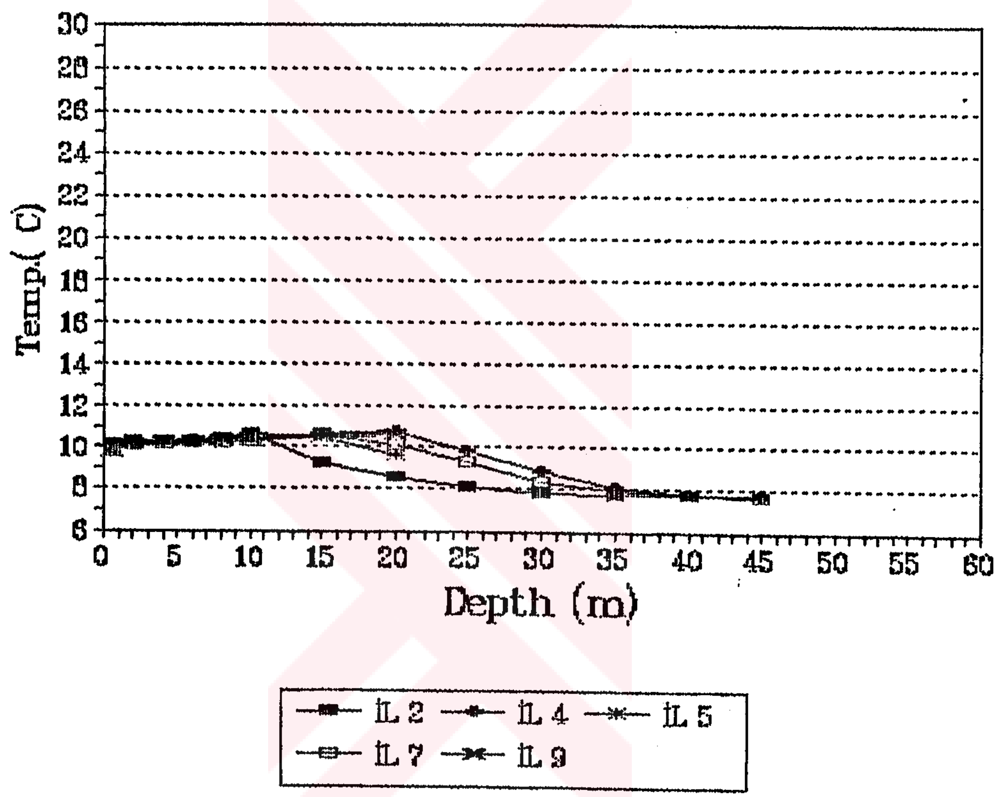


Dissolved oxygen saturation profiles .
09/06/1987

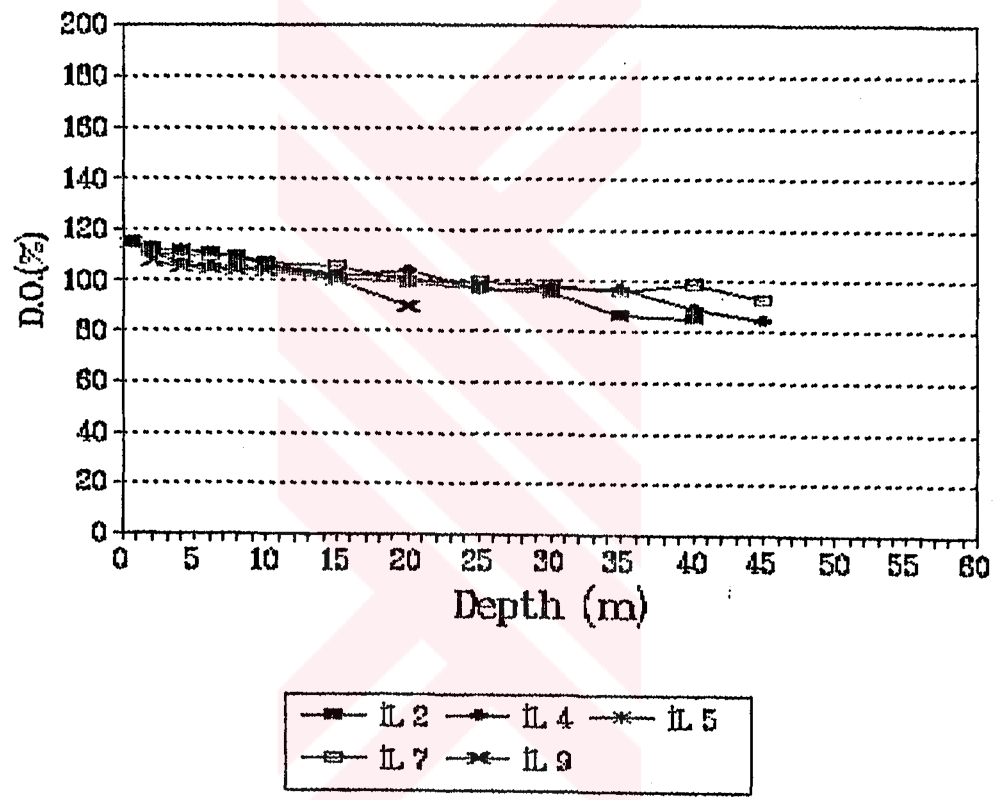
Temperature and D.O. Saturation Values Measured for Different Stations in Lake İznik .

05/05 /1988

	İL2	İL2	İL4	İL4	İL5	İL5	İL7	İL7	İL9	İL9
m	T	DO%	T	DO%	T	DO%	T	DO%	T	DO%
0.5	10.11	115	9.99	114.1	9.89	115.1	9.75	115.1	9.75	114.1
2	10.2	112.5	10.09	110.8	10.07	112	10.03	110.1	10.08	107.2
4	10.25	111.3	10.29	105.7	10.14	111.8	10.11	109	10.23	104.9
6	10.29	110.6	10.33	105	10.25	110.3	10.15	109.2	10.28	104.7
8	10.4	108.1	10.36	104.4	10.32	109.3	10.18	109.2	10.31	103.6
10	10.59	105.9	10.38	104.3	10.64	106	10.28	106.9	10.35	102.7
15	9.22	100.7	10.57	101.1	10.41	101.8	10.66	105.3	10.48	99.68
20	8.56	98.77	10.74	103.5	9.58	101.5	10.07	99.5	10.64	89.7
25	8.06	96.98	9.79	96.44			9.26	99.29		
30	7.81	95.02	8.81	97.17			8.31	98.09		
35	7.68	86.86	8.12	97.05			7.97	96.02		
40	7.68	85.14	7.72	88.77			7.75	99.01		
45			7.68	84.5			7.65	92.64		
50										
55										
60										



