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THE NORTHERN NILE DELTA LAKES AND THEIR FISHERIES

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THE NORTHERN NILE DELTA LAKES AND THEIR FISHERIES

I. INTRODUCTION

This paper presents an overview of the northern Egyptian Nile delta lakes, highlighting those factors which best characterize the fishery or agricultural development potentialities. The four lakes, Maryut, Edku, Burullus, and Manzala, are littoral lakes along Egypt's Mediterranean coast. Maryut and Edku are small lakes near Alexandria; Burullus is a long thin lake in the mid-delta region, and Manzala is located on the eastern end of the delta extending from the Damietta branch of the Nile to Port Said (Figure 1).

The River Nile, greater than 6,700 km in total length, drains an area of about three million square kilometers. During the years 1958-64, it was estimated that the annual sediment load of the Nile was 111 million tons (Holeman, 68) and that the average annual discharge at the sea was 89,297 million cubic meters. By 1979, the annual discharge from the Aswan High Dam was in the order of 55,500 million cubic meters per year, resulting in a discharge to the sea of 26,635 million cubic meters, which included 7,165 million cubic meters of irrigation water and 19,470 million cubic meters of drainage water (Mancy, 80). The Nile divides into two branches some 20 km northwest of Cairo, which is itself about 170 km from the Mediterranean coast. The Rosetta branch to the west is 239 km long, while the Damietta branch to the east is about 245 km long. It is these branches, and the canals that lead from them, that provide water

Figure 1

Map showing the location of Lakes Maryut, Edku, Burullus and Manzala. The lakes are adjacent to the Mediterranean Sea, and lie between the cities of Alexandria in the west, and Port Said in the east.

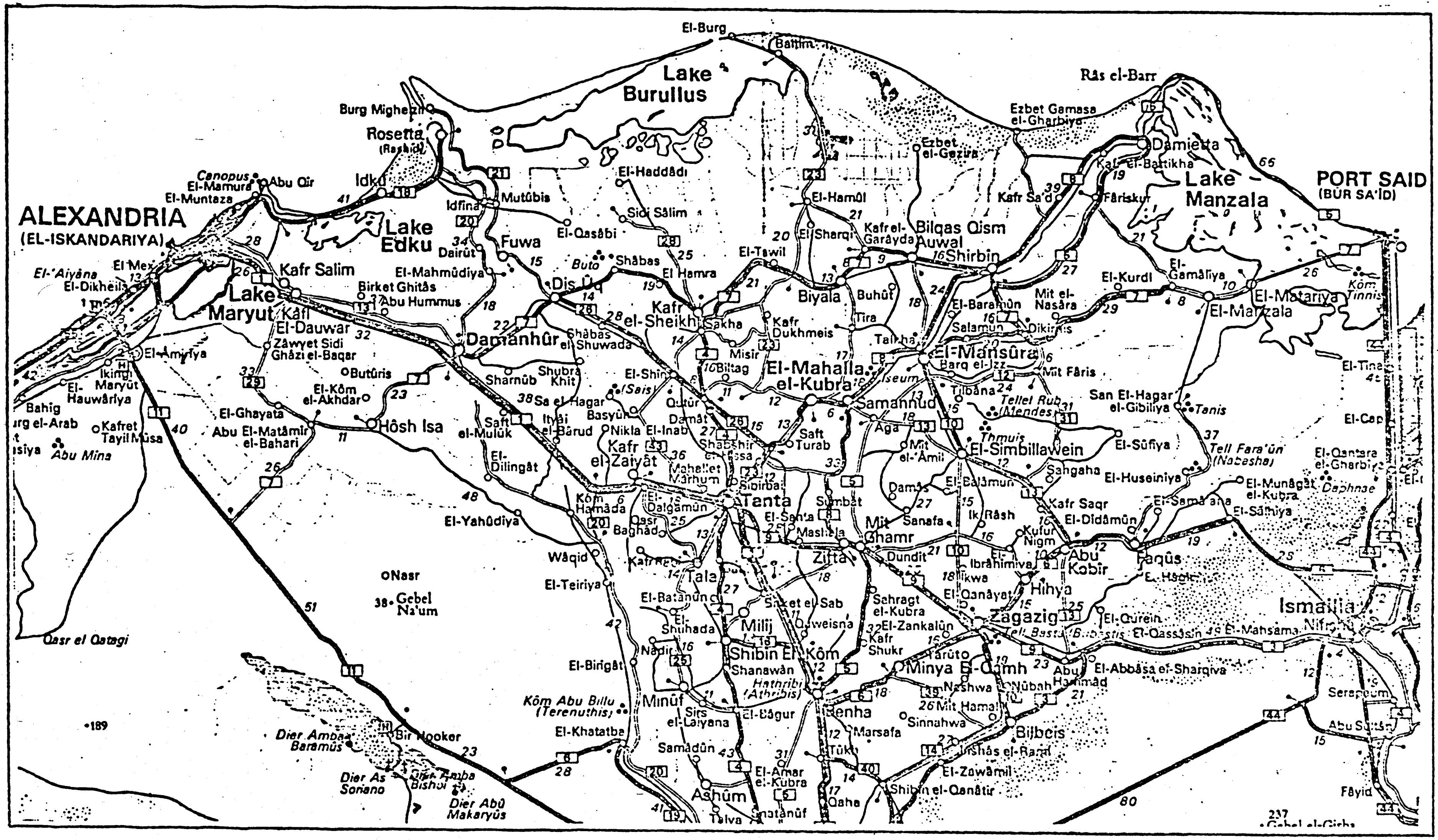

FIGURE 1 LOCATION OF LAKES

for the agricultural activities of the Nile delta, and ultimately feed the four northern delta lakes.

As the proximate reservoirs of the Nile water before it flows to the Mediterranean, these lakes are the sites of the last Egyptian uses of the water. On the one hand, this offers opportunities for sewage and waste processing as well as for fish production; on the other hand, the quantities and qualities available to the lakes are determined by up-river activities and their requirements, not by the requirements of the productive activities within the lakes.

Over the past twenty years, the four northern lakes have produced between 40-50% of the total Egyptian fish landings and fishing incomes. The Ministry of Agriculture estimates that in 1980 the lakes yielded 72,000 metric tons of fish, or about 45% of the total Egyptian landed fish catch. It has been estimated that with improved fishing methods and fishery management practices the lakes could have produced upwards of 100,000 tons of fish in 1980, an increase of about 40% (Chase Trade Information Corporation, 82). The Ministry of Agriculture projects that the actual fish yields from the northern lakes can be tripled by the year 2000. Constraints on achieving these goals will be identified and discussed throughout this paper.

These lakes currently have an area of about 394,000 feddans. If the hypersaline portion of Lake Maryut is disregarded, there are 373,670 feddans, Today these lakes are about 26% smaller than they were in the 1953-55 period, largely due to large scale public land reclamation projects which have drained parts of the lakes for conversion to agricultural uses, although small scale private land reclamation efforts, silt build-up, and growth of reeds and vegetation have all been factors in reducing the size of the lakes. Further reclamation plans for the northern lakes by the Egyptian government amount to more than half of the currently remaining areas (El Kholei, 80).

A general view of the alternatives for development for the four northern lakes has been presented by El Kholei (80). The basic policy issues regarding the development of these northern lake resources are where, when, how, and to what extent fisheries should be promoted and where, when, and how these lakes should be reclaimed for agricultural uses. A review of past reclamation experiences in the lakes' region is required to highlight the possibilities and the constraints on socially profitable alterations of these lakes. Similarly, a review of the efficiency and productivity of the lakes as fisheries is required to determine the alternative development potential of the fishing resources of these lakes.

This paper first presents an historical description of the development of the resources of each of the four lakes. Having established the history and current resource status of each of the lakes, the paper then examines the crucial issues facing policy makers regarding the optimal development of the lakes' resources.

This study makes four contributions: 1) it compiles in one source an overview of the resources of each delta lake; 2) it presents original estimates of the areas of the lakes, as measured by Landsat satellite imagery (see Appendix); 3) it presents an analysis of the value of the northern lakes fisheries; and

4) it identifies several crucial research questions requiring answers for determining the optimal uses of these northern Egyptian lakes.

II. LAKE MARYUT

A. Physical Description:

Lake Maryut is a long, thin lake along the Mediterranean coast extending southeastward from Alexandria, which separates the lake from the sea in the northern section of the lake. The lake is effectively compartmentalized into distinct areas by roads, canals and drains. The freshwater areas near Alexandria, north of the Mersha Matruh causeway, are referred to as the lake proper, the area of which is 16,240 feddans. (See Figures 2c and 3.) In the long extension from the Mersha Matruh causeway to the southwest the water is saline to hypersaline and extremely shallow. When approaching Alexandria by car along the Cairo-Alexandria Desert Road, the first sight of Maryut is of this southwest extension, which is usually a reddish color due to aquatic organisms tolerant of high salinity.

The lake proper, which is dark blue in Figure 3, is itself divided into four areas by the Cairo-Alexandria Desert Road running to the northeast and the Umum Drain running to the northwest. The northern sections of the lake proper, located north of the Umum Drain, occupy about 6,200 feddans and comprise Lake Maryut's fishery, the most important part of which is the NW section. The SW and SE sections, located south of the Umum Drain, are usually referred to as drainage basins and are not very productive for fishing. Lastly, the lake is further compartmentalized by the Nubaria Canal which enters the lake from the edge of the land reclamation El Nahda Scheme in the south, runs northward through the SE section, across the desert road, across the SW section, the Umum Drain, and finally runs westward

Figure 2

Changes in the Size and Shape of Lake Maryut During the Period 1955-1981

2 a L. Maryut in 1955, redrawn from topographical maps.
2 b L. Maryut in 1973, drawn from Landsat imagery.
2 c L. Maryut in 1981, drawn from Landsat imagery.

During the period 1955-1973, considerable portions of L. Maryut were either reclaimed for development or allowed to dry out. The remaining lake area is compartmentalized as a result of the building of road, rail, and waterways. There has been little change in lake size between 1973 and 1981. The reed beds, however, are more extensive and there is considerable commercial activity within the southern extension.

Key

Reed beds and/or marshland.

Reed beds and/or other aquatic vegetation.

--- Approximate outline of southern extension.

FIGURE 2 LAKE MARYUT

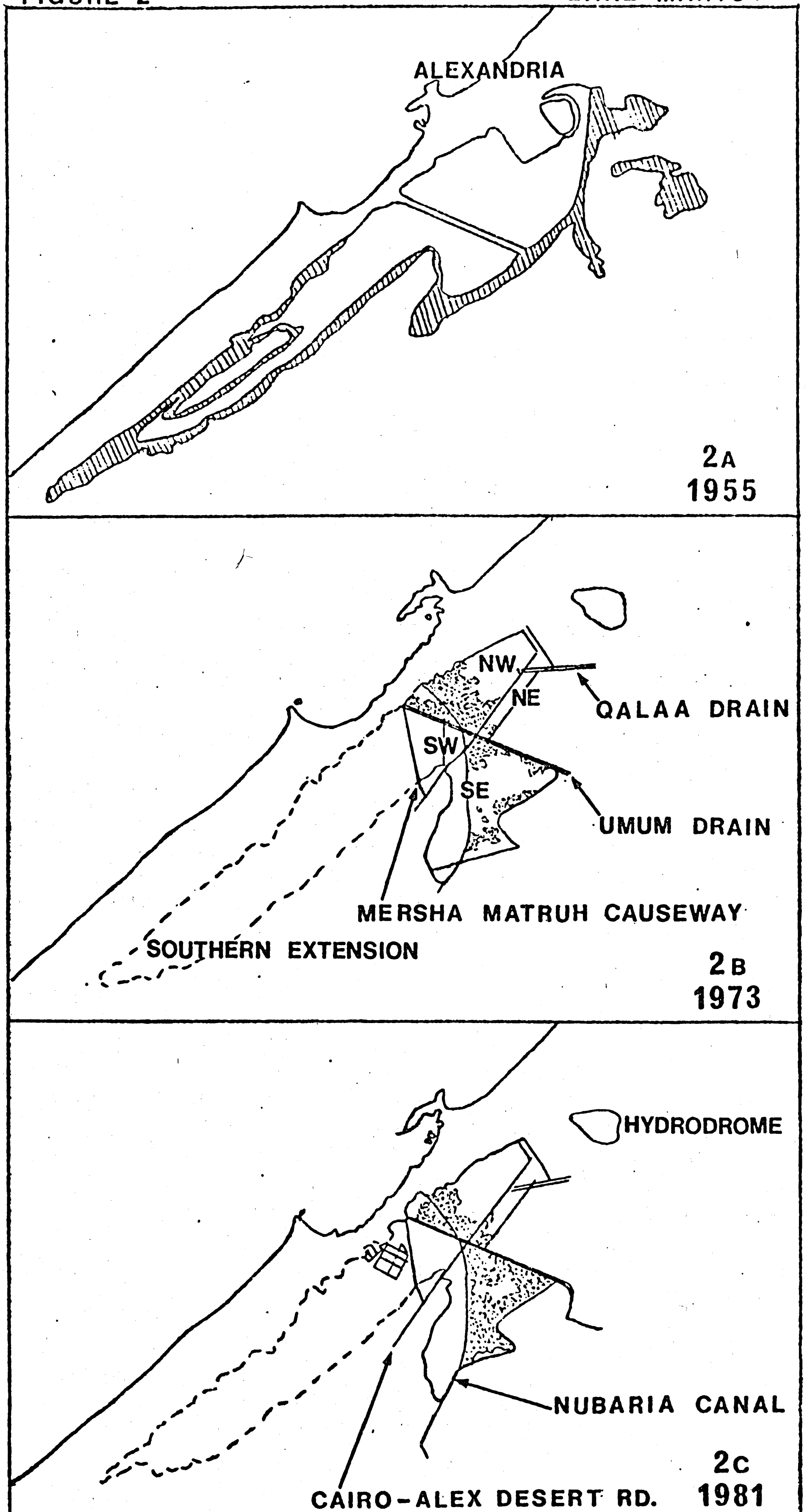

Figure 3

across the edge of the NW section.

Maryut's water sources are the Umum Drain and the Qalaa Drain, which drain the Beheira Governorate, Alexandria's urban and industrial wastes, and a few small drainage outfalls. Lake depth rarely exceeds 120 cm (Aleem and Samaan, 69a). Since the lake surface is maintained at about 3 m below sea level, this means that the lake bottom is generally 3-4 m below sea level. Lake Maryut is the only one of the northern delta lakes being studied that does not have a lake-sea opening, or boughaz. The lake is maintained at the desired level by the El Mex Pump Station which lifts the water from Maryut and discharges it into a short channel that carries the water to the sea.

B. Water Quantity and Quality:

There is some disagreement in the literature regarding the major source of water for Lake Maryut. El Wakeel, Morcos and Mahlis (70), state that the major source of water is the Umum Drain. Other sources also mention seepage from the Umum Drain as being a significant input. Wahby and El Moneim (79) say that the Qalaa Drain is practically the only source of water. The other sources of water for the lake primarily arise from the wastes of the city of Alexandria. There are three sewer outfalls on the Kabbary Road (Wahby and El Moneim, 79), and the Industries Pump Station discharges 31,000 cubic meters per day into the northeast corner of the NE section of the lake.

The only "unpolluted" water sources are the Umum Drain and the few other small drainage outfalls. The phosphate concentration in the Umum Drain is a moderate 0.11 gm per cubic meter

(Wahby and El Moneim, 79). All the other water inputs are polluted, since even the Qalaa Drain receives sewage and industrial wastewater, giving it a high phosphate concentration of 1.61 gm per cubic meter (Wahby and El Moneim, 79) and a chloride concentration of 9.7 gm per liter (Wahby, Kinawy, El Tabbach, & Moneim, 78).

Average rainfall is about 200 mm per year, falling between December and February, and evaporation is between 84 and 189 mm per month, averaging 1550 mm for the year (Aleem and Samaan, 69a).

Most of the data that follows on water quality was obtained for the NW and NE sections of the lake by Aleem and Samaan (69a, 69b) and Wahby, Kinawy, Tabbach, and Moneim (78). The water temperature varies between 12 degrees centigrade in the winter and 29 degrees centigrade in the summer. The dissolved oxygen concentration is usually between 5-6 gm per cubic meter, though it varies from anoxic to about 11 gm per cubic meter. The pH lies between 6-11, and nitrate concentrations have shown peaks of 1.1-1.6 in winter and low values of 0-0.2 gm per cubic meter in the summer. Phosphate phosphorus concentrations are from 0.6-2.5, with a lake average of 0.99 gm per cubic meter. The values for chloride concentrations average 3.5 gm per liter, ranging from 1-19.89 gm per liter, the highest value being about the salinity of seawater.

