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REVIEW AND EVALUATION OF HYDRAULIC PROBLEMS AT THE HYDRAULIC RESEARCH AND EXPERIMENTAL STATION DELTA BARRAGE, UNITED ARAB REPUBLIC

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PREFACE

This report of a visit to Cairo and the Delta Barrage, United Arab Republic, 5 May-6 June 1963, was prepared by Mr. Donald C. Bondurant, Chief, Sediment Section, Missouri River Division, Omaha, Nebraska, and Mr. Frederick R. Brown, Chief, Hydrodynamics Branch, Waterways Experiment Station, Vicksburg, Mississippi, both of the U. S. Army Corps of Engineers, for submittal to the Agency for International Development, who had requested the visit, through the Office of the Chief of Engineers. The visit was made under the authority of Contract Nos. 1015 and 1016, Project No. 263-AA-11-AC-5.

The trip to the United Arab Republic by Messrs. Bondurant and Brown was made with the concurrence of Brigadier General Robert F. Seedlock, Division Engineer, U. S. Army Engineer Division, Missouri River, and Colonel Alex G. Sutton, Jr., CE, Director, U. S. Army Engineer Waterways Experiment Station.

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REVIEW AND EVALUATION OF HYDRAULIC PROBLEMS AT THE HYDRAULIC RESEARCH AND EXPERIMENTAL STATION DELTA BARRAGE, UNITED ARAB REPUBLIC

PART I: INTRODUCTION

Purpose of Visit

1. In response to a request from the Agency for International Development (AID), Washington, D. C., for the services of the Corps of Engineers in providing technical assistance to the Hydraulic Research and Experimental Station of the Ministry of Public Works, United Arab Republic, Messrs. Donald C. Bondurant of the U. S. Army Engineer Division, Missouri River, and Frederick R. Brown of the U. S. Army Engineer Waterways Experiment Station visited Cairo and the Delta Barrage, United Arab Republic, during the period 9 May-9 June 1963. Travel authorization numbers AID 3-P-4239 and AID 3-P-4240, dated 3 May 1963, indicated the purpose of travel to be "in connection with Hydraulic Research and Experiment Station."

2. In a conference with Mr. Malcolm Jones, AID Bureau for Near East and South Asia, Mr. Edwin A. Anderson, Coordinator of AID programs in Egypt, and others in Washington, D. C., on 6 May, the objectives of the mission were outlined as follows: to review and evaluate problems being studied by means of hydraulic models at the Hydraulic Research and Experimental Station, with special emphasis on sedimentation problems in the Nile River as affected by construction of the high Aswan Dam; and to review the physical plant of the Experimental Station and its instrumentation requirements. A final report was desired at the end of the tour.

3. After the Corps of Engineers representatives arrived in the United Arab Republic, in discussion with the U. S. AID officials and officials of the UAR Ministry of Public Works and the Hydraulic Research and Experimental Station, the objectives of the mission were confirmed.

Acknowledgments

4. Upon arrival in Cairo, Egypt, Messrs. Bondurant and Brown

reported to the office of Dr. Frank D. Venning, Acting Food and Agriculture Officer, Food and Agriculture Division of AID. Mr. Vard M. Shepard, Food and Agriculture Officer, was in the United States on leave. Dr. Venning provided logistic support as required and arranged for direct contact with the Director of the Hydraulic Research and Experimental Station, Dr. Ahmed Ali Eldarwish. Assistance also was rendered by the Deputy Director, Mr. D. Alan Strachan; Training Officer, Mr. Thomas F. Lerch; Personnel Assistant, Miss Lucy S. Bergland; and the secretary in the Food and Agriculture Division, Miss Joan H. Leary.

5. The Corps of Engineers representatives were extended numerous courtesies, including luncheons and field trips, and attended various meetings at which the problems of concern were discussed with officials of the Ministry of Public Works, Officers of the Suez Canal Company, University of Cairo faculty members, and other engineers. The following is a partial list of those individuals:

Mr. Ahmed Ali Kamal, Under Secretary of State, Ministry of Public Works

Mr. Mohamed Medani, Under Secretary of State, Ministry of Public Works

Mr. Hakim Mahdi, Under Secretary of State, Ministry of Public Works

Dr. Mahmoud Bakir, Assistant Secretary of State

Dr. Abdel Fallah Fahmy, Director of Office, Under Secretary of State, Ministry of Public Works

Mr. Hussein Fahimy, Inspector General, Nile Control

Mr. Hassin Soliman, Inspector General for Irrigation

Mr. Abdel Salam Hashim, Inspector General for Research

Dr. Youssef Simaika, Technical Advisor, Ministry of Public Works (formerly Under Secretary of State)

Dr. Mahmoun Dehgadi, General Company for Research and Ground Water (Regwa)

Mr. Hassib El Dafrawy, Inspector General for Irrigation, Giza Province

Dr. El Deeb, Chief Engineer, Suez Canal

Dr. Hassan Ismail, Director, Suez Canal Laboratory and Professor of Hydraulics, University of Cairo

Dr. Anwar Khafagi, Vice Dean, College of Engineering, University of Cairo

Professor Y. K. Gayed, Head, Mechanical Power Dept., University of Cairo

Dr. A. Fathy, ex-Professor of Hydraulics, University of Alexandria

Mr. Hamed Soliman (Pasha), formerly Executive Director of the National Committee for Irrigation and Drainage

Dr. Serge Leliavsky (deceased), former Consultant to the Ministry of Public Works

Dr. Gamal Mostafa, former Director of the Delta Barrage Laboratory and currently president of a cement company

Particular acknowledgment is made of the many courtesies extended by Mr. Ahmed Ali Eldarwish, Director of the Delta Barrage Laboratory, and Dr. Ali Fahmi El Kashif, former Director of the Delta Barrage Laboratory and currently the Managing Director of the General Company for Research and Ground Water (Regwa).

Scope of This Report

6. For clarity, this report has been divided into five parts. Part II is a description of the Nile River and its importance to Egypt. Part III contains a description of the Hydraulic Research and Experimental Station, the staff, future plans, and comments and recommendations. Part IV concerns the degradation of the Nile River and possible research pertaining thereto. Part V is a summary of findings and recommendations. Appendices A and B describe current investigations at the laboratory and desired instrumentation, respectively.

PART II: THE NILE RIVER, ITS IMPORTANCE TO THE LIFE AND ECONOMY OF EGYPT

7. The Nile River is formed by three major tributary systems, the White Nile, Blue Nile, and Atbara, which drain a humid area of equatorial Africa. However, from the confluences of the Atbara throughout the approximately 1500 miles of its course to the head of the delta near Cairo, the stream flows through an arid region with no tributaries of consequence. At the head of the delta, the river divides into two distributaries, the Damietta and Rosetta Branches, which continue approximately 100 miles to the Mediterranean Sea.

8. Rainfall throughout most of Egypt is generally less than 2 in. per year, and the flow accumulated in the upper tributary system of the Nile is essentially the only surface water available in the country. Some areas of subsurface water are currently being developed, but these are only a small fraction of the total. More than 90 percent of the population, and practically all the agriculture and industry of the country are crowded within the confines of the Nile valley. In addition to being the primary source of water for domestic, agricultural, and industrial use, the stream above the head of the delta is the major artery of transportation. The Nile is literally the lifeline of Egypt.

9. Floodwaters of the river have irrigated the valley throughout history; however, the floods occur in August and September rather than during the periods which would better correspond to agricultural needs. A program of storage and diversion structures to enable more efficient distribution and use of the water was inaugurated with the completion in 1861 of the Delta Barrage at the head of the delta. Subsequently, additional structures were completed on the main stem and on the two delta branches, and one was constructed on the White Nile. Although this program involved storage as well as diversion, the total storage provided was only slightly over 5,000,000 acre-ft, which allowed only a moderate control during flood periods.

10. Currently, the high Aswan Dam is under construction. This project, located approximately 20 miles upstream from the upper main-stem structure (the low Aswan Barrage) and about 580 miles above the head

of the delta, will provide complete storage regulation except for extreme floods. It will also effectively divide the river so that only that portion downstream will currently need be considered in the controls. Statistics on that portion of the stream are:

Length (Aswan Barrage to head of delta)	560 mi
Fall	223 ft
Average slope (varies from 8.6 to 6.5 cm/km)	0.4 ft/mi
Width, 500 to 700 meters	approximately 0.5 mi
Flow, maximum natural	approximately 450,000 cfs
Flow, minimum natural	approximately 40,000 cfs

11. The regulated discharge with the high Aswan Dam in operation will decrease from Aswan downstream, since the only replacement for the water withdrawn will be some return flow or drainage from irrigated areas. During years of high flow, the release at Aswan will be about 143,000 cfs for the period August 20 through May, and 98,000 cfs from June 1 to August 20. During years of normal and low flows, the corresponding values will be 98,000 cfs and 52,000 cfs. Anticipated discharges during the August-May period at the various control structures downstream are shown in the following table:

Location	Distance from Low Aswan Barrage miles	Discharge, cfs	
		High Years	Normal and Low Years
Aswan Barrage	0	143,000	98,000
Esna Barrage	98	130,000	85,000
Naji Hamadi Barrage	212	123,000	78,000
Asuit	319	99,000	54,000
Delta	560	97,600	52,700
Mediterranean Sea	660 (approx)	45,000	0

12. The Aswan Barrage is founded on rock, which almost immediately dips below the surface. The remaining structures are founded on sand, which is stated to have a depth of more than 100 ft; they are, essentially, multiported and gated structures on a slab base with upstream and downstream sheet pile cutoffs.

13. There are two major considerations involving the section of the

river and valley below Aswan with which the Corps of Engineers representatives were concerned: (a) the Hydraulic Research and Experimental Station established at Delta Barrage to aid in the solution of problems of river control, irrigation, and appurtenant works, and (b) the problem of degradation of the Nile River as affected by completion of the new high Aswan Dam project. These are discussed individually in Parts III and IV following.

PART III: THE HYDRAULIC RESEARCH AND EXPERIMENTAL STATION

Description

14. The Hydraulic Research and Experimental Station is located 25 km (about 15 miles) north of Cairo on the left bank of the Nile River immediately downstream from the Damietta Barrage. The laboratory consists of an administration building, main experimental hall, South and North Test Fields, two halls for flumes, workshops, and storage area. It operates directly under the Ministry of Public Works for the purpose of conducting:

- a. Fundamental research in river hydraulics, open channel flow, sediment transport, and design and maintenance of irrigation works.
- b. Applied research for the Irrigation Department of the Ministry of Public Works involving the study of river training problems by models.

15. The present laboratory facilities occupy an area of about 6 acres, although additional land to the east and west of the existing site is available for future expansion. Plate 1 shows the general arrangement of existing laboratory facilities.