Temperature profiles for different stations .
05/05/1988

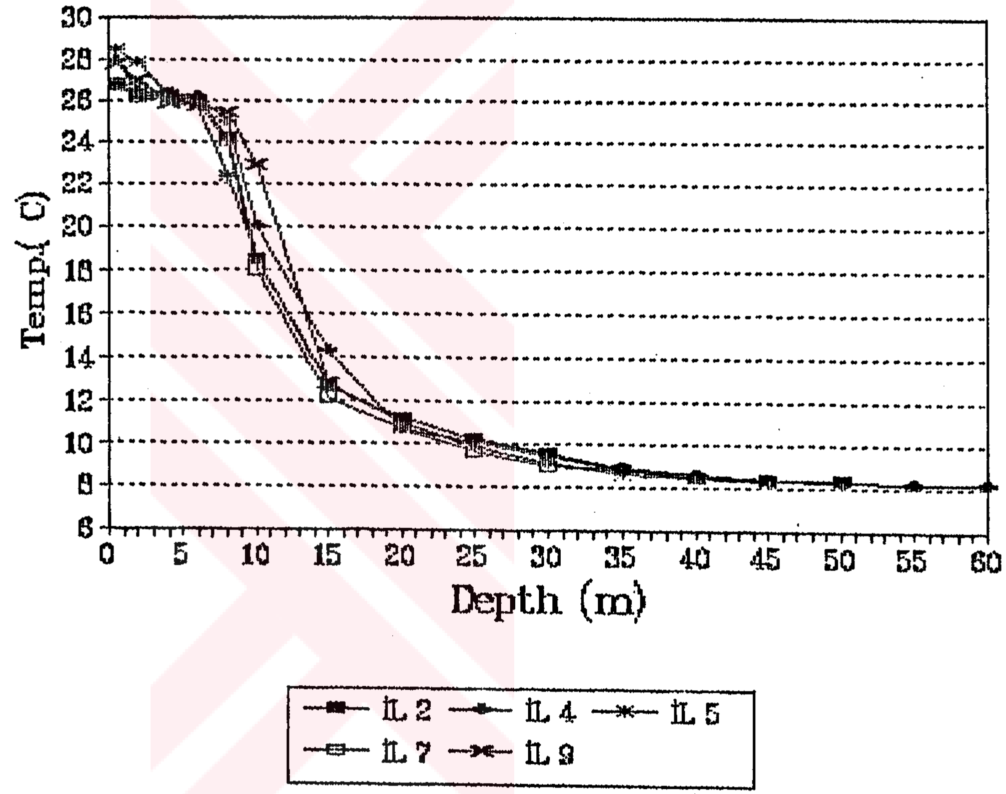


Dissolved oxygen saturation profiles
05/05/1988

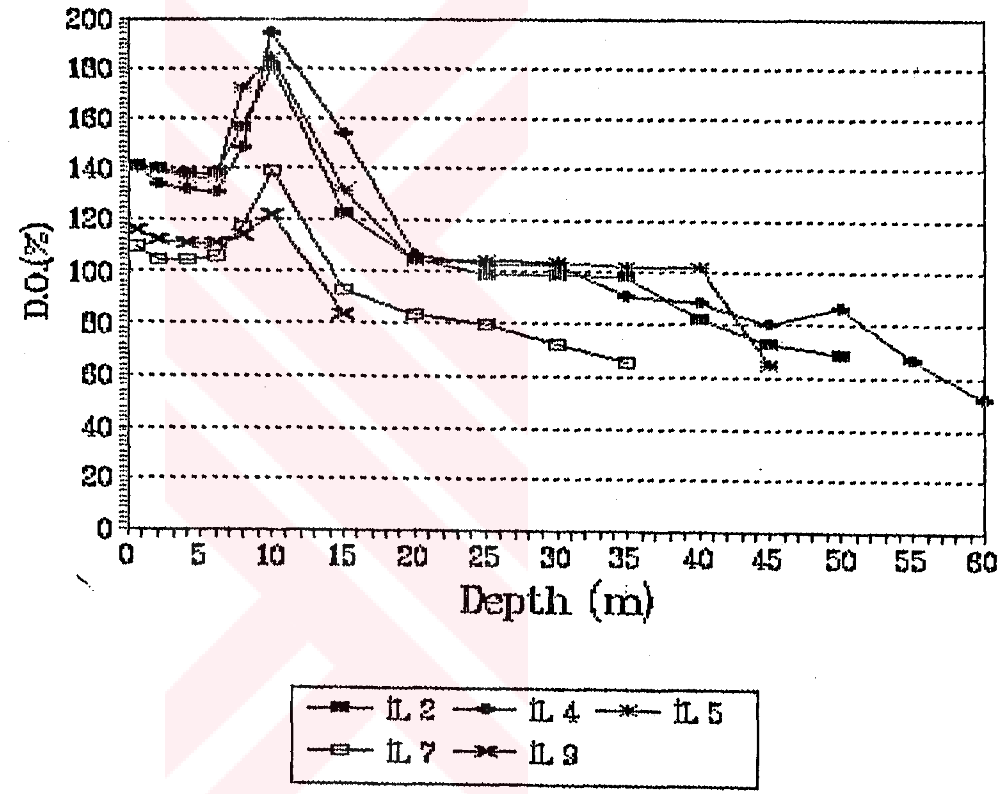
Temperature and D.O. Saturation Values Measured for Different Stations in Lake İznik .

07/07 /1988

	İL2	İL2	İL4	İL4	İL5	İL5	İL7	İL7	İL9	İL9
m	T	DO%	T	DO%	T	DO%	T	DO%	T	DO%
0.5	26.65	140.6	27.89	139.9	28.39	139.4	26.77	109.1	27.75	115.4
2	26.32	139.3	26.45	133.3	27.81	138.7	26.15	104.5	26.96	111.5
4	26.1	137.6	26.28	131.6	26.19	135.7	25.97	104.2	25.85	110.4
6	25.98	137.4	26.09	130.2	25.7	136	25.77	105.4	25.66	110.5
8	24.22	156	24.95	147.8	22.38	172.1	24.01	116.3	25.4	113.4
10	18.55	180.8	20.03	194.7	18.5	184.4	18.05	138.7	22.91	121.7
15	12.69	122.4	14.3	153.5	12.75	130.6	12.17	92.48	12.84	83
20	11.2	104.5	10.69	106.1	10.98	103.6	10.7	83.82		
25	10.21	98.79	10.05	102.6	9.84	104.1	9.66	79.65		
30	9.57	99.07	9.43	102.5	9.14	103.9	8.97	72.08		
35	8.87	98.4	8.89	90.59	8.67	102	8.88	65.16		
40	8.44	81.97	8.57	88.56	8.44	102				
45	8.37	72.72	8.4	80.43	8.35	64.78				
50	8.39	68.86	8.33	86.87						
55			8.3	66.51						
60			8.25	52.3						