C. Soils:

The soils along the perimeter of the lake are highly variable. Soils to the east of the lake proper, in the Abis Scheme reclamation area (Figure 3), range from clay and clay loam topsoils to more permeable clay loam or sandy loams in the subsoils. Subsoil shell layers are also present, giving the soils a good calcium carbonate concentration. The soils of the El Nahda Scheme reclamation project, located south and east of the lake, are more variable. In the more elevated areas to the west the soils are sandy, while to the east are finer textured clay soils of lacustrine origin. The soils between Maryut and the Mediterranean Sea are composed of Mediterranean coastal sands (Hunting, 80).

The sediments on the bottom of the lake are mainly derived from the suspended load carried into the lake by the drain waters, resulting in silts and clays near the drains grading into a clay-silt-sand mixture as one goes further from the drains. The soils of the lake contain about 8.25% organic matter and have an average grain size of 42.5 μ (El Wakeel and Wahby, 70c).

D. Vegetation and Agricultural Activity:

The city of Alexandria occupies the land along the western shores of Lake Maryut, and as one travels southwest the urban sprawl gives way to desert. Desert conditions also prevail along the eastern side of the saline portion of the lake all the way to the Desert Road. The only agricultural activity in the region of the lake is in the El Nahda Scheme, in the Abis Scheme, and in the area between the lake and the hydrodrome, a 1,200 feddan freshwater lake formerly part of and to the northeast of Maryut.

The productivity of the soils in the El Nahda Scheme is highly variable, though broad beans, wheat, barley, maize, watermelons and vegetables are grown. The density of vegetation, shown as the color red in Figure 3, is clearly much lower in the El Nahda Scheme than in the Abis Extension and the agricultural lands to the east of Maryut. Although the soils are of good agricultural quality in the Abis area, the agricultural productivity has fallen short of expectations because of irrigation water shortages and high soil salinity caused by poor drainage and a high water table, which reaches as high as 0.2 meters in some areas (Hunting, 80).

The density of the reed beds in Lake Maryut (the red area within the lake in Figure 3) is an inverse function of water salinity. Thus, there is no vegetation in the lake south of the Mersha Matruh Causeway, nor is there any vegetation in the basins west of the Nubaria Canal. *Phragmites* (reeds) grow along the margins of the rest of the lake, especially near the El Mex Pump Station and the Umum Drain. *Typha* (bullrushes) is found with the *Phragmites* at the margins of the Umum Drain (Aleem and Samaan, 69b). *Potamogeton* (pondweed) is found in the NE area (Wahby and El Moneim, 79).

E. Lake Maryut Fishery:

Lake Maryut has the most productive fishery of any of the delta lakes in terms of landed fish catch or income generated per feddan. In 1977, Maryut produced 13,300 tons of fish, for an average of 4.42 tons for each of the lake's 3,009 licensed fishermen. This catch was valued at LE 6.8 million, or LE 2,260 per fisherman. The average net income produced for the 1970-77 period was LE 1,189 per fisherman, more than 6 times that of Lake Edku, more than 3 times that of Burullus, and 93% of that in Manzala. The average catch for 1970-77 per feddan (based on the 1973 lake area estimate) was 0.424 tons, almost 8 times that of Edku, more than 6 times that of Burullus and more than 4 times that of Manzala.

In 1977, there were 1,003 licensed boats, all of which were third class boats and nearly all of which were small canoe-like faloukas. A wide variety of fishing gear is used, with net fishing being the most common; however, as in every lake, almost every method of fishing technique is used, including common methods such as wire traps and catching by hand (Bisso, 81). The most productive areas in the NW and NE sections of the lake are intensively fished, and the fishing as well as the marketing is well organized. Most of the official fish catch is marketed through the Alexandria Fish Marketing Company.

Since Lake Maryut has no lake-sea connection, there is no recruitment of fish from the sea. There are eels, carp, and catfish among the catch, but throughout the 1970's, Maryut's catch was between 90-95% Tilapia, a low-value, but highly productive, rapidly maturing fish that thrives in Maryut's nutrient rich waters.

F. Development History and Alternatives:

Lake Maryut, of all the delta lakes, is the one that has been most adapted to agricultural, fishery, urban, and industrial uses.

It is difficult to state an accurate figure for the total area of Lake Maryut. Rzoska (76) reported an area of 62,000 feddans. Measurement of the lake area from 1955 topographical maps yielded a figure of 54,770 feddans for the entire water body, of which about 34,900 feddans was open water. The area of the lake to the north of the Mersha Matruh Causeway in 1955 was 31,370 feddans. This study focuses on the area of the lake proper, since the southeastward saline extension of the lake has been effectively separated from the rest of the lake and is used only for salt production, industrial waste disposal, or as industrial sites. Furthermore, it is not possible to accurately measure the area of the saline extension by the use of Landsat imagery. It can be seen in Figure 3 that the lake appears to be foreshortened in the saline southwesterly portion. This part of the lake is both extremely shallow and turbid, and it is apparently beyond the power of the Landsat satellite instruments to resolve the differences between shallow muddy water and damp land. (See Appendix for a discussion of the Landsat imagery measurement techniques.) Thus, all that shows of this area in Figure 3 is the triangle of lake close to the El Mex Pump Station which has moderately deep water. Something of the lake outline can be discerned in Figure 3, but this southwestern portion is certainly not easy to see. Neither the area north of the Mersha Matruh Causeway nor any of the other lake measurements were affected by this problem.

Changes in lake size and shape from the 1950's to 1981 are set out in Table 1 and Figures 2a, 2b, and 2c. Between 1955 and 1973, Maryut shrank from 31,610 to 16,280 feddans, a reduction

Table 1

Changes in Lake Size, Lake Maryut

(Area Northeast of the Mersha Matruh Causeway)

Year		Feddans
1950's	(1)	32,610
1955	(2)	31,370
1973	(3)	16,280
1981	(3)	16,240

Source: (1) Salah, 1961
(2) Topographical Map
(3) Landsat Satellite Imagery

of about 48% over 18 years. This loss of area is due primarily to government-sponsored land reclamation projects.

The Abis Scheme was begun in 1948 with the draining of a section of Maryut. The project was expanded substantially in 1961 by the reclamation of the Abis Extension which took approximately 7,000 feddans from the NE section of the lake. El Kholei (66) did an economic evaluation of the Abis projects, concluding that it would take about 64 years for the total costs of the projects to be recovered. Hunting (80) pointed out that the Abis Scheme is the only large reclamation project that has been described as fulfilling the two goals of agricultural and community development. In the Abis Extension area, reclamation proceded quickly and yields were very good in the early years; by 1972, yields of rice and broadbeans were close to national averages, although yields of wheat and maize were still only 66% of the national averages. However, since 1972, the situation has deteriorated, and Hunting (80; 3,A-14) concludes, "Annual shortages of irrigation water, poor drainage and the high water table are now reversing the process of reclamation."

Reclamation for the El Nahda Scheme, mainly located about 40 km south of Alexandria and east of the Desert Road, began in 1964 with the drainage of some of the SE section of the lake. The whole project extends over 30,000 feddans, most of which is sandy soils except on the eastern side of the project where there are low-lying clay soils, giving rise to drainage problems. The water is supplied to the area by the Nubaria Canal. Numerous problems have plagued this project, including inadequate water supplies, high water table and resalinization of the soils, inadequate housing and social facilities, and multiple bureaucratic reorganizations. Despite efforts to distribute land in parcels of similarly productive land, a survey in 1975 revealed wide disparities in yields and incomes generated, the most productive 25% of the farmers surveyed receiving an average gross farm income of LE 697, compared to the middle 50% receiving LE 230, and the least productive 25% receiving a gross farm income of LE -19 (Hunting, 80).

These examples reveal how lengthy and difficult reclamation projects can be. Water quantity and quality constraints are present even when the soil types are suitable for reclamation. Leaching of saline soils requires considerable fresh water, and adequate drainage is required to prevent resalinization of the soils.

The water quality problems also confront the development potential of the lake's fishery. The NW section of the lake, near Alexandria, is shallow, relatively fresh, and very nutrient rich (eutrophied). In parts the lake bed is very anaerobic and high concentrations of toxic wastes entering from Alexandria are helping to accelerate eutrophication of the lake. The Alexandria Wastewater Master Plan Study (Camp, 77) concluded that between 1977-2000 there would be about a 280% increase in the volume of contaminated waste water to be processed by the lake. Wahby, Kinawy, El Tabbach, and Moneim (78) conclude that the pollution is so severe that the NW section should be drained by a (lower) Umum Drain and replenished with fresh water to dilute the heavy pollution load carried into the lake. Maryut's proximity to Alexandria has both positive and negative aspects. On the one hand, the high productivity of the lake is due in large part to the nutrient-rich inputs derived from Alexandria's wastes, but on the other hand, continued development of Alexandria is likely to overload the lake, both with nutrients and with toxic wastes endangering both the fish and the people who consume the fish.

Numerous efforts are being made to increase fish production in the Alexandria area. A recent loan from the World Bank was made to finance the establishment of a 3,100 feddan fish farm in the Maryut valley, 26 km southwest of Alexandria (MacLaren Marex, Inc.,80; Egyptian Gazette, 4/8/81). Another 120 feddan area in the northernmost end of Maryut is being developed into a fish farm by the Alexandria Governorate and the Catholic Relief Services as a part of a food security program; fish from the fish farm will be distributed through mobile kiosks at less than the government fixed prices, with at least 50% of the production being sold locally.

Lake Maryut has already been tailored to agricultural, industrial, fisheries, and urban uses to an extent that it must be considered a "domesticated" lake. The southern saline extension will undoubtedly continue to be developed for urban and industrial uses. Efficient lake management and water quality control will be required to preserve the productive Maryut fishery as Alexandria continues to develop.

III. LAKE EDKU

A. Physical Description:

Lake Edku, the smallest and least productive of the northern delta lakes, is located about 30 km to the northeast of Alexandria. About 19 km long and 6 km wide, Edku's main axis lies in an east-west direction (See Figures 4c, 5, & 6). The area of the lake is 27,470 feddans. The lake margins on the north and east are relatively straight, being delineated by a road and canal, respectively. The lake margins on the west and south show many irregularities and are bound by small islands forming sheltered ponds (Samaan, 74).

The only sources of water coming into the lake are two agricultural drains which enter the lake from the southern edge and from the eastern side of the lake. The water flow is generally from east to west, discharging into Abu Qir Bay in the Mediterranean Sea. The lake-sea connection, the boughaz, is at the town of Maadiya.

Interrupting the flow of water from the drains in the south and east to the boughaz in the northwest of the lake are several chains of islands which compartmentalize the lake into several distinct areas. The Maadiya area, near the boughaz, is separated from the rest of the lake by the island of Geziret El Nagaa. The island chains extending northeasterly from the southern edge of the lake create several relatively independent ponds. A particularly isolated area into which the Berzik drain flows is called Lake Ghitas.

The lake is shallow, with a range of between 50 and 150 cm (Saad, 76). The deepest area of the lake extends from the

Figure 4

Changes in the Size and Shape of Lake Edku During the Period 1953-1981

4a L. Edku in 1953, redrawn from topographical maps.
4b L. Edku in 1973, drawn from landsat imagery.
4c L. Edku in 1981, drawn from Landsat imagery.

The eastern portion of Lake Edku was reclaimed in the Edku (Idku) Scheme and the decrease in lake size is clearly evident in Fig. 4b. Minor changes in lake size and shape occurred between 1973 and 1981, primarily in the south where the Berzik Drain enters the lake.

The extensive vegetation in this lake is not indicated on these maps. The intermittant wetlands to the east are outlined by a broken line.

FIGURE 4 LAKE EDKU

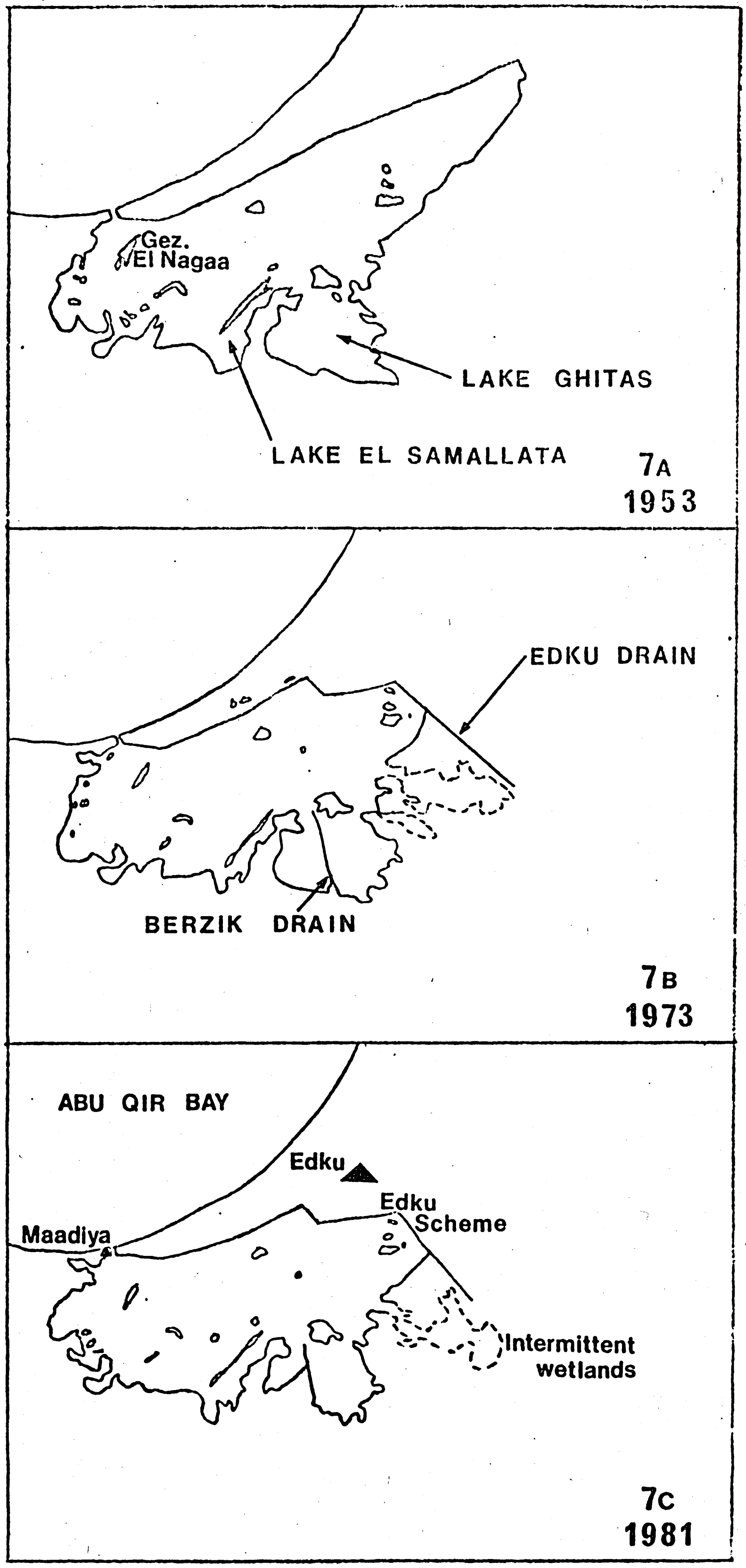

Figure 5

Computer enhanced false color image from a Landsat satellite pass over Egypt on July 22, 1973, showing Lake Edku. The extensive areas of aquatic vegetation in the lake appear as solid red. Land based agricultural activity is characterized by geometric shapes due to the use of fields. The Edku (Idku) Scheme reclamation project area lies to the northeast and east of the lake.

Healthy vegetation appears bright red, clear water appears blue-black, and sediment-laden water appears powder blue.

Scale: 1 inch = 1.82 miles approx.
1 cm = 1.15 km approx.