16. The administration building (photograph 1) of masonry construction is two stories in height, and covers an area of about 350 sq m. The first floor houses mechanical analysis, photographic, drafting, and administrative groups; the second floor is occupied by the technical staff and a library. The building is adequately furnished for the purposes intended.

17. The main experimental hall is located adjacent to the administration building and has an area of about 750 sq m, only a portion of which is currently available for model construction. Photograph 2 is an interior view of the hall. This hall can be provided with Nile River water diverted from the pool upstream of the Damietta Barrage by a special canal; the total drop in head is about 5 m. Maximum capacity is about 3000 liters per sec (about 100 cfs) which is limited only by flow in the approach canal. However, because of suspended material in the water, use of Nile River water has been discontinued. Instead, a system of pumps and sumps at the main experimental hall and elsewhere is used as a source of water for model operation. Artesian wells have been constructed to depths of 50 to 150 m

as required to fill the sumps. The water is circulated through the models until it becomes dirty, after which it is wasted to the river. The sumps are then cleaned and refilled with fresh, clear artesian water.

18. Three volumetric calibration tanks located adjacent to the main experimental hall were designed to measure flow passing through the main hall. These tanks are 5.5 m deep and are 12.1 by 9.5 m, 7.45 by 5 m, and 4 by 6 m in cross section. However, practically no use is being made of them becaus of insufficient drop from the canal into the main hall to the bottom of the volumetric tanks. Also, suspension of the use of Nile River water mentioned previously obviates their use under present conditions. The tanks could be used for the purpose intended if the water level of the models or devices being calibrated could be raised to ground level.

19. The South Test Field (photographs 3-5) is an open area (not covered) of about 2.5 acres. Originally, Nile River water was available by a system of small channels. However, use of the river water has been replaced with a recirculating system of pumps, constant head tanks, and artesian well water. The pumps in the South Test Field are of the centrifugal type with the power for operation provided by combustion engines and belt drives. The pumping system does not appear to be very efficient and operates to advantage only in the event of a power failure.

20. The North Test Field (photographs 6 and 7) of about 3 acres was developed after the south area, and is much superior for model work. A transsite, corrugated-type roof covers an area about 140 by 50 m. On the west side of the covered area, a masonry partition wall about 1.5 m high separates the work area from a public road. Water is supplied to the models by two centrifugal-type pumps of 500- and 200-liters-per-sec (17 and 7 cfs) capacity at heads of 5.5 m. Flow passes into a constant head tank, and thence to a covered circulating channel connected directly to the individual models. Actually, the method used to supply the models does not utilize the constant head tank for its intended purpose. The pumps are electrically driven with 220-volt, 50-cycle current. Clear artesian water stored in a sump is the source of water. Dust blown into the shelter, particularly from the public road, quickly causes the water to become extremely dirty. Photographs 8 to 11 show a typical movable-bed model and model construction crew at work in this area.

21. There are three flumes, one of which is located in the North Test Field while the other two are in separate masonry buildings. The first is of steel comstruction, 45 cm wide by 30 cm deep by 20 m long, with a glass side panel, and is adjustable for slope. A second, occupying all available space in its building, is of wood and glass, 45 cm by 60 cm by 39.3 m, with a collector and small electric pump and piping for recirculating sediment. Water is supplied directly from a constant head tank and wasted into a sump. The newest facility is a glass-sided flume, 1 m by 1 m by 28 m, in a masonry building 6 m wide by 48 m long (photograph 12). Water is supplied from a constant head tank through four pipes containing flow nozzles for measurement of discharge, and tailwater levels are controlled by a vertical vane-type tailgate. There is sufficient space in the building for extension of the flume and for construction of another similar flume if desired.

22. The workshops consist of a carpenter shop with the normal complement of planers, band saws, table saws, lathes, etc., and another shop for miscellaneous purposes such as sheet metal work and construction of measuring devices.

Staff

23. The current staff of the hydraulic laboratory consists of 15 engineers, 7 of whom were absent in other countries for training purposes, and about 35 laborers. Photograph 13 shows the Director; photograph 14 shows the staff and the two Corps of Engineers representatives. The laboratory operates directly under the Irrigation Department of the Ministry of Public Works. Dr. Hassan Zaky is the Minister of Public Works. A technical committee of 14 members, made up of personnel of the laboratory staff and of other agencies of the Ministry, serves in an advisory capacity to the Director, Eng. Ahmed Eldarwish. Chairman of the committee is Eng. A. Aly Kamal, Under Secretary of State of the Ministry of Public Works.

Work Load

24. It is understood that the laboratory budget for 1962 was

20,000 Egyptian pounds ($47,000), whereas the current budget will amount to about 40,000 Egyptian pounds ($94,000). About 18 projects were under way or had just been completed at the time of the Corps of Engineers representatives' visit. Of this number, about nine were active. This appears to be about the maximum work load that can be carried on by the existing staff. A detailed description of the projects noted at the laboratory is given in Appendix A.

Future Plans

Plant

25. The Director of the laboratory stated that immediate plans call for the construction of walls for the covered area of the North Test Field to prevent dust from entering the test area. It also is planned to revise the water distribution system by connecting models directly to the constant head tank rather than through the circulation channel as is now done.

26. A new test shelter about 100 m long by 40 m wide is planned for construction on a site to the west of the public road through the laboratory site. This new test area would be equipped with its own artesian well system for water and would be served by a new constant head tank and pumping system. Piping layouts would be developed along one wall of the shelter to permit easy connection of models to the constant head tank. Flow measuring devices would be installed in these pipelines.

27. A possible alternate site under consideration is the area to the east of the North Test Field. Development of this site would require filling by natural river siltation to raise it above flood levels. This site would have to be developed within the next year as no floods are expected after closure of the new Aswan Dam. If and when the alternate site is developed, it might be possible to utilize the constant head tank of the North Test Field by the addition of several pumps to the system. Ultimate development of the site should include a separate supply system similar to that proposed above. When the new site or sites are developed, it is planned to abandon the South Test Field.

28. Plans also are being studied for installing a complete floor cover in the main experimental hall. This would provide additional test area which could utilize the capability of the existing calibration tanks,

or could provide additional office or laboratory space as the need might dictate. For example, the area could readily be adapted for use of a soils and/or an instrumentation laboratory, neither of which is included in the present organization.

Training of staff

29. Subject to the availability of funds, it is understood that three members of the staff of the laboratory are to be given training in the United States. Mr. Ahmed Ali Eldarwish, the Director, is to receive 4 months of training in river hydraulics, research administration and techniques, and instrumentation for model and field use. This training will be obtained at the California Institute of Technology, the St. Paul District of the Corps of Engineers, the University of California at Davis, and the King Engineering Corporation at Ann Arbor. Several alternate locations for training also were suggested, but no action is to be taken at this time. Mr. Eldarwish has a B.S. degree in Civil Engineering from the University of Cairo, and an M.S. degree in Hydraulic Engineering from Louisiana State University.

30. Messrs. Mahmoud Mohamed Aly and Tewfik Aly Eid are scheduled to receive 12 months training in river hydraulics. The tentative schedule calls for 6 months at the Waterways Experiment Station, 4 months at the Bureau of Reclamation, and 1 month each at the Vicksburg and Memphis Districts of the Corps of Engineers. The tours at the Vicksburg and Memphis Districts are principally for training in the use of the echo sounder for river measurements.

Instrumentation

31. The laboratory desires to procure electronic measuring equipment for model and field use to refine the accuracy of measurements. Emphasis was placed on procurement of miniature flowmeters and a magnetic flow-measuring device for accurate calibration purposes in the laboratory; for field use, emphasis was placed on procurement of echo sounder type devices. The office of the Inspector General, Nile Control, has several echo sounders; however, the Bludworth model noted was equipped with an inboard transducer with transducer wells required to be welded to the hull of the boat in which it is to be used. This would discourage its use on a part-time basis by the agencies of the Ministry of Public Works. Attached as

Appendix B is a summary of a report on instrumentation prepared by the Director of the laboratory following a tour of the hydraulic laboratories at Wallingford, England, and Delft, Holland.

Comments and Recommendations

General

32. The Hydraulic Research and Experimental Station at the Delta Barrage resembles hydraulic laboratories all over the world both in appearance and manner of operation. As in other laboratories, the work is directed toward solution of the problems most common in the area. In the case of the Hydraulic Research and Experimental Station, work is concerned chiefly with Nile River problems and associated irrigation practices. For the most part, work is confined to the solution of particular problems, although some applied research is going on to study irrigation structures, water wheels "Tanabish," and variations in the Parshall flume.

33. This laboratory, if developed to its possible potential, should perform the same function with respect to the Nile River and appurtenant works as the Waterways Experiment Station does with respect to the work of the Corps of Engineers in the United States. While there can be no question of the value of the experience gained during the many years of work on controls for the Nile, the gaining of such experience inevitably requires trial-and-error procedures in which construction cost precludes the trial of alternate designs and causes the errors to be "locked in." In the laboratory, alternates can be tested and errors eliminated at relatively little expense, and it is inconceivable that the Delta Barrage Laboratory should not be used extensively for this purpose if adequately developed. For this purpose, however, it should be enlarged and supplied with additional space, equipment, and trained personnel.

Staff

34. Although the total engineering staff is listed as 15, the absence of seven engineers on training missions in foreign areas does little to assist the current work program. The proposed departure of the Director and two additional members of the staff will further lower the immediate work potential. However, before the departure of the two staff

members, some of those now in a training status will have returned to augment the staff. The assignment of engineers for advanced training and education in foreign schools and laboratories is excellent. In fact, this is the best kind of assistance that can be obtained, although the training may not improve the laboratory unless the engineers stay in this field of work. Some action is required by the Egyptian government to improve the status of the engineer at the laboratory either by an increase in salary or by increased recognition. For example, there have been four directors of the laboratory in the past ten years. More and better work and research can be accomplished by a stable staff.

35. The present Director of the laboratory, Mr. Ahmed Ali Eldarwish, is qualified for accomplishment of the work in progress. He has visited and worked in most of the foremost hydraulic laboratories of the world. Therefore, he is familiar with their techniques and procedures and can apply those he considers best suited to his requirements at the Delta Barrage Laboratory. However, he cannot personally give attention to all the administrative details pertinent to the operation of the laboratory and the technical details that must be resolved on each project. He must have additional assistants to give him more time for the broader objectives of the laboratory. The engineers on the staff seem qualified, but each has several projects and can only work on one at a time.

