RESTRICTED

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INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT

# PRELIMINARY REPORT

# ON THE SADD EL-AALI PROJECT

# EGYPT

February 28, 1956

Department of Technical Operations

# N O T E

This preliminary report on the Sadd el-Aali project has been prepared on the basis of certain assumptions of which the most important are that (1) the design of the project will not be radically changed, (2) the cost currently estimated will not be substantially increased, and (3) the amount of water available to Egypt after completion of the project will be sufficient to irrigate 1.3 million feddans of additional land.

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| | | |
|---|---|---|
| One Egyptian Pound (£E 1.0) | = | U. S. \$2.87 |
| One Piaster (1/100 £E) | = | U. S. \$0.0287 |
| One Millieme (1/1000 £E) | = | U. S. \$0.0028 |
| One Feddan | = | 1.038 acres |
| One Ardeb | = | 5.6 bushels |
| One cubic meter (M3) | = | 1.31 cubic yards |
| One Milliard (of M3 of water) | = | 0.801 million acre feet (of water) (MAF) |
| One cubic meter per second (M3/sec.) | = | 35.31 cu. ft/sec. |
| One Meter | = | 3.281 feet |
| One Kilometer | = | 0.621 miles |
| One Square Kilometer | = | 0.386 square miles |
| One Metric Ton | = | 1.102 short tons |
| One Kilogram (kg) | = | 2.205 pounds (avdp.) |
| 1,000 Watts | = | 1 kilowatt (KW) |
| 1,000 Kilowatts | = | 1 Megawatt (MW) |
| One Kilowatt (KW) | = | 1.341 horsepower (HP) |
| One Horsepower (HP) | = | 0.746 kilowatts (KW) |

# PRELIMINARY REPORT
# ON THE SADD EL-AALI PROJECT

## EGYPT

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## SUMMARY

1. This report is a preliminary appraisal of a project, proposed by the Government of Egypt, to build a high dam (Sadd el-Aali) on the Nile approximately 6½ kilometers upstream from the existing Aswan Dam. The reservoir will have a capacity of 130 milliards (billion) cubic meters. Its primary purpose is storage for irrigation use of essentially all of the annual run-off of Nile flood waters. In addition the project will include 720,000 kw of installed power. Flood protection for the downstream areas will be provided by the dam and navigation conditions improved.

2. The dam itself, which is estimated to require ten years to build, and the power generating facilities and transmission lines are estimated to cost LE 167 million ($481 million) exclusive of interest during construction. When the costs of irrigation and drainage works, land reclamation and settlement, public utilities and indemnities are added, the entire program is estimated to entail an investment of LE 418 million ($1,200 million). Interest during construction on the public investment will raise the total further to LE 460 million ($1,320 million). Of this amount at least LE 323 million ($927 million) will be public investment of which in turn LE 136 million ($390 million) will require foreign exchange.

3. The project is technically sound. Its reservoir capacity is the optimum to enable the maximum volume of Nile water to be made useable. It would be an integral and essential part of any over-all scheme for the full development of the Nile water resources. It does not conflict with, but rather supplements, the so-called Century Storage scheme which, by providing over-year storage in the equatorial lakes, would smooth out the long wet and dry cycles, whereas Sadd el-Aali would provide basically for the storage of annual flood water and smooth out the shorter-run annual fluctuations in the river flow. Sadd el-Aali can perform this function more effectively than other proposed reservoirs on the Nile which because of inadequate storage capacity would not in the aggregate ensure a controlled supply of water for irrigation comparable to that provided by Sadd el-Aali.

4. The project would be the dominating feature of Egyptian economic development over the next decade and would no doubt strain Egypt's financial resources.[1/]

5. Before the project can be carried out there must be agreement with the Sudan on two points:

(a) Indemnities: The reservoir created by Sadd el-Aali would extend some 550 kilometers upstream, about 200 kilometers of which are within the Sudan. An agreement with the Sudan regarding the indemnity to be paid for flooding Sudanese territory will accordingly be necessary; and

1/ See report "The Economic Development of Egypt" No. A.S. 40-a

(b) Division of Water: Due to fluctuations in the present run-off and to the limited capacity of existing storage reservoirs, the useable irrigation supplies vary widely from year to year, but on the average Egypt's annual use is 49.2 milliards and Sudan's is 3.6 milliards, both measured at Aswan.1/ The Sadd el-Aali reservoir would not only stabilize the amount of water available for irrigation in Egypt, but also make available additional annual supplies amounting (after allowing for evaporation lost) to about 19 milliards, measured at Aswan. It has been assumed in this report, for the purpose of appraising the project, that the eventual division of the additional supply between Egypt and the Sudan would permit the irrigation of 1.3 million feddans of new lands in Egypt.

6. The most important benefits of the project would be in the field of agriculture. Water rather than land is the limiting factor for agricultural production and essentially all the presently developed supplies are now utilized. The cropped land available for the large and rapidly expanding agrarian population has diminished from 0.90 feddans2/ per head in 1927 to 0.70 in 1953. The increase in population in Egypt, now at a rate of about 2½% per year, makes it essential that additional irrigation supplies be developed. In Egypt, agriculture cannot be carried on without irrigation. Moreover, a substantial increase in agricultural production and income is required to give a much needed impulse to the development of other sectors of the economy -- industry, trade and finance -- which otherwise are likely to stagnate. The Egyptian Government expects that the project would enable Egypt to (1) increase the irrigated area by 1.3 million feddans, i.e. from 6.15 to 7.45 million feddans, (2) convert about 670,000 feddans of basin irrigated land to perennial irrigation, and (3) increase yields by improving drainage and assuring a more regular water supply. As a result, agricultural income is expected to rise ultimately by 45%.

7. The second most important benefit would be derived from the electric power which would be generated at the dam. In the first stage, the power plants would have a capacity of 720,000 kw, one-half that ultimately to be developed at the dam. Present capacity for electric generation in Egypt totals about 500,000 kw and this is being increased by the construction of new thermal capacity and by the Aswan power scheme to almost 1,200,000 kw. The addition of the Sadd el-Aali station would thus increase the total supply of power in Egypt to approximately 1,900,000 kw or about four times the present supply. Developing demand will probably require this capacity some time between 1971 and 1973. The additional investment cost (LE 101 million) caused by the incorporation of power features in the project is warranted because it would make possible the delivery of power at load centers in Cairo and the Delta at a cost substantially below that of thermal power.

8. The navigation and flood control benefits, though ancillary, are not unimportant. By stabilizing the flow of the Nile in Egypt throughout the year, Sadd el-Aali would make possible year-around navigation of the Nile and its

1/ Losses of 20% occur between the point of measurement in the Sudan (Sennar Dam) and Aswan, the point of measurement in Egypt.

2/ One feddan equals 1.038 acres.

and downstream canals, thus lowering the cost of bulk transport. By effectively controlling floods, the project would save the Government certain recurring expenditures for flood control and eliminate damage to land resulting from seepage and infiltration during the flood season.

9. Major benefits from the project cannot be expected until after the completion of the dam in 10 years' time and the full benefits are not likely to be realized until some ten years after that. When the upstream coffer dam is finished after the fifth construction year, there would be some improvement in the control of the Nile, resulting in a modest increase in the supply of irrigation water and raising the amount of firm power which can be generated at the power station now under construction at the existing Aswan dam.

10. The investment in the project although large, would not be unreasonable in relation to the aggregate economic and financial benefits which will flow from it. The total annual economic benefits, in terms of additional national income, would ultimately amount to more than a third of the investment. In financial terms, the net potential income from power would be more than enough to pay off the entire power investment -- LE 101 million -- within 15 years' operation. Meanwhile, the government's general tax revenues, including those derived directly and indirectly from the project, would be large enough to allow for service of the debt not retired from power revenues.

PRELIMINARY REPORT

SADD EL-AALI PROJECT

E G Y P T

# I. BACKGROUND

## A. Introduction

The Government of Egypt proposes to build a large dam on the Nile River primarily in order to store flood waters for irrigation use, but also to generate large quantitiesof electric power, provide flood protection and improve navigation. Pursuant to a request by the Egyptian Government, this report appraises the merits of this project, known as Sadd el-Aali (High Dam). The project study is based on information obtained by Bank representatives (Messrs. Hathaway, Joosten, and Coolhaas, consultants, and Messrs. de Wilde and Bass), preliminary engineering studies and reports prepared by Hochtief (a German firm), data submitted by the National Production Council (an Egyptian Government agency established in January 1953), and by the Sadd el-Aali Authority and the report and advice of the International Board of Consultants.1/ The data obtained are sufficient for an adequate appraisal.

It is a large and ambitious project by any standards of comparison. According to the preliminary designs, which have been appraised as being sound by an experienced group of international consultants, the reservoir will have a capacity of 130 milliards 2/, enough to store the seasonal floods, smooth out the flow of the river for irrigation use, navigation and power production, and contain a dead storage volume for deposition of silt sufficient for at least 500 years.

Construction of the dam and initial power facilities is estimated to require approximately ten years and to cost LE 167 million (exclusive of interest during construction).3/ The entire program, except for a later doubling of the power capacity, is estimated to require a total investment of approximately LE 460 million over a period of sixteen years. Of this, at least LE 281 million (LE 323 million including interest) will be public investment including foreign exchange outlays of LE 123 million. The project provides for generating facilities of 720,000 kw, one-half the ultimate capacity, an Aswan-Cairo transmission line and interconnections, and irrigation developments to increase the area of perennially irrigated lands by 1,970,000 feddans including conversion to perennial irrigation of 670,000 feddans of land now irrigated by the basin method and capable of producing only one crop per year.

For irrigation purposes, the project would increase the present annual supplies of water, now about 53 milliards in normal years in Egypt and

1/ See pages 16 and 17, describing the International Board of Consultants.
2/ A milliard, as used throughout this report, represents a thousand million cubic meters.
3/ Equivalent to US $481 million, at exchange of LE one - $2.87.

the Sudan, by another 19 milliards. Egypt hopes it will be able to use about ten milliards of this for increasing the area under irrigation from 6.15 to 7.45 million feddans.[1]

Egypt, substantially without rainfall, is wholly dependent on Nile waters for its livelihood. Outside the irrigated areas which comprise less than 3% of the total, the country is desert. About 22 million people live on the productive six million feddans. Population pressure on the land is severe and the situation is becoming more acute each year because of the exceedingly rapid population growth in the country. By far the largest portion of the population, about 60%, are engaged in agriculture and live in villages and hamlets. Farms are small. Of the holdings of agricultural land more than half are less than one feddan and the average for all holdings is about 2-1/4 feddans.

Water is the limiting factor for the area of land that can be cultivated and of the quantity and kinds of crops that can be produced. Under the present development of the Nile, relatively little additional land could be served with dependable irrigation water and additional output can, in the main, be achieved only by raising yields which are already very high. The population is increasing annually by approximately 2½% or at present by about one-half million, and at its current rate will double in less than 30 years. An immediate and broad scale approach to the development of the Nile water resources for their most efficient use is thus called for.

## B. Existing Utilization and Storage of Nile Waters

A map of the Nile Basin is included in the appendix. A reference to it, together with a very brief description of the Nile system gives an idea of the river's potentialities but at the same time emphasizes that the problems for its development and use are both extensive and intricate. The Nile is the dominating feature of the northeast quarter of Africa. Its basin embraces Egypt, the Sudan, Uganda, one-third of Ethiopia and parts of Kenya, Tanganyika, Ruanda-Urandi and the Belgian Congo. All along its more than 4,000 mile course people are affected by the river or by the water which helps form it.

The river is characterized by a regular flood cycle with the rise taking place in Egypt during July and August. Usually the peak of the flood is reached in early September, at which time the river begins to fall and reaches a minimum flow the following May. The annual recorded run-off at Aswan has varied from about 45 to 137 milliards, the annual mean for the last 54 years being about 83.7 milliards. Of this amount in an average year about 29 milliards, or 35%, wastes to the sea.

### Hydrology

The known history of the hydrology of the Nile dates back further than that of any other river of the world. Measurements have been continually made at a river gauge erected near Cairo about 641 A. D. and records are available for most of the time since then. The three principal streams making up the "Main Nile," - the designation given the reach from Khartoum to the sea -

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1/ One feddan equals 1.038 acres.

are the Blue Nile, the White Nile, and the Atbara. The maximum discharge of the Nile considered at Aswan occurs on about September 8 each year. At this time the water components contributed by these three rivers in an average year are as follows:

| | Millions $M^3$/day | Percent Total discharge |
|---|---|---|
| White Nile | 70 | 10 |
| Blue Nile | 485 | 68 |
| Atbara | 157 | 22 |
| Total | 712 | 100 |

The minimum discharge is about 45 million $m^3$ per day, less than one-fifteenth the maximum and it occurs on about May 10. The flow from the above rivers is relatively very different in low flow:

| | Millions $M^3$/day | Percent Total discharge |
|---|---|---|
| White Nile | 37.5 | 83 |
| Blue Nile | 7.5 | 17 |
| Atbara | 0 | 0 |
| Total | 45 | 100 |

The Blue Nile originates in Lake Tana, a large equatorial lake in northern Ethiopia which itself contributes about 7% of the total discharge of the river. The Blue Nile is fed by many tributaries in Ethiopia and also by a number in the Sudan of which the Rahad and the Dinder, contributing about 10% of the annual discharge, are the most important.

The White Nile flows from a series of equatorial lakes which drain a large area having heavy tropical rainfall - Lake Victoria, the largest with a surface of 67,000 square km. located on the border of Uganda, Tanganyika and Kenya and draining into Lake Kioga, a relatively much smaller lake immediately to the north in Uganda and which in turn drains by the Victoria Nile into Lake Albert; and Lake George and Lake Edward, companion lakes on the Congo-Uganda border, both of which also feed into Lake Albert. The annual contribution of these lakes to the White Nile, which has its source at the outlet of Lake Albert, is set forth in Table No. 1.

Table No. 1

Inflow and Outflow, Equatorial Lakes

| | Lake Victoria | Lake Kioga | Lakes George and Edward | Lake Albert |
|---|---|---|---|---|
| | (Milliards) | | | |
| Inflow from tributaries | 16.0 | 24.1 | 2.2 | 25.0 |
| From rainfall on Lake | 98.0 | 8.0 | 3.4 | 4.6 |
| Total | 114.0 | 32.1 | 5.6 | 29.6 |
| Evaporation | 93.0 | 12.4 | 3.6 | 4.9 |
| Outflow | 21.0 | 19.7 | 2.0 | 24.7 |
| Flows into: | L. Kioga | L. Albert | L.Albert | White Nile |

It will be noted that the loss from evaporation on these lakes roughly equals the rainfall on them during the year. The White Nile, carrying the outflow from Lake Albert, receives the contribution of waters from other torrents and attains an annual volume of 27.3 milliards by the time it reaches Mongalla where it becomes known as the Bahr el Jebel in the reach through the Sudd marshes in southern Sudan between Mongalla and Malakal. In the Sudd marshes it loses about half its volume of water and joins the Sobat just above Malakal to form the main reach of the White Nile. The Sobat river is formed by two main branches, the Baro and the Pibor, of which the Baro produces the greater quantity of water. All of the Baro and a good part of the Pibor water comes from Ethiopia. Both rivers are large streams in the wet season, June to December, but have an insignificant flow during the dry season. The Bahr el Jebel and the Sobat contribute an annual flow of 14.3 and 13.3 milliards respectively making the headwater flow in this reach of the White Nile 27.6 milliards in an average year.

The White and the Blue Niles join at Khartoum in the Sudan to form the Main Nile. Some distance downstream the Atbara River, which has its headwaters in Ethiopia, empties into the Nile. During the period from January to June it is dry, but during the peak flood it contributes as much as 22% to the discharge of the Nile measured at Aswan.

## Historical Development

### 1. Use of Nile Waters

Irrigation has been practiced in the Nile Valley since the beginnings of agriculture in predynastic times. Tradition has it that the building of dykes to contain floodwaters for the first basin irrigation practices began about 3400 BC. Under this ancient system, the land is divided into basins of from one thousand to 40 thousand feddans by the construction of dykes, and flood waters are let into the compartments to a depth of one or two meters. After from 40 to 60 days, when the river has fallen, the areas are drained and a crop is produced by use of the residual moisture. In addition, the deposition of silt, under this system of irrigation, adds to the soil fertility. There still remain in Egypt today about 670,000 feddans watered by a very effective system of basin irrigation, although only one crop annually is produced. Modern perennial irrigation development, as we know it, achieved by means of large scale control structures for diversion and storage of water for supplying irrigation canals throughout the year, dates in Egypt from the completion of the first barrage in 1861. By 1890 the area under perennial irrigation in Egypt was 2.9 million feddans, and this used up the whole of the natural flow of the river during the low period before any storage dams were built. At that time there remained in Egypt about 2 million feddans under basin irrigation. The first storage dam, Aswan, was completed in 1902 and, at the height first constructed, stored one milliard.

A decade later plans began to mature for further conservancy works. In the Sudan a barrage was planned which would supply irrigation for 100,000 feddans in the Gezira triangle where the Blue and White Niles meet. But the exceptionally low water in 1913 (one of the four lowest in recorded history) showed that a storage dam at Sennar would be necessary and that with a reservoir of the capacity originally proposed, 300,000 feddans could be irrigated. At the same time the Egyptian Government was considering construction of a dam at Gebel Aulia on the White Nile not far from Khartoum. Progress on this scheme was interrupted by World War I.

In 1920 the Egyptian Government outlined a series of projects under the title of "Nile Control."1/ These consisted of the Gebel Aulia dam, the Sennar dam, an additional barrage (Nag Hamadi) on the Main Nile in Egypt, an Upper Blue Nile dam and developments in the Sudd Region and for Lake Albert storage, but the accuracy of the data on which the proposals were based was widely attacked and the "Nile Control Commission," an international body composed of three engineers, was appointed by the Egyptian Government. The British Government and Cambridge University each nominated one member. The American Government nominated Mr. H. T. Cory. This Nile Control Commission was asked:

a. to report on the physical data on which certain of the Nile control projects had been based;

b. to report on the best allocation of the increased available water at each stage of development; and

c. to advise on the apportionment of costs of the proposed works.

In its report dated August 25, 1920 the Commission unanimously supported the underlying data and a majority recommended a "workable solution" of the problem of apportioning costs. On the division of additional Nile waters, however, the Commission found it impossible at that time to reach

1/ Based on a report, "Nile Control," by Sir Murdock MacDonald, then adviser to the Egyptian Ministry of Public Works.

agreement.[1/]

Although the Egyptian Government delayed action on both Gebel Aulia and Nag Hamadi, the Sudan proceeded with the construction of the Sennar dam which was completed in 1925. This proved to be a more expensive undertaking than originally estimated and to justify the costs the method of operation was changed so as to irrigate a much larger area (now actually 890,000 feddans) than the 300,000 feddans originally planned for.

Because of these activities and as a result of agreement between Great Britain and Egypt, another group, designated as "The Nile Commission,"[2/] was established in 1925 "for the purpose of examining and proposing the basis

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1/ Mr. Cory proposed that the following general formula be applied:

1. Each country should have "a vested right in perpetuity to the supply of water when and as beneficially used by it during the past few years; 2. the unappropriated water possible of use...should be divided...so as... in each case to permit irrigation of like percentages of the superficial area of arable land unwatered but irrigable and lying within the watershed of the stream; 3. the cost of all works ... as well as all maintenance and operation charges ... should be shared on the basis of the quantity of conserved water each shall be entitled to receive measured at the point of conservation." However, if either country does not wish to or cannot "advance its share of the first cost of any conservation work, its failure to do so in no sense stops it from eventually participating in the full use of the works aforesaid upon due payment of its proper share of the cost." Mr. Cory added: "... it may be well to notice the suggestion sometimes made that the allocation of water should be based upon, or at least take into account, the population of the moment. Such an idea is untenable ... the very essence of water rights is that lands acquiring them should be assured of continual irrigation in future."

The two British commissioners "were unable to decide precisely what proportion of the increased supply of available water ... should be allocated to Egypt and the Sudan respectively, because it has been impossible to obtain sufficient data on which to base any reliable forecast of the probable rate of increase of irrigation in the Sudan." As to Mr. Cory's views they stated: "We feel that, while his findings may be theoretically correct, it is impossible, on financial and other points, to apply them in present circumstances."

The majority view prevailed and no action was taken under Mr. Cory's formula. The formula which he proposed has served, however, as the base for certain of the proposals in the current Egyptian-Sudanese discussions concerning a division of the additional Nile waters which the Sadd el-Aali will make available.

2/ Appointed January 1925, with Mr. Canter Cremers, a Dutch engineer, as Chairman and with Mr. R. M. MacGregor and Mr. Abdel Hamid Suleiman Pasha as members.

on which irrigation can be carried out with full consideration of the interests of Egypt and without detriment to her natural and historic rights." The report of this Commission, dated March 21, 1926, was incorporated in an exchange of notes in May 1929 between Great Britain and Egypt which is known as the "Nile Waters Agreement" of 1929.

2. The "Nile Waters Agreement" of 1929

The March 1926 report provides for "working arrangements," drawn up by the authorities of Egypt and the Sudan, to control the operation of storage and the use of water in the Sudan. It goes further and specifies that, except with the previous agreement of Egypt, no works should be constructed or measures taken on the Nile or on its tributaries, in the Sudan or in the territories under British administration, which would affect the flow of the river in such a way as to cause prejudice to the interests of Egypt.

This "Nile Waters Agreement" is the basis of the present allocation of water to the Sudan. It was intended to provide "a practical working arrangement which would respect the needs of established irrigation, while permitting such program of extension as might be feasible under present conditions and those of the near future, without at the same time compromising in any way the possibilities of the more distant future." The "working arrangements" were based upon recognition of the fact that for many years past the whole of the natural flow of the river during the low period had been used for irrigation in Egypt, and by pumps already established in the Sudan. This established irrigation had to be respected, and to permit this, it was provided that the Sudan's further requirements at this time of year should be met entirely from stored water.

The period when the whole flow was already so used was found to begin on 19th January at Sennar, but for convenience the "restricted period" was defined as beginning on 1st January, there being added to the Sudan's entitlements agreed quantities of water to be taken from the river from 1st to 18th January. The water used on all additional areas under pump irrigation in the "restricted period" is replaced in the river by the release of corresponding quantities of water from Sennar reservoir in compensation. The whole use of water by the Sudan during the restricted period is recorded in the annual "Water Account," in which the Sudan receives credit for the contents of Sennar reservoir and her other entitlements, and is debited with all the amounts of water used under the various heads. The Nile Commission found that the "restricted period" ends, and the "period of surplus" begins, on 15th July at Sennar (provided by that date the rising flood has reached a certain minimum discharge). During the "period of surplus," the Sudan is entitled to take water into the Gezira Canal up to certain maximum daily rates, to fill the Sennar reservoir, and to flood the areas under basin irrigation in the Northern Province so far as the natural rise of the flood permits. Irrigation by pumps is unrestricted from July 15 to December 31.

3. Other Developments

A further raising of Aswan reservoir was not included among the projects considered by the Nile Commission. However, in 1929 the Egyptian

Government approved a large program of irrigation works which included both this project and the previously deferred project for the Gebel Aulia reservoir. The second raising of the Aswan dam was completed in 1933, increasing the capacity of the reservoir to 5.4 milliards. The construction of Gebel Aulia reservoir was completed in 1937; its capacity was 3.6 milliards, but owing to heavy losses of water by evaporation in the reservoir and during transmission down the river, it increased the water available at Aswan only by about 2.5 milliards.

## C. Operation of Existing Irrigation Reservoirs

Use of Nile water is presently limited to the amount that can be obtained from the limited capabilities of the storage dams which are located at Aswan in Egypt and at Gebel Aulia and Sennar in the Sudan. The combined capacities of the Aswan, Gebel Aulia and Sennar dams is about 8.1 milliards.

### Aswan Reservoir

The present Aswan Dam can be filled to R.L. 121[1/] and has a capacity of 5.411 milliards at this level. During normal years, storage in the reservoir begins when the river has fallen to 91.0 on the Aswan gage which occurs generally in the early part of October. Filling is completed by the end of January and storage is released as soon as the natural river begins to fall below irrigation requirements.

### Sennar Reservoir

The Sennar Dam, situated on the Blue Nile in the Sudan about 200 miles south of Khartoum, was first filled in December 1925. The reservoir is used to irrigate the Gezira plain in the Sudan and originally had a storage capacity of 781 million $m^3$, which was sufficient to supply about one million feddans. During the period of 1950-52 the dam was raised to provide additional storage and the reservoir now has a capacity of 929 million $m^3$, or about one milliard.