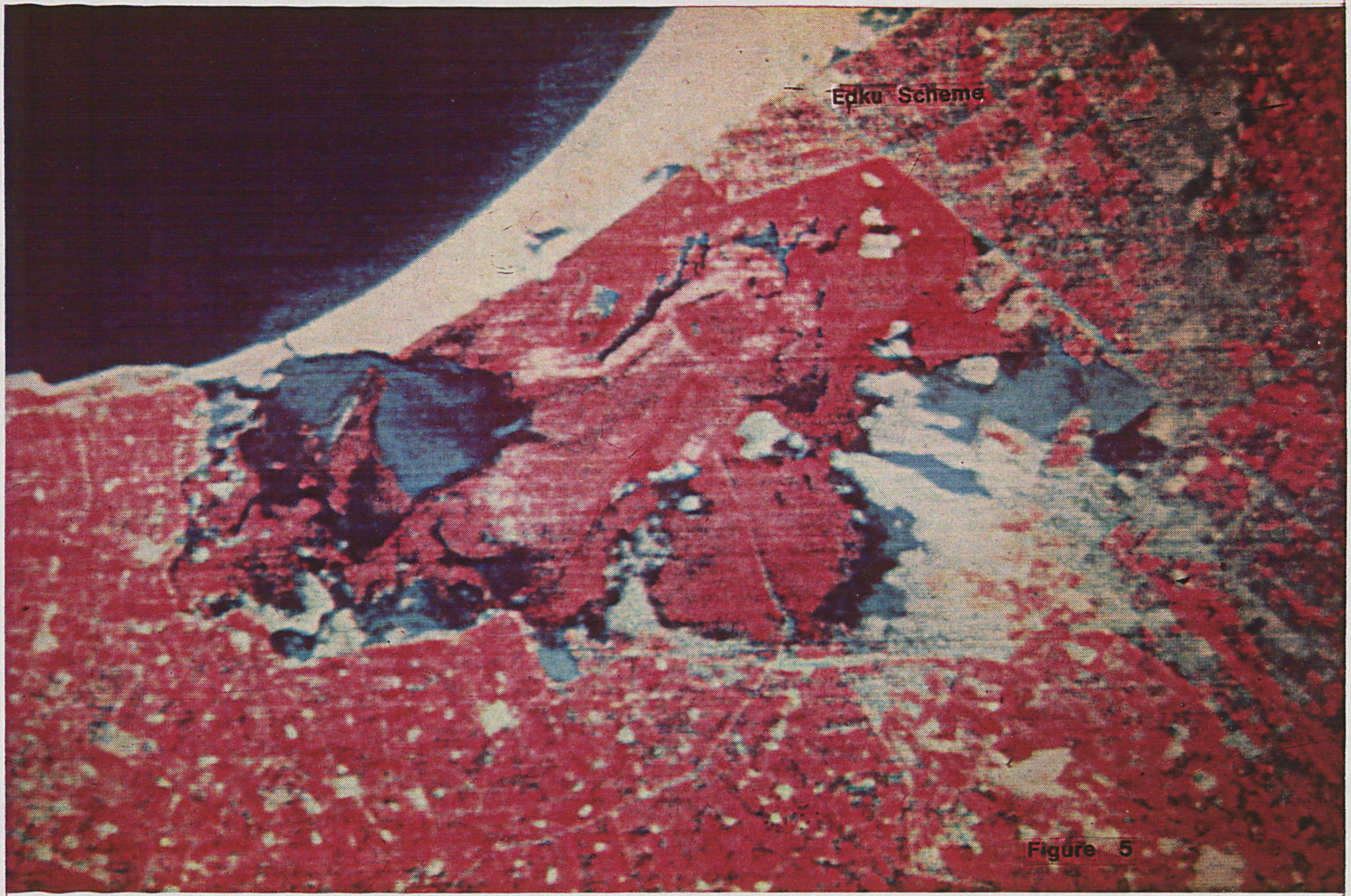

Figure 5

(See back of page for Figure 6 legend.)

Figure 6

Computer enhanced false color image from a Landsat satellite pass over Egypt on May 10, 1973, showing Lake Edku. Healthy vegetation appears bright red and clear water appears blue-black. It is difficult to differentiate between the powder blue of sediment laden water, intermittant wetlands, and irrigated agriculture.

Scale: 1 inch = 1.97 miles approx.
1 cm = 1.25 km approx.

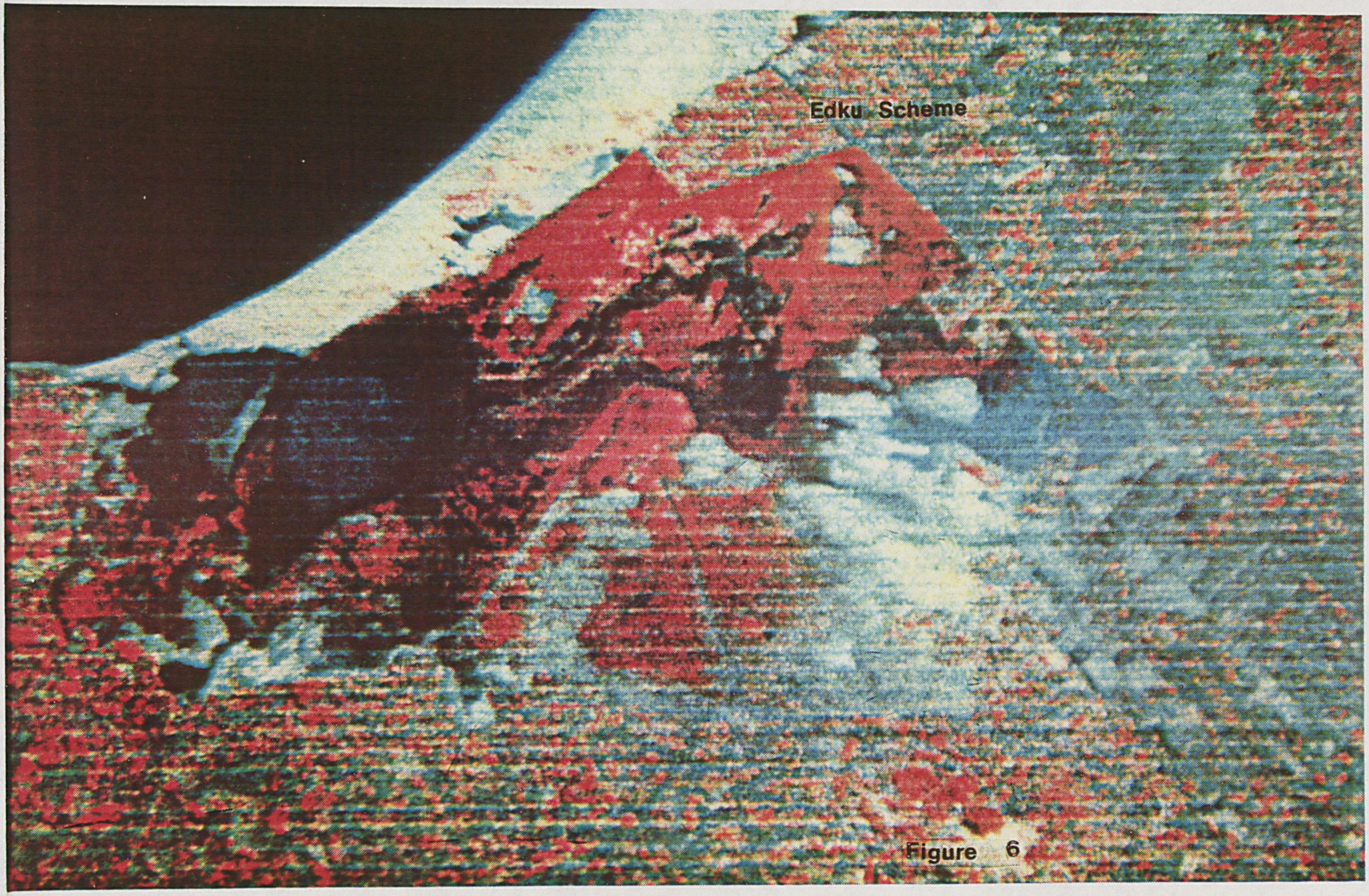

Figure 6

Geziret El Nagaa to the east-southeast, achieving a depth range of between 110-150 cm (Samaan, 74).

B. Water Quantity and Quality:

The two agricultural drains emptying into Lake Edku are the Berzik and the Edku. The Berzik Drain opens into the area of the lake on the southern shore called Lake Ghitas, while the Edku Drain discharges on the eastern shore of the lake through several outlets (Samaan, 74). The water is lifted several meters into the lake through hydrolic pumps. Most of this water is drain water from Beheira Governorate. In 1969 the total inflow into the lake from the drains was 2,062 million cubic meters (Saad, 76), which resulted in the lake level being 11-16 cm above sea level. Because of this low level, wind-driven sea water will occasionally invade the Maadiya area. Samaan (74) suggests that the water budget of the lake is 110 million cubic meters, which means that theoretically the water in the lake could be renewed in less than a month.

Summer temperature maximum is about 28.5 degrees centigrade, and the winter minimum about 14.5 degrees centigrade (Samaan, 74; Saad, 76). These two researchers give values of between 7.6 and 9.5 for pH. Oxygen concentrations of between 8-10 grams per cubic meter were reported by Nasr, Hashim, and Aleem (63). There is some variation between reported phosphate concentrations; Nasr, Hashim, and Aleem (63), gave a value of 0.02 grams per cubic meter for the lake, while Samaan (74) quotes 0-1.5 grams of phosphate per cubic meter.

The salinity of the lake is affected by inflows, rainfall, evaporation, and wind direction. The inflows result in the lake having choloride concentrations of 0.47-0.94, with a seawater-influenced maximum of 10.2 grams of choloride per liter (Samaan, 74). Saad (76) noted that there was a range for the lake of between 1.19-5.09 grams of choloride per liter except in the Maadiya region, where values ranged from 0.49 to 23.24, with an average value of 4.42 grams per liter (Saad, 76). The penetration of seawater into the lake generally occurs in the spring and summer, when the prevailing wind is from the North. Wind speeds tend to be between 1-16 knots (Samaan 74). Rainfall generally occurs between December and February, with 200 mm average annual value. The rate of evaporation ranges between 64-165 mm per month. Evaporation for the year 1969 was 1,432 mm, and for 1970 it was 1,446 mm (Samaan, 74).

C. Soils:

Between the lake and the Mediterranean Sea there is only Mediterranean coastal sand. In the east, in the Edku reclamation scheme, the soils are generally clay or silty clay in texture (Hunting, 80). Some sandy soils, derived from coastal dunes, are present at the northernmost part of the reclamation project. The southern and western shores are probably derived from fluvio marine deposits of the coastal plains.

The lake bottom is mainly composed of clay, with some sand, and is generally considered to be muddy. The lake bottom changes from clay to sandy as one moves from east to west (Samaan, 74). The northern and western borders of the lake have a sand-silt mixture which changes as one goes towards the

Maadiya region, where it is almost all sand (Saad, 76; Samaan, 74). Mollusc, tubeworm, and barnacle shells are plentiful throughout the lake.

D. Vegetation and Agricultural Activity:

There is intense agricultural activity in the western and southern lakeshore regions, which extends eastward to the Berzik Drain area. The area between the Berzik and Edku Drains (Figure 5) is much less amenable to agricultural use, with that portion closest to the Edku Drain being the least productive. The reclaimed land in the Edku scheme was, in 1973 (Figures 5 and 6), very heterogeneous in vegetative cover and certainly less productive than the old lands. The area of coastal sands between the lake and sea (Figure 6) shows some vegetation, and recent ground truth surveys have shown this area to be planted in date palms with some vegetables grown for local markets.

Cropping patterns in the Lake Edku region follow the traditional three year cropping pattern with cotton, rice and vegetables grown in the summer and short berseem, long berseem, and either wheat, barley, beans or vegetables grown in the winter.

The distribution of aquatic plants in Lake Edku is mainly controlled by water depth, shelter against currents and distance from the mouth of a drain. The lake boundaries and island margins have dense stands of the emergent plants, Phragmites and Typha, which extend out until the lake reaches a depth of about 50 cm. The bottom of the eastern section and the southern and western margins support the submerged plants, Potamogeton and Ceratophyllum. The floating plants, Lemna (duckweed), Spirodela (duckweed) and Eichornia (water hyacinth) are also present. Graphic demonstration of the rapid growth of aquatic plants in Lake Edku can be seen clearly by comparing two computer-enhanced false color satellite images. Potamogeton (pondweed) and Ceratophyllum commence growth in the spring (Figure 6) and by summer (Figure 5) cover about 50% of the whole lake (Samaan, 74). These plants die off in the winter, but Cladophora (a hair-like alga which forms mats when present in large numbers) is present in the autumn and winter.

E. Lake Edku Fishery:

The third largest of the delta lakes in terms of fishing area, Lake Edku is the least productive in terms of fish yields. Intensively fished, in 1977 Lake Edku produced about 2,058 tons of fish valued at approximately LE 700,000. Having about 7.5% of the area of the northern lakes, Edku produced about 4.5% of the total value of fish produced by the four lakes. With approximately 4,300 licensed fishermen, the average catch per fisherman amounted to only about 480 kg and about LE 163 in value. In the period 1970-77, the average net income per fisherman was only LE 191. This was the lowest of the northern lakes, only about 15% of the average net income produced by fishermen on Lake Manzala and about 52% of that produced on Burullus. These relatively low incomes generated by fishing in Edku are consistent with the observation that many Edku fishermen are only part-time fishermen.

In 1977 there were about 1,438 licensed boats operating on the lake. Thus, there were about 3 licensed fishermen per licensed boat. Nearly all of these boats were small (about 5 m in length) canoe-like faloukas. Since the open lake area is small, the boats are generally much smaller than those on Burullus or Manzala. All types of fishing gear are used on this lake as on the others, including trammel nets, seine nets, and wire traps (Bisso, 81). However, since much of the lake is overgrown with hydrophytes and there is ample plant growth in the shallow waters, large numbers of fishermen use wire traps. Marketing of fish is usually done immediately upon the fishermen's return to port; perhaps as much as half of the actual fish catch is weighed in at government weighing stations.

Edku is comparable to Burullus in one measure of productivity for fish production, the standing stock of bottom fauna in open areas. Some 50%-80% of Edku, however, is overgrown with water reeds and other aquatic plants, which is not a good environment for the first link in the food chain, phytoplankton. Due to this hydrophyte growth the average daily production of phytoplankton per unit area is only about 16% and the biomass of the bottom fauna per unit area is only about 22% of that in Maryut, a very productive lake (Samaan, 74). Correspondingly, Edku's fish yield is only about 7% of the catch per fisherman in Maryut.

F. Development History and Alternatives:

The lake was formerly much larger than today. Its current area of 27,470 feddans is only about 77% of its 1953 area (Table 2). A 3,000 feddan reclamation project at the extreme northeast of the lake was well underway when, using topographical maps,

Table 2

Changes in Lake Size, Lake Edku

Year		Feddans
1953	(1)	35,770
1973	(2)	28,480
1981	(2)	27,470

Source: (1) Topographical Map
(2) Landsat Satellite Imagery

the area was estimated to be 35,770 feddans. By 1973, the lake area, measured from Landsat satellite imagery, had been reduced to 28,480 feddans. This measurement is only slightly less than values (30,000 to 31,186 feddans) given in a number of publications (Salah, 61; Samaan, 74; Saad, 76; Rzoska, 76; and Banoub, 79). The reduction in lake area was largely due to the government-sponsored reclamation projects on Edku. There was less change in the lake's area or shape (Figures 4b and 4c) between 1973 and 1981. The area of Lake Edku in 1981 was estimated by Landsat imagery to be 27,470 feddans. This loss of about 1000 feddans of area between 1973-81 is thought to be due largely to private land reclamation efforts along the edges of the lake.

The Edku Project was one of the land reclamation and settlement projects begun in 1948. By 1959 there were about 2,700 feddans of Edku reclaimed. Between 1959 and 1962 about 2,000 feddans were distributed to 699 settlers. The typical settler had 3 feddans and earned about LE 315 in 1963-64, but only 41% of this income was derived from agriculture. Most settlers were originally fishermen, and in the mid-1960's they were still dependent for more than 40% of their income on fishing. About 10% of the original settlers had left their land to return to fishing by the mid-1960's, presumably because it was more profitable to engage in fishing than in agriculture.

The Edku Scheme reclaimed another 7,700 feddans from the eastern shores of Edku beginning in 1961. About half of this land was distributed to settlers in the 1960's, while the remainder was sold in auction in 1977. Average crop yields by the settlers are generally within 75% of the national averages. However, many of those who who purchased their land in 1977 have been short of water, which has led to crop failures and low returns (Hunting, 80).