Temperature profiles for different stations .
07/07/1988

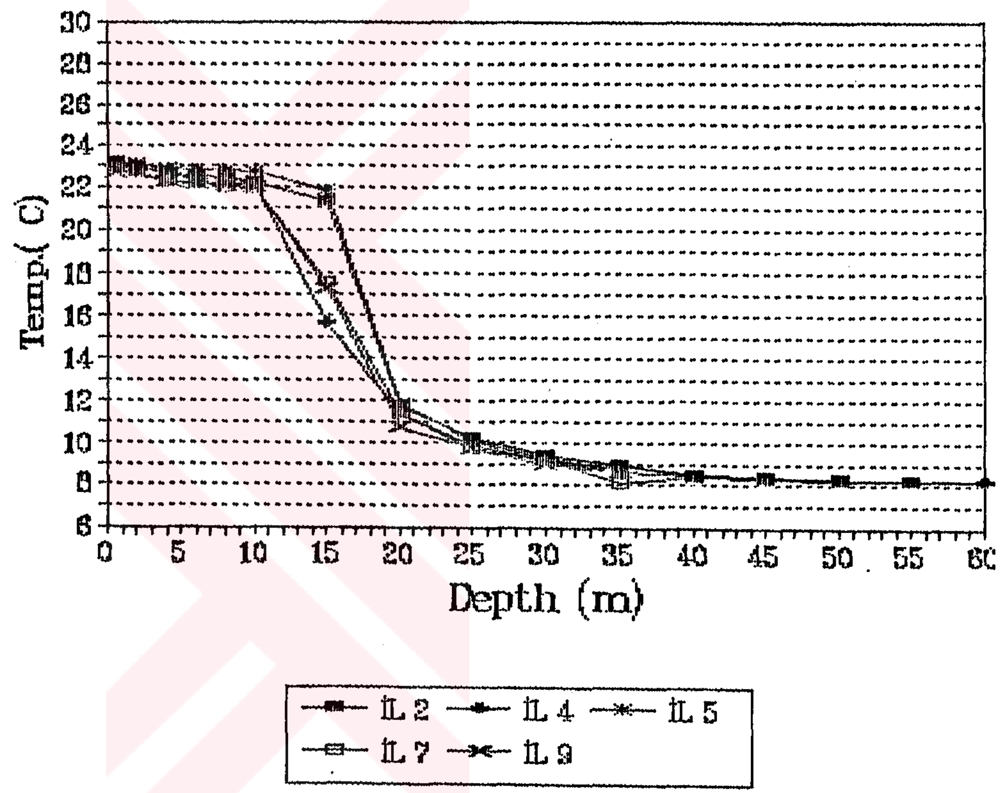


Dissolved oxygen saturation profiles .
07/07/1988

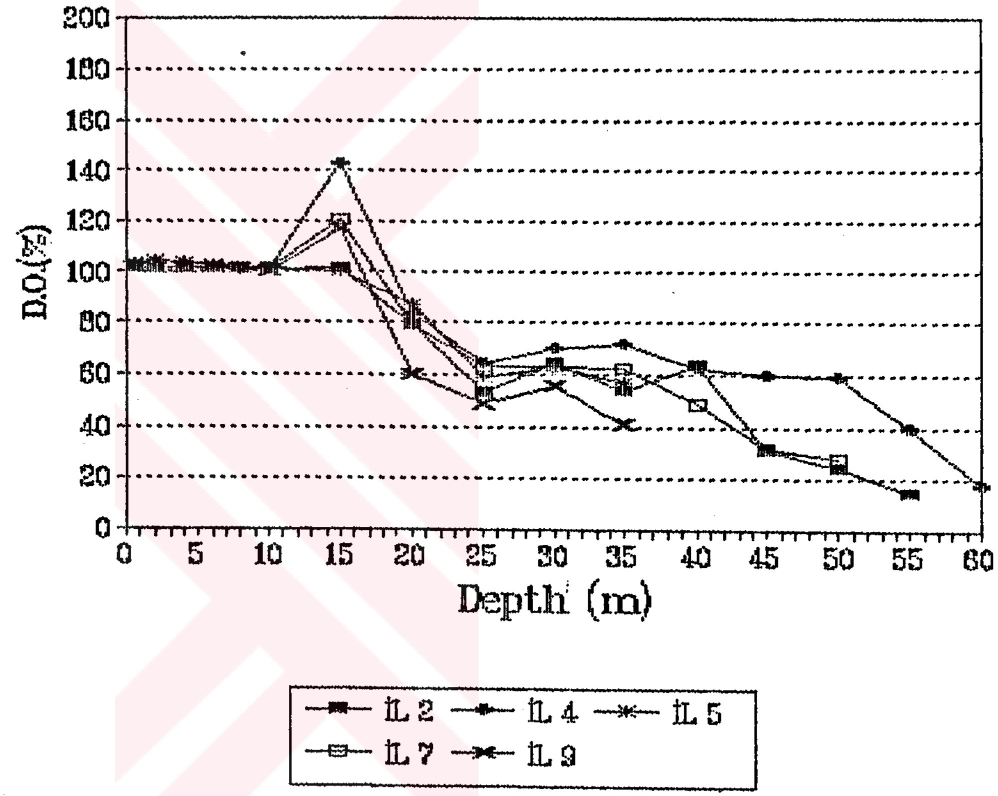
Temperature and D.O. Saturation Values Measured for Different Stations in Lake İznik .

21/09 /1988

	İL2	İL2	İL4	İL4	İL5	İL5	İL7	İL7	İL9	İL9
m	T	DO%	T	DO%	T	DO%	T	DO%	T	DO%
0.5	23.16	101.9	22.79	102	23.13	102.9	22.96	101.5	22.66	102
2	22.94	101	22.67	101	23.09	104	22.93	101.1	22.62	101.7
4	22.61	101.2	22.24	101.6	22.86	103.7	22.69	100.9	22.29	101.7
6	22.51	101	22.18	101.6	22.82	102.2	22.34	101.5	22.09	101.7
8	22.42	100.9	22.13	100.6	22.79	101.5	21.97	101.5	22.05	101.3
10	22.23	100.8	22.09	100.5	22.75	101.7	21.88	101.1	21.95	100.2
15	21.35	101.7	15.62	142.8	21.85	100.3	17.54	120.5	17.29	117
20	11.7	78.61	11.32	83.15	11.87	86.95	11.3	79.3	10.82	60.16
25	10.25	53.38	9.83	64.34	10.1	58.89	9.7	62.91	9.77	48.6
30	9.44	64.53	9.17	69.67	9.28	63.01	9.15	63.21	9.03	55.81
35	8.98	53.97	8.67	71.39	8.76	56.78	8.08	62.61	8.65	40.71
40	8.48	63.53	8.43	62.17			8.4	48.61		
45	8.36	30.73	8.31	60.03			8.35	31.55		
50	8.3	24.33	8.25	59.73			8.34	27.92		
55	8.25	14.29	8.23	39.75						
60			8.24	17.66						