36. To assist with sedimentation problems encountered on the Nile, it is suggested that a modest soils laboratory be developed at the Delta Barrage by the government and one or two soils engineers added to the staff. If electronic instrumentation is procured as planned, it is suggested also that an instrumentation group be added to the staff with one or more electronic engineers in charge of the instrumentation. The addition of one or more electronic engineers to the staff is a necessity to maintain electronic equipment in good working condition.

37. Close association with the University staff also is recommended for possible consultant services and/or employment during the holiday season. The University also could be a source of engineering assistants (students) for employment during the summer season. Perhaps an agreement could be arranged with the University wherein work at the Delta Barrage Laboratory could be applied toward receipt of an advanced degree.

Model techniques

38. Model techniques employed are generally in accord with standard practices. Although moderately distorted models are being used, the selection of slightly smaller scale ratios would result in models more economical to construct and easier to verify because of the smaller quant... flow and areas involved. The same comment could be made concerning some of the undistorted models. In some instances a slightly distorted model would be preferable to an undistorted model because of the roughness involved. Additional field data on stage heights and bottom configuration would add to the accuracy of model results. It appears in some instances that model results could be questioned because of the lack of sufficient field data.

39. Consideration should be given to the use of movable-bed material other than Nile River sand, although the lack of local supplies and prohibitive cost of purchase and shipping from foreign sources currently preclude the use of materials commonly available in laboratories elsewhere. The investigation of possible substitutes for Nile River sand could be a research project for the next several years. Plastics or crushed brick at present appear to be about the most feasible substitutes.

40. Wind and dust are problems, particularly for those models not under cover. The wind distorts water levels, while the dust contaminates the water supply and surface of movable beds. Construction of walls around the North Test Field and construction of a new shelter to the west of the administration building should help to alleviate this problem.

Plant facilities

41. As funds can be made available by the Ministry of Public Works, it is recommended that certain improvements and additions to facilities be accomplished. Specifically it is recommended that the roofed area covering the North Test Field be enclosed with a wall to prevent wind and dust from interfering with model operation. It also is recommended that plans be formulated for construction of a shelter, complete with water-supply facilities, for development of a west test field.

42. The entire floor of the main experimental hall should be at ground level to more fully utilize the area covered by the hall. When the floor is completed, the area could readily be used for additional office space, laboratory space, or test purposes.

43. The technical library for use of the staff should be increased in volume. As a minimum, all of the American Society of Civil Engineers publications should be procured through subscription in the immediate future; also subscriptions to such technical magazines as La Houille Blanche, Institute of Civil Engineers, and others should be obtained.

44. An effort should be made to improve and utilize the existing calibration volumetric basins. The improvement of the main experimental hall may assist in solving this problem.

45. An additional piece of research equipment which would contribute to the capability of the laboratory is an air tunnel and/or a water tunnel for many types of studies. Although there is no immediate need for the equipment, it should be kept in mind for possible future construction or procurement.

46. Inasmuch as there will probably be several aspects of the degradation problem requiring study in the future, the laboratory should be equipped for this purpose. The flumes currently available are adequate, but the 20-m flume in the North Test Field and the 39-m flume currently equipped for sediment recirculation should both be revised to be completely recirculating with independent electric pumps and orifice plates or venturi sections for control and measurement of the flow. A vertical return pipe with facilities for sampling total sediment load should be included in the system for the 39-m flume, but should not necessarily be required for the 20-m flume, since the latter will be most useful for establishing transport characteristics of materials used in movable-bed models, or for other investigations of sediment movement.

Water supply

47. Water-supply facilities for the laboratory are good, particularly with the use of artesian wells rather than the river. However, the dust, mentioned previously, quickly contaminates the water being circulated and requires frequent cleaning of the sumps.

48. The gasoline-motor-driven pumps utilized chiefly in the South Test Field should be replaced with electric motors as funds will permit. The use of centrifugal-type pumps and constant head tanks is good, although the full value of the constant head tank is not being utilized in the North Test Field where flow is distributed by means of a perimeter channel.

Consideration should be given to the direct connection of models with the constant head tank and use of venturi meters, orifice plates, or flow nozzles as replacement for weir measuring devices. In all probability the constant head tank in the North Test Field is only of sufficient capacity to supply this area. Development of the additional areas proposed would require the construction of additional water-supply facilities.

49. The intermediate constant head tank supplying the glass flume in the new hall appears to have insufficient weir length to maintain a constant head for a flow of 15 liters per sec. A possible solution is to throttle the overflow to a mere trickle; baffling of the inflow to the tank also may be required.

50. When the West Test Field is developed, it is recommended that a constant head tank, piping, and sump be so arranged that flexibility of operation is possible. The sump could be constructed as a channel along one side of the shelter to store water and also permit installation of pumps for supplying water directly to a particular model. This is done in the North Test Field at the present time. Piping arrangements along the west wall of the shelter from the constant head tank also would permit easy connection of the model to the constant head tank. Initial pump installation should consist of three pumps with capacities of about 300, 150, and 75 liters per sec. Efforts should be made to locate manometers for recording inflow adjacent to the control valves leading to the models.

Field data

51. There was a general lack of adequate prototype data, particularly in the movable-bed models, for satisfactory verification, and it was pointed out that available field equipment would not permit sounding during other than low flows. It is suggested that facilities be provided for laboratory personnel to obtain the required data, including water-surface elevations at all critical locations, discharge data, and samples of both suspended load and bed materials. The latter will be necessary for transport studies for degradation predictions. It is believed that the field data should be procured by engineers of the Ministry of Public Works. However, if personnel and staff are not available, laboratory personnel must be used to secure the desired data.

Instrumentation requirements

52. The Hydraulic Research and Experimental Station could effectively utilize some additional instrumentation. Mechanical equipment could be constructed at the laboratory as the need arises. However, procurement of certain photographic and electronic equipment would provide a capability for measurements not now available. Equipment recommended for immediate procurement is listed below:

a. Photographic recording equipment.

(1) High-speed motion picture camera for research such as that under way on the water wheel tests.

(2) Polaroid camera for immediate recording of phenomena as they occur on the models.

b. Midget current meter (two required initially).

(1) Visual and automatic recording.

(2) Several impeller wheels should be provided to cover a complete range of velocities expected.

c. Miscellaneous electronic measuring devices together with direct writing and photographic recording oscillographs.

(1) Linear potentiometers for displacement measurements as a function of time.

(2) Accelerometers of various ranges for vibration measurements.

(3) Electrical pressure cells of assorted sizes and ranges for measurement of fluctuating pressures and/or turbulence research.

(4) Strain gages for force measurements.

d. Field measuring devices for use on the river.

(1) Echo sounders.

(2) Subsurface current direction indicators.

(3) Current meters.

(4) Sediment samplers.

53. Each of the above-listed types of equipment should be thoroughly investigated prior to purchase to insure that it will satisfactorily fulfill a potential requirement. Additional comments concerning instrumentation for field measurements are contained in the portion of this report concerning degradation of the Nile River resulting from construction of the high dam and possible sedimentation research pertaining thereto.

54. Additional equipment that would prove useful, although not of immediate necessity, might include:

a. Automatic stage recording and transmitting devices for use with extremely large river models.

b. Magnetic or sonic flow measuring devices for calibration purposes.

Other types of instrumentation might become necessary if the present scope of work is broadened to include types of work not now foreseen. Specialists in the instrumentation field could quickly adapt much of the preceding equipment to fill many and varied needs.

Conclusions

55. Many of the preceding recommendations and suggestions have been made without regard for immediate need, cost, or utility. Only the Director of the laboratory is in a position to set priorities on the basis of requirements and availability of funds and qualified personnel. Obviously, if the staff of the laboratory is not increased, the ability to carry on an increased work program is subject to question. Likewise, if qualified personnel are not available to assemble, operate, and maintain the electronic equipment desired, the equipment will serve little or no useful purpose. The recommendations made, however, should be a guide for the overall development and growth of the Hydraulic Research and Experimental Station, which should be expanded to provide a capability for research not only on the Nile River but in many other areas of possible interest to the Ministry of Public Works.

PART IV: DEGRADATION OF THE NILE

The Problem

56. The Nile River, downstream from the low Aswan Dam, is a sand-bed stream which currently appears to be in a balanced regimen. The slope of the stream varies, generally from 8.6 to 6.5 cm per km, averaging about 0.4 ft per mile. The bed material has a median diameter of approximately 0.2 mm, with the 90 percent size, as disclosed by a number of borings to depths of 10 m (32.8 ft), varying from 0.4 mm to 1.0 mm with isolated instances of material up to 5 mm (above Esna Barrage) and 3 mm (below Esna Barrage). The normal suspended sediment load is reported* as 134 million tons per year, with 30 percent listed as fine sand (0.02 to 0.2 mm) and none coarser than 0.2 mm. On the basis of the definition of sand as material coarser than 0.0625 mm, the sand percentage in suspension would average only about 10 percent. There is no reasonable method, other than approximate analytical procedures, of determining the quantity of material moving as bed load. It is believed that this approximates 10 percent of the total suspended load.

57. The operation of the high Aswan Reservoir will result in a change from the existing regimen; i.e., it is probable that the entire sediment load entering the reservoir will be deposited and retained there and that the clear water released therefrom will tend to regain a load equal to its transport capacity by eroding the bed and/or banks of the river downstream. Based on experiences in other African reservoirs, it is possible that the clay fraction of the sediments might be susceptible to the formation of density flows; on the other hand, the size and thalweg slope of the reservoir are not such as would encourage density flows. In either case, this factor should not influence the degradation process to any appreciable extent.

58. There is, at present, a great diversity of opinion as to the probability and possible extent of future degradation. Mr. Y. M. Simaika,

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* N. Boulos, Silt in the Aswan Reservoir, Cairo Govt. Printing Offices, 1959 (copied from Y. M. Simaika, Preliminary Report, Degradation of the Nile Due to the Interception of Silt in the High Aswan Reservoir).

Technical Advisor to the Ministry of Public Works and former Under Secretary of State, considers that degradation will be negligible, basing his opinion on cross-section surveys at a gaging site some 30 km downstream from the low Aswan Dam during periods when that dam was utilized to store [illegible] At the other extreme, Mr. A. Fathy, ex-Professor of Hydrau-[illegible] at the University of Alexandria, considers a bed drop in excess of 11 m (36 ft) to be possible. The intermediate view is reported by Dr. Gamal Mostafa on the basis of an analytical transport study, with ultimate values of 8.5 m, 9.0 m, 7.0 m, and 6.5 m below the structures in order from Aswan downstream. Several consultants, including Dr. L. G. Straub and Dr. Hunter Rouse, are understood to be currently employed to advise the Egyptian Government on the problem; however, no information on their conclusions was given.