Reclamation in Edku has been quite successful, despite some start up problems, particularly the slow development of social services, and despite the failure to commit the necessary water to the last part of the scheme that was sold to private individuals. The clay soils at the eastern end of the lake were good for agriculture and relatively easy to reclaim, coming into production within 3 to 4 years after drainage. Importantly, the lake area sacrificed was among the least productive fishery areas of the lake.

If efforts are made to improve the fishing productivity of Edku, the most important program would be weed control and dredging operations. The World Bank/FAO Development Center is presently considering developing a 2,700 feddan deep pond aquaculture project to draw water from the Edku Drain (MacLaren

Marex, Inc., 80). Another 14,300 feddans of Edku are currently planned for reclamation. If little is done to rectify the low productivity of the eastern end of Edku, the value of the fishery given up to reclamation will undoubtedly be low.

IV. LAKE BURULLUS

A. Physical Description:

Lake Burullus is located along the Mediterranean Shore, between the Rosetta and Damietta branches of the Nile, and lies between longitudes 30 deg. 35 min. E and 31 deg. 8 min. E and latitudes 31 deg. 22 min. N and 31 deg. 37 min. N. It is about 57 km long and 14 km wide and is thus the second largest of the northern delta lakes. There are a number of islands and reed beds in the lake (see Figures 7, 8, and 9), and if these are included in the estimate of lake area, the Landsat imagery shows the lake as being about 114,520 feddans.

The islands of Lake Burullus, primarily located in the middle section where the lake is widest, are not sufficiently large to compartmentalize the lake, but expanding reed beds around their margins increasingly restrict the free flow of water (see Figures 7, 8, and 9).

The lake has a range of depths from 50-200 cm with an average depth of about 1 m (Hashem, El Maghraby & El Sedfy, 73; El Sedfy and Libosvarsky, 74). Saad (76), however, suggests that the lake is slightly deeper, ranging from 70-240 cm in depth, there being an increase as one goes from east to west and from south to north. The eastern area near the town of Baltim has a depth of only 15-20 cm. This area is commonly free of water when the northeast winds blow; there is a concommitant increase in lake water level in the west at this time.

All of the drains and canals that flow into Lake Burullus enter the lake on the southern shore. The lake opens out into the Mediterranean Sea at Boughaz El Burullus, at the northeast

Figure 7

Changes in the Size and Shape of Lake Burullus During the Period 1953-1981.

7a L. Burullus in 1953, redrawn from topographical maps.
7b L. Burullus in 1973, drawn from Landsat imagery.
7c L. Burullus in 1979, drawn from Landsat imagery.
7d L. Burullus in 1981, drawn from Landsat imagery.

With the exception of El Hamoul Scheme whereby the easternmost portion of Lake Burullus has been reclaimed, there has been little change in the basic shape of L. Burullus over the past 28 years.

Key Reed beds and/or other aquatic vegetation.

FIGURE 7 LAKE BURULLUS

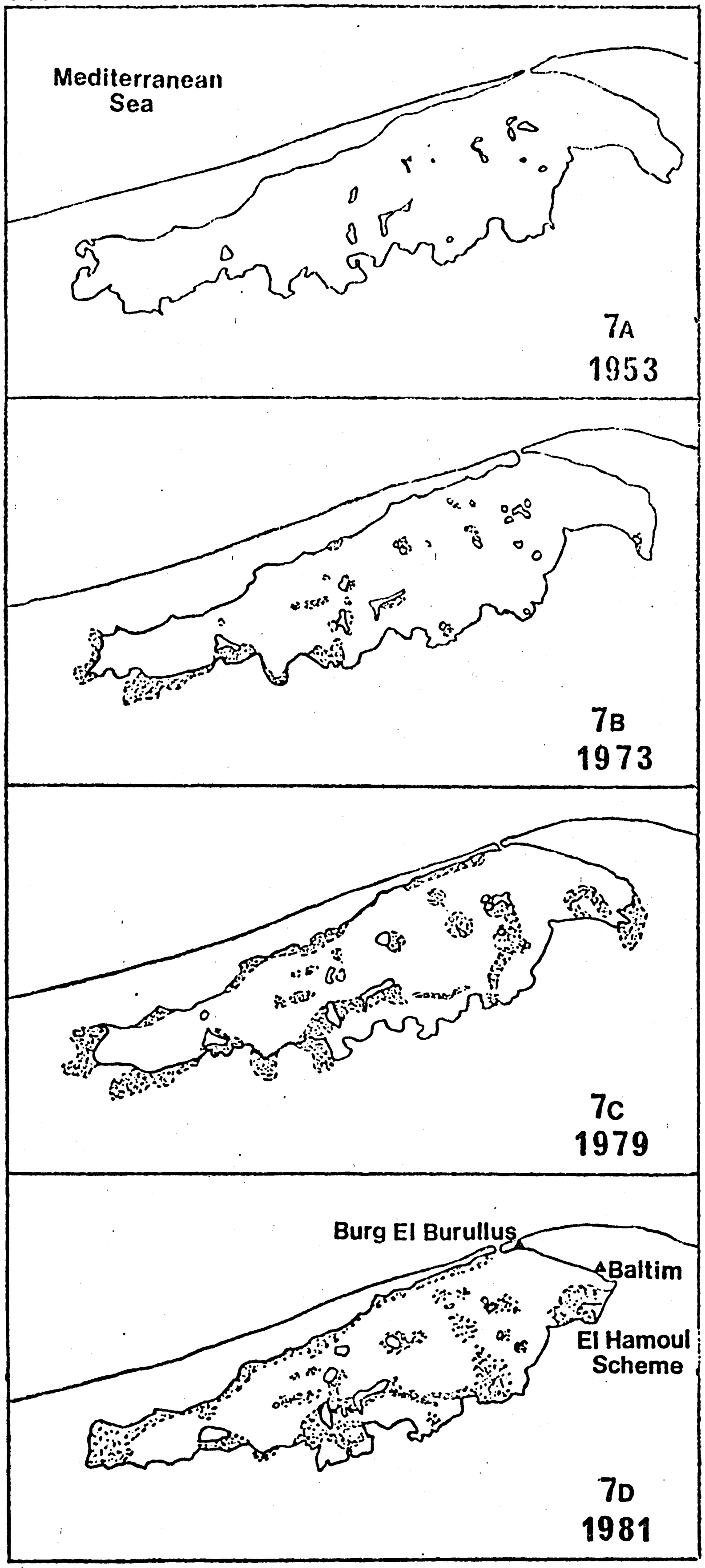

Figure 8

Computer enhanced false color image from a Landsat satellite pass over Egypt on May 10, 1973, showing Lake Burullus. The El Hamoul reclamation scheme is located on the eastern shore of the lake. Healthy vegetation appears bright red. The clear Meditteranean waters appear blue-black, and the sediment-laden water of the lake appears powder blue.

Scale: 1 inch = 6.90 miles approx.
1 cm = 4.37 km approx.

Figure 8

(See back of page for Figure 9 legend.)

Figure 9

Computer enhanced false color image from a Landsat satellite pass over Egypt on March 22, 1979, showing Lake Burullus. Healthy vegetation appears bright red, clear water appears blue-black, and sediment-laden waters of the lake appear greenish-blue on this image.

Scale: 1 inch = 4.67 miles approx.
1 cm = 2.96 km approx.


El Hamoul Scheme
Figure 9

corner of the lake, close to the fishing port of Burg El Burullus. The opening is 400-500 m wide, and during storms seawater readily invades this part of the lake.

Khafagy and Manohar (79) have studied the stability of the Egyptian coast and have concluded that the Burullus outlet area has always been unstable and is in a critical condition at the present time. The narrow coastal strips separating the sea from the lake on each side of the Boughaz are susceptible to the formation of breaches, and the protective dunes on the eastern side have been rapidly eroding.

B. Water Quantity and Quality:

Listed from west to east, the drains and canals that enter the lake on the southern shore are the Brimbal canal, drain #11, drain #9 (Nashart outfall), drain #8, drain #7, Tira Pump Station (from Nassar Drain), Gharbai Drain, and Burullus Drain. El Sedfy and Libosvarsky (74) conducted a study to compare the effects of the completion of the Aswan High Dam on the lake and the volume of inflowing water. In 1967, the flow from 4 drains was 1,736 million cubic meters and that from the Brimbal canal, 515 million cubic meters. This inflow resulted in an average lake water level of 0.25 m above sea level. In 1970, two new canals, the Nassar and the Burullus, were in operation. Their flows, together with the increased flows in the other drains, brought the inflow of water from drains to 3,207 million cubic meters. Nile water from the Brimbal canal was slightly reduced, to 144 million cubic meters, but there was still a sufficient increase to raise the average level of the lake water to 0.33 m above sea level. All of the drainage water entering the lake must be lifted several meters by pumps.

Water temperature in the lake closely follows that of the air. In winter the temperature is usually 12.5-15.5 degrees centigrade, while in summer it reaches 26-29 degrees centigrade (El Maghraby, Hashem, & El Sedfy, 74).

Since the drains generate a lake-sea current (Saad, 76), the lake is generally low in chloride concentration except when the prevailing winds drive seawater into the lake. In their assessment of the effects of the Aswan High Dam on Lake Burullus, El Sedfy and Libosvarsky (74) found that the chloride concentration range in the lake decreased from 0.7-20.7 to 0.5-18.3 grams per liter. In another study El Maghraby, Hashem, & El Sedfy (74), measured the range of chloride concentrations for different parts of the lake and found that in the west it ranged between 0.2-1.1 grams per liter, in the middle 0.9-2.01, south of the Boughaz 6.5-10.1, and at the Boughaz itself 19.4-21.3, similar to the chloride concentration of open sea water.

C. Soils:

The lake is separated from the Mediterranean Sea by a strip of Mediterranean coastal sand varying in width from about 4.5 km in the west of the lake to about 0.5 km near the Boughaz. This soil type can readily be recognized in Figures 8 and 9. The area east of the Boughaz and going towards the town of Baltim is also covered with Mediterranean coastal sands. Soils in the eastern end of the lake which were reclaimed in the government-sponsored El Hamoul Scheme are clays or clay loams of about 1 m depth, overlying marine shells, sands, and silts (Hunting, 80). The soils along the southern border of the lake are very saline silts and clays.

The bottom of the lake near the lake-sea connection is sand, mixed with silty materials, while in the southern part of the lake it is silt or mud (Saad, 76). Thus, both in and near Lake Burullus, the soils are sandy to the north and clay, silty, and sandy to the south, where they vary greatly in type, quality, and depth from area to area.

D. Vegetation and Agricultural Activity:

Landsat satellite passes over Lake Burullus in 1973 and 1979 have provided images which show the extent of vegetative cover in the lake region (Figures 8 and 9). No agricultural activity is apparent for some 4-5 km south of the southern shores of the lake, and in the southwest the demarcation between farming and bare land is very clear. In the southeast there tends to be an even greater distance between the lake shore and agricultural activity, although some scattered farms exist even in this area. The area near Baltim is intensively cultivated, mainly in date palms.

The absence of agricultural activity near the lake is due to several factors, including poor soil types, high soil salinity, inadequate irrigation water and saline water in the water table.

The Landsat image from 1973 (Figure 8) shows reed beds around the shore of the lake, with the greatest concentration in the southwest corner. El Sedfy and Libosvarsky (74), found that the increased flow of fresh water into the lake due to the construction of the Aswan High Dam resulted in a vast increase in the amount of reeds on the eastern shore. By 1979 (Figure 9), there had been an increase in the extent of reed beds around the islands of the lake and in the area near the Hamoul reclamation in the east. Information from a satellite pass in 1981 (Figure 7d) shows a further increase in reed cover near the Hamoul reclamation as well as increases along the southern and western shores.

E. Lake Burullus Fishery:

With about 31% of the delta lakes area, Burullus produced only about 21% of the landed fish tonnage in all the delta lakes in the 1970-77 period. In 1977 Burullus produced almost 6,600 tons of fish valued at about LE 3.4 million. Approximately 8,500 licensed fishermen in 1977 produced an average of 772 kg each, for an average value per fisherman of about LE 398. For the period 1970-77, the average net income per fisherman was LE 368, almost twice that of Edku, but only 31% of that in Maryut and 29% of that in Manzala.

Lake Burullus has the most productive Mullet fishery of the delta lakes due to the wide lake-sea connection, which allows high recruitment of Mullet fry from the sea each year. The Mullet grow to be many times the size of Tilapia and are valued per kilo at several times the price of the more common species. The warm, shallow waters and large amounts of organic materials available for food form ideal grounds for Mullet fry to develop, particularly in the calm areas near the shores and around the islands. Five different species of Mullet habitate various areas of Burullus according to their tolerance of salinity, turbidity, and food availability conditions (El Maghraby, Hashem & El Sedfy, 74). Throughout the 1960's and 1970's Burullus produced the highest proportion of Mullet out of total fish catch of any of the lakes. In 1977, about 19% of the official fish catch was the high valued Mullet. The lake with the next highest proportion was Manzala with 6.4%.

In 1977, there were 2,844 licensed boats on Burullus, entirely classed as third class boats. The boats on Burullus are larger than those on Maryut or Edku. There are a considerable number of large markebs and many intermediate size faloukas and large size canoe-like boats. The often turbulent water in this long, windy lake, requires larger boats. One often sees strings of smaller boats for use at the fishing site being towed along behind larger ones going to or from the fishing grounds. While there is some wire trap fishing done in the shallow areas near some of the islands and along the shoreline, most fishing in Burullus uses various forms of net fishing.

Several factors account for the weak performance of Burullus as a fishery. The new hydrological regime brought about by the construction of the Aswan High Dam has significantly affected the fertility of the lake. On the one hand, the lake no longer receives the fertilizing Nile sediments which were formerly brought by the yearly floods. On the other hand, there has been an increase in the nutrient-poor drain waters flowing to Burullus. An investigation of the impact of the new water regime on Burullus concludes that a gradual decrease of fish production is expected (El Sedfy & Libosvarsky, 73; Libosvarsky, Lusk, & El Sedfy, 72). Furthermore, Burullus, like Edku, receives none of the nutrient-rich sewage which flows to Maryut and Manzala.

F. Development History and Alternatives:

One-sixth of the area of Lake Burullus has been given up to reclamation schemes since 1953. Its size in 1953, estimated from topographical maps, was about 136,190 feddans (Table 3). Aleem

Table 3

Changes in Lake Size, Lake Burullus

Year	Feddans
1953 (1)	136,190
1973 (2)	124,830
1981 (2)	114,520

Source: (1) Topographical map
(2) Landsat Satellite Imagery

and Samaan (69), Samaan (74), El Sedfy and Libosvarsky (74), and Saad (76) variously estimated the lake area to be between 120,000 and 146,000 feddans. Use of Landsat imagery from 1973 provided an estimated lake area of 124,830 feddans, most of the reduction in area being due to the large government sponsored reclamation project, the El Hamoul Scheme, begun in 1956. The decrease in lake size between 1973 and 1981, when the lake area measured 114,520 feddans, was due to reclamation from the eastern shore of the lake (see Figures 7c and 7d), growth of reeds near the mouths of drains, and the formation of ponds and small private land reclamations on the southern shores of the lake.

The areas near Lake Burullus are not conducive to productive agriculture, nor are they easy to improve. The experiences of the El Hamoul Scheme, a large government reclamation project in the southern and eastern regions of Burullus begun in 1956, are indicative of some of the problems faced by development and reclamation projects in this area. By 1960, the El Hamoul Scheme had reclaimed about 2,500 feddans in the Helmea zone, situated between the Bahr El Tira and Gharbia Drains. By mid-1972, a total of 70,100 feddans had been reclaimed, of which 30,800 were farmed as a state farm and 31,700 were distributed to 7,518 families, giving an average holding size of 4.2 feddans. By 1979, 23 years after the project was begun, some 70,000 feddans had been distributed to 13,412 settlers, some 8,900 feddans had been sold at auction, and 48,500 feddans had been leased to the Delta Sugar Company, an Egyptian-French joint venture (Hunting, 80).

According to the El Hamoul Scheme management, only about 50% of the distributed land had achieved marginality in 1979. One survey in the summer of 1977 in Hafir Shehab, part of the reclaimed area east of Burullus, found that settlers farmed a total of 41,000 feddans, of which only 68% was under crops. Furthermore, they achieved about 60% of the national average yield of rice and less than 40% of the national average yield of cotton. These are poor yields for lands which have been in the process of reclamation for 15-20 years.