Temperature profiles for different stations
21/09/1988

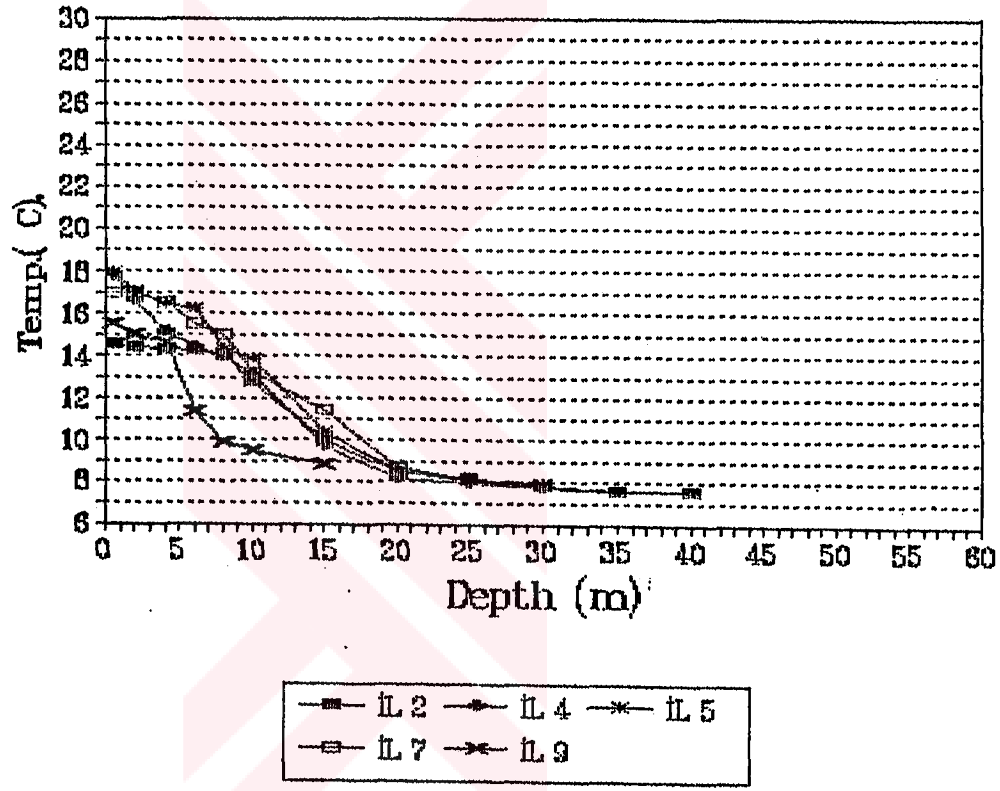


Dissolved oxygen saturation profiles .
21/09/1988

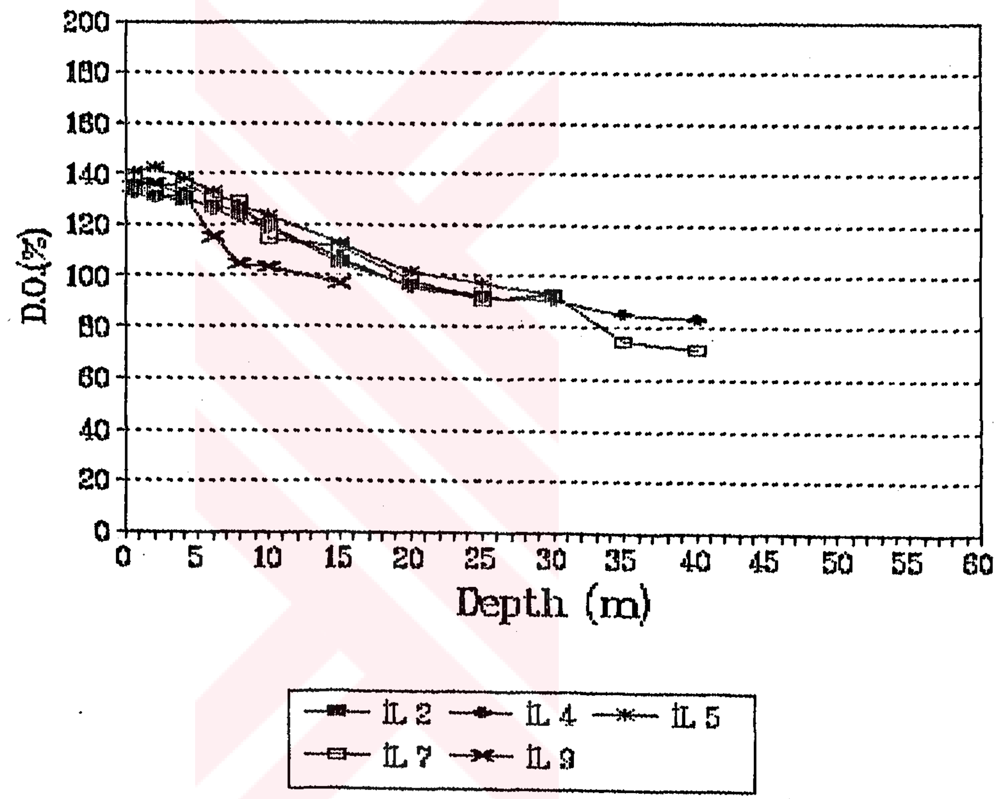
Temperature and D.O. Saturation Values Measured for Different Stations in Lake İznik .

24/04 /1989

	İL2	İL2	İL4	İL4	İL5	İL5	İL7	İL7	İL9	İL9
m	T	DO%	T	DO%	T	DO%	T	DO%	T	DO%
0.5	14.49	135.3	17.75	131.7	17.91	139.9	16.98	137.2	15.49	134.3
2	14.41	130.7	16.61	130.2	17.01	141.5	16.97	134.6	14.92	136.2
4	14.32	129.1	15.15	131	16.47	137.3	16.57	135.9	14.63	130.9
6	14.22	127.4	14.43	125.3	16.18	132.7	15.52	130.2	11.36	114.4
8	14.04	125.3	13.95	122.5	14.29	127.2	15.01	129.2	9.93	104.4
10	12.72	119.5	13.1	117.5	13.88	123.2	13.19	114.2	9.53	103.4
15	10	104.7	9.72	106.8	10.36	112.4	11.4	111	8.86	96.83
20	8.43	96.39	8.16	94.85	8.54	101.4	8.68	97.86		
25	8.2	91.9	7.97	91.28	8.07	97	8.11	90.05		
30			7.69	90.28	7.92	92.15	7.81	92.33		
35			7.57	84.78			7.61	74.43		
40			7.54	83.63			7.54	71.51		
45										
50										
55										
60										