The irrigation season in the Gezira begins in the middle of July, after the reservoir level has been raised sufficiently to divert water through the main canal. In October and November, after the crest of the flood has passed, the reservoir is raised to full level. This stored water remains until January when the natural supply falls short of the combined requirements of Sudan and Egypt and after which the Sudanese must draw only on the supply stored in the reservoir. Irrigation of cotton in the Gezira ends in March.

### Gebel Aulia Reservoir

The Gebel Aulia dam in the Sudan 40 kilometers south of Khartoum on the White Nile was completed and partially filled in 1937. The water surface

1/ Reservoir level, or elevation in meters above sea level.

thereafter was raised 50 centimeters higher each year until the design level was reached in 1942. The maximum head on the dam is around 6.5 meters and the capacity at full reservoir is about 3.6 milliards.

The stored water is used entirely by Egypt for irrigation. Filling begins in July and is completed in October, the rate of filling depending a great deal upon the stage of the Blue Nile as the reservoir is operated to provide a measure of flood protection for Egypt during the filling period. Storage is released beginning in February and the reservoir is emptied usually by the first of May.

## D. Schemes for Overall Development of the Nile

The further development of the Nile and the apportionment of the benefits therefrom among the inhabitants of the Nile Basin has been the preoccupation of river planners for a long time; and in view of the wide political and economic implications of this subject, it has naturally also created much controversy.

Any future planning regarding the use of the Nile water resources must obviously take into account the Nile as a whole and proceed from the assumption that no development project can be undertaken without consideration of its effect on the entire river and the inhabitants of the Nile Basin. Water conservation and utilization, to the extent that it alters the regime of the river or the availability of water in any part of the Basin, is inextricably bound up with the life and habits of the people affected.

Probably the best known and most comprehensive scheme was proposed, after years of investigations and planning, by Messrs. Hurst, Black and Simaika, experts on the staff of the Egyptian Ministry of Public Works. It was brought out under the title "The Future Conservation of the Nile" as Vol. VII of the series "The Nile Basin" published by the Ministry in 1946.

The authors of the report discussed in detail the principles of overyear storage which had been advanced in the Nile Control plan of 1920, and set out the various projects which in their opinion represented a comprehensive scheme of development for the Nile as a unit to meet the expected future needs of Egypt and the Sudan. They made their projections on the basis of records of natural flow over a period of 100 years and hence characterized the scheme as "Century Storage." The basic need for the Century Storage scheme develops from the fact that due to the variations in the river flow from year to year there would be many years when the annual storage reservoirs at Aswan and Sennar particularly could not be filled with silt-free or storable water, with the result that in a low year there would be a double shortage resulting from the combination of low flow and inadequate storage. Since this shortage could only be met with hold-over storage from a previous period, a plan for overyear storage was considered necessary.

The "Century Storage" scheme when presented was described as "a comprehensive plan for the development of the Nile," the component parts of which were to work in conjunction with the existing reservoirs to supplement the natural flow of the river. The accompanying schematic diagram of the projects included in the Century Storage illustrates how the scheme works as a unit.1/ The main projects in the scheme are:

a) A large reservoir in Lake Victoria, controlled by a dam at the Owen Falls, to form the main reservoir for Century Storage, and to also provide hydroelectric power for use in Uganda. By means of this reservoir water will be stored in good water years to supplement the supply of bad ones.

b) A regulating barrage downstream of Lake Kioga to create an auxiliary for the Lake Victoria reservoir. By maintaining storage in Lake Kioga, an increase of the discharge from Lake Victoria can be passed on without having first to raise the level of Lake Kioga, thus avoiding a delay of two or three months.

c) A reservoir in Lake Albert to control water from the Semlike River and also the large quantity which in time of unusually heavy rain comes from the tributaries of Lake Kioga. The Lake Albert dam will be the regulator which controls the amount of water sent down from the lake plateau to the Sudan and Egypt.

d) The Jonglei Diversion Canal between Jonglei and Malakal to carry a large quantity of water which would otherwise flow in the Bahr-el-Jebel and spill into the swamps of the Sudd region, where it would disappear by evaporation and transpiration. Thus the regulated water from Lake Albert would be able to pass the swamps with only a relatively small loss as compared with the 50 per cent lost at present.

e) A dam at the outlet of Lake Tana, if the lake is used to its full capacity, to provide water for increase of cultivation in the Sudan, a measure of Century Storage and a reserve in case of an emergency in Egypt, such as was caused by the record low flood of 1913.

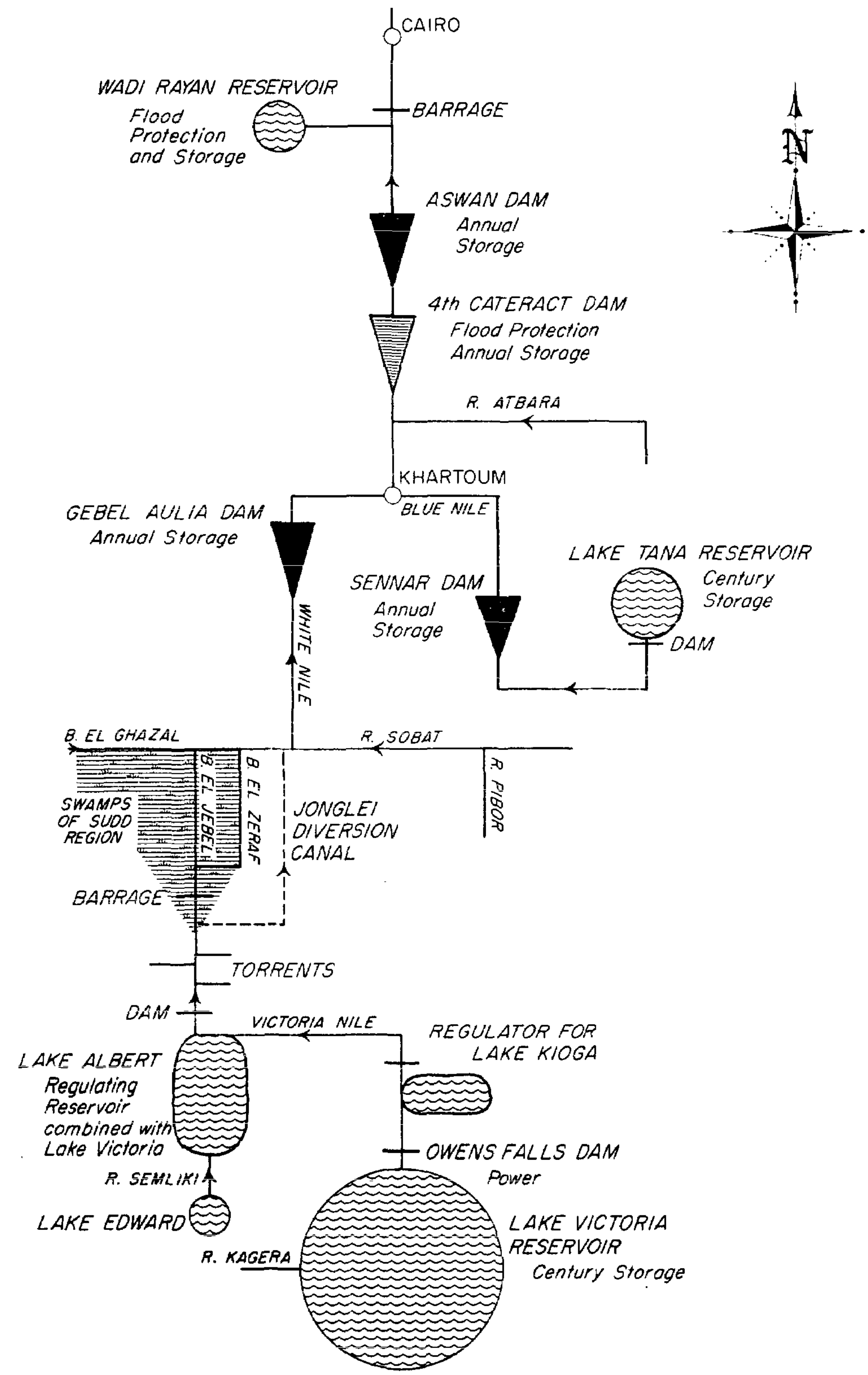
In addition to the overyear storage reservoirs the plan contemplated that two additional annual storage reservoirs would be constructed, as follows:

f) A Main Nile reservoir which could store in the average year about three milliards and, in addition, up to five milliards of flood waters during the unusual flood. One of the sites for a dam for such a reservoir was near Merowe at the Fourth Cataract, and the alternate site was near the Dal cataract between Merowe and Wadi Halfa.2/

g) As a supplementary project a barrage across the Nile to divert water into the Wadi Rayan depression which is located near Beni Suef, about 100 kms.

1/ From "The Nile," by H. E. Hurst.

2/ The Merowe and Wadi Rayan projects were under study by Sir M. MacDonald and Partners. It was reported that later studies indicated that the capacities of both reservoirs could be increased somewhat. Under the revised scheme Merowe could provide 3 milliards and Wadi Rayan 3.5 milliards during the timely period.




**SCHEMATIC DIAGRAM OF PROJECTS IN THE CENTURY STORAGE SCHEME**

AUGUST, 1955

IBRD-214

south of Cairo. It has a maximum depth below sea level of 50 meters and storage would be limited to the evaporation from the lake, probably around 1.2 milliards annually.[1] The main value of the project would be for flood protection, although some beneficial use could be made of the stored water for irrigation.

The need for these two annual storage reservoirs would be eliminated by construction of the Sadd el-Aali project.

Owen Falls Dam - Lake Victoria

In 1949, agreement was reached between Britain and Egypt for the construction by Uganda of the dam at Owen Falls, to provide overyear storage in Lake Victoria, and a large hydroelectric power station. The regulation of Lake Victoria is the very simple one of maintaining an outflow from the lake equivalent to the long time mean. The dam is now complete and the power station is in operation, but use of the lake for storage will not begin until compensation due to flooding that Egypt should pay is settled and sufficient time has elapsed to enable harbor and other works round the shores of the lake to be altered to suit the future increased range of water levels.

Lake Kioga

The records of the losses of the Victoria Nile in passing through Lake Kioga do not cover an adequate period of time to give an accurate index of the flow regime but indications are that Lake Kioga is probably a source of a net loss ranging from 1½ to 4½ milliards a year. There is a possibility of constructing an embanked channel to shut off the Victoria Nile from the lake and save most of the indicated loss. The possibility of constructing an embanked channel or utilizing Lake Kioga for storage has been deferred, pending future investigations.

Lake Albert

The question of the volume of water to be stored under the Century Storage scheme in Lake Albert is still unresolved. Uganda has proposed a storage limitation of 14.5 ms. on the Butiaba gage (the official recording station for the lake) under normal operating conditions and 18.5 ms. under maximum flood conditions, but oppose a higher lake level because it would flood a rather large area of agricultural land. The Egyptian Government would like to raise the level of Lake Albert for Century Storage to around 35 ms. on the Butiaba gage which would provide storage under normal conditions of about 139 milliards and which would take care of the natural rise of the lake level in a high runoff year such as 1917-18. The Sudan is expected to support the conclusions of the Jonglei Investigating Team which recently recommended that the permissible level on the Butiaba gage should be 25 ms. since storage at this level would equalize the long-time mean annual discharge from the lake.

1/ See footnote 2, page 10.

Jonglei Scheme

Water flowing from the equatorial lakes to join those of the Sobat near Malakal to form the main White Nile must pass through the wide marshy flood plains where, as mentioned above, water spills through the swamps for miles on either side of the winding main channel. Only about half the water entering the region, known as the Sudd, emerges notwithstanding the addition of nearly a meter of rainfall during the year. A recognized necessary adjunct to the Century Storage scheme is, therefore, a canal to bypass the marshes. Such a canal would be cut from Jonglei on a direct line about 280 kms. in distance to the present White Nile channel near Malakal. Under the Jonglei scheme three canals would be cut in six stages and when completed would have a combined capacity of 80 million $m^3$ per day (80 M/d). According to the original schedules, the canal capacity would be completed to the 55 M/d stage by 25 years after work is initiated. If the Sadd el-Aali project is constructed, the 55 M/d (or as presently proposed, the 60 M/d) stage, which would allow the timely flow[1/] to be increased by 7 milliards, would be sufficient for the optimum advantage from the scheme. Some advantage would be obtained after about 13 years of the construction period when the first cut is scheduled for completion with a capacity of 10 M/d which would increase the timely flow by one milliard. Reasons given for undertaking the project by steps is that it would permit present navigation to be maintained and would provide a minimum of interference with the living habits of the natives in the Sudd Marsh region. About a million people will be affected by the contemplated alteration of the river regime and river-rain pasture [2/] for approximately a quarter of a million animal units [3/] will be lost.

Because of the very great importance of this project the Governor General of the Sudan in 1946 appointed the Jonglei Investigating Team to study in detail the proposals submitted by the Egyptian Government, and after a full investigation of all facts and alternatives, to make a report and recommendations. The Team, whose work covered the period from 1948 to 1954, has just completed its report which has been published. The Team recommended modifications in the proposed engineering works and in the methods of operation of the project so as to lessen the impact on the people affected. The Team also recommended that compensatory measures, mainly for irrigation, drainage and for agricultural development, be undertaken in the region entailing a capital cost of about LE 12 million and involving the use of about 0.6 milliard of water annually. It suggested that the period of construction be extended longer than the 25 years now contemplated so as to make more gradual the changes in the hydrological regime and facilitate the readjustments within the zones affected.

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1/ "Timely flow" or "timely period" refers to the portion of the year (February 1 to July 31, in Egypt) during which natural flow in the river is insufficient to meet irrigation requirements.

2/ The intermediate flood plain, adjacent to rivers, lying between the swamps and the highlands.

3/ One animal unit is one head of cattle or 8 sheep or goats.

Lake Tana Storage

In 1935 an agreement was reached between the technical representatives of the governments of Egypt and the Sudan for development of a reservoir in Lake Tana in Ethiopia. The project is expected to provide a net benefit of 2.7 milliards of storage which, after deducting losses in transit, should provide about one milliard of additional irrigation water for both Egypt and the Sudan if the net additional supplies were divided equally. If and when the Century Storage scheme is executed, Egypt and the Sudan agree that the overall benefits may be increased by operation of the Lake Tana storage in conjunction with that in the equatorial lakes. However, their proposed negotiations with the Government of Ethiopia are at a stand-still.

Supplies estimated to be developed by Century Storage

Century Storage as planned can only be considered in combination with the natural flow of the river. Hence Century Storage projects are designed to function in low water years to supplement the natural Nile flow in the timely period from February through June. The authors of the Century Storage scheme estimate that the quota it would dependably deliver during the timely period of low water years would, on the average, amount to 7.3 milliards measured at Aswan.

Table No. 2

Supplies Estimated from Century Storage

| | | Milliards |
|---|---|---|
| Natural river, February-July mean | | 15.4 |
| Storage in Aswan, Gebel Aulia and Sennar | | 8.1 |
| Total of present mean supply | | 23.5 |
| Additional average annual supply dependably delivered by Century Storage: | | |
| From equatorial lakes | 5.2 | |
| From Lake Tana | 2.1 | |
| Sub-total, guaranteed from over-year storage | | 7.3 |
| Total, without additional annual storage | | 30.8 |

According to Egyptian estimates, the supplemental annual storage reservoirs of Merowe and Wadi Rayan included in the Century Storage proposals would provide respectively 3.0 and 1.2 milliards in the February to July period thus raising the total annual supplies to 35 milliards.[1/]

1/ Under later planning the Merowe and Wadi Rayan reservoirs would be enlarged somewhat which, in turn, would increase the February to July supplies by an estimated 2.3 milliards. See footnote on page 10.

It must be pointed out, however, that the additional supply provided in dry years through greater overyear storage facilities in the lakes could, as far as the equatorial lakes are concerned, be made available only if the Jonglei scheme were carried out and the losses in the Sudd marshes were greatly reduced. The supplemental waterflow would also vary from year to year and would be largest in years of abnormally low supply. The range in withdrawals would be between about five and eleven milliards annually with a careful account being kept to avoid depletion of the reserves.

Estimated cost of Century Storage

Accurate cost estimates for the projects included in the Century Storage scheme cannot be made at this stage of the planning. The Egyptian Government has made global cost estimates however, and has estimated benefits in water as follows:

Table No. 3

Estimated Costs and Water Benefits from Projects in the Century Storage Scheme

| Project | Approx. Cost LE Millions | Net Feb. through July benefit in Milliards (measured at Aswan) | |
|---|---|---|---|
| Lake Tana reservoir | 8.0 | 2.10 1/ | |
| Equatorial lakes | | | |
| Lake Victoria reservoir | 4.5 2/ | (included in Sudd canalization) | |
| Lake Kioga reservoir | 4.0 | | |
| Lake Albert reservoir | 13.0 | | |
| Sudd Canals | | | |
| First cut, 10 M/d | 5.5 | 0.75 ) | 5.20 total |
| First canal 27½ M/d | 8.0 | 1.45 ) | |
| Second canal 55 M/d | 8.0 | 3.00 ) | |
| Third canal 80 M/d 4/ | 6.0 | 3.00 3/ | |
| Fourth Cataract (Merowe) dam 4/ | 35.0 | 3.00 | |
| Wadi Rayan reservoir 4/ | 30.0 | 1.20 | |
| Totals | 122.0 | 14.50 | |

1/ To be shared equally between Egypt and the Sudan.
2/ Egypt's share of cost only.
3/ This canal would be used only in exceptionally low water years.
4/ Not needed if Sadd el-Aali is constructed.

## II. THE SADD EL-AALI PROJECT

Against this background the Sadd el-Aali project, which has been conceived only in recent years, must be examined not only in order to assess its technical feasibility and soundness but also to determine whether it is consistent with a proper scheme for the development of the Nile River water resources as a whole along the lines set forth in the preceding pages.

### A. Technical and Engineering Aspects

The proposition that it is feasible to construct a high dam on the Main Nile in Egypt with a reservoir large enough to store the annual flood flow, considering the deposition of silt, was tested by a thorough discussion among experienced engineers and hydrologists, notably in the New Delhi conference on High Dams in 1951, with the consensus that it would be practical to build such a project. With this point favorably decided the Egyptian government engaged the German engineering firm of Hochtief and Dortmunder Union to make an investigation of possible sites and preliminary designs of such a project. Following this the Government retained the services of a group of international experts, having experience with the particular conditions to be encountered on the project, to appraise the soundness of the proposed site and design.

This group, called the International Board of Consultants, was composed of the following:

Dr. Karl Terzaghi of Winchester, Massachusetts, an internationally known expert on dam design, probably known best as the originator of modern techniques in soil mechanics and foundation engineering.

Mr. I.C. Steele of Piedmont, California, a consulting engineer and formerly Vice President and Chief Engineer of the Pacific Gas and Electric Company, San Francisco, California.

Dr. Lorenz G. Straub of Minneapolis, Minnesota, head of the Department of Civil Engineering and Director of St. Anthony Falls Hydraulic Laboratory, University of Minnesota.

Mr. Andre Coyne of Paris,France, a prominent internationally known consulting engineer who has been responsible for the design and construction of more than 50 large dams.

Dr. Max Preuss of Essen, Germany, who has designed and supervised construction of numerous dams utilized in supplementing the water supply for the Ruhr district of Germany.

In addition to the Board of Consultants, the Egyptian Government, upon the recommendation of Dr. Terzaghi, retained the services of Mr. E. Ischy, Director of Soletauche, Paris, France, who has broad experience with the current methods of grouting foundations for dams including those constructed on cohesionless sediments.

According to their contracts with the Egyptian Government, the consultants were given the following assignments:

a. To study the designs proposed and give their opinion thereon; to propose any modifications to the design that they might consider necessary to insure safety from the hydraulic and military point of view; or to improve it technically or to reduce its cost without impairing its technical suitability for all conditions.

b. To study problems of sedimentation and scour that might result from construction of the dam.

c. To propose any other alternative construction and/or design which would, in their opinion, be better or more suitable for the high dam.

d. To study and check the program and methods of execution and materials for construction, bearing in mind the flood conditions and water requirements for irrigation.

e. To study and check the estimates for all items.

f. To recommend the important basic points to be included in the specifications for materials and method of construction.

Conclusion of the International Board of Consultants

The consultants considered two different sites, No. 1, located 6.5 kilometers (kms) upstream from the existing Aswan Dam, and No. 2 known as Kalabsha site, located about 45 kms upstream from Site No. 1. Although the stream channel at the Kalabsha site is much narrower than Site No. 1, the terrain on both sides of the valley is so low that the crest of the dam would have a length of about 20 kms. Foundation conditions at Site No. 2, were inferior and impervious materials were not to be found in the general area. Also the topography at Site No. 2 would make it difficult to construct a dam equipped with an upstream clay blanket. The consultants, therefore, decided that the dam should be built at Site No. 1.

The important conclusions of the consultants 1/ for Site No. 1 are:

a. A rockfill dam equipped with a clay core, an upstream blanket and grout cutoff, with the dimensions proposed by the consultants, is as safe as the safest among the existing earth and rockfill dams resting on sediments because it is protected against failure by two independent lines of defense; an upstream blanket and a grout cutoff.

b. Because of the vital importance of a satisfactory solution of the diversion problem in the construction of the project, the problem of the design and construction of the cofferdam received special consideration. The consultants concluded that a cofferdam can be built across the Nile Valley upstream of the dam site without any risk whatsoever of a failure during or after the construction of the cofferdam. Hence, it is established beyond any doubt that the dam can be built in accordance with the design.

1/ "Report by the Board of Consultants on the State of the Project for the High Aswan Dam," November 28, 1954.

c. The time required for constructing the dam depends entirely on the time at which the excavation of the diversion tunnels will be completed. Every year of delay in the completion of the diversion tunnels delays not only the completion of the dam by at least one year, but it also increases the cost of construction of the dam on account of the restrictions which will be imposed on the regime in the existing Aswan Dam. Therefore, the consultants considered it essential that the excavation of the diversion tunnels should be started without delay.

General Features of the Dam

In the layout of the dam, the diversion tunnels are to be located on the right (East) bank and the power tunnels, powerhouse, and emergency spillway on the left (West) bank. The riverbed at the centerline of the dam is at elevation 85 ms above sea level and the crest would be at elevation of 196 ms, giving a maximum height of 111 meters or about 365 feet. Available data indicate that the backwater from the dam would extend some 550 kms upstream to the third cataract which is about 200 kms within the Sudan. The final topographic maps now under preparation by the Army Map Service, Corps of Engineers, Department of the Army, (U.S.A.), may change this distance somewhat as the backwater may extend only to Dal cataract, a distance of 500 kms. The town of Wadi Halfa in the Sudan will be flooded. The population displaced by the reservoir, both in Egypt and the Sudan, estimated at 60,000 to 70,000 will have to be relocated. 1/

The following is a summary of pertinent information on the dam and reservoir: Length of the dam between abutments, 5,000 ms; length of river channel section, 550 ms; base of dam along stream channel, 1,300 ms; top of flood control pool, 182 ms; top of irrigation pool, 175 ms; top of sediment storage, 147 ms; base of sediment storage 85 ms. Placement of all materials in the dam, 44,000,000 $m^3$; placement of rockfill, 27,060,000 $m^3$; placement of dune sand, 4,600,000 $m^3$; placement of clay core, 2,885,000 $m^3$; placement of coarse and fine filter, 2,710,000 $m^3$; placement of silt, 1,500,000 $m^3$. Storage volume of reservoir, 130 milliards, of which 30 milliards is dead storage for deposition of silt, 70 milliards is for irrigation and 30 milliards for flood control.

Diversion Tunnels

The river diversion plan provides for seven unlined diversion tunnels, 16.5 meters in diameter. After completion of the dam, the diversion tunnels are to be used for flood control purposes. The diversion tunnels average about 2,160 ms in length and the seven tunnels will have a discharge

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1/ An accurate estimate of the population requiring relocation will depend on surveys of the reservoir area.

capacity under a head of 20 meters of 11,000 $m^3$ per second. The excavation of the diversion tunnels totals 7,957,000 $m^3$, all of which will be placed in the cofferdam and the main dam.

The Power Station

The power station will be located in underground caverns in the left or West bank approximately on the axis of the dam and will ultimately comprise four stations each equipped with four sets of Francis type turbines with generator each of a capacity of 90,000 kw (120,000 hp). Of the 16 units ultimately provided for, eight will be installed initially. A restudy is now under way to assess the desirability of installing a fewer number of larger turbo-generators than originally planned, perhaps 120 to 135 MW, while maintaining the total capacity of the first stage, to be built during the initial ten years, at about 720,000 kw as originally planned.