The reclamation efforts on one wasteland area of the Scheme about 30 km from Burullus were so unsuccessful that the government decided to establish the model El Zawia Fish Farm on the land. This fish farm is quite successful except for the fact that it has been operating at 1/3 to 1/2 of its capacity due to the shortage of water supplies in the area. This shortage of water in the mid-delta not only affects the El Zawia Fish Farm but also affects many of the private fish farmers in the area as well as the agricultural farmers. There were numerous reports of limited crop yields, particularly in rice, due to irrigation water shortages during 1980-81.

While there are some feddans within the El Hamoul Scheme which have proven to be very productive, the general experience in the region of Lake Burullus indicates that there are a number of limitations to using this area for agricultural development. Highly variable soil conditions, many sandy soils, high salinity conditions, and inadequate irrigation water, are all conditions which limit the profitability of reclamation efforts. Water availability limitations also constrain the further development of fish farming in the area. Currently, however, a joint Egyptian-Italian governorate-level study of the development potential of the Burullus area, both for fisheries and for agriculture, is underway.

V. LAKE MANZALA

A. Physical Description:

Located in the northeast corner of the delta, the largest of the Egyptian littoral lakes, Lake Manzala, lies between longitudes 31 deg. 45 min. E and 32 deg. 50 min. E and latitudes 31 deg. N and 31 deg. 35 min. N. The three largest population centers on its shores are Port Said to the east, Damietta to the west, and El Matariya to the south. The area of Lake Manzala as measured by Landsat imagery is 215,440 feddans. If the island and reed beds are excluded, there are only 166,480 feddans of open water. Associated with the lake are a further 37,300 feddans or more of marshland and 24,500 feddans of intermittant wetlands (MacLaren, 82). See Figures 10 and 11.

There have always been a number of small islands in the lake. They are of varying sizes and their ground material may be sandy, clay, or formed of Cardium shells. The presence of these islands divides the lake into a number of basins (Wahby and Bishara, 77), each of which has a distinctive character in terms of the kinds of water and fish present. In recent years the number and size of the islands have increased so that, in 1981, the islands comprised 48,900 feddans, or 23% of the total lake area. Figures 10a-10d illustrate this increase from 1953 to 1981.

For descriptive and analytical purposes the lake may be divided into four sectors: the Northern Sector located in the northwest corner; the Western and Eastern Sectors in the middle of the lake; and the Southern Sector, extending southeast of Matariya (Figures 1, 10, and 11). About three-quarters of the

Figure 10

<u>Changes in the Shape and Size of Lake Manzala During the Period 1953-1981.</u>

10a	L. Manzala in 1953, redrawn from topographical maps.
10b	L. Manzala in 1973, drawn from Landsat imagery.
10c	L. Manzala in 1979, drawn from Landsat imagery.
10d	L. Manzala in 1981, drawn from Landsat imagery.

Three drains, the Hadous, Ramsis, and Bahr El Baqar Drains all open into the southern portion of the lake, and it is here that enriched water and a highly productive <u>Tilapia</u> fishery are found.

The lake itself contains numerous islands and much aquatic vegetation which are shown undifferentiated in these maps. These can also be seen in the accompanying Landsat image. The rapid and relatively recent decrease in open water area due to settlement of these islands in the lake is perhaps the most striking feature of Lake Manzala.

Key:
N	Northern Sector
W	Western Sector
E	Eastern Sector
S	Southern Sector

FIGURE 10 LAKE MANZALA

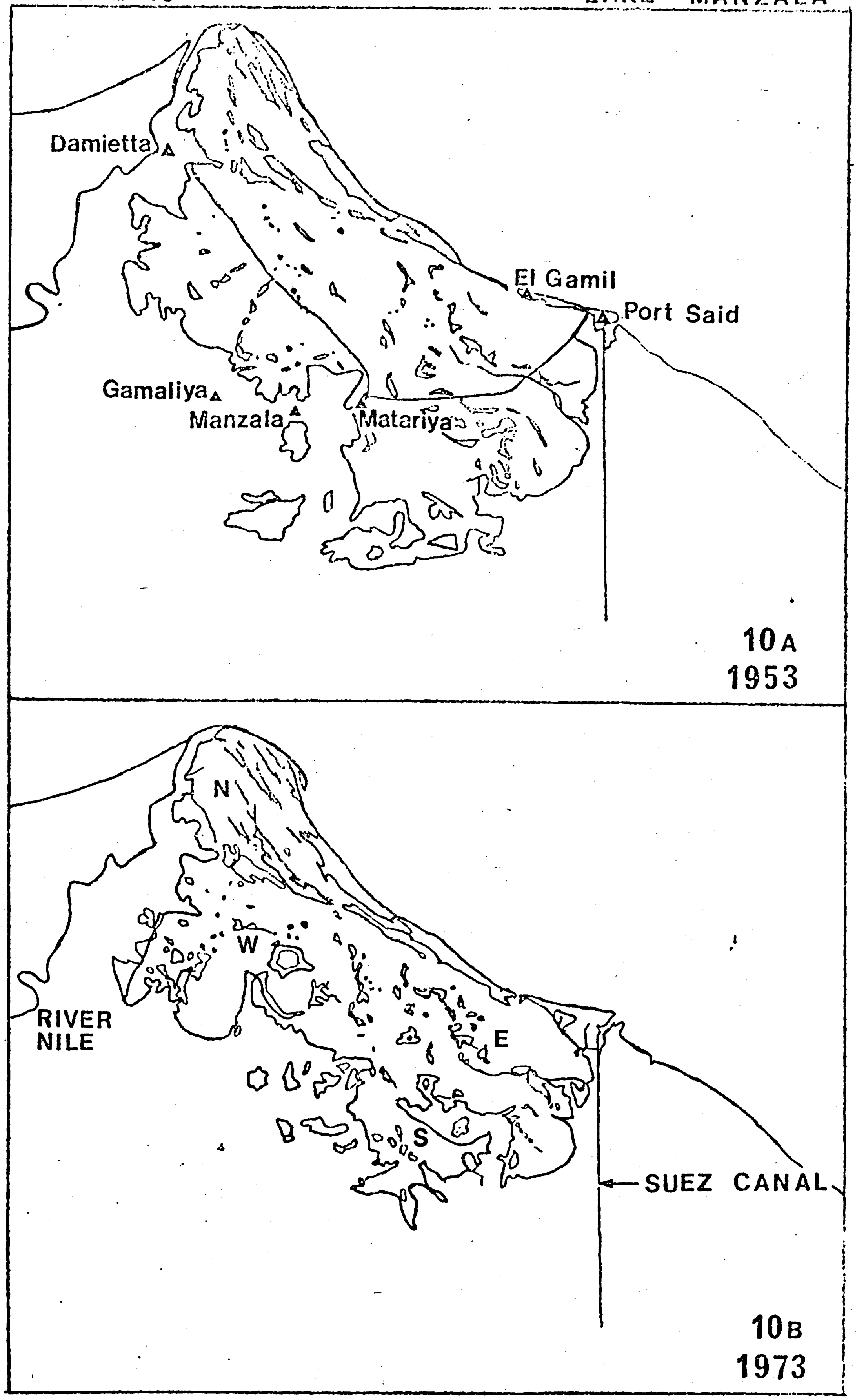

FIGURE 10 continued LAKE MANZALA

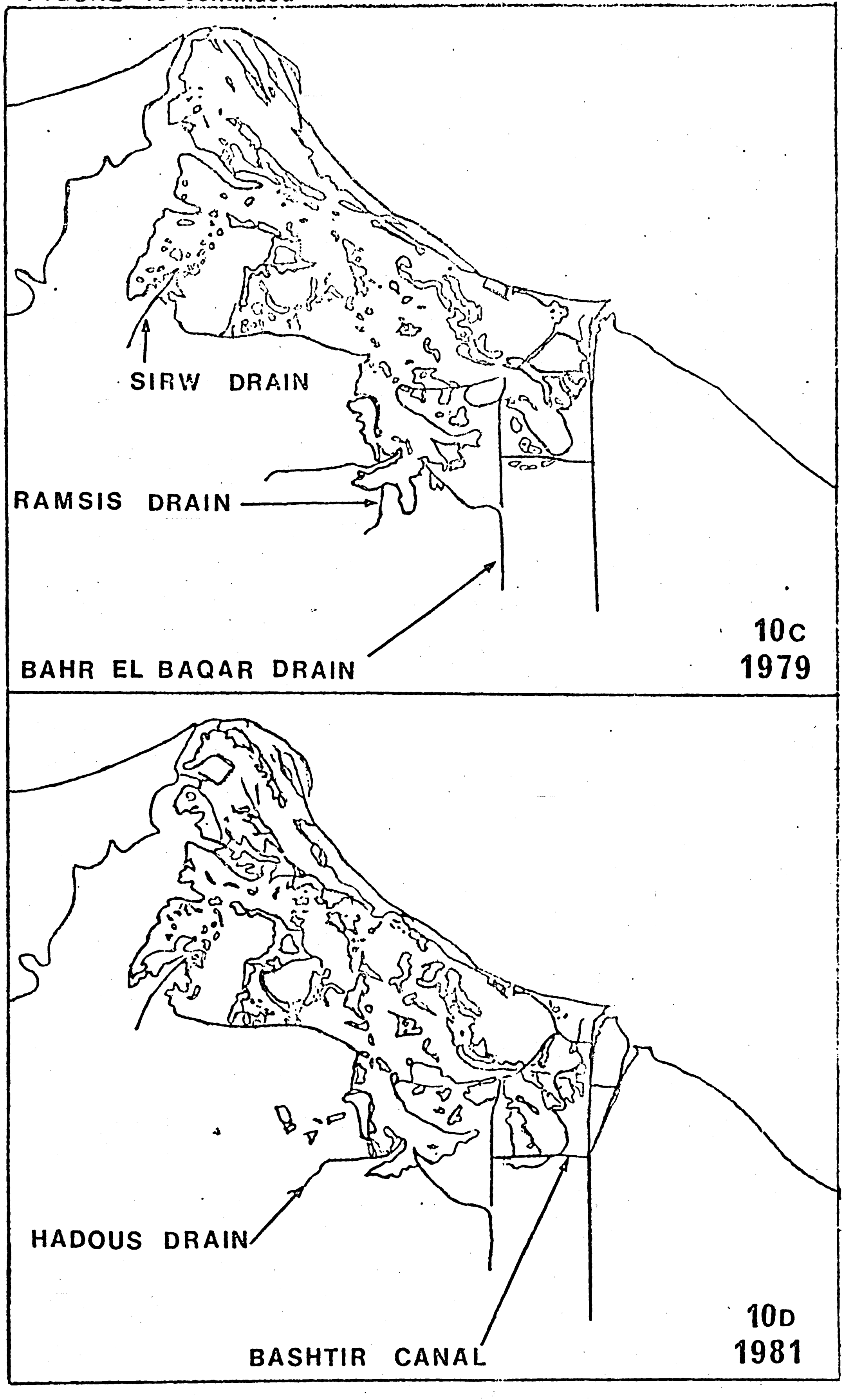

Figure 11

Computer enhanced false color image from a Landsat satellite pass over Egypt on March 22, 1979, showing Lake Manzala. Note the extensive agricultural activity along the banks of the Hadous, Ramsis and Bahr El Baqar Drains. Hosha fishing is important in the area where these drains enter Lake Manzala, as well as on the numerous islands within the lakes.

Healthy vegetation appears bright red, clear water appears blue-black, and sediment-laden water appears powder blue.

Scale: 1 inch = 5.6 miles approx.
1 cm = 3.58 km approx.

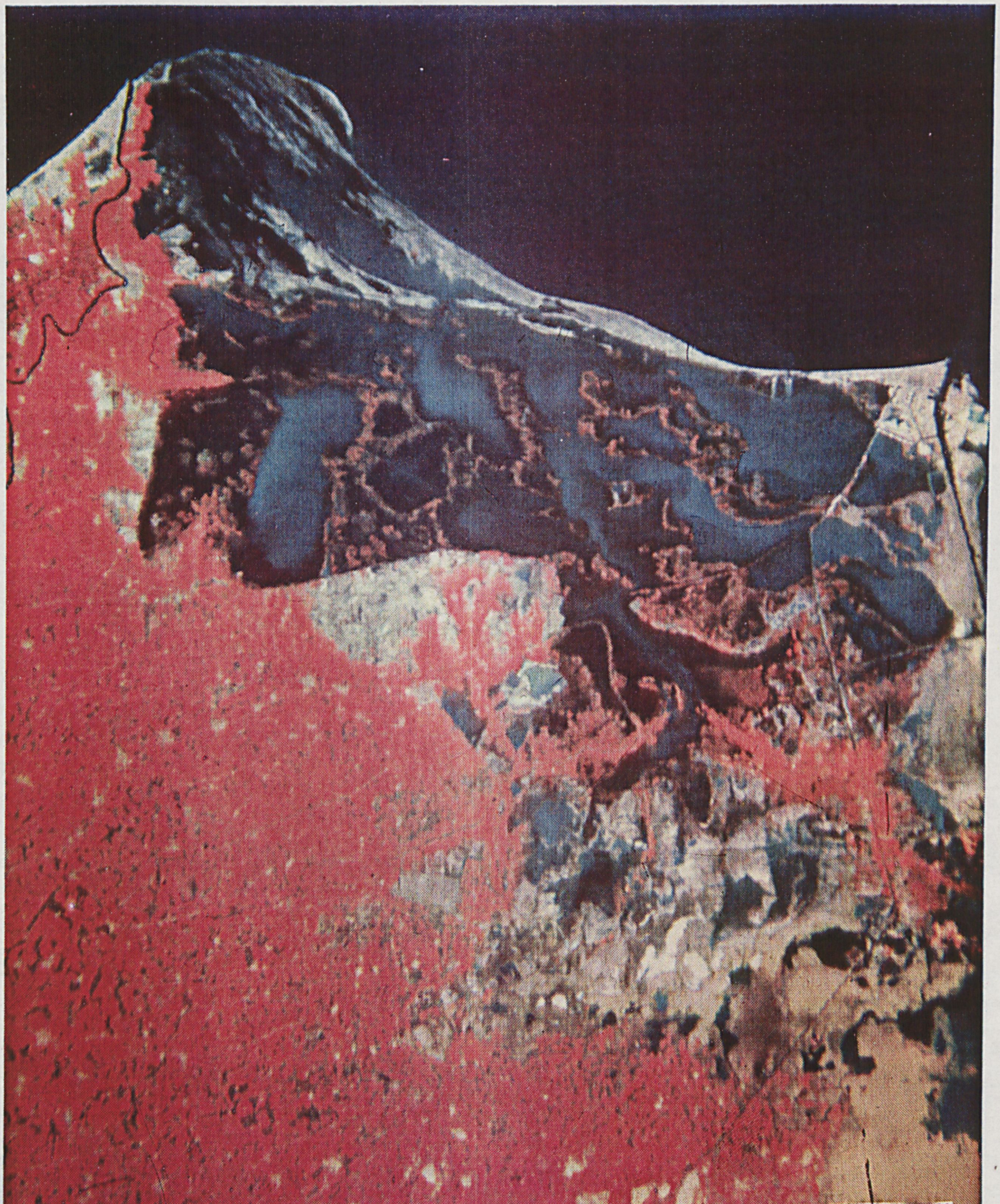

Figure II

water flowing into Lake Manzala enters via the Hadous and Bahr El Baqar Drains in the southern sector and flows out to the Mediterranean via the boughaz in the Eastern Sector at El Gamil, about 10 km west of Port Said. The Southern and Eastern Sectors are thus brackish, while the Western and Northern Sectors are more marine in character. The boughaz is located on the thin strip of sand separating the lake from the Mediterranean Sea which stretches from Port Said northwestward to the Damietta branch of the Nile.

The water level in the lake is subject to variations (El Wakeel & Wahby, 70a). Before the Aswan High Dam was constructed, the water level was increased by inundations of the Nile floods, and it still experiences an increase in height during the Mediterranean Sea's annual high tides in the early summer. The lake depth is usually cited as being about one meter. Shaheen and Yousef (78) state that 25% is less than 60 cm in depth; 50% is within the range of 60-100 cm; and the remaining 25% is more than 100 cm deep.