Temperature profiles for different stations .
24/04/1989

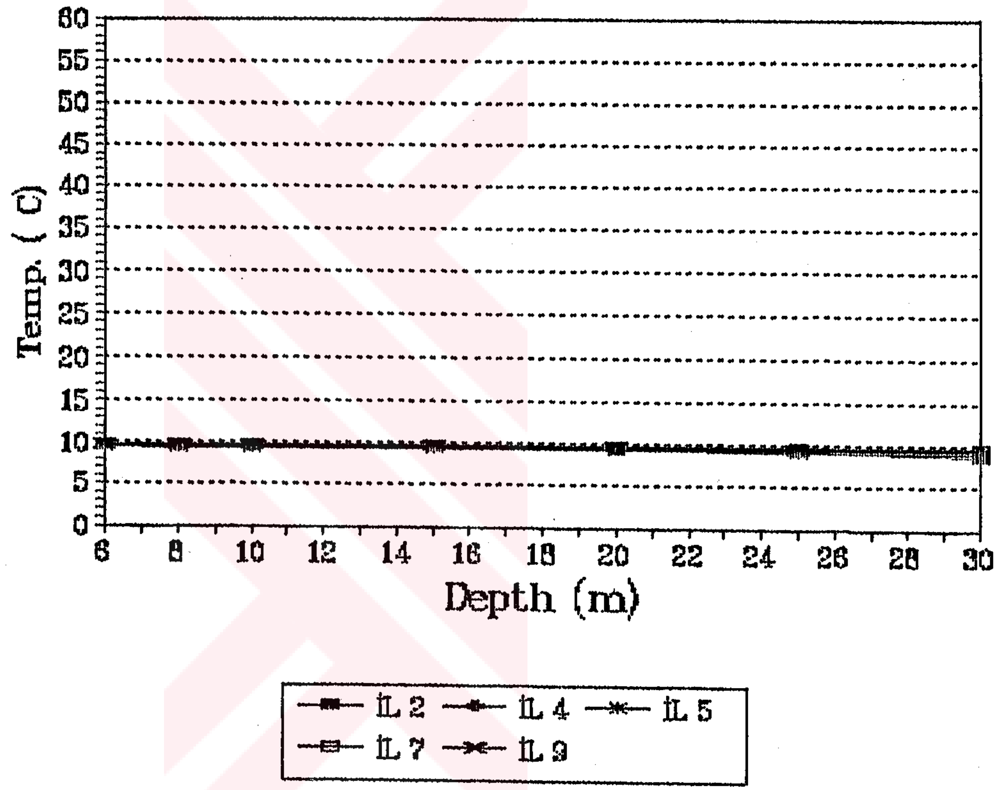


Dissolved oxygen saturation profiles
24/04/1989

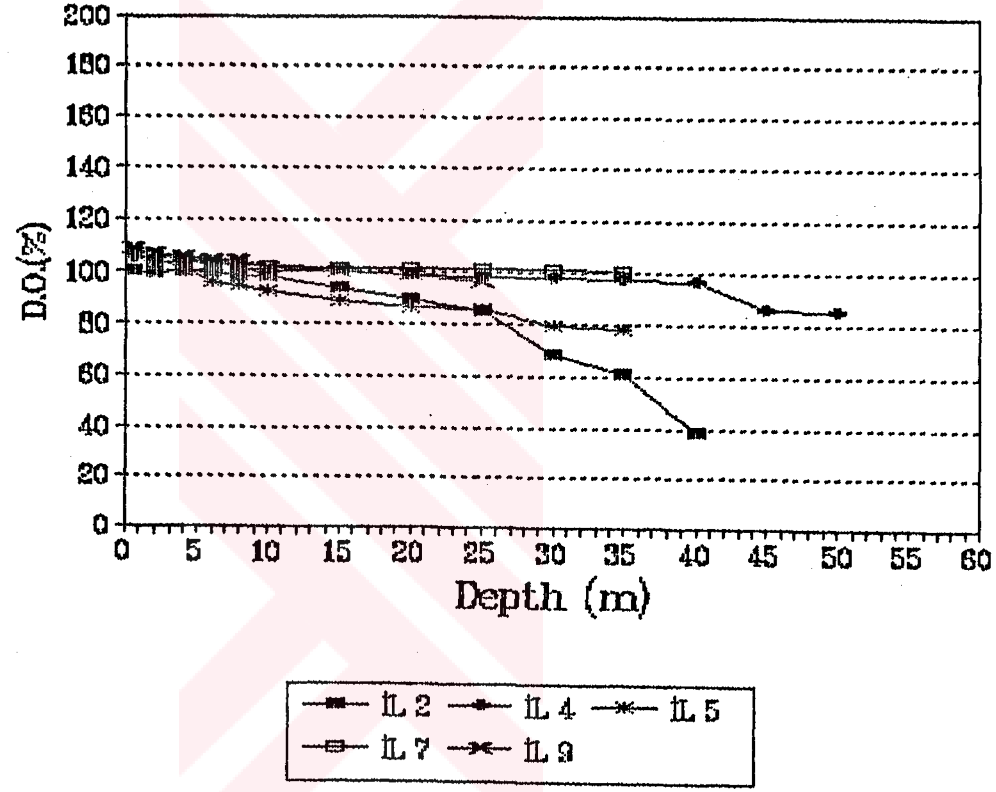
Temperature and D.O. Saturation Values Measured for Different Stations in Lake İznik .

20/12 /1989

	İL2	İL2	İL4	İL4	İL5	İL5	İL7	İL7	İL9	İL9
m	T	DO%	T	DO%	T	DO%	T	DO%	T	DO%
0.5	9.95	99.76	10	105	9.86	107.8	10.01	107.7	9.82	108.5
2	9.85	99.37	9.71	103.2	9.59	103.7	9.74	105.8	9.78	106.7
4	9.62	100.1	9.62	102.7	9.54	101	9.69	104.5	9.75	105.6
6	9.53	99.28	9.58	102.5	9.44	95.93	9.67	103.4	9.71	104.8
8	9.49	98.06	9.56	101.6	9.38	94.71	9.65	102.7	9.7	104.2
10	9.48	97.82	9.55	100.4	9.25	92.83	9.64	102.2	9.65	101.6
15	9.44	94.12	9.53	99.67	9.23	88.77	9.63	101.7	9.63	100.4
20	9.36	89.76	9.52	99.12	9.21	86.54	9.63	101.5	9.62	99.1
25	9.25	85.22	9.51	98.56	9.16	85.85	9.62	101.5	9.53	96.11
30	8.86	68.74	9.51	98.25	9.1	79.49	9.62	101.2		
35	8.72	61.49	9.51	97.76	9.09	78.32	9.62	100.8		
40	8.35	38.7	9.5	96.88						
45			9.28	86.8						
50			9.26	85.63						
55										
60										