The inlets to the four primary power tunnels are in the immediate vicinity of the upstream tow of the dam. The 4 power station caverns are placed deep into the granite in the left Nile bank with their longitudinal axis in a straight line and approximately under the axis of the dam. The site of the intake tunnels is at elevation 130 meters above sea level, and is fixed in relation to the minimum upstream reservoir level of 147 meters. The power tunnels, excavated in solid granite, are to be concrete lined (in contrast to the unlined diversion tunnels in the right bank.)

The power water tunnel of each of the four caverns is circular with a diameter of 12.7 meters and bifurcates first into two tunnels of 9 meter diameters leading to the gate chambers. From here the tunnels are again bifurcated into 6 meter tunnels each equipped with a butterfly valve to control the inlet of water to the separate turbines. Each power station will be equipped with two surge tanks connecting with the upstream side of the draft tubes. Outlet water from each two turbines will be collected on the downstream side into tailwater tunnels of 11.5 meters diameter.

Each cavern will be equipped with two overhead 150 ton cranes. Air conditioning equipment is included in the design. Each of the four transformer caverns will be equipped with 8 single phase transformers of about 85,000 kw each. The installation includes a stand-by for each three transformers in service. Transformation will be from 15 to 400 kv, with provision made for transmission at the latter voltage to Cairo, a distance of approximately 770 kms.

The 9,115,000 $m^3$ of rock excavation from the power intake tunnels, power caverns, surge chambers, inlet and outlet basins will be used in making the fill for the main dam. In order to minimize storage and rehandling of materials, these excavations will be scheduled in the 5th, 6th and 7th years of the construction period. The construction equipment and organization from the diversion tunnel excavations work will thus be available for the power tunnel work. In order to benefit from the economic handling of materials, excavations will be completed for the contemplated ultimate power installations while the main dam is under construction.

## Design of the Dam

Hochtief submitted to the consultants two alternative designs for the dam. One design involved protection of the dam against seepage by means of a clay blanket on the upstream side of the core combined with a broad inverted filter on the downstream side ("horizontal sealing"), and the other for construction of the dam with a short upstream blanket and a concrete cut-off wall extending from the base of the clay core to the surface of the bed-rock, some 250 ms below the base of the clay core ("combined solution").

The Board of Consultants adopted the design for a "dam with horizontal sealing", recognizing that as a defense against possible damage in wartime the design should be supplemented by plugging the voids of the coarsest layers of the subsoil in the river channel under the dam by injecting into the sediments a clay slurry with a slight admixture of portland cement and some chemicals. The dam would thus be protected against failure by two lines of defense, (a) the blanket, and (b) the grout curtain.

## Design and Construction of Upstream Cofferdam

The primary function of the upstream cofferdam during construction is to divert the water of the Nile into the diversion tunnels. The lowest portion of its base is at elevation 85 and the top elevation 135. The principal difficulties associated with the construction of the upstream cofferdam are due to the fact that the major portion of the construction materials must be deposited on the bottom of a body of water with a depth of at least 20 meters and that a body of water which will flow over the crest of the cofferdam during the period of construction may reach discharges of as much as 10,000 $m^3$ per second. The consultants concluded that the lower part of the cofferdam could be safely built during the three years required for the excavation of the first four diversion tunnels by depositing and compacting the construction materials in horizontal layers up to elevation 105. However, the existing Aswan Dam which controls water levels up to elevation 121 greatly facilitates the construction of the upstream cofferdam and permits the control of possible scour of materials from the cofferdam.

Of particular interest in connection with the proposed water regulation during construction is the fact that during the fifth construction year the reservoir created by the cofferdam could be held at elevation 125 meters thereby providing an additional storage of 1.5 milliards over and above that normally stored at Aswan Dam at elevation 121. During the sixth year this additional storage would be raised to 3 milliards. More recently certain Egyptian experts have indicated that as much as 6 milliards could be temporarily stored behind the cofferdam. However, until it is definitely established that storage of such volume would be compatible with the safety of the cofferdam, it would be inadvisable to rely on this higher estimate.

Program of Construction

The consultants agreed that the dam could be built within the time limit of 10 years, however, they also stressed the importance of first establishing an adequate organization for preparing the customary plans and specifications and correlating the results of experimental examination with the design of various portions of the structure, such as the design of the outlet works for the diversion tunnels and of digesting the results of field investigations and observations.

Problems of Sedimentation and Scouring

Because of the volume of sediment transported by the Nile during certain seasons of the year, construction of the Sadd el-Aali Dam will create problems that may be divided as follows:

1. Deposition of sediments in the reservoir;

2. Deposition and erosion of sediments immediately upstream and downstream of the dam itself;

3. Problems of sedimentation and scouring in the Nile River from Aswan to the Mediterranean Sea.

The torrential rainfall on the Abyssinian plateau helps to bring down large quantities of silt in the Blue Nile during the flood period. Studies of the annual sediment deposits of the Nile at Luxor, made in connection with excavations of ancient temples extending as far back as 3,000 B.C., show that for the past fifty centuries, at least, the Nile between Aswan and Cairo has been depositing part of its silt load with a resultant aggrading of the streambed. Captain H. G. Lyons (Physiography of the Nile) states that the average rise of the streambed due to these deposits is about 0.10 meters per century, so that some 5 meters of alluvial sediment has been laid down in historical times. Upon the basis of available sediment records, it has been assumed that 90 million tons of suspended and bed load would be deposited in the reservoir each year and that after consolidation, these deposits would amount to about 60 million $m^3$ annually. The reservation of 30 milliards for the deposition of silts would thus provide storage for that purpose for a period of 500 years.

The existing dam at Aswan is operated to permit high river flows to pass without significant retardation and the reservoir is filled from the receding flood waters each season. Consequently, there is now little deposition of Nile River sediments in the existing Aswan reservoir.

Lowering of the streambed through controlled scouring (degradation), within limits, would be beneficial to the valley, notwithstanding the special remedial measures that would be necessary at the main canal diversion structures and navigation locks. The Egyptian Government has retained Dr. L. G. Straub especially for the purpose of mapping out a program of aggradation and degradation studies, principally concerned with degradation that might occur in the Nile River channel downstream from the Aswan Dam following completion of the Sadd el-Aali project.

## B. Storage Capacity in Relation to Water Supply

Although records of river stage have been obtained since 1870 on the Nile below Aswan, an accurate calibration of the stage-discharge relation for this gage was not available until construction of the Aswan Dam was completed in 1903. Shortly thereafter, the discharge sluices for the dam were accurately calibrated and reliable records are available thereafter as all flows have been passed through the sluices of the dam. Discharge records of the Nile for the period 1870-1902 have been computed using the stage-discharge curve obtained by means of the records subsequent to 1902. The high flood discharge for the period 1870-1902 may be somewhat questionable, but the summer supply over the entire period is considered to be less than 5% in error. The stream-flow records at Aswan for the period 1870-1902 are considered satisfactory and for the period that is so critical in the determination of the storage requirements for Sadd el-Aali, namely 1899-1953, the flow records are very reliable.

### Available Water Supply at Aswan

All of the Egyptian publications pertaining to water supply place a great deal of emphasis on the flow of the Nile during the "timely" (1 February-31 July) and "untimely" (1 August-31 January) seasons at Aswan. However, the construction of the Sadd el-Aali dam would, for all practical purposes, entirely control the runoff of the Nile River at the site. Therefore, in considering the Sadd el-Aali project, the division of the water year into two separate periods ceases to be of any significant importance to Egypt although remaining of importance to the Sudan.

The annual runoff of the Nile River at Aswan has varied from about 63 to 137 milliards annually, with the exception of the one year 1913-14, when the annual runoff was only 45.5 milliards. Obviously, no sound policy of irrigation expansion can be based on such a variable supply.

The average runoff of the Nile River at Aswan for the period 1870-1953 (83 years) is 92.9 milliards. Examination of the records for the period 1870-1898 discloses that the runoff was well above the 83 year mean, averaging 110.3 milliards whereas for the most recent 54 years of record, 1899-1953, the average runoff was only 83.7 milliards.

Storage of Flood Waters in Sadd-el-Aali Reservoir

The quantity of surplus water made available for use through construction of Sadd el-Aali and the share on which Egypt could depend for use is appreciably affected by up-stream consumptive uses. Except in the Sudan these uses for irrigation developments have been inconsequential and as far as can be foreseen will, as a practical matter, remain so. Egypt has been utilizing the low flow of the Nile for centuries and, as new storage has been created as in the cases of the Aswan, Gebel Aulia and Sennar dams agreements have been made between Egypt and Sudan, the countries most concerned, for a division of the additional supplies. The proposal for the construction of such a reservoir as Sadd el-Aali brings the problem into sharp focus as Egypt would be enabled to use the total run-off of the Nile and, in the absence of an agreement with other countries affected, particularly the Sudan, might establish preferential rights to the entire supply under the Doctrine of Appropriation. In order to justify the expense of the project Egypt must have assurance of the uninterrupted use of at least the minimum quantity of water required to make the project viable.

Supplies developed by Sadd el-Aali

The Sadd el-Aali reservoir, with usable or live storage of 70 milliards for irrigation and an additional 30 milliards for dual use of flood control and irrigation, (the remaining 30 milliards being reserved as dead storage for deposition of silt) has been determined to be of the optimum capacity to enable the maximum volume of Nile water to be made usable. Such a storage would, on the average, provide a minimum of 82 to 83 milliards per annum, from which losses in the reservoir would have to be deducted.[1/]

The losses in the new reservoir, based on studies of the existing Aswan reservoir, were estimated by the Government of Egypt to amount to approximately 10 milliards annually. This estimate is based on the average annual daily loss by evaporation from the Aswan reservoir of 7.4 millimeters, or 2.66 meters per year. This loss when applied to the net surface of the full reservoir of 3,810 square kilometers (after deducting the area of the natural river included) between levels 175 and 182 indicates an annual loss of 10.1 milliards or about 7.8% of the gross storage.

In the Aswan reservoir the actual experience of loss is computed to be 7% of the gross storage and if this percentage is applied the resulting estimate of losses in Sadd el-Aali, when full, would be 9.1 milliards annually As the reservoir falls the losses are continually reduced, due to the reduction of the surface area. When the flood storage is withdrawn, for example, losses from the volume remaining (100 milliards) would occur at an annual rate of between 7 and 8 milliards. No attempt was made to reflect seepage losses in the figures. Net seepage or absorption loss in the Aswan reservoir, considering return flow, has been variously estimated between 0 to 0.9 milliards annually. In view of these calculations, the Egyptian estimate of

1/ Report: "Hydrological Investigations on How the Maximum Volume of the Nile Water May be Made Available for Development in Egypt and the Sudan" by Hurst and Black, January 23, 1955.

losses appears rather high and it seems justifiable to assume that the losses in Sadd el-Aali will not exceed 9 milliards annually. Furthermore, after completion of Sadd el-Aali, the operation of the Gebel Aulia reservoir for the benefit of Egypt may be discontinued because of its relatively high losses (nearly 2 milliards out of a total reservoir capacity of 3.6 milliards). This would reduce overall losses and thus provide an additional factor of safety in the amount of supplies to be developed by Sadd el-Aali.

If from the average controlled annual flow of 82.5 milliards estimated to be obtainable by the Sadd el-Aali reservoir, 9 milliards would be lost by evaporation, a net supply of 73.5 milliards would remain. Egypt's present requirements of 49.2 milliards and Sudan's of 3.5 milliards, together with the 2 milliards lost at Gebel Aulia gives a total measured at Aswan of 54.8 milliards which when deducted from the net supply indicates a surplus of 18.7 milliards to be apportioned between Egypt and Sudan, as indicated in table 4.

Table No. 4

Nile Supplies Developed by Sadd el-Aali

| Nile Supplies | | Milliards, measured at Aswan |
|---|---|---|
| Average Annual controlled supply available after construction of Sadd el-Aali | | 82.5 |
| Deduct: | | |
| Egypt's use | 49.2 | |
| Losses at Gebel Aulia | 2.0 | |
| Sudan's use | 3.6 | |
| Total to be deducted | 54.8 | 54.8 |
| New mean annual supplies to be stored in Sadd el-Aali | | 27.7 |
| Estimated annual loss in Sadd el-Aali | | 9.0 |
| Net of new usable supplies developed by Sadd el-Aali | | 18.7 |

Egyptian engineers have contended however that a certain volume of water should be set aside for riparian uses such as navigation, domestic uses, sanitary uses and salinity control, and that this volume should not be charged against Egypt's irrigation allotment. During certain years moreover it is necessary to discharge some excess water from the reservoir. It is Egypt's contention that 4 milliards should be allocated for these purposes.

The contention that a substantial allowance should be made for navigation use particularly does not appear to be valid. On the Nile, outflow to the sea is blocked at the end of the flood season making, in effect, inland lakes back of the barrages and in the irrigation canals. Additional flow would not be required to maintain navigation depths in these waterways in the sense ordinarily necessary in flowing streams.

Capacity and Operation of the Sadd el-Aali Reservoir

The water level in the Sadd el-Aali reservoir would be lowered at least to elevation 175 each year prior to the annual Nile flood so that 30 milliards of storage capacity would be available for flood protection. Actually the top 30 milliards of capacity would perform a dual function for irrigation and flood protection. During years of high flow the reservoir would always be filled at the end of the flood season, but during years of subnormal flow it would be necessary to draw on hold over storage to make up for the deficit in flood runoff.

Reservoir regulation studies based on runoffs for the period 1870-98 show that the reservoir would be completely filled each year. However, under conditions like those prevailing during the period 1899 to 1953, which includes many years of subnormal runoff, the reservoir would be almost entirely depleted of reserve storage during such a period. The degree of depletion will depend on the level of irrigation water use and somewhat upon the division of the supplies between Sudan and Egypt. Reservoir operation calculations were made by Egyptian engineers for the period 1899 to 1953 on two assumptions. In the first case, it was assumed for the purpose of calculations only that an additional 19.2 milliards (measured at Aswan) were divided 10.8 milliards to Egypt and 8.4 milliards to Sudan so as to bring total uses in the two countries to 60 and 12 milliards respectively. Under the premise that the reservoir was full at the beginning of the period, this hypothetical operation indicated that all withdrawals would have been met and that a small but adequate reserve above dead storage of 6.2 milliards would have remained at the end of the low cycle in 1916. However, if circumstances were such that the reservoir started to fill at the beginning of this period of subnormal runoff, the active or live storage in the reservoir would have been depleted at the end of the 1914 irrigation season. In fact, it would have been necessary to draw on the 30 milliards of storage reserved for sediment to the extent of 5.2 milliards.

In the second case, it was assumed for the purpose of calculations that only an additional 16.2 milliards (measured at Aswan) were divided 10.8 milliards to Egypt and 5.4 milliards to the Sudan so as to bring total uses in the two countries to 60 and 9 milliards respectively. Under this assumption, the proposed capacity of 100 milliards is sufficient to take care of Egypt's requirements even though storage would begin at the beginning of a series of years of subnormal runoff such as those prevailing from 1899 to 1953.

If a reasonable compromise can be reached on the division of the surplus water between Egypt and Sudan, the proposed irrigation and flood control capacity in the Sadd el-Aali reservoir of 100 milliards is fully justified on the basis of preliminary regulation studies. The well defined flood season of the Nile permits the dual use of the top 30 milliards of storage in the reservoir for both flood control and irrigation, thus providing an added factor of safety for irrigation storage.

## C. Relation of Sadd el-Aali to Comprehensive Nile Development

### Long-term or Century Storage

The Century Storage scheme outlined previously would not, except for the two annual storage projects included in it, conflict in any way with, or be a substitute for Sadd el-Aali. Greater storage capacity in the equatorial lakes would smooth out the long dry and wet cycles of runoff on the Nile and would make worthwhile the construction of the Jonglei canals to reduce flood losses in the Sudd, thereby increasing the quantity of water arriving in the Sudan and Egypt. Supplementing this there must be adequate annual storage capacity to provide a stable flow of the Nile throughout the year. Sadd el-Aali would perform this function and thereby make unnecessary the Merowe and Wadi Rayan projects. It would stabilize the annual flow of the Nile between Aswan and the sea, prevent in most years the wastage to sea of flood waters, provide complete flood protection for all downstream territory and provide a potential for an enormous quantity of electric power in Egypt. It would provide some hold-over storage from years of abnormally high run-off for use in dry years, but this hold-over storage would, of course, be limited to the actual flow arriving at the reservoir and the capacity of the reservoir is not sufficient to store the excess from a long period of wet years.

Thus after Sadd el-Aali is finished it will not only be possible but also desirable to proceed with the equatorial lakes storage and Jonglei schemes. These would on the average increase the annual flow obtainable from the White Nile by 5.2 milliards and thus yield important benefits supplementing those of Sadd el-Aali. Moreover, they would ensure that no spilling would occur at Sadd el-Aali during unusually high flood years. Altogether they would make it possible to conserve completely the entire runoff of the Nile under all conditions.

The timing for the execution of the two schemes is widely different. Sadd el-Aali should be built in ten years, with at least some benefits accruing after the fifth construction year from the storage by the up-stream cofferdam. The utilization of surplus from the Century Storage scheme will be limited until realization of the Jonglei scheme which will take 25 years or longer. Some benefits, however, can be realized after about thirteen years, by completion of the Jonglei canal to partial capacity.

### Sadd el-Aali as substitute for other annual storage schemes

Sadd el-Aali is, however, a substitute for other annual storage schemes including the Merowe and Wadi Rayan projects added to the Century Storage scheme by the Hurst-Black-Simaika study. The most comprehensive of such proposals was made in January, 1954 by Mr. H. A. Morrice, 1/

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1/ "The Development of the Main Nile for the benefit of Egypt and the Sudan", issued January 23, 1954.

adviser to the Sudan Irrigation Department, who recommended a series of dams, listed below, to be located on the main Nile and to serve the multi-purpose objectives of irrigation, flood control, navigation and power for the benefit of both Egypt and Sudan. The global estimate of the cost of the projects in the Morrice proposal was in the order of LE 200 million.

Table No. 5

Projects in the Morrice Proposal

| Project | Probable Storage (milliards) | Probable Power (kw thousands) |
|---|---|---|
| Sabaloka gorge, near 6th cataract | - | 35 |
| Fifth cataract | 2 | 75 |
| Hamdab island, at tail of 4th cataract | 10 | 150 |
| Dal cataract, between 2nd and 3rd cataracts | 25 | - |
| Semna gorge, between 2nd and Dal cataracts | 5 | 190 |
| Second cataract | 3 | 110 |
| | 45 | 560 |

Not included in the list is the Wadi Rayan reservoir about 100 km. south of Cairo (already mentioned and which would have a maximum flood storage capacity of from 1.2 to 3.5 milliards, a very small portion of which would be usable for irrigation), or the Roseires project on the Blue Nile for which planning is already in an advanced stage and which would have a capacity of 3 milliards.

All these reservoirs combined would have a storage capacity of less than 50 milliards as compared with 100 milliards for Sadd el-Aali. They could hardly be regarded as a substitute for Sadd el-Aali. According to water management studies their combined capacity would be inadequate to regulate the Nile for irrigation. The relatively small size of the reservoirs make insufficient provision for silting, would provide inadequate holdover capacity from year to year and permit very little flood control.

Some storage will have to be created in Sudan to enable utilization of Nile water in the Sudan. One project, the Roseires dam, has already been worked out for this purpose. It is to be built on the Blue Nile at the Damazin rapids about 100 kilometers downstream from the Ethiopian border. While originally planned for a storage of about one milliard, Sudan's consulting engineers now advise that its capacity be increased to impound 3 milliards at an estimated cost of LE 21.2 million.

## D. International Aspects of the Project

The Nile is preeminently an international river, the river basin embracing the whole or parts of eight countries, and there have been a number of international negotiations and agreements affecting various existing and proposed uses and controls of the Nile. The Sadd el-Aali project is complementary to the various proposals and arrangements which have been made for over-year storage in the great Central African Lakes, to the Jonglei Scheme for passing waters by the Sudd marshes, and to the Lake Tana storage project. No proposal has ever been seriously considered, nor for practical reasons is there any likelihood of a project in the future, which would divert a significant quantity of water from the Nile or its tributaries upstream of the Sudan or Egypt to the prejudice of either of those countries.[1/] Although Ethiopia and one other of the equatorial lake countries have expressed concern over the proposal to construct the Sadd el-Aali project, information available to the Bank does not indicate that its construction will have an adverse effect on any of them.

But an international agreement between Egypt and the Sudan, including the assent of the Sudanese to the Sadd el-Aali project is essential. The reservoir created by the project would flood Sudanese territory and if the Sudan assents thereto, compensation will have to be paid by Egypt. The two countries have taken steps to reach an agreement as to the division of the new supplies of water, estimated at about 18.7 milliards, which the project will make available for use. Negotiations between Egypt and the Sudan were begun late in 1954 and a number of proposals and counterproposals have been discussed by the two governments, but thus far no agreement has been reached on these matters.

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1/ Furthermore, Article III of the treaty between Great Britain and Ethiopia establishing the frontier between the Sudan and Ethiopia, signed at Addis Ababa on May 15, 1902, binds Ethiopia "not to construct, or allow to be constructed, any work across the Blue Nile, Lake Tana, or the Sobat which would arrest the flow of their waters into the Nile except in agreement with His Britannic Majesty's Government and the Government of the Sudan".

## E. ORGANIZATION AND MANAGEMENT

The Government of Egypt will administer and direct all aspects of the Sadd el-Aali project. The project was sponsored as being of vital importance to the country by the Permanent Council for the Development of National Production, a new agency of the Government created by the Revolutionary Junta for the purpose of studying, promoting and executing, where necessary, projects to develop and exploit the natural resources of Egypt, including both the products of the soil and of industry, as well as projects for the development and expansion of internal and external trade.

### The Sadd el-Aali Authority

Subsequently, the Government has created an autonomous organization called the "Sadd el-Aali Authority" to which has been delegated the responsibility for organizing, planning and supervising the Sadd el-Aali project. This is a high level body not only to carry out the project by making the basic policy decisions regarding contract arrangements and supervision of the project, but also with authority to call on all other departments of the Government to perform duties necessary to its completion. The membership of this body as presently constituted is as follows:

- Wing Commander Hassan Ibrahim, Minister of State for Production Affairs
- Mr. Ahmad Abdou El-Sharabassy, Minister of Public Works
- Dr. Abdel Monem El-Kayssouny, Minister of Finance and Economics
- Dr. Mohamad Abo-Nosseir, Minister of Commerce and Industry
- Dr. Abdel-Galil El-Emary, Managing Director of the Nile Ginning Co.
- Mr. Hussein Fahmy, President of the Permanent Council for the Development of National Production
- Colonel Samir Helmy, Member of the Permanent Council for the Development of National Production - Secretary General of the Sadd el-Aali Authority
- Dr. Mohamad Ahmad Selim, Member of the Permanent Council for the Development of National Production
- General Fathy Rezk, Head of the Supplies and Provisions
- Mr. Ahmad Fouad, Member of the Permanent Council for the Development of National Production
- Dr. Mustafa Fathy, Permanent Under-Secretary of State for Ministry of Public Works
- Dr. Hassan Zaky, Head of the Sadd el-Aali Administration

Extensive use of consultants has been availed of in developing preliminary plans for the Sadd el-Aali project. Among the more important services has been that rendered by Hochtief and Dortmunder Union in making surveys, borings, and preliminary plans and estimates. This phase of the engineering work was completed in late 1954. The role and composition of the International Board of Consultants and the assignments thus far completed have been described earlier in this report. The Authority has made arrangements with these consultants to continue periodic reviews of the designs, specifications and construction methods for the project, and to advise the Authority on technical management and on the solution of technical problems as they arise during execution of the project.

The Bank, in its letter of April 8, 1955 from President Black to the Egyptian Ambassador, advised the Egyptian Government that in its considered opinion the Authority should retain a firm or group of firms of consulting engineers specializing in the various aspects of the project and should delegate to them the organization, planning and technical supervision of the project. The Bank in giving its advice suggested that the consulting engineers would draw into one effective organization the competent Egyptian technologists as well as the supplementary foreign experts required.

The Authority, after considering the alternatives of employing a consulting engineering firm or of building an independent organization around a corps of experienced key personnel under direct employment by the Government, decided to adopt the former course of action and on October 30, 1955 signed a contract with the firm of Sir Alexander Gibb and Partners to act as consulting engineers to the Authority on the civil works sector of the dam and, furthermore, to have overall responsibility for review and coordination, and for advising the Authority with respect to the engineering work on all the other phases of the project. Prior to the consummation of the contract with Sir Alexander Gibb and Partners, representatives of the Bank, at the invitation of the Authority, met with the parties concerned to comment on the qualifications of the consulting engineers for a job of this character and on the proposed terms of the contract.