59. Prior to further analysis of the degradation probability, it might be well to consider the implications. The most obvious and apparently the most serious effect would be on the main stem structures. Inasmuch as the low Aswan Dam is founded on rock, the foundation problem would not be unduly severe although a major increase in the head differential would introduce stability problems which could seriously affect the operation of the structure and appurtenant works. The remaining structures, being founded on sand, would almost certainly be destroyed if the bed downstream were permitted to be eroded to any appreciable depth. At a minimum, extensive corrective measures would be required to forestall such a contingency. The problem of navigation approaches to the locks is also of great importance.

60. Since there are no tributaries of consequence, head-cutting would be no problem; however, the canal system is adjusted to the existing sediment load, and some difficulty might arise with a change in sediment load. The potential of this problem was not investigated, but a statement by Mr. Fathy* as to the fine sand encountered in one instance indicates that there is an appreciable movement of riverbed material.

61. Mr. Fathy also expresses concern as to the coastal formations in the Mediterranean along the northern shores of the delta, where there is

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* A. Fathy, Considerations on the Degradation Problem in the Aswan High Dam Scheme.

a continuous, fairly strong west-to-east current. Under normal degradation processes, it is unlikely that any effect would be noticeable here for many years; on the other hand, control structures to protect existing river works could conceivably cause degradation to be apparent in the lower reaches in a much shorter time. The question deserves consideration, but will not be included in this report.

Analytical Investigations

62. Analytical studies of degradation must be based on two-dimensional transport formulae, and their application to three-dimensional problems inevitably involves assumptions and approximations requiring the exercise of considerable judgment. The formulae also involve certain inaccuracies arising principally from the effect of the sediment, including variable bed form roughness and turbulence effects. On the other hand, a recent recapitulation of experienced degradation below the Fort Randall Dam on the Missouri River showed excellent agreement with results of analytical studies insofar as sediments of 0.2 mm and larger were concerned.

63. The analytical study by Dr. Gamel Mostafa was reasonably complete, involving a time scale to indicate progression. Since Dr. Mostafa's work for his doctorate was accomplished in the field of sediment transport at the University of Minnesota and is well known, it is considered that a detailed recomputation on essentially the same bases would be redundant; therefore, an independent check was made on a limited basis to determine the limit of degradation without regard to time scales or controls. For this purpose, available bed samples were studied, and a material of 0.5 mm (approximately the 90 percent size; i.e., 90 percent of the material was finer than 0.5 mm) selected as the armoring material. Utilizing critical transport values determined for Missouri River sand, and the anticipated controlled release of 143,000 cfs, the limiting slope was computed to be 0.00001. For this purpose the formula used was the critical tractive force formula proposed by Dr. L. G. Straub; $S_e = T_c/\gamma d$, where S_e is the critical energy slope, T_c the critical tractive force, γ the specific weight of the fluid (62.4 lb per cu ft), and d the depth in feet. The computation indicated, for example, a limiting degradation of 7.0 m below

the low Aswan Dam as compared with the ultimate value of 8.5 m by Dr. Mostafa's analysis. In consideration of the assumptions required, particularly as to channel width, this is an excellent correlation.

64. Although the degradation values predicted in this manner will offer serious problems and will require extensive and expensive controls, they are intermediate between the previously mentioned extremes predicted by Mr. Simaika and Professor Fathy. It is only reasonable to explore the reasoning involved in these predictions.

65. Mr. Simaika has made an excellent analysis of bed changes below the low Aswan Dam during a number of years, including several periods when partial flood reduction was accomplished by storage above Aswan. The apparent fallacy therein lies in the facts that the only data available to him were for the stream gaging station some 30 km downstream, and that the storage times involved were too short to be effective at that distance.

66. Professor Fathy utilized the tractive force formulae, deriving his limiting tractive force value from an experienced flow wherein no sediment was transported, at least in suspension. This is equivalent to basing the limiting slope on the existing bed mixture and denying the concept of selective movement with final armoring by a material comprising perhaps 10 percent or less of the original mixture. He does, in fact, express a doubt as to that concept in respect to the Nile without verification from a number of streams in addition to those few where data are available to show its occurrence. While there is certainly a divergence of professional opinion in this respect, his computations otherwise utilize generally the same procedures as used by the writer in developing the limiting condition. Professor Fathy was one of the earliest and most persistent advocates of the fact that degradation would be a serious problem on the Nile, and in consideration of the disastrous consequences which would be possible if the problem occurred before it was recognized, his efforts deserve special mention.

67. In summation of the various computations, it is believed that, if uncontrolled, degradation values on the order of those computed by Dr. Mostafa are possible. These should be considered limiting, rather than probable, values, however, for essentially all assumptions involved in a degradation analysis are conservative in nature. For example:

a. Width: A degrading channel may widen, but unless it becomes entrenched in a resistant formation it cannot be less wide. Widening of the channel would result in a smaller average depth and, thus, a steeper limiting slope.

b. Variation in bed materials: If bed material samples are inaccurate with respect to the finer fractions, the rate of degradation may be higher than computed, but the armoring material will still be present and the limiting slope will be valid. On the other hand, if the samples fail to show the coarse material actually present, a heavier armor will be available and the limiting slope will be steeper.

c. Insufficient sampling to show local areas of heavier materials: The presence of such local areas, if they do exist, will provide local controls to reduce the net degradation. They cannot increase it.

d. Inaccuracies of computation procedures: Experience at the Fort Randall project indicates that the probable errors increase with the finer sediments and decrease with the coarser particles; thus, while the initial rate of degradation may well exceed the computed values, the limiting computations are not apt to be exceeded. In this connection again, an initial computation of degradation below Fort Randall, based on a limiting slope for the original bed mixture, gave a value of 15 ft as contrasted with a value of 3 ft for a computation based on selective transport. The latter method appears to be well verified by experienced degradation at that location.

68. Other assumptions are involved, but the only one which cannot be defined as conservative is the assumption of a rectangular, rather than a V-shaped cross section. The experience available in this respect, however, indicates that the deeper sections of a V-shaped channel will have a greater form roughness associated with a lesser transport, and that an average value as assumed for a rectangular section is reasonable.

Sedimentation Investigations

Field surveys

69. There is, unfortunately, no way to determine in advance the degree to which actual degradation will approach computed values. In the case of the Nile River, the low Aswan Dam, the point at which degradation will be initiated, is founded on rock, and degradation will not be unduly detrimental except to navigation until the head differential through the

structure begins to approach the permissible maximum. This will permit some time for observation at the site to obtain data for checking analytical and other procedures.

70. It is suggested that a series of survey ranges be established and permanently marked. Ranges should be spaced approximately at 1 to 2 km for the first 5 km downstream, 5 km for the next 25 km, and 10 km thereafter to the Esna Barrage. This spacing will permit comprehensive observations in the reach in which degradation activity will be initiated, together with index observations which will permit additional intermediate ranges to be established downstream as the activity progresses.

71. All ranges should be surveyed when located, to provide firm data on conditions existing prior to closure of the high Aswan Dam. Ranges within the first 10 km should be surveyed several times at about 30-day intervals to indicate normal changes or shifts. The survey should include accurate cross sections, suspended sediment samples, and bed-material samples at each range, together with discharge and water-surface slope measurements and a profile of the thalweg of the bed. Bed-material samples should include only the top 1 or 2 in., as this is the material actually in motion at a given time, and in the event of dune formations in the bed, care should be taken that the sample is obtained at or upstream from the dune crest rather than near the toe.

72. The cross sections, discharge, water-surface slope, and bed-material samples will provide data which can be utilized in analytical procedures. The suspended sediment samples will provide data by which that portion of the computations relating to suspension, and thus by inference the remainder, can be checked. A computation procedure such as the Einstein method, which permits analysis of the movement of the various material sizes rather than mass movement, should be used. This investigation can be immediately accomplished since it requires only data for an existing situation; however, recurrent surveys after closure of the high Aswan Dam will give factual data on degradation as it occurs, and will permit extension of the computations on a time basis to check selective movement of the sediment.

Laboratory investigations

73. It has been suggested that the problem be investigated in the

hydraulic laboratory. This suggestion is pertinent; however, it must be recognized that such investigation will serve only as an aid to analytical study rather than as a model depicting the actual occurrence. A three-dimensional, movable-bed model to reproduce selective movement of the bed materials would not be feasible due to the difficulty in obtaining model bed materials even approximating the scales required. In addition, the model could reproduce only a limited river reach, and its value in representing other reaches would be no greater than that of a two-dimensional scale model.

74. The latter could be much more easily designed and operated as a flume study, inasmuch as the greater flow depths available in a flume would permit a much wider range of selection for model bed materials. The benefits of a scale study would not normally be justified, however. It would not have any particular advantage over a direct scale flume study other than that of providing a more convincing comparison to counter the argument, advanced in some quarters, that the behavior of a large stream like the Nile, particularly with respect to sediment movement, does not necessarily follow the behavior noted in smaller streams or in laboratory flumes. Under the circumstances existing, such an investigation at the Delta Barrage Laboratory would be an interesting and probably a rewarding project provided that material suitable for the model bed materials could be obtained.

75. A study of almost equal value, and one which can readily be conducted with available materials, is a flume study of selective bed movement and ultimate armoring under conditions of degradation. Essentially, the investigation would consist of introducing a clear water flow over a bed of movable materials having a normal range and distribution of material sizes. Measurements, in addition to the usual flow data (depth, velocity, and slope) would include vertical velocity distribution, suspended sediment quantities, sizes, and distribution, and quantities and sizes of material moving as bed load. Each test would run, at constant discharge and slope, until an armor layer formed to inhibit further material movement, at which time samples would be taken of the bed surface and of the bed to depths representing several increments of size of the surface armoring material in order to analyze the armor formation. These data would then be applied

to various transport formulae to check and verify the use of the formulae in degradation computations.

76. The test should be repeated for several increments of slope, discharge, and bed-material mixtures, and observations should be made of the forms of bed-material movement as an adjunct to the understanding of the problem. One or more runs representing a normal hydrograph rather than a constant discharge could be made, primarily as an illustrative test, but the major benefit would be by observation of the bed through a glass-walled flume, and by intermittent sampling of the bed to demonstrate the selective and progressive movement of materials with the varying flows.

77. There has been, insofar as the writer is aware, only one prior flume study of degradation. This was accomplished, under a contract of the U. S. Army Engineer Division, Missouri River, with the University of California at Berkeley, by Mr. A. S. Harrison. Only a limited number of copies of the report on this work were published, and copies are no longer available from the Missouri River Division; however, the investigation demonstrated the principle of selective movement and final armoring, and the data confirmed analytical processes utilizing the Einstein formula.