Temperature profiles for different stations .
20/12/1989

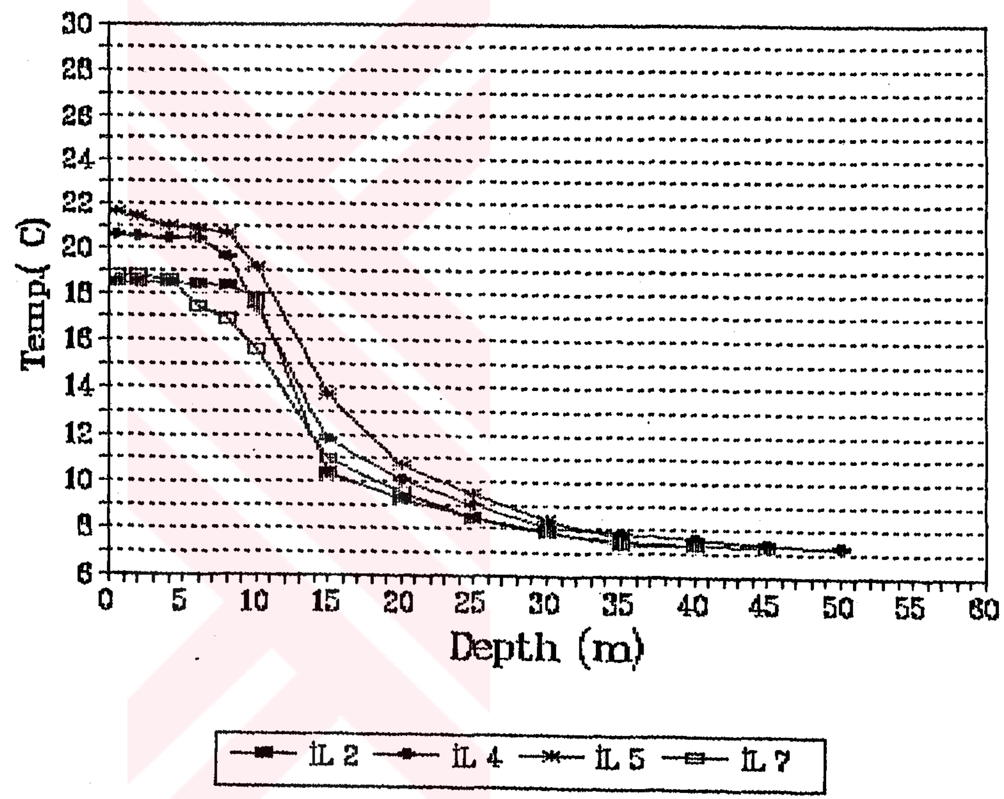


Dissolved oxygen saturation profiles .
20/12/1989

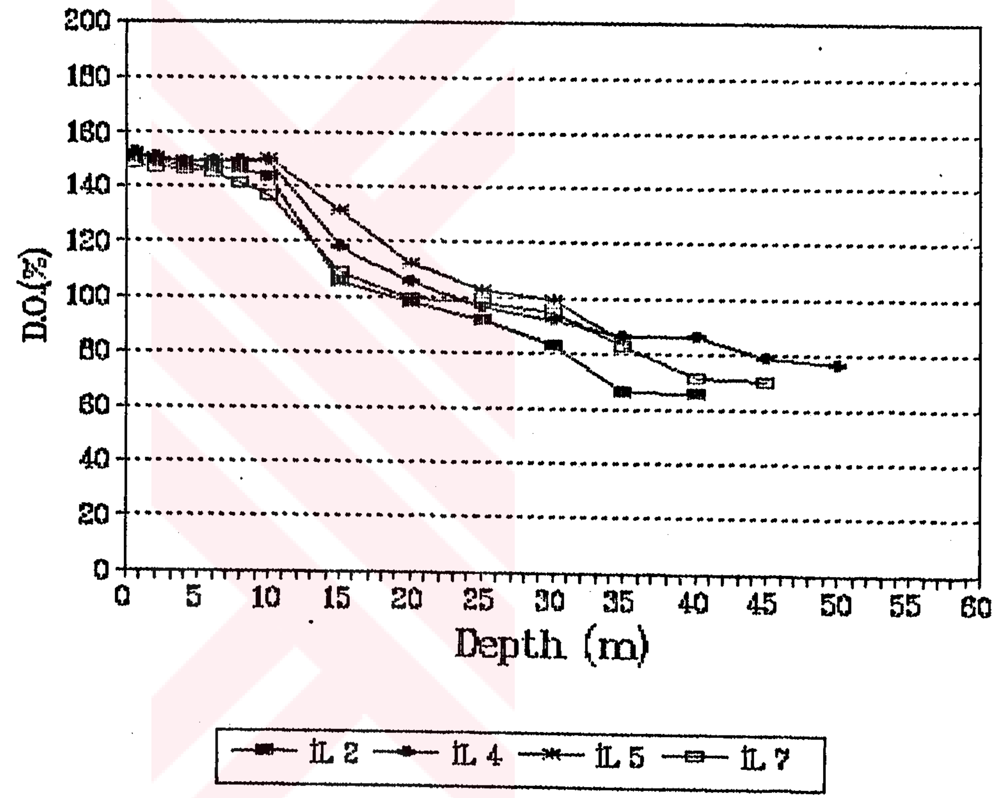
Temperature and D.O. Saturation Values Measured for Different Stations in Lake İznik .

30/05 /1990

	İL2	İL2	İL4	İL4	İL5	İL5	İL7	İL7
m	T	DO%	T	DO%	T	DO%	T	DO%
0.5	18.45	150.2	20.54	152.8	21.58	152.2	18.82	148.6
2	18.44	148.9	20.48	150.9	21.34	150.2	18.82	146.9
4	18.43	147.5	20.45	149.5	20.97	149.5	18.6	146.3
6	18.38	146.9	20.39	149.3	20.82	150	17.42	145.5
8	18.33	146.3	19.55	149.7	20.64	148.7	16.84	141.4
10	17.77	143.8	17.34	149.5	19.15	150.4	15.54	136.5
15	10.32	105.6	11.72	118.1	13.66	131	10.92	108.8
20	9.24	97.84	10.05	105.4	10.65	112.4	9.5	99.57
25	8.46	91.9	8.93	96.21	9.42	102.7	8.39	98.27
30	7.86	82.49	8.06	91.69	8.36	99.27	7.75	94.45
35	7.33	66.16	7.78	86.01	7.63	84.57	7.47	82.81
40	7.33	65.51	7.58	85.97			7.32	71.24
45			7.33	78.88			7.3	70.1
50			7.28	76.41				
55								
60								



Temperature profiles for different stations .
30/05/1990



Dissolved oxygen saturation profiles .
30/05/1990

PH VALUES

STATION	İ L 2				İ L 4				İ L 5				İ L 7				İ L 9			
DATE	S	M	B	A	S	M	B	A	S	M	B	A	S	M	B	A	S	M	B	A
09/22/86																				
11/20/86									9.1	9.1	9.1	9.1	9.2	9.2	8.9	9.1	9.2	9.2	8.8	9.1
06/09/87	8.6	8.6	8.5	8.6	8.7	8.6	8.6	8.6	8.7	8.7	8.6	8.7	8.8	8.8	8.7	8.8	8.8	8.8	8.7	8.8
09/30/87																				
10/26/87													9.1	8.9	9.2	9.1	9.1	8.9	8.8	9.9
05/04/88	8.4	8.5	8.5	8.5	8.6	8.6	8.5	8.6	8.3	8.4	8.4	8.4	8.5	8.5	8.5	8.5	8.6	8.6		8.6
07/07/88	8.8	8.6	8.6	8.7	8.8	8.6	8.6	8.7	8.8	8.6	8.6	8.7	8.9	8.7	8.7	8.8	8.9	8.9	8.7	8.8
09/20/88	8.9	8.8	8.7	8.8	8.8	8.6	8.6	8.7	8.9	8.6	8.7	8.7	8.9	8.6	8.6	8.7	8.9	8.7	8.7	8.8
04/24/89	8.8	8.6	8.7	8.7	8.6	8.6	8.6	8.6	8.5	8.4	8.3	8.4	8.9	8.5	8.7	8.7	8.7	8.6	8.6	8.6
12/20/89	8.9	8.8	8.8	8.8	8.8	8.9	8.9	8.9	8.9	8.9	8.8	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9
05/30/90	8.6			8.6	8.6	8.4	8.4	8.5	8.6	8.5	8.5	8.5	8.6	8.5	8.4	8.5				
07/16/92																				

(Source : D.S.İ. 1.Bölge Müdür.)
(S = Surface , M = Medium , B = Bottom , A = Average)

SUSPENDED SOLIDS CONCENTRATIONS (mg/l)

STATION	İ L 2				İ L 4				İ L 5				İ L 7				İ L 9			
DATE	S	M	B	A	S	M	B	A	S	M	B	A	S	M	B	A	S	M	B	A
09/22/86									6			6	6.4			6.4	5.2			5.2
11/20/86									18			18	73	37	49	53		12	43	27
06/09/87									5.6			5.6	2			2	7.6			7.6
09/30/87	67	45	33	48	6.8	11	5.2	7.7	27	35	16	26								
10/26/87													27	16	34	25	16	22	31	23
05/04/88	4.8	13	7.6	8.4	10	8.4	16	12	24	9.2	43	25	9.2	25	78	37	31	10	11	17
07/07/88																				
09/20/88																				
04/24/89																				
12/20/89	4	40	32	25	2.4	31	47	27	11	25	15	17	0.4	14	20	11	48	55	31	45
05/30/90	53			53	22			22	38			38	46			46				
07/16/92	69	66	56	64	93	40	35	56	26	91	56	57	25	23	69	39				

(Source : D.S.İ. 1.Bölge Müdür.)
(S = Surface , M = Medium , B = Bottom , A = Average)

TOTAL PHOSPHORUS CONCENTRATIONS (mg/m3)