As a result of its study the Bank concluded that the Gibb firm could render satisfactory engineering services on the project, especially so under the contemplated arrangements whereby the firm will supplement its staff by the addition of specialists where necessary. Although under the terms of the contract the function of the Gibb firm is to "advise and assist" the Authority on all important matters of engineering, the contract provides the framework within which the Gibb staff can properly perform satisfactory engineering services on the project. The Authority's officers have assured the Bank that it is the intention to seek Gibb's recommendations on all important engineering questions, and outlined to Bank representatives the scope of a future statement of working relationships between Gibb, the Authority, the International Board of Consultants and the Contractors as evidence of this intention. The Bank was assured, furthermore, that all such proposed working relationships will be discussed and agreed upon with the Bank in the event of Bank participation.

The Authority has awarded four separate consulting contracts (for hydraulic tests, grouting tests, sand compaction tests and a study of the layout of the underground works) to very competent specialized firms. The results of these tests will be reviewed by Gibb, and where appropriate also by the International Board of Consultants.

Construction Work

Contracting procedures were extensively discussed at conferences held in Washington late in 1955 and in Cairo at the beginning of 1956 between representatives of the Bank and the Government. It was agreed that previous plans to let all the works in a single negotiated contract to an international consortium would be abandoned and contracts for the component parts of the project would be subject to selective international competition. Over-all scheduling and coordination of construction contracts will be managed by the Consulting Engineers.

Management after Completion

After completion of Sadd el-Aali, the project will require careful management and expert operation. Besides ordinary maintenance, the operating problems will naturally fall into two quite different categories, those relating to water management for the benefit of irrigation and the business of generating and distributing power. Coordination between the two, while it should be close, need not be difficult once priorities for water use are established as an operating policy. Egypt possesses an outstanding irrigation service with a well-trained and experienced organization. The management of this dominant phase of the project presents no problem. A complete reorganization of the Government's power administration will, however, be necessary.

An Autonomous Power Authority

Completion of the project will create a problem of coordinated operation of all the power generation and transmission facilities in Egypt, most of which will be Government-owned. The problem is made more urgent by the fact that the initial availability of the large power resource created by Sadd el-Aali will make necessary the drastic reorganization of transmission and distribution systems, tariffs, and previous methods of conducting the power business. Steps taken at the outset for the handling of the Sadd el-Aali power supply will have a crystalizing effect on the country's system and power policies for decades to come.

The Government has general plans for the establishment of an autonomous Government-owned corporation to bring about the unified operation of its power facilities and for their coordination with private utilities and industry. While the precise form for the agency has not been determined, the Government recognizes that an organization to plan and manage a business such as the power business must be flexible and able to make day-to-day decisions promptly. In addition to the organizational autonomy necessary to enable it to function efficiently and successfully, it should have a large degree of financial autonomy to enable it, for example, to make extensions and alterations to the power system to best meet the requirements of the business operations served.

The Production Council has taken a forward step in this matter by the employment of the Electricite de France (EDF) to assist it in its studies and power planning. Under the terms of a contract entered into in March 1954 between the Council and EDF, the company was engaged to conduct the necessary studies and recommend a desirable organization and power policy for the Government, together with drafts of needed legislation. The surveys and studies being carried out by EDF encompass the full range of physical and technical factors which should influence the establishment of a sound power program for Egypt, including a study of the country's resources for the production of power, transmission and distribution problems, forecasts of demands for electric energy, costs of production, rate structure, etc. The company's report, which will be used as the basis for further discussions and planning of the power program, was completed in September 1955. The information contained in it has been used in appraising the power aspects of the Sadd el-Aali project.

## F. COST OF THE PROJECT

The total investment cost of the entire project, including one-half the ultimate power installations (i.e. 720,000 KW out of 1,440,000 KW), the transmission lines, and the land reclamation and settlement program, and extending over a period of sixteen years, is estimated as follows:

Table No. 7

Cost of Sadd el-Aali Project (in millions)*

| | Foreign Exchange (US$) | Foreign Exchange (£E) | Local Cost (£E) | Total Cost (£E) | Total Cost in Equivalent US$ |
|---|---|---|---|---|---|
| 1. The dam and civil works | 149 | 52 | 58 | 110 | 316 |
| 2. Power equipment and transmission facilities | 126 | 44 | 14 | 57 | 165 |
| 3. Irrigation and related facilities | 72 | 25 | 78 | 104 | 297 |
| 4. Indemnities and resettlement | 6 | 2 | 8 | 10 | 29 |
| Sub-Total | 353 | 123 | 158 | 281 | 807 |
| 5. Interest during construction | 37 | 13 | 29 | 42 | 120 |
| Sub-Total, public investment | 390 | 136 | 187 | 323 | 927 |
| 6. Private (or public) investments in reclamation and housing | n.a. | n.a. | 137 | 137 | 393 |
| Grand Total Investment | 390 | 136 | 324 | 460 | 1,320 |

Exchange at £E one = $2.87

* Figures rounded.

The estimates of cost are reasonable and are the best obtainable considering the present stage of development of engineering planning for the project. With the exceptions noted below, the estimates of cost given above were as prepared by the engineers of the Egyptian Government in collaboration with Hochtief. They were based on local conditions and costs, including experience on the power scheme now under construction at Aswan.

The International Board of Consultants reviewed these estimates in considerable detail but did not accept full responsibility for them, although appraising them as reasonable. Representatives of the Bank spent several days with the staff of the Production Council checking the cost estimates and comparing unit cost values with the existing contract prices at Aswan Dam. As a result of these dicussions the estimate for the contingency for the civil works and power items was increased from 5% to 10%. An over-all contingency for the project has not been added, for the reason that a contingency allowance is included in the estimates for the several phases of the project.

It should be noted that the estimate in this report differs from that of the Egyptian Government in a number of respects:

(1) An additional investment of LE 15 million in transmission lines and interconnections has been added on the ground that such facilities are necessary in order to ensure that all of the power to be generated at Sadd el-Aali will be effectively marketed. The Egyptian Government estimates make provision for the main Aswan-Cairo transmission line, but not for additional transmission and distribution links in the delta below Cairo. The addition to the estimate for transmission lines was based on the recommendations of Electricite de France to the Egyptian Government after the original estimate was compiled, and on unit costs applicable to Egypt. Considerable additional public investment for distribution facilities will be necessary for expansions of existing systems and for service to new areas. In the normal operation of distribution services, contemplated to be a function of the municipalities, the receipts from sale of power are usually adequate to develop the systems without, as a rule, any call on the Government Budget. The total public expenditure for the project would need to be correspondingly increased, however, if this policy, now contemplated, is not followed.

(2) The cost of the major irrigation, drainage and pumping works has been increased slightly (by LE 2 million) in line with more recent figures submitted by Egyptian experts. It should be noted that these cost estimates cover only one million feddans (aside from the conversion of basin-irrigated land) because it is expected that irrigation and drainage facilities for 300,000 feddans costing LE 11,650,000 will have been completed by the middle of 1956. Although not included in the estimate of projected expenditures, the latter sum should be considered part of the total cost of the project even though it has already been spent.

(3) The new estimate includes LE 19.5 million for investment in roads, public utilities, schools, hospitals, etc., on the 1.3 million feddans of reclaimed land, while the Egyptian Government had made no allowance for

such investment. On the basis of conversations with Egyptian officials, it was considered reasonable to estimate this investment at approximately LE 15 per feddan.

(4) The cost of reclaiming the new land (other than that of major irrigation and drainage works) and of housing on the new land has been added to the over-all investment required by the project. This additional investment totaling LE 136.5 million, could be either private or public, although, for reasons to be enumerated later, it would be preferable to have it undertaken by private enterprise. The reclamation expenditure would be for the construction of subsidiary irrigation and drainage canals, land levelling, de-salting where necessary, and appropriate cropping to bring the land up to normal standards of fertility. The cost has been calculated on the basis of recent experience. For housing an allowance of LE 25 per feddan has been made. This is substantially below the expenditures now being incurred in certain model settlement projects which have been undertaken by the government but on a standard which can hardly be envisaged for all new land.

(5) To take into account the need for financing interest payments on loans contracted for the project an amount of LE 42 million has been added as "interest during construction" for the 10-year period required to build the dam.

A tentative attempt to project these expenditures year by year has been made in table No. 8 below. The total investment would be made over a period of about 16 years. During the first 10 years total public and private investments to be financed would average almost LE 35 million annually, and necessary public investment almost LE 30 million per year. Around 90% of the total public investment would fall in the first 10 years. The total direct foreign exchange component of public investment would be approximately LE 136 million or an annual average of LE 13 million in the first 10 years.

Of the total public investment of LE 323 million (including interest during construction), LE 222 million would be necessary irrespective of whether or not power facilities were installed at Sadd el-Aali. In other words, LE 101 million is the additional investment necessitated by the installation of the power plant. The latter includes the cost of the civil works for the power features in the dam, such as power tunnels and caverns, and of the turbines, generators, transmission lines and such other mechanical and electrical facilities as would be directly required for power. All these total LE 88.5 million, to which a proportionate amount of the allowance for interest during construction, namely LE 12.5 million, has been added.

It is expected that these estimates will require further revision when more detailed planning will make it possible to determine more accurately the total expenditures on the various components of the projects and the probable scheduling of these expenditures.

TABLE NO. 8

SADD EL-AALI PROJECT - EGYPT

ESTIMATED INVESTMENT COST OF HIGH ASWAN DAM AND RELATED WORKS
(LE Millions)

| INVESTMENT COST YEARS: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I. PUBLIC | | | | | | | | | | | | | | | | | |
| Dam and Civil Works (Stage One) | | | | | | | | | | | | | | | | | |
| Total | 11 | 11 | 8 | 8 | 8 | | | | | | | | | | | | 46.0 |
| Foreign | 10 | 6 | 3 | 3 | 2 | | | | | | | | | | | | 24.0 |
| Dam and Civil Works (Stage Two) | | | | | | | | | | | | | | | | | |
| Total | | | | | 12 | 13 | 11 | 10 | 9 | 9 | | | | | | | 64.0 |
| Foreign | | | | | 10 | 6 | 3 | 3 | 3 | 3 | | | | | | | 28.0 |
| Turbines and Generators | | | | | | | | | | | | | | | | | |
| Total | | | | | 2 | 2 | 4.5 | 3.5 | 2.5 | 1.5 | | | | | | | 16.0 |
| Foreign | | | | | 2 | 2 | 4 | 3 | 2 | 1 | | | | | | | 14.0 |
| Transmission Line to Cairo | | | | | | | | | | | | | | | | | |
| Total | | | | 2 | 4 | 4 | 5 | 5 | 4.5 | | | | | | | | 24.5 |
| Foreign | | | | 2 | 3.5 | 3.5 | 3.5 | 3.5 | 2.5 | | | | | | | | 18.5 |
| Additional Transmission Lines and Interconnections | | | | | | | | | | | | | | | | | |
| Total | | | | 0.5 | 1 | 0.5 | 1.6 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.5 | | 17.0 |
| Foreign | | | | 0.5 | 0.5 | 0.5 | 1.1 | 1.1 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | | | 11.5 |
| Sub-Total, Construction | | | | | | | | | | | | | | | | | |
| Total | 11.0 | 11.0 | 8.0 | 10.5 | 27.0 | 19.5 | 22.1 | 20.2 | 17.7 | 12.2 | 1.7 | 1.7 | 1.7 | 1.7 | 1.5 | | 167.5 |
| Foreign | 10.0 | 6.0 | 3.0 | 5.5 | 18.0 | 12.0 | 11.6 | 10.6 | 8.8 | 5.3 | 1.3 | 1.3 | 1.3 | 1.3 | | | 96.0 |
| Conversion of Basin Lands to Perennial Irrigation | | | | | | | | | | | | | | | | | |
| Total | | 1 | 3 | 5 | 6 | 6 | | | | | | | | | | | 21.0 |
| Foreign | | | | 1 | 1 | 1 | | | | | | | | | | | 3.0 |
| Reclamation Costs: Includes Irrigation Pumping Stations, Main Canals, Drainage for one million feddans | | | | | | | | | | | | | | | | | |
| Total | | | 7 | 9 | 8 | 7 | 7 | 5 | 5 | 5 | 5 | 2 | | | | | 60.0 |
| Foreign | | | 2 | 6 | 3 | 2 | 2 | 2 | 2 | 1 | 1 | | | | | | 21.0 |
| Other Public Works: Includes Public Utilities, Roads, Community Facilities | | | | | | | | | | | | | | | | | |
| Total | | | | | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 2.5 | | 22.5 |
| Foreign | | | | | | | 0.5 | 0.5 | | | | | | | | | 1.0 |
| Indemnities and Resettlement | | | | | | | | | | | | | | | | | |
| Total | | 3 | 3 | 3 | 1 | | | | | | | | | | | | 10.0 |
| Foreign | | 1 | 1 | | | | | | | | | | | | | | 2.0 |
| I. TOTAL PUBLIC INVESTMENT | | | | | | | | | | | | | | | | | |
| (a) Excluding interest during construction | | | | | | | | | | | | | | | | | |
| Total | 11.0 | 15.0 | 21.0 | 27.5 | 43.0 | 33.5 | 30.1 | 27.2 | 24.7 | 19.2 | 8.7 | 6.7 | 4.7 | 4.7 | 4.0 | | 281 |
| Foreign | 10.0 | 7.0 | 6.0 | 12.5 | 22.0 | 15.0 | 14.1 | 13.1 | 10.8 | 6.3 | 2.3 | 1.3 | 1.3 | 1.3 | | | 123 |
| Interest during construction | | | | | | | | | | | | | | | | | |
| Total | | | | | | | | | | | | | | | | | 42 |
| Foreign | | | | | | | | | | | | | | | | | 13 |
| Total | | | | | | | | | | | | | | | | | 323 |
| Foreign | | | | | | | | | | | | | | | | | 136 |
| Domestic | | | | | | | | | | | | | | | | | 187 |
| II. PRIVATE (OR PUBLIC) INVESTMENT | | | | | | | | | | | | | | | | | |
| Reclamation | 3.0 | 6.0 | 6.0 | 3.0 | 3.0 | 6.0 | 6.0 | 6.0 | 2.0 | 1.0 | 8.0 | 14.0 | 12.0 | 10.0 | 10.0 | 8.0 | 104 |
| Housing | | 2.0 | 3.0 | 2.0 | 1.0 | 1.0 | 2.0 | 3.0 | 0.5 | 0.5 | 0.5 | 1.0 | 3.0 | 5.0 | 5.0 | 3.0 | 33 |
| Total | 3.0 | 8.0 | 9.0 | 5.0 | 4.0 | 7.0 | 8.0 | 9.0 | 2.5 | 1.5 | 8.5 | 15.0 | 15.0 | 15.0 | 15.0 | 11.0 | 137 |
| III. GRAND TOTAL INVESTMENT | | | | | | | | | | | | | | | | | |
| (a) Excluding interest during construction | | | | | | | | | | | | | | | | | 418 |
| (b) Including interest during construction on public investment | | | | | | | | | | | | | | | | | 460 |

## III. ESTIMATED RESULTS FROM THE PROJECT

The benefits from the project will be derived from increased agricultural production, from the production of electric power, from savings in water transportation costs due to improved conditions for navigation, and from savings in flood prevention measures and from avoidance of flood damage. Income to the Government will be derived from increased land and export taxes, sales of public lands, and sale of electric power.

There follows an analysis of these various aspects - agriculture, power, and navigation and flood control - followed by an overall summary of economic benefit from the project as a whole.

### A. Agricultural Aspects of the Project

The principal justification of the Sadd el-Aali project is that it will make possible a substantial and absolutely necessary increase in agricultural output. According to the calculations of the Egyptian Government, the project will (1) raise the irrigated area by 1.3 million feddans, or from the present total of 6.15 million to 7.45 million, (2) permit the conversion of about 670,000 feddans of basin-irrigated land to perennial irrigation, and (3) increase yields by improving drainage and assuring a more regular supply of water.

#### Agricultural Output and Population

For Egypt a considerable extension of the cultivated area is imperative. Recent decades have witnessed a growing pressure of population in relation to the cropped area. The table below shows clearly that both the total population and the agrarian population have increased much more rapidly than the total cultivated or cropped area. In 1953, for instance, the cropped area per head in the total population was only 0.42 feddans as compared with 0.61 feddans in 1927.

Table No. 9

Population and Cultivated Areas

| | 1927 | 1937 | 1947 | 1953 |
|---|---|---|---|---|
| Index: Total population | 100 | 112 | 134 | 154 |
| Index: Agrarian population | 100 | 120 | 122 | 134 |
| Index: Cultivated area | 100 | 95 | 104 | 110 |
| Index: Cropped area | 100 | 97 | 106 | 108 |
| Number of crops per unit | 1.56 | 1.60 | 1.59 | 1.53 |
| Cultivated area: | | | | |
| (a) in feddans per capita, total population | 0.39 | 0.33 | 0.33 | 0.28 |
| (b) in feddans per capita, agrarian population | 0.90 | 0.77 | 0.76 | 0.70 |
| Cropped area in feddans per capita total population | 0.61 | 0.52 | 0.48 | 0.42 |

That there was no corresponding decline in the standard of living was due to the increase in income in other sectors of the economy, primarily in industry. During the last few decades Egypt witnessed considerable industrial development. Thus employment in manufacturing establishments with 10 or more workers increased from 110,800 in 1927 to 243,100 in 1954. The cotton and rayon textile industry has developed so rapidly that Egypt no longer has any net import requirements. The production of other consumer necessities such as beverages, canned foodstuffs, vegetable oils and soap, matches, paper and cardboard has also expanded rather rapidly, as has the output of fertilizers, cement and glass. All these developments have made it possible to maintain though not to raise the existing low-standard of consumption per capita despite the growing population.

Now that industries have expanded enough to cover all or a large part of the country's requirements and the possibility of further substitution of domestic manufactures for imports has at least been drastically limited, industrial growth in the future is likely to be largely conditioned by the development of additional purchasing power in the domestic market. Egyptian industry which still requires substantial protection against foreign competition will certainly be unable to capture a large foreign market for some time to come. The principal determinant in its growth will be agricultural output, for the agricultural sector not only contributed directly about a third of the estimated national income in 1953, but made possible much of the income from trade and services and supplied a large part of the raw materials processed in industry. Agricultural products, moreover, account for 95% of Egypt's exports.

Egypt therefore faces the prospect of a considerable decline in the standard of living unless agricultural production can be rapidly expanded. This requirement is all the more urgent because the population is already growing at an annual rate of 2.5% and all signs point to a further increase rather than a decline in this rate.

The Project and Agricultural Yields

While the primary effect of the Sadd el-Aali project will be to expand the cropped area, it will also raise yields. The existing dams on the Nile can to some extent smooth out the seasonal fluctuations by storing some of the flood waters in the three-month period August-October, during which about two-thirds of the annual discharge of the Nile takes place, and releasing this water during the months of low flow. It will thus make possible (1) a controlled and even discharge of water for use in Egypt throughout the year, and (2) a stabilization of the water supply from year to year.

As the result of the controlled discharge of the Nile, yields will be improved by preventing shortages in irrigation water during some years and, above all, by facilitating better drainage. An incidental effect will also be the stabilization of the area planted to rice. At present the rice area reflects sharply the fluctuation in the availability of water from year to year. Each year the Government determines the rice acreage in the light of water expected to be available. Thus in the last 15 years the area planted to rice has varied from a low of 373,609 feddans in 1952 to a high of 785,724 feddans in 1947; the total paddy harvested has ranged from about 515,000 to 1,318,000 tons, and the highest yield has exceeded the lowest yield by as much as 41%.

Improved drainage will greatly influence yields. In the last two decades yields of most crops have shown a tendency to decline (see Table No. 10). A combination of factors - deterioration in the quality of seeds and varieties as well as poor drainage - has probably been responsible for this trend. Poor drainage is certainly an important factor in depressing yields, particularly in the northern part of the delta where the water table is very high. Both the fluctuations in the water table and the rather high level of the water table affect yields adversely. During the flood season the water table rises rapidly, only to recede again. For a crop such as cotton which develops its root structure during the period of a falling water table, the subsequent rise in the water level during the season when the crop is maturing has a definitely harmful effect. Continuous irrigation over many years has generally raised the water table, thus leading to water-logging and the accumulation of salts in the surface soil by the evaporation of water drawn up from the high water table.

Table No. 10

Index of Yields per Feddan

| Period | Wheat | Maize | Millet | Rice | Cotton Lint | Beans | Sugar Cane | Lentils | Chick-peas |
|---|---|---|---|---|---|---|---|---|---|
| 1935-39 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 1940-44 | 83 | 77 | 87 | 83 | 104 | 102 | 83 | 105 | 91 |
| 1945-49 | 82 | 84 | 83 | 102 | 102 | 99 | 94 | 95 | 91 |
| 1950-54 | 93 | 86 | 94 | 104 | 95a/ | 91 | 98 | 91a/ | 92a/ |
| 1953 | 98 | 88 | 94 | 100 | 103 | 91 | 102 | 98 | 92 |
| 1954 | 109 | 88 | 83 | 119 | n.a. | 101 | 104 | n.a. | n.a. |

a/ 1950-53

Open drainage canals have provided only a partial solution and are impracticable in areas of established intensive cultivation where open drains would cut too much into the available land. In the northern delta tile drains have been installed in an attempt to cope with this problem, but this requires an investment of LE 25 per feddan. Up to 1954, 45,000 feddans had been provided with such drains. Further installations have now been deferred, until an experimental program now under way determines more exactly their effect and the optimum depths and spacing of the drains. In the same area experiments have also been launched with well drainage in the hope that such wells will not only help to lower the water table but will supply supplemental water for irrigation.

The virtually complete control over the flow of the Nile which will be effected by the building of Sadd el-Aali will improve drainage conditions by keeping the water supply in the canals at a level which will be both uniform and substantially below those now obtaining in flood conditions. This will tend both to stabilize and lower the underground water table.

Yields will in general increase as a result of the lower and more stable water table and the more even distribution of irrigation water throughout the year. However, the extent of increase cannot be accurately assessed in the absence of adequate research data. It is a question of the adequacy of the average water supply not only in relation to the needs of the plants but also of requirements for leaching the soil. Less water should be necessary for leaching because the lower water table will reduce the upward movement of salts. However, water in excess of actual plant needs may still be necessary to leach the surface soil. Consequently yields, particularly over the longer term, will depend on the adequacy of water supply in relation to requirements which are not definitely known. This reinforces the need for a vigorous program of field research into water requirements, drainage and other agronomic factors likely to affect crop yields. Such experiments should be carried out under conditions which would approximate as closely as possible those respecting water use, canal water levels and drainage as would obtain after completion of Sadd el-Aali. Apart from the major soil types of the existing irrigation areas, they should also be undertaken on any new major soil types likely to be brought under irrigation, even if special provision of water to the experimental areas is necessary before completion of major works. The existing program of research should be considerably expanded to meet these needs.

In projecting, elsewhere in this report, the agricultural output which is likely to be attained after the completion of Sadd el-Aali, we have assumed a general improvement of yields in the future. We have not found it possible, however, to distinguish between the effects of the project as discussed above and other factors which should improve yields in the future. Admittedly, the yields achieved in Egypt are already among the highest in the world thanks to intensive cultivation, substantial use of fertilizer 1/ and crop rotations which contribute effectively to the maintenance of high levels of fertility. Nevertheless, further improvement can reasonably be expected. The present Government already has under way a 3-year program, begun in 1953-54, for the propagation and distribution of greatly improved wheat, hybrid corn, rice and cotton seeds. The results of this program are promising. A considerable increase in the use of fertilizer, which should become profitable with lower fertilizer prices in the future, should also help to raise yields substantially. For example, it is likely that a second dressing of 20 kg. nitrogen per feddan on wheat would increase output by about 20%. Similarly, rice yields may well improve with larger applications of phosphate. Finally, the establishment of a well-staffed extension service would help to disseminate knowledge of the best agricultural techniques. Since 1953 the Ministry of Agriculture has been seeking to establish an extension service quite independent of the existing

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1/ In the 4-year period 1950-53 the average use of fertilizer on all crops except berseem or Egyptian clover was 109 kg. per feddan (260 kg. per hectare). In 1953 Egypt used 654,680 tons of nitrogen fertilizer (117,822 tons N content) and 77,756 tons of single superphosphate.

field services which are primarily engaged in the encorcement of cropping regulations and the dissemination of certified seeds.

Considering all these possibilities, we believe it is reasonable to expect the following increases in yields over the next two decades (in kg. per feddan):

Table No. 11

| | Recent Average a/ | Projected for 1975 |
|---|---|---|
| Wheat | 914 | 1,100 |
| Barley | 971 | 1,050 |
| Rice (white) | 1,125 | 1,450 |
| Maize | 920 | 1,200 |
| Millet | 1,078 | 1,250 |
| Cotton | 233 | 250 |
| Beans | 701 | 800 |
| Peanuts | 776 | 800 |
| Sesame | 332 | 365 |
| Sugar Cane | 2,380 | 2,600 |
| Onions | 6,350 | 6,750 |
| Fresh vegetables | 6,750 | 7,400 |
| Tomatoes | 6,320 | 7,000 |
| Potatoes | 6,700 | 7,000 |
| Oranges | 7,070 | 8,500 |
| Grapes | 4,900 | 5,000 |
| Other orchard fruit | 6,200 | 7,000 |

a/ In some cases 1952 and 1953; in others, 1953 and 1954.