78. The study recommended above for the Delta Barrage Laboratory would duplicate, to some extent, Mr. Harrison's work, but it is believed to be advisable always that a single investigation of any given type be checked by a further independent study. In any event, the Nile River project would involve materials of much smaller sizes, would work directly with Nile River material, would provide experience to engineers directly concerned with the Nile, and would add appreciably to the stature of the Nile River analyses.

79. It is suggested that this study be complemented by, and preferably preceded by, a series of flume tests utilizing a completely recirculating flume to establish transport characteristics of the Nile River bed material under balanced transport conditions with varied flows.

PART V: SUMMARY

80. The work of the Hydraulic Research and Experimental Station at the Delta Barrage is important to the welfare of the United Arab Republic (Egypt) and will become more so upon completion of the high Aswan Dam, the modernization of navigation facilities, and with increased irrigation demands. Although the caliber of the staff of the laboratory is being continually improved through training programs offered to engineers, the employment of a full-time technical assistant, especially in the sedimentation field, is desirable. No one on the present staff has had practical experience in the conduct of full-scale degradation investigations on the Nile River and sediment research studies in the laboratory. Degradation problems will arise upon closure of the Nile River by Aswan Dam scheduled for next May, and work should begin immediately toward the development of solutions. The staff has some knowledge and experience on the conduct of hydraulic river models, although additional training is desirable. Procurement of more detailed field information with which to insure accuracy of model results also is indicated.

81. It is recommended that the following assistance, listed in order of priority, be given by the Ministry of Public Works, subject to the availability of funds.

- a. Training of engineers of the laboratory at schools and government agencies of the United States and elsewhere with emphasis on sediment studies, both laboratory and field, and river hydraulics.

- b. Procurement of a full-time technical assistant experienced in practical and laboratory sedimentation research for a period of two years. If it is not possible to procure a single individual, use of one or more consultants at periodic intervals should be considered.

- c. Procurement of equipment for field surveys such as a survey boat, echo sounder, and suspended and bed-load samplers.

- d. Completion of walls of the existing shelter in the North Test Field.

- e. Conversion of two flumes to be completely recirculating with provisions for measuring total sediment load.

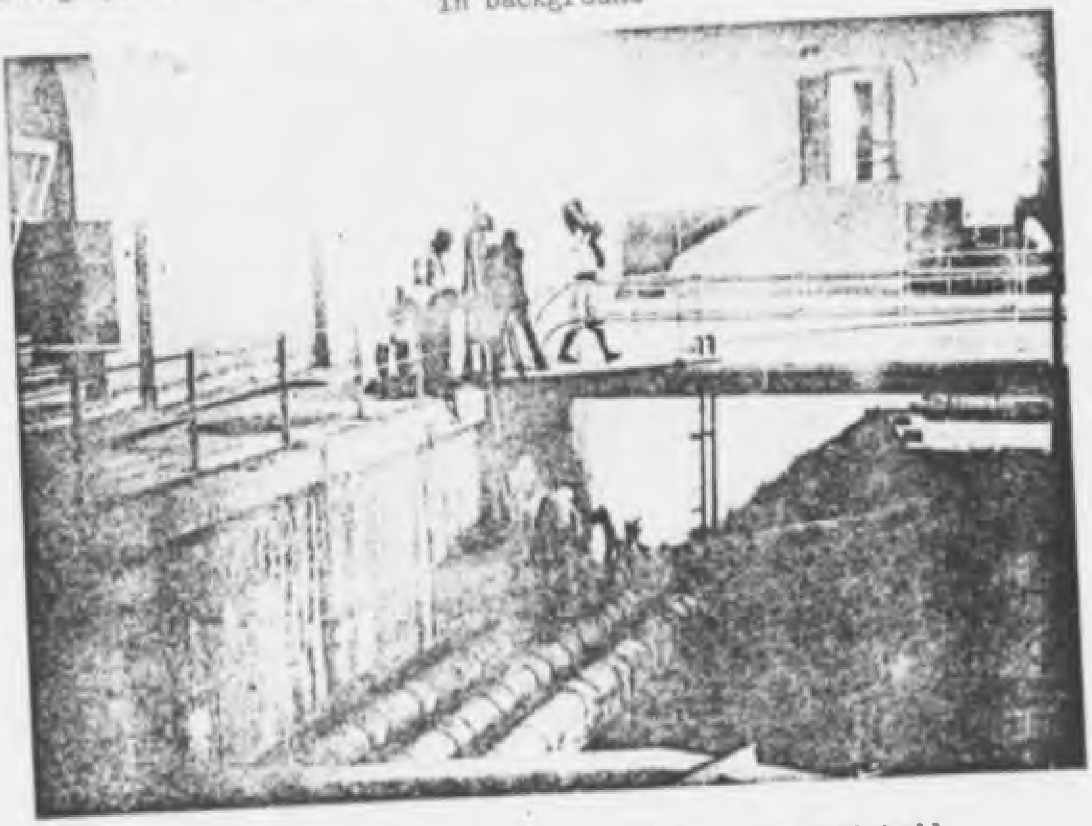
- f. Procurement of electronic laboratory equipment (basic components) such as linear potentiometers, accelerometers, pressure cells, and strain gages, together with necessary recording equipment.

g. Construction of proposed new test shelter for model work in area to west of present administration building.

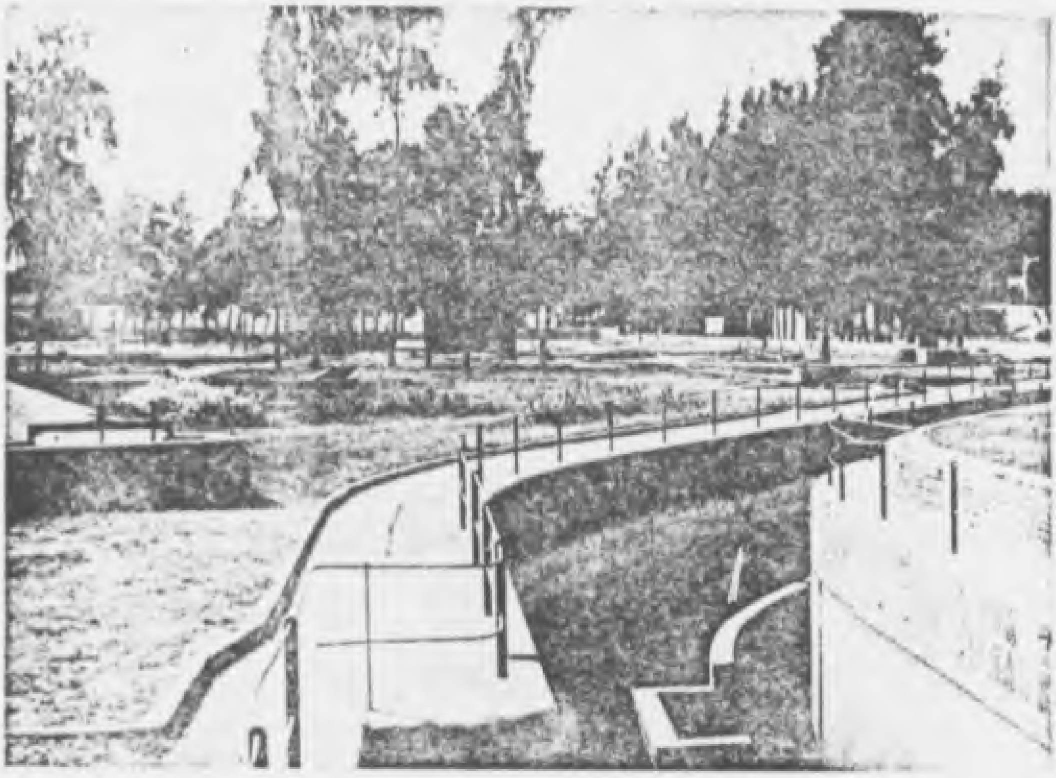
h. Procurement of equipment for plastic shop and replacement of existing worn shop equipment

These items will probably require a five-year program, although items a through c should be accomplished during the coming year if possible.

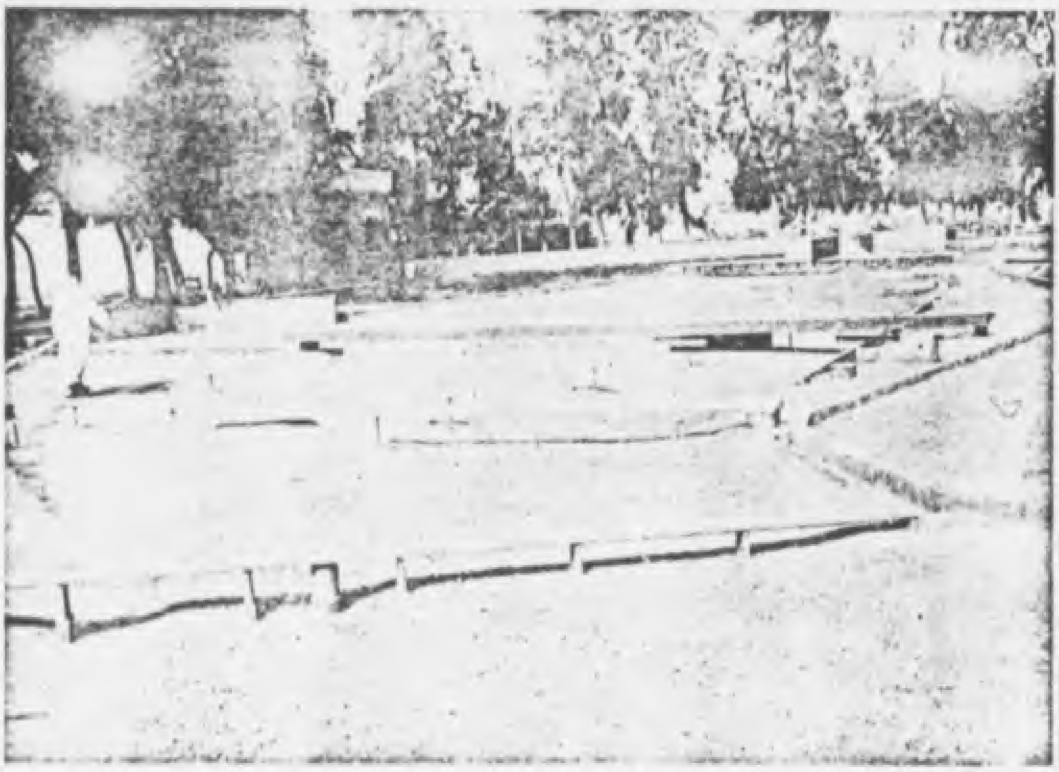
Photograph 1. View of experimental hall with administration building in background