B. Water Quantity and Quality:

The water flowing into Lake Manzala comes from seven major freshwater or drainage canals, plus sewage from the urban centers of Cairo, Port Said, Damietta, Matariya, Manzala, and Gamaliya. Total water inflow is estimated at 6,740 million cubic meters per year, which is equivalent to about six times the volume of the lake. Only 4% of this water is fresh water, with the remainder being supplied from the agricultural and urban waste drains. The Hadous Drain supplies almost half of

Manzala's water input, while the Bahr El Baqar Drain supplies about a quarter of the water input.

The quality of the water in the lake is affected by the location of the drains, and the quantity and quality of the water flowing into the lake, the compartmentalization of the lake into basins by the islands of the lake, the location of the boughaz, and the direction of the prevailing winds. The most significant of these is the location of the drains and the quality of their flows.

The Hadous, Sirw, Faraskur, and Ramses Drains all have typical agricultural drainage water which would be of moderate quality for agricultural use. The drain at Matariya has a somewhat higher salinity since it drains newly reclaimed lands. Water from the Bahr El Baqar Drain, however, is quite different. The Bahr El Baqar serves as a wastewater stabilization facility for Cairo's sewage, allowing this wastewater to become biologically degraded into a nutrient-rich "soup" by the time it reaches the lake. Even though the capacity of the drain is overloaded, as evidenced by the complete lack of oxygen in the terminal portion of the drain, aerobic conditions are established shortly after the drain waters mix with those of the lake, and the drainwaters provide nutrients supporting a large phytoplankton population, and ultimately, a large Tilapia stock.

While the Bahr El Baqar supplies about 60% of the nutrients supplied to Manzala, the Hadous supplies another 23%. Because they both flow into the Southern Sector, this area has high phosphorus and nitrogen concentrations; oxygen concentrations fluctuate widely due to the high number of phytoplankton, and the concentration of chloride varies according to that of the inflowing drainwaters. Chloride concentrations have been found to vary between 0.2 and 2.0 gm Cl/liter (El Wakeel and Wahby, 70c; Wahby, Yousef & Bishara, 72; MacLaren, 82). Temperature and pH values are equivalent to those in the rest of the lakes, with an annual temperature range of 12-30 degrees centigrade (Shaheen and Yousef, 78; MacLaren, 82) and pH values of 7.8-8.5 (El Wakeel and Wahby, 70c) or pH 7.34-10.0 (MacLaren, 82).

Two areas characteristically different from the main water body are the area near the boughaz, where the chloride concentrations can be affected by seawater pushed in by the wind when the prevailing wind direction is from the northeast, and the Northern Sector and western areas of the Western Sector. This northwest corner of Manzala suffers from a net water loss in the summer and from seawater intrusion facilitated by the summer northwesterly wind, resulting, at times, in water more salty than seawater.

C. Soils:

There are three major soil types present along the shores of Lake Manzala, being Mediterranean coastal sands, fluvio-marine deposits of the coastal plains, and sandy river terraces from the old deltaic plain. Mediterranean coastal sands occupy the entire coastal strip which separates Manzala from the sea, starting just north of Damietta and continuing north, then southeastward to Port Said. On the western and southern sides of the lake, between Port Said and Gamaliya, are fluvio marine deposits of the coastal plains. These consist primarily of highly saline and sodic montmorillonitic clays, covered with a thin fluffy layer of clay. Factors which limit the use of these soils include difficult tillage, high salinity, high sodicity (alkalinity), a low infiltration rate, and low hydrolic conductivity. Continuing around the southwest corner of the lake, one finds sandy river terraces from the Old Deltaic Plains between Gamaliya and Damietta. These soils have a light yellowish-brown topsoil and a reddish subsoil and are moderately to high calcareous. The soils of the river terraces are generally highly saline, and the major limitations to their use for irrigated agriculture are their low water holding and nutrient retention capacities, and their high infiltration and subsoil permeability. Drainage, however, is good (MacLaren, 82).

The borders of the lake, which are affected by drains and canals, are covered with silty clay of medium grain size, 85.6 μ. This silty clay bottom extends into the lake, giving way to a sand-silt-clay bottom which in turn encircles an area of clay-sand in the center of the lake. The clay-sand is a form of clay enriched with shell and sand grains. Thus, there is a basinwards increase in grain size of the sediments.

The percentage of organic matter in the substrate decreases with increasing grain size. There is as much as 7.3% organic matter in the substrate at the mouth of the Bahr El Baqar Drain, though the average on the perimeter of the lake is between 3-5%. This decreases to 2-3% in the basin. In the NW Sector, where the substrate is sandy, the organic content is only 0.5% or less. The average for the lake is 2.56% (MacLaren, 82). A similar trend is observed with the distribution of the concentration of phosphorus (El Wakeel and Wahby, 70b).

D. Vegetation and Agricultural Activity:

A variety of crops are grown in the region around Lake Manzala, and the area supports quite a large number of cattle. The main summer crops are rice, cotton, maize, soybeans and vegetables. The major Nili crops are maize and vegetables. The important winter crops are berseem, wheat or barley, and maize. Less than 2% of the cropped land is given over to permanent crops such as dates. Cattle breeding is an important activity on the marginal lands, especially on the islands and between the drains.

A computer-enhanced color composite of the lake region from 1979 is shown in Figure 11. The reddish areas indicate agricultural activity around the western and southern shores of the lake and along the side of the main drains entering the lake in the south and southeast. There is a complete lack of agricultural activity in the coastal plains between the mouth of the Damietta branch of the Nile and Port Said. The land to the south of Port Said and west of the Suez Canal is also bereft of plant cover of any significant quantity. There appears to be little agricultural activity around the perimeter of the Southern Sector except for the margins of both the Bahr El Baqar and Hadous Drains. The area near the towns of Matariya, Gamaliya and Manzala shows the productivity differences between the old and new lands. The relatively new reclamation to the north of these towns contains little or no vegetative cover, as seen by the absence of red color (Figure 11) in the area just south of the center of the main lake body.

There is no agricultural production on the lake islands, with the exception of cattle raising. The marshes and reedy swamps of the southern shores of the lake and the shores of the islands within the lake are covered with dense stands of rooted plants such as Phragmites, Typha, Ceratophyllum, Potamogeton, and Najas (Shaheen and Yousef, 78).

E. Lake Manzala Fishery:

Lake Manzala has the largest and most productive fishery of any of the delta lakes. In 1977, Manzala's 8,286 licensed fishermen landed 23,055 tons of fish, for an average catch per fisherman of 2,780 tons. Manzala yielded 51% of all delta lakes fish caught in 1977. Over the 1970-77 period Manzala yielded net incomes per fisherman of LE 1,276, slightly higher than those produced in Maryut, and several times those produced in Edku or Burullus. The average catch per feddan, on the other hand, was only 0.1 tons per feddan, about 24% of that of Maryut. Being such a large lake, sizeable low-productivity areas must be averaged with some of the most productive fishing grounds in Egypt. Yields in the Southern Sector, near Bahr El Baqar Drain are over one ton per feddan, while large areas in the Western and Northern Sectors yield less than 50 kg per feddan per year (MacLaren, 82).

In the 1920's Manzala was a dominant Mullet fishery, with Mullet accounting for 56% of the catch in the 1920-29 period. As the water regime gradually changed, Mullet yields fell to 22% in the late 1950's, then to 9.2% in the period 1972-76, and finally to 2.2% in 1979-80. Today, Mullet are most abundant in the Western and Northern Sectors and along the coastal strip of the Eastern Sector, areas having higher salinities and relatively low turbidity. Tilapia, on the other hand, which accounted for only 20% of the catch in the 1920-29 period, increased to 64% of the total catch in 1962-66, and to 85% in 1979-80. Manzala is now clearly a nutrient-rich freshwater Tilapia fishery, supplemented by some Mullet, Crustaceans (amounting to about 6% of the catch in 1979-80), eels, catfish, and several other freshwater species. During this transition from a marine to a freshwater fishery (1920's -1980), Manzala's fish yield increased seven fold, the total value per unit area increased by three times, and employment increased by more than 5 times (MacLaren, 82).

In 1977, there were 2,695 licensed boats on Manzala, of which all were third class except for 2.5% which were second class boats. While about 37% of the boats are the small canoe-like faloukas, particularly used in the Southern Sector Tilapia fishing grounds, some 63% of the fishing vessels are the larger, wide-beam sailing markebs, ranging from 7-10 meters in length (MacLaren, 82). Some of these are very large boats, capable of carrying 18-20 people and hundreds of meters of fishing nets. Virtually every fishing method known is used on Manzala, including trammel nets (the most common), seine nets, surround net methods, frame nets for trawling, wire traps, hand catching and illegal methods such as the Taweeta nets.

While there are some "collector boats" operating on the lake, most fish are sold to small traders as the fishermen come to shore. Matariya is by far the largest landing site, acting as the landing dock for about 55% of all boats on the lake (MacLaren, 82).

One fishing technique uncommon on other delta lakes but very common on Manzala is hosha (or "howash"). Technically an illegal fishing method, hosha contributes 33% of the total Manzala catch (MacLaren, 82). Hoshas are "in-the-lake" enclosures with narrow openings to the lake through which the fish enter. Depending on the location in the lake, between several times a month to several times a year the openings are closed, the water drained, and the fish are harvested. Although fish of all sizes are caught, MacLaren (82) argues that the rapid growth and productivity of the Tilapia eliminate the problem of reducing fish stocks. MacLaren found approximately 45,000 feddans of hosha-type fishing operations; this amounts to about 17% of the total area of the main body of Lake Manzala. When hosha techniques are used in a rich nutrient-fed area such as the Southern Sector, it serves as a form of modified fish farming. In less nutrient-rich areas hosha is potentially destructive of the fish stocks, as it harvests fish in all age cohorts.

F. Development History and Alternatives:

Lake Manzala has been steadily decreasing in size since records were started in the early 1900's (Table 4). In the early 1900's, its area was estimated at 407,000 feddans. During the following 80 years its size has steadily decreased until 1981 when it was only 215,440 feddans, including only 166,480 feddans of open water.

Table 4

Changes in Lake Size, Lake Manzala

Year		Feddans		
		Total	Open	Marshland
1900's	(1)	407,000	--	--
1949	(1)	350,000	--	--
1953	(2)	303,390	--	--
1973	(3)	232,770	197,240	--
1979	(1)	239,540*	194,400	37,300
1979	(3)	219,170*	194,800	--
1981	(3)	215,440	166,480	--

Source: (1) MacLaren, 82
(2) Topographical Map
(3) Landsat Satellite Imagery

* Differences due to interpretation of lake-marsh boundaries.

Land reclamation in the west and south has been the principal cause for the decrease in size. Changes in the size and shape of Lake Manzala between 1953-81 can be seen in Figures 10a-10d. During this time, Manzala shrank by 29%. Large government schemes near Damietta and Matariya have decreased the effective lake size, though one scheme immediately to the south of Matariya was halted after poldering had been done, and it is still unfinished, awaiting a decision on the value of land reclamation in this area.

As the dominant delta lake, the future development of Manzala will to some extent determine the future of all of the lakes. The extensive Lake Manzala Study (MacLaren, 82), which took several years to produce, has developed a 20 year plan for the future of Manzala. The major recommendations of the study have recently been adopted and funded by the Egyptian government. Presumably, the Lake Manzala Study plan is the optimal development scenario for the lake and the region. In this plan about 30% of the land presently used for fisheries will be converted to agricultural use. In addition, the plan calls for fisheries enhancement via projects designed to improve the dispersion of the nutrient rich drain waters (from the Bahr El Baqar), extensive use of hosha fishing, fish farm developments, and improvement of the Mullet fisheries in the Northern and Western Sectors.

The study compared net rates of return to alternative developments in several areas of the Manzala region. The plan rejected as not economically viable two proposed reclamation schemes for 67,900 feddans along the Mediterranean coastline. This was based on the difficulties encountered in attempting to reclaim sandy soils. The study recommended projects to enhance the Mullet fishery as a better economic alternative. The study also recommends against continuing reclamation in the North Husseniya Valley Project, a 65,000 feddan reclamation effort that would have reclaimed substantial areas in the productive Tilapia fishery grounds in the Southern Sector. This lake area would have accounted for almost half of the project area. Such a reclamation for agriculture would increase outputs, net returns, and employment only by about 10%, costing LE 900 per feddan and taking up to 11 years to obtain. In addition, an equivalent of 50% of the existing fish production in the Tilapia fishery would be lost. Many smaller projects were also evaluated as part of a general plan for the development of the Lake Manzala area.

Manzala's tremendous fish yields are quite dependent on the input of Cairo's sewage. If plans to treat Cairo's sewage for disposal on land reclamation sites were to be realized, it would have a devastating impact on Manzala's fish yields. This insecurity in the supply of nutrients for increasing fish yields highlights the general problem of being at the end of the Nile water system.

One important case in which the availability of water is the major constraint on reclamation in the Manzala area is the proposed El Salam Canal, which is the key element in the Ministry of Irrigation's current plan for transporting water to new reclamation areas in the Sinai. Water will be taken from the Damietta branch of the Nile, near Faraskor, and will run south of Manzala, picking up fresh water from the Hadous and Sirw Drains, before running to the Sinai. Guariso, Whittington, Zikri and Mancy (81) consider many policy alternatives before concluding that the maximum benefit to Sinai and Eastern Delta (southeast of Lake Manzala) development plans is reached after only one-third of the land available for reclamation is used. Furthermore, the net benefits reach zero if up to one million feddans are reclaimed, and if all the land available (about 1.4 million feddans) were reclaimed, Egypt would suffer a substantial annual economic loss (Guariso, Whittington, Zikri, & Mancy, 81). The problem is inadequate irrigation water supplies. The development of the Sinai will compete with the reclamation of Manzala for the limited fresh water.

VI. NORTHERN LAKES FISHERIES DEVELOPMENT ISSUES

The major issues concerning the development of the northern lakes' resources are the current and potential value of the lakes' fisheries, the value of the lakes' resources in alternative uses such as agriculture, and the constraints on alternative development options due to water availability and other limitations. An accurate assessment of the value of the fisheries to Egypt is essential to policy decisions since the value of the fisheries resources given up is clearly a cost of converting the lakes to alternative uses. This value must be compared with that generated by the best alternative uses of these lakes. Except for the urban and industrial encroachment on Lake Maryut, agriculture is the most competitive alternative to further fisheries development. An optimal development plan also requires consideration of the costs of and constraints on further fisheries development as well as those of converting the lakes from fisheries to agriculture.

If a low-valued fishery could be converted easily and inexpensively to high-valued agricultural uses, these considerations would not be major issues. However, as the overview of each northern lake has revealed, these lakes fisheries, or at least part of them, are quite productive and cannot be sacrificed except to extremely productive alternative uses. The overviews also highlight the difficulties involved in converting lake areas to productive agriculture and present some of the constraints to rapid and extensive lake reclamations.

The problems of determining the value of Egypt's northern lakes fisheries are addressed in the next section. This is followed by a discussion of the agricultural development alternatives and the constraints on the development of these areas.

A. The Value of the Fisheries:

The northern lakes' fisheries are important to Egypt. In 1977, their yield was about 45,000 tons of fish, valued at approximately LE 23 million. This amounted to more than 50% of the total inland yield and more than 40% of the total value of Egyptian fish production (El Kholei, 80). By 1980 fish yields had increased to 72,000 tons, about 45% of the total inland fish catch. These figures, however, under-represent the value of the fisheries to Egypt for several reasons. First, poor reporting undervalues the fisheries for Egypt. Some estimates suggest that the fishing yields have been underestimated by 50% or more, while the numbers of licensed boats and fishermen are commonly thought to be underestimated by at least 40% (MacLaren, 82.) Second, since much of the fish is marketed at government set prices substantially lower than their domestic or international free market prices, the reported values of fish production underestimate the real value to Egypt. Third, even if the fish catch were correctly reported and valued, the figures would under-represent the fisheries value to Egypt because the fisheries are not operating at their full potential. Current fishing practices encourage over-fishing, or excessive exploitation of the fish populations, reducing sustainable fish yields below those attainable. The following discussion focuses on this last and most important reason for arguing that the northern lakes fisheries are an asset worth far more to Egypt than reported fish catch values indicate.