## Extension of the Cropped Area

The extension of the cropped area, however, will be the principal result of Sadd el-Aali. A small part of this increase will come from the conversion to perennial irrigation of the 670,000 feddans of basin-irrigated land, still remaining in Upper and Middle Egypt. This land, which is divided into empoldered "basins", is flooded for three months during the period of high water. After the water recedes crops are planted and mature on the water accumulated in the soil. The principal crops are wheat, lentils, fenugreek, chickpeas, beans and sesame. Only one crop is grown annually, although here and there a second crop may be cultivated with the help of water from shallow wells. The cropping intensity - i.e. the proportion of cropped to cultivated area - is therefore only 105 as compared with 153 (in 1953) for Egypt as a whole. Under present conditions it is impossible to install a system of continuous or perennial irrigation on this land because the basin lands provide a measure of necessary flood control and there is simply not enough water for irrigation during three-quarters of the year. By permitting the controlled discharge of the annual flow of the Nile throughout the year, Sadd el-Aali will make possible perennial irrigation of these basin lands. The amount of water required annually by these lands will not increase, but it will simply be distributed evenly over the whole year. Cropping throughout the year will thus become possible raising the cropping intensity to the level elsewhere in Egypt and permitting more diversification.

The greater part of the increase in the cropped area will, of course, come from the irrigation of new land; and it is therefore necessary to examine how large an expansion of the irrigated area can be brought about by Sadd el-Aali.

## 1. Selection of Areas for Irrigation

The Egyptian authorities believe that the additional water that will be available to Egypt after the construction of Sadd el-Aali will irrigate 1.3 million feddans of new land. Up to the present the Government has only very roughly blocked out the areas that might be newly irrigated. These, together with the amount of water estimated to be required annually to irrigate them, are set forth in the following table:

Table No. 12

Areas Proposed by the Egyptian Government for Irrigation and their Water Requirements

| Location | | Area in Feddans | Annual Water Requirements: $M^3$ per Feddan | Annual Water Requirements: Total (billion $M^3$) |
|---|---|---|---|---|
| Upper Egypt | (1) | 175,000 (general crop rotation) | 9,000 | 1.6 |
| | (2) | 75,000 (sugar cane rotation) | 12,000 | 0.9 |
| Middle Egypt | | 150,000 | 8,000 | 1.2 |
| Lower Egypt | | | | |
| Delta | (1) | 150,000 (cotton rotation) | 7,500 | 1.1 |
| | (2) | 150,000 (rice rotation) | 8,000 | 1.2 |
| Western Desert | | 400,000 | 12,000 | 4.8 |
| Eastern Desert | | 200,000 | 12,000 | 2.4 |
| Total | | 1,300,000 | 10,000 | 13.1 |

Half of these areas would be irrigated by free flow (gravity) and the other half by lift (pumping). It should be noted that these areas would require about 13.1 milliard $m^3$ of water and that the Egyptians hope to use another 0.6 milliard to expand vegetable and citrus cultivation on about 200,000 feddans.

The Egyptian authorities recognize that a final determination of the size and location of the areas to be irrigated can only be made after considerably more data are collected on the soils of the potentially irrigable areas. Over the next few years the Egyptian Government will have to carry out a study leading to the final selection of areas to be irrigated in the light of (1) the comparative fertility of soils in various areas, (2) the comparative quantity of water required by different soils, (3) the types of crops that could be grown in various areas, and their comparative marketability, and (4) relative costs of development and provision of water. A program of this kind, which would seek to achieve irrigation and cropping schemes that would ensure an optimum economic yield for the water made available by Sadd el-Aali, entails soil classification, research into cropping patterns and marketing studies.

The broad phase soil survey, based on aerial photography and soil sampling, is well under way and should be completed rapidly once the aerial photographic laboratory, now under construction, is available. This survey will provide the broad soil classification which will enable certain areas to be eliminated and selection of the more promising areas for detailed soil survey. The detailed survey will give a preliminary indication of the relative fertility and water requirements of the various soil types. Once the most promising soil types have been determined research centers should be, as previously discussed, established on each. Only field research can give reliable answers to the many agronomic questions which are essential before final selection of the new areas. The market studies should concentrate particularly on potential export crops which could be developed on new lands. The Egyptian authorities, in cooperation with ICA technicians, propose to work out a full program of soil survey and research early in 1956. The program would presumably be submitted to the Bank for consideration.

2. Water Requirements

The most important consideration governing the selection of areas for irrigation will be the amount of water required. Irrespective of the amount of additional water assured to Egypt by an eventual agreement with the Sudan, it will be vital to use this water for as large an extension of the irrigated area as possible.

The areas tentatively selected by the Egyptian authorities seem by comparison with the present average use of water per feddan to require an excessive amount of water. They appear to include far too much desert land. The tentative program, as given above, would reclaim, for example, 400,000 feddans of desert land in the newly created Liberation Province and 200,000 feddans of eastern desert along the Ismailia canal and in the Sinai peninsula. If this much desert land is irrigated in Lower Egypt, together with the land in Middle and Upper Egypt, it is likely to require far more water than will be available. Moreover, much of the desert land is poor and is likely to attain the yields now achieved on cultivated land only after many years of carefully planned cropping. In the Liberation Province, where a reclamation project has been carried on during the last two years, the present use of water averages about 20,000 $m^3$ per feddan annually and is not expected to be below 15,000 $m^3$ in the future. On the other hand, in the Lake Mariut region of the Delta, where the so-called Abis reclamation project is being carried out, the annual use of water during the first three years when salt must be leached from the soil amounts to about 16,000-18,000 $m^3$ per feddan, but is expected to be reduced progressively to 9,000 $m^3$ and, upon completion of reclamation, to probably no more than 7,000 $m^3$.

Data from various sources indicate that at the moment about 8,000 $m^3$ of water (measured at Aswan) is used on the average for irrigation of one feddan of land. There is an element of doubt in all calculations. Furthermore, the amount of water used during the flood season (August-October inclusive), when much water runs to the sea, can only be estimated. According to the National Production Council, actual average releases of water at Aswan during the periods February-July and November-December of 1950-53 amounted to 5,100 $m^3$ per feddan and the estimated use of flood water was 2,700 $m^3$ or a total of 7,800 $m^3$ per year. Hurst has calculated the irrigation duty, measured at Aswan, at 7,370 $m^3$ per feddan in Lower Egypt and 8,390 $m^3$ in Upper Egypt, or at an average of 7,750 $m^3$ for Egypt as a whole. Information gathered by the Bank Mission on water use in various parts of Egypt indicates that the amount of water used on the present cultivated area of 6.15 million feddans is in the neighborhood of 49.2 milliard $m^3$ or an average of 8,080 $m^3$ per feddan as measured at Aswan. Since, however, this estimate is based on uncontrolled use of water during the flood period, it probably overestimates the use which would take place under fully controlled use. It is therefore reasonable to accept the amount of water required for the existing area at 6.15 million x 7,750 $m^3$ or 47.6 milliards.

How much land could be irrigated with an additional supply of water depends both on the location and type of land and on the types of crops to be grown. According to the experience on state agricultural farms in the Middle Delta, a three-year crop rotation incorporating one crop of rice requires an annual amount of water, measured at Aswan, of about 8,760 $m^3$ per feddan, while the same crop rotation substituting maize for rice requires only about 7,560 $m^3$. In Middle Egypt a three-year crop rotation system, with maize, calls for about 8,000 $m^3$ per feddan annually. Sugar cane and orchards take far more water than the normal rotations including summer and winter crops. In Upper Egypt experience indicates that a four-year sugar cane rotation (3 years cane and 1 year other crops) requires between 12,000 and 15,000 $m^3$ per feddan annually. Citrus grown in the Delta apparently needs only 5,600-6,400 $m^3$ of water per feddan, but when cultivated in Middle and Upper Egypt, where the climate is hotter and the soil different, takes respectively 9,000 $m^3$ and 12,000 $m^3$. These requirements, when measured at Aswan, total respectively about 6,600-7,700, 10,350 and 12,600 $m^3$.

In the light of these considerations it should be possible to select for irrigation areas which would require on the average not much more water than those already being cultivated in Egypt. For instance, it appears feasible to increase substantially the amount of land to be reclaimed and irrigated in the delta at the expense of desert land slated for reclamation. In the northern delta considerable land is still available for reclamation, and the cost of reclaiming it does not appear higher than that for desert land. The advantage of reclaiming such areas as compared with retaining them for fishing will, of course, have to be considered. While a final selection of areas must await the careful investigation outlined above, we can assume, for the purpose of calculating the benefits of the project, that a much heavier emphasis will be given to reclamation and irrigation in the delta and that the distribution of the areas ultimately chosen will not be far different from those given in Table 13.

Table No. 13

| | Areas to be Irrigated (feddans) | Water Requirements (milliard $m^3$) |
|---|---|---|
| Lower Delta | 700,000 | 5.6 |
| Upper Egypt | 250,000 | 2.5 |
| Middle Egypt | 150,000 | 1.2 |
| Desert Land in Lower Egypt | 200,000 | 2.1 |
| Total | 1,300,000 | 11.4 |
| Allowance for extension of citrus and vegetable cultivation | | 0.6 |
| Total Water Requirements | | 12.0 |

It should be noted that a program of this general distribution would involve the use of an annual average of only 8,770 $m^3$ of water per feddan, as compared with the 10,000 $m^3$ assumed in the program tentatively blocked out by the Egyptian authorities. The total amount of water required would be about 12 milliard $m^3$ which would theoretically leave for the Sudan only 6.7 milliard $m^3$ out of the total additional annual supply of 18.7 milliards as measured at Aswan. However, this 6.7 milliards would amount to about 8 milliards when measured at the probable withdrawal point in the Sudan. Moreover, not all of the 12 milliard $m^3$ required for the above program would need to come out of the additional 18.7 milliards made available by Sadd el-Aali. After the High Dam is finished Egypt will presumably be able to dispense with the use of the Gebel Aulia reservoir where 2 milliard $m^3$ of water is lost annually at present. Economies in existing use would probably make an additional supply of 1.6 milliards available (see page 41). In addition it is possible that further economies can be effected in the use of irrigation water. It is often contended that too much water is generally used for irrigation in Egypt and that accordingly a larger area could be irrigated if more efficient water usage could be introduced. It is highly desirable to determine the possibility of effecting such economies by undertaking experiments in various areas for the determination of the optimum irrigation duty taking into account not only the water required by the plant itself but also that needed to keep the soil free from accumulated salt by leaching.

## Projected Increase in Agricultural Production and Income

For the purpose of calculating the economic benefits of Sadd el-Aali we have therefore assumed that it will be possible to irrigate an additional 1.3 million feddans as the direct and indirect consequence of the construction of the High Dam. In addition it is quite probable that in the next two decades 150,000 feddans can be irrigated with underground water. Thus the total cultivated area would probably increase from 6,150,000 feddans in 1953 to 7,600,000 feddans after Sadd el-Aali and all the attendant land reclamation are finished. Owing to the conversion of basin-irrigated lands to perennial irrigation, the total cropped area would increase more than proportionately - from 9,366,000 feddans in 1953 to about 12,750,000 feddans. The overall cropping intensity would rise from 153 to 168.

The Egyptian Government has made no attempt to project in detail the additional agricultural output which would result from Sadd el-Aali. The Bank Mission therefore had to make its own estimates on the basis of the most reasonable assumption regarding the areas likely to be irrigated and of the cropping patterns which, judging from past experience, will be feasible in these areas. Additional detailed studies may well result in a still better selection of land and cropping patterns than these assumed here, but any final calculation is unlikely to show a less favorable impact on agricultural output and income than is set forth in Table 14.

This table projects the cropping pattern that may emerge after Sadd el-Aali is completed, which for the purpose of estimating is assumed as 1975, and estimates what the total agricultural income might be as compared with 1953. The projection is based on the assumption that the irrigation and reclamation program tentatively outlined by the Egyptian authorities will be revised as indicated above. The cropping pattern suggested for the future is not radically different from that now prevailing. In fact, there cannot be drastic shifts from one crop to another. A choice cannot for the most part be made between individual crops, but rather between crop rotation schemes. Certain crop rotations have become well established in Egypt, and long experience has shown them to be well adapted for the maintenance of soil fertility. Except in the basin lands and in areas devoted more or less continuously to vegetables, sugar cane and orchard crops, a three-year crop rotation is the common practice. In the lower and middle Delta, for instance, the principal rotation schemes are: (1) cotton (February-September), wheat, or barley, or beans (October-May), maize (July-December), berseem (December-April), and rice (May-November); or (2) cotton (February-September), berseem (October-April), maize (June-October), wheat or other winter crop (November-May) and berseem (October-January). In the same area a two-year cropping system including cotton, beans or barley, rice and berseem, is often used on salty lands. In the Upper Delta generally similar rotation schemes are practised, though often with more emphasis in the inclusion of winter and summer vegetables. In Middle and Upper Egypt millet often takes the place of maize in the rotation and more barley is grown in relation to wheat. In the Aswan province of Upper Egypt little cotton is cultivated. In the cane growing areas, primarily in Upper Egypt, sugar cane occupies the land for three-year periods alternating with a year of other crops combined sometimes with fallow.

Within the limits set by the need to maintain these generally desirable cropping systems, the projection of agricultural output set forth in Table No. 14 gives a somewhat greater emphasis to certain crops. In the field of cereals, for example, provision has been made for a more than proportionate increase in the rice area on the ground that water will be

## TABLE NO. 14

### PROJECTION OF CROPPED AREA . AGRICULTURAL INCOME IN EGYPT

| | 1953 | | | 1975 | | | Prices Used for Valuation of Output (LE per ton) a/ | |
|---|---|---|---|---|---|---|---|---|
| | Area (Feddan 000's) | Production (Tons 000's) | Gross Farm Value (LE 000's) | Area (Feddan 000's) | Production (Tons 000's) | Gross Farm Value (LE 000's) | 1953 | 1975 |
| Wheat | 1,790 | 1,547 | 42,216 | 1,945 | 2,139 | 59,892 | 28.00 b/ | 28.00 |
| Barley | 116 | 103 | 2,373 | 100 | 105 | 2,415 | 23.00 | 23.00 |
| Maize | 2,015 | 1,853 | 36,398 | 2,385 | 2,862 | 56,209 | 19.64 | 19.64 |
| Millet | 486 | 582 | 10,476 | 550 | 688 | 12,384 | 18.00 | 18.00 |
| Rice | 423 | 435 c/ | 13,920 | 900 | 1,295 c/ | 33,670 | 32.00 d/ | 26.00 d/ |
| Beans | 299 | 209 | 7,322 | 490 | 392 | 13,740 | 35.05 | 35.05 |
| Lentils & chickpeas | 76 | 40 | 2,800 | 145 | 84 | 5,880 | 70.00 | 70.00 |
| Fenugreek | 53 | 33 | 1,146 | 70 | 45 | 1,563 | 34.75 | 34.75 |
| Peanuts | 31 | 24 | 1,050 | 100 | 80 | 3,200 | 43.75 | 40.00 |
| Sesame | 39 | 13.5 | 820 | 68 | 25 | 1,520 | 60.79 | 60.79 |
| Sugar-Cane | 104 | 238 | 7,140 | 175 | 455 | 13,650 | (30.80 e/ | (30.00 e/ |
| -Beet | | | | 30 | 66 | | ( | ( |
| Onions | 37 | 220 | 4,136 | 66 | 450 | 8,460 | 18.80 | 18.80 |
| Fresh vegetables | 179 | 1,282 | 11,793 | 249 | 1,845 | 16,789 | 9.10 | 9.10 |
| Tomatoes | 84 | 439 | 4,734 | 128 | 896 | 8,691 | 10.78 | 9.70 |
| Potatoes | 27 | 187 | 2,570 | 79 | 553 | 6,598 | 13.74 | 13.74 |
| Oranges | 26 | 184 | 2,732 | 75 | 638 | 9,493 | 14.88 | 14.88 |
| Grapes | 19 | 94 | 2,291 | 40 | 200 | 4,874 | 24.37 | 24.37 |
| Other fruit | 49 | 304 | 6,911 | 70 | 490 | 11,138 | 22.73 | 22.73 |
| Cotton | 1,324 | 919 f/ | 85,916 | 2,035 | 1,492 f/ | 119,360 | 93.49 | 80.00 |
| Berseem | 2,132 | -- | 41,912 | 3,000 | | 62,030 | | |
| Meat & dairy products | | | 52,428 | | | 84,760 | | |
| Poultry | | | 10,929 | | | 15,300 | | |
| Fish | | | 7,000 | | | 5,000 | | |
| Other crops | 47 | | 1,019 | | | 500 | | |
| TOTAL | 9,366 | | 360,032 | 12,750 | | 552,116 | | |
| Cost of Production | | | 104,440 | | | 162,000 g/ | | |
| | | | 255,592 | | | 390,116 | | |

a/ Prices per ton include valuations for by-products such as chaff, bran, straw, stalks, seeds, etc.
b/ Corrected for overvaluation due to high domestic price support of wheat. The price used in the Egyptian official estimate of national income for 1953 was LE 36.45 per ton.
c/ Milled rice.
d/ Price of LE 25.33 used in Egyptian 1953 national income calculation increased to LE 32 - to allow for undervaluation.
e/ Corrected for overvaluation due to high domestic price support of cane sugar. The price used in the Egyptian official estimate of national income for 1953 was LE 37.80.
f/ Seed cotton equivalent to 318,000 and 508,750 of lint cotton in 1953 and 1975 respectively.
g/ Increase more than proportionate to the rise in cropped area owing to disproportionately large expansion of crops with high cost of production and allowance for greater use of fertilizers (latter offset, however, by anticipated decline in price).

available to raise and stabilize rice output and that this crop can make an important contribution to Egypt's exports. In sugar there is the possibility of making Egypt virtually self-sufficient both by expanding the area in cane and by growing sugar beets which experiments carried on during the last few years have shown to be surprisingly well adapted to conditions in certain parts of Lower Egypt. The cultivation of considerably more potatoes and tomatoes has been stressed in the expectation that Egypt should be able in the long run to establish a market for these products in southern and western Europe, particularly because the potato crop matures very early and tomatoes can be grown the year-around. Considerable expansion has also been envisaged for oranges and grapes which are already being grown with conspicuous success and which might well be marketable abroad in the long run, particularly if they are processed in some form. Finally, it is anticipated that the area in peanuts can increase substantially because this crop is well suited to certain desert areas likely to be irrigated and should find a market abroad.

The changes envisaged in the pattern of production are slight and would not be difficult to bring about, particularly since they are a continuation of trends already discernible in the past. The cultivation of tomatoes and potatoes, for example, has been rising markedly. Even with the contemplated further use in output, it is not expected that by about 1975 they will occupy more than 1.62% of the total cropped area as compared with 1.08% in 1953. The area in fruit has expanded from an average of 63,588 feddans in 1935-39 to 96,000 in 1953, or by a little over 50%. An additional increase by about 90% over the next two decades is not an unreasonable expectation, and even at the end of this period orchards would only account for 1.45% of the cropped area. The production of peanuts has also been rising, and peanuts should prove to be a particularly suitable and remunerative crop on newly irrigated desert land. The area in rice has been restricted only because of the water supply. Once more water is available, there will be ample incentive to raise the production of rice; and the Government is well equipped to provide the necessary seed.

Table 14 also shows the total gross and net value of the agricultural output that may eventually be attained as compared with those in 1953. The prices used in calculating the value of future output are generally the same as those in 1953. If these prices decline or rise, farm income will, of course, be affected, but to the extent that products are consumed in the domestic market there will be offsetting effects on the real income of consumers. For products like rice and cotton which are to a considerable extent sold abroad, possible price changes in the world market have been taken into account. For cotton, it has also been assumed that the expansion in area would be almost wholly confined to the relatively short-staple, lower-priced Ashmouni variety rather than the long-staple, high-priced Karnak. For Karnak, there is a limited and rather inelastic demand, while Ashmouni can be readily sold in competition with the still shorter staple American cotton provided the premium now prevailing is reduced.

According to the projection, the gross value of agricultural output would rise from LE 360 million to LE 552 million or by about 53%, whereas the net value would increase from LE 256 to LE 390 million or by 52%. The increase in the net value is slightly smaller because of the assumed shift to certain crops such as orchard crops which cost relatively more to produce. The total rise in the net value - LE 134 million - cannot be fully attributable to the effect of Sadd el-Aali alone. Perhaps up to 15% might be due to other measures to raise yields and to well irrigation, leaving a net of about LE 114 million attributable to Sadd el-Aali.

This net amount has been calculated by deducting all production costs such as fertilizers, seeds, etc., other than labor. For the purpose of determining the cost to the economy of producing the agricultural products it was not considered appropriate to include labor costs, both the imputed value of the farmers' own labor or actual wages of hired labor. With the rapid growth in the population, Egypt will continue to have a large supply of redundant labor. It should therefore be possible to till the new lands without any adverse effect on the production of goods and services in the non-agricultural sectors of the economy.

A further small contribution to agricultural income might come from the gently sloping land around the borders of the Sadd el-Aali reservoir which would become available for one-crop cultivation when the water is drawn down every year. Perhaps 200,000-300,000 feddans might be so cultivated to a catch crop like vegetables or berseem. If one takes the lower limit of this area and estimates the net value of the crops conservatively at LE 10 per feddan, the additional benefit would be LE 2 million per year, raising the total to LE 116 million.

From this amount it is necessary still to deduct the cost to the Government of operating and maintaining the new irrigation and drainage network. If the annual cost of maintenance and depreciation is put at 0.5% of of the total investment in irrigation and drainage works (ca. LE 60 million) and 5% of the pumping stations, the total would be LE 1.46 million. To this should be added the cost of operating the pumps, which might raise the total to around LE 4 million a year. The total net benefit would then be somewhere about LE 112 million annually.

The full effect of the project on agricultural output and income will not be felt before five or ten years after completion of the dam. The dam itself, together with major irrigation and drainage works, will take a minimum of ten years to build. The reclamation of land involves, among other things, a special cropping regime over a period of up to five years to bring the new land up to the average standard of yield now prevailing in Egypt. In addition, roads will have to be built, utilities installed and housing and public buildings constructed. Altogether, therefore, even if construction work is begun promptly, 15 to 20 years will pass before the full fruits of the project are realized. This does not mean that there will be no benefits in the meantime. Cropping can begin as part of the land reclamation process as soon as the dam is completed and water is stored after the first flood season, although yields on the new land will be low in the initial years. Moreover, after the completion of the cofferdam which will take only five years, an additional controlled supply of water of 3 milliard $m^3$ annually will become available. This additional water will be used for the conversion of the 670,000 feddans of basin-irrigated land to perennial irrigation.

While the total annual water requirements of this land will not be greater after its conversion to perennial irrigation, it will impose new demands on the supply during the low water season of January to July. The supply in this season will remain critical until the whole of the annual flow of the Nile is effectively controlled upon the completion of the High Dam, thereby eliminating differences of supply that now obtain as between the flood period and the low-water period. It is expected that the additional water during the critical period required after the conversion of the basin-irrigated land will be almost 5,000 $m^3$ per feddan. The increase in the supply available during this period by the cofferdam will therefore be entirely absorbed by the conversion of the basin-irrigated land.

It has already been mentioned that, according to some Egyptian authorities, it may be possible to raise the storage level behind the cofferdam sufficiently to make another 3 milliards $m^3$ available one year after the cofferdam is completed. If further investigation substantiates this claim, the more immediate benefits of the project will be greatly increased. This will be especially advantageous because the Egyptian Government expects to complete by the middle of 1956 major irrigation and drainage facilities for 300,000 feddans. At present the water for this area (shown in Table 15) can be found only if wells are installed or if other irrigated areas are deprived of some water.

Table No. 15

Areas for which Irrigation Works are Scheduled for Completion by Mid-1956

| | | |
|---|---|---|
| Lower Egypt | | |
| North Delta Area | | 105,000 feddans |
| Nubarieh Canal | | 80,000 " |
| Tahrir (Liberation) Province | | 24,000 " |
| Abis Area (Egyptian-American Rural Improvement Service) | | 25,000 " |
| | Sub-Total | 234,000 " |
| Upper Egypt | | |
| Abnub Basin Conversion | | 31,000 feddans |
| Fayum-Kom Oshim | | 13,000 " |
| | Sub-Total | 44,000 " |
| Desert Land | | 21,000 " |
| | Total | 299,000 feddans |

If a further 3 milliard $m^3$ becomes available, it would be possible to irrigate this entire new area without decreasing the supply to existing irrigated areas and still leave some water for the stabilization of the fluctuating area now devoted to rice cultivation in the delta.