Photograph 2. Interior view of experimental hall



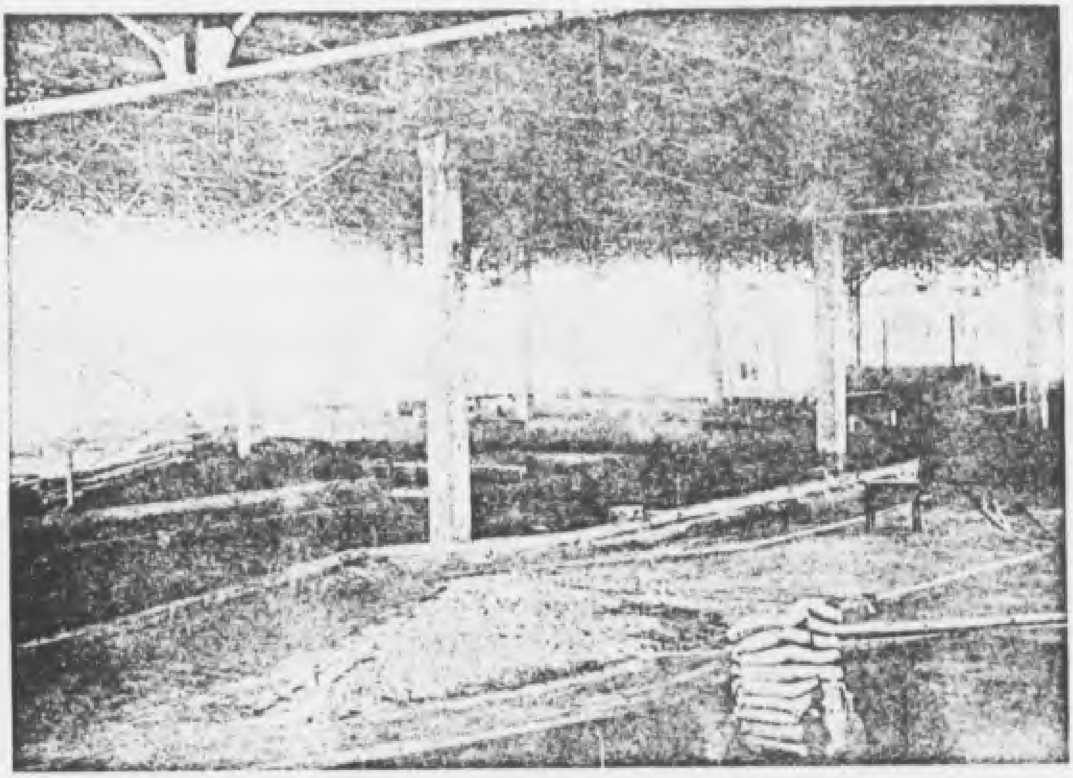
Photograph 3. View of South Test Field from administration building



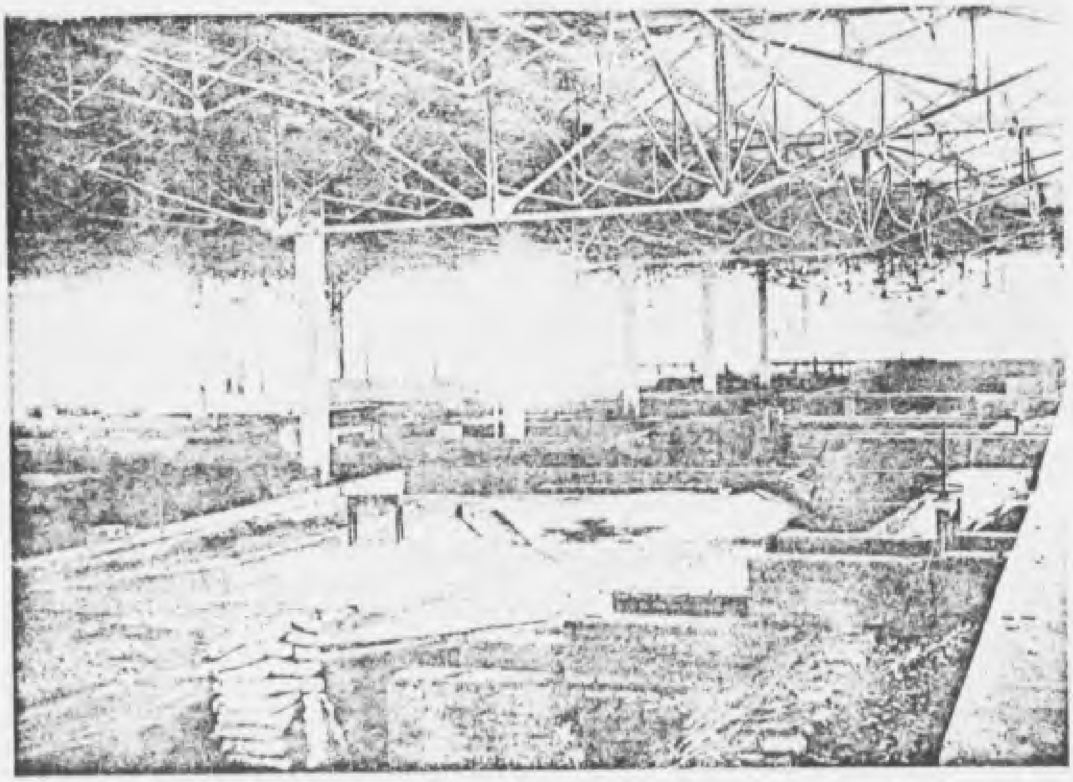
Photograph 4. View of river model in South Test Field

NOT REPRODUCIBLE

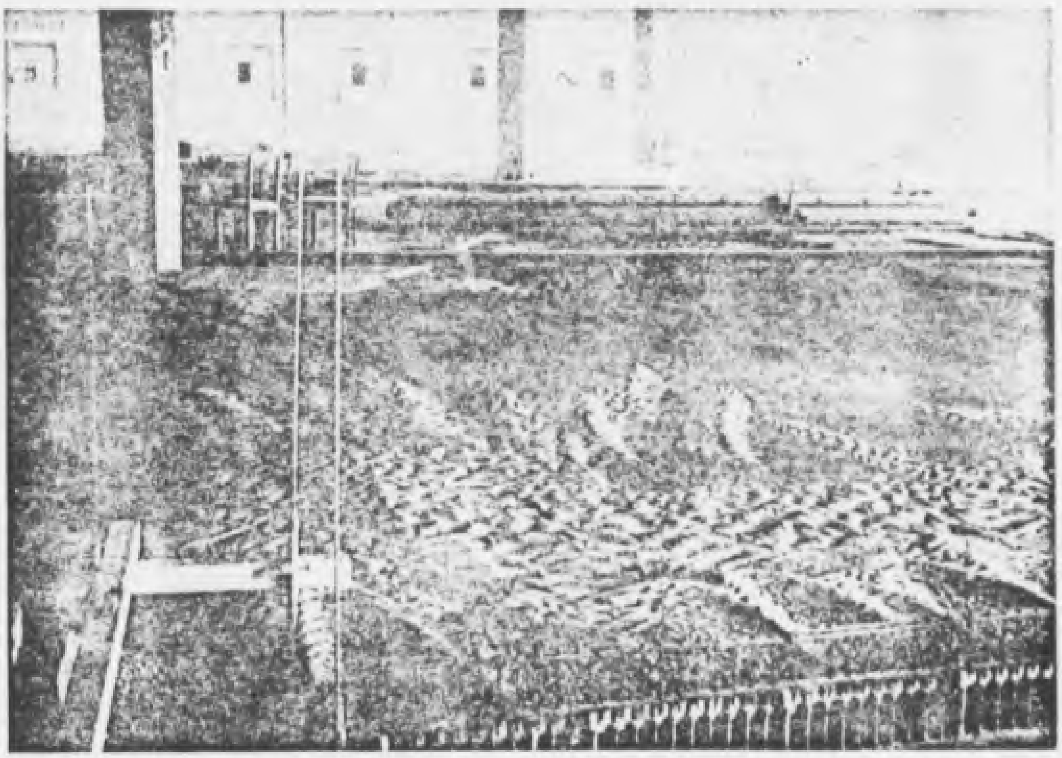
Photograph 5. View of South Test Field looking toward administration building



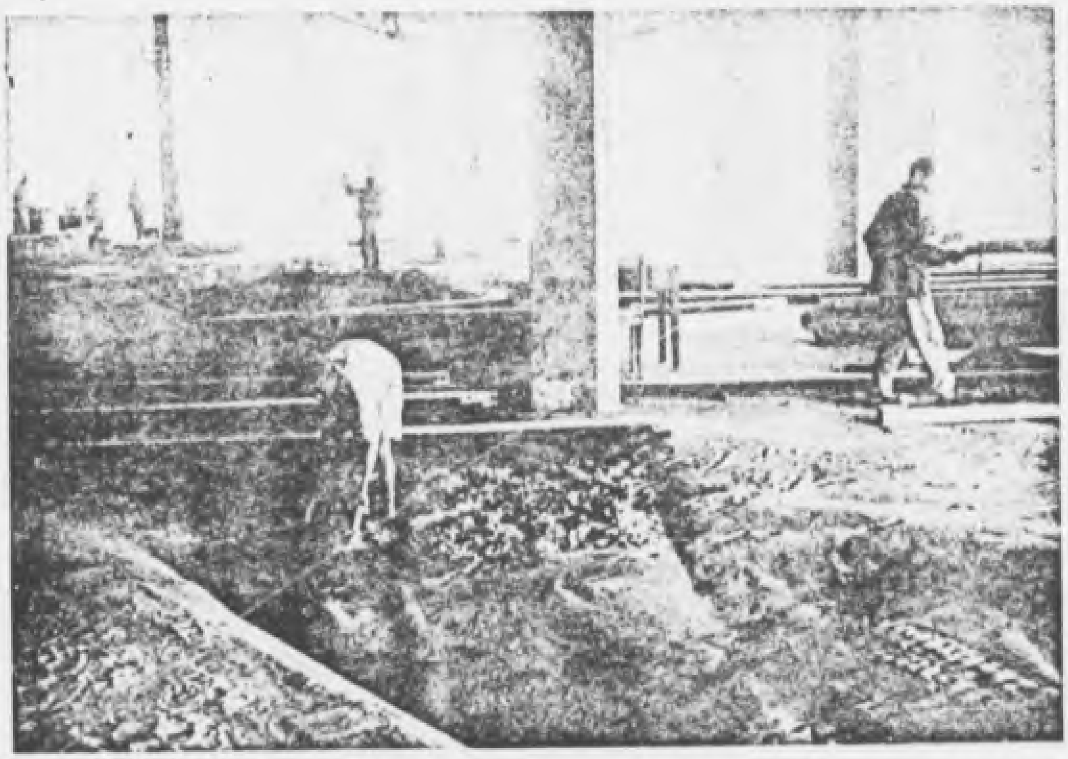
Photograph 6. Models within shelter on North Test Field