Egypt is not reaping the maximum benefits from its northern lakes fisheries because there is essentially open access to these fisheries. Many of the world's ocean and lakes fisheries are facing the same management problem (Larkin, 78). The lakes are currently owned publically, and government attempts have been ineffective in curbing fishing effort by licensing of boats and fishermen, taxing fishing yields, and establishing regulations on acceptable fishing gear and techniques. Open access fisheries encourage additional fishing effort until earnings from fishing are driven down to the levels attainable in alternative (agricultural) employment. Government price policies which indirectly tax agricultural production lower the returns to the major alternative to fishing, thereby encouraging additional fishing efforts. The fisheries will produce the maximum sustainable fish production for Egypt at a level of fishing effort that harvests only as many fish as are annually replenished by recruitment from other water bodies or by the natural productivity of the fish stocks. Additional fishing effort harvests more fish than are annually produced, thereby reducing the sustainable annual harvests of fish for the future (Clark, 73). There are numerous indications that the northern lakes' fisheries have been over-fished.

Unfortunately, fish populations cannot be observed. However, the behavior of fish yields can provide strong indications of the behavior of the underlying fish populations. Fish yields and the incomes they generate are measures of the economic productivity of the fisheries, while the daily gross primary production of carbon by the phytoplankton population, and the proportion of calcareous materials in the bottom muds of the lakes are measures of the biological productivity of the lake and thus of the fisheries. Biological productivity data for a lake is indicative of the fish populations supportable by the lake environment, independent of any harvesting of the fish. Table 5 presents some indicators of the productivity of the

Table 5

Some Measures of Lake Productivity

		Maryut	Edku	Burullus	Manzala
Net Income/ Fisherman, 70-77 (1)	LE	1189	191	368	1276
Net Income/ Feddan, 70-77 (1)	LE	196	30	24	34
Fish Yield/ Feddan, 70-77 (1)	Tons/ Fed	.424	.055	.068	.100
Calcareous Material in Lake Bottom Mud, 1974 (2)	%	62.29	40.20	41.70	48.74
Gross Primary Production (3)	Gm C/Cubic Meter/Day	5.06	.06	---	(4) 2.0

Sources: (1) Reid and Rowntree, 82; Khadr, 78.
(2) Saad, 74.
(3) Aleem and Samaan, 69.
(4) MacLaren, 82.

northern lakes. Maryut and Manzala, the two most biologically productive lakes, are, respectively, the recipients of Alexandria and Cairo nutrient-rich sewage. Edku and Burullus, with their lower biological productivities, are dependent solely on ordinary agricultural drain waters. The correspondence of the fish yields with the natural biological production of the lakes indicates a correspondence between fish yields and the lakes' fish populations. Trends in the fish yields can then indicate the effects of intensive fishing pressures on the fish populations.

Over-fishing can explain several features of the long term trends and annual variations in the size and composition of the lakes' fish catch. Explanations for these variations include the new water regime following the construction of the Aswan High Dam, the initiation or cessation of the 1967 or 1973 wars, or other external factors (Banoub, 79; El Sedfy & Libosvarsky, 74). While external factors have surely influenced the northern lakes' fish yields, a consistent explanation for all of the variations in the fish yields can be found in the open access nature of the fisheries and the fishing practices in the lakes.

Although data is not available to indicate the changing fishing effort over the past several decades, several factors can be identified which encouraged intensified fishing effort from the 1950's and 1960's into the 1970's. Lake reclamations in the late 1950's and 1960's forced the same numbers of fishermen to intensify fishing efforts on the remaining lake areas. Continuing rapid population growth increased the numbers available for fishing. Furthermore, during the mid-1960's, implicit taxes on agricultural activities were being increased as part of the government's development and price policies; this increased the attractiveness of fishing relative to farming. While these factors increasing fishing intensity were at work, the fish yields were falling. Between 1962-77, total inland lakes fisheries output fell by about 18% (El Kholei, 80). This strongly indicates that increased fishing effort depleted fish stocks in the lakes, reducing annual yields.

Another indication of over-fishing in the northern lakes is the variation in species composition of the fish catch in recent decades. One major change in the fish catch species composition has been the decline in the high-valued Mullet and the increase in the low-valued Tilapia proportions of the total fish catch. Post Aswan High Dam changes in the salinity regime are not the onyl factors responsible for this phenomenon. It is commonly understood in the fisheries literature that in a multi-species fishery, the increasing intensity of fishing effort on the more (biologically) productive species, in this case the Tilapia, will deplete the stocks of the less (biologically) productive species, in this case the Mullet (Larkin, 77). This effect of the intensive fishing effort on the Mullet yields has been exacerbated by a brisk, although illegal, trade in Mullet fry which are captured at the sea openings and from within the lakes to be sold to private fish farms. Further, while these lakes had more than 20 species of edible fish only about 30 years ago, today the number of edible species in the lakes numbers only 4-5. Intensive fishing effort can explain these trends in the fish yields.

One of the strongest indications of over-fishing in the northern lakes is the great variation from year to year in their fish yields. Table 6 shows the northern lake fish yield variability. Between 1962-1977, for the three smaller lakes the

Table 6

Northern Lakes Fish Yield Variability

	Coefficient of Variation			
	Maryut	Edku	Burullus	Manzala
1907-35 (MacLaren, 82)	---	---	---	.195
1962/3-1971/2 (CAPMAS Data)	.521	.642	.426	.134
1970-76 (IOF Data)	.820	.751	.305	.134

standard deviation of fish yields varied from 30% to more than 80% of the average fish yields. Manzala showed less variation, with the standard deviations running from 13.4% to 19.5% of mean fish yields; this would be expected because it is so much larger than the other lakes.

Intensified fishing effort combined with the oscillation of the fish catch data suggest that the fisheries are being over-exploited relative to the optimum sustainable fish yields (Clark, 76). Table 7 presents fish catch and licensed fishermen data for all four lakes for the eight-year period 1970-77. Developed to facilitate comparisons among the lakes, the data in Table 7 were constructed from official data series of the

TABLE 7

NORTHERN EGYPTIAN LAKES FISH PRODUCTION

	MARYUT	EDKU	BORULLUS	MANZALA	LAKES
1970					
FISH YIELD-TONS	1900	1298	9229	20546	32973
FISHERMEN-NUMBER	2700	3957	8816	8220	23693
TONS-FISHERMAN	0.70	0.33	1.05	2.50	1.39
1971					
FISH YIELD-TONS	2213	834	6908	22232	32187
FISHERMEN-NUMBER	2421	3942	8616	8058	23037
TONS-FISHERMAN	0.91	0.21	0.80	2.76	1.40
1972					
FISH YIELD-TONS	3105	667	8218	20743	32733
FISHERMEN-NUMBER	3036	4014	8076	8571	23697
TONS-FISHERMAN	1.02	0.17	1.02	2.42	1.38
1973					
FISH YIELD-TONS	6734	1219	7278	21566	36797
FISHERMEN-NUMBER	3027	3945	8565	7599	23136
TONS-FISHERMAN	2.22	0.31	0.85	2.84	1.59
1974					
FISH YIELD-TONS	13190	1385	8938	27567	51080
FISHERMEN-NUMBER	3114	3927	8655	8724	24420
TONS-FISHERMAN	4.24	0.35	1.03	3.16	2.09
1975					
FISH YIELD-TONS	15000	2534	11251	25461	54246
FISHERMEN-NUMBER	3362	3942	8745	9228	25277
TONS-FISHERMAN	4.46	0.64	1.29	2.76	2.15
1976					
FISH YIELD-TONS	8304	2518	9720	25170	45712
FISHERMEN-NUMBER	3609	4100	8925	9732	26366
TONS-FISHERMAN	2.30	0.61	1.09	2.59	1.73
1977					
FISH YIELD-TONS	13300	2058	6587	23055	45000
FISHERMEN-NUMBER	3009	4314	8532	8286	24141
TONS-FISHERMAN	4.42	0.48	0.77	2.78	1.86
1970-1977 AVERAGE					
FISH YIELD-TONS	7968	1564	8516	23293	41341
FISHERMEN-NUMBER	3035	4018	8616	8552	24221
TONS-FISHERMAN	2.54	0.39	0.99	2.73	1.70

SOURCE: COMPILED FROM MOA, IOF, AND CAMPMAS DATA; ALSO KHADR, 78.

Ministry of Agriculture, the Institute of Oceanography and Fisheries, and CAPMAS, and are presumed to underestimate the actual yields by one-third or more. These data reveal that when the number of fishermen declines (increases), the total fish catch in each lake tends to increase (decrease) in following years. Also, fishing effort responds to fish yields. A decrease (increase) in fish catch per fisherman and in net income per fisherman leads to a decrease (increase) in the number of licensed fishermen in the following year. These dependency relationships are statistically significant by a Chi-Square test at a 2.5% level. These interdependencies between fish catch and numbers of fishermen are largely responsible for the great variations in fish yields from year to year. As fishing intensity increases, the fish population begins to deteriorate, fish yields decline, and fishermen respond by decreasing their effort until the fish stocks build up again. As the fish stocks increase, fish yields per unit of effort increase, making fishing a more attractive alternative to farming pursuits. An increase in fishing effort follows, which, after a period, again reduces fish stocks, fish catch, and returns to fishing. This oscillating behavior of fishing effort and fish catch indicates that the intensive fishing effort is over-exploiting the fisheries, reducing actual yields below the optimum sustainable yields. Thus, the potential annual net income generated by the lakes fisheries could be substantially greater than current fishery management practices allow.

These features of the northern lakes' fish yields--the long term trends in the size and species composition of the fish catch and the annual variations in fish catch--are explained by the fishing intensity and the fishing practices. The open-access nature of the lakes fisheries has clearly reduced the potential value of the lakes as fisheries. While under-reporting and under-valuation of the fish catch misrepresents the value of the fisheries to Egypt, the over-exploitation of the fish populations in the lakes reduces actual yields substantially below those attainable, wasting a valuable natural resource. The combined effects of the under-reporting, under-valuation, and over-fishing could reduce the reported value of fish catch to a small fraction of the value of the real potential fish yields of the northern lakes. A thorough study of the lakes' fish populations and the impact of alternative fishing practices is required to determine the actual losses sustained by the lakes under the current fishery management practices.

B. Fisheries and Reclamation Development Alternatives:

El Kholei (80) estimated that between 1962-77, reclamation efforts reduced the four northern lakes' areas by 13%. The Lake Manzala Study (MacLaren, 82) concludes that Manzala is only 63% of its 1920-29 estimated area, the reduction being attributed to land reclamation, silt build-up, and increased vegetation. Our estimates show Maryut east of the Mersha Matruh Causeway is currently only 52% of its 1955 area. Edku, Burullus, and Manzala are 77%, 84%, and 71%, respectively, of their 1953 areas. Overall, the four northern lakes are currently 74% of their 1953-55 size. Since current drainage and reclamation plans call for the reclamation of almost 58% of the remaining lake areas, it is important to examine the implications of and returns to this policy (El Kholei, 80). Figure 12 shows the extent of the proposed reclamations to the year 2000.

The returns per feddan in alternative uses provide one basis for comparison between the use of the lakes as fisheries and as agricultural land. Table 5 shows that, except for Maryut, the average net income per feddan generated in the lakes is LE 34 or less, substantially below acceptable returns for agricultural production. Maryut's higher net income per feddan, LE 196, can be attributed to the conversion of its less productive areas to non-fisheries uses. The average number of feddans of lake area per licensed fisherman over the 1970-77 period was as follows: Maryut, 2.7 feddans per fisherman; Edku, 7.4; Burullus, 15.2; and Manzala, 30.1. The larger areas per fisherman in Edku, Burullus, and Manzala also produce a lower fish yield per feddan than that in Maryut, suggesting that the former lakes have large unproductive areas.

There have been few comparisons of the productivity of the lakes' fisheries with agriculture. However, the recent Lake Manzala Study (MacLaren, 82) did a general analysis of the net economic returns per feddan to agriculture and fisheries in the Manzala area. The results are presented in Table 8. The value of output from reclaimed agricultural land is LE 500 per feddan per year, as compared to LE 430 for fisheries in the productive Southern Sector, LE 190 for the Eastern Sector, and only LE 35 for the Western Sector of Lake Manzala. Valued at economic prices, the net economic returns per feddan per year are LE 325 to reclaimed (clay) soils for agriculture, LE 290 for the

FIGURE 12 LAND RECLAMATION ON THE NORTHERN LAKES, 1977-2000

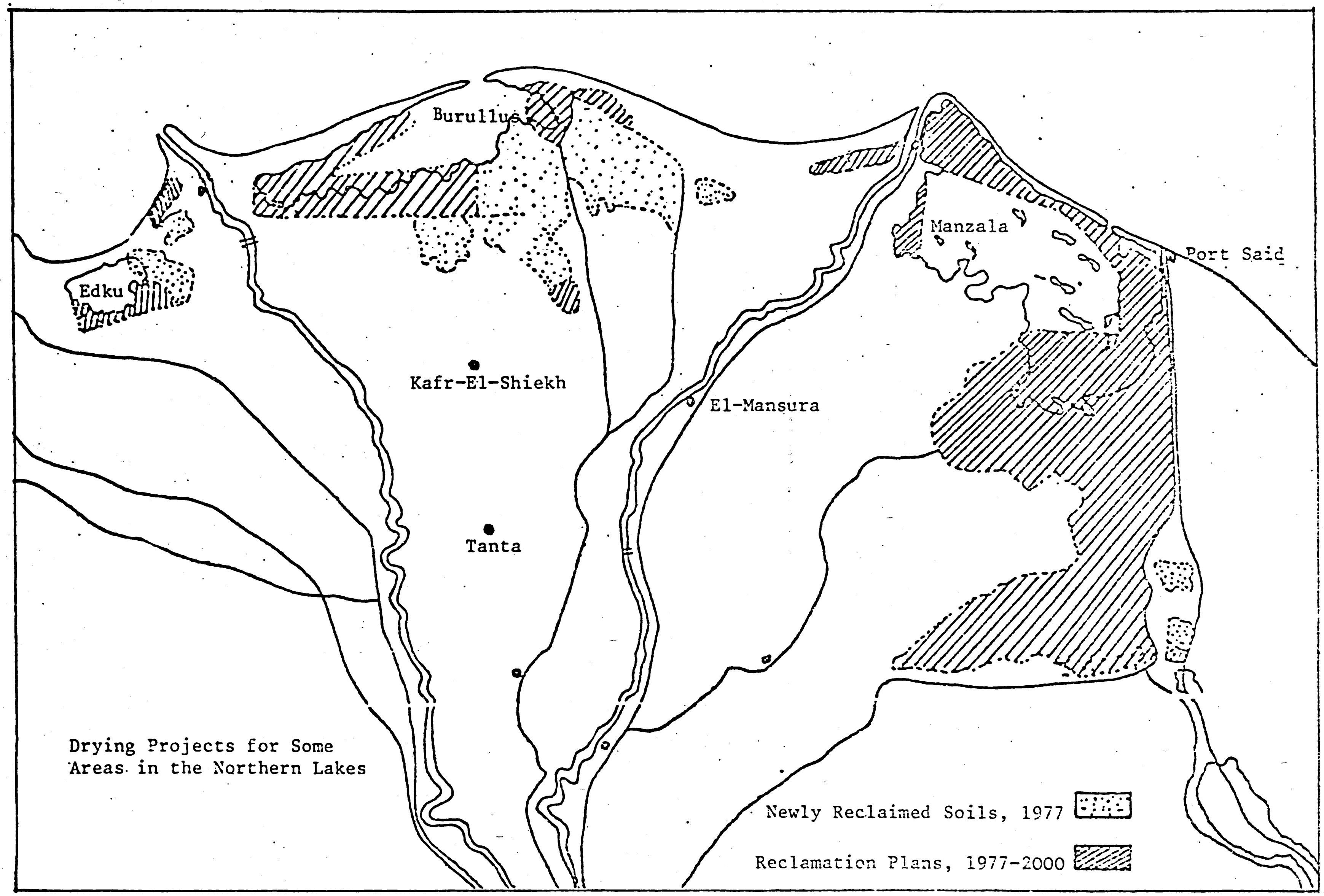

Table 8

Comparative Merits of Future Agriculture and Fisheries Development, Lake Manzala

	Agriculture (Reclamation)	Fisheries Sectors Southern	Eastern	Western
Output LE/Fed/Yr	500	430	280	35
Net Economic Return LE/Fed/Yr	325	290	190	16
Employment/Fed Number	330	310	230	50
Average Water Use Cubic Meter/Fed/Day	20 (Irrigation)	120 (Drain)	80 (Drain)	0-40 (Drain)

Source: MacLaren, 82

Southern Sector fisheries, LE 190 for the Eastern Sector, and LE 16 for the Western Sector. Thus, agriculture yields greater returns per feddan than do fisheries, in the general case. Open lake fishing can be quite productive, but it can hardly compete with agriculture in terms of productivity per feddan. However, the productive Southern Sector of Manzala actually approaches the productivity of agriculture in terms of output, net economic returns, and employment generation. This illustrates that even open-access fisheries can compete effectively with agriculture if the fishery is richly supplied with nutrient inputs.