## Indirect Benefits

The increase in agricultural income will entail important ancillary benefits for the economy as a whole. As already indicated, agricultural income is likely in the future to be the most important determinant in the development of total national income and particularly of income in the commercial, industrial and financial sectors of the economy. The economic report points out that for various reasons non-agricultural income may rise somewhat more rapidly than agricultural income. By the time the benefits of Sadd el-Aali are fully realized total national income may have risen by around 55% to 60%. This increase will probably approximate the growth in the population which will meanwhile have taken place. However, the benefits flowing from Sadd el-Aali will undoubtedly provide a further fillip to the development of Egyptian industry which in the intervening period will have increased its efficiency and broadened its activities. Moreover, there is some prospect that the decline in the mortality rate which has been and is taking place will in the long run be followed by a decline in the birth rate, thus diminishing the current high rate of population growth.

## Projected Balance of Trade in Agricultural Products

It is interesting to examine also how the expected development of agricultural output and national income is likely to affect Egypt's balance of trade in agricultural products. The exact impact is difficult to forecast, if only because the effect of possible changes in per capita income on the consumption of various products cannot be accurately predicted. If per capita incomes will still be below present levels, for instance, the per capita consumption of such food staples as cereals and beans is less likely to drop than, say, the consumption of livestock products. The table below indicates the possible balance of trade in the year 1975 if per capita consumption ranges between 90% and 100% of that in recent years. It shows that Egypt would have a substantially larger deficit in wheat, but a considerably bigger export surplus in rice than in the period 1948-52. Cotton exports could be about 50% greater and there would also be a larger surplus of onions which is Egypt's second or third ranking export. Egypt would be enabled to export substantial quantities of tomatoes, potatoes, citrus and grapes, although if prices decline with the considerable expansion in output, which might well happen, domestic consumption might rise and the surpluses indicated by the table might prove to be much smaller.

Table No. 16

Foreign Trade Balance in Agricultural Products

(Net import -; Net export +; in '000 tons)

| | Average 1948-52 | 1975 |
|---|---|---|
| Cereals other than rice | | |
| Wheat | - 728.9) | - 1,378 to - 2,222 |
| Barley | - 3.6) | |
| Maize and millet | - 89.5) | |
| Rice (white) | + 178.5 | + 460 to + 527 |
| Cotton | + 244 | + 383 to + 396 |
| Beans | - 10.0 | - 35 to - 94 |
| Lentils and chickpeas | - 2.0 | 0 to + 8 |
| Fenugreek | - | - 10 to - 16 |
| Peanuts (in shell) | - | + 46 to + 49 |
| Sesame | - 1.5 | 0 to + 2 |
| Onions | + 106 | + 131 to + 162 |
| Tomatoes | - | + 66 to + 139 |
| Potatoes | - 16 | + 182 to + 219 |
| Oranges | - 2.4 | + 188 to + 232 |
| Grapes | - 1.0 | + 40 to + 56 |

Incentives for Private Land Reclamation

The realization of the agricultural production envisaged ultimately following the completion of Sadd el-Aali will depend not only on government initiative and investment but also on private enterprise and investment. The government will have to provide for the construction of the dam and power facilities, the major irrigation and irrigation canals together with necessary pumping stations, and such roads, public utilities and public buildings as are required for settlements on newly irrigated land. However, the actual reclamation of the land and building of housing for settlers can and should be left predominantly to private enterprise and capital. To be sure, the government is now carrying out certain reclamation projects, involving also the construction of model villages, in the Lower Delta and the Liberation Province. Some elements in the present government undoubtedly like to see the government carry on this work on a larger scale on the ground that this is the only way to ensure a significant improvement in the standard of life in the rural areas. Others, who appear more influential, recognize that as large a role as possible should be given to private capital and enterprise and accordingly want the new land to be turned over to private companies for reclamation and subsequent resale. For a number of reasons this course appears much sounder. First of all, the government is likely to find it difficult enough to raise by taxation and borrowing the funds for necessary works which cannot by their very nature be financed or undertaken by private enterprise. On the other hand, experience in Egypt indicates that private capital is rather readily forthcoming whenever adequate profit opportunities are offered. Land reclamation is one of these tasks which has in the past been successfully undertaken by private companies. Secondly, the reclamation and settlement of 1.3 million feddans may well be too large an undertaking for the government. Finally - and this is perhaps most important - reclamation and settlement undertaken by the government is likely to be much more costly. The experience with the Abis project in the lower Delta and with the Liberation Province project indicates that the government would probably build villages on a standard considerably higher than that which Egypt can afford on a large scale. The investment in housing, for example, would probably be double the amount - £E 32.5 million - included in the cost estimate given earlier in this report.

The terms on which companies would be permitted to acquire land for reclamation and to resell it will be of vital importance. Unless the terms provide an adequate profit incentive, private companies will be unwilling to undertake the work essential to bring the land into cultivation. The Government has decided that the land holdings of such companies will not be subject to the limitations of the agrarian reform law; and, as a special encouragement, land development companies have been included, under existing legislation, among those entitled to certain tax concessions. It has also stipulated that such companies will have to sell the reclaimed land within 25 years from acquisition (or the date on which water becomes available) and subject to conditions ensuring that not too many large holdings will be created and that the limitations of the agrarian reform law are respected. Beyond this, however, the terms of purchase and resale have apparently not been determined; and particularly the question whether or not there shall be restrictions on the resale price of the land after reclamation is still under discussion. These questions will have to be settled in a manner which will ensure that the private investment necessary to realize the full economic benefits of the project will be forthcoming.

The creation of conditions which would provide adequate incentives for investment in land reclamation by private companies is hardly likely to raise the price of reclaimed land so much that small cultivators would not be interested in acquiring it. Because of the continued population pressure on the land the peasants will undoubtedly be willing to pay extraordinarily high prices in order to appease their "land hunger". If companies seek to exploit this land hunger by setting unjustifiably high prices, the government may have to intervene by establishing, through legislation, equitable policies governing land sales.

## B. Electric Power Aspects of the Project

At present, electric power is generated in Egypt by about 50 public and private agencies, with individual stations ranging from 100 kw in the smaller diesel plants to a maximum of 100,000 kw in the new Cairo North thermal power station owned by the Cairo Electricity and Gas Administration. The total installed capacity in 1954 was approximately 500,000 kw, and in that year the peak load was about 272,000 kw and the total energy generated was 1,300 million kwh.

The Republic of Egypt owns nearly all the public utility power stations and transmission systems with the exception of the Cairo Choubrah power station (which supplies about 40% of the power in the Cairo area) and the Alexandria Karmouz power station (which supplies about 70% of the power in the Alexandria area). These two stations are owned and operated by the Societe Egyptienne d'Electricite and the Lebon Co. respectively. Taken together these non-government-owned utilities contribute about 57% of the energy generation in Egypt. The remaining 43% of power generation is produced by the Ministry of Public Works, the Egyptian Republic Railways, and by miscellaneous private industrial companies for utilization in their own factories.

### Available power after completion of the project

For the purpose of assessing the power requirements to be met from the project, it was necessary to relate the new power potentialities to growth in demand in Egypt and to the adequacy and economy of service from existing facilities. Since neither of these elements is static a date of completion of the power facilities had to be assumed. Consequently, for the purpose of calculations in this report, power from Sadd el-Aali was assumed to become available January 1, 1965.

Prior to 1965, new thermal capacity is scheduled to be completed at the Cairo North, El Tabbin and Cairo South stations totalling 285,000 kw. By about 1960 the Aswan power station with capacity of 360,000 kw should be completed also. Completion of the first stage of the Sadd el-Aali power station will add another 720,000 kw. Assuming that no private industrial generating plants are built in the meantime, the addition of all these plants will bring the total installed capacity in Egypt to approximately 1,900,000 kw.

In assessing the portion of this capacity which could be considered to be effective it has been assumed that 10% of the present plants will be out of service or in reserve. The Aswan station will be affected by the reservoir levels both before and after completion of the cofferdam and the high dam and its effective capacity will vary according to water availability. Also it is prudent to consider that one of the Sadd el-Aali units could be out of service at any time. The effective capacity, in relation to the above installed capacity, after completion of Sadd el-Aali, will, therefore, be as follows:

Table No. 17

Total Electrical Generating Capacity in Egypt at Completion of Project

| | Installed Capacity KW | Effective Capacity KW |
|---|---|---|
| The total of all existing plants prior to 1955 | 500,000 | 450,000 |
| The new Cairo North, El Tappin and Cairo South units | 285,000 | 210,000 |
| Aswan Power Station | 360,000 | 200,000 |
| Sadd el-Aali | 720,000 | 630,000 |
| Totals | 1,865,000 | 1,490,000 |

## Effect of Sadd el-Aali on Aswan Power

The hydraulic conditions now existing at the Aswan dam are such as to cause the output of power to vary widely from low water to flood seasons. When the reservoir is full in January, the upstream level may reach 122 meters, the corresponding downstream level being about 88.5 so that the maximum head for power production is 33.5 meters. In July, the reservoir level is dropped to 100, or even 97 with a corresponding drop in the head. Again during the flood rise from late July to mid-October the head at the dam with sluice-ways open to prevent deposition of silt, is only 8 or 9 meters. The result of this is that the power from the station now under construction at Aswan will not exceed 50,000 kw for four months of each year. Although the total generation from the Aswan station would amount to about 1,800 million kwh annually, only about one-fourth would be firm power.

The Sadd el-Aali reservoir will stabilize the flow of the river at Aswan, thus converting practically all the Aswan power to a firm basis. Because the two dams must be operated as a unit for the regulation of flow, and because the level of the reservoir downstream from Sadd el-Aali must not exceed 108 meters, the quantity of power to be produced annually at Aswan will be approximately the same, about 1,800 million kwh, but more of it will be firm power and consequently have a higher value. A considerable additional potential economic value, therefore, will be realized at the Aswan power station attributable to the Sadd el-Aali project.

With the Aswan basin held at the required operating level of 108 meters, the approximate average annual energy available from the two generating stations will be:

| | |
|---|---|
| At Aswan station | 1,800 million kwh |
| At Sadd el-Aali station | 4,200 million kwh |
| From both stations | 6,000 million kwh |

Power potential from second and third stages of Sadd el-Aali

Although still under study as to the number and size of units to be installed, the power scheme at Sadd el-Aali at present contemplates the installation in three construction stages of a total of 16 turbo-generator sets, only eight of which are included in the project. The Government plans to add the additional generators when power use in Egypt justifies. Calculations indicate that the potential generation in an average year of the Sadd el-Aali station, when fully completed and considering simultaneous operation of 15 of the 16 units, would be approximately 8,000 million kwh. Thus with the full complement of units at Sadd el-Aali the potential power generation from it in combination with Aswan will be almost 10,000 million kwh annually.

The sustained flow from the Sadd el-Aali reservoir based on irrigation withdrawals for Egypt, will be approximately 1,890 $m^3$ per second. With an average of 15 units in operation under full capacity load at Sadd el-Aali, a flow of 1,740 $m^3$ per second would be utilized. Since a 50% load factor is estimated for the foreseeable future, a large surplus of flow would be available for additions of generating equipment in the future if a need for additional capacity develops.

Electricity use forecasts

The questions of the extent to which and the rate at which power from the Sadd el-Aali project will be profitably utilized in the economy of Egypt are not subject to precise determination. There are serious difficulties in the way of any reasonably reliable forecasts of load growth in underdeveloped countries. The present use of electricity in Egypt, particularly, does not furnish the point of departure for consumption forecasts usual for countries which have been electrified for some time. Besides the total peak load of about 272,000 kw generated by all electrical generating plants in Egypt there is an additional peak load of the equivalent of approximately 300,000 kw produced in mechanical energy. The total consumption of power is thus not the electrical consumption alone but the total of this consumption and the mechanical power produced by thermal motors, or somewhat more than double that which appears in electric power consumption statistics.

The Bank has been supplied with two separately made projections of load growth in Egypt, one prepared by the Egyptian Electricity Commission and the other by Electricite de France, consultants to the Government of Egypt in studying and planning a comprehensive power development.

Forecast by EEC

The forecasts by the Egyptian Electricity Commission (EEC) separately considered existing and potential power use in several separate categories. Use for public utility purposes, which includes the principal cities of Cairo and Alexandria and the commercial and industrial use supplied by the utilities in these areas, was estimated to increase at a fixed rate which would cause it to double every eight years.

Electric consumption of private industries was predicted to double each ten years. The power supply to industry would come from the Sadd el-Aali system with a gradual retirement of small existing industrial plants beginning when the new supply becomes available. A similar replacement of dispersed mechanical power units in industrial plants was anticipated with about one-fourth of this load taken over initially in 1965 and about 80% by 1975.

Power for Government irrigation and drainage was estimated to develop according to reclamation plans of the Ministry of Public Works. Drainage pumping was estimated to remain unchanged but pumping for irrigation, which is planned to be double in 1965 over use in 1954, is expected to increase about tenfold by 1975 due to development of new lands and conversion of basin irrigation areas, both requiring pumping.

A rather rapid electrification of railroads was predicted by EEC, with the use for this purpose increasing about sevenfold (over 1954) by 1965, and another fourfold by 1975, reaching a consumption of 600 million kwh by that year. EEC included use for fertilizer production as presently planned.

In summary EEC reached the conclusion that power use in Egypt would increase from the present approximately 1,300 million kwh to 5,000 million by 1965 and to 12,000 million by 1975. The corresponding increase in peak load would be from the present 272 Mw to 1,050 Mw by 1965 to 1,610 Mw by 1970 and to 2,364 Mw by 1975. (See Appendix 1, showing the forecast graphically.)

Forecast by EDF

The forecast of Electricite de France (EDF) is the average of two forecasts, one of which is characterized as optimistic and the other pessimistic. The forecast assumes that electrical load growth will take place at a rate which would approach the growth of total energy use (i.e. electrical plus mechanical) and that such total energy use will increase at an annual rate of 6-1/2%, or doubling in approximately 11 years. As electrical energy is to replace little by little mechanical motors, it would increase initially at a considerably accelerated rate. EDF, therefore, established its graphic projection of growth in electric power use as beginning with the present electrical peak and approaching asymptotically the total increase curve starting from the combined total of electrical and mechanical energy use. The resulting projection of electricity use begins at a rate of growth of approximately 11% per annum and by 1975 essentially reaches the selected overall rate of growth of 6-1/2% per annum. Irrigation and drainage uses were included in the composite use. The power for the Government's fertilizer plant was included in the total forecast. No attempt was made in the EDF forecast to differentiate between the rates of growth for various classes of use such as for general public utility purposes, industrial, irrigation and drainage and the like.

The EDF forecast shown graphically on Appendix I reaches the conclusion that the peak demand will increase from the present 272 Mw to 950 by 1965 to 1,400 Mw by 1970 and to 1,900 Mw by 1975, or somewhat lower values than projected by EEC.

## The Power Market in Egypt

In making forecasts of electricity use it is obviously necessary to take into account the general economic background against which power growth is to be projected. As is elsewhere indicated in this report, there is reason to suppose that the national income by 1975 may be about 60% higher than at present, but that the per capita income by that date may be no greater than, and possibly even lower than, it is today. Thus we cannot expect any increase in the average standard of living which is already quite low and does not permit of the widespread household use of electricity. It is probable, too, that the rate of industrial growth in Egypt will not be as rapid in the future as in the past. It is necessary then to examine how power consumption will develop under these conditions.

## Power use in the metropolitan areas, municipalities and agglomerations

An analysis of the growth in the peak load and energy generated in the Cairo area for the past ten years shows an average yearly peak load increase of 11.5%, indicating a redoubling period of use in about 6.5 years. In 1953 the values of watts per capita and kilowatt-hours per capita was 30.6 and 131.8 respectively. In the Alexandria area the rate of growth for the number of consumers, the peak load and for power consumption indicates a current doubling period of approximately 7 years. For the whole of Egypt power use has increased in the last 20 years at a rate to cause doubling each 8 years, and during the last 8 years the average annual rate of increase has been 11%, or doubling each 6-1/2 years.

The rural electrification potential in Egypt is not comparable to that in more developed countries. Outside the larger metropolitan areas there are now already electrified 56 agglomerations with a total population of 1,464,100 (by the 1947 census) in which the mean of the average annual electricity use per person is 40 kwh, with a mean of utilization hours of approximately 3,400. There are 439 additional agglomerations of over 5,000 inhabitants with a combined population of over 3 million (1947 census) where no electric service is available. Six of these have 20,000 inhabitants or over, and 50 others are 10,000 or over.

## Use by private industries

Of the total power consumed in Egypt in 1954 of 1,300 million kwh, slightly more than one-third was produced in power plants owned and operated by private industries. The increase in the numbers of private industrial power plants and in power generation by them in the period from 1950 to 1954 inclusive has been rather phenomenal and indicates that industries have not been able to obtain adequate or dependable power supplies from the public utilities at reasonable cost. The extent to which Sadd el-Aali power can capture the existing industrial market and supply industrial expansion will depend, to a large measure, on the Government's ability to transmit power to the locations desired and on its rate policies. As an additional indication of the power potential for private industries, it is estimated that installed mechanical power in dispersed private stationary engines comprises a total of about 514,000 kw equivalent, about 30% of which was installed prior to 1940.

Governmental uses for irrigation, drainage and railway electrification

Irrigation by pumping is widespread in upper Egypt where the yearly variation of water levels is great between the flood period and the rest of the year. Drainage by pumps is predominant in lower Egypt where the variation of water levels is reduced and where lands are at low levels with consequent poor drainage.

The execution of the Sadd el-Aali project will control the downstream discharge of the river, preventing flooding of low lands and gradually bringing about a stabilization of the water table. The effect of this will be that the demands of energy will be increased on existing pump irrigation stations and reduced on existing drainage stations. Much of the basin areas to be converted to perennial irrigation will require pumping. The irrigation of large areas of new lands at higher contour levels is contemplated and this will also require pumping.

According to tabulations supplied by the Ministry of Public Works, it is now operating electrical generating stations for irrigation and drainage with total installed capacity of 87,000 kw which generate about 82 million kwh annually. Most of this power is produced in thermal stations although two hydroelectric stations, one at Fayoum and one at Naga-Hamadi, produce small amounts. In addition, the Ministry operates mechanical power pumping stations with a capacity totaling about 250,000 kw almost half of which was installed prior to 1940. In predicting future power use for irrigation and drainage purposes, it is planned to convert these loads to the more economical source of power from the Government's transmission system.

The Egyptian Republic Railways (ERR) now own two main power stations, one in Abou Zaabal of 3,550 kw and one in Alexandria of 5,000 kw. Both supply workshops and other Governmental departments. ERR has under way the electrification of its Cairo-Helwan line and plans to carry out studies to determine the feasibility, in terms of capital and operating costs, of converting more of the national railroads to electricity when Sadd el-Aali power becomes available. The obstacles to a broad scale electrification of the Egyptian railroads, such as the magnitude of the investment required and the operational problems involved, are such as to indicate that provision for the power required need not be included in the forecasts at this time.

Forecast adopted in this report

Against this background the forecasts of EEC and EDF are considered somewhat sanguine. For the purpose of appraisal by this report, two projections have been made for the purpose of establishing a range of values of expected benefits from electric power from the project. The first of these projections, designated forecast A, (see Appendix II) adopts the 6-1/2% rate of overall growth for all uses other than for Government irrigation and pumping and for new industrial demand. For irrigation and pumping the Government's schedule was adopted. Development of new industrial uses was assumed at a rate of annual increase of approximately 3% based on the present use of mechanical power for industrial purposes. In addition it was assumed that 240,000 kw (about 80%) of the present mechanical energy produced and used in existing industries will be converted to electrical energy by 1975 and supplied from public utility sources.

The second of these projections, designated as forecast B (see Appendix III), is based on as complete as possible breakdown of present consumption of power, including mechanical power, by various types of uses, and on a separate projection of growth for each of these uses. Under forecast B it is assumed that general public utility uses of electricity, excluding industry and the requirements for drainage and irrigation, will increase at an annual rate of 7.6%, causing it to increase fivefold by 1975; that industrial power consumption, including that now supplied by mechanical means, will only double by 1975, and that in the interval 1965-1975 mechanical power now used in industry will be replaced by electric power; and, as in forecast A, Government irrigation and drainage use will develop as scheduled in the project. The resultant overall rate of increase for use of power in nongovernmental enterprises under this forecast is approximately 8% annually.

The fivefold increase for general power uses indicated above may seem rather high. It must be admitted that too little is known about the factors which determine the growth of power demand under varying circumstances, and particularly at different income levels. All that can be said is that Egypt has been experiencing a rather rapid growth and that experience in other underdeveloped countries indicates that the increase in power consumption has been far outstripping the rise in national income. Even under conditions of relatively static per capita income power consumption appears to rise rather rapidly. In essence the increased use of electricity, as the increased use of motor cars and motor transports, is a reflection not simply of a rise in incomes, but of a changing way of life. In Turkey, for example, the consumption of electricity during the 15-year period 1938-1953 rose by 279% while real income per capita increased only around 15%. In Japan power consumption rose by 70% from 1938 to 1953 even though consumption was already at a very high level in 1938 and both industrial production and per capita incomes were about the same at the end of this period as at the beginning. During the same period there was probably no significant change in per capita income in India, but the consumption of power supplied by public utilities rose by 161%.

Comparison of forecasts

A comparison of the total peak loads under the several forecasts described above, and as illustrated graphically on Appendix I, is as follows:

| | Peak in Mw | | | | |
|---|---|---|---|---|---|
| Forecast | 1954 | 1960 1/ | 1965 1/ | 1970 1/ | 1975 1/ |
| EEC | 272 | 628 | 1050 | 1610 | 2364 |
| EDF | 272 | 600 | 950 | 1400 | 1900 |
| A | 272 | 611 | 926 | 1480 | 2164 |
| B | 272 | 576 | 791 | 1219 | 1747 |

Provision has been made in the forecasts for fertilizer production at a synthetic nitrogen plant in which power will be used for the production of hydrogen by electrolysis of water.

1/ Includes 150 Mw for fertilizer plant

While forecasts A and B are intended to establish a range of expected power use on which benefits from the power aspects of the project may be evaluated, it is possible that forecast A, like those of EEC and EDF, is somewhat optimistic. It is, therefore, preferable to assume that the more conservative of the forecasts, B, is more likely to prove valid. Consequently, calculations of benefits from power operations of the project have been based on this more conservative forecast.

Interconnected transmission network

The projections used in this report assume that adequate provision will be made for a network to transmit power to all areas of potential use in Egypt. Thus, in addition to the main transmission line from Aswan to Cairo included in the project, it will be necessary to progressively develop an interconnected transmission system with Alexandria, Suez, Port Said and other main communities as demand increases. Electricite de France has stressed the importance of immediate plans for such a long range program including the standardization of voltages, the planning of distribution facilities and the establishment of logical tariffs. The forecasts of power use included in this report are based on the assumption that such a comprehensive power distribution system will be established and that the power system will be efficiently managed.

Installed capacity at Sadd el-Aali

A comparison of the estimated peak loads derived from the several forecasts given above with the effective installed capacity on the system (see Appendix I) indicates the requirements for new installed capacity to meet demand both in terms of amounts and time. Assuming the installation of the first 8 units of Sadd el-Aali will begin about 1963 and be completed in 1965, there will be excess capacity on the system according to forecast A until January 1971 and according to forecast B until December 1973. Within the range of these dates all the installed generating capacity, including existing thermal plants, should be utilized and additional generating capacity would need to be completed, either by construction of additional units at Sadd el-Aali or of new thermal plants.

In the interim period, after 1965 and until one or the other of the above dates, there will be more or less idle capacity on the system and from the single point of view of adequacy of power supply it would be possible to re-schedule the time of completion of the Sadd el-Aali units to more nearly conform to the schedule of growth in demand. Studies indicate, however, that in spite of the fact that a cost must be included for the maintenance of existing thermal plants in standby condition, Sadd el-Aali power can be delivered in Cairo, after transmission losses, at a cost below the fuel costs of producing power in the thermal stations. From the standpoint of system economy, therefore, it is desirable to complete according to schedule the construction of the first 8 units at Sadd el-Aali, thereby gaining all the construction economies possible, and to operate these hydro units in preference to the Cairo thermal units. The latter will serve as useful back-up and reserve. By the time of its completion in 1965 the peak load on the system will require operation of the entire effective capacity at Sadd el-Aali.