STATION	İ L 2				İ L 4				İ L 5				İ L 7				İ L 9			
DATE	S	M	B	A	S	M	B	A	S	M	B	A	S	M	B	A	S	M	B	A
09/22/86																				
11/20/86																				
06/09/87	10	3	125	46	0	25	60	28	13	40	48	34	3	8	18	10	10	13	35	19
09/30/87	6	54	12	24	8	26	54	29	10	28	76	38								
10/26/87													7	21	75	34	32	10	88	43
05/04/88	14	40	20	25	10	24	30	21	24	10	38	24	14	10	36	20	16	16	12	15
07/07/88	0	12	3	5	0	14	54	23	0	8	26	11	0	2	16	6	0	0	0	0
09/20/88	0	32	44	25	0	20	64	28	0	32	44	25	2	26	26	18	0	0	16	5
04/24/89	38	38	38	38	72	100	74	82	84	86	110	93	86	96	94	92				
12/20/89	16	26	70	37	20	20	28	23	32	40	46	39	40	16	16	24	22	22	26	23
05/30/90	20	26	60	35	10	24	16	17	20	26	44	30	46	16	14	25	22	40	26	29
07/16/92	72	52	110	78	70	46	44	53	26	42	22	30	70	98	44	71				

(Source : D.S.İ. 1.BÖLGE MÜDÜR.)
(S = Surface , M = Medium , B = Bottom , A = Average)

THE CONCENTRATIONS OF AMMONIA-NITROGEN (mg/m3)

STATION	İ L 2				İ L 4				İ L 5				İ L 7				İ L 9			
DATE	S	M	B	A	S	M	B	A	S	M	B	A	S	M	B	A	S	M	B	A
09/22/86									320	255	345	307	40	170	355	188	240			240
11/20/86									45	95	100	80	200	450	155	268	110	310	435	285
06/09/87	230	215	240	228	130	70	285	162	35	232	250	172	420	340	195	318	206	215	250	224
09/30/87	120	115	75	103	215	435	310	320	390	680	265	445								
10/26/87													509	266	225	333	240	280	222	247
05/04/88	75	135	140	117	110	75	13	66	500	300	300	367	255	230	257	257	205	212	310	242
07/07/88	50	0	45	32	70	0	10	27	70	0	115	62	35	110	165	103	20	125	140	95
09/20/88	0	55	45	33	75	90	165	110	35	135	40	70	20	110	55	62	15	25	30	23
04/24/89	0	100	0	33	65	60	150	92	0	0	0	0	0	0	0	0	45	0	150	65
12/20/89	115	40	90	82	100	45	25	57	25	10	55	30	0	0	110	37	90	175	125	130
05/30/90	549			549	508	365	591	488	278	393	504	392	444	296	508	416				
07/16/92	36	31	34	34	31	39	30	33	23	24	24	24	24	25	25	25				

(Source : D.S.İ. 1.Bölge Müdür.)
(S = Surface , M = Medium , B = Bottom , A = Average)

THE CONCENTRATIONS OF NITRITE-NITROGEN (mg*10/m3)

STATION	İ L 2				İ L 4				İ L 5				İ L 7				İ L 9			
DATE	S	M	B	A	S	M	B	A	S	M	B	A	S	M	B	A	S	M	B	A
09/22/86									0	18	136	51	0	8	18	9	54			54
11/20/86									74	74	89	79	0	0	0	0	45	0	0	15
06/09/87	0	0	7	2	0	0	3	1	40	18	43	34	40	36	40	39	32	43	18	31
09/30/87	14	47	72	44	0	14	10	8	14	18	0	11								
10/26/87													0	0	0	0	0	0	0	0
05/04/88	33	36	47	39	25	33	36	31	80	7	58	48	29	34	11	25	58	22	7	29
07/07/88	0	0	10	3	17	102	222	114	72	6	68	49	0	3	6	3	0	0	54	18
09/20/88	0	14	10	8	32	43	32	36	36	76	40	51	43	65	65	58	0	10	7	6
04/24/89	104	100	107	104	107	100	93	100	104	107	86	99	114	107	117	113	45	42	52	46
12/20/89	31	27	42	33	27	20	27	25	27	31	27	28	27	24	49	33	38	27	34	33
05/30/90	30			30	20	10	30	20	30	20	20	23	10	10	20	13				
07/16/92	20	30	20	23	20	50	20	30	10	30	30	23	30	60	30	40				

(Source : D.S.İ. 1.Bölge Müdür.)

(S = Surface ,M = Medium , B = Bottom , A = Average)

THE CONCENTRATIONS OF NITRATE-NITROGEN (mg/m3)

STATION	İ L 2				İ L 4				İ L 5				İ L 7				İ L 9			
DATE	S	M	B	A	S	M	B	A	S	M	B	A	S	M	B	A	S	M	B	A
09/22/86									6	21	29	19	3	6	21	10	2			2
11/20/86									4	2	3	3	1	61	76	46	9	21	37	22
06/09/87	2	9	11	7	4	10	27	14	1	2	8	4	23	7	13	14	6	5	13	8
09/30/87	14	20	17	17	7	22	40	23	27	31	37	32								
10/26/87													33	23	16	24	23	18	7	16
05/04/88	1	13	15	10	1	5	35	14	74	5	7	29	32	10	14	19	9	14	38	17
07/07/88	5	9	14	9	18	20	50	29	14	9	20	14	1	1	14	5	7	17	48	21
09/20/88	12	23	12	16	10	12	1	8	4	5	5	5	2	2	26	10	14	18	17	16
04/24/89	3	11	7	7	9	7	17	11	54	14	32	33	37	28	0	22	20	10	19	16
12/20/89	10	13	17	13	10	6	16	11	6	24	13	14	27	26	14	22	12	26	19	18
05/30/90	13			13	4	10	16	10	4	5	13	7	26	12	27	22				
07/16/92	4	6	10	7	40	24	34	33	58	46	20	41	60	16	64	47				

(Source : D.S.İ. 1.Bölge Müdür.)

(S = Surface , M = Medium , B = Bottom , A = Average)

CHLOROPHYLL-a CONCENTRATIONS (mg/m3)

STATION	İ L 2				İ L 4				İ L 5				İ L 7				İ L 9			
DATE	S	M	B	A	S	M	B	A	S	M	B	A	S	M	B	A	S	M	B	A
09/22/86									4.38				8.06				2.43			
11/20/86									1.45				0.56				1.69			
06/09/87	2.5				3.2				2.95				2				4.34			
09/30/87	4.48				5.81				3.61											
10/26/87													6.14				5.76			
05/04/88	0				0.35				2.09				1.27				2.34			
07/07/88	0.82				1				2.89				1.91				2.6			
09/20/88	0.36				1.08				0.18				0.94				1.17			
04/24/89	4.7				9.94				14.1				11.7				9.34			
12/20/89	1				1.74				1.39				1.74				0.7			
05/30/90	4.13				2.43				5.82				3.17							
07/16/92	4				3.34				3.61				4.7							

(Source : D.S.İ. 1.Bölge Müdür.)

(S = Surface , M = Medium , B = Bottom , A = Average)

REFERENCES

Barth T.W.F.,Theoretical Petrology,Wiley,New York,1972 .

Blazka,P.,"Cycles,Forms and Availability of Phosphorus in Fresh Water," in H.Tiessen(Ed.),Phosphorus Cycles in Terrestrial and Aquatic Ecosystems,pp.232-243,Univ. of Saskatchewan,Canada,1989.

Brink,N.,"Factors Affecting Mass Transport From Farmland" in J. Paavalainen,P.Vakkilainen(eds.) Proc. International Seminar on Land Drainage,pp.456-473,Helsinki University Technol.,1986.