Agriculture does not always represent the optimal use of the open lake areas, even of a relatively unproductive lake. As the reviews of past reclamation experiences on the delta lakes reveal, lake reclamation for agricultural production is a lengthy, costly, and difficult process. In particular, the variability of the results bears highlighting. Reclamation efforts require great selectivity and targeting of projects to be successful. In addition, the loss of the value of a fishery must be counted among the costs of a land reclamation project in a lake area. Agriculture may be a superior land use in the general case, but to justify changing lake into land requires that the net returns to agriculture also exceed the value, however low, of the fishery given up.

Water quantity and quality requirements are another basis for comparing development alternatives in the northern lakes. According to Table 8, lakes fisheries require two to six times as much water as does agriculture. Fish farms, similarly, require about three times as much water as does agriculture per feddan per year. This apparent advantage of agriculture, however, is limited because the supplies of irrigation quality water are limited, while lake fisheries as well as fish farms can use agricultural drain water which is unsatisfactory for further agricultural use.

The lack of available fresh irrigation water is a constraining factor on the extent to which the lakes could be converted to agricultural uses. The process of reclamation itself is very water-demanding, particularly during the leaching phase. Using increased quantities of agricultural land will increase the requirements for irrigation water. The quest for increased supplies of irrigation water has led to studies investigating reusing agricultural drainage water by diluting it with fresh water (El Guindi and Amer, 79; Water Master Plan, 81). While the scarcity of irrigation quality water creates strong competition for available supplies among alternative agricultural developments, the fisheries can await the multiple use and reuse of the water.

While agricultural and fisheries development may compete for suitable land resources, they are complementary in their water requirements. Land reclamation and increased agricultural production generate an increase in drainage water which is useable for further fisheries development. The increasing availability of low quality waste and drain water, as urbanization and agricultural expansion continue, increases the attractiveness of fisheries developments. Egypt is extremely fortunate to have these northern delta lakes as the final reservoirs for its waste and drain waters, allowing these waters to be used productively one more time before being discharged to the Mediterranean. The fisheries are the water user of last resort.

Land reclamation of the northern lakes area, then, is expected to prove economically justifiable only on carefully and judiciously selected sites, where the reclamation process is easy and inexpensive, the soils are good for agriculture, the area is assured of ample supplies of fresh water for reclamation and irrigation, and the lake areas given up are poor fisheries. By contrast the fisheries are justifiably preserved and improved in order to ensure full economic use is being made of Egypt's waste and drain waters, in areas unsuitable for agricultural reclamation either because of soil or water constraints, and where the alternative agricultural developments cannot generate sufficient net returns to offset the returns to the fisheries which would be sacrificed.

C. Policy Research for the Northern Lakes Development:

This overview of the development alternatives of the four northern Nile delta lakes and their fisheries has explored the history and current condition of the northern lake resources in addition to examining some of the policy issues which must be dealt with in determining the optimal development plan for these lake resources. The current organization of the lakes' fisheries results in the wasting of a large part of the value of these fisheries to Egypt. In addition to better reporting and correct valuation of the fish catch, the lakes' fisheries require a re-organization of the fishing industry and its management and fishing practices if the fisheries are to be fairly compared with alternative uses of the lakes.

Several policy-relevant research questions arise from this study. First, in addition to the usual attempt to determine which lake soils are suitable for reclamation, procedures should be developed for determining which areas of the lakes can be sacrificed at little cost to the total fishery yields. The lakes have already been sufficiently reduced in area so that further reclamation efforts should await a thorough assessment of the lakes' eco-systems to distinguish between lake areas which are and are not essential to the continued productivity of the lakes fisheries as a whole. Second, a thorough analysis of the water economy of the lakes is required to determine the water requirements of further fisheries development and to examine the impact of the water availability of alternative qualities of water on alternative lake development scenarios. Third, a thorough study of the interrelationships between the fishing and agricultural labor markets as they affect fishing effort on the lakes is required to determine the mechanisms through which intensive fishing effort limits the contribution of the northern lakes' fisheries to the economy. Fourth, the consequences for income distribution and social equity of alternative fishery management practices must be explored in order to identify socially acceptable policies. An integrated fishing-processing-marketing approach will be required, since improved fisheries management will reduce the number of fishermen while increasing the demand for labor to process and market the increased fish yields. The results of such research could provide the basis for a workable fisheries management policy for the lakes.

This study has demonstrated that Egypt has valuable resources in its northern delta lakes and their fisheries. Unfortunately, these lakes' resources have not been well preserved or developed. The lakes and their fisheries are a slowly depleting resource, being wasted for lack of adequate planning and management. A comprehensive lakes development program which focuses on the development of the fisheries resources as well as on the development of alternatives to fisheries in the lakes must precede the preservation of and maximization of the net returns from Egypt's valuable northern lakes' resources.

APPENDIX

The Application of Landsat Satellite Imagery to the Interpretation of Land Use Data

Information on land use changes can be obtained in a number of ways, but the most suitable method for this study is to use available Landsat satellite imagery. Information on the size and shape of these lakes prior to the availability of Landsat imagery has been obtained using topographical maps from 1953 and 1955. Landsat imagery has been used for subsequent years.

Landsat satellites orbit the earth at approximately 920 km (570 miles) altitude and acquire global coverage on frames 185 km (115 miles) per side every 18 days. The current generation of Landsat satellites provides a spatial resolution element of + or - 0.45 hectare (1.07 feddan), which is satisfactory for this study.

Images generated by these satellites can be obtained in black and white in one of four bands (bands 4 through 7) or as false color composites. False color composites are generated by exposing 3 of the 4 black and white bands through different color filters onto color film. Band 6 black and white images emphasize vegetation and show the sharpest demarcation of the boundary between land and water. It is these that have been used to determine the size of each lake in the early 1970's and 1980's. On the false color images, healthy vegetation appears bright red rather than green, clear water appears black, sediment-laden water appears powder blue and urban centers appear blue or blue-grey. Using these images, it is possible to observe the intensity of agricultural activity in the lands surrounding the lakes, to differentiate between formal agriculture and naturally occuring lakeside vegetation and to try to distinguish between marshland and emergent/reclaimed land.

The use of Landsat imagery is not without its problems. Seasonality, or the time of imagery acquisition, is an important factor in the interpretation of vegetation data. Short-term (daily/weekly) changes in crops occur during the growing season. These are related to time of ploughing, growing and harvesting, irrigation practices and crop stress in droughts. Medium-term changes (monthly/seasonally) result from crop rotation, pruning and thinning of fruit crops and seasonal variation in grassland. Medium-term changes in aquatic vegetation result from seasonal growth patterns and harvesting. To help overcome such problems, it is important to undertake ground truth surveys. Ideally, such a survey is undertaken near the time of satellite pass.

For the purposes of this study, knowledge of the Egyptian agricultural year, outlined below, is invaluable. The Egyptian agricultural year starts in November and is divided into three overlapping seasons.

Winter: Crop planting starts in October and extends through December. Winter crops are harvested from April to June.

Summer: Crop planting starts in March and extends through June. Summer crops are harvested in the period from August to November.

Nili: Crops are planted in July and August and are harvested in October and November.

In addition to the three seasonal patterns, there are permanent crops which occupy the land for an extended number of years.

In the northern part of the delta, the two most significant winter season crops are berseem and wheat. Other crops include barley, tomatoes, horse beans, flax, and other vegetables. In the summer, rice, cotton, and maize are important, together with vegetables and ground nuts. The Nili season crops are primarily maize and vegetables.

Certain identification of dry land as opposed to marshland, aquatic vegetation as opposed to incipient agricultural activity, and ponding as a precursor to land reclamation as opposed to fishing activities, was difficult. The resulting maps (Figures 2, 4, 7, 10) are believed to represent fair and reasonable outlines of the lakes. Ground truth surveys will result in greater familiarity with these lakes, and it is possible that the current interpretation of the boundaries of the southern shores of both Lakes Burullus and Manzala may require modification.

The information set out in Tables 1, 2, 3, and 4 is derived from the lake sizes and shapes shown in Figures 2, 4, 7, and 10. It is believed that these data form a fair basis from which to make comparisons between lakes on sizes and rates of reclamation.

REFERENCES

Aleem, A.A., and Samaan, A.A. Productivity of Lake Mariut, Egypt. Part I, Physical and Chemical Aspects. Int. Revue Ges. Hydrobiol., 54(3), 313-355, 1969a.

Aleem, A.A., and Samaan, A.A. Productivity of Lake Mariut, Egypt. Part II, Primary Production. Int. Revue Ges. Hydrobiol., 54(4), 491-527, 1969b.

Bisso, M.W.S. Fish Wealth of Egypt: An Economic and Geographical Study. M.A. Thesis, College of Arts, Alexandria University, 1981.

Banoub, M.W. The Salt Regime of Lake Edku (Egypt) Before and After the Construction of Aswan's High Dam. Arch. Hydrobiol., 85(3), 392-399, 1979.

Camp, Dresser and McKee International, Inc. Alexandria Wastewater Facilities Development Program. ARE Ministry of Housing and Reconstruction/Camp Dresser & McKee Int., Boston, 1977.

Chase Trade Information Cooperation. The Production and Processing of Egyptian Livestock, Poultry, and Fish Products, Sectional Survey 2. ARE General Authority for Investment and Free Zones, 1982.

Clark, C.W. The Economics of Overexploitation. Science, 181, 630-634, 1973.

Clark, C.W. Mathematical Bioeconomics: The Optimal Management of Renewable Resources. John Wiley & Sons, New York, 1976.

Egyptian Gazette. $14 Million IBRD Fish Farm Loan. P.2, April 8, 1981.

El Guindi, S.M., and Amer, M.H. Re-Use of Drainage Water for the Delta Area, Part II. Drainage Research Institute, A.R.E. Ministry of Irrigation, UNDP, IBRD, Cairo, 1981.

El Kholei, Osman. Costs and Returns of Reclamation in Abis Project: An Economic Analysis. Annals of Agricultural Science, Ain Shams University, Cairo, 11(1), 257-285, 1966.

El Kholei, Osman. A Research Proposal: An Economic Investigation of Reclaiming Soils of Northern Egyptian Lakes versus Their Development for Fish Production. Submitted to ADS/Egypt, December, 1980.

El Maghraby, A.M., Hashem, M.T., and El Sedfy, H.M. Species Composition and Distribution of the Mullet Fry in Lake Borollus, Egypt. Bull. Inst. Ocean. and Fish., 4, 1-32, 1974.

El Sedfy, H.M. and Libosvarsky, J. Some Effects of Aswan High Dam on Water and Fishes of Lake Borullus, A.R.E. Zoo. Listy, 23(1) 61-70, 1974.

El Wakeel, S.K. and Wahby, S.D. Hydrography and Chemistry of Lake Manzala, Egypt. Arch. Hydrobiol., 67(2), 173-200, 1970(a).

El Wakeel, S.K. and Wahby, S.D. Texture and Chemistry of Lake Maryut Sediments. Arch. Hydrobiol. 67(3), 368-395, 1970(b).

El Wakeel, S.K. and Wahby, S.D. Bottom Sediments of Lake Manzala, Egypt. Journ. Sedimentary Petrology, 40(1), 480-496, 1970(c).

El Wakeel, S.K.; Morcos, S.A. and Mahlis, A.M. The Major Cations in Lake Maryut Waters. Hydrobiologia 36(2), 253-274, 1970.

Farid, M.S., Hefny, K., and Amer, A. Hydrological Aspects of the Nile Delta Aquifer. Conference on Water Resources Planning in Egypt. University of Cairo/MIT/Min. Irrigation, Egypt, June, 1979.

Guariso, G., Whittington, D., Zikri, B.S., and Mancy, K.H. Nile Waters for Sinai: Framework for Analysis. Water Resources Research, 17(6), 1585-1593, 1981.

Hashem, M.T., El Maghraby, A.M. and El Sedfy, H.M. The Grey Mullet Fishery of Lake Borollus. Bull. Inst. Ocean and Fish, 3, 29-54, 1973.

Holeman, J.N. The Sediment Yield of Major Rivers of the World. Water Resources Research, 4, 737-747, 1968.

Hunting Technical Services, Ltd. Comparative Analysis of Reclamation Experience. Suez Canal Regional Integrated Agricultural Development Study. UNDP/EGY/76/001-6. Ministry of Development and New Communities, Cairo, A.R.E., 1980.

Khadr, N.A.E. Final Report on "Fisheries" in Egypt from 1970-1976. Master Plan for Water Resources Use and Development, ARE Ministry of Irrigation, Cairo, 1978.

Khafagy, A. and Manohar, M. Coastal Protection of the Nile Delta. Nature and Resources, 15(1), 7-13, 1979.

Larkin, P.A. An Epitaph for the Concept of Maximum Sustained Yield. Trans. American Fisheries Soc., 106(1), 1-11, 1977.

Larkin, P.A. Fisheries Management--An Essay for Ecologists. Annual Review of Ecology Systems, Annual Reviews, Inc., 9, 57-73, 1978.

Libosvarsky, J., Lusk, S., and El Sedfy, H.M. Fishery Survey Carried Out at Lake Borullus, A.R.E., in the Spring of 1971. Praha Academia, 1, p.41, 1972.

MacLaren, Marex, Inc. Fish Farming in Egypt: A Scenario to the Year 2000. A.R.E. Ministry of Irrigation, UNDP and IBRD, Cairo, 1980.

MacLaren Engineers, Planners, & Scientists, Inc. Lake Manzala Study. ARE/UNDP/EGY/76/001-07. Cairo, 1982.

Mancy, K.H. Water Quality Studies on the River Nile and Lake Nassar. Egyptian Academy of Scientific Research Technology. Universiy of Michigan, 1980.

Nasr, A.B., Hashim, M.A. and Aleem, A.A. The Flora of Lake Edku and Particular Reference to Bethic Diatoms. Bull. Fac. Sci. Alex. Univ. 5, 219-235, 1963.

Rzoska, J. (ed). Delta Lakes of Egypt. The Nile: Biology of an Ancient River, 309-312. <Monographiae Biologicae 29>. The Hague: W. Junk, B.V., 1976.

Saad, M.A.H. Calcareous Deposits of the Brackish-water Lakes in Egypt. Hydrobiologia, 44(4), 381-387, 1974.

Saad, M.A.H. Studies on the Nature and Composition of the Sediments of Two Egyptian Lakes Found under Different Local Conditions. Limnologica, 11(1), 1-8, 1976.

Salah, M.M. Biological Productivity of Lake Mariut and Lake Edku. Notes and Memoirs, N. 63. Hydrobiological Institute of Alexandria, 1961.

Samaan, A.A. Primary Production of Lake Edku. Bull. Inst. Ocean and Fish., A.R.E., 4, 259-317, 1974.

Shaheen, A.H. and Yousef, S.F. The Effect of Cessation of Nile Flood on the Hydrographic Features of Lake Manzalah, Egypt. Arch. Hydrobiol., 84(3), 339-367, 1978.

Shaheen, A.H. and Yousef, S.F. The Effect of Cessation of Nile Flood on the Fishery of Lake Manzala, Egypt. Arch. Hydrobiol., 85(2), 166-191, 1979.

Wahby, S.D., Yousef, S.F., and Bishara, N.F. Further Studies on the Hydrography and Chemistry of Lake Manzalah. Bull. Inst. Oceanogr. Fish, A.R.E., 2, 401-422, 1972.

Wahby, S.D., and Bishara, N.F. Physical and Chemical Factors Affecting Fish Distribution in Lake Manzalah, Egypt. Acta Ichthyologica et Piscatoria, 7(1), 15-30, 1977.

Wahby, S.D., Kinawy, S.M., El Tabbach, T.I., and Abdel Moneim, M.A. Chemical Characteristics of Lake Maryut, a Polluted Lake South of Alexandria, Egypt. Estuar. Coastal Marine Science, 7(1), 17-28, 1978.

Wahby, S.D., and El Moneim, M.A.A. The Problem of Phosphorus in the Eutrophic Lake Maryut. Estuar. Coastal Marine Science, 9(5), 615-622, 1979.

Water Master Plan. Water Quality. Technical Report No. 7. UNDP-EGY/73/024. A.R.E. Ministry of Irrigation, UNDP, IBRD, Cairo, 1981.