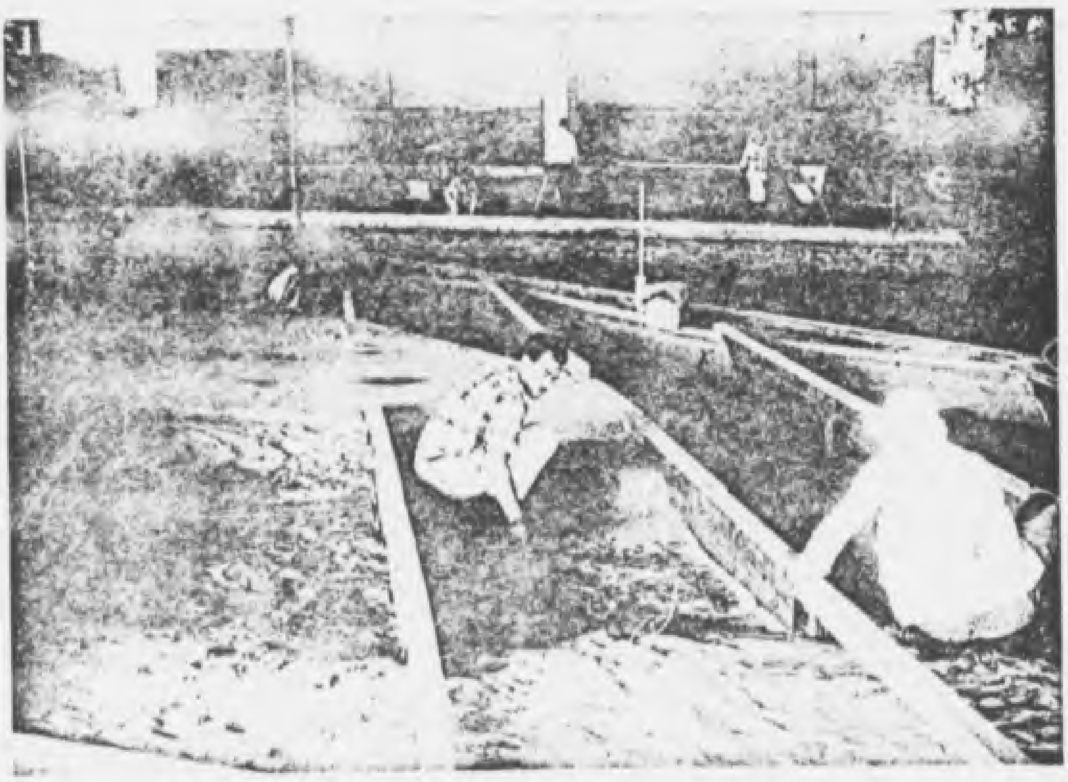
Photograph 7. Models within shelter on North Test Field



Photograph 8. Movable-bed model within shelter covering the North Test Field

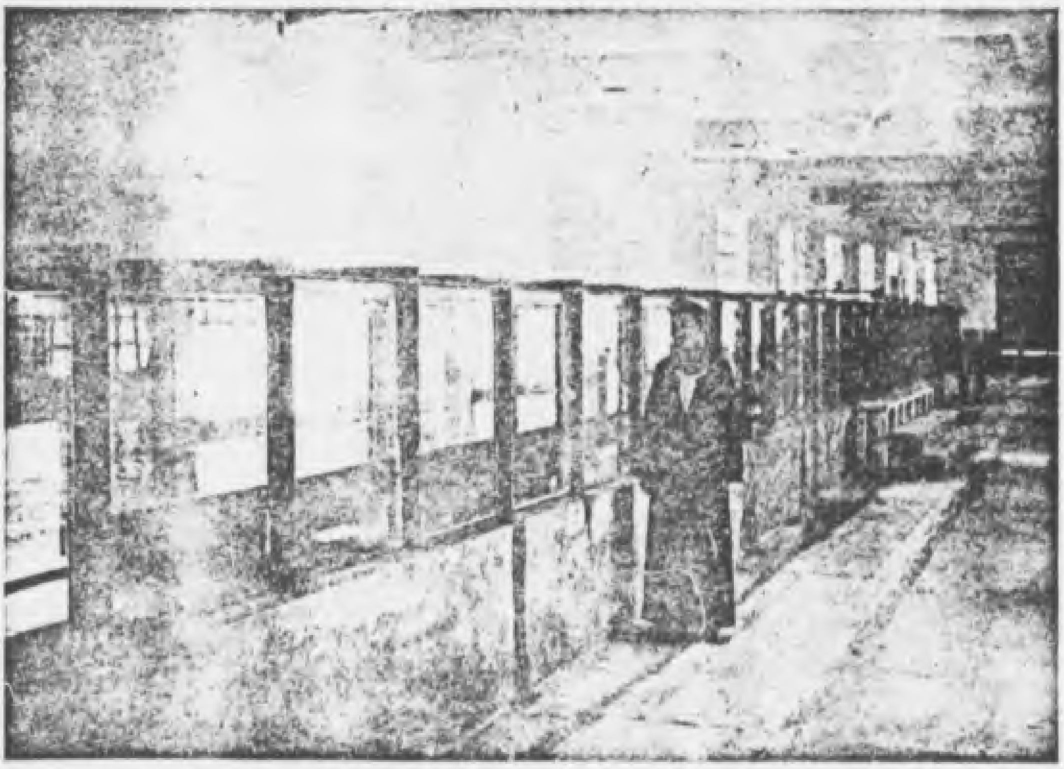


Photograph 9. Workers molding movable-bed model

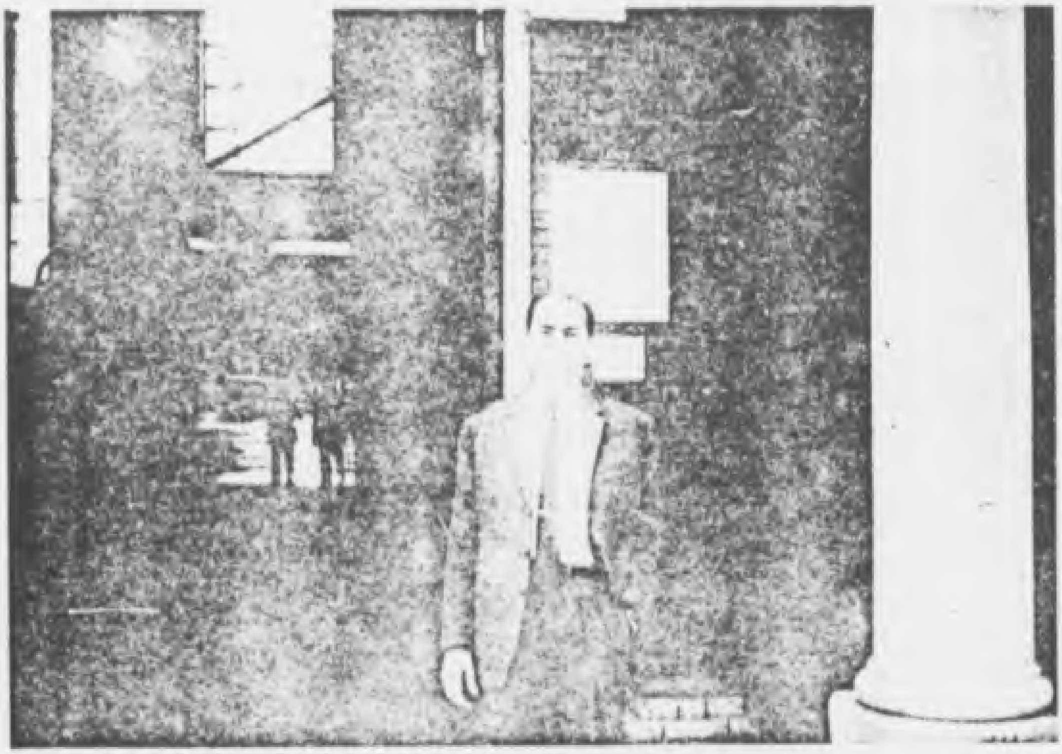


Photograph 10. Molders shaping Nile River sand to sheet metal templets

Photograph 11. Typical model construction crew



Photograph 12. Glass flume in the new flume hall



Photograph 13. Eng. Ahmed Ali Eldarwish, Director

Photograph 14. Staff of the Hydraulic and Experimental Station with Corps of Engineers representatives