Broberg,O. and G.Persson,"External Budgets for Phosphorus , Nitrogen and Dissolved Organic Carbon for the Acidified Lake Gardsjön," Arch.Hyrobiol.,Vol.99,pp.160-175,1984.

Carlson,R.E.,"A Trophic State Index for Lakes,"Journal of Limnology and Oceanography,Vol.22(2),pp.361-369,1977.

D.S.İ.1.Bölge Müdürlüğü,İznik Gölü Hidrolojisi Planlama Ek Raporu,Bursa,1984.

House,W.A. and H.Casey,"Transport of Phosphorus in Rivers,"in H.Tiessen(Ed.),Phosphorus Cycles in Terrestrial and Aquatic

Ecosystems,pp.253-282,Univ. of Saskatchewan,Canada,1989.

Jeffers,N.J.,Systems Analysis and Modeling Strategies in Ecology.The Use of Mathematical Models in Water Pollution Control.University of New Castle,U.K,1973.

Jones,J.R. and R.W.Bachmann,"Prediction of Phosphorus and Chlorophyll Levels in Lakes,"Journal WPCF,Vol.48,pp.2176-2182 ,1976.

Karpuzcu,M.,Suların Besi Maddesi İle Kirlenmesi ve Bir Matematik Model,Teknik Rapor,41,İTÜ,1982.

Kauppi,L.,"Effects of Drainage Basin Characteristics on the Diffuse Load of Phosphorus and Nitrogen,"Publ. Water Res. Inst.,National Waters Board,Finnland NO:30,pp.21-41,1984.

Keller,H.M.,"The Export of Nutrients from Forest Lands. A literature Review,"in G.Jolankai and G.Roberts(eds.),Land Use Impacts on Aquatic Systems,pp.35-50,Budapest,1983.

Linsley,R.K. and J.B.Franzini,Water Resources Engineering, Magraw-Hill,International Student Edition,1984.

Lorenzen,M.W.,"Predicting the Effects of Nutrient Diversion on Lake Recovery" in E.J.Middlebrooks, D.H.Falkenborg and T.E.Maloney(Eds.),Modeling the Eutrophication Process, pp.205-211,Ann Arbor Science,1973.

Mater,B.,İznik Gölü ve Çevresinin Kirlilik İrdelenmesi,1. Teknik Rapor.İstanbul,1988.

Ryding,S.O.,"On the Role of the Relative Distribution of Nutrient Supplies to and Nutrient Losses from Drainage Basins and Potential Production of Runoff Waters as Managerial Tools When Planning Land Use Impacts on Aquatic Ecosystems," in G. Jolanka and G.Roberts(eds.),Land Use Impacts on Aquatic Systems,pp.238-255,Budapest,1983.

Soyupak,S.,A.F.Çilsiz,N.Yücel,T.Torunoğlu,E.Şentürk and A. Kaya,"Keban Baraj Gölünde (Palu-Elazığ Arası) Su Kirlenmesi Problemi,"Doğa Tr. J. of Engineering and Env.Sciences,Tübitak ,Vol.17,pp.301-314,1993.

Sonzogni,W.C.,P.C.Uttormak and G.F.Lee,"A Phosphorus residence Time Model:Theory and Application,"Journal of Water Research,Vol.10,pp.429-435,1976.

Stumm,W. and J.J.Morgan,Aquatic Chemistry,Wiley-Inter-science ,New York,1970.

Uttormak,P.D.,J.D.Chapin and K.M.Green,Estimating Nutrient Loadings of lakes from nonpoint sources.EPA 660/3-74-020 Environmental Protection Agency.Washington.112-1974.

Vetz,C.J.,Applied Streams Sanitation,Wiley-interscience,New York,1970.

Vollenweider,R.A.,"Possibilities and Limits of Elementary Models Concerning the Budgets of Substances in Lakes,"Arch. Hydrobiol.,Vol.66,pp.1-36,1969.

Vollenweider,R.A.,"Advances in Defining Critical Loading Levels for Phosphorus in Lake Eutrophication,"Mem.Ist.Ital. Idrobiol.,Vol.33,pp.53-83,1976.

Vollenweider,R.A.,"Scientific Fundamentals of the Eutrophication of Lakes and Flowing Waters,With Particular Reference to Nitrogen and Phosphorus as Factors in Eutrophication," OECD,Paris,1971.

Whittaker,R.,Communities and Ecosystems,Macmillan,New York, 1975.

REFERENCES NOT CITED

Bachmann.R.W. and J.R.Jones,"Phosphorus Inputs And Algal Blooms In Lakes,"Iowa State Journal of Research.Vol.49, pp.155-160,1974.

Baş,Z. and M.Oğuz,"Statistical Eutrophication Modelling of the Lakes in Isparta and Its Environs,"Inter. Jor. Env. Studies,Vol.36,pp.285-302,1990.

Chapra,S.C.,"Total Phosphorus Model For the Great Lakes," Journal of the Env. Eng. Div.,Vol.12846,pp.147-161,1977.

Chen,C.W.,"Concepts and Utilities of Ecologic Model,"Proc.A. Soc. Civil Eng. Journal of Sanitary Eng. Div. Vol.96,1970.

Dillon,P.J. and F.H.Riger,"The Phosphorus-Chlorophyll Relationship in Lakes,"Limnology and Oceanography J. Vol.19 pp.767,1974.

Dillon,P.J.,"The Application of the Phosphorus Loading Concept to Eutrophication Research,"Scientific Series NO 46 Inland Waters Directorate,Ontario,Canada,1975.

D.S.İ.1.Bölge Müdürlüğü,"İznik Gölü Revizyon Raporu,"Bursa, 1975.

Emery,R.M.,C.E.Moon and E.B.Welch,"Delayed Recovery Of a Mesotrophic Lake After Nutrient Diversion,"Journal WPCF Vol. 45 pp.913,1973.

Imboden,D.M.,"Phosphorus Model of Lake Eutrophication,"Jour. of Limnology and Oceanography,Vol.19,pp.297-304,1974.

Karpuzcu,M.,Çevre Mühendisliğine Giriş,İ.T.Ü.,1984.

Kirchner,W.B. and P.J.Dillon,"An Empirical Method Of Estimating the Retention Of Phosphorus In Lakes,"Water Resources Research,Vol.11,pp.182,1975.

Lee,G.F. and R.A.Jones,"Recent Advances In Assessing Impact Of Phosphorus Loads On Eutrophication-Related Water Quality," Water Resources Vol.16,pp.503,1982.

Likens,G.E.(Ed.),"Nutrients and Eutrophication,"Special Symposia,The American Society of Limno.and Ocean.,Vol.1,1972.

Lorenzen,M.W.,D.J.Smith and L.V.Kimmel,"A Long Term Phosphorus Model for Lakes:Application to Lake Washington,"in Modeling Biochemical Progresses in Aquatic Ecosystems, pp.75 - 91.

Lung,W.S.,R.P.Canale and P.L.Freedman,"Phosphorus Models for Eutrophic Lakes,"Jour. of Water Research,Vol.10,pp.1101 -

1114 ,1976.

Snodgrass,W.J. and C.R.O'Melia,"Predective Model for Phosphorus in Lakes,"Journal of Env.Sci.and Tech.Vol.9, pp.937-944,1975.

Standard Mrthod for the Examination of Water and Waste Water, New York,1976.