Another implication of these studies is that it may be advantageous for the Government of Egypt to complete construction of the second stage of Sadd el-Aali earlier than the 1971-73 dates mentioned above so as to take advantage of power production from such additional hydro units rather than to operate continuously the thermal units in existing Cairo plants. A decision on this point can be made after actual experience verifies the conclusion of studies to date.

Benefits from Sadd el-Aali power

Assessment of the benefits to the country's economy to be derived from the power resources of Sadd el-Aali raises two questions: (1) What is the relationship of the net value to the Egyptian economy of power contributed by the project (including that contributed indirectly by firming up Aswan power) to the investment cost incurred by the addition of power facilities; and (2) is the cost/benefit ratio for the Sadd el-Aali hydro facilities (taking the investment cost as only the extra investment in Sadd el-Aali necessitated by power) definitely more favorable than the cost/benefit ratio for possible alternative thermal capacity?

For a study of the first question a determination was made of the quantity of usable power contributed by the project. This varied from year to year according to forecasts of use and estimates were made according to forecast B, the more conservative of the several forecasts. (See Table No. 18.)

In computing the power supply available from Sadd el-Aali, account has been taken of the reduced cost of producing fertilizer in the Aswan plant because of the firming-up effect of the new reservoir on the Aswan power station, thus increasing manufacturing operations from 8 to 12 months annually. The Bank has estimated this saving in the range of LE 15 to LE 20 per ton of contained nitrogen. For the estimated annual production of 71,000 tons of nitrogen, the saving in cost attributable to Sadd el-Aali reservoir would approximate LE 1.25 million annually.

In estimating the value of power to the economy it is appropriate to take as a measure the price at which consumers would be willing to absorb the entire power supply. In actual practice, it is admittedly difficult to forecast the price at which the large block of additional power to be supplied by Sadd el-Aali could be sold. Presumably the price should be low enough to induce industrial consumers to forego the use of alternative power supplies, whether mechanical power or industrially-generated electricity, and also to encourage general consumers to increase their power consumption.

If the Sadd el-Aali power were sold at 4 milliemes per kwh wholesale, the retail price, including an adequate margin for costs of distribution and profits on distribution, could be fixed at 8.25 milliemes per kwh. 1/ Such a price would be substantially below the cost of production of industrial

1/ Distribution cost on the Government's system in the Cairo area in 1953-54 was 2.6 mms/kwh; a 25% margin above costs of purchased power (4.0 mms/kwh) and of distribution services (2.6 mms/kwh) is assumed.

power plants or the cost of mechanical power and would thus offer sufficient incentive to switch to public power. It would also greatly encourage additional consumption by the general consumer, particularly considering the fact that public power in Cairo is now sold at a composite rate of 17.08 milliemes. The valuation of Sadd el-Aali power at a wholesale price of 4 milliemes per kwh is therefore believed to be quite conservative.

This is in essence "the price the traffic would bear." The total value of power at this price would represent not only the gross economic benefits derived from power but also the maximum gross income, in financial terms, from the sale of power. With respect to the latter, the Government might, of course, elect to fix the actual power rate below what "the traffic would bear," thus sharing the economic benefits with the power consumers but reducing its own income from power. It should be noted that the cost of producing power will be substantially below this assumed price, as will appear from Table No. 20.

The resulting calculation of the economic benefits derived from Sadd el-Aali power is reproduced in Table No. 18. This calculation takes into account not only the value of power estimated according to the method set forth above, but also the savings in the cost of producing fertilizer at Aswan resulting from the effect of Sadd el-Aali in firming-up the power to be generated at the hydroelectric plant at Aswan dam.

Comparison of economic cost of thermal and hydro power

It is now necessary to examine whether the additional investment in Sadd el-Aali necessitated by the installation of hydro power facilities - namely LE 88.5 million plus interest during construction or a total of LE 101 million - would be worthwhile in the light of the alternative cost of supplying an equivalent supply of power in new modern thermal plants. For estimating construction costs of such plant the investment was taken at LE 60 per installed kw, or allowing 15% for reserve and as unavailable, at LE 70 per effective kw. Fuel consumption was estimated at 300 gms per kwh which should be obtainable in modern plants. A comparison of benefits from such thermal power stations for the years 1965, 1970 and 1975, and according to forecast B, shows that in each instance the incremental investment in Sadd el-Aali power facilities would be more advantageous (see Table No. 19). This comparison is, of course, based on present prices for fuel in Egypt and on thermal plants of presently achievable efficiency. It may be that further technological advance in thermal plant design would permit the construction of more efficient plants. However, even if the efficiency of future thermal plants were increased by as much as 100%, Sadd el-Aali would still provide the more economical source of electric power. This is quite apart from the consideration that the Sadd el-Aali plant would utilize for production of electric power an Egyptian natural resource, inexhaustible in character, rather than fuel oil which might well have to be imported in large part.

Table No. 18

COST - BENEFIT RATIO, SADD EL-AALI POWER

| | | 1965 | 1970 | 1975 |
|---|---|---|---|---|
| I. | Investment in power facilities (£E millions) 1/ | 78 | 101 | 101 |
| II. | Total Sadd El-Aali power consumed, Forecast B, (millions kwh) | 1,625 | 3,877 2/ | 4,077 2/ |
| III. | Gross annual economic value, (£E millions) 3/ | 7.75 | 16.76 | 17.56 |
| IV. | Annual Cost (of II) to the economy (£E millions) | | | |
| | (a) operating cost | 0.40 | 0.40 | 0.40 |
| | (b) maintenance of transmission facilities | 0.18 | 0.25 | 0.25 |
| | (c) depreciation of power plant and transmission facilities ($2\frac{1}{2}$% p.a.) | 1.95 | 2.53 | 2.53 |
| | (d) stand-by cost of CEGA thermal plants 4/ | 0.29 | 0.14 | - |
| | (e) Total (£E millions) | 2.82 | 3.32 | 3.18 |
| V. | Net annual economic benefit from power, (£E millions) | 4.93 | 13.44 | 14.38 |
| VI. | Economic yield on investment in power facilities (per cent) | 6.32 | 13.31 | 14.24 |

1/ Includes assumed interest during construction.
2/ Includes 400 million kwh in 1970 and 800 in 1975 of seasonal power at 50% value of firm power.
3/ Value assumed at 4 mms/kwh; also includes £E 1.25 million annual saving in cost of manufacturing fertilizer.
4/ Existing thermal plants in full or partial stand-by.

Table No. 19

ECONOMIC BENEFIT OF POWER FROM
THERMAL PLANT EQUIVALENT TO SADD EL-AALI

| | | 1965 | 1970 | 1975 |
|---|---|---|---|---|
| I. | Investment in power facilities (£E millions) 1/ | 40 | 73 | 76 |
| II. | Total power consumed, (kwh millions) | 1,625 | 3,877 | 4,077 |
| III. | Gross annual economic value (£E millions) 2/ | 6.50 | 15.51 | 16.31 |
| IV. | Annual Cost of II to the economy, (£E millions) | | | |
| | (a) operating costs | 1.63 | 3.88 | 4.08 |
| | (b) maintenance of transmission facilities | 0.05 | 0.12 | 0.12 |
| | (c) cost of fuel, assuming 300 gms./kwh | 3.02 | 7.19 | 7.56 |
| | (d) depreciation of power plant and transmission lines (2.79% p.a.) | 1.12 | 2.04 | 2.12 |
| | Total | 5.82 | 13.23 | 13.90 |
| V. | Net annual economic benefit (£E millions) | 0.68 | 2.28 | 2.41 |
| VI. | Economic yield on investment, (per cent) | 1.70 | 3.12 | 3.17 |

1/ Includes assumed interest during construction.
2/ Value assumed at 4 mms/kwh, or approximately 20% below generating cost in most efficient existing thermal station.

Potential Financial Results of Sadd el-Aali Power Operations

Since we have assumed that after completion of the project an autonomous agency will be created to conduct the business of generating and distributing power, an estimate has been made of the financial outcome of operations of Sadd el-Aali power facilities. It should be noted that financial results thus estimated closely parallel the estimated economic results. Table 20 sets forth in a preliminary way and in broad quantitative terms the prospective net income of the power plant both inclusive and exclusive of depreciation and suggests a possible allocation of the potential net cash income. This statement, which extends over a period of fifteen years following completion of the plant, is based on the following assumptions:

1) that the installation of the initial 720,000 kw (8 units) of generating capacity will be completed to a stage permitting operation of at least one-half the units by 1965, the first year of assumed operation at partial capacity and for the estimated costs as shown on page 31.

2) that the estimated system demands will have developed as shown on our estimate "B" (the most conservative indicated in the report);

3) that the amount of demand in kw and energy in kwh to be supplied by the Sadd el-Aali plant, and which are based on estimate "B", will be as shown in the first column of Table 20;

4) that the estimates of annual operating expenses, maintenance, standby expenses and depreciation accruals are the same as used in Table 18;

5) that the power will be sold at the wholesale price of 4 milliemes per kwh (1.15¢ U.S. equivalent), namely at the same rate as is used in the economic analysis;

6) that funds for construction of the "public" portion of the entire project, estimated at LE 281 million (see Table 8) together with LE 42 million of estimated interest during construction, or a total of LE 323 million, will have been arranged for so that the projected construction schedule will be met;

7) that the portion of the necessary capital investment pertaining to the electrical power plant, including transmission lines and substations at Cairo and other load centers, will be LE 101 million;

8) that an average interest rate on borrowed funds, local and foreign, of 3.75% be used.

9) that the total capital cost of the electrical power facilities, LE 101 million, which includes 12.5 million of estimated interest during construction, be amortized over the 15 years assumed to begin in 1966 and ending 1980; this assumes a maximum maturity of 25 years. The borrowing is assumed to be dated 1955 and funds will be drawn down over the 10 year period ending 1965;

TABLE NO. 20

ESTIMATE OF ANNUAL EARNINGS AND DEBT RETIREMENT

SADD EL-AALI POWER

| | Projected Income | | | | | | Allocation of Net Cash Income | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Kwh Delivered | Gross Revenue @ 4 mms/Kwh | Cost of Operation Including Standby | Depreciation @ 2½% | Net Revenue after Depreciation | Net Revenue before Depreciation or net cash Income | Debt at Beginning of Year | Amount Assigned for Debt Service 66-2/3% of Net Cash Income | Interest @ 3.75% | Amortization | Contribution to Reserves 33-1/3% of Net Cash Income | Cumulative Reserves |
| | | | | | | (All figures in millions) | | | | | | |
| 1965 | 1,625 | LE 6.50 | LE 0.87 | LE 2.03 | LE 3.61 | LE 5.63 | LE 101.00 | LE 3.79 1/ | LE 3.79 | - | LE 1.84 1/ | LE 1.84 |
| 1966 | 2,060 | 8.24 | 0.85 | 2.15 | 5.24 | 7.39 | 101.00 | 4.93 | 3.79 | 1.14 | 2.46 | 4.30 |
| 1967 | 2,497 | 9.99 | 0.84 | 2.27 | 6.88 | 9.15 | 99.86 | 6.10 | 3.74 | 2.36 | 3.05 | 7.35 |
| 1968 | 2,913 | 11.65 | 0.82 | 2.39 | 8.44 | 10.83 | 97.50 | 7.22 | 3.65 | 3.57 | 3.61 | 10.96 |
| 1969 | 3,288 | 13.15 | 0.81 | 2.51 | 9.83 | 12.34 | 93.93 | 8.23 | 3.52 | 4.71 | 4.11 | 15.07 |
| 1970 | 3,877 | 15.51 | 0.79 | 2.63 | 12.09 | 14.72 | 89.22 | 9.81 | 3.35 | 6.46 | 4.91 | 19.98 |
| 1971 | 3,917 | 15.67 | 0.76 | 2.63 | 12.28 | 14.91 | 82.76 | 9.94 | 3.10 | 6.84 | 4.97 | 24.95 |
| 1972 | 3,957 | 15.83 | 0.73 | 2.63 | 12.47 | 15.10 | 75.92 | 10.07 | 2.85 | 7.22 | 5.03 | 29.98 |
| 1973 | 3,997 | 15.99 | 0.70 | 2.63 | 12.66 | 15.29 | 68.70 | 10.19 | 2.58 | 7.61 | 5.10 | 35.08 |
| 1974 | 4,037 | 16.15 | 0.68 | 2.63 | 12.84 | 15.47 | 61.09 | 10.31 | 2.29 | 8.02 | 5.16 | 40.24 |
| 1975 | 4,077 | 16.31 | 0.65 | 2.63 | 13.03 | 15.66 | 53.07 | 10.44 | 1.99 | 8.45 | 5.22 | 45.46 |
| 1976 | 4,077 | 16.31 | 0.65 | 2.63 | 13.03 | 15.66 | 44.62 | 10.44 | 1.67 | 8.77 | 5.22 | 50.68 |
| 1977 | 4,077 | 16.31 | 0.65 | 2.63 | 13.03 | 15.66 | 35.85 | 10.44 | 1.34 | 9.10 | 5.22 | 55.90 |
| 1978 | 4,077 | 16.31 | 0.65 | 2.63 | 13.03 | 15.66 | 26.75 | 10.44 | 1.01 | 9.43 | 5.22 | 61.12 |
| 1979 | 4,077 | 16.31 | 0.65 | 2.63 | 13.03 | 15.66 | 17.32 | 10.44 | 0.65 | 9.79 | 5.22 | 66.34 |
| 1980 | 4,077 | 16.31 | 0.65 | 2.63 | 13.03 | 15.66 | 7.53 | 10.44 | 0.28 | 7.53 2/ | 7.85 2/ | 74.19 |

1/ To meet the first year's interest of LE 3.79 millions the amount of net cash income assigned to Debt Service has been increased by LE 0.04 millions and the contribution to Reserves reduced by that amount.
2/ In the final year the contribution to reserves includes LE 2.63 millions not required for Debt Service.

10) that the amount of fixed annual allocations to debt service is limited to only 66 2/3% of total available annual cash (net earnings plus depreciation).

As shown in Table 20, a debt of LE 101 million which represents the entire capital cost of the electric power including the related transmission facilities can be repaid out of earnings in the 15 year period ending with 1980. In addition, in the same period, there will be approximately LE 74 million ($212 million U. S. equivalent) over and above requirements of operation and debt service. With total debt service limited to 66 2/3% of the annual net earnings before depreciation, the annual coverages would be about 1.5 times.

Net earnings after depreciation which are assumed to start at LE 3.61 million in 1965, would represent a return that year of only 3.5% on the entire LE 101 million of estimated capital requirements for the electric power system. However, the rate of return would increase rapidly as shown in the following:

Table No. 21

| Year | Net After Depreciation (LE Millions) | Percentage |
|---|---|---|
| 1965 | 3.61 | 3.4% |
| 1966 | 5.24 | 5.0 |
| 1967 | 6.88 | 6.6 |
| 1968 | 8.44 | 8.0 |
| 1969 | 9.83 | 9.4 |
| 1970 | 12.09 | 11.5 |
| 1971 | 12.28 | 11.7 |
| 1972 | 12.47 | 11.9 |
| 1973 | 12.66 | 12.0 |
| 1974 | 12.84 | 12.2 |
| 1975 and thereafter | 13.03 | 12.4 |

Thus, as indicated above, the potential rates of return on the capital investment for power facilities, including interest during construction, are quite satisfactory and support the economic justification of the electric power portion of the Sadd el-Aali project.

## C. Improvement in Navigation and Flood Control

While the economic justification of Sadd el-Aali rests in essence on the increase in agricultural output and in power supply, there are certain incidental economic benefits which must be mentioned. An effective control over floods would be established and conditions of inland water navigation would be greatly improved. These incidental benefits, however, are difficult to assess in quantitative terms.

### Flood Protection

The benefits arising from the control of floods would be of two types: (1) certain savings in government expenditures which could in the future be used for productive investment or for constructive services to the community, and (2) the prevention of certain losses in national output and income which now result from inundations and infiltration during periods of high flood.

At present the government has to spend about LE 1.5 million per year to cope with the consequences of the flood cycle of the Nile. An elaborate system of levees and bunds has to be maintained to prevent floods. Because of the silting of the river bed by flood waters the levees have gradually been raised until they are now about 1 meter higher than in 1874. With the help of these levees the Nile can carry a flood of 7,750 $m^3$ per second, and at this volume the surface of the river is about 1.5 meters above the level of the adjoining land. High floods such as those in 1929, 1934, 1938 and 1946 and the extraordinary floods of 1874 and 1878, create special problems of flood protection. Even during normal years considerable manpower and some equipment is engaged in patrolling the Nile in the flood season, and the levees must be strengthened at critical points. On flood protection proper the Egyptian government spends annually close to LE 600,000. At the same time the silt brought down during the flood season entails an annual outlay of about an equivalent amount on clearing canals, drains and branches of the Nile. Finally, the annual floods substantially increase the cost of pumping out drainage canals. Altogether the government would save a total annual expenditure of about LE 1.5 million when the floods are effectively controlled. Since most of this expenditure is for labor, the economic cost of this labor, which is generally abundant, is negligible. The saving of this expenditure should therefore be considered not a part of the economic benefits of the project, but rather a part of the impact of the project on government finances.

In recent decades there have apparently been no large-scale inundations during the flood season. Now and again, however, some land is flooded with consequent damage to production. Moreover, during the flood season there is excessive water seepage and infiltration through levees and canal banks which tends to aggravate the drainage problem. The Egyptian authorities estimate the annual loss in national income owing to these two factors at LE 10 million. Unfortunately, there is no way of checking this estimate or of determining the basis for a different estimate. In order to keep the estimate of benefits rather conservative, we have rather arbitrarily assumed that the loss in national income which would be obviated is only LE 5 million per year.

Improvement in Navigation

Since Egypt possesses about 3,350 kilometers of navigable waterways, inland water transport has always played a considerable role. Barge fleets are said to have a total capacity of 130,000 to 140,000 tons, and sailing feluccas a capacity of perhaps 200,000 tons. In recent years barges have carried on the average 825,000 tons annually, and feluccas perhaps another 2,000,000 tons consisting primarily of sand, stone and other bulky materials, much of them carried over relatively small distances. By comparison, the Egyptian State Railways carried about 4.7 million tons of commercial freight in 1952-53 and trucks are estimated to transport 3 million tons per year in other than purely local traffic. The primary economic contribution of inland waterways lies in the transport of heavy, bulky materials at a cost well below that of rail or road transport.

The sharp fluctuations in the flow and level of water in the river and canals greatly interfere with navigation at present. During the flood season navigation has to be virtually interrupted for a period of 60 days, partly because there is insufficient clearance under stationary bridges and partly because upstream traffic becomes exceedingly difficult. During the low water period navigation over certain stretches of the inland waterways again becomes impossible owing to shallow water. It is not improbable that the tonnage carried by inland waterways would increase by between one-fourth and one-third once the water level becomes more or less stabilized as the result of Sadd el-Aali.

The National Production Council claims that improved navigation would increase national income by about LE 5 million annually. This again seems a rather excessive expectation. If the Ministry of Finance and Economy is correct in assessing the "value added" by inland water transport of LE 2.9 million for 1953; the increase owing to a possible greater volume of traffic would at the most be LE 1 million. Even allowing for the fact that other sectors of the economy would gain from the resulting reduction in costs of transport, it is unlikely that the total annual economic benefit would exceed LE 2 million.

Altogether it is possible that the total annual benefit arising from improved navigation and flood control will run in the neighborhood of LE 7 million. This estimate, however, can at best be considered only an "educated guess," since there is little factual evidence on which to base a calculation.

## D. Economic and Financial Benefits of Entire Project

### Overall Economic Costs and Benefits

In separate sections we have treated the net annual economic benefits of the project in the fields of agriculture, power, flood control and navigation. By the year 1975 or 1976, when the project will have reached full fruition, assuming completion in the period 1965-1967, (except for the possible second phase of the power development which we have not considered), these benefits will be as follows (in LE 000,000's):

| | |
|---|---|
| Agriculture | 112 |
| Power | 14 |
| Flood control & navigation | 7 |
| Total: | 133 |

In each field the economic benefits have been calculated net of the cost of maintaining (or depreciating) and operating that portion of the total capital investment which is directly attributable to that aspect of the project. It is still, however, necessary to take into account the cost of maintaining the dam and attendant civil works which exclusive of the part already included in the analysis of the power aspects, involve a total investment of LE 91 million and is an item of joint cost. These facilities may be said to have an indefinite life provided they are properly maintained. We have accordingly allowed only maintenance as a cost element and at the rate of 0.5% per year. Since this would amount to only LE 455,000 it can be ignored as insignificant to the economic analysis.

Account should be taken, however, of the fact that this total benefit will not be realized for a long time. As already indicated, the first agricultural benefits would begin to accrue on a modest scale after the completion of the cofferdam, i.e., after approximately five years from start of construction. Additional agricultural benefits would begin to accrue upon the completion of the main dam, i.e., in about 10 years' time, and would mount gradually until they reach a maximum in or about the year 1975 or 1976. A small portion of the benefit in electric power would accrue from the completion of the cofferdam which would help to firm up power generation by the power plant now under construction at the existing Aswan dam. The Sadd el-Aali power plant itself can begin operating at partial capacity prior to final completion of the dam and its capacity will be fully utilized soon after 1970, according to the projection of power demand we consider most probable. The full navigation and flood control benefits would be realized once the main dam is finished.

The approximate time incidence of the economic benefits is shown in Table 22.

Table 22

Economic Benefits and Investment
(£E 000,000's)

| Time from start of Project | Annual Net Benefits: Agri-culture | Power | Flood Control & Navigation | Total | Investment: Total | Ratio Net Benefit to Investment |
|---|---|---|---|---|---|---|
| 5 years | 11 | 1.3 | - | 12.3 | 164.3 a/ | 7.5% |
| 10 years | 20 | 4.9 | 7 | 31.9 | 362.6 a/ | 8.8% |
| Final | 112 | 14.2 | 7 | 133.2 | 470.9 a/ | 28.3% |

a/ Including £E 11.6 million expected to be spent by mid-1956 on irrigation and drainage facilities for about 300,000 feddans.

As will be seen from this table, the net economic benefit or, in other words, the net increase in national income will be rather small until the dam is completed. In the first five years of construction, no benefits will be realized and during the next five years following the building of the upstream cofferdam the benefits will be modest. Thereafter, however, the benefits will rise sharply primarily as the result of the expansion of agricultural production. When the full fruits of the project are realized, the increase in national income directly attributable to the project will be about 28% of the total investment including interest on the public investment during the ten year construction period of the dam.

It should be noted that the benefits from the 6th to the 10th year would be substantially higher than those shown in Table 22 if further investigation should substantiate the claim of some Egyptian authorities that 6 milliard rather than 3 milliard $m^3$ of additional water could be stored behind the cofferdam one year after its completion. In that event it would be possible to provide water for about 600,000 feddans of new land. As a result it is probable that the economic benefits in the form of higher agricultural output would steadily rise from the 6th year to a total of perhaps £E 33 million in the 10th year. By that year the ratio of net benefits to the investment would then be over 12%.

In evaluating the relationship of the investment to the benefits a number of factors should be borne in mind:

(1) The investment is rather high because all of the investment incidental to the expansion of the cultivated area, including housing, schools, hospitals, public utilities, etc. have been included.

(2) The cost-benefit relationship will improve still further when ultimately, as the result of further growth in the power demand, it becomes necessary to install generating capacity at the dam in addition to the 720,000 kw now contemplated. Since much of the investment for this second phase of the power installation, including the power tunnels, concreting work, etc., amounting in all to LE 31 million (exclusive of interest during construction) will already have been made, the incremental investment will be much smaller in relation to the additional benefits than for the first phase of the power program.

(3) The rather conservative price at which power has been valued leaves out of account the benefits which are likely to accrue to industry from the advantage of using a more economical power supply than at present.

(4) Above all, the benefits summed up in Table 22 do not include the very great indirect effect which the increase in agricultural income is likely to have on income in other sectors of the economy including industry, trade, finance and other services. As already indicated, agricultural income will be the primary determinant of the development of national income as a whole. A roughly corresponding increase in income in the non-agricultural sectors cannot, of course, be simply added to the income effect of Sadd el-Aali since additional investment will also be required in these sectors. However, the proportion of this additional investment to the income generated will probably be more favorable than the proportion of the investment in Sadd el-Aali to the increase in income directly attributable to this project. The commercial and financial sectors will certainly be able to handle a larger volume of trade without a proportionate increase in investment; and, in view of the existence of some idle capacity, the same may well be true of transport and industry in part.

In view of the factors indicated above, the total increase in national income directly and indirectly attributable to Sadd el-Aali may ultimately be in the range of 35 to 40% of investment. Thus the project would have an overall capital-output ratio which justifies the conclusion that the investment would be economically worthwhile.