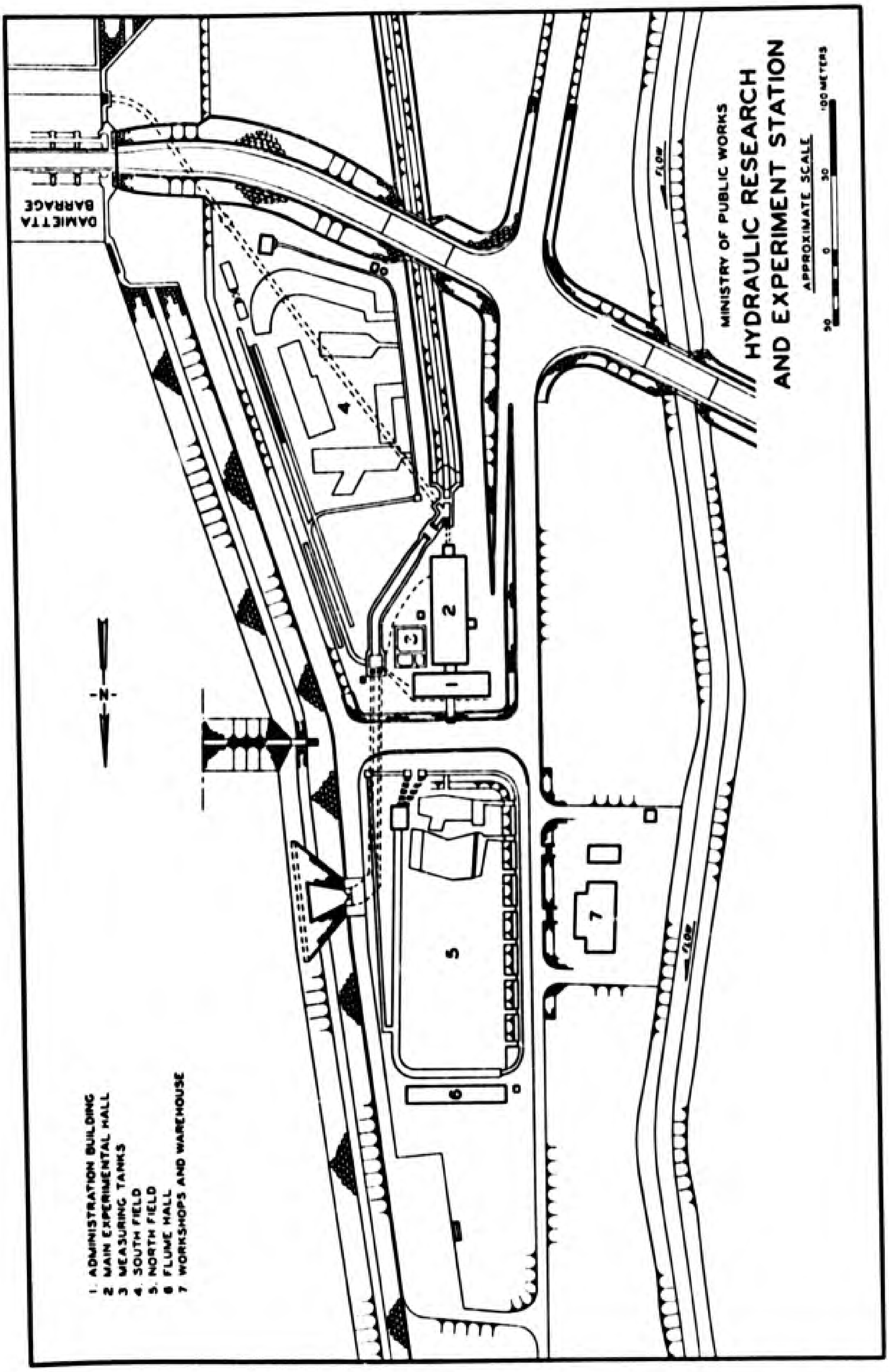

MINISTRY OF PUBLIC WORKS
HYDRAULIC RESEARCH
AND EXPERIMENT STATION
APPROXIMATE SCALE
50 0 50 100 METERS
1. ADMINISTRATION BUILDING
2 MAIN EXPERIMENTAL HALL
3 MEASURING TANKS
4. SOUTH FIELD
5. NORTH FIELD
6 FLUME HALL
7 WORKSHOPS AND WAREHOUSE
DAMIETTA BARRAGE
N
FLOW
FLOW

PLATE I

APPENDIX A: CURRENT PROJECTS

Main building

1. Aswan Hydro-Electric Power Project (Low Dam). Studies have been completed on a 1:50-scale model of the four tunnels to study the effect of tunnel linings upon the total head loss and losses at the inlet and outlet. Current thoughts are that the tunnel liners should be omitted. The tunnels are curved in plan (similar to those of Fort Peck Dam), are uncontrolled, are D-shaped although the cross-sectional area is enlarged at the downstream end. Destruction of the model was completed during our tour of duty.

2. Improvement of the manufacture of irrigation water wheels "Tanabish."* Variables under investigation include the shape of buckets or vanes, lift, and motive power. The California pipe method for measuring discharge is being used. Efforts had been made to record photographically the flow phenomena during operation.

South field

3. River training at the intake of Damietta Branch.* A 1:75-scale undistorted model, with fixed bed, is being used to study the distribution of flow into the Damietta and Rosetta Branches of the Nile. Currently, about 80 percent of the flow is being passed through the Rosetta Branch. Erosion of the head of El Shicar Island, separating the two branches, also is a problem. Verification of the model is in progress. However, the model is so large and wind effects on model surfaces are such that problems are being encountered. Overall length of the model is about 75 m (250 ft). Verification problems also are being encountered because the model surfaces are too rough.

4. Kafr Elzayat Bend.* A 1:70-scale model with a fixed bed is being used to develop a system of dikes which will shift the main river channel to such an extent that scour around the piers of two bridges crossing the river will be reduced. It is doubtful whether a fixed-bed model or the training works proposed will accomplish the purpose of the model. The shifting of the channel is such that only a movable-bed model can provide a qualitative answer as to whether the training works are accomplishing

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* Active studies.

the desired effects. Problems downstream from the bridges still will be encountered because of the sharpness of the bends. Some protection of the right bank from caving probably will be required.

5. Parshall flume.* A 1:10-scale model of the Parshall flume is under study to effect improvements in design for both free and submerged conditions. Variations of the downstream portion of the walls of the flume and in the slope of the bottom hump are under investigation.

6. Irrigation structure.* A vane-type irrigation structure for control of flow from one irrigation channel to another is under investigation. Vibration of the vanes because of unequal forces on the sides of the vanes is a possibility. No scale model is considered, as the results are to be applicable to many sizes of irrigation structures.

Sedimentation studies

7. Flume studies of silt movement. A wood and glass flume about 45 cm wide by 60 cm deep by 39.3 m long was made to study the effect of the interception of silt in the high Aswan Reservoir upon the Nile River downstream of the dam. The model was inactive as Mr. Hassan W. W. Aly, who had been conducting the study, was in the United States for training. This flume is located in a shelter constructed for the purpose, and has its own circulating system with water being supplied directly from a constant head tank and wasted into a sump.

North field

8. Wurno Irrigation Scheme in Nigeria.* A distorted model to scales of 1:600 horizontal and 1:15 vertical is being used to study the relocation of levees and construction of a rock spillway in the ridge to the northeast of a reclaimed area. Whether any difficulties are being experienced by the high degree of distortion (40:1) is unknown.

9. Glass flume. A steel flume with a glass side panel about 45 cm wide by 30 cm deep by 20 m long had just been completed. Apparently the flume was used for the first time for the preliminary tests to study movement of Nile River sand proposed by Corps of Engineers representatives.

10. Aswan Dam (low). A 1:100, undistorted scale model was being used to study downstream conditions. Material to be excavated from the outlets

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* Active studies.

of the power tunnels was to be deposited in the Nile without raising water levels to any extent. Model tests indicated, and were supported by field tests, that material could be deposited without an appreciable increase in stage height (30-45 cm). The model was removed during the week of 26 May.

11. Scour around bridge piers. Research was concerned with the effect of the angularity of the piers on the resulting scour. A sand bed was being used. No tests were being conducted.

12. Improvement of water wheels "Tanabish." Additional studies of the water wheel, similar to those being conducted in the main building, were under way. No active tests were noted.

13. Ibrahima Canal. Studies of a canal to reduce cross-sectional area by use of spur dikes were under way. Velocities through the reach were desired which would maintain the channel depths without silting.

14. River training D. S. Nag Hamadi.* A distorted-scale model (horizontal 1:150, vertical 1:50) with a movable bed is being used to study training works required below an existing barrage to divert the channel to the right of Dome Island where it now goes to the left. In order to obtain bed movement, it was necessary to add excessive supplementary slope. This was accomplished during the final days of the visit of the Corps of Engineers representatives, so it is not certain that the movement was either general or representative. It may be necessary to rebuild the model to a greater distortion or to use a lighter weight bed material.

15. Karinein Diversion Channel. The study is complete and the model partially dismantled. A 1:50-scale, undistorted model was used to study diversion of flow from the main channel into a diversion channel.

16. Aswan Dam sluices. Studies had been completed on a model of the existing sluices in the low dam to determine coefficient data when the sluices were discharging in a free, submerged or transition stage condition.

17. Pump intake study.* A new model has just been placed in operation to investigate the silting of intakes at a pumping station on the Nile River. This model has scales of 1:150 horizontal and 1:75 vertical, and has for its purpose the realignment of the main river channel to prevent silting.

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* Active studies.

18. New model.* Construction of a new model of a reach of the Nile River about 15 km upstream from Cairo was started on 26 May. This model has for its purpose the elimination of silting in a diversion canal.

19. Scour below a barrage.* These tests are a continuation of some started a year ago, and have for their purpose the study of the effect of the slope of the upstream face of the sill on scour below the barrage.

New hall for flume studies

20. Gate study.* A gate study is being conducted on a section model at a scale of 1:20. The model is located in a glass flume 1 m by 1 m by 28 m. Possible vibration of the gate is feared due to submergence and the roller action created by the tailwater downstream. The gates are of plastic mounted on roller bearings to reduce friction to a minimum. Self-recording float gauges are being used to record head and tailwater elevations. Studies of vibration of gate hoist cables and scour below the sill also are under way.

* Active studies.

APPENDIX B: INSTRUMENTATION

1. The following items of equipment are described in detail in a report prepared by Mr. Ahmed Ali Eldarwish after a visit to the hydraulic laboratories at Wallingford, England, and Delft, Holland. Only the items described are listed together with comments of the Corps of Engineers' representatives concerning each piece of equipment and its application to laboratory use.

Flowmeters

a. Miniature, liquid flowmeter with automatic recording equipment. This is a good piece of equipment and could be used to advantage in any hydraulic laboratory. The individual gauge wheels could be used for visual as well as automatic recording.

b. Automatic curve reader. This is an excellent piece of equipment for use in operating tidal models. The French engineers in the laboratory at Chatou have developed this equipment to a greater extent than the device described in the report.

c. Magnetic flow-measuring device. This is an excellent device for accurate measurement of flow, but is very expensive; the cost increases rapidly as the size of device increases. The report discussed procurement of one device for 4-in.-diameter pipe. The range of flow measurement possible would be 0-50 liters per sec (0-1.8 cfs) and the cost would be about 2,500 Egyptian pounds ($5,880).

d. Ott laboratory current meter. This type of current meter is good.

e. Miniature current meter, Wallingford Laboratory. The miniature current meter in use at Wallingford would probably be of more general use at the Delta Barrage Laboratory than the meter described in a above. However, efforts would have to be made to keep the model water as clean as possible to prevent interference from debris.

Other devices

f. Bed level plotter. The cost of a bed level device is in the neighborhood of about 10,000 Egyptian pounds ($23,500), which is too costly for general model use. Manual procedures are usually sufficiently accurate for the purpose. The bed level plotter was developed at the Wallingford Laboratory.

g. Sonic depth sounder for laboratory and field use. This is a device which is useful only if research on bed roughness as affected by bed movement is being conducted. For the ordinary river model, only measurements of average bed surfaces are desired. The sonic depth recorder was developed at the Fort Collins, Colo., laboratory.

h. Sediment samplers. Devices for procuring samples of bed load and material in suspension are generally necessary for field observations only. See recommendations for sediment research and possible development of a sampler for flume use.

2. Other instruments listed in Mr. Eldarwish's report as being in use at the Wallingford Laboratory are:

a. Automatic water-level recorders with transmitters of various types

b. Volumetric tank point gauge

c. Depth meter for field use

d. Current meter rating tank

e. Wave recorder, float operated and of the twin wire type

f. Wave-height analyzer

g. Model tide recorders and tide controls

h. Manometer recorders

i. Constant level devices