PN-ABX-006
967-55

ECONOMIC AND TECHNICAL

FEASIBILITY STUDY

FOR

BRIDGE AND DAM

ACROSS COTONOU LAGOON

COTONOU, DAHOMEY
WEST AFRICA

Prepared for

DEPARTMENT OF STATE
AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D.C.

by

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APRIL 1972

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May 1, 1972

Mr. Albert P. Disdier, Director
Office of Capital Development & Finance
Bureau for Africa
Department of State
Agency for International Development
Washington, D. C. 20523

Dear Sir:

We are pleased to forward to you, herewith, the completed Economic and Technical Feasibility Study for Bridge and Dam across the Cotonou Lagoon, Cotonou, Dahomey.

This report contains the details of in-depth studies made in accordance with the scope of work required by our contract AID/afr-724.

The results of the studies clearly indicate that a new four-lane bridge, located near Boulevard Saint Michel, is needed to alleviate extremely congested traffic conditions. The studies also show that a dam, located near the lagoon mouth, will provide an effective protection against erosion in the lagoon as well as enable to considerably reduce the intrusion of sea (and therefore also salinity) into Lake Nokoue.

Even when the potential benefits to the fishing in Lake Nokoue are disregarded, and only vehicle operating savings and erosion reduction are considered, the benefit/cost ratio for the recommended construction (bridge with dam) is still high. The cost of the dam is also amply justified when its cost is compared to fishing benefits alone.

As requested by letter, from WARCDO Abidjan, the contingency item in the construction estimates has been increased to 20 percent.

It has been a pleasure to work for A.I.D. on this project and we look forward to have again an opportunity to be of service.

Very truly yours,

SANDERS & THOMAS, INC.

Abraham Perera

Abraham Perera, P. E.
Assistant Vice President

AP/dke

ACKNOWLEDGEMENTS

The success of this study would not have been possible without the cooperation and the expertise of many persons.

The project team of Sanders & Thomas, Inc. wishes to express, herein, their appreciation to officials and staff of the various public and government agencies in Cotonou for their assistance:

Ambassador Matthew Looram and Staff - U.S.A. Embassy, Cotonou

Mr. V. Gbaguidi	-	Director, Department of Public Works
Mr. F. Achade	-	Chief of Services, Highways and Bridges
Mr. E. Paraiso	-	Director of Hydraulic Services
Mr. L. Akpovi	-	Ministry of Plan
Mr. R. Agnamey	-	Director of Topographic Service
Mr. F. Monteiro	-	Urbanism and Habitat Service
Mr. B. Bidouzo	-	Ministry of Economic Affairs
Mr. E. Azandegbe	-	Director, Department of Fisheries
Mr. R. L. Welcome	-	United Nations, Aide to Department of Fisheries
Mr. C. Couratin	-	Chief of Delegation, B.C.E.O.M.
Mr. R. Lacroix	-	Director of Autonomous Port of Cotonou
Mr. J. P. Aste	-	Chief of Laboratory, L.N.B.T.P.
Mr. P. Fourn	-	President of the Cotonou Chamber of Commerce

The enthusiasm and the efforts of the staff of Service Topographique and Service de l'Hydraulique, who worked in the field with the Sanders & Thomas team, as well as the excellent work of some 40 local personnel, who helped with the traffic counts, is also gratefully acknowledged.

The team of Sanders and Thomas, Inc. consisted of the following:

Mr. A. Perera	-	Project Engineer
Mr. G. Beierling	-	Traffic Engineer
Mr. M. Bessalel	-	Hydraulic Engineer
Mr. N. Gerber	-	Urban Planner
Mr. J. Toth	-	Bridge Engineer

Mr. Robert Busenburg was a special consultant to Sanders and Thomas, Inc. for Transportation Economics.

Last but not least, appreciation is expressed to the Dahomean people, whose freindliness and warmth helped to make the visit and work in Dahomey a pleasurable and a happy experience for the Sanders & Thomas team.

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SECTION I

SUMMARY OF FINDINGS AND RECOMMENDATIONS

A. TECHNICAL FEASIBILITY STUDIES

1. Cotonou City Planning

Cotonou has developed at a relatively rapid pace since the completion of its deep-sea port in 1959. As the best and most direct link to the world markets, for both Dahomey and Niger, the Port of Cotonou has played an important role in the economic growth of Cotonou. At present, there are some 40 industrial establishments in Cotonou and at least 23 more are being planned to locate there in the near future. Several new large regional developments are likely to have a strong influence in the future growth of Cotonou. Among them are the recently discovered limestone deposits near Onigblo and the offshore drilling for petroleum near Porto-Novo.

Cotonou is estimated to triple its size from the present population of 150,000 to a population of 450,000 in 1996. This will require that Cotonou develop all its available areas within city limits as well as those areas beyond city limits adjacent to Lake Nokoue. An expansion towards the northern areas of Cotonou is therefore essential. In recognition of this, the Cotonou City Master Plan recommended that a new bridge, a large central market, and a new City Hall be constructed near the lagoon in the vicinity of Boulevard Saint Michel.

For the purpose of predicting the rate of growth of various city zones, an analysis was made of residential densities and land uses within Cotonou. The potential factors aiding or inhibiting the growth of each zone have been related to transportation needs of people and goods across the lagoon in order to evaluate the relative merits of two bridge alternatives.

2. Traffic

A detailed traffic survey was made at Cotonou bridge in November of 1970. The collected data included volume counts and origin-destination survey by vehicle categories. Separate counts were made on a weekday, market day, and a holiday. From the results of these counts, a base 1970 traffic data were established. Time series for determination of future traffic growth rates have been obtained for the years 1960 to 1970 from available traffic records of the Ministry of Public Works in Cotonou. The 1970 average daily traffic by traffic categories and the average probable growth rates are as follows:

	1970 Average Daily Traffic	Probable Growth Rate
Passenger Cars, Taxis and Light Trucks	10,400	6.0%
Buses	640	5.0%
Trucks (over 2 tons)	1,650	5.0%
Motor Bicycles	8,200	8.0%
Pedal Bicycles	9,000	8.0%
Pedestrians	11,400	4.5%

The above growth factors were modified for each city zone in relation to its potential growth. All growth rates have been reduced to 75% of the initial rate in the last 10 years of the study period. The resulting average daily traffic was as follows:

	1970	1977	1987	1996
Passenger Cars, Taxis, etc.	10,400	15,694	28,934	45,461
Buses and Trucks	2,290	3,161	5,078	7,285
Pedal and Motor Bicycles	17,200	29,783	71,816	149,621
Pedestrians	11,400	15,845	28,152	47,710

In addition to the bridge traffic, a survey was made of the boat traffic in the lagoon. The number of passengers crossing the lagoon was as follows:

Market Day	10,585
Weekday	4,364
Holiday	2,200

Speed, delay and capacity studies revealed the following for the existing Cotonou bridge (in terms of equivalent vehicle units per hour):

Practical capacity (with no delays)	1,800 EVU
Maximum capacity (with 3.5 minutes average delay)	2,500 EVU

The average speeds across the bridge and in various areas of Cotonou have been observed at various traffic densities. At practical capacity on the bridge, the average speed was 8 k.p.h.

Factors were derived to determine the proportions of the traffic which would use the new bridge at Boulevard Saint Michel. These diversion factors vary from 1977 to

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1996. Initially (in 1977), only drivers from zones nearest to Saint Michel would use the new bridge. Later, as the congestion at the existing bridge increases, drivers from other zones would also divert to Saint Michel bridge.

The following tables show the distances between zones via each bridge and the traffic distribution in 1977 and 1996 (see map in Appendix A, page A-1.):

Zonal O-D	Distance (Km) A	B
1-5	2.0	5.3
1-6	2.4	3.4
1-7	3.3	4.0
1-8	3.6	5.7
1-9	7.2	9.2
2-5	4.9	6.9
2-6	5.4	5.3
2-7	6.2	5.7
2-8	6.5	7.4
2-9	10.1	10.8
3-5	3.5	4.2
3-6	4.0	2.6

Zonal O-D	Distance (Km) A	B
3-7	4.8	3.0
3-8	5.1	4.7
3-9	8.6	8.2
4-5	4.0	4.4
4-6	4.6	2.9
4-7	5.4	3.2
4-8	5.6	4.9
4-9	9.2	8.4
5-10	8.4	8.1
6-10	9.0	6.5
7-10	9.8	6.9
8-10	10.1	8.6
9-10	13.6	12.1

A = distance via existing bridge.
B = distance via Saint Michel bridge.

	1977		1996	
	C	D	C	D
Passenger Cars, Taxis, etc.	9,807	5,887	21,285	24,176
Buses and Trucks	1,859	1,293	2,626	4,696
Pedal and Motor Bicycles	17,327	12,456	53,776	95,845
Pedestrians (incl. boatpass.)	10,749	5,095	25,176	22,533

C = traffic volume via existing bridge.
D = traffic volume via Saint Michel bridge.

With the volume of traffic as shown for 1996, both bridges will begin to be congested and therefore, a third bridge across Cotonou Lagoon will become necessary.

3. Subsoil Exploration

Review of previous subsoil exploration data and the results of the dynamic penetrometer tests near the Boulevard Saint Michel bridge site indicate that a pile supported substructure for the bridge is feasible. A maximum settlement of approximately 3 centimeters is anticipated for the bridge.

The data obtained from a single core boring near the site of the proposed dam reveal a deep compressible clay stratum. A settlement of 30 to 50 centimeters is anticipated for the dam. This problem will be overcome through appropriate construction procedures explained in Section V.

4. Hydraulic Studies

Theoretical hydraulic studies by Sanders & Thomas, Inc., based on previous data and mathematical model studies of SOGREAH Laboratory of Grenoble, France, indicate that the proposed dam will reduce sufficiently the velocity of flow during flood conditions to eliminate the erosion in the lagoon.

Sanders & Thomas, Inc. studies indicate also that the tidal inflow into the lagoon will be reduced by the proposed dam to less than 10% of the present volume. Consequently, it is to be expected that salinity also will be reduced to sufficiently low levels to eliminate the terredos in Lake Nokoue.

With the terredo and the erosion problem eliminated, it is hoped that the former ecological and fishing conditions in Lake Nokoue will be restored.

5. Existing Bridge

The existing bridge is essential to the lagoon crossing traffic in Cotonou. Its useful life, however, is limited to approximately only 10 more years. In order to prolong the usefulness of the existing bridge, additional repairs are recommended. The necessary additional repairs of the bridge substructure, funded by FAC, have been completed in part. The remaining repairs are expected to be completed by 1974.

The repairs of the bridge deck are included in the work to be done in the new bridge and dam construction contract. Included in the repair work is the reconstruction of the concrete deck, new wider sidewalks, new lighting system, and the painting of the bridge girders.

6. Proposed New Bridge and Approach Roads

Two alternatives were considered for a new bridge across the Cotonou Lagoon. They consisted of either a parallel bridge next to the existing one, or a bridge near Boulevard Saint Michel.

The parallel bridge was planned to be only two lanes wide, while the Saint Michel bridge required four lanes. The reason for this choice was the fact that the approaches at the existing site could not function as more than four lane roadways. Thus, the combination of the existing and the new bridge needed not to have more than four total lanes. With a new bridge located at Boulevard Saint Michel, it is possible to provide a total of six lanes crossing the lagoon--four at Boulevard Saint Michel, and two at the existing bridge.

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The approach roads for the Saint Michel bridge are longer than those at the parallel bridge. They are planned to be constructed four lanes wide. Their total length is 1.7 kilometers.

The remaining 7.6 kilometers of approach roads connecting the Saint Michel bridge to the International Route No. 11 will be constructed as a two lane roadway with FED funds.

7. Proposed Dam

The primary function of the dam will be to prevent the erosion in the Cotonou Lagoon but at the same time the dam will help to reduce the salinity in Lake Nokoue.

The dam will consist of a sand and rock fill, 3 meters wide at the top and having side slopes of 2 on 1. The rock material for the proposed dam will be quarried at Dassa-Zoume, approximately 155 kilometers to the north, and will be transported to Cotonou by OCDN railroad. The sandfill will be obtained from the sandbar near the lagoon mouth.

8. Other Erosion Control Alternatives

A rock mat placed under the new bridge has been considered as an alternate method of protecting the bridge foundation against erosion. While considerable cost saving is thus achieved (as compared to the cost of a dam), no benefits are possible with respect to the fishing in Lake Nokoue and the time for construction of the bridge is increased by seven months due to the fact that construction must be interrupted during the flood season.

9. Project Scheduling

The final design for the recommended improvements will require 12 to 18 months. The letting of contract will require a minimum of six months. The construction is estimated to take 24 months. The final design should begin no later than in January of 1973 if the proposed construction (with the exception of the existing bridge repairs) is to be completed by January of 1977. To meet this target date, it will also be necessary that the construction of the dam be completed before the flood season of 1975. With the dam in place, waterborne construction operations will be possible through the flood season, and thus the remainder of the work could proceed without interruption. If an accelerated schedule is adopted for final design, it may be possible to complete the construction by January, 1976.

10. Summary of Costs

The costs have been estimated for both the American and Foreign procurements. For American procurement it was assumed that most materials other than gravel, sand and rock will be imported from U.S.A. For Foreign procurement it was assumed that

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only materials and equipment not available locally would be imported. The costs include contingencies, design and construction supervision (1.00 US Dollar = 270.00 Fr. CFA).

Description of Construction	Costs (Millions)			
	American Procurement		Foreign Procurement	
	Fr. CFA	U.S. Dollars	Fr. CFA	U.S. Dollars
Repairs of Existing Bridge	148.7	0.55	142.2	0.53
Parallel Bridge	715.0	2.64	546.0	2.02
Parallel Bridge Approaches	38.6	0.14	41.9	0.16
Saint Michel Bridge	1,000.2	3.70	849.4	3.15
Saint Michel Bridge Approaches*	172.9	0.64	203.0	0.75
Erosion Protection (Rock Mat)	150.1	0.56	143.4	0.53
Dam	576.0	2.13	508.8	1.88

* Additional 180 millions Fr. CFA, to be funded by FED, for 4.9 km of two-lane road are included in the economic analysis.

Description of Construction	Costs (Millions)			
	American Procurement		Foreign Procurement	
	Fr. CFA	U.S. Dollars	Fr. CFA	U.S. Dollars
Recommended Construction:				
Repairs of Existing Bridge	148.7	0.55	142.2	0.53
Saint Michel Bridge	1,000.2	3.70	849.4	3.15
Saint Michel Bridge Approaches	172.9	0.64	203.0	0.75
Dam	576.0	2.13	508.8	1.88
Total	1,897.8	7.02	1,703.4	6.31

B. ECONOMIC FEASIBILITY STUDIES

1. Economic Alternatives and Expected Benefits

The alternatives considered for the economic justification of the project are tabulated below:

ALTERNATIVES	COST	EXPECTED BENEFITS
(A) No improvements	(a) Repairs of Existing Bridge Deck (b) Repairs of Existing Bridge Abutments (c) Maintenance Bridge Foundation (d) Maintenance - Existing Bridge Approaches	None

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ALTERNATIVES	COSTS	EXPECTED BENEFITS
(B) New Parallel Bridge (Without Dam)	Same as (a), (b), (c), and (d) above (e) New Parallel Bridge (f) Parallel Bridge Approaches (g) Parallel Bridge Foundation Protection	1. Reduction in congestion delays at the two bridges.
(C) New Parallel Bridge (With Dam)	Same as (a), (b), (d), (e), and (f) above (i) Dam (j) Loss of Shrimp Harvest	1. Reduction in Congestion delays at the two bridges. 2. Elimination of erosion in Cotonou Lagoon. 3. Improved fishing in Lake Nokoue.
(D) New Bridge at Saint Michel Boulevard (Without Dam)	Same as (a), (b), (c), and (d) above (k) New Bridge at Saint Michel Boulevard (l) Saint Michel Bridge Approaches (m) Saint Michel Bridge Foundation Protection (n) Maintenance - Saint Michel Bridge Approaches	1. Reduction in Congestion delays at the existing bridge. 2. No congestion or delays at Saint Michel Bridge.
(E) New Bridge at Saint Michel Boulevard (With Dam)	Same as (a), (b), (d), (i), (k), (l), and (m) above	1. Reduction in congestion delays at the existing bridge 2. No congestion or delays at Saint Michel Bridge 3. Elimination of erosion in Cotonou Lagoon 4. Improved fishing in Lake Nokoue
(F) (Evaluated against fishing benefits only)	(i) Dam (j) Loss of Shrimp Harvest	1. Elimination of erosion in Cotonou Lagoon 2. Improved fishing in Lake Nokoue

2. Benefit/Cost Analysis and Internal Rates of Return

For each improvement alternative, a benefit/cost analysis was made and internal rate of return determined for both the American and the Foreign procurements. The values of benefits, discounted at 10% to 1975, were as follows (1.00 US Dollar = 270 Fr. CFA)

Alternative	Net Benefits (Millions)			
	American Procurement		Foreign Procurement	
	Fr. CFA	U.S. Dollars	Fr. CFA	U.S. Dollars
Parallel Bridge Without Dam *	19,580	72.5	19,735	73.1
Parallel Bridge With Dam *	19,154	70.9	19,369	71.7
Saint Michel Bridge Without Dam*	25,479	94.4	25,606	95.0
Saint Michel Bridge With Dam *	25,052	92.8	25,241	93.5
Dam (Only fishing benefits considered)	2,310	8.6	2,310	8.6

* Includes only vehicle operating savings and erosion benefits.

The benefit/cost ratios and internal rate of return were as follows:

Alternative	American Procurement		Foreign Procurement	
	B/C	IRR	B/C	IRR
Parallel Bridge Without Dam *	15.05	44%	17.31	48%
Parallel Bridge With Dam *	11.09	38%	12.86	41%
Saint Michel Bridge Without Dam*	13.10	38%	14.14	39%
Saint Michel Bridge With Dam *	10.57	34%	11.60	35%
Dam (Only fishing benefits considered)	4.00	29%	4.50	30%

* Not including fishing benefits

The calculation of time savings due to lessening of congestion and therefore, time for travel has not been considered in the economic analysis because the reduction in vehicle operating costs above provides sufficiently high rates of return.

3. Sensitivity to Changes in Traffic Data, Expected Savings and Costs

The benefit/cost analysis and internal rates of return were tested for sensitivity to changes in traffic growth rates and diversion factors, reduction in expected savings and increase in construction costs. The various changes were all included simultaneously in the analysis. They were as follows:

Base 1970 traffic data	Reduced by	10%
Traffic growth rates	Reduced by	20%
Diverted traffic to Saint Michel Bridge	Reduced by	15%
Vehicle Operating Savings	Reduced by	15%
Fish Benefits	Reduced by	50%

The results were as follows:

Alternative	American Procurement		Foreign Procurement	
	B/C	IRR	B/C	IRR
Parallel Bridge Without Dam *	10.85	30%	12.57	32%
Parallel Bridge With Dam *	7.87	26%	9.20	28%
Saint Michel Bridge Without Dam *	7.30	26%	7.92	27%
Saint Michel Bridge With Dam *	5.79	23%	6.40	24%
Dam (Only fishing benefits considered)	1.60	16%	1.85	17%

* Not including fishing benefits

4. Expected Financial Impact of Proposed Construction

The absence of a new bridge across the Cotonou Lagoon would lead to much greater congestion and loss of time in the future. This would, without doubt, deter normal traffic growth and the pattern of future urban development of Cotonou. The result will be that residential, cultural, and economic growth will take place in areas of Cotonou which will minimize the need to cross the lagoon.

A new bridge will have, in the long run, a definite impact on reduction of delays and a more favorable commercial and industrial development in both the west and east parts of Cotonou with consequent potential for increased employment. It will, therefore, also have an indirect influence towards, and a future increase in governmental tax revenues.

C. RECOMMENDATIONS

1. Proposed New Construction

It is recommended that a new bridge across the Cotonou Lagoon be constructed four lanes wide and located near Boulevard Saint Michel. It is also recommended that a dam, located near the mouth of the lagoon, be constructed for the purpose of eliminating erosion in the lagoon. Although less expensive construction (rock mat) could be used for

prevention of erosion, the potential additional benefits from improvement of fishing yields in Lake Nokoue more than justify the additional costs of the dam.

2. Additional Improvements of the Existing Bridge

All necessary repairs to the existing bridge substructure are expected to be completed by 1974 with FAC funds.

The repairs to the superstructure can only be made after a new bridge is constructed and open to traffic.

It is recommended, therefore, that the repairs to the existing bridge deck be included in the new bridge and dam construction contract.

The recommended repairs include complete reconstruction of the bridge deck with wider sidewalks, rehabilitation of the lighting system and the painting of steel girders.

3. Construction Scheduling

It is recommended that the final design be completed in sufficient time to provide for letting of the contract and the beginning of construction not later than by January 1975. This will permit the completion of the dam before October of that year, and enable the construction operations to proceed without interruptions during the flood season. Every effort should be made, however, by the funding Agency to help implement procedures which would allow to adopt an accelerated project schedule so that construction could begin one year sooner than estimated in Section XI of this report.

SECTION II

GENERAL

A. SUMMARY OF THE PROBLEM AND PREVIOUS STUDIES

1. Brief Description of the Problem

Following the construction of the deep water ocean port a. Cotonou in 1959, serious ecological disturbances occurred in Lake Nokoue and in the Cotonou Lagoon.

In the past, the Cotonou Lagoon was blocked at its mouth near the ocean, by a sandbar. The sandbar was washed away at intermittent periods by the flood force of the Oueme River, but it would then quickly be re-established by the strong littoral sand drift of the ocean currents. After the construction of the Port of Cotonou, the ocean currents were deflected out to sea, and the littoral drift transporting the sand was pushed further to the east. The lagoon, therefore, remained permanently open to the ocean. As a consequence, the lagoon began to be eroded, and Lake Nokoue became infested by terredos (marine borers).

The invasion of the lake by the terredos caused considerable loss of wooden fish traps called "akadjas" and, therefore, reduction in the yield of the fish catch. The erosion of the channel of the Cotonou Lagoon undermined the pile substructure of the existing International Bridge. At the same time, the rapid growth of the City of Cotonou resulted in greatly increased traffic across the bridge. The latest traffic surveys made at the bridge show that the number of vehicles crossing during peak traffic hours already exceeds the capacity of the bridge and that serious congestion results at the bridge approaches.

The Dahomean Government therefore undertook to seek help for the purpose of correcting the problems in Lake Nokoue and the Cotonou Lagoon. Several engineering and economic studies were made by French, German, and U.S.A. agencies and several different solutions were suggested. All of the reports, however, recommended a new bridge to alleviate the traffic congestion and a dam in the lagoon to control the erosions and to block the terredo invasion of Lake Nokoue.

2. Studies by BCEOM (1963 and 1968)

In 1963 the French governmental agency, Bureau Central d'Etudes pour les Equipments d'Outre-Mer (BCEOM), undertook the study of the general feasibility of constructing a water control structure (dam) and a bridge in the lagoon. Six different alternatives were considered, and costs were evaluated. At the same time, BCEOM

had commissioned the hydraulic laboratory SOGREAH of Grenoble, France, to make mathematical model studies of the Oueme River delta (consisting of Lake Nokoue and Cotonou and Porto-Novo Lagoons) for the purpose of determining the essential hydraulic parameters and design criteria for the proposed dam.

In 1968, after the fishing situation in Lake Nokoue and the erosion in the Cotonou Lagoon become critical, BCEOM made extensive surveys, and prepared a preliminary design for a dam with sliding gates, at the site near Boulevard Saint Michel with provisions to allow the building of a bridge across the dam spillway, at a future date. The primary objective was to improve the fishing in Lake Nokoue by controlling the inflow of the ocean tides, and, therefore, the salinity intrusion, as well as preventing the penetration of the terredos into the lake through the Cotonou Lagoon.

Additional model studies were made by SOGREAH at this time to evaluate the magnitude of the forces expected to be generated upstream and down stream of the proposed dam spillway.

The BCEOM studies, field surveys, and hydrographic measurements in the Cotonou Lagoon, as well as the Report on Model Studies by SOGREAH, have provided a very valuable source of information and data for later studies by Sanders & Thomas, Inc.

3. Holzman Proposal (1969)

This proposal was a modification of the 1968 BCEOM plans by the German firm of Philip Holzman A.G. The modification consisted mainly in the use of three large concrete gates operated by electric motors rather than 350 small wooden planks operated manually, as proposed by BCEOM.

4. Reconnaissance Report by Sanders & Thomas, Inc. (1970)

In 1970, the Agency for International Development, Washington, D.C., engaged Sanders & Thomas, Inc. to review the previous proposals for a dam-bridge and to re-examine the problem in the Cotonou Lagoon. At the same time, Agency for International Development requested that a brief traffic survey be performed at the existing bridge to evaluate the volume of the various categories of traffic crossing the lagoon, and to determine what percentage of the total traffic was of international origin.

The conclusion reached by Sanders & Thomas, Inc. at the completion of their reconnaissance study was that both a dam and a bridge were needed. The traffic at the existing bridge was quite heavy and nearing its full capacity. The existing bridge had deteriorated and was in need of repairs. At the same time the erosion in the lagoon continued to be a problem, although its rate had slowed down.

The reconnaissance study also concluded that significant cost savings could be achieved if the bridge and the dam were not combined, but were located at separate sites. An in-depth engineering and economic feasibility study was recommended to evaluate more precisely the construction costs and the economic benefits to be derived from each of the various feasible engineering alternatives.

B. OBJECTIVES OF IN-DEPTH FEASIBILITY STUDY

1. Statement of Work

The scope of work for the Feasibility Study was outlined in the Reconnaissance Report by Sanders & Thomas, Inc. The final statement of work was formulated after detailed discussion with the staff of the Agency for International Development about objectives to be attained and potential difficulties to be overcome. Primary objectives were an in-depth technical study to evaluate with sufficient accuracy, the construction costs of the proposed capital improvements, and an economic analysis to evaluate the potential benefits to be derived therefrom.

The principal items of the statement of work included the following:

a. Field Work in Dahomey:

(1) Traffic volume and origin-destination surveys.
(2) Channel soundings and test borings.
(3) Existing bridge survey.
(4) Gathering of necessary and useful technical, cost, planning, and economic data.

b. Work in Home Office:

(1) Determination of additional rehabilitation needs for the existing bridge.
(2) Preliminary design and construction cost estimates for the new bridge and the dam.
(3) Hydraulic studies to determine the desirable characteristics of the proposed dam in terms of erosion, flood flow, salinity intrusion, and silting.
(4) Analysis of test borings in terms of foundation design requirements.
(5) Analysis of accumulated field traffic data to predict future traffic distribution, growth, and bridge capacity requirements.
(6) Review of the City of Cotonou master planning and determination of future city zonal growth and transportational needs.
(7) Economic analysis and determination of benefits to be expected from proposed construction, as well as benefit/cost ratios and internal rates of return for various construction alternatives considered.

(8) Evaluation of construction priorities essential for the realization of maximum immediate benefits.

(9) Report describing the work done and containing the engineering data, preliminary design, cost estimates, and the economic justification of the recommended capital improvement.

2. Engineering Alternatives and Costs

The engineering alternatives for a new crossing of the Cotonou Lagoon were narrowed down in the Reconnaissance Report by Sanders & Thomas, Inc. to two locations: (a) parallel bridge on the upstream side of the existing bridge, and (b) a bridge located further up the lagoon in line with Boulevard Saint Michel.

The engineering alternatives for the erosion prevention and restoration of former ecological conditions for the fishing in Lake Nokoue, were essentially confined to a dam with a fixed weir, located at the mouth of the lagoon, downstream from the existing bridge.

In the Feasibility Study, however, it was deemed desirable to include consideration of alternate erosion prevention measures (such as rock mat for the protection of bridge foundation) which would not, at the same time, benefit the fishing. Thus the dam would be considered, alternately, as a structure either helping only to eliminate the erosion problem in the lagoon or also helping to improve the fishing in Lake Nokoue.

It would become, therefore, possible to compare the cost of the dam with the cost of other feasible erosion preventive measures and to evaluate whether (a) the benefits to be derived from a new lagoon crossing could justify the construction of a dam or (b) should alternate erosion protection measures prove to be less expensive than the dam, evaluate whether the cost of the dam could be justified by considering only the benefits expected from improved fishing in Lake Nokoue.

3. Economic Alternatives

In order to determine the total value of benefits to be obtained from the proposed construction, it is necessary to first calculate the costs for the case in which no improvements are made other than the repairs of the existing bridge. The repairs of the existing bridge and the maintenance of the existing approaches are necessary in order to insure that the existing bridge would continue to function until the end of the study period (1977 to 1997). In this case, the major portion of the total costs is contributed by the vehicle operating costs due to the delays and the congestion at the existing bridge.

With the construction of a new bridge, the crossing delays and the congestion will be greatly reduced or eliminated. The difference in vehicle operating costs

between the "no improvement" case and various "new bridge" alternatives, constitutes the vehical operating savings (benefits). Other benefits are derived from the construction of the dam in terms of elimination of erosion problems in the lagoon and improvement of the fishing in Lake Nokoue.

Vehicle operating costs and benefits are discussed in detail in Section XII of this report.

The construction and maintenance costs, the years in which they are incurred, and the expected benefits for each economic alternative considered, are summarized in Table II-1.

In the economic analysis, all costs are discounted to the year 1975 using a minimum discount rate of 10% for the determination of benefit/cost ratio. The reliability of results (sensitivity) is then tested by reducing the Traffic Growth Rate (20%), Vehicle Operating Savings (15%), 1970 Traffic Volumes (10%), Volume of Diverted Traffic to Saint Michel Bridge (15%), and Fishing Benefits (50%).

C. FIELD WORK IN DAHOMEY BY SANDERS & THOMAS, INC.

1. Traffic Surveys

Traffic Surveys were conducted in Cotonou during a period of four weeks in November of 1970. The surveys were accomplished with the help of 44 local personnel and police provided to the Consultant by the Ministry of Public Works, Cotonou.

The survey included volume counts and origin-destination counts at the existing bridge, volume and origin-destination counts of the boat traffic near the landing at the Saint Michel central market, and turning movement counts at selected intersections. Speed studies were also made along present and proposed access routes, in order to determine average running speeds on paved and laterite roads.

2. Hydrographic Surveys

Hydrographic surveys, conducted by the Sanders & Thomas, Inc. team in the Cotonou Lagoon, were accomplished with the help of the following:

a. Service de l'Hydraulique - which provided a motor boat equipped with sonar apparatus and crew.
b. Service Topographique - which provided a ground crew to monitor and locate the waterborne work.
c. Cotonou office of Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM) - which also provided a boat equipped with OTT meter (flow velocity meter).

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TABLE 2-1

Alternatives	Costs	Years In Which Costs Are Incurred	Expected Benefits
(A) No improvements	(a) Repairs of Existing Bridge Deck (b) Repairs of Existing Bridge Abutments (c) Maintenance - Existing Bridge Foundation (d) Maintenance - Existing Bridge Approaches	1978 1975 1996 each year (1977 to 1996)	None
(B) New Parallel Bridge (Without Dam)	Same as (a), (b), (c), and (d) above (e) New Parallel Bridge (f) Parallel Bridge Approaches (g) Parallel Bridge Foundation Protection (h) Maintenance of Parallel Bridge Foundation Protection	Same as (a), (b), (c), and (d) above 1975 1975 1975 1996	1. Reduction in congestion delays at the two bridges
(C) New Parallel Bridge (With Dam)	Same as (a), (b), (d), (e), and (f) above (i) Dam (j) Dam Maintenance (k) Loss of Shrimp Harvest	Same as (a), (b), (c), (e), and (f) above 1975 1995 each year (1976 to 1997)	1. Reduction in congestion delays at the two bridges 2. Elimination of erosion and salinity problems 3. Improved fishing in Lake Nokoue
(D) New Bridge at Saint Michel Boulevard (Without Dam)	Same as (a), (b), (c), and (d) above (l) New Bridge at Saint Michel Boulevard (m) Saint Michel Bridge Approaches (n) Saint Michel Bridge Foundation Protection (o) Maintenance - Saint Michel Bridge Approaches (p) Maintenance - Saint Michel Bridge Foundation Protection	Same as (a), (b), (c), and (d) above 1975 1975 1975 each year (1977 to 1996) 1996	1. Reduction in congestion delays at the existing bridge 2. No congestion or delays at Saint Michel bridge
(E) New Bridge At Saint Michel Boulevard (With Dam)	Same as (a), (b), (d), (i), (j), (k), (l), (m), and (o) above	Same as (a), (b), (d), (i), (j), (k), (l), (m), and (o) above	1. Reduction in congestion delays at the existing bridge 2. No congestion or delays at Saint Michel Bridge 3. Reduction in traveled distance (Saint Michel Bridge traffic) 4. Elimination of erosion and salinity problems 5. Improved fishing in Lake Nokoue
(F) Dam (Evaluated against fishing benefits only)	(i) Dam (j) Dam Maintenance (k) Loss of Shrimp Harvest	1975 1995 each year (1976 to 1997)	1. Elimination of erosion and salinity problems 2. Improved fishing in Lake Nokoue

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In the course of the hydrographic work, channel cross section measurements were made at the sites of the proposed bridge and of the dam. Flow velocity and flow volume were also measured near the site for the proposed bridge at Boulevard Saint Michel.

3. Existing Bridge Survey

A survey was made of the existing bridge superstructure and substructure. Measurements were made of the upstream and downstream elevations of the channel bottom, near the bridge piles, to evaluate the progress of the erosion and consequent loss of pile embedment. Meetings were held with the responsible officials of the Ministry of Public Works and the Cotonou office of BCEOM, relative to proposed immediate and future repair work for the bridge.

4. Other Surveys

Miscellaneous surveys were conducted throughout the City of Cotonou to collect data useful for planning and economic studies. Numerous meetings were held with representatives of Ministere du Plan, the Chamber of Commerce, the Port of Cotonou and industry.

During these city surveys, data were gathered on the characteristics of the various city zones from which their future growth potential could be evaluated. From the meetings with representatives of the government and industry, information was obtained relative to the Master Plan and the prospects for the future of Cotonou.

The sum total of the information obtained was then reviewed and evaluated, and further surveys were made to improve, where feasible, the reliability of the data collected.

D. FIELD WORK BY SUBCONTRACTORS AND OTHER CONSULTANTS

1. Subsoil Surveys and Testing by SASIF and LNBTP

In order to acquire sufficient subsoil data for a preliminary evaluation of the proposed bridge and dam foundation construction costs, two subcontractors were engaged to perform core boring, penetrometer, and laboratory testing. The subcontractor for the core boring work (at the site of the proposed dam) was Societe Africaine de Sondages, Injections Forages de Cote d'Ivoire of Abidjan, Ivory Coast. The subcontractor for the penetrometer and laboratory tests was Laboratoire National de Batiments et Travaux Publics of Cotonou, Dahomey.

2. Fishery Survey by NMFS Biological Laboratory

In conjunction with the work and studies of Sanders & Thomas, Inc., the Agency for International Development has engaged the services of the National Marine Fisheries Service Biological Laboratory of Seattle, Washington to survey and evaluate the present conditions of the fishing in Lake Nokoue and to determine the requirements for an improvement of the present deteriorating situation. The field survey of fisheries in Lake Nokoue was made by Dr. Richard B. Thompson of the NMFS Biological Laboratory. His findings and recommendations are detailed in a report, completed in July, 1971, entitled "Report of Fishery Reconnaissance to Lake Nokoue", Dahomey. The same report also includes an economic evaluation of expected fishery benefits by George K. Tanonaka. The benefits are evaluated on the premise that the present problems in the lake will be eliminated.

SECTION III

CITY OF COTONOU - PLANNING ANALYSIS

A. REGIONAL AND URBAN CHARACTERISTICS

1. Geographic Location and Economic Importance

Cotonou is the commercial and economic capital of the Dahomean republic. It is built on the shore of the Gulf of Benin and is located 90 kilometers west of Togo, 40 kilometers east of Nigeria, and 600 kilometers south of the Niger and Upper Volta borders.

The geographical importance of Cotonou is twofold. It is a transit relay point for the traffic between Ghana, Togo, and Nigeria. At the same time, it is the principal access point to and from the Atlantic Ocean for the capital city of Niamey, in Niger. Cotonou is therefore a focal point of international transit of people through its airport and of supplies and merchandise through its deep-sea port.

The city of Cotonou is located between the Atlantic Ocean shore to the south and Lake Nokoue to the north. It is divided by the lagoon, which presently has only one common crossing for pedestrian, vehicular, and railroad traffic. To date, the city growth has developed primarily along an east-west axis along the ocean shore. The portion of the city west of the lagoon, however, has a limited amount of land available for further development. This area, which is limited from further expansion by the International Airport to the west, Lake Nokoue to the north, the lagoon to the east and the ocean to the south, is estimated to be 60% urbanized at present. Though the city has spread only to limited extent, it is on the eastern side of the lagoon that the largest amount of available land is to be found.

The western portion of Cotonou is characterized by the airport, the commercial and hotel areas, the port, the Presidential Palace, the various governmental buildings, and the foreign embassies, all located along the ocean shore. The main native residential area extends from there to the north, towards Lake Nokoue and the western shore of the lagoon. The city hospital, the Army headquarters, the OCDN railroad tracks and station, and the great central market are also situated in this part of the city.

The eastern portion of Cotonou contains the industrial zone, situated mainly along the route to Porto-Novo, and the less developed areas with less affluent residential population, situated to the north of the route to Porto-Novo and near the eastern shore of the lagoon.

The main sources of employment in the city are the government, the foreign embassies, the port, the hotels, the shopping district, the airport on the western side, and the industrial zone on the eastern side.

The great central market, located at Boulevard St. Michel along the western bank of the lagoon, is also a major point of economic activity. It is a place where the native population as well as the European community of Cotonou comes daily to shop for food, fuel, and small handicrafts. It is here, also, that the fishing villagers living around the shores of Lake Nokoue bring their catch to be sold. Every fourth day being market day, large crowds come not only from Cotonou itself, but also from the Dahomean countryside and even as far as Togo and Nigeria. There are also many other local markets, but they only serve local neighborhood needs.

2. Distribution and Composition of Population

Cotonou was not always the leading population and commercial center in Dahomey. Rather, it existed as a small, quiet community for many years, and was not nearly as important as Porto-Novo or Ouidah. Not until the post World War II period did Cotonou begin to burgeon. According to unofficial estimates by governmental sources, the present (1970) population of Cotonou ranges between 100,000 and 130,000, while an additional 30,000 to 40,000 persons reside in the immediate suburban environs (e.g., Akpakpa, Agblangandan, and Agbato on the eastern side of the lagoon, and Zogbo and Kounoumou on the western side). Until the official results of a comprehensive population census (which is scheduled to be undertaken in 1971) are made known, the present population for Cotonou cannot be ascertained with any degree of accuracy.

For the purpose of this report, the assumption will be made that the present population within the Cotonou city limits is 115,000 and that there are 35,000 persons residing in the suburbs.

Because of the great dependence of the suburban population on Cotonou for employment, shopping, culture, entertainment, and the like, it is logical that the city and the suburbs are considered as a single entity. On the other hand, for the purposes of estimating future population, and its potential effect on transportation demands within the city (particularly in regard to the lagoon crossing), it is essential that the population of Cotonou, per se, be differentiated from the combined figure for Cotonou and its suburbs.

The latest available census data (December 1959) indicate that Cotonou, within its municipal boundaries, contained 13,700 households with a population of 61,900 consisting of the following:

Population	Origin
60,560	African
1,190	European
150	Eurafrican and Assimilated

These figures were underestimated due to crude methods employed in making the census. Estimates were probably 10% too low for Africans and 20% too low for Europeans.

The suburban population was estimated to be approximately 20,000 outside Cotonou municipal limits and 60,000 in the fishing villages, around Lake Nokoue.

The recorded African population (1959) consisted of 91% native Dahomeans. The following Table III-1 (Ville de Cotonou, Recensement de Decembre 1959), shows their origins and gives an indication of the population movement from other parts of Dahomey to Cotonou.

TABLE III-1

ORIGINS OF DAHOMEAN POPULATION IN COTONOU
(1959)

	Men	Women	Totals	%
COTONOU	10,109	10,167	21,076	38.2
PORTO-NOVO	4,350	3,923	8,173	14.8
OUIDAH	4,798	4,793	9,591	17.4
ABOMEY	3,022	2,865	5,887	10.7
SAVALOU	768	735	1,503	2.7
PARAKOU	208	222	430	.8
DJOUGOU	93	90	183	.3
NATITINGOU	72	51	123	.2
KANDI	98	97	195	.4
ATHIEME	2,686	2,996	5,682	10.3
NIKKI	28	27	55	.1
POBE	159	140	299	.5
ABOMEY-CALAVI	1,064	948	2,012	3.6
	28,155	27,054	55,209	100.0

A more detailed discussion of the estimated present and projected future distribution of the population in various areas of Cotonou is given in Subsection D.

3. Influence of Regional Development on City Growth

The future growth of Cotonou is difficult to predict. At best, one can attempt to look at the past development and at the future potential of the city in terms of its importance for Dahomey, as well as in terms of the future regional developments which undoubtedly will have their effect on what happens in Cotonou.

In the past, Cotonou has developed at a relatively rapid pace, particularly after the completion of the deep-sea port. To what extent the building of the port has stimulated the development and location of industry in Cotonou cannot be precisely established, but it is certain that without the port facilities, the growth of the Cotonou industrial zone would have been much slower. At present, there are some 40 industrial establishments in Cotonou. Approximately 23 more are being planned in the near future. A detailed discussion of the present and future economic prospects for Dahomey and Cotonou is given in Section XII.

In terms of city planning, it is important to observe how the economic growth of Cotonou was aided and accelerated through capital improvements, proper zoning, and development of available city lands. In this context we can relate the regional developments which have had, and will have, an effect on the city, and which also point to the type of capital improvement needed for city growth. The construction of the port, for example, was needed to provide a better cargo transportation facility and a better link to the ocean for Niger as well as for Dahomey. In turn, to make the Cotonou port fully useful for Niger traffic, improvement of the road between Parakou and Malanville is presently needed. The completion of this road project, in turn, will have its effect on increased economic activity in Cotonou. Similarly, in the near future, several large regional developments, when completed, and if successful, will certainly have a strong effect on Cotonou. Among these are the recently discovered limestone deposits at Onigblo near Pobe and the exploration and drilling for petroleum offshore near Porto-Novo. The raw limestone will be processed into cement at Onigblo, but it will require an improved roadway link (including an improved lagoon crossing) to Cotonou for local distribution and export. The petroleum will probably be stored on the eastern side of Cotonou and will also need an improved lagoon crossing for better access to the port and the rest of Dahomey. All of these developments cannot help but stimulate increased employment and economic activity in Cotonou. Additional local development will follow the construction of a new roadway facility or a new bridge crossing over the lagoon. Similar to the commercial area which developed around the western approaches to the existing bridge, it is certain that new commercial establishments will spring up near the approaches of a new bridge.

The future growth of Cotonou will depend on the opportunities for employment, education, recreation and municipal services which the city will be able to provide. Thus, the rate of the population growth will be determined not only by the birth and mortality rates in the city, but also by the rate of influx of people from the surrounding areas in search of gainful employment. At present, the influx into Cotonou seems to continue in spite of lack of opportunity for employment. However, in the future, it is likely to reduce considerably if the employment opportunities in the city do not keep pace with the demand. A plan for an orderly development of the social and economic future of the city is provided by the Cotonou Master Plan (Ville de Cotonou, Project, directeur de principe, 1962).

B. SUMMARY AND REVIEW OF COTONOU MASTER PLANNING

1. General Summary of Cotonou Master Plan (1961 and 1962)

The Cotonou Master Plan was developed through two reports. The first, prepared by Mr. B. Reynard of Societe d'Etudes pour le Development Economique et Social (SEDES), was essentially a survey of existing social and economic conditions of the city and its suburbs. The second report was more properly concerned with the detailed planning of the city and therefore constitutes the true master plan. It was prepared by Messrs. A. Arsac and K. Mestoudjian, architects and urban planners of Paris, France, under the sponsorship of Societe Centrale pour L'Equipment du Territoire (SCET).

The 1961 Report was limited, in its recommendations, to the immediate needs of Cotonou through 1965. They included:

a. Improvement of housing for 17,000 city households and 500 in the fishing villages.

b. Increase in the number of elementary school facilities and creation of new secondary education centers.

c. Development of more health services around the recently-constructed new hospital.

d. Construction of a better Town Hall.

e. Reserving sufficient land for future sports activities.

f. Sanitary and storm sewer system for Cotonou and suburbs.

g. Improvement and paving of city streets.

h. Improving and organizing city water and electric distribution.

i. Planning the future organization of public transports.

The 1962 report contained a detailed analysis of various urban problems and proposed the course of action in terms of future prospects for Cotonou.

Four basic criteria were set as a basis for all planning:

a. Subordination of the new master plan to the requirements of the new port and related industries.

b. Subordination of the new master plan to the location and plans for Independence Square and administrative buildings around it.

c. Extension of Cotonou beyond the present city boundaries.

d. Improvement, by stages, of traffic flow and separation of residential and industrial traffic.

The zoning was then reviewed and the following proposals were made:

a. Location of Industries in the areas which offer most direct access to the port and to other modes of transportation.

b. Location of all government administrative offices around Independence Square.

c. Location of housing in areas adjacent to sources of employment and recreation. Where space is limited, such as in the central business district, high-rise buildings should be permitted. Public transportation should be extended to reach the areas beyond present city boundaries.

The proposals for the transportation improvements in Cotonou were confined to considerations of rail traffic only, and no discussion was offered relative to car or truck transportation, probably because the problems of streets and highways transportation were treated in a separate report entitled "Principles of Bridgehead Study".

2. Summary of Bridgehead Study (1961)

This study was also prepared by Messrs. Arsac and Mastoudjian. It preceded the extensive and detailed 1962 report and was intended mainly to develop an integrated solution to the following:

a. Location of a new bridge.

b. Improvements for the Lagoon Market (Saint Michel Market).

c. Location of the new Town Hall.

d. Development of the west bank of the lagoon.

These four items were deemed inseparable and vital for the future development of Cotonou. The report states that an orderly arrangement demands that a central market, the new bridge, and an improved Town Hall be located in the geographical center of the city. A western boulevard along the lagoon would then provide a north-south access artery which would connect at the market with an east-west artery (Saint Michel Boulevard).

The report concluded by stating that if all of its recommendations were implemented, the economic interests of the city would be well served through increased commercial activity along the two boulevards and in the new market, as well as improved accessibility to the center of Cotonou by means of the bridge and the west bank boulevard.

3. Review of Master Plan Recommendations

The many recommendations of the Cotonou Master Plan have been quite closely enforced to date. The officials of the Ministere du PLAN and of Travaux Publics strongly endorse the recommendations of the Bridgehead Study.

In terms of transportation aspects and the objective to stimulate expansion of the city to the north towards Lake Nokoue, one can only agree with the Master Plan. The idea of creating a focal center of town by means of a modern Town Hall adjacent to a big central market, both located at the crossing of two perpendicular arteries (Saint Michel Boulevard and the proposed west bank boulevard) is quite attractive. It serves the triple purpose of promoting commercial investments, centralizing city administration, and developing faster access. A second lagoon crossing, by means of a new bridge, would provide a closer tie between the eastern and western portions of Cotonou, and, at the same time, it would allow the fishermen of Lake Nokoue a more convenient and shorter trip to the market. It would also provide faster access to the industrial zone located on the eastern side of the lagoon for the people who are now living in, or in the future, will want to locate in the northwestern part of Cotonou. The inter-regional traffic would also have a faster, less congested route to use for passing through Cotonou, and thus avoid the delays inherent to downtown traffic.

C. MAJOR LAND-USE ELEMENTS

1. Road Transportation

International Route No. 11 is the most important east-west route in Dahomey. It includes the existing bridge across the Cotonou Lagoon. Because this coastal thoroughfare connects Accra (Ghana), Lome (Togo), Cotonou, Porto-Novo, and Lagos (Nigeria), its significance to the Dahomean economy cannot be overstated. As economic conditions improve in West Africa and inter-regional commerce grows, international vehicular travel through Cotonou is bound to assume increasing importance.

While the International Route is the most important road serving Cotonou and its environs, there are several other roads in Cotonou which are also heavily traveled at present and which may take on added significance in the future. The importance of these streets is perhaps best indicated by the number of gasoline service stations already located there. Presently in Cotonou there are some 40 gasoline stations supplied by seven foreign companies. The bulk of these establishments are located along the more important streets in the city, as follows: ten on International

Route, ten on Boulevard Saint Michel, nine or Rue des Cheminots (which leads directly into the port), and six on Avenue de la Republique.

There are also other roads which carry substantial amounts of traffic, primarily because of commercial development along their length. Among these are Avenue Delorme and Avenue Steinmetz.

The existing bridge across the lagoon is undoubtedly the most important road transportation link in the entire city of Cotonou. Because it is the only lagoon crossing through which one can have access between the eastern and western parts of Cotonou, it is also a vital link for intracity as well as inter-regional traffic flow. It is, however, rapidly becoming unable to serve adequately the large traffic using it. The fact that the OCDN railroad also uses the bridge, makes the situation even worse.

The existing bridge is a scene of frequent traffic congestion, especially when a train crosses the bridge. Therefore, a new crossing with good approaches is sorely needed.

In terms of economic importance, one must view the need for an improved crossing as an absolute necessity if a faster and safer movement of people and goods is to be obtained. A new lagoon crossing could greatly improve the Cotonou road system in the following ways:

a. It would reduce travel time, delays, and vehicle operating costs.

b. It would make Cotonou more accessible to its eastern and western halves.

c. It would promote better economic development.

d. It would reduce the probability of accidents.

It should be pointed out that as Cotonou grows, additional road improvements will become necessary. Among these are (in order of their importance):

a. A boulevard along the west bank of the lagoon. This improvement will be needed to permit fast north-south travel and also to connect the existing bridge to other future bridges across the lagoon. A well planned boulevard along the lagoon could offer considerable economic and recreational benefits in terms of parklike as well as attractive commercial development. A considerable amount of engineering study for this project has already been completed by BCEOM through funds advanced by FAC (Protection des Berges de la Langune de Cotonou, BCEOM, 1966).

b. A paved road along the line of the existing laterite road on the eastern side of the lagoon, passing near the Catholic and Moslem cemeteries and the Yacht Club. This project, if carried to Agbato, would help accelerate the development of the lands in the northeastern part of Cotonou.

c. A laterite road at P.K. 3[1] near the Cotonou radio station, leading south to the ocean shore. This project would help to develop valuable lands in the southeastern part of Cotonou.

2. Commercial and Industrial Development

There are two major shopping areas in Cotonou.

The first is a European-type market area, located along the International Route No. 11 on the western side of the lagoon, near the existing bridge. The retail and service stores in this commercial area are housed in permanent-type structures. Among the various businesses are modern self service food shops as well as clothing, shoes, and other merchandise stores. There are also restaurants, pharmacies, travel agencies, and a movie theater. Through this area, the International Route No. 11 is heavily traveled, and the flow of traffic is constantly interrupted by cars seeking to park near the shops or making turns to or from side streets.

The second major market in Cotonou is primarily a native African-type market, also located on the western side of the lagoon near the intersection of Avenue de la Republique and Boulevard Saint Michel. This facility is officially known as the Lagoon Market, but is also known as the Saint Michel Market. It has a distinctively native flavor and is used by shoppers and purveyors of goods from Togo and Nigeria, as well as from all parts of Dahomey. Presently all business is conducted either completely in the open or in opensided stalls covered by tin or thatched roofs.

Several other less important local markets on both sides of the lagoon cater to the small daily needs of the local neighborhood. A large fish market located along the eastern side of the port is a scene of busy activity every morning, when the ocean-going fishing boats bring their catch to be sold. This market will assume increasing importance in the future since a refrigerating plant and a fishing harbor are presently being constructed nearby.

In terms of future growth potential, the Saint Michel Market is, by far, the most important. The Cotonou Master Plan calls for fairly extensive improvements at the Saint Michel Market which will convert it into an all-weather facility where the

[1] P.K.'s are points along the OCDN railroad tracks denoting the distance in kilometers from the OCDN railroad station in Cotonou. Thus, P.K. 5 denotes a point five kilometers east of the station.

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local arts, crafts, and products may be displayed to the best advantage. Included in the future plans for this Market is a marina along the lagoon shore, which would permit the docking of small boats and "pirogues." Thus, the fishermen from Lake Nokoue could easily bring their catch for sale at the Saint Michel Market. The Master Plan also calls for the construction of new municipal buildings near this Market, including a new City Hall. It is also at this location that the Master Plan recommends the construction of a new bridge across the lagoon.

The great majority of industrial development in Cotonou is located in two sections of the city. The largest of these is on the eastern side of the lagoon along the International Route and contains the most recent and largest industries. The older industries are located on the western side of the lagoon in the triangular-shaped area between the railroad line leading to the old wharf, the lagoon, and the Atlantic Ocean.

There are also other smaller industrial establishments beyond the confines of these areas, most of them on sites located near the International Route as it traverses Cotonou.

The Cotonou Master Plan calls for the greatest amount of future industrial development to take place around the port, including the utilization of land now being created by the action of littoral drift, which is depositing sand west of and against the new port jetty and the shoreline.

The area surrounding the port is a logical and desirable location for future industry. It is also probable that industrial expansion will continue further east along the International Route and that there will be intensification of industrial development in the area near the old wharf.

In the future, when the northeastern areas of Cotonou begin to be developed, it may prove advantageous to locate new industry there. By thus providing new employment opportunities for the future residents of this area and a ready labor source for the prospective industry, more people may be attracted to the area and, therefore, its development would be accelerated.

3. Residential Density and Living Arrangements

Population density in Cotonou is relatively low compared to other large West African cities. Based on a city land area of approximately 39.8 square kilometers and a population of some 115,000 the present gross density of 6600 persons per square kilometer, or 66 persons per hectare. Of course, because so much of Cotonou consists of undeveloped marshland and non-residential areas containing plantations, governmental buildings, industry, market places, and port facilities, the distribution of the population presents a somewhat different picture. In the nearly fully developed residential section of the city bounded on the north by Avenue de la Republique, on the east by the lagoon, on the south by the railroad, and on the west by a line extending

north from the Place de l'Independence, the gross density is substantially more than the overall city figure—perhaps two to three times as great. In terms of average net residential density, it is estimated that the present citywide figure is about 13 households, or 66 persons per net residential hectare.

The typical residential accommodation in the developed sections of Cotonou consists of a single household unit in one corner of a lot with an open courtyard on two sides. There is also a fair amount of one- and two-story multiple-family structures containing, in most instances, separate apartments (sometimes only one room) accommodating an individual household. There are few apartment buildings in Cotonou more than three stories in height, a fact easily substantiated by a skyline view of the city.

In most cases, there are between four and ten lots per block, each lot containing between 500 and 750 square meters of land. Lately, however, there has been some evidence of further construction activity within the lots, a situation which, if allowed to continue unabated, could prove troublesome. The toleration of greater residential densities in the already built-up sections of the city will lead to overcrowding of land, result in loss of open space, light, and air, and bring additional pressures on community facilities, services and transportation system. Higher residential densities should be permitted only through careful planning, so that all environmental factors may be given proper attention.

Based on past and present trends, it would appear that Cotonou has set out on a relatively low-density residential course – a life style quite different from that of other large West African cities: Abidjan, Dakar, and Lagos, for example, where high density multifamily residential quarters are more numerous. In Cotonou, on the other hand, net residential densities are relatively low, and the population is not yet concentrated.

It is this density aspect of Cotonou that is so important insofar as transportation considerations are concerned. The low-density, spread-city pattern of development means that more people will have to travel greater distances for the journey-to-work trip, the shopping trip, the social trip, the educational trip, and the recreational trip. The interplay among the areas on the eastern side of the lagoon and those on the western side must necessarily increase as spread-city pattern takes its mature form.

The future growth of Cotonou will require changes in the existing residential densities. These changes will vary in accordance with the physical and geographical characteristics of each area of Cotonou. An attempt to predict the changes to be expected and the potential growth of the various areas of Cotonou is made in subsection D which follows.

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D. ANALYSIS OF INTRACITY ZONES

1. Description and Characteristics of Zonal Limits

Cotonou, within the present city limits, encompasses approximately 39.8 square kilometers or 3,980 hectares of land. For the purposes of a more detailed analysis, the city has been divided into eight zones which are described below. Tables III-2 and III-3 give the estimated 1970 residential density, and population and land use distribution data for each of these zones. The boundaries of the eight zones are shown in the Cotonou City map, page A-1 in the Appendix. This map shows both the present and future proposed city streets. Figure 3-1 shows a general plan of the city of Cotonou and its environs and gives, also, a good indication of the presently populated and unoccupied areas in and around Cotonou.

ZONE NO. 1 is essentially a triangular area bounded by Rue du Dahomey on the north, the Cotonou Lagoon on the east, the Atlantic Ocean on the south, and the railroad leading to the port on the west. It contains 2.2 square kilometers of land, and is estimated to have a total 1970 population of 20,500.

This area may be considered the central business district of Cotonou, although the intensity of physical development and human activity is further increased by virtue of the fact that the port, various governmental offices, hotels and railroad station, industry, and residential quarters, are also located here. The residential quarters of this zone occupy approximately 36% of the total zone area, but it has the highest residential density per hectare. The existing bridge across the lagoon, which is actually the extension of the International Route, connects this zone with the east bank of the city.

ZONE NO. 2 is an irregularly-shaped rectangular area bounded on the north and east by the OCDN railroad tracks, on the south by the ocean, and on the west by the Cotonou International Airport. This area contains 7.6 square kilometers of land (exclusive of the sand being deposited against the shore jetty), and is estimated to have a total population of 11,000.

Among the major features in Zone No. 2 are the most modern residential quarters in the city, the major foreign embassies, the Presidential Palace, and other governmental installations, such as the hospital and the military camps. The Cotonou International Airport, including the terminal, service buildings, hangars, and the runway, occupy a large area (2.0 km^2) at the western end of this zone. While there are long range plans to relocate this facility to a new site west of the city, it is highly improbable that this will occur in the next decade or two. The residential areas of this zone represent approximately 20% of the total zone area. The International Route No. 11 traverses this zone from its northern to its eastern limits. A native residential area known as Cadjehoun is also included in Zone No. 2.

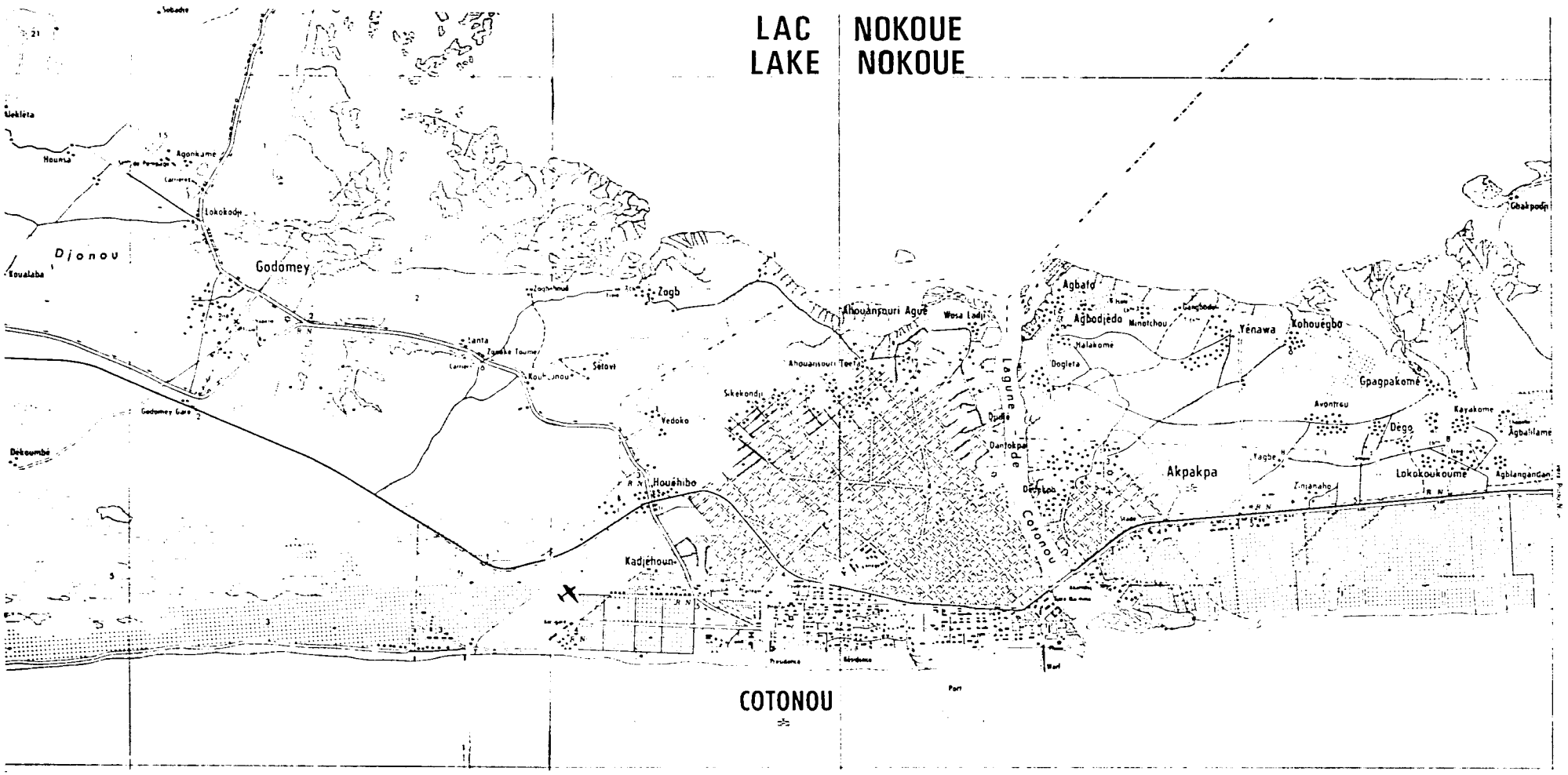
ZONE NO. 3 is an irregularly-shaped rectangular area bounded on the north by the open as well as unopen portions of Avenue de la Republique, on the east by the lagoon, on the south by Rue du Dahomey and OCDN railroad tracks and on the west by the

TABLE III-2

ESTIMATED PRESENT RESIDENTIAL DENSITY AND POPULATION OF COTONOU (1970)
(WITHIN CITY LIMITS ONLY)

Zone No.	Gross Area (Hectares)	Net Residential Density		Estimated Net Residential Area (Hectares)	Estimated Household Population	Estimated Total Population *
		Households Per Hectare	Persons Per Hectare			
1	220	32	160	100	16,000	20,500
2	760	10	50	160	8,000	11,000
3	910	14	70	450	31,500	36,000
4	960	10	50	470	23,500	25,250
5	300	12	60	100	6,000	7,500
6	80	24	120	50	6,000	6,750
7	110	10	50	80	4,000	4,000
8	640	10	50	100	5,000	5,000
Total	3,980	13	66	1,510	100,000	115,000

* It is assumed that an additional 15%, or 15,000 persons, live in Cotonou but do not have permanent places of residence. Their allocation by zone is as follows: Zone No. 1 - 30%, or 4,500 persons; Zone No. 2 - 20%, or 3,000 persons; Zone No. 3 - 30%, or 4,500 persons; Zone No. 4 - 5%, or 750 persons; Zone No. 5 - 10%, or 1,500 persons; Zone No. 6 - 5%, or 750 persons; Zones No. 7 and No. 8 - none.



COTONOU – PLAN GENERAL
COTONOU – GENERAL PLAN

FIG. 3-1

TABLE III-3

LAND USE DISTRIBUTION IN COTONOU (1970)

Zone No.	Areas In Square Kilometers							Percent Underdeveloped	
	Total Zone Area	Developed Areas				Underdeveloped Areas			
		Within City Limits		Outside City Limits *					
		Residential	Other	Residential	Other	Within City Lim.	Outside City Lim. *	Within City Lim.	Outside City Lim. *
1	2.2	0.8	1.4	-	-	0.0	-	-	-
2	7.6	1.4	4.2	-	-	2.0	-	26	-
3	9.1	4.8	0.3	-	-	4.0	-	44	-
4	4.6	2.7	0.2	-	-	6.7	-	70	-
5	3.0	1.0	1.4	-	-	0.6	-	20	-
6	0.8	0.6	0.1	-	-	0.1	-	12	-
7	15.0	0.5	0.1	0.4	0.0	0.5	13.5	45	97
8	7.6	0.4	1.4	0.3	0.1	4.6	0.8	72	58
Total	54.9	12.2	9.1	0.7	0.1	18.5	14.3	47	95
		21.3							

* Entire Area Is On The Eastern Side Of The Lagoon

International Route No. 11. This zone contains 9.1 square kilometers of land, and is estimated to have 36,000 residents within its borders, making it, by far, the most populated zone.

Predominantly residential in character, this zone also contains part of the Saint Michel Market complex on the west bank of the lagoon and many small business establishments along the north-south streets between Zone No. 1 and Boulevard Saint Michel, which is also a major commercial thoroughfare. The extreme western part of this zone contains marshy lowlands which is undoubtedly the reason why it remains largely underdeveloped at present.

ZONE NO. 4 is a trapezoidal-shaped area bounded on the north by Lake Nokoue, on the east by the lagoon, on the south by Avenue de la Republique, and on the west by the city boundary. This is the largest zone of the eight, having 9.6 square kilometers of land. The 1970 population is estimated to be 25,250.

Residential development is the major land use feature in the southeastern part of this zone, while vacant land predominates in the northern and western parts where there are large expanses of marshy lowlands. However, even these areas are beginning to be used for residential development. There are already new settlements springing up here, three of which are known as Sikecondji, Awansouri-Toeta, and Djidje. The Saint Michel Market is located in the extreme southeastern corner of Zone No. 4, where it adjoins the market in Zone No. 3.

ZONE NO. 5 is an irregularly-shaped rectangular area on the eastern side of the lagoon, bounded on the north by an unnamed, wide laterite road located along the northern limits of the sports stadium known as Stade Pleven and the Moslem cemetery, on the east by the north-south line passing through P.K. 3.2 near the Cotonou radio station, on the south by the ocean, and on the west by the lagoon. This area, generally known as Akpakpa-Dodome, encompasses 3.0 square kilometers of land, and has an estimated population of 7,500. It contains petroleum storage facilities and industrial establishments along the International Route (the Porto-Novo Road). Residential development is located around the perimeter of this zone and in the section north of the International Route. Stade Pleven, which is the major soccer stadium in Dahomey, attracts large crowds at each game. The existing bridge and the International Route east of the lagoon, as well as the Catholic and Moslem cemeteries, also are located in this zone.

ZONE NO. 6 is a triangular area located on the eastern side of the lagoon. It is bounded on the north by an unnamed laterite road which passes near the Catholic Mission and, in accordance with the Cotonou Master Plan, is proposed to become the major connecting road to the new bridge.

On the south, Zone No. 6 is bounded by an unnamed wide laterite road near the sports stadium and on the west, by the lagoon. Zone No. 6 has 0.8 square

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kilometers of land, and contains an estimated 6,750 persons. This is the smallest zone, but it has the second highest population density per hectare.

This zone is practically all residential in character. The only vacant tracts of any magnitude exist along the lagoon. These tracts are largely subject, at present, to flooding during the rainy season. (Only a small village called Dedokpo is situated in this area on relatively higher ground, and is not subject to flooding.)

ZONE NO. 7 is a rectangular area bounded on the north by Lake Nokoue, on the east by a north-south line passing through a point near P.K. 7, on the south by the unnamed laterite road near the Catholic Mission and on the west by the lagoon. This area has 15 square kilometers of land and an estimated population of 4,000.

Of the total area in this zone, only 1.1 square kilometers are within the city limits. About 6% of the total area is occupied by dwellings. Thus, Zone No. 7 has the least population of all the zones, and, at the same time, it has the largest area of vacant land. Included in Zone No. 7, besides the portion within the city limits, are the villages of Agbato, Agbodjedo, and Avontrou.

ZONE NO. 8 is essentially a rectangular area bounded on the north by the unnamed laterite road near the Catholic Mission, on the east by the north-south line passing through P.K. 6, on the south by the ocean and on the west by the north-south line passing through P.K. 3. This zone contains 7.6 square kilometers of which only 6.4 square kilometers are within city limits. Zone No. 8 has an estimated population of 5,000 and is largely underdeveloped at present. It contains the Cotonou radio station (Service Radio) and some industrial establishments. Included in this zone are the villages of Zinjanaho and Agbalangandan. There are also scattered residential areas near the ocean beach.

2. Prospects for Future Zonal Growth

Assuming a compound annual growth rate of 4.5%, the population in and around Cotonou will increase to 450,000 by 1995. Table III-4 shows how this growth would be apportioned between the city and the suburbs by 5-year intervals. It should be noted that a large portion of the expected population growth will come from immigration, as well as from natural increase (births minus deaths). In the period 1952-1959, for example, a total of 22,000 persons—mostly between 18 and 35 years of age—moved to Cotonou and vicinity primarily from rural areas elsewhere in Dahomey.

It may be assumed that with full development (in 1995), 50% of the city's land area will be used for residential purposes, while the remaining 50% will be used for commerce, industry, public streets, institutions, and other urban purposes. Within the Cotonou city limits there will be 2,000 hectares required for residential use. This means that practically all of the lands in the northern section of the city near Lake Nokoue will be used for residential purposes. At a net density of 78 persons or 16

TABLE III-4

POPULATION GROWTH ESTIMATES IN COTONOU AND VICINITY
BY FIVE-YEAR INTERVALS
1970-1995

	1970	1975	1980	1985	1990	1995
Cotonou	115,000	143,000	178,000	222,000	239,000	239,000
Suburbs	35,000	44,000	55,000	69,000	122,000	211,000
Total	150,000	187,000	233,000	290,000	361,000	450,000

Note: Assuming a 4.5% compound annual population growth rate, Cotonou will reach its theoretical maximum population of 239,000 in 1990. All population increase thereafter will occur in the suburbs.

households per residential hectare (a density slightly in excess of the present conditions), there will be approximately 209,000 persons living in Cotonou. This figure represents the city's maximum holding capacity, exclusive of the unallocated population; 239,000 if such persons are included. It is obvious, therefore, that any population projection substantially beyond this figure could not materialize within the city limits unless substantial changes take place, with respect to the physical development pattern and residential densities.

If the entire projected area-wide population is to materialize in Cotonou alone by 1995, the following must occur: 1) the present single household density pattern would have to be restructured to permit a substantial amount of multi-family residences, 2) the open yards around existing single household units would have to be replaced by additional residential structures (each lot would thus accommodate two, three, four or more single household units), and 3) new, presently underdeveloped areas in the city would have to be developed with multifamily residences.

If one or more of these developments do not occur to any significant extent, Cotonou itself will not be able to absorb the entire area-wide population projected to 1995 within the present city limits. Rather, the major part of the anticipated growth during the next 25 years will have to take place in the immediately adjacent suburbs and outlying areas.

The 450,000 persons projected to reside in the area by 1995 would represent an increase of 300,000 persons over the 1970 figure. However, Cotonou, within its city limits, would be able to absorb only 239,000 persons — 124,000 more than at present. The remaining 176,000 persons would have to establish themselves outside city limits. Thus, it must be assumed that beyond the next one to two decades, a Cotonou regional area will begin to take shape within the city of Cotonou, the heavily populated core being surrounded by residential suburbs extending towards Lake Nokoue to the north, Porto-Novo to the east, Abomey-Calavi to the northwest, and Ouidah to the west.

It is within the context of the demand for physical space to locate and house the projected future population of Cotonou, that we can attempt to predict the probable growth within each of the eight city zones. The estimated increase in residential densities and population growth in various zones are shown in Tables III-4 and III-5.

ZONE NO. 1 is expected to continue to be the commercial hub of activity in the future, and will probably grow in stature as the port expands and new commercial and industrial establishments replace some of the areas presently being used for residential purposes. It is likely, too, that while residential acreage diminishes, the residential density will increase as multifamily housing is built in this very convenient part of Cotonou.

ZONE NO. 2 has great potential for industrial development on the substantially large

TABLE III-5

ESTIMATED FUTURE RESIDENTIAL DENSITY AND POPULATION OF COTONOU (1995)
(WITHIN CITY LIMITS ONLY)

Zone No.	Net Residential Density		Estimated Household Population	Estimated Net Residential Area (Hectares)	Estimated Total Population*	Additional Population Since 1970	Percent Increase	25-year Growth Factor
	Households Per Hectare	Persons Per Hectare						
1	33	165	16,500	100	22,500	+2,000	10	0.5
2	14	70	21,000	300	27,000	+16,000	146	3.7
3	15	75	48,000	640	55,500	+19,500	54	1.8
4	16	80	48,000	725	61,000	+35,750	142	3.7
5	14	70	12,500	180	14,000	+6,500	87	2.5
6	29	131	9,800	75	11,300	+4,550	68	2.2
7	18	88	8,800	100	10,300	+6,300	158	3.8
8	20	60	34,400	575	37,400	+32,400	648	8.3
Total	16	78	209,000	2,695	239,000	+123,000	107	3.0

* It is assumed that an additional 15% of the population or approximately 30,000 persons, will live in Cotonou but will not have permanent places of residence. Their future allocation by zone is as follows: Zone No. 1 - 20%, or 6,000 persons; Zone No. 2 - 20%, or 6,000 persons; Zone No. 3 - 25%, or 7,500 persons; Zone No. 4 - 10%, or 3,000 persons; Zone No. 5 - 5%, or 1,500 persons; Zone No. 6 - 5%, or 1,500 persons; Zone No. 7 - 5%, or 1,500 persons and Zone No. 8 - 10%, or 3,000 persons.

tract of land which will develop as a sandfill west of the port jetty, by the action of the littoral drift. A considerable amount of sand has already accumulated in this area.

The potential of this land for industrial development is tremendous, given its ready access to the port and the International Route. Moreover, the entire economic value of this "new" land will add a great deal to the wealth of the city. Use of the Crespin Concession lands (located along the ocean to the southeast of the airport) for industrial development is also a distinct possibility. Although the areas available for residential development in this zone are limited, the residential population of this zone will increase substantially in number, due to the fact that locating near the ocean is highly desirable. The main area likely to develop residentially is located between the airport road and the ocean.

ZONE NO. 3 will require considerable effort to reclaim the large area of marshy lowlands to the weat. It is expected, however, that residential development of these presently open tracts will continue. Perhaps the major change in the eastern portion of this zone will be increased commercialization of the north-south streets abutting Zone No. 1 (e.g., Avenue Steinmetz, Avenue Delorme, etc.), and Boulevard Saint Michel, which lead into the site of the proposed new bridge and market place in the northeastern corner of this area. Along with the construction of the bridge, it is expected that Avenue de la Republique will be paved and improved.

ZONE NO. 4 development will also depend on the extent to which marshy lowlands will be reclaimed. In spite of the cost and the problems involved in filling the marshy areas, it is expected that residential development of the vast expanses of presently vacant land in Zone No. 4 will be the major change witnessed there, over the next 25 years. The new bridge and market place near Saint Michel Boulevard are located in the southeastern corner of this zone. The new bridge, with its approaches, and the improved Saint Michel Market could prove to be major factors providing stimulus for an accelerated development of Zone No. 4.

ZONE NO. 5 will continue to grow, as it has in the past, through industrial development along the International Route No. 11. Its southeastern portion, primarily along the ocean shore, could become a prime area for residential or possibly hotel development.

ZONE NO. 6 will remain primarily a residential area. It is likely to develop mostly along the lagoon, provided that low areas, subject to flooding, are filled in and made more suitable for additional residential use. Possibly some recreational use similar to the Yacht Club, already located there, could also be developed along the lagoon shore. If the International Route No. 11 is relocated, and a bridge is constructed at the Saint Michel site, some commercial development will undoubtedly be established in this zone along the eastern approach road to the new bridge.

ZONE NO. 7 will probably experience larger growth than any other area in Cotonou.

It is interesting to observe that Zone No. 7 has a theoretical holding capacity for a population of 135,000, assuming that it would achieve a residential density of 18 households or 90 persons per hectare. This density would be slightly larger than that which presently exists in Zone No. 3.

A good deal of the land in Zone No. 7, near Lake Nokoue, is marshy and may take a long time to be developed. Nevertheless, the potential for development of Zone No. 7 is great. Considering even the most conservative estimates of population growth in Cotonou and taking into account the relatively limited amount of available space in most of the other zones, it is inevitable that Zone No. 7 be fully populated and developed. The potential impact of the growth of Zone No. 7 on intracity transportation is immense. In fact, a large part of the need for a new bridge at the Boulevard Saint Michel location as well as a west bank boulevard, could probably be justified on the basis of expected future growth in Zone No. 7 alone. These two capital improvements will be essential in providing quick access for the residents of Zone No. 7 to the important commercial, industrial, and governmental installations in Zones No. 1 and 2, and to the Saint Michel Market in Zone No. 4.

ZONE NO. 8 will undergo both industrial and residential growth. Industrial development will prevail along the lands adjacent to the International Route. Most of this zone, however, will develop residentially. Zone No. 8 should experience the largest increase in residential population within the city limits, with most of the initial growth occuring in the southern area where cooler temperatures, due to the proximity of the ocean, are likely to attract early development.

E. URBAN GROWTH POTENTIAL FROM A NEW LAGOON CROSSING

1. Planning Objectives for Selection of Bridge Site

In the Reconnaissance Report by Sanders & Thomas, Inc., two sites were chosen as having the most merit for the location of a new bridge across the Cotonou Lagoon. One site was near Boulevard Saint Michel, and the other was near the existing bridge. The choice was made primarily on the strength of engineering and construction cost considerations. In Section XII of this report, each site is also evaluated on the basis of economic benefits to be derived in terms of improved traffic flow and vehicle operating costs. It is useful, however, to also consider other objectives which undoubtedly will contribute to the economic growth of Cotonou, but which are difficult to quantify. Therefore, they cannot be included in the benefit/cost calculations. Thus, the new bridge should be located with the following objectives:

a. Displace the city's center of gravity to the north, closer to its geographical center.

b. Provide access to areas of the city suitable for future development.

c. Facilitate and improve the operations of the city's governmental and municipal services.

d. Develop easier communications and access between the eastern and western halves of Cotonou, thus allowing for better use of the recreational, cultural, and economic resources of the city, by its residents.

The choice of the site near Boulevard Saint Michel would satisfy all of the listed criteria, while the site near the existing bridge would satisfy only the last two.

2. Residential, Cultural, and Recreational Aspects

There is no doubt that in future years Cotonou will have to expand northward in order to provide room for the expected population growth. As the city begins to expand, it will become necessary to build additional streets, water, sewer, telephone and electric service lines in the newly-populated areas. In addition, new school facilities, parks, and recreational improvements will also be required. Above all, a good access road will be necessary to initially provide quick and easy travel to existing facilities in southern and eastern portions of the city; this will be needed only until new facilities are built in the developing areas. This road should be planned and located so that it ultimately can become a major transportation link in the city road system. In order to promote the development of the northern areas of the city, the Cotonou Master Plan wisely suggested the location of a large central market near Boulevard Saint Michel. This was accomplished in 1963. Today, the central market,

also known as the Lagoon Market, is a focal point of daily activity. Every fourth day, it is especially crowded with people bringing merchandise and products from as far as Ghana, Togo, and Nigeria. Thus, once a week, the Lagoon Market assumes a truly international character.

In Africa the city market is often a place where people from small villages have their first contact with an "urbanized" civilization. Thus, the market, beyond being a place for exchange of goods, also serves as an educational and a social function. It becomes a place where people gather to talk, exchange news and learn new things. The market, therefore, affords an opportunity to the villager to sell his wares and at the same time satisfies his basic desire to become more "civilized" by exposing himself to an urbanized environment.

It makes good sense, therefore, to locate a "central" market near the future geographical center of the city. A new bridge and approach roads located near Boulevard Saint Michel admirably serve the goal of helping the northward expansion of the city, and of providing better access to the Lagoon Market, as well as a more centrally-located link for intracity and through traffic.

3. Governmental Facilities and Services

Most of the governmental buildings in Cotonou are located near the ocean shore, within an area extending from the airport to the lagoon. The state government buildings include the Presidential Palace at the Independence Square, the military camp, Service Hydraulique, Travaux Publics, Ministry du Plan and others. The municipal buildings and services include the Hospital, the Chamber of Commerce, the Post Office and the Town Hall. It is obvious that the municipal government and services should be located in the future in a more centralized location. Again, the Cotonou Master Plan proposes that the town hall be relocated nearer to the future geographic center of the city — namely, near the Lagoon Market. The advantages are obvious. As the city expands in a northern direction, the administration of the municipal functions and services will become increasingly difficult as compared to the present. The existing Town Hall is entirely too small and inadequate to house the number of municipal employees and officials which will be needed to successfully manage city affairs. A new Town Hall, built in a more centralized location, can be planned, initially, as a more modest building, but with plenty of room for future expansion. Indirectly, the expansion and the growth of the city will create more opportunities for employment in the private as well as public sectors. The advisability of providing better access to all parts of the city, in terms of better municipal government and services, once again reinforces the choice of the site at Saint Michel Boulevard for a new bridge across the lagoon.

4. Economic Growth and Prospects for Employment

The successful growth of Cotonou, in terms of opportunities for employment,

will require an expansion in both the private as well as governmental operations. Although it is doubtful that in the near future the influx of new commercial and industrial establishments will keep pace with the demand for employment, the city population will continue to grow due to both the birth rate, as well as immigration from the rural areas. Unless the municipal and state governments succeed in getting sufficient funds through increased tax revenues, it will not be possible to provide the necessary administration and services which an expanded city will need. It is to be hoped, however, that the increase in population will generate the development of a good number of small businesses which cater to the basic needs, such as clothing stores, bakeries, building trades, etc. These small establishments, in turn, will supplement large investors and industry to provide a necessary tax base from which the city government can finance the needed expansion of their services. The tax base could then be enlarged by encouraging new large commercial and industrial concerns to locate in Cotonou and by helping the small local businesses to prosper and increase in numbers by keeping their tax burdens to a minimum. This could be achieved through continued tax incentives and through efficient use of tax revenues.

Whether the economic growth, employment, and tax revenue problems are solved or not, the choice of a site for the new bridge should be planned to be near the area where growth must take place. Again, the choice of the site at Saint Michel Boulevard seems to best satisfy such a goal.

SECTION IV

TRAFFIC STUDIES

A. OBJECTIVES

1. Required Data for Economic Studies

Traffic studies were necessary to provide a) the essential data for calculation of vehicle operating costs in the economic studies in Section XII and b) the basis for the calculation of maintenance costs for the bridge approach roads.

The largest proportion of the benefits of the various proposed alternatives derive from savings in the vehicle operating costs. These are composed of costs due to operating vehicles at various speeds on different types of road surfaces and of costs due to starting and stopping cycles and delays in congested conditions.

The necessary traffic data are obtained from three main areas of study. These are: 1) volume counts, 2) origin-destination surveys and 3) speed and delay studies.

2. Traffic Composition and Volume Counts

The counting of the traffic volume for each vehicle type crossing the Cotonou Lagoon on the existing bridge was needed for the following purposes:

a. To determine daily and hourly variations of traffic.

b. To provide the basis for the determination of average daily traffic.

c. To provide a basis for the evaluation of probable future traffic growth, together with the previously available counts.

d. To determine the maximum practical capacity of the existing bridge in terms of traffic flow.

Included in the traffic volume counts were also the pedestrian traffic using the existing bridge and the boat traffic in the lagoon.

3. Origin-Destination Survey

This survey was needed to determine the following:

a. The number of daily trips between various zones of Cotonou.

b. The expected future distribution of the traffic between the existing bridge and the proposed new bridge at the Boulevard Saint Michel Site.

A minimum sample of 10% of the total traffic for each vehicle type was deemed necessary to obtain valid origin-destination data for economic studies.

4. Speed and Delay Studies

The speed studies were necessary in order to determine the average speeds with which the various vehicles operate on laterite (earthen) and paved roads within the limits of the City of Cotonou, as well as crossing speeds on the existing bridge in congested and non-congested conditions.

The data developed from speed and bridge crossing studies were used as the basis for evaluating the traffic capacities of the existing and proposed bridges and the congestion delays to be expected as a result of traffic growth.

5. Bridge Capacity Requirements

The bridge capacity-width requirements for the new bridge can be determined from the data on traffic growth and distribution at each bridge site. Included in the bridge capacity considerations are the pedestrian traffic and the effect of vehicular traffic composition on speeds and safe operation on the bridge.

B. DATA AVAILABLE FROM PREVIOUS TRAFFIC SURVEYS

1. Traffic Counts by the Ministry of Public Works–Cotonou

The Ministry of Public Works (Travaux Publics) has kept a record of the traffic crossing on the existing lagoon bridge during the years 1960 through 1970. Counts were made manually, twice a year (generally in March and September), each one continuing for an entire week. The counts were obtained for each class of vehicle: namely, motor bicycles, passenger cars, small trucks (0.8 to 2.0 tons), medium trucks (2.0 to 10.0 tons), and large trucks (over 10.0 tons).

The collected data show many discrepancies, but nevertheless are quite useful. The inconsistencies were probably caused by the inexperience of the personnel performing the traffic survey as well as the difficulty in classifying the vehicles. In Cotonou it is not unusual to see passenger vehicles used for cargo-hauling purposes or small trucks loaded much beyond their normal capacity. Large trucks, on the other hand, are often used for transporting people instead of cargo thus functioning as a bus.

The results of the Ministry of Public Works counts have been used together with later data obtained by Sanders & Thomas, Inc. to determine the apparent growth rate for each vehicle class. (See Figures 12-1, 12-2, 12-3, and 12-4 in Section XII).

2. Dahomey Land Transport Study

In November and December of 1967, and in January of 1968, traffic volume counts were performed at the Cotonou bridge by N. D. Lea and Associates, a Canadian engineering consultant, using automatic traffic counters.

Compared to manual counts taken in the same year by Ministry of Public Works personnel, it appears that the automatic counters recorded volumes from 9% to 54% higher. The average excess is about 26%. If the counts recorded by the automatic counters are reduced by approximately 26%, one obtains results quite close to those obtained by Sanders & Thomas, Inc. a year later.

Nevertheless, the results of the automatic counters are useful in that they give traffic volume data during a continuous three-month period. It was possible, therefore, to obtain a sufficiently long trend to establish the relative variation of traffic during the various days of the week, as well as hourly variation during a 24-hour period.

3. Traffic Survey by Sanders & Thomas, Inc.

In January of 1970, Sanders & Thomas, Inc. performed an 18-hour traffic count at the Cotonou bridge. During this count, volumes were recorded for various classes of vehicles as well as for pedestrians. The results have closely matched the results obtained by N. D. Lea and Associates in terms of relative variation of hourly traffic during a day.

Additional counts were performed on the International Route at the entrance and exit of Cotonou currently with the bridge counts. It was thus possible to establish that approximately 75% of the total bridge traffic is local Cotonou traffic. It was also determined from observation of auto license tags that approximately 1% was of international origin.

C. VEHICULAR TRAFFIC ACROSS EXISTING BRIDGE (NOVEMBER 1970)

1. Traffic Composition and Volume Counts

The volume counts at the existing bridge were done manually by six teams of counters working six hours each. A team was stationed at each end of the bridge and was instructed to count the traffic coming from one direction. Each team consisted of one time keeper and three counters, with each counter recording the volume of categories of traffic assigned to him every 15 minutes.

The six categories of traffic consisted of the following:

a. Passenger cars, taxis, station wagons and light trucks (less than 2 tons) were considered as one category since they all have similar operating characteristics.

b. Busses.

c. Trucks (over 2 tons).

d. Motor bicycles.

e. Pedal bicycles.

f. Pedestrians.

The counting was conducted on a market day, a non-market weekday, and on a holiday. Additional counts were performed on the same days as the origin-destination survey in order to have a direct comparison between them.

The following Table IV-1 shows the total daily traffic volumes for each of the traffic categories and types of days on which they were counted.

TABLE IV-1

NOVEMBER 1970 TWO-WAY TRAFFIC - COTONOU BRIDGE

Traffic Category	Week Day	Market Day	Holiday
Passenger Cars, Taxis Station Wagons and Light Weight Trucks (under 2 tons)	11,024	10,135	8,272
Busses	698	678	431
Trucks (over 2 tons)	1,737	2,257	574
Motor Bicycles	8,252	8,770	6,898
Pedal Bicycles	9,075	9,981	7,245
Pedestrians	10,167	11,913	10,953

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The average daily traffic was computed by using the following proportions: 25% of market day traffic [1], 20% of Sunday and holiday traffic [2], and 55% of the week-day traffic. Since the actual count was conducted over an 18-hour period, it was necessary to increase the 18-hour totals by approximately 2% to account for the traffic between 11:00 PM and 5:00 AM. There was no need to make adjustments for seasonal variation of traffic since, in Cotonou, unlike the rural areas of Dahomey, there is no significant change in traffic during the dry or rainy seasons. Thus, the following results were obtained for the average daily traffic:

TABLE IV-2

TWO-WAY AVERAGE ANNUAL DAILY TRAFFIC COTONOU BRIDGE
(NOVEMBER 1970)

Traffic Category	Average Annual Daily Traffic
Passenger Cars, Taxis, Station Wagons and Light-Weight Trucks (under 2 tons)	10,400
Busses	640
Trucks (over 2 tons)	1,650
Motor Bicycles	8,200
Pedal Bicycles	9,000
Pedestrians	11,400

During the 12-hour period from 7:00 AM to 7:00 PM comprising 85% of the total traffic the heavier directional volume includes 51% of the total two-way volume. During this same period, the heavier direction 15-minute count contains 54% of the total 15-minute two-way traffic volume.

The directional analysis of the car, bus, and truck volumes indicates that westbound volumes are slightly larger in the morning hours and that eastbound

[1] Market day occurs every fourth day.

[2] Holidays occur approximately 20 times a year. Sunday traffic was found to be similar to holiday traffic.

traffic is slightly larger in the afternoon. The motor bicycle volumes do not vary for either direction, while the peddle bicycle volumes are distributed approximately 55% westbound in the morning and eastbound in the early evening. Pedestrian traffic was 69% westbound in the morning and eastbound in the evening.

The hourly variations of two-way traffic volumes for each type of traffic category are shown in Figures 4-1 through 4-6. For each category three graphs are shown: one for a market day, one for a nonmarket day (weekday), and one for a holiday or Sunday. The graphs include the indication of the time when the bridge was closed to vehicular traffic due to the passage of the train. The train crossed the bridge on the average of eight times per day.

From the graphs in Figures 4-1 through 4-6, it can be seen that all traffic has peaks in the morning and in the evening with a pronounced decline around 2:00 o'clock in the afternoon. The highest hourly two-way volumes for each traffic category are shown in Table IV-3.

Table IV-4 shows the one-way peak traffic during a 15-minute period within the peak hours listed in Table IV-3.

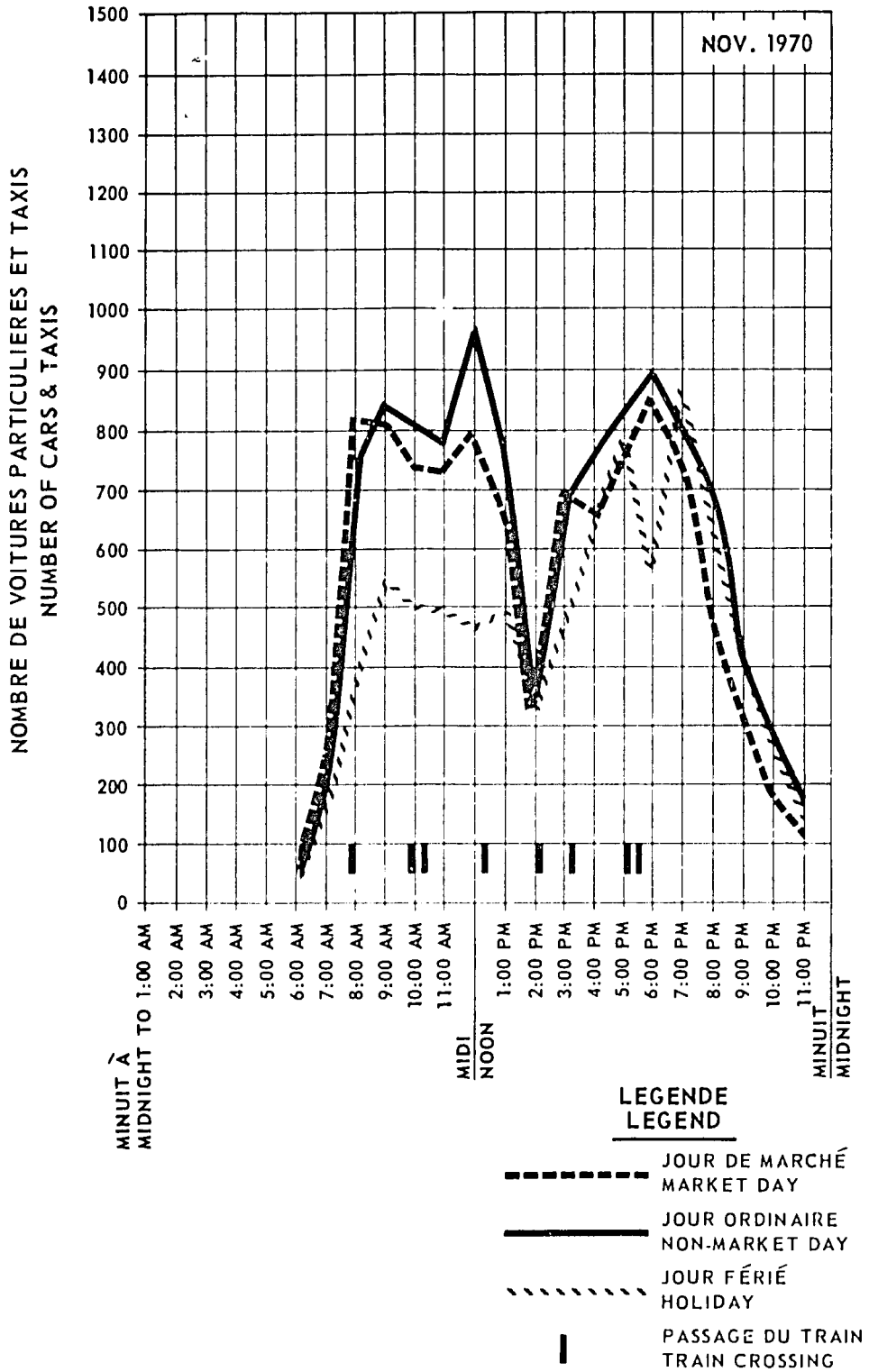
Other 15-minute one-way peak traffic periods not occurring within the peak hour periods are shown in Table IV-5. Some of these occurred right after the passage of the train.

2. Effect of Market Day and Seasonal Variations

As indicated by the traffic volume counts, the effect of market day is felt in a different way for each type of vehicle. It appears that on a market day the volume of passenger cars, taxis, light trucks, and busses declines, while that of heavier trucks, both motor and peddle bicycles, and pedestrians increases. In all cases the increase or decrease is not large; it varies only between 6 and 10 percent. In the case of trucks weighing over 2 tons, however, the market day traffic increases by 30%. This probably can be explained by the fact that trucks carry heavy loads of merchandise and produce for sale on the market.

There were no significant differences in the origin-destination characteristics of the traffic between a weekday and a market day. Although an origin-destination survey was not conducted on a holiday, it is possible that a drop in the ratio of short to long trips would have been noted and that the percentage of international trips would have also declined.

The seasonal variations of traffic in Cotonou are believed to be insignificant. Although all of the city streets (with the exception of a few main arteries such as the International Route No. 11, Boulevard Saint Michel, and Avenue Steinmetz) are not paved, the rainy season does not affect their serviceability to any great extent.



PONT DE COTONOU-VARIATION HORAIRE DE LA CIRCULATION
COTONOU BRIDGE-HOURLY VARIATION OF TRAFFIC VOLUMES

FIG. 4-1

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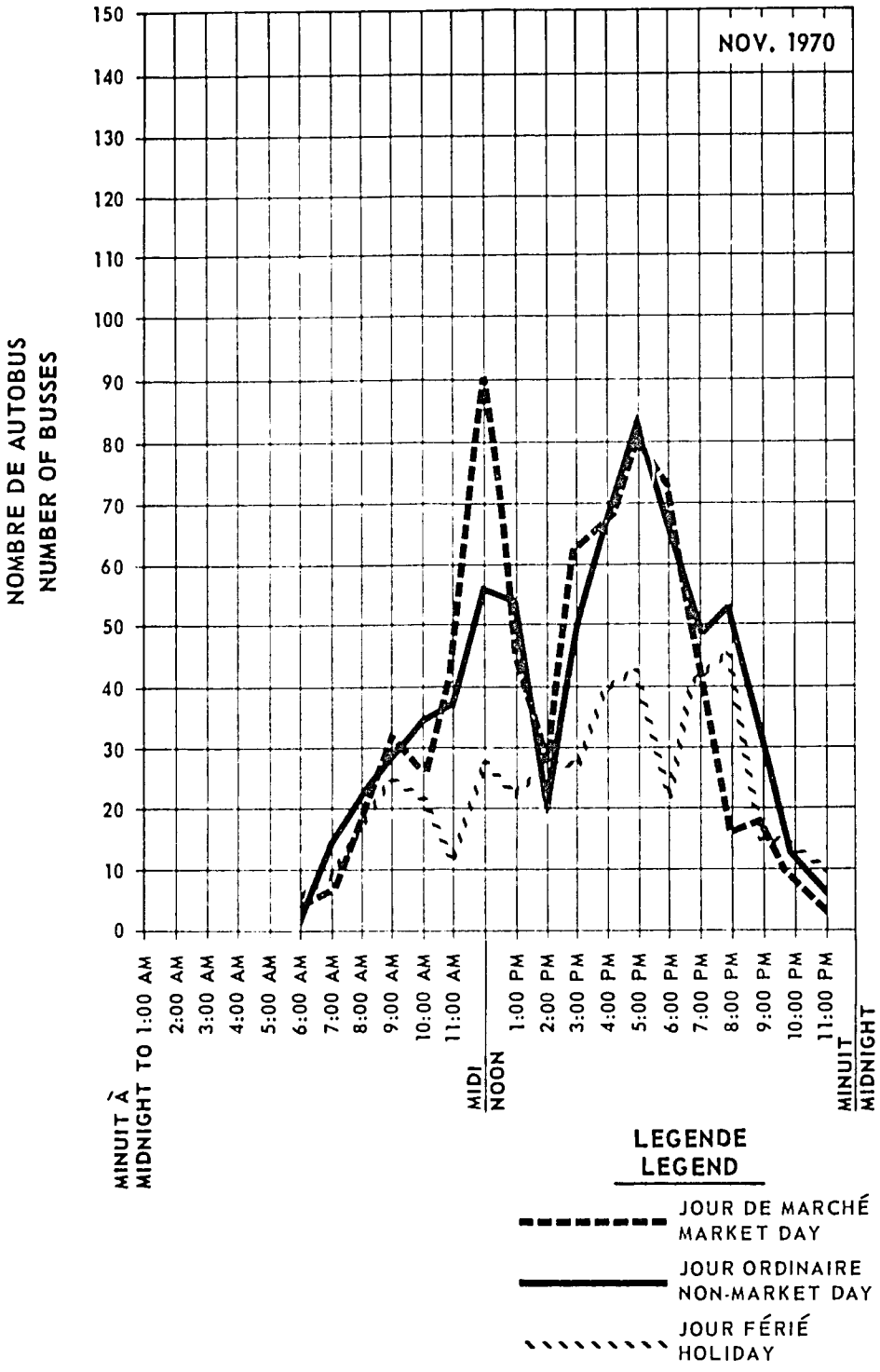
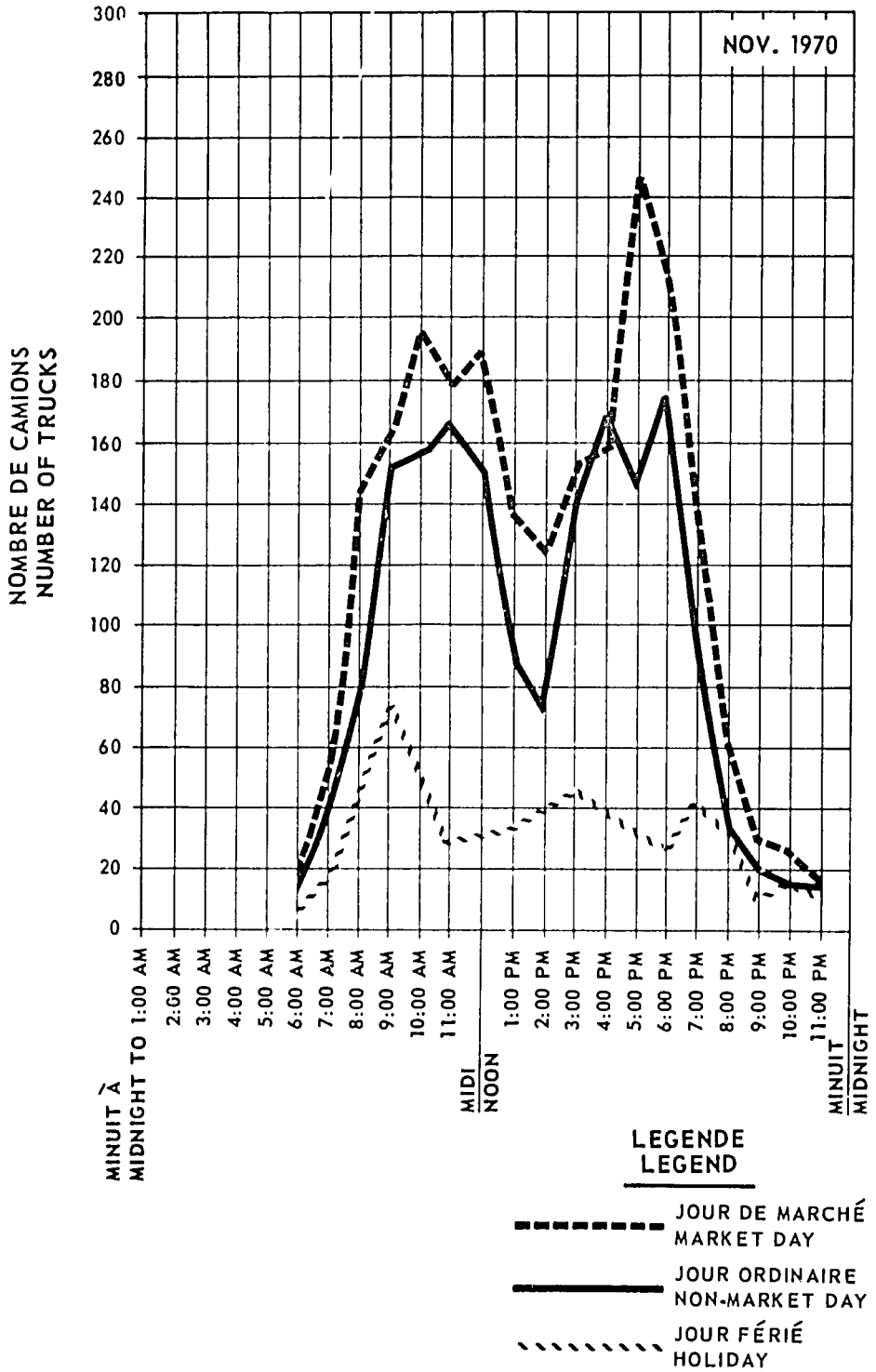


PONT DE COTONOU–VARIATION HORAIRE DE LA CIRCULATION
COTONOU BRIDGE–HOURLY VARIATION OF TRAFFIC VOLUMES

FIG. 4-2



PONT DE COTONOU-VARIATION HORAIRE DE LA CIRCULATION
COTONOU BRIDGE-HOURLY VARIATION OF TRAFFIC VOLUMES

FIG. 4-3

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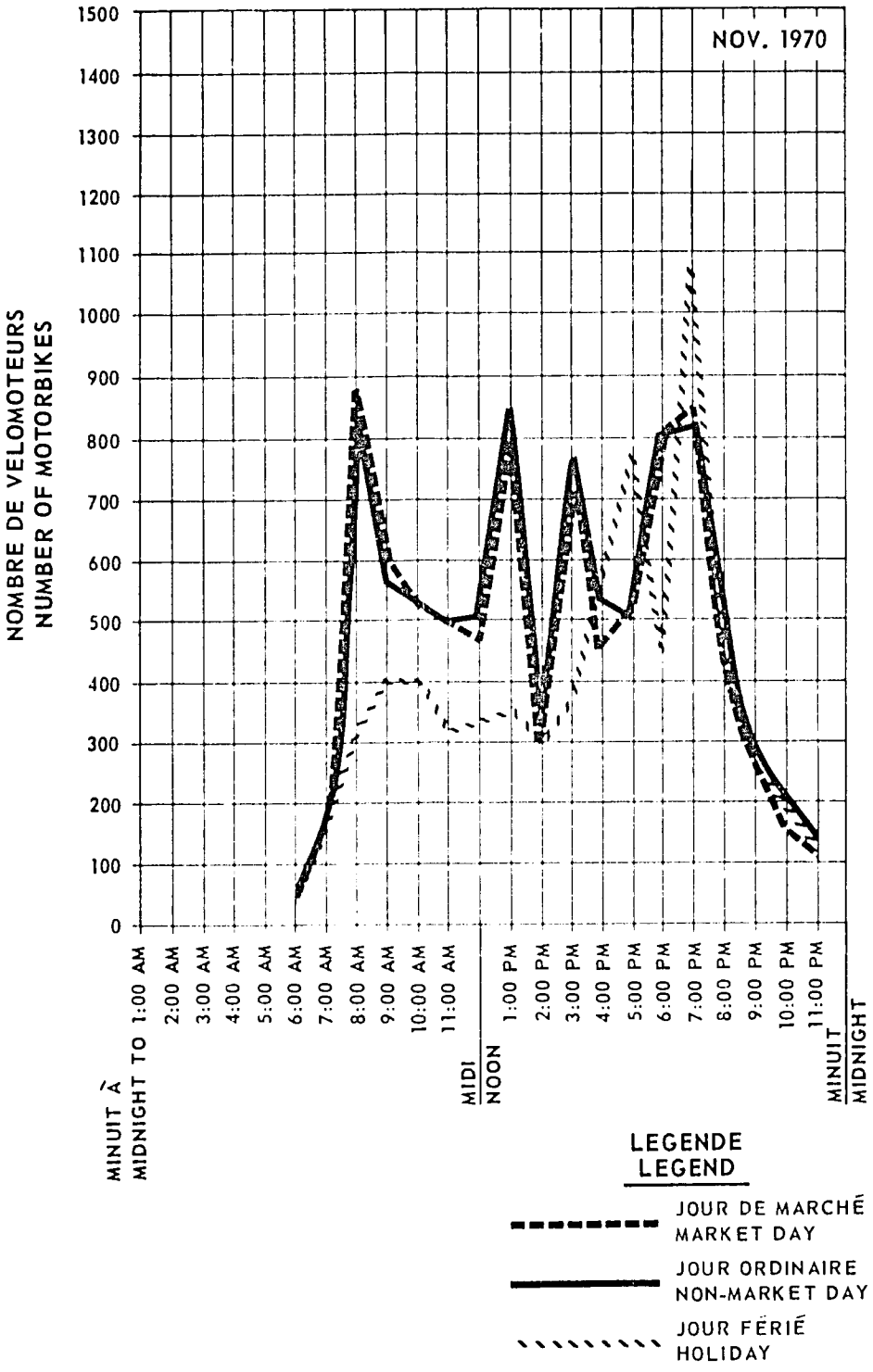
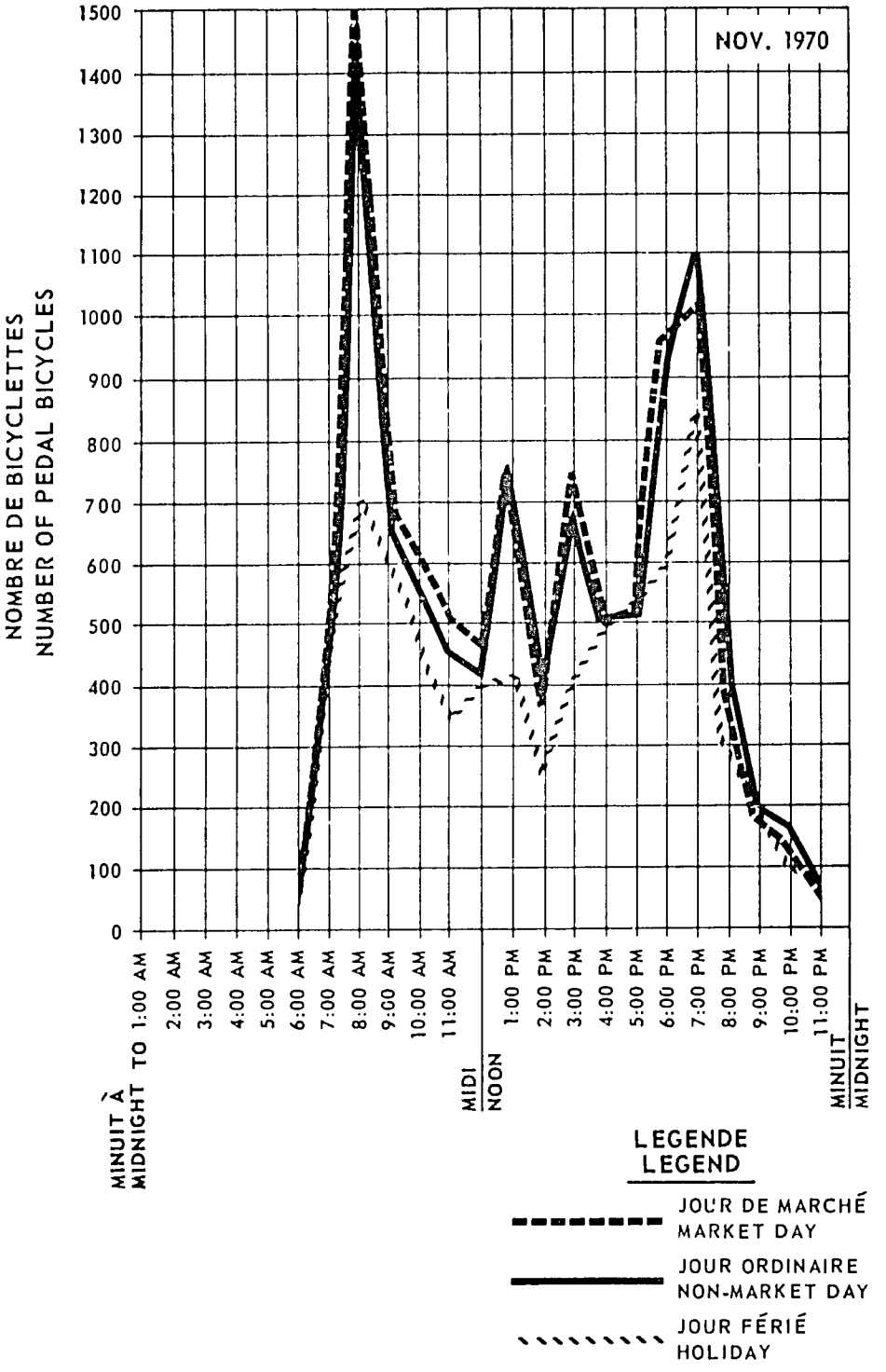


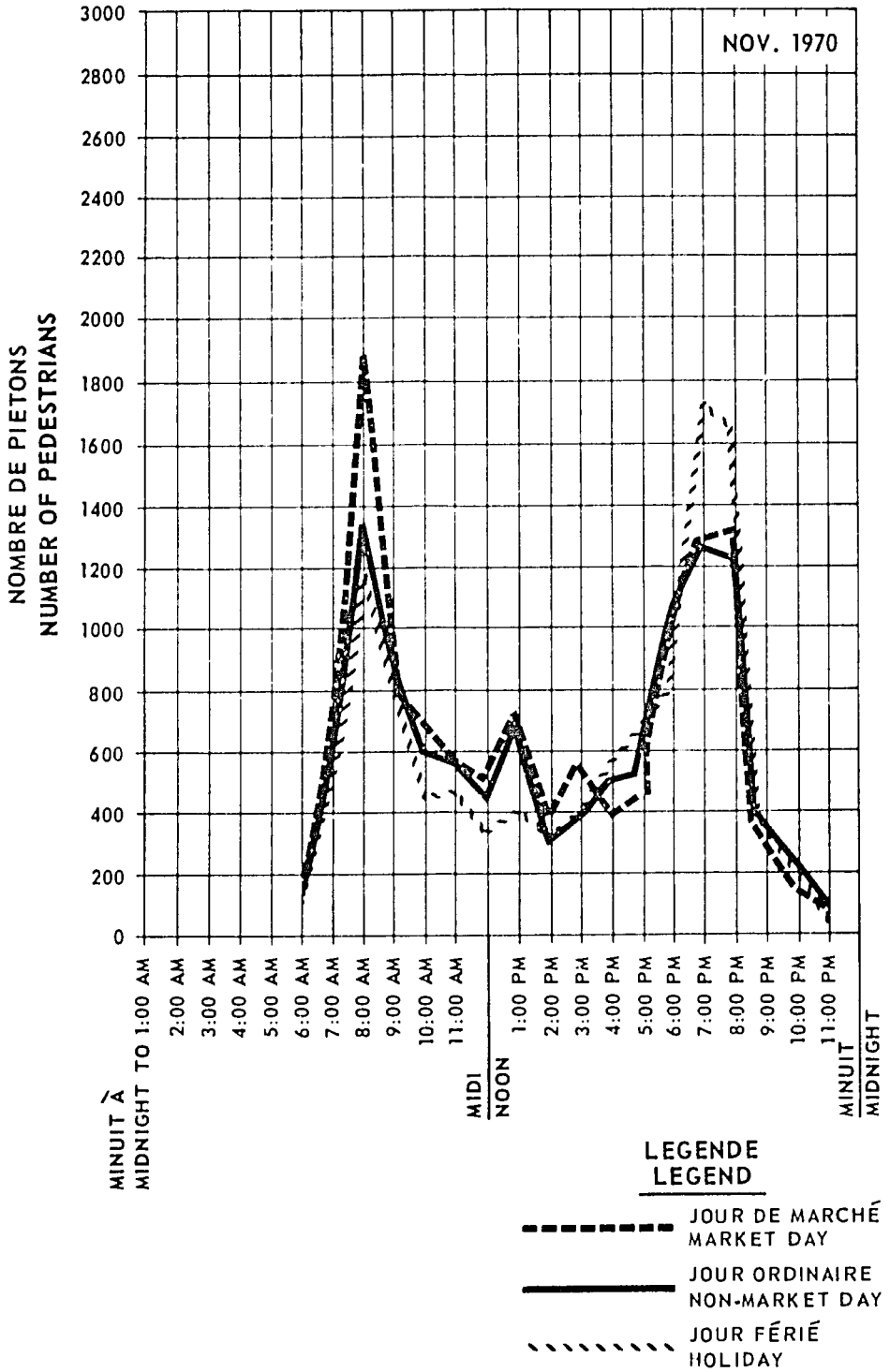
PONT DE COTONOU–VARIATION HORAIRE DE LA CIRCULATION
COTONOU BRIDGE–HOURLY VARIATION OF TRAFFIC VOLUMES

FIG. 4-4



PONT DE COTONOU-VARIATION HORAIRE DE LA CIRCULATION
COTONOU BRIDGE-HOURLY VARIATION OF TRAFFIC VOLUMES

FIG. 4-5



PONT DE COTONOU–VARIATION HORAIRE DE LA CIRCULATION
COTONOU BRIDGE–HOURLY VARIATION OF TRAFFIC VOLUMES

FIG. 4-6

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TABLE IV-3

PEAK HOUR TWO-WAY TRAFFIC - COTONOU BRIDGE
(NOVEMBER 1970)

Traffic Category	Morning		Afternoon	
	Volume	Hour	Volume	Hour
Cars	1,029	11:00-12:00	1,015	5:15 - 6:15
Busses	104	11:15-12:15	93	4:30 - 5:30
Trucks	208	9:00-10:00	292	5:00 - 6:00
Motor Bikes	1,070	7:15- 8:15	1,116	6:30 - 7:30
Pedal Bikes	1,487	7:00- 8:00	1,237	5:30 - 6:30
Pedestrians	1,898	7:00- 8:00	2,261	6:30 - 7:30

TABLE IV-4

PEAK 15-MINUTE ONE-WAY TRAFFIC - COTONOU BRIDGE
(NOVEMBER 1970)

Traffic Category	Morning			Evening		
	Volume	Direction	Time	Volume	Direction	Time
Cars	188	WB	11:45-12:00	170	WB	5:15 - 5:30
Busses	20	WB	11:45-12:00	19	WB	4:45 - 5:30
Trucks	32	WB	9:00- 9:15	68	WB	5:30 - 5:45
Motor Bikes	171	EB	7:45- 8:00	440	WB	6:35 - 6:45
Pedal Bikes	226	EB	7:45- 8:00	185	WB	5:45 - 6:00
Pedestrians	413	EB	7:00- 7:15	468	EB	7:15 - 7:30

TABLE IV-5

MAXIMUM 15-MINUTE ONE-WAY TRAFFIC PRECEEDING
THE PEAKS IN TABLE IV-4 - COTONOU BRIDGE
(NOVEMBER 1970)

Traffic Category	Volume	Direction	Time (PM)
Cars	201	WB	6:45 - 7:00
Busses	24	WB	4:45 - 5:00
Pedal Bikes	228	WB	6:00 - 6:15

3. Origin–Destination Survey

This survey was conducted during a 12-hour period at the eastern and the western ends of the Cotonou bridge. At each end, a team of four interviewers aided by a policeman would stop a passenger car, a truck or bus, a motor or peddle bicycle or a pedestrian and would record the origin and destination of each. The entire operation was supervised by the engineers of Sanders & Thomas, Inc. in order to insure that a random, uniformly chosen sample of the traffic was obtained. The survey proceeded with many initial difficulties. One of the problems was the lack of sufficient room to pull the vehicles out of the stream of traffic during the interview and allow the rest of the traffic to proceed undisturbed. Another problem was to insure a precise answer relative to the place of origin or destination. Additionally, a very serious problem was the absence of a policeman at the precise time at the beginning of the survey work or the unwillingness of some of the policemen to stay during the entire six-hour period. It was necessary, therefore, to repeat the survey work several times in order to obtain usable data. In spite of the difficulties, however, the survey teams eventually succeeded in obtaining a sufficient number of responses with usable information. The survey work was conducted in two 6-hour shifts on a market day and a weekday.

The final results consisted of 1,763 usable responses for the passenger cars, taxis, etc., 767 for busses and trucks, 1,230 for motor and pedal bicycles and 1,280 for pedestrians.

Eash answer obtained during the interviews at the bridge was later marked with a number corresponding to the zone of the city where the origin or destination was located.

The zones were the same as those described in Section III. Two additional zones were used in the origin-destination survey denoting areas outside Cotonou. Zone No. 9 denoted any area west of Cotonou (Abomey Calavi, for instance) and Zone No. 10 denoted any area east of Cotonou (Porto-Novo, etc.). Thus, Zones No. 9 and 10 denoted an external trip, while all the others denoted an intracity trip (See Map, page A-1 in the Appendix A).

From the origin-destination survey, the percentage of trips between any two zones was determined and tabulated by each vehicle type and also for pedestrian trips. The results are shown in Tables IV-6 through IV-9.

The results obtained for a market day and a weekday were quite similar, indicating that they could be combined rather than shown separately. In general, for a few trips where there was a significant increase in traffic on a market day, the combined result was adjusted to reflect that market day occurs only every fourth day.

TABLE IV-6

PASSENGER VEHICLES, TAXIS, STATION WAGONS AND LIGHT TRUCKS
(UNDER 2 TONS)
(Percentage Of Trips Between Zones)*

Zone	5	6	7	8	9	Total
1	17.7	4.6	0.8	10.4	17.1	50.6
2	5.2	1.2	0.1	2.6	2.3	11.4
3	10.1	3.5	1.0	5.1	4.7	24.4
4	3.8	1.4	0.4	2.7	1.4	9.7
10	1.0	0.5	0.0	0.5	1.9	3.9
Total	37.8	11.2	2.3	21.3	27.4	100.0

* Results based on 1763 responses representing 17% of average daily traffic

TABLE IV-7

TRUCKS (OVER 2 TONS) AND BUSSES
(Percentage Of Trips Between Zones)*

Zone	5	6	7	8	9	Total
1	17.5	0.7	0.0	25.2	15.8	59.2
2	3.5	0.0	0.1	2.1	1.7	7.4
3	2.6	0.3	0.0	3.3	5.9	12.1
4	1.2	0.0	0.0	0.9	0.1	2.2
10	2.7	0.1	0.3	7.2	8.8	19.1
Total	27.5	1.1	0.4	38.7	32.3	100.0

* Results based on 765 responses representing 33% of average daily traffic.

TABLE IV-8

MOTOR BICYCLES AND PEDAL BICYCLES
(Percentage Of Trips Between Zones)*

Zone	5	6	7	8	9	Total
1	18.9	8.0	4.2	11.0	1.2	43.3
2	3.2	2.0	0.8	1.2	0.2	7.4
3	16.0	5.9	1.6	10.7	0.9	35.1
4	6.9	1.5	0.2	4.6	0.2	13.4
10	0.3	0.2	0.0	0.3	0.0	0.8
Total	45.3	17.6	6.8	27.8	2.5	100.0

* Based on 1230 responses representing 7% of average daily traffic.

TABLE IV-9

PEDESTRIANS
(Percentage Of Trips Between Zones)*

Zone	5	6	7	8	9	Total
1	22.0	18.8	6.6	5.1	0.6	53.1
2	3.2	1.5	0.8	1.6	0.1	7.2
3	14.4	10.5	2.9	3.5	0.9	32.2
4	2.7	0.9	0.6	1.7	0.0	5.9
10	1.1	0.2	0.2	0.0	0.1	1.6
Total	43.4	31.9	11.1	11.9	1.7	100.0

* Based on 1280 responses representing 11% of average daily traffic.

Half of the passenger cars and taxis had either an origin or a destination in Zone No. 1, 1.5% of all traffic was of international origin.

Fifty-nine percent of all the trucks and busses originated in or was destined for Zone No. 1. The most frequent trip was between Zones 1 and No. 8. International truck traffic was 5.6% and international bus traffic was 8.8%.

Forty-five percent of all peddle and motor bicycles had origin or destination in Zone No. 5; 43% in Zone No. 1. The most frequent trip was between Zones No. 1 and No. 5 (19%) and Zones No. 3 and No. 5 (16%). Only one motor bicycle was recorded as having an international destination (Lagos).

Using the computed average daily traffic and the percentages shown in Tables IV-3 through IV-6, it is possible to obtain the traffic volume for every zonal origin-destination pair. Thus, the number of vehicles that could be expected to divert to a new bridge at the Boulevard Saint Michel site can be computed.

The number of passengers was also counted and recorded during the origin-destination survey. The average number of passengers observed in the private cars was 2.23, while that in the taxis was 4.84. These numbers include the driver of the vehicle.

The average number of passengers observed in the trucks was 3.36. The number of passengers in the buses was 15.9 including the driver.

The responses from the origin-destination survey were analyzed to determine the center of gravity of each zone. These are shown in the map of the City of Cotonou, page A-1 in the Appendix.

The centers of gravity of each zone were used to determine the average length of the trip between zones for the purpose of calculation of vehicle operating costs for each trip.

The determination of centers of gravity was further verified by turning movement counts at selected intersections.

4. International Traffic

From the origin-destination survey percentages and the average daily traffic figures, we can calculate the following results for the international traffic:

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TABLE IV-10

1970 INTERNATIONAL TRAFFIC - COTONOU BRIDGE

Traffic Category	Daily Average	Annual Average	Percent of Total Traffic
Passenger Cars	156	5,700	1.5
Busses	56	56	8.8
Trucks	92	3,340	5.6
Motor Bicycles	15	550	0.2
Total	319	11,360	16.1

D. BOAT TRAFFIC ACROSS COTONOU LAGOON

1. Description of Boat Traffic

Cotonou Lagoon is traversed every day by a substantial amount of boat traffic. The bulk of the passenger and cargo traffic is carried by five or six ferry boats usually consisting of a flat bottom wooden boat powered by an outboard motor. The ferry boats carried at times as many as 60 passengers together with their bundles of produce and other miscellaneous cargo. The other boat traffic consisted of dugout canoes known locally as "pirogues". The pirogues usually carried less than ten passengers and were navigated by means of oars or wooden poles which were pushed against the lagoon bottom.

The pirogues were by far the most numerous type of boat. Most of them usually came from the fishing villages around Lake Nokoue, but many also came from the east shore of the lagoon. The ferry boats served mainly the cross lagoon traffic by providing passenger transportation from the eastern side of the lagoon to the Saint Michel Market on the western side. Some of the ferry boats brought passengers from Porto-Novo or places as far away as the Nigerian border. In general, the rates charged for travel on the ferry boats were very low. They ranged from 5 to 20 Fr. CFA per person. The low fares probably can explain why so many people used this type of transportation in preference to walking or taxis.

2. Boat Passenger Counts and Origin-Destination Survey

The boat passenger traffic counts and the boat origin-destination survey were conducted simultaneously. One team consisting of three interviewers was placed at each of the major landings at the Saint Michel Market on the west bank of the lagoon. The two landings were located approximately 0.2 kilometers north of the site for the proposed new bridge. The survey was conducted during a 12-hour

period from 7:00 AM to 7:00 PM on a market day, weekday and holiday. The counts were kept for each individual 15-minute period. The results of the survey are shown in Table IV-11.

TABLE IV-11

1970 BOAT PASSENGER TRAFFIC - COTONOU LAGOON
(Average For Weekday And A Market Day)

Description	Number of Passengers	Time
Peak Hour-Morning Two-Way Traffic	1,115	7:00- 8:00 AM
Peak Hour-Afternoon Two-Way Traffic	923	6:00- 7:00 PM
Peak 15-Minute One-Way Traffic West Bound	430	7:30- 7:45 AM
Peak 15-Minute One-Way Traffic Eastbound	294	6:45- 7:00 PM

The total daily boat passenger traffic was as follows:

Market Day	10,585
Non-Market Day	4,364
Holiday	2.200

The boat passenger traffic was distributed 75% westbound in the morning on a non-market day, and 80% westbound in the morning on a market day. There was an equal eastbound traffic in the afternoon. The hourly variation of boat passenger volumes is shown in Figure 4-7.

The origin-destination survey shows that none of the boat passengers originated in or were destined for Zones No. 1, 2, 8 and 10. The results of a two-day survey period of the boat traffic are shown in Table IV-12. The zonal destinations shown are for the boat. Some passengers may have had destinations beyond that of the boat; however, the questioning of passengers revealed that such cases were few. There were 12 passengers coming by boat from Nigeria during the market day survey.

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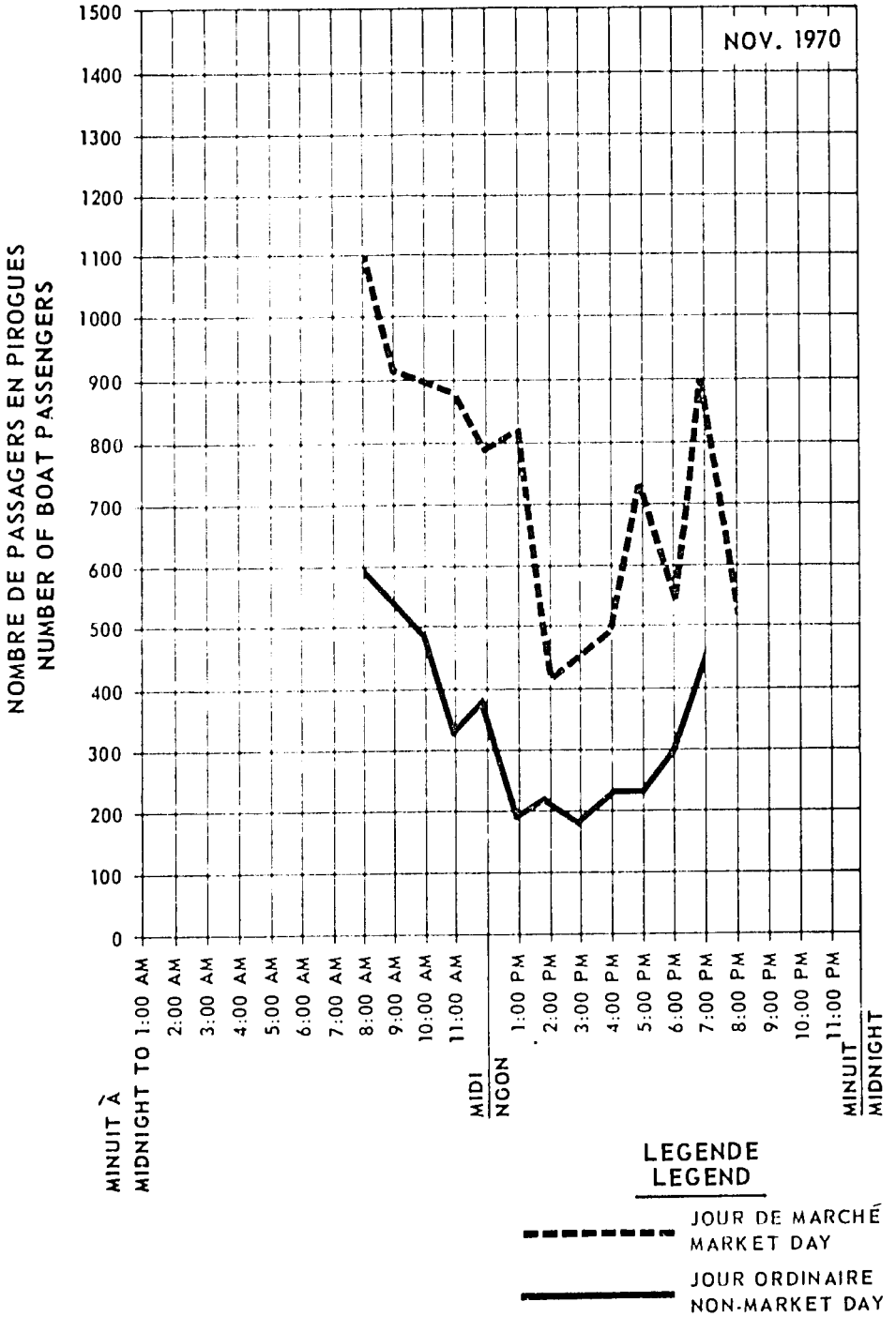

LAGUNE DE COTONOU–VARIATION HORAIRE DE LA CIRCULATION DES PIROGUES
COTONOU LAGOON–HOURLY VARIATION OF BOAT TRAFFIC

FIG. 4-7

TABLE IV-12

1970 BOAT PASSENGER TRAFFIC - COTONOU LAGOON
(Percentage Of Trips Between Zones)

Zone	5	6	7	8	9	Total
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.1	57.3	0.0	0.0	1.9	59.3
4	0.0	36.4	4.1	0.0	0.2	40.7
10	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.1	93.7	4.1	0.0	2.1	100.0

3. Effect of Alternate Bridge Sites on Future Boat Traffic

As can be noted from Table IV-12, most of the boat traffic transported people between Zones No. 3 and 6 and Zones No. 4 and 6. Most of this traffic was by means of ferry boats. If a new bridge were located at a site adjacent to the existing bridge, there would be no changes in ferry boat traffic. However, if a new bridge were constructed at the Boulevard Saint Michel site, most of the boat passengers would probably cross the lagoon on the new bridge. Therefore a new bridge at the Boulevard Saint Michel site could put all but a few of the ferry boats out of business.

Most of the pirogues came from Agbato and Lake Nokoue fishing villages and usually went to the Saint Michel Market. The pirogue traffic, therefore, would not be affected by the choice of the new bridge site. The fact that 94% of the people in Zones No. 3, 4 and 6 want to cross the lagoon each day indicates that a new bridge is very much needed in the vicinity of Boulevard Saint Michel. At present, most of the people crossing the lagoon by boats are the least affluent citizens of Cotonou. Therefore, it is expected that most of these people will be initially walking across the new bridge. Because of this, sufficiently wide sidewalks will be required to allow a pedestrian traffic of over 12,000 people (in 1977) to cross comfortably. At some future date, with economic growth, many of these people may be crossing by bicycle or car.

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E. SPEED AND DELAY STUDIES

1. Speed Studies

The average speed of traffic flow was determined by driving a passenger car in the stream of traffic in selected areas of Cotonou at various times of the day. The speeds ranged from an average of about 15 kilometers per hour on laterite roads to 80 kilometers per hour on the International Route in the eastern portion of Zone No. 8. Some of the observed speeds are listed in Table IV-13:

TABLE IV-13

AVERAGE SPEED OF VEHICULAR TRAFFIC IN COTONOU

Name of Road	Type of Road	Location	Average Speed
International Route No. 11	Paved	Western Part Zone No. 2	55 KM/HR
International Route No. 11	Paved	Eastern Part Zone No. 2	40 KM/HR
International Route No. 11	Paved	Western Part Zone No. 1	32 KM/HR
International Route No. 11	Paved	Eastern Part Zone No. 1	24 KM/HR
International Route No. 11	Paved	Eastern Part Zone No. 8	80 KM/HR
Avenue Steinmetz	Paved	Zone No. 1	32 KM/HR
Avenue de la Republique	Laterite	Eastern Part Zones No. 3 & 4	20 KM/HR
Road Near Catholic and Moslem Cemeteries	Laterite	Zone No. 6	10 KM/HR

On laterite roads, the speed basically tended to be slower as the conditions of the road became worse, due to ruts. Paved roads, on the other hand, were generally in fair condition, and the speed depended mainly on the amount of traffic using the roads.

The average speeds on the existing bridge varied depending on the degree of congestion. When the volume of traffic crossing the bridge was relatively low the average speed of bridge traffic was as high as 40 kilometers per hour. During times of congestion, usually right after the passage of the train, the average speed on the bridge would fall to 10 kilometers per hour. By field observation of traffic volumes and corresponding speeds of traffic, a relationship between speed and traffic volume was derived. This is shown in graphical form in Figure 4-8.

Figure 4-8 shows that the maximum one-way volume of traffic that can cross the existing bridge is approximately 1260 equivalent vehicle units per hour [3] per lane and that the average running speed at that volume is approximately 10 kilometers per hour. Figure 4-9 shows how speed varies with traffic density.

Normally, the plotting of traffic speed versus traffic density results in approximately a straight line. However, the plotting of field data obtained from observation of Cotonou bridge traffic does not result in a straight line. This is due to the effect of vehicles unable to maintain speeds above 25 kilometers per hour, such as bicycles and motorcycles. In low density traffic these slower vehicles have little effect on the overall traffic flow, since the faster vehicles are able to cross into the opposing lane and pass them. In densities exceeding 18 vehicles per kilometer, however, the effect of slower vehicles begins to have its effect. As the opportunities for passing a slower vehicle decrease, the overall traffic begins to conform to a speed equal to that of the slowest vehicle.

The speed of traffic on the bridge approaches during the congestion time was even less than that of the traffic on the bridge. The congestion time occurred usually right after the train had passed and cleared the bridge. For 10 to 20 minutes thereafter, traffic on the bridge was at capacity and was traveling at approximately 10 kilometers per hour. At the same time, the speed of the traffic on the approaches was only 8 to 10 kilometers per hour. On the western approach road the speed tended to be always slower than that on the eastern approach road due to interference caused by traffic coming from the side streets.

2. Determination of Delay Time and Congestion Distance

In order to evaluate the potential congestion, delay time and vehicle standing time at the Cotonou bridge in the future years, it was first necessary to determine the maximum possible volume of traffic that can cross the bridge in a period of time. Due to the fact that the traffic in Cotonou is composed of a mixture of many categories of vehicles, it is best to define the bridge capacity in terms of "equivalent vehicle units". For this purpose each category of vehicles is weighted according to its effect on the traffic flow.

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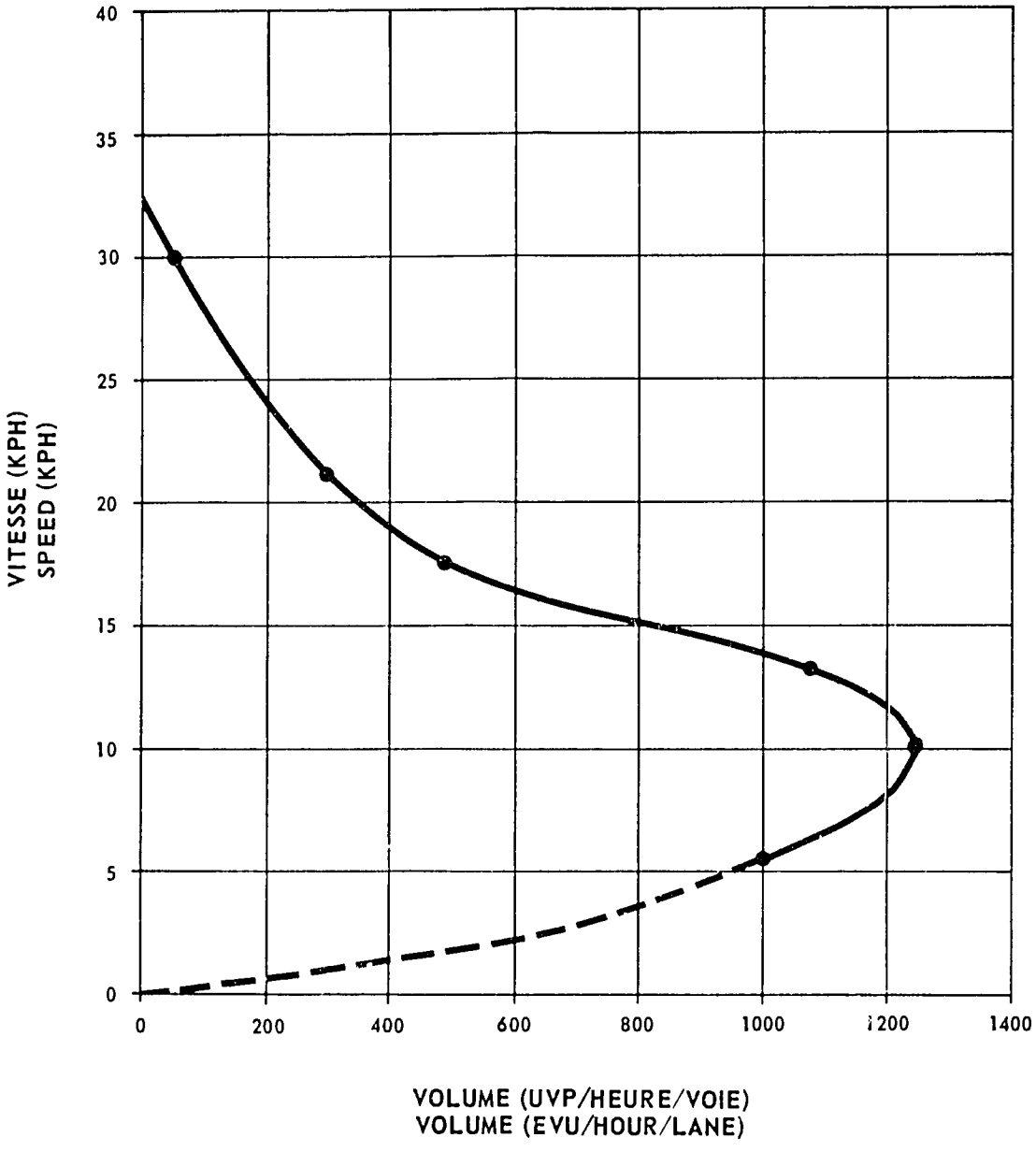
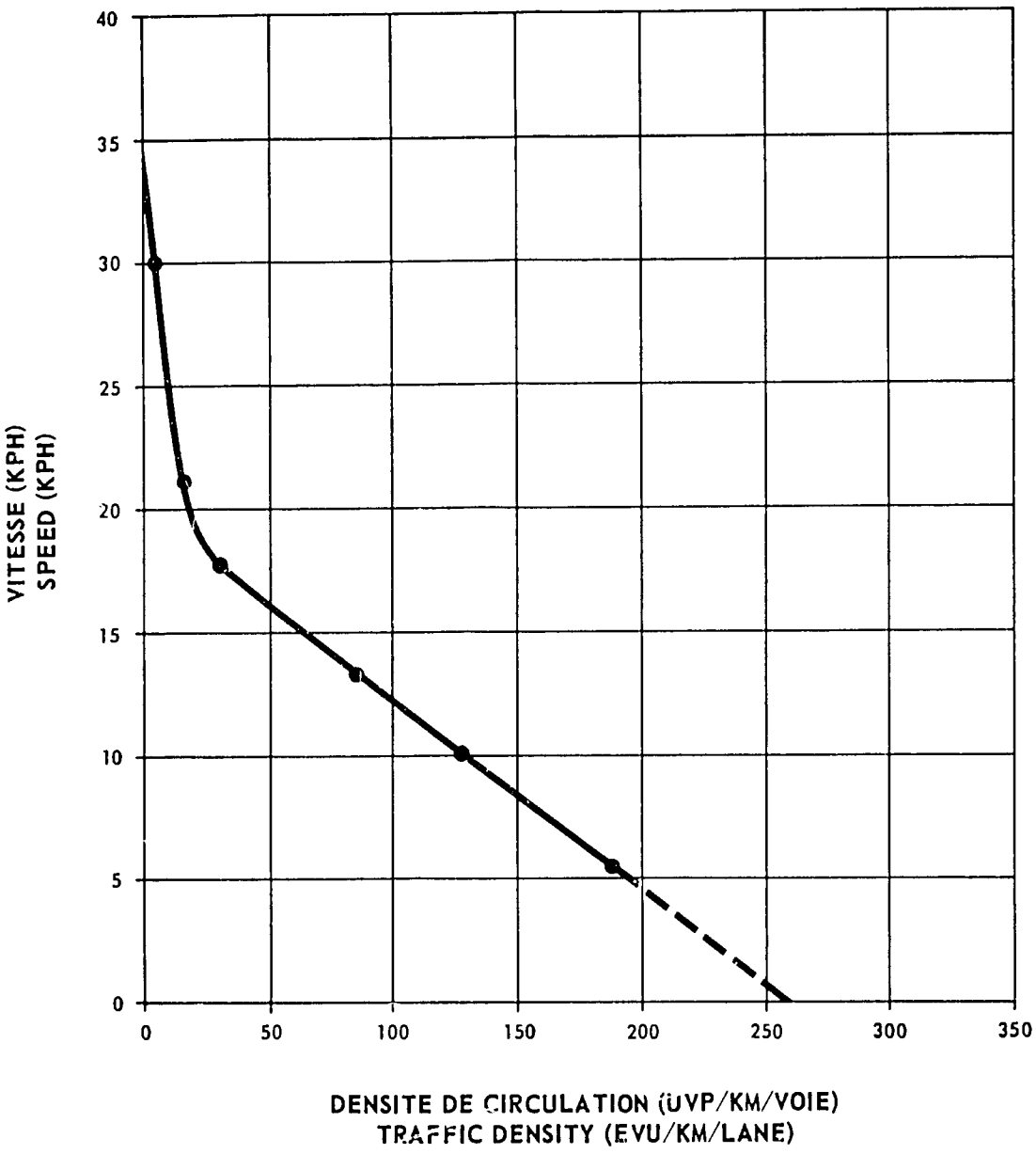
[3] See also the discussion in subsection IV, E, 2 which follows.



LEGENDE
LEGEND

UVP=UNITÉS VOITURES PARTICULIÈRES
EVU=EQUIVALENT VEHICLE UNITS

FIG. 4-8



LEGENDE
LEGEND

UVP=UNITÉS VOITURES PARTICULIÈRES
EVU=EQUIVALENT VEHICLE UNITS

FIG. 4-9

Cars, taxis, station wagons, and small trucks were weighted as one vehicle unit each; trucks over 2 tons and busses were weighted as two vehicle units each; and the pedal bicycles, motor bicycles and motorcycles were weighted as one-quarter vehicle unit each. A graph of hourly variation of traffic on the basis of equivalent vehicle units is shown in Figure 4-10. Calculated two-way peak EVU volumes from field count data are shown in Table IV-14.

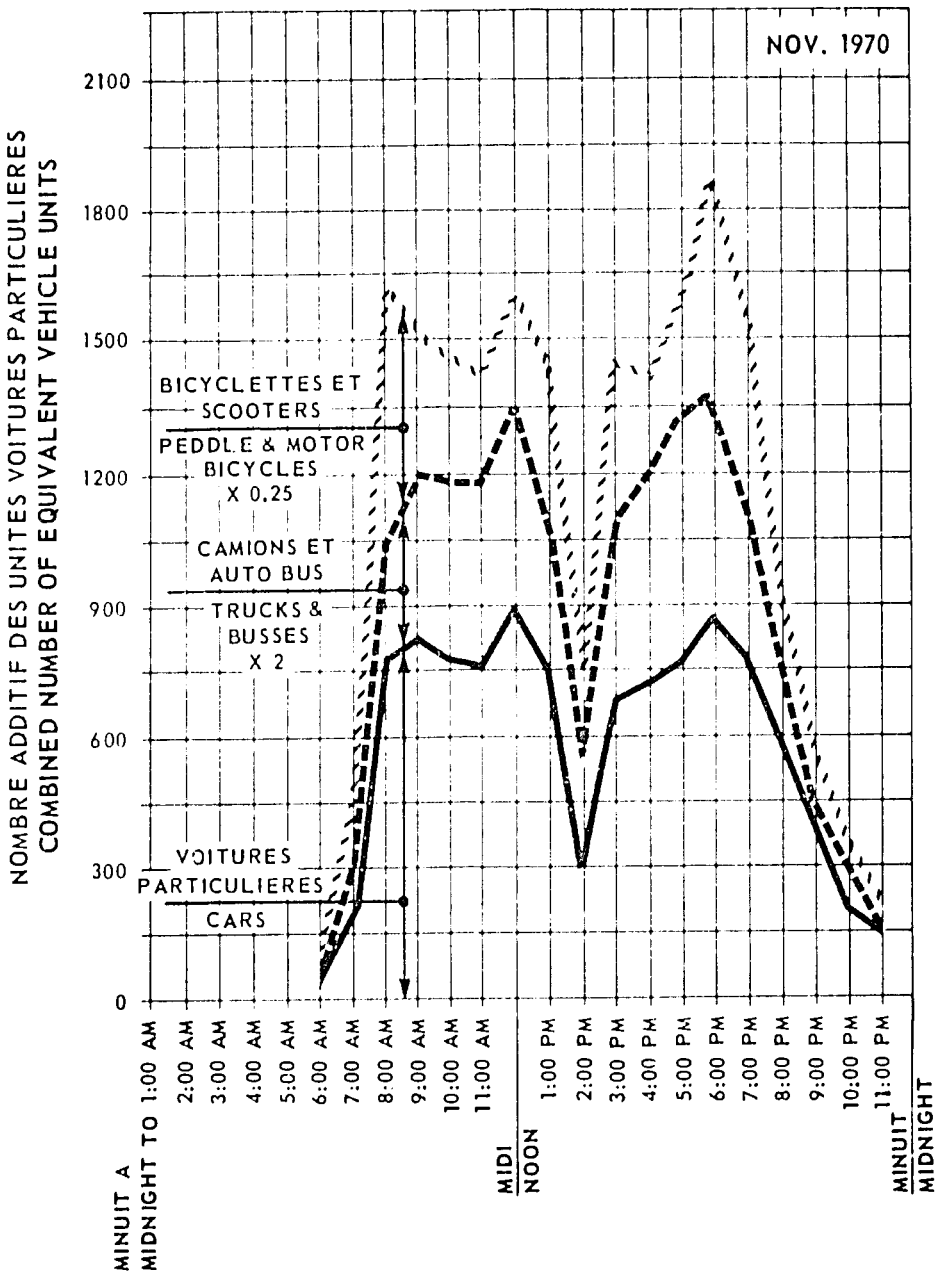
It can be seen, from Table IV-14, that, although the actual number of vehicles counted in each category during peak hours varied considerably, the calculated maximum EVU volume does not vary much. This indicates that the EVU peak figures represent the practical upper limit of the traffic capacity for the existing Cotonou bridge without creating congestion at the approaches. Table IV-14 also shows that the existing bridge in 1970 was already near its traffic capacity during two hours in the morning (7-8 and 11-12 A. M.) and in the evening (5-6 and 6-7 P. M.). Thus, 4 one-hour periods during the day are at or near peak capacity.

TABLE IV-14

PEAK HOUR TRAFFIC, TWO-WAY EQUIVALENT VEHICLE UNIT VOLUMES
COTONOU BRIDGE (NOV. 1970)

Hour	Passenger Cars	Trucks and Busses	Pedal and Motor Bicycles	2X(3)	1/4X(4)	EVU (1)+(5)+(6)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
5-6 PM	835	360	1694	720	423	1978
5-6 PM	850	288	1695	576	424	1850
5-6 PM	937	207	1743	414	436	1787
5-6 PM	896	208	1858	416	464	1776
6-7 PM	759	253	2010	506	502	1767
6-7 PM	905	139	2008	278	502	1685
11-12 AM	1015	217	1350	434	338	1787
7-8 AM	805	167	2381	334	595	1734
11-12 AM	813	340	929	680	232	1725
7-8 AM	852	142	2355	284	589	1725
11-12 AM	945	223	1031	446	258	1649
7-8 AM	781	98	2314	196	579	1556

The greatest number of equivalent vehicle units crossing the bridge in both directions was recorded in a 15-minute period from 12:00 to 12:15 PM, on November 19, 1970. During this period, 313 passenger cars, 68 trucks and busses and 791 pedal and motor bicycles were counted. If the same traffic volume had continued



PONT DE COTONOU–VARIATION HORAIRE DE LA CIRCULATION
COTONOU BRIDGE–HOURLY VARIATION OF TRAFFIC VOLUMES

FIG. 4-10

for the remaining 45 minutes, the hourly volume would have been 2,584 EVUs. Of course, this would require that the approaches to the bridge be at full congestion, so that peak traffic intensity can be maintained during the entire hour. Under much congestion, the maximum number of EVUs that could cross the existing Cotonou bridge in one hour would be approximately 2500. Table IV-14, however, shows that on the average, the maximum practical hourly capacity does not exceed 1,800 EVUs. With this hourly volume, short delays and congestion have been observed at the bridge approaches. Thus, we can assume that when two-way traffic at the Cotonou Bridge reaches 1,800 EVUs, the approaches will just begin to be congested and the traffic will start to experience delays.

Delay time (standing time) occurs within the total time required for a vehicle to reach the bridge from a point where it first encounters congestion. From this point, the vehicle progresses towards the bridge at extremely slow speeds and is forced to make numerous stops and starts. Delay time is the sum of all short standing times that occur within the congested distance.

Delay time will occur every time that the hourly volume of vehicles approaching the bridge exceeds 1,800 EVUs. In order to be able to estimate the amount of delay time when the traffic volume is between 1800 EVU/hr (practical capacity) and EVU/hr (maximum capacity), it was necessary to observe the distribution of traffic volume in peak hours. It was found that the distribution of the four 15-minute periods averaged approximately 32%, 26%, 23% and 19% of the total hourly volume. It is obvious that, at maximum capacity, the distribution during each 15-minute period must be equal. It follows that whenever the 15-minute volume exceeds 25% of the hourly volume, there will be delays.

The actual behavior of traffic in congested conditions is difficult to predict. As the traffic volume becomes excessive, and the area of congestion spreads along the bridge approach road and into side streets, the number of factors which influence the traffic behavior also increases, and the entire situation becomes quite complex. In order to calculate the delay time, a mathematical model was established, in which an attempt was made to take into account most of the factors determining the traffic operation in congested conditions. With high traffic volumes and highly congested conditions, the mathematical model approximates the actual situation by applying conservative factors which produce equivalent results.

For purposes of delay time calculation, it was assumed that there will be a one-minute delay for every 200 EVUs over 1800 EVU/hr. This delay will affect the entire hourly traffic. Once the hourly volume exceeds 2500 EVU/hr, however, the excess of traffic above the first 2500 EVUs will have to wait a full 60 minutes before it is able to cross the bridge.

The following example shows assumed distribution of hourly EVU traffic volumes between 5:00 AM and 10:00 PM for a congested day, and the method of delay time calculation.

Hour	EVUs/hr	EVUs Delayed Less Than 60 Minutes	Delay in Minutes	EVUs Delayed 60 Minutes	Delay in Minutes
5- 6 AM	85	-	-	-	-
6- 7	695	-	-	-	-
7- 8	2669	2669	3.5	169	60.0
8- 9	2576	2576	3.5	245	60.0
9-10	2444	2444	3.2	189	60.0
10-11	2337	2337	2.7	26	60.0
11-12	2441	2441	3.2	-	-
12- 1 PM	1005	-	-	-	-
1- 2	1880	1880	0.4	-	-
2- 3	2425	2425	3.1	-	-
3- 4	2532	2532	3.5	32	60.0
4- 5	3075	3075	3.5	607	60.0
5- 6	2120	2120	1.6	227	60.0
6- 7	1680	1680	-	-	-
7- 8	1127	-	-	-	-
8- 9	398	-	-	-	-
9-10	63	-	-	-	-
Total Delayed EVUs		26179		1495	
Average Delay (minutes)			2.8		60.0
Total EVUs/day = 29988					

In the example, it is shown that from 7:00 to 8:00 AM there were 2669 EVUs. Thus all are delayed 3.5 minutes, and the excess over 2500 becomes delayed 60 minutes. From 10:00 to 11:00 AM there were 2337 EVUs. All get delayed (2337 - 1800)/100 = 2.7 minutes and there are no cars that are delayed 60 minutes. From 3:00 to 4:00 PM there are 2532 EVUs. All are delayed 3.5 minutes and 32 EVUs become additionally delayed 60 minutes. The next hour (4:00 to 5:00 PM) there are 3075 EVUs. To these we must add 32 EVUs which are waiting from the previous hour. Thus 3075 EVUs are delayed 3.5 minutes and (3075 + 32 - 2500) = 607 EVUs are delayed 60 minutes.

The average delay time for each of the EVUs that experienced delay would be:

$$(26,179 \times 2.8 + 1,495 \times 60.0)/(26,179) = 6.2 \text{ minutes}$$

However, in order to adjust this delay to one applicable to the entire daily traffic, we must prorate the EVUs experiencing delay to the total number of EVUs in the day. Thus we get:

$$(26,179/29,988) \times 6.2 = 5.4 \text{ minutes}$$

For a four-lane bridge, or roadway approach, the delay time was calculated in a similar manner, assuming 5600 EVUs/hr as practical capacity and 7200 EVUs/hr as maximum capacity.

To calculate the congested distance, it was assumed that, in congested conditions, one EVU occupies a length of 4 meters. Thus, a passenger car of European manufacture (such as a Citroen or a Peugot) would occupy a length of 4 meters while a truck or a bus (having a weighted value of two) would occupy a length of 8 meters.

Using the example previously cited, the average number of EVUs per hour experiencing delays would be: 26,179/10 = 2,618, and the congested distance would be (2,618 x 4) x (26,179/29988) = 9,142 meters.

The actual distance of congestion is not, however, spread in a single line. As traffic approaches the bridge from various origins and reaches the point of congestion, the waiting vehicles will be spread in several directions away from the bridge. For this reason, it was assumed that all traffic from a zone originates at the zone's center of gravity. In calculating the costs of operating vehicles through a congested area, the computed congestion distance was compared to the actual distance between centers of gravity of each zonal origin-destination pair. If it was smaller, the calculated congestion distance was used. If it was larger, the actual distance between the centers of gravity was used.

The calculated delay times and congested distances for each year of the study period are shown in Tables XII-15 through XII-17 in Section XII.

For the purpose of calculating the delay costs, the maximum delay used was 60 minutes even if the calculated time exceeded 60 minutes, because, most likely, the pattern of hourly traffic distribution in a typical day would change.[4] As the delay time increases and begins to be excessive the drivers would probably tend to avoid the trip across the bridge. Other modes of transportation may come into use, such as ferry boats carrying passengers and cargo across the lagoon. Gradually the growth of the vehicle fleet in Cotonou may decrease or stop altogether.[5]

The effect of a train crossing the existing bridge during an hour of full congestion will be a reduction of time available for the vehicular traffic to use the bridge. Since the train presently eliminates the use of the bridge for about 10 minutes, for all traffic except bicycles and pedestrians, it is in effect equivalent to 10/60 of the peak EVU volume. Actually, as the traffic congestion increases, the delays due to the train will also increase, since it will take more time to clear the way for the train through the vehicular traffic. The bridge capacity due to

[4] See also the discussion of level of service volumes and the relation of total daily volume on level of service capacities in subsection F.

[5] The economic consequences of high degree of congestion are discussed in Section XII.

the train during a congested hour would be reduced by at least 10/60 x 1800 EVUs or 300 EVUs. Thus the traffic capacity of the bridge during a train crossing would be only 1500 EVUs. This indicates that the total delay of 60 minutes could be reached much sooner than calculated.

F. CAPACITY REQUIREMENTS FOR THE NEW BRIDGE

1. Expected Future Traffic at Alternate Bridge Sites

The projected future traffic distribution at each alternate bridge site by traffic categories and vehicular traffic expressed in equivalent vehicle units (EVUs) is shown in Tables IV-17 through IV-19.

TABLE IV-15

FUTURE TRAFFIC AT EXISTING BRIDGE SITE
PARALLEL BRIDGE ALTERNATIVE

Year	Cars	Trucks and Busses	Pedal & Motor Bicycles	Pedestrians	EVUs
1977	15,694	3,161	29,783	15,845	29,463
1982	21,353	4,012	45,802	20,835	40,829
1987	28,934	5,078	71,816	28,152	57,045
1992	37,079	6,175	106,258	37,081	75,994
1996	45,461	7,285	149,621	47,710	97,438

It should be noted that there were 5,486 (ADT) passengers per day in 1970 crossing the lagoon by boat. It is expected that at least 95% of these will become additional bridge pedestrian traffic. The expected total pedestrian traffic on the new bridge at Boulevard Saint Michel is shown in Table IV-18.

TABLE IV-16

FUTURE TRAFFIC AT EXISTING BRIDGE SITE
SAINT MICHEL BRIDGE ALTERNATIVE

Year	Cars	Trucks and Busses	Pedal & Motor Bicycles	Pedestrians	EVUs
1977	9,551	1,829	17,741	10,749	17,644
1982	13,044	2,270	25,640	13,529	23,996
1987	17,690	2,796	37,013	17,179	32,537
1992	22,625	3,303	50,184	21,101	41,778
1996	27,637	3,780	64,728	25,176	51,381

TABLE IV-17

FUTURE TRAFFIC AT BOULEVARD SAINT MICHEL SITE
SAINT MICHEL BRIDGE ALTERNATIVE

Year	Cars	Trucks and Busses	Pedal & Motor Bicycles	Pedestrians	EVUs
1977	6,143	1,332	12,042	5,095	11,818
1982	8,308	1,741	20,162	7,310	16,832
1987	11,244	2,281	34,803	10,973	24,508
1992	14,454	2,871	56,074	15,979	34,215
1996	17,824	3,504	84,893	22,533	46,057

TABLE IV-18

FUTURE PEDESTRIAN TRAFFIC
AT SAINT MICHEL BRIDGE

Year	Pedestrians		Total
	From Table IV-19	From Boat Traffic	
1977	5,095	7,230	12,325
1982	7,310	10,373	17,683
1987	10,973	15,571	26,544
1992	15,979	22,675	38,654
1996	22,533	31,975	54,508

2. Effect of Traffic Composition and Number of Lanes on Levels of Service

In order to determine the traffic capacity requirements for the new bridge, the expected composition of traffic must be considered. The composition of traffic will not be the same at both alternate locations. At the existing site, a parallel bridge will not carry as much pedestrian traffic as will a new bridge at the Boulevard Saint Michel site. At each location, also, the relative percentage of each category of vehicles will differ. Tables IV-19 and IV-20 show how the projected number and percentage of each category of vehicles varies at each alternate bridge site during the study period.[6] In each case, the pedal and motor bicycles constitute the largest proportion of the total vehicular traffic.

[6] See Section XII for the discussion of vehicle growth rate.

TABLE IV-19

COMPOSITION OF TRAFFIC AT EXISTING BRIDGE SITE
PARALLEL BRIDGE ALTERNATIVE

Vehicle Type	1977		1987		1996	
	ADT	%	ADT	%	ADT	%
Cars	15,694	32.3	28,934	27.3	45,461	22.5
Trucks/Busses	3,161	6.5	5,078	4.8	7,285	3.6
Motor/Bikes	29,783	61.2	71,816	67.9	149,621	73.9
Total	48,638	100.0	105,828	100.0	202,367	100.0

TABLE IV-20

COMPOSITION OF TRAFFIC AT EXISTING BRIDGE SITE
SAINT MICHEL BRIDGE ALTERNATIVE

Vehicle Type	1977		1987		1996	
	ADT	%	ADT	%	ADT	%
Cars	9,807	33.8	13,555	29.6	21,285	27.4
Trucks/Busses	1,859	6.4	1,956	4.3	2,626	3.4
Motor/Bikes	17,327	59.8	30,320	66.1	53,776	69.2
Total	28,993	100.0	45,831	100.0	77,687	100.0

TABLE IV-21

COMPOSITION OF TRAFFIC AT BOULEVARD SAINT MICHEL SITE
SAINT MICHEL BRIDGE ALTERNATIVE

Vehicle Type	1977		1987		1996	
	ADT	%	ADT	%	ADT	%
Cars	5,887	30.0	15,379	25.6	24,176	19.4
Trucks/Busses	1,293	6.6	3,130	5.2	4,696	3.8
Motor/Bikes	12,456	63.4	41,496	69.2	95,845	76.8
Total	19,636	100.0	60,005	100.0	124,717	100.0

To obtain the greatest possible capacity there must be opportunity for the faster vehicles to pass the slower ones. If two lanes are provided in each direction instead of one, there will be an opportunity for passing, and the average speed of traffic will be faster. The bicycles will have less effect on the traffic flow because there will be one extra lane for the bicycles to move out of the way or be passed. However, the relative difference in speed between them and the faster vehicles will also increase. Thus the effect of bicycles on the traffic flow will be felt at lower densities of traffic due to the faster average speeds. The same method may be used, for both the two- and the four-lane traffic, in determining equivalent vehicle units.

At this point it is useful to introduce the concept of level of service. The Highway Capacity Manual, applicable for the traffic in USA, defines levels of service from A to F. Although the type of traffic in Cotonou is much different from that in the United States of America, the level of service concept can still be used.

Level of Service A is obtained at low traffic densities and no problems occur.

Level of service B is defined as stable flow with drivers having reasonable freedom to select their speed and lane of operation.

Level of service C is defined as being a stable traffic flow but with speeds or volumes of traffic above which conflicts and delays would begin to occur. The freedom to select a lane, or pass a vehicle is restricted.

Level of service D exists when stable traffic flow is interrupted for short periods of time and congestion begins. The freedom to select a lane or pass a vehicle is lost, and the traffic is forced to conform to the speed of the slowest vehicle.

Levels of service E or F exist when traffic flow is interrupted with increasing frequency and stoppages occur with longer times of delay.

The capacity of a multi-lane facility (such as a four-lane bridge) generally increases by a factor larger than the number of lanes.

For a vehicle composition which is typical in the United States the following maximum capacities are usually accepted for uninterrupted flow of traffic.

TABLE IV-22

TWO AND FOUR LANE ROADWAY CAPACITIES (U.S.A.)

Type of Facility	Number of Lanes in Each Direction	Hourly Capacity (EVU)		Speed KPH
		Per Lane	Total	
2-lane roadway	one lane	1,000	2,000	50
4-lane roadway	two lanes	2,000	8,000	50

The composition of traffic crossing the Cotonou Lagoon contains a large proportion of slower moving vehicles (pedal and motor bicycles) and the entire traffic in general tends to move at speeds substantially slower than 50 kph. For this reason, the following capacities are adopted at various levels of service, as can be seen in Table IV-23.

TABLE IV-23

ROADWAY CAPACITIES AND LEVELS OF SERVICE
TWO AND FOUR LANE ROADWAYS (COTONOU-DAHOMEY)

Type of Facility	Number of Lanes in Each Direction	Hourly Capacity (EVU)		Levels of Service	Speed KPH
		Each Lane	Total		
Two-lane roadway	one lane	Less than 150	Less than 300	A	50
		150 - 400	300 - 800	B	32
		400 - 650	800 -1300	C	20
		650 - 900	1300 -1800	D	12
		900 -1250	1800 -2500	E	8
		Over 1250	Over 2500	D	
Four-lane roadway	two lanes	Less than 200	Less than 800	A	50
		200 - 600	800 - 2400	B	32
		600 - 1000	2400 - 4000	C	20
		1000 - 1400	4000 - 5600	D	12
		1400 - 1800	5600 - 7200	E	8
		Over 1800	Over 7200	F	

The level of service volumes for the two lane roadway, shown in Table IV-23, are based on actual field observations of the traffic at the Cotonou bridge. Primarily, they reflect the limitations with respect to traffic capacity of the bridge itself, which is only two lanes wide. The approaches to the existing bridge, with some improvements, could function as a four-lane roadway, if a wider bridge were available.

The level of service volumes for a four-lane roadway (or bridge) was determined using judgment and taking into account the composition of traffic, observed behavior of the traffic, and the restrictions which exist at the bridge approaches. In the case of the bridge approaches for the bridge near Boulevard Saint Michel, there will be less interference from the cross traffic in the immediate vicinity of the bridge and there will be no interruptions due to train traffic. Also at high traffic volumes the congestion will spread into the side streets and this condition will begin to reduce the level of service in areas beyond the immediate bridge approaches.

In order to take this into account, the level of service volumes were further adjusted. For the purpose of calculating the delay times and congested distances, the

maximum hourly volumes for each level of service were reduced by a ratio of actual daily volume to the following limiting volumes:

At the existing bridge site:

With two-lane bridge - 30,000 EVUs/day (bridge governs)
With four-lane bridge - 40,000 EVUs/day (approaches govern)

At the Boulevard Saint Michel site:

With two-lane bridge - 30,000 EVUs/day (bridge governs)
With four-lane bridge - 50,000 EVUs/day (approaches govern)

As an example, in 1985, the projected daily volume for the parallel bridge alternative is 50,206 EVUs/day. For a four-lane bridge, at level of service C, the maximum volume would be: (1 - 0.1021) x 4,000 = 3,592 EVUs.

3. Determination of Required Bridge Width

Consideration of levels of service is useful in determining whether the new bridge under either alternative ought to be a two- or a four-lane bridge. Hourly traffic volumes for each alternative at two-year intervals, during the study period, are shown in the Appendix. From these, it is possible to determine the number of hours of each level of service that will exist in the future years, at the existing and the proposed bridges under either alternative. Tables IV-24 through IV-27 show the levels of service with either a two- or a four-lane new bridge at Boulevard Saint Michel. With the parallel bridge alternative, only a two-lane new bridge is considered, so that, in

TABLE IV-24

LEVELS OF SERVICE (1977 TO 1996) PARALLEL BRIDGE ALTERNATIVE
(Two-Lane Existing Bridge with a Two-Lane New Bridge)

Year	Levels of Service (Hours Per Day)					
	A	B	C	D	E	F
1977	10	12	2	0	0	0
1979	9	9	6	0	0	0
1981	9	4	11	0	0	0
1983	8	5	11	0	0	0
1985	8	4	6	6	0	0
1987	7	4	2	9	2	0
1989	7	3	2	3	9	0
1991	7	2	3	1	5	6
1993	6	2	2	2	1	11
1996	5	2	1	1	1	14

combination with the existing two-lane bridge, a four-lane crossing is provided. It was explained earlier that the approaches at the existing bridge site could not function as more than four lanes. It would, therefore, be of no benefit to provide more than a total of four lanes on the two bridges under the parallel bridge alternative.

It can be seen from Table IV-24 that in 1989 there will be more than nine hours of level of service E. This indicates that in 1989 the parallel bridge alternative will become inadequate to serve the traffic across the lagoon.

In Tables IV-25 and IV-26, levels of service are shown for the new bridge at Boulevard Saint Michel. Table IV-25 shows that with a two-lane bridge there would be more than nine hours of level of service E in 1985.

TABLE IV-25

LEVELS OF SERVICE (1977 TO 1996) SAINT MICHEL BRIDGE ALTERNATIVE
(Two-Lane Bridge at Boulevard Saint Michel)

Year	Levels of Service (Hours Per Day)					
	A	B	C	D	E	F
1977	9	6	9	0	0	0
1979	9	6	9	0	0	0
1981	8	5	10	1	0	0
1983	8	4	4	7	1	0
1985	7	3	2	1	11	0
1987	7	3	2	1	8	9
1989	7	2	2	1	2	10
1991	7	2	2	1	2	10
1993	5	2	1	1	1	14
1996	4	2	1	1	1	15

TABLE IV-26

LEVELS OF SERVICE (1977 TO 1996) SAINT MICHEL BRIDGE ALTERNATIVE
(Four-Lane Bridge at Boulevard Saint Michel)

Year	Levels of Service (Hours Per Day)					
	A	B	C	D	E	F
1977	17	7	0	0	0	0
1979	13	11	0	0	0	0
1981	12	12	0	0	0	0
1983	12	12	0	0	0	0
1985	10	14	0	0	0	0
1987	9	11	4	0	0	0
1989	9	5	10	0	0	0
1991	8	5	11	0	0	0
1993	8	4	11	1	0	0
1996	8	4	2	10	0	0

Table IV-26 shows that with a four-lane bridge extremely high levels of service are obtained and that the traffic conditions never fall below level D.

The levels of service at the existing bridge, functioning together with a four-lane bridge at Boulevard Saint Michel, are shown in Table IV-27.

TABLE IV-27

LEVELS OF SERVICE (1977 TO 1996) SAINT MICHEL BRIDGE ALTERNATIVE
EXISTING BRIDGE (Two Lanes)

Year	Levels of Service (Hours Per Day)					
	A	B	C	D	E	F
1977	8	4	7	5	0	0
1979	8	4	4	8	0	0
1981	8	4	1	11	2	0
1983	8	4	1	9	2	0
1985	7	4	2	9	2	0
1987	7	3	2	7	5	0
1989	7	3	2	2	10	0
1991	7	3	2	1	9	2
1993	7	2	3	0	6	6
1996	7	1	2	2	1	11

Thus, it can be seen that in 1989 the four-lane bridge at Boulevard Saint Michel still maintains level of service C while the existing two-lane bridge has just reached the condition of excessive hours of Level E.

After 1989, more traffic will shift to Saint Michel bridge.[7] If we assume that sufficient traffic is removed from the existing bridge to obtain nine hours of level of Service E in 1996, the levels of service shown in Table IV-28 will exist at the two bridges.

Table IV-28 shows that in 1996 both bridges will become inadequate and that at that time, a third bridge across the Cotonou Lagoon will become necessary.

[7] None of the additional diverted traffic is considered in the economic analysis on the assumption that the benefits obtained would be equal to additional cost due to longer travel.

TABLE IV-28

1996 LEVELS OF SERVICE SAINT MICHEL BRIDGE ALTERNATIVE
(Maximum Traffic Diversion to Saint Michel Bridge)

Year	Levels of Service (Hours Per Day)					
	A	B	C	D	E	F
Existing Bridge	7	3	2	3	9	0
Saint Michel Bridge	6	2	2	5	8	0

In view of restricted approach conditions at the existing bridge site, it is not possible to obtain there, a six-lane vehicular crossing of the lagoon. A four-lane crossing would become inadequate in 1988. With a four-lane bridge at Boulevard Saint Michel and the existing two-lane bridge a six-lane crossing is feasible and appears adequate up to 1996. Acceptable levels of service will be obtained only if sufficient diversion takes place. The use of Saint Michel bridge by traffic that normally would prefer to use the existing bridge should be greatly facilitated when the proposed West Bank Boulevard is completed.

SECTION V

SUBSOIL EXPLORATION

A. OBJECTIVES

1. Foundation Considerations for the Proposed Dam

The objective of the preliminary subsoil exploration program at the site of the proposed dam was to determine the type and nature of the subsoils and their effect on the design and construction requirements. Since occurrence of compressible soils would result in construction problems and increased cost for the dam, it was necessary to include in the preliminary subsoil investigation, at least one test boring, laboratory testing and engineering analysis.

2. Foundation Considerations for the Proposed Bridge

The preliminary foundation investigation program at the site of the proposed bridge was undertaken to determine the feasibility of piles as a substructure. Additional costs in the bridge foundation would be incurred and expensive settlement would result if the sand strata overlaying the compressible soils were found to be loose. In this case, either stabilizing the foundation or adopting another type of substructure would be required. The preliminary subsoil investigation included field testing and engineering analysis of recent and previous data.

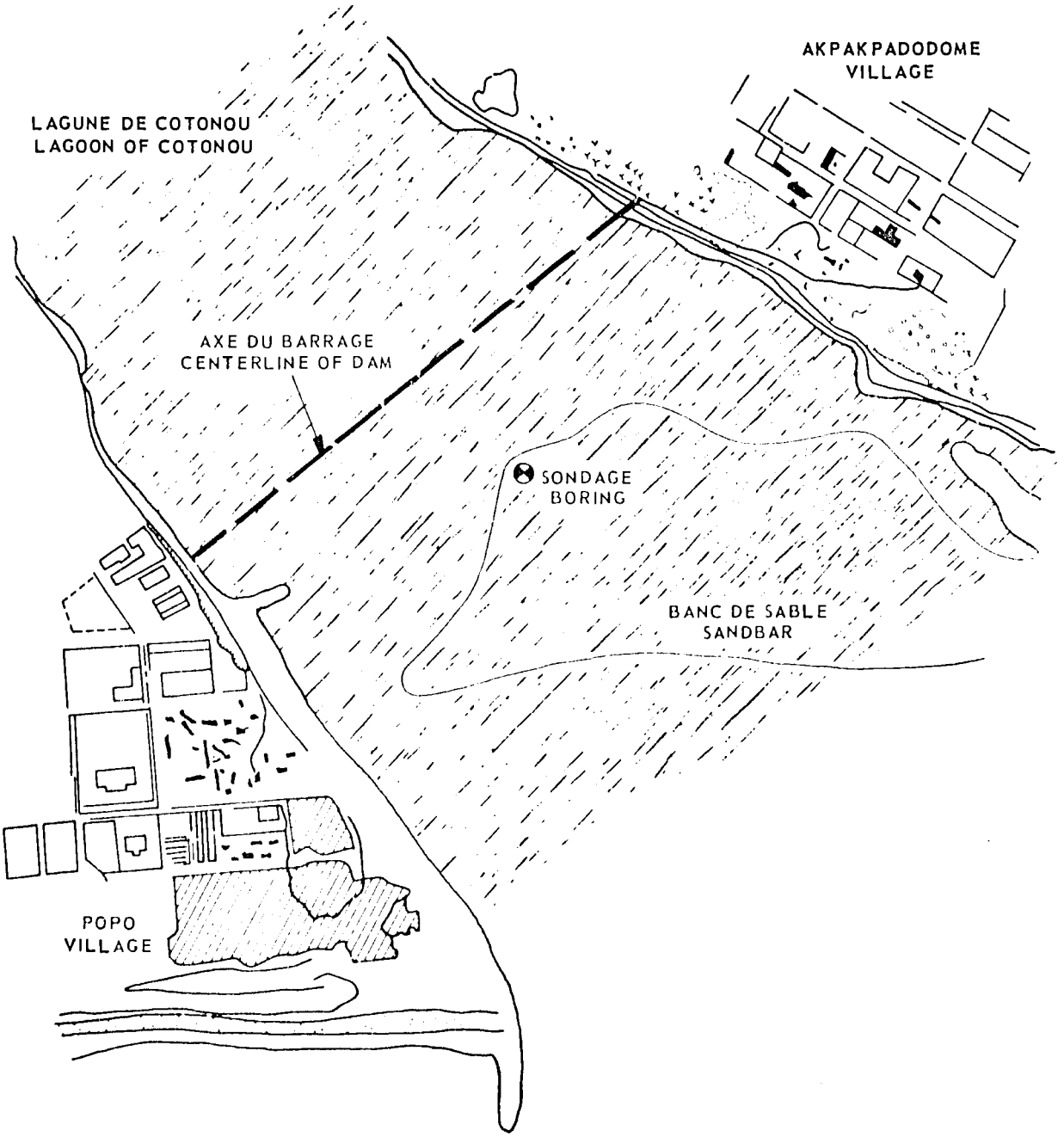
B. FIELD INVESTIGATIONS

1. Core Boring Work by SASIF Near the Site of the Dam

a. General

One boring was made by the Societe Africaine de Sondages Injections Forages of Abidjan, Ivory Coast (SASIF) near the location of the proposed dam (See Figure 5-1). Locating the boring at the exact location of the dam would have required the construction of a platform in approximately three meters of water. Due to tidal action and water velocity, this would have been too difficult and expensive.

The boring work was made with a drill rig equipped to make the standard penetration test as it progressed into the subsoil. The total depth of the boring, at its completion, was 25 meters. The work took seven days and was completed on August 7, 1971. It included continuous sampling (disturbed type), six standard penetration tests, and two undisturbed samples.



SONDAGE ENTRÉE DU CANAL
CORE BORING AT LAGOON MOUTH

FIG. 5-1

b. Standard Penetration Tests

The standard penetration test consisted of advancing a sampling spoon into the soil by means of a hammer and recording the number of blows required to advance the sampler one foot (30 cm). The sampler is first advanced 6 inches (15 cm), and then the number of blows, N, counted during the advancement of the next 12 inches (30 cm) is recorded. The hammer weighs 140 pounds (63.5 kg) and falls 30 inches (76.0 cm). The sampler has an exterior diameter of 1-7/8 inches (52.2 mm). Its interior diameter is 1-3/8 inches (37.5 mm) which is also the diameter of the soil sample obtained. Six standard penetration tests were made as follows:

SPT No. 1	From 5.00 m	to	5.45 m	N = 2
SPT No. 2	From 8.00 m	to	8.45 m	N = 67
SPT No. 3	From 11.00 m	to	11.45 m	N = 41
SPT No. 4	From 14.00	to	14.45 m	N = 25
SPT No. 5	From 17.00	to	17.45 m	N = 8
SPT No. 6	From 19.00	to	19.45 m	N = 2

2. Penetration Tests by LNBTP at the Bridge Site Near Boulevard Saint Michel

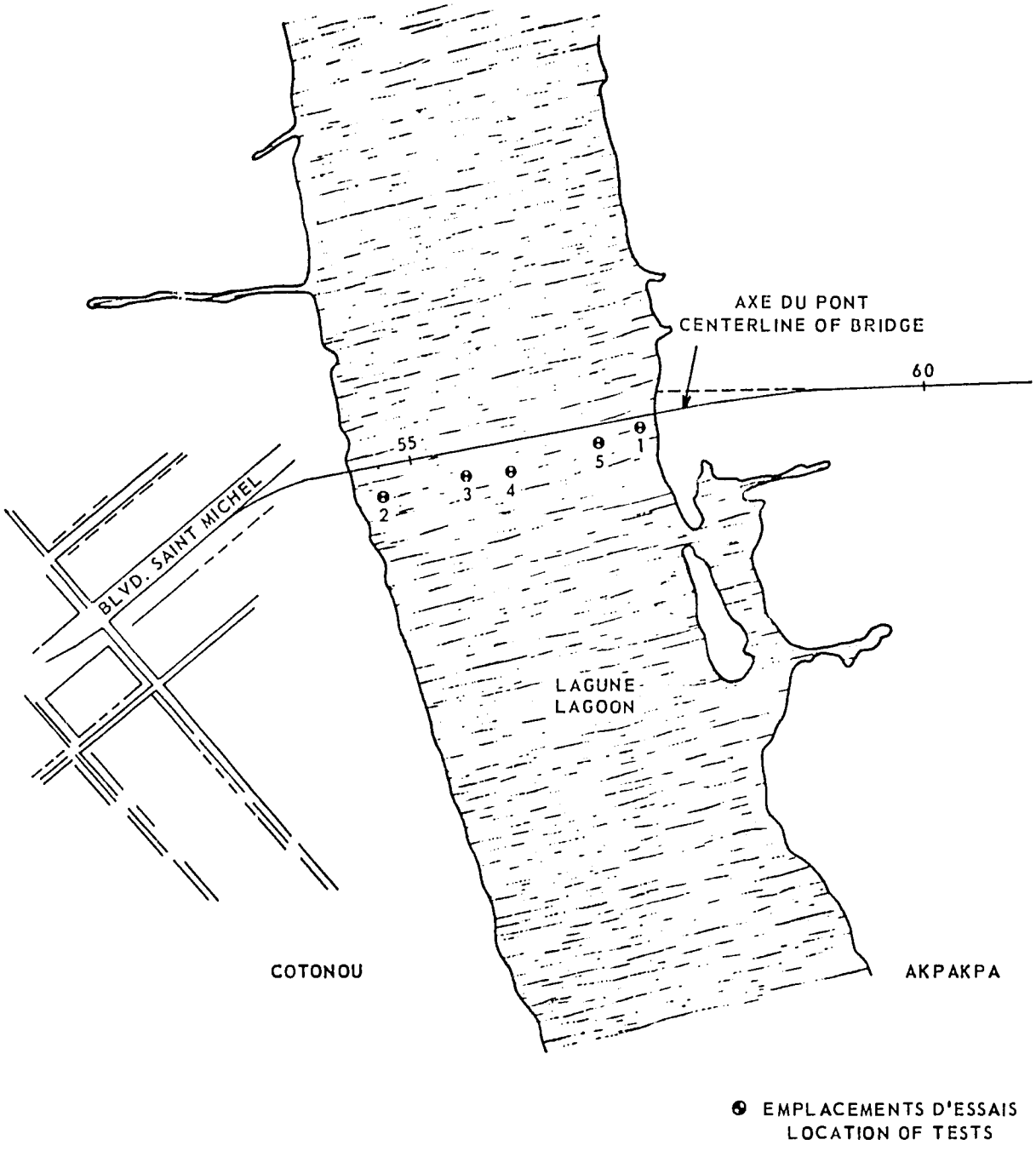
Five dynamic penetrometer tests have been made by the Laboratoire National du Batiment et des Travaux Publics of Cotonou, Dahomey (LNBTP) near the location of the proposed new bridge at Boulevard Saint Michel. One additional dynamic penetrometer test was made near the point of the SASIF core boring. The location, depth, and results of the penetrometer tests are shown in Figures 5-2 through 5-9.

The equipment used was a heavy dynamic penetrometer of the BORRO type. The test consisted of pushing into the subsoil a cylindric shaft having an area of 10 square centimeters and having a conical point at the bottom with an area of 15.2 square centimeters. The conical point was abandoned at the bottom of the test hole when the shaft was retracted. The shaft was advanced by means of a hammer weighing 70 kg and falling 50 cm. The resistance to penetration was calculated as follows:

$$R_p = \frac{M^2 H}{A e \ (M+P)}$$

where:

R_p = resistance to penetration, expressed in bars (kg/cm^2)
M = weight of the hammer in kg
H = height of drop in cm
P = weight of the shaft in kg
A = area of the shaft in cm^2
e = unit penetration of the shaft (per blow of the hammer) in cm

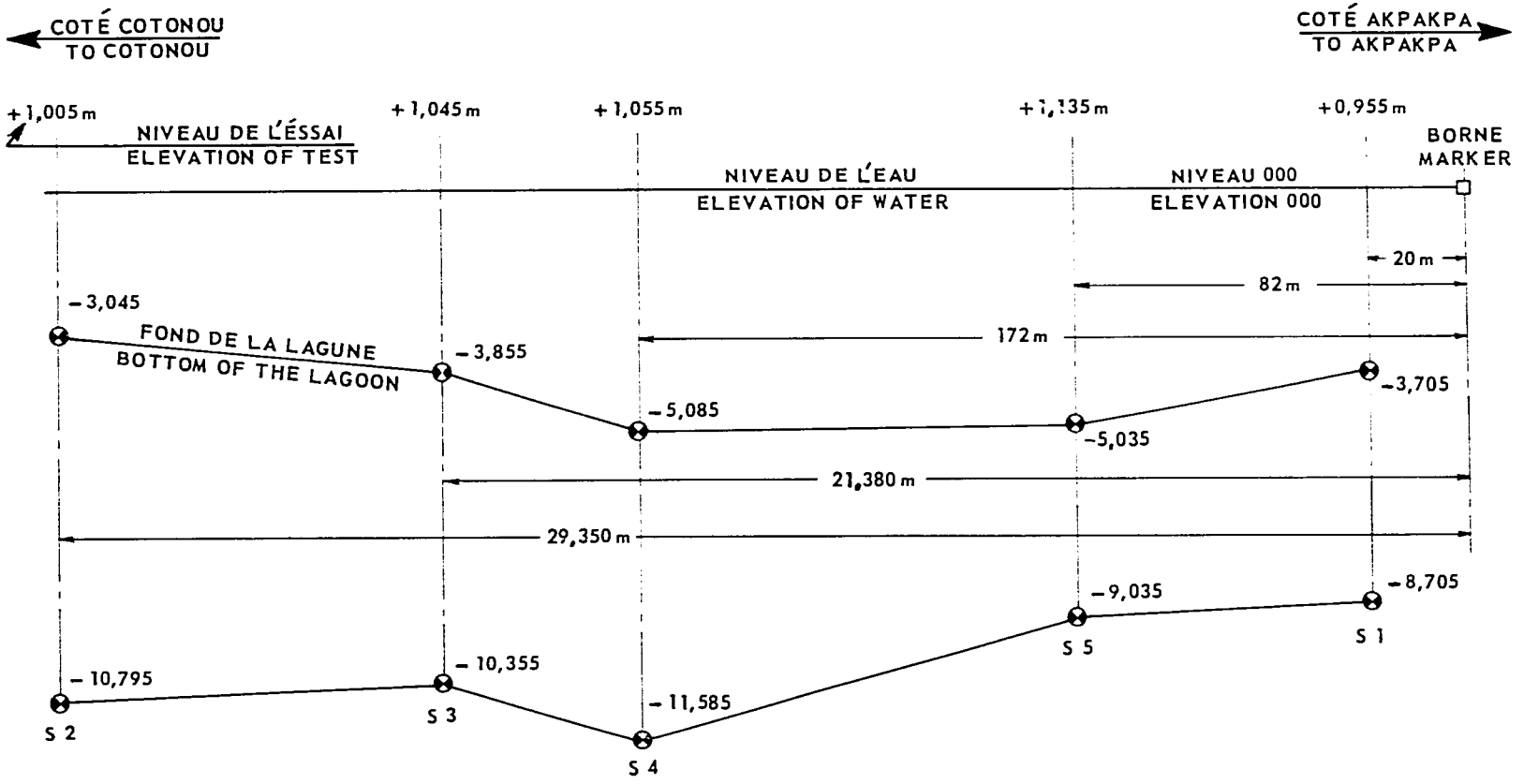


ESSAIS PENETROMETRIQUES SUR LA TRACE DU NOUVEAU PONT
PENETROMETER TESTS ALONG THE ALIGNMENT OF THE NEW BRIDGE

FIG. 5-2

L.N.B.T.P COTONOU

PONT-BARRAGE LAGUNE COTONOU
BRIDGE-DAM COTONOU LAGOON



EMPLACEMENT DES SONDAGES
LOCATION OF PENETROMETER BORINGS

FIG. 5-3

SANDERS & THOMAS INC.

PONT-BARRAGE-LAGUNE COTONOU
BRIDGE-DAM-COTONOU LAGOON

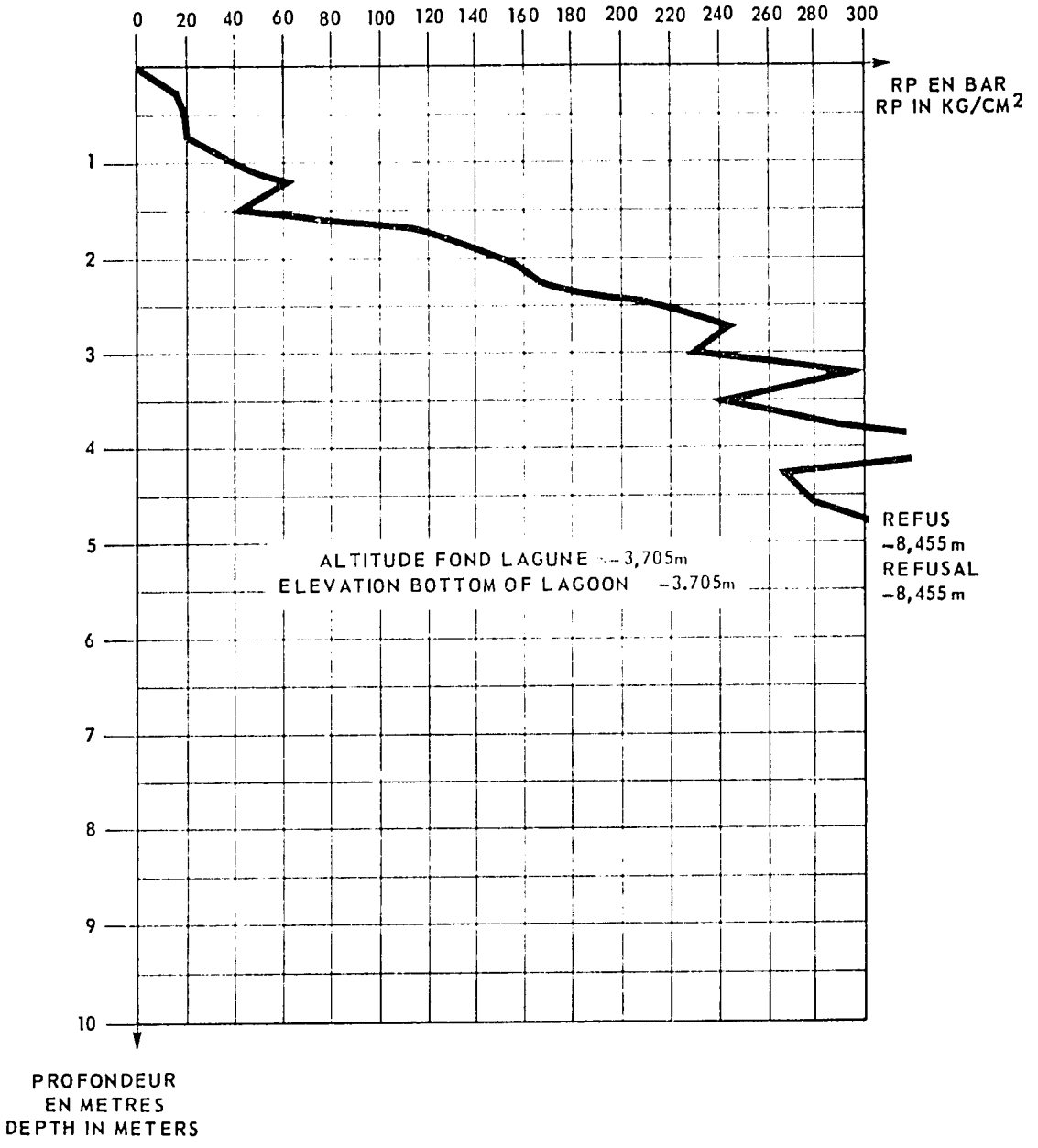


DIAGRAMME PENETROMETRIQUE DYNAMIQUE LOURD BORRO POINT DE SONDAGE: P1
DYNAMIC PENETROMETER GRAPH HEAVY PENETROMETER,
BORRO TYPE-TEST POINT: P1

FIG. 5-4

PONT-BARRAGE-LAGUNE COTONOU
BRIDGE-DAM-COTONOU LAGOON

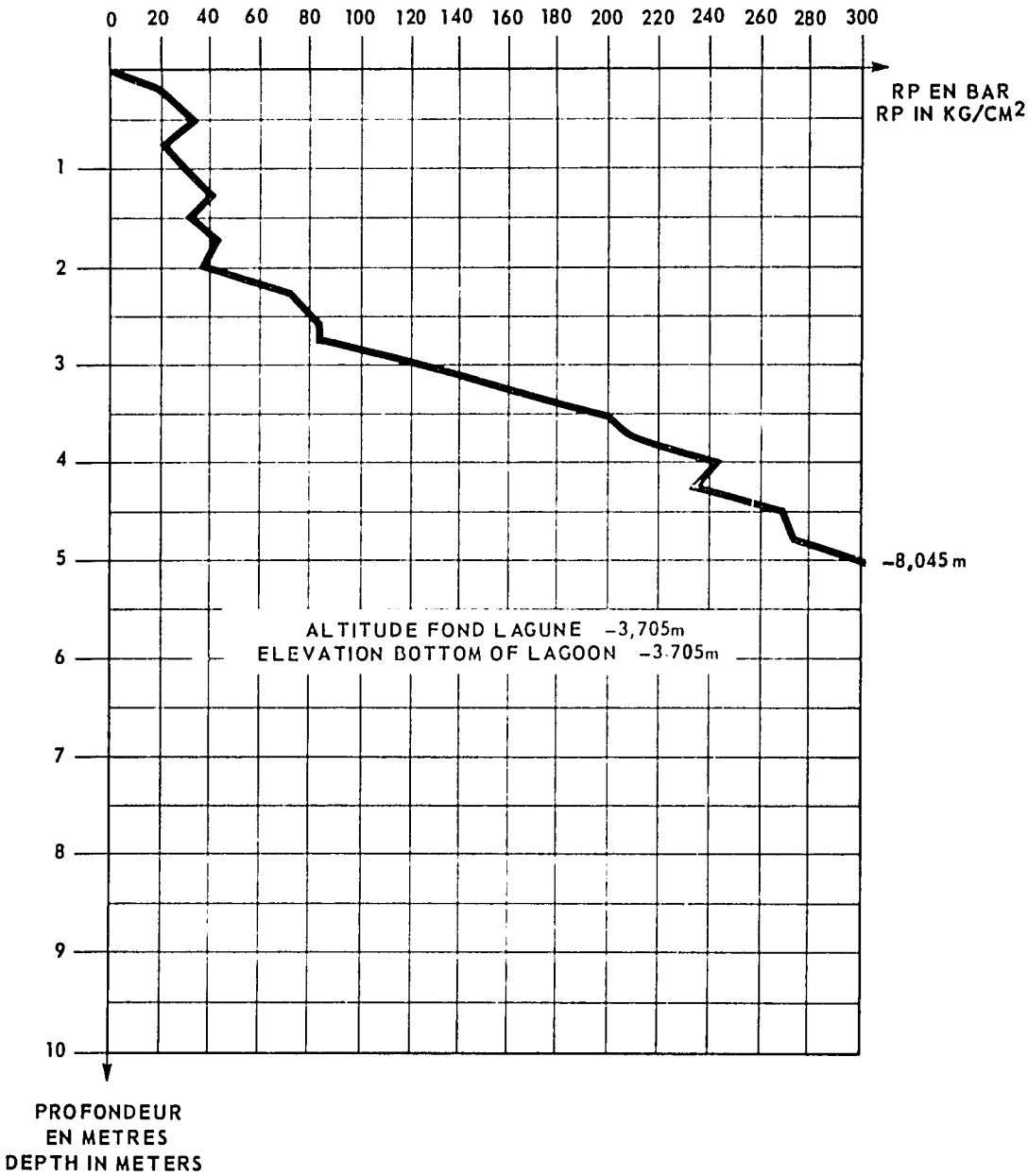


DIAGRAMME PENETROMETRIQUE DYNAMIQUE LOURD BORRO POINT DE SONDAGE: P2
DYNAMIC PENETROMETER GRAPH HEAVY PENETROMETER,
BORRO TYPE-TEST POINT: P2

FIG. 5-5

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PONT-BARRAGE-LAGUNE COTONOU
BRIDGE-DAM-COTONOU LAGOON

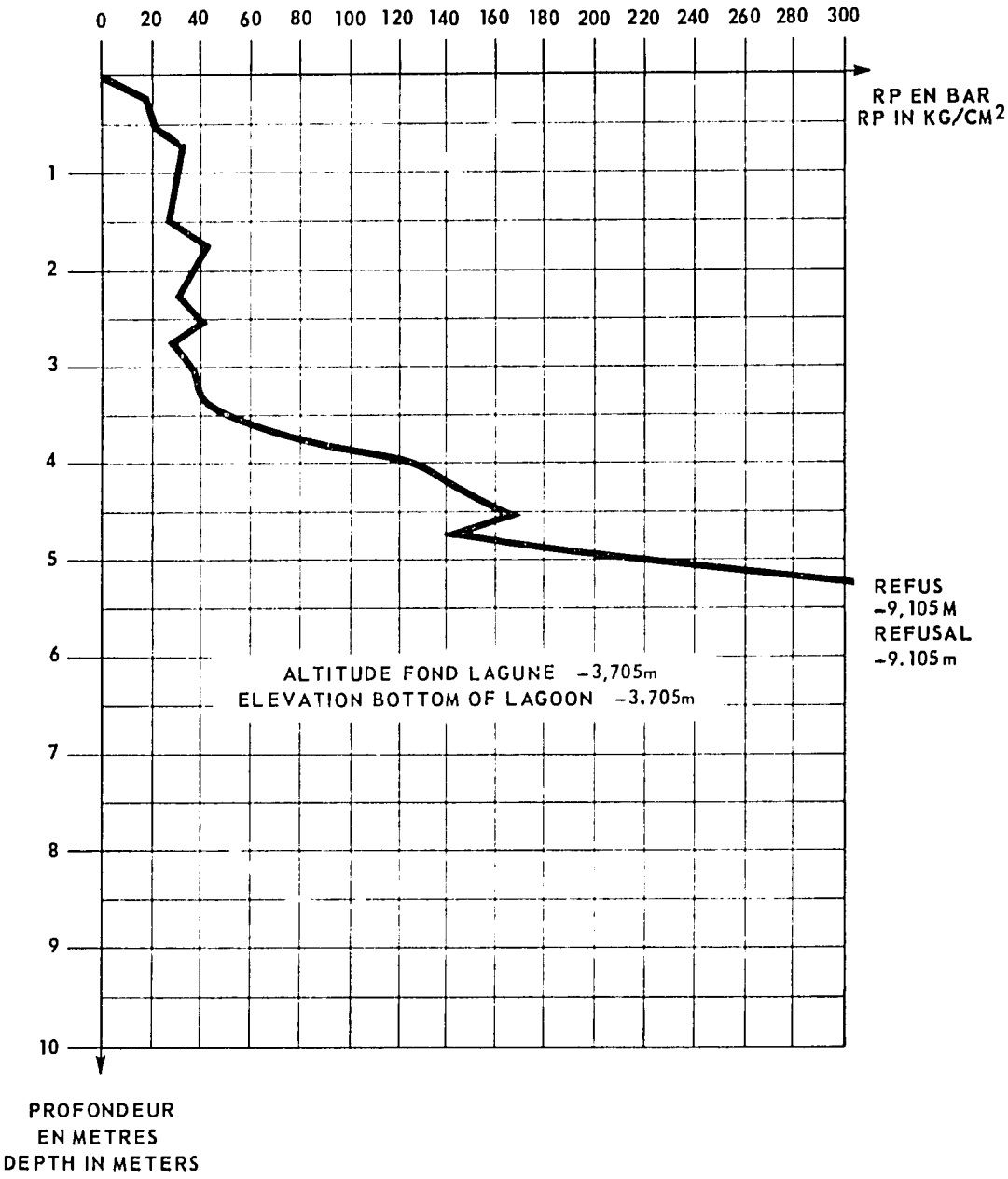

DIAGRAMME PENETROMETRIQUE DYNAMIQUE LOURD BORRO POINT DE SONDAGE: P3
DYNAMIC PENETROMETER GRAPH HEAVY PENETROMETER,
BORRO TYPE-TEST POINT: P3

FIG. 5-6

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PONT-BARRAGE-LAGUNE COTONOU
BRIDGE-DAM-COTONOU LAGOON

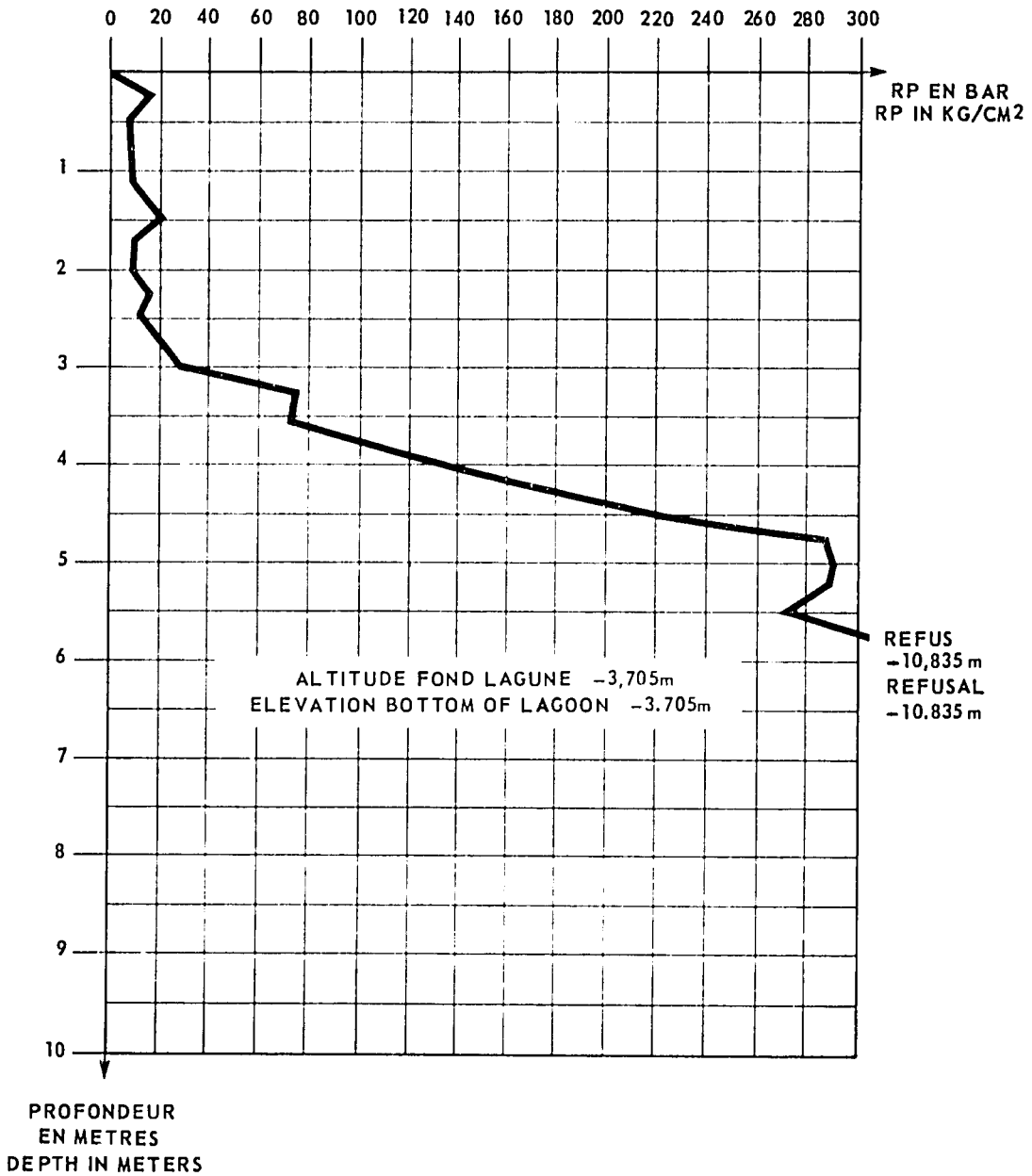

DIAGRAMME PENETROMETRIQUE DYNAMIQUE LOURD BORRO POINT DE SONDAGE: P4
DYNAMIC PENETROMETER GRAPH HEAVY PENETROMETER,
BORRO TYPE-TEST POINT: P4

FIG. 5-7

103

PONT-BARRAGE-LAGUNE COTONOU
BR''GE-DAM-COTONOU LAGOON