This conclusion regarding the economic soundness of the investment is reinforced by the consideration that the alternative opportunities of raising national output by other, non-agricultural investment projects are extremely limited. While there are opportunities for certain industrial projects and some expansion of industrial output may take place gradually as labor and managerial skills improve and production costs are brought down, it has been made clear in this report and the economic report that a substantial increase in agricultural income is needed if income from industry, commerce and other sources is to expand significantly. Without Sadd el-Aali the growth in the economy is likely to lag greatly behind the probable increase in the population. Under these circumstances, this would result in a steady pressure on the standard of living, with serious implications for the future social and political evolution of the country. While Sadd el-Aali may offer little prospect that Egypt will be able thereafter to enjoy a higher standard of living than at present, it will prevent, as a minimum, a disastrous deterioration in this standard and will, as already pointed out, give

Egypt a transition period which will provide opportunity for broadening the industrial base of the country and slowing up the present rate of population growth.

## The Financial Results

The problems involved in financing the project during the construction period are discussed in the economic report. Here it is proposed only to examine the effect of the project on the government's income and to determine whether the income and savings accruing to the government will be sufficient to meet all the financial charges growing out of the project.

The direct financial results of the project can be calculated by adding (1) probable government receipts from newly irrigated land, particularly in the form of land taxes, (2) potential revenue from power, and (3) savings in flood control expenditures.

In Egypt special charges are not made for irrigation water. Since in essence there is no agricultural land other than irrigated land, the land tax is in effect also an irrigation tax. This tax is assessed on the basis of the yield of the land and is reassessed once improvements increasing the yield are completed. It may be expected that the tax on newly reclaimed and irrigated land will be about LE 4 per feddan. The additional tax that will be imposed on basin land which has been converted to perennial irrigation may be about LE 2 per feddan. Thus the total additional government revenue from 1.3 million feddans of newly irrigated land and 670,000 feddans of converted basin land will ultimately approximate LE 6.5 million per year. As a result of the increase in production and export of rice and cotton, on which export taxes are levied, the total amount of export taxes collected may also be higher by about LE 1 to 2 million per year.

Additional revenue will also be derived from the sale of public land which will be put under irrigation. How much of such land will be sold will depend on the ultimate selection of areas for irrigation, but it may well be considerable. In view of the lack of information regarding the amount of public land likely to be sold and the price that will be charged, no calculation has been made of the income accruing to the government on this amount. However, it may well exceed LE 25 million.

The net cash income from power based on a rather conservative estimate of the power rate which could be charged will, as pointed out previously in the report, rise ultimately to around LE 15.5 million per year. This sum is net of operating and maintenance costs, but inclusive of the cash reserves for depreciation which in principle are available for debt retirement.

The savings in government expenditures resulting from effective flood control have already been estimated elsewhere in this report at about LE 1.5 million per year.

Thus when the project comes to full fruition the total annual increase in government revenues plus savings in government expenditures would be about £E 25.0 million quite apart from the proceeds of possible public land sales. From this sum must be deducted the cost to the government of maintaining the dam and maintaining and operating the necessary drainage and irrigation works which has already been estimated at about £E 4.0 million. The net improvement in the government's financial position resulting directly from the project would accordingly be around £E 21 million.

As in the case of the economic benefits, the financial benefits will accrue in the main only after the completion of the dam, i.e. after ten years. Their incidence in time may be set forth roughly as follows (in £E millions):

Table 23

| | Years after Beginning of Construction | | |
|---|---|---|---|
| | 5 | 10 | Ultimate |
| Receipts from agriculture | 1.5 | 3 a/ | 8.0 |
| Income from power | - | 5.6 | 15.7 |
| Flood control savings | - | 1.5 | 1.5 |
| Total | 1.5 | 10.1 a/ | 25.2 |

a/ Subject to upward revision if more water can be stored behind the cofferdam.

By comparison with the economic benefits, the increase in government income derived directly from the additional agriculture will be extremely modest as long as the present system of taxation is maintained. Taxes on agriculture have always been light, and most of the government revenue from agriculture accrues indirectly through taxes on trade, finance and industry whose income is largely dependent on agriculture. On the other hand, the potential net cash revenues from power are large. Moreover, since they will not be commingled with tax receipts, they can be more easily used to retire debt contracted in connection with the Sadd el-Aali project. In a preceding section of this report it has already been shown that of the government charges, a wholesale rate of 4 milliemes per kwh, the net cash income over a 15-year period would be sufficient to pay off a debt of £E 101 million, equivalent to the investment in power facilities, and still leave a surplus estimated to be £E 74 million.

The question arises, however, whether government revenues from the project would be sufficient to pay off all loans contracted for the project. In examining the possibility of retiring such loans it should be pointed out that there is no need, on economic grounds, to make the investment self-liquidating within a few decades. Apart from the investment in power, most of which has a more limited life and all of which could easily be paid off within 15 years, the project will continue to serve the economy for an indefinite number of years. With proper maintenance, Sadd el-Aali will be able to supply irrigation water for centuries. In other words, as a counterpart of any debt contracted for the project the government will have an asset of great and enduring value. At the higher level of national income which the project will make possible, the government can carry a much larger public debt than at present.

The debt contracted for the project cannot, of course, be expected to have a maturity equal to the life of the project. It has already been indicated that the cash income from power would be sufficient to retire a debt of at least LE 101 million which would more than cover service on the foreign loan or loans of LE 70 million which, it has been assumed, would be contracted for the project. The domestic debt, insofar as it is not paid off from net power revenues during the first 15 years after the completion of the dam, would presumably have to be refinanced, particularly since this debt would carry shorter maturities, namely 10 to 15 years, than the foreign debt. Thus, during the 15 year period when the LE 101 million investment in power is being paid off, the government may have to meet maturities on part of the remainder of the debt or, as a minimum, will incur the interest charges on this remaining debt. After the initial 15 year period the net income from power would become available for the retirement of the remaining debt, thus gradually eliminating the need for refinancing.

The government's total tax revenues are likely in the future to be sufficient to service a rather large debt. It has already been indicated that Egypt's national income will probably be at least 55% higher than at present when the full fruits of Sadd el-Aali are realized. On this basis it can be expected that the government's tax revenues would, as a minimum, be 50% greater. These additional revenues will, of course, be largely used to finance an inevitable intervening expansion of government services. The regular government budget (exclusive of receipts and expenditures of public enterprises), out of which debt service will for the most part have to be provided, would then total approximately LE 300 million. Within this total it should not be difficult to provide for additional interest charges of about LE 6.4 million and sinking fund payments of perhaps another LE 3.6 million to provide a reserve for debt retirement when and if that should become necessary or desirable. A total annual financial charge of this dimension would represent only about 3% of the government budget.

## IV. CONCLUSIONS

The project represents the most feasible and economic method of obtaining a very large volume of over-year storage of heretofore wasted flood waters of the Nile River which is essential for expanding crop production. The location is the most suitable on the Main Nile for a project of this nature and is strategic for full flood protection of Egypt. A valuable asset in electric power will also be developed by the project.

Water, rather than land, is the limiting factor for agricultural production in Egypt. The cropped land available for the large and rapidly expanding agrarian population in 1953 was only 0.70 feddans per head as compared with 0.90 feddans in 1927. The increase in population in Egypt, now at a rate of about 2.5% per year, makes it essential that additional irrigation supplies be developed.

The design of the project is sound and the estimated cost and construction schedule is reasonable. The benefits to be derived from the project justify the costs.

The reservoir capacity of the project is the optimum obtainable. The design capacity would provide regulation of the Nile for a minimum draft approximately equal to the average river discharge for the past 55 years. Furthermore, increase in design capacity would rapidly approach the limit of diminishing returns because of the increased ratio of evaporation losses. These losses for the selected reservoir volume, although large in actual amount, are in fact less in proportion to the storage obtained than for any other reservoirs on the river.

Of the various schemes proposed for annual regulation, Sadd-el-Aali is unquestionably superior, since other proposed annual storage reservoirs would even in the aggregate have insufficient storage capacity because all the other reservoirs that have been proposed would not even in the aggregate make available for irrigation as much water as Sadd el-Aali.

The project is consistent with, and would be an effective contribution toward the sound development of the Nile Basin as a whole. It provides basically annual storage and thus is not a substitute for the Century Storage scheme which is designed to regulate long wet and dry cycles. The two are therefore complementary.

The soundness of the project, however, is dependent on certain conditions:

a. There should be a satisfactory agreement between Egypt and the Sudan (i) for the division of water resources after development by the project, and (ii) for relocation of population displaced by the construction of the reservoir.

b. The Government of Egypt should make satisfactory arrangements or provision for the finances needed for the completion of the project and of the additional facilities required to assure the successful utilization of the water and electric power resources developed.

c. The Government should initiate a program leading to the selection of areas to be irrigated in a way which will ensure the maximum economic return from the additional water made available by the project.

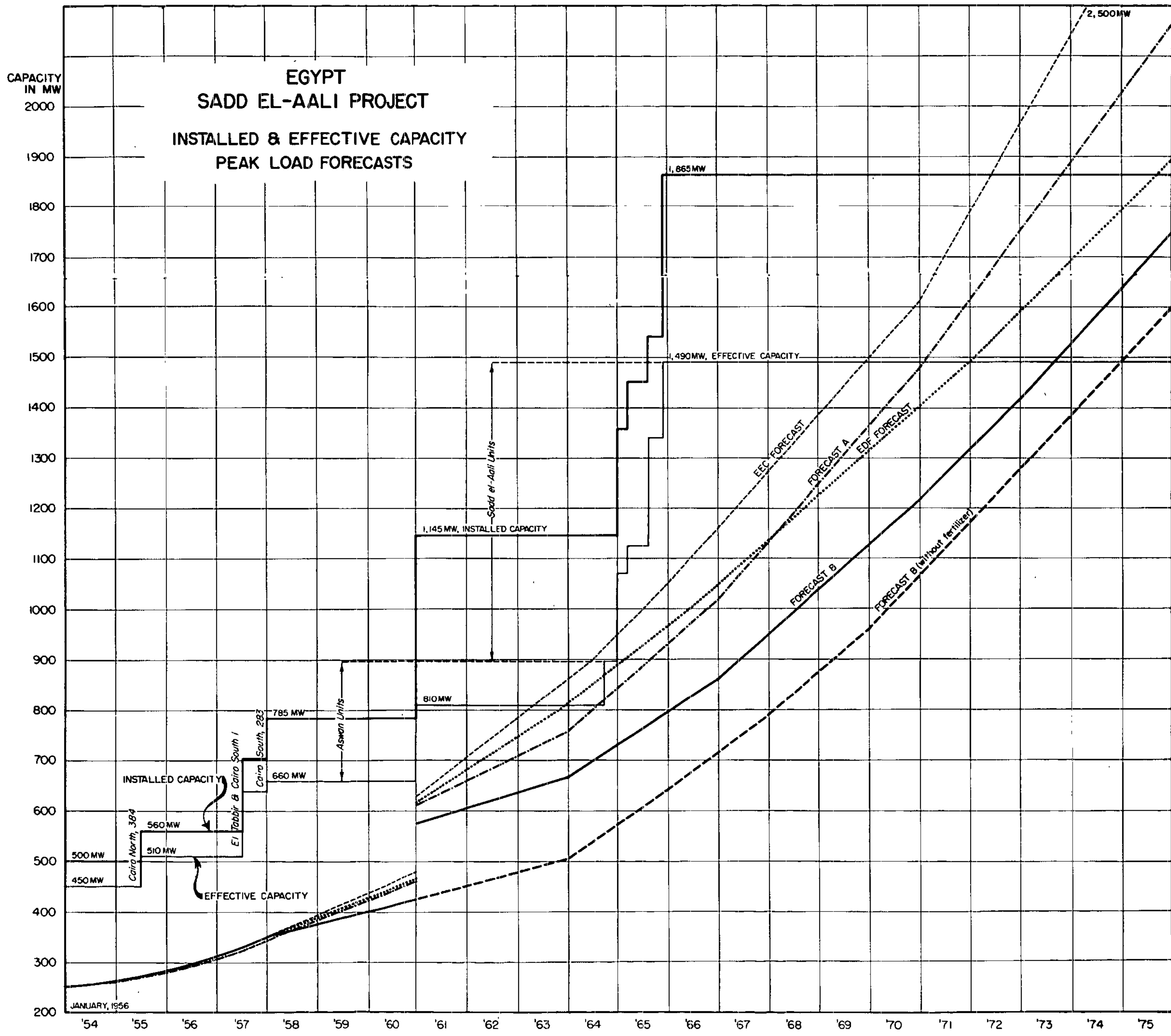
d) The Government should devise policies and legislation which would ensure that the private investment necessary to reclaim the new lands would be forthcoming.

e) In addition to the consultants already selected for the civil works portion of the project (Sir Alexander Gibb and Partners), properly qualified consultants should be selected and given responsibility for technical supervision of the other phases of the project. The services of all consultants should be continued throughout the construction period, and should include the preparation of plans, specifications, bidding documents, analysis of bids and supervision of construction.

f. Great care should be exercised in selecting qualified prime contractors for construction.

g. The International Board of Consultants should, in accordance with present plans, be continued during the period of design and construction of the project to provide needed advice on over-all design, construction methods and unusual technical problems that may develop during execution of the project.

h. The Government should take steps to establish an appropriate power authority to take charge of the transmission and sale of electric power and integrate it into an overall supply for the country under marketing and tariff arrangements which will assure its most effective utilization under sound business management.


EGYPT
SADD EL-AALI PROJECT
INSTALLED & EFFECTIVE CAPACITY
PEAK LOAD FORECASTS
CAPACITY IN MW
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
'54
'55
'56
'57
'58
'59
'60
'61
'62
'63
'64
'65
'66
'67
'68
'69
'70
'71
'72
'73
'74
'75
2,500 MW
1,865 MW
1,490 MW, EFFECTIVE CAPACITY
1,145 MW, INSTALLED CAPACITY
Sadd el-Aali Units
810 MW
785 MW
660 MW
Aswan Units
Cairo South, 283
El Tabbin & Cairo South I
Cairo North, 384
INSTALLED CAPACITY
EFFECTIVE CAPACITY
560 MW
510 MW
500 MW
450 MW
EEC FORECAST
FORECAST A
EDF FORECAST
FORECAST B
FORECAST B (without fertilizer)
JANUARY, 1956

APPENDIX I

## FORECAST A

### GROWTH IN PEAK LOAD AND COMMERCIAL SALES

(Columns (2) to (9) inclusive, kw thousands; column (10) kwh millions)

| Year (1) | Electric Peak Exclusive of Irrigation & Drainage (2) | New Industrial Peak (3) | Conversion of Mechanical to Electrical (4) | Total Commercial Peak (5) | Government Pumping for Irrigation & Drainage (6) | Fertilizer Plant Peak (7) | Total Peak (Cols. 5, 6 & 7) (8) | 50% Commercial Peak (1/2 Col. 5) (9) | Total Commercial Sales (10) |
|---|---|---|---|---|---|---|---|---|---|
| 1953 | 257 | | | 257 | 15 | | 272 | 129 | 1,130 |
| 1954 | 268 | | | 268 | 15 | | 283 | 134 | 1,174 |
| 1955 | 285 | | | 285 | 16 | | 301 | 143 | 1,253 |
| 1956 | 304 | 4 | | 308 | 16 | | 324 | 154 | 1,349 |
| 1957 | 323 | 8 | | 331 | 16 | | 347 | 166 | 1,454 |
| 1958 | 344 | 16 | | 360 | 17 | | 377 | 180 | 1,577 |
| 1959 | 367 | 33 | | 400 | 17 | | 417 | 200 | 1,752 |
| 1960 | 391 | 52 | | 443 | 18 | 150 | 611 | 222 | 1,945 |
| 1961 | 417 | 71 | | 488 | 18 | 150 | 656 | 244 | 2,137 |
| 1962 | 444 | 92 | | 536 | 18 | 150 | 704 | 268 | 2,348 |
| 1963 | 476 | 114 | | 590 | 19 | 150 | 759 | 295 | 2,584 |
| 1964 | 508 | 137 | 20 | 665 | 19 | 150 | 834 | 333 | 2,917 |
| 1965 | 541 | 163 | 40 | 744 | 32 | 150 | 926 | 372 | 3,259 |
| 1966 | 576 | 189 | 60 | 825 | 44 | 150 | 1,019 | 413 | 3,618 |
| 1967 | 614 | 218 | 80 | 912 | 66 | 150 | 1,128 | 456 | 3,995 |
| 1968 | 653 | 250 | 100 | 1,003 | 88 | 150 | 1,241 | 502 | 4,398 |
| 1969 | 696 | 282 | 120 | 1,098 | 110 | 150 | 1,357 | 549 | 4,765 |
| 1970 | 741 | 317 | 140 | 1,198 | 132 | 150 | 1,479 | 599 | 5,247 |
| 1971 | 789 | 354 | 160 | 1,303 | 154 | 150 | 1,606 | 652 | 5,712 |
| 1972 | 841 | 392 | 180 | 1,413 | 176 | 150 | 1,738 | 707 | 6,193 |
| 1973 | 895 | 434 | 200 | 1,529 | 198 | 150 | 1,877 | 765 | 6,701 |
| 1974 | 953 | 478 | 220 | 1,651 | 216 | 150 | 2,017 | 826 | 7,236 |
| 1975 | 1,016 | 526 | 240 | 1,782 | 232 | 150 | 2,164 | 891 | 7,805 |

Assumption: Use increases at rate of 6-1/2% per annum, doubling in 11 years; that 1953-5 mechanical peak will be converted to electrical 1964-75; that Government irrigation and pumping will be as forecast by MPW.

# FORECAST B

## GROWTH IN PEAK LOAD AND COMMERCIAL SALES

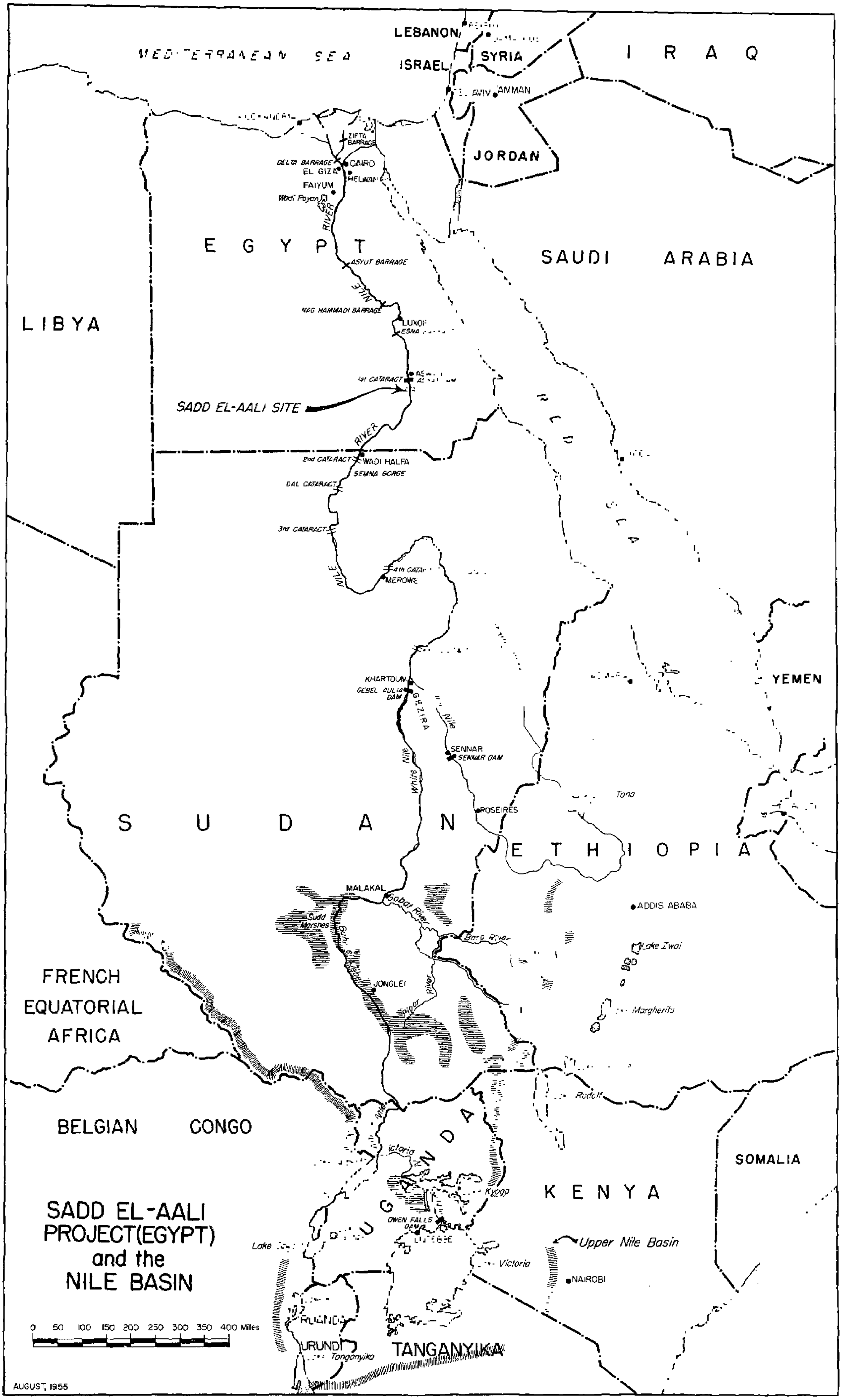
(Columns (2) to (8) inclusive, kw thousands; column (9) kwh millions)

| Year (1) | Electric Peak Exclusive of Industry (2) | Industrial Peak (3) | Conversion of Mechanical Power to Electrical (4) | Total Commercial Peak (5) | Government Pumping for Irrigation & Drainage (6) | Total Peak Including Fertilizer Plant (7) | 50% Commercial Peak (Excludes Fertilizer) (8) | Total Commercial Sales (Excludes Fertilizer) (9) |
|---|---|---|---|---|---|---|---|---|
| 1953 | 117 | 140 | | 257 | 15 | 272 | 129 | 1,130 |
| 1954 | 125 | 149 | | 274 | 15 | 289 | 137 | 1,200 |
| 1955 | 134 | 158 | | 292 | 16 | 308 | 146 | 1,279 |
| 1956 | 145 | 168 | | 313 | 16 | 329 | 157 | 1,375 |
| 1957 | 156 | 179 | | 335 | 16 | 351 | 168 | 1,472 |
| 1958 | 168 | 190 | | 358 | 17 | 375 | 179 | 1,568 |
| 1959 | 180 | 202 | | 382 | 17 | 399 | 191 | 1,673 |
| 1960 | 193 | 215 | | 408 | 18 | 576 | 204 | 1,787 |
| 1961 | 208 | 229 | | 437 | 18 | 605 | 219 | 1,918 |
| 1962 | 224 | 243 | | 467 | 18 | 635 | 234 | 2,050 |
| 1963 | 240 | 259 | | 499 | 19 | 668 | 250 | 2,190 |
| 1964 | 258 | 275 | 20 | 553 | 19 | 712 | 277 | 2,427 |
| 1965 | 277 | 292 | 40 | 609 | 32 | 791 | 305 | 2,672 |
| 1966 | 298 | 311 | 60 | 669 | 44 | 863 | 335 | 2,935 |
| 1967 | 320 | 331 | 80 | 731 | 66 | 947 | 366 | 3,206 |
| 1968 | 345 | 351 | 100 | 796 | 88 | 1,034 | 398 | 3,486 |
| 1969 | 370 | 374 | 120 | 864 | 110 | 1,124 | 432 | 3,784 |
| 1970 | 400 | 397 | 140 | 937 | 132 | 1,219 | 469 | 4,108 |
| 1971 | 430 | 422 | 160 | 1,012 | 154 | 1,316 | 506 | 4,433 |
| 1972 | 462 | 448 | 180 | 1,090 | 176 | 1,416 | 545 | 4,774 |
| 1973 | 500 | 477 | 200 | 1,177 | 198 | 1,525 | 589 | 5,160 |
| 1974 | 542 | 507 | 220 | 1,269 | 216 | 1,635 | 635 | 5,563 |
| 1975 | 585 | 540 | 240 | 1,365 | 232 | 1,747 | 683 | 5,983 |

Column (3) - 1953 industrial peak was 140,000 kW, and in addition industry had a mechanical peak of 250,000 kW equivalent (out of 514,000 kW equivalent installed). Thus total industrial energy used 1953-55 was 390,000 kW equivalent.

Column (7) - Includes 150,000 kW after 1960 for fertilizer plant.

Assumption: In period 1955-75, public utility uses (other than industry) will increase 5 fold and industry use will double. Government irrigation and drainage according to schedule forecast by Minister of Public Works.




SADD EL-AALI PROJECT(EGYPT) and the NILE BASIN

IBRD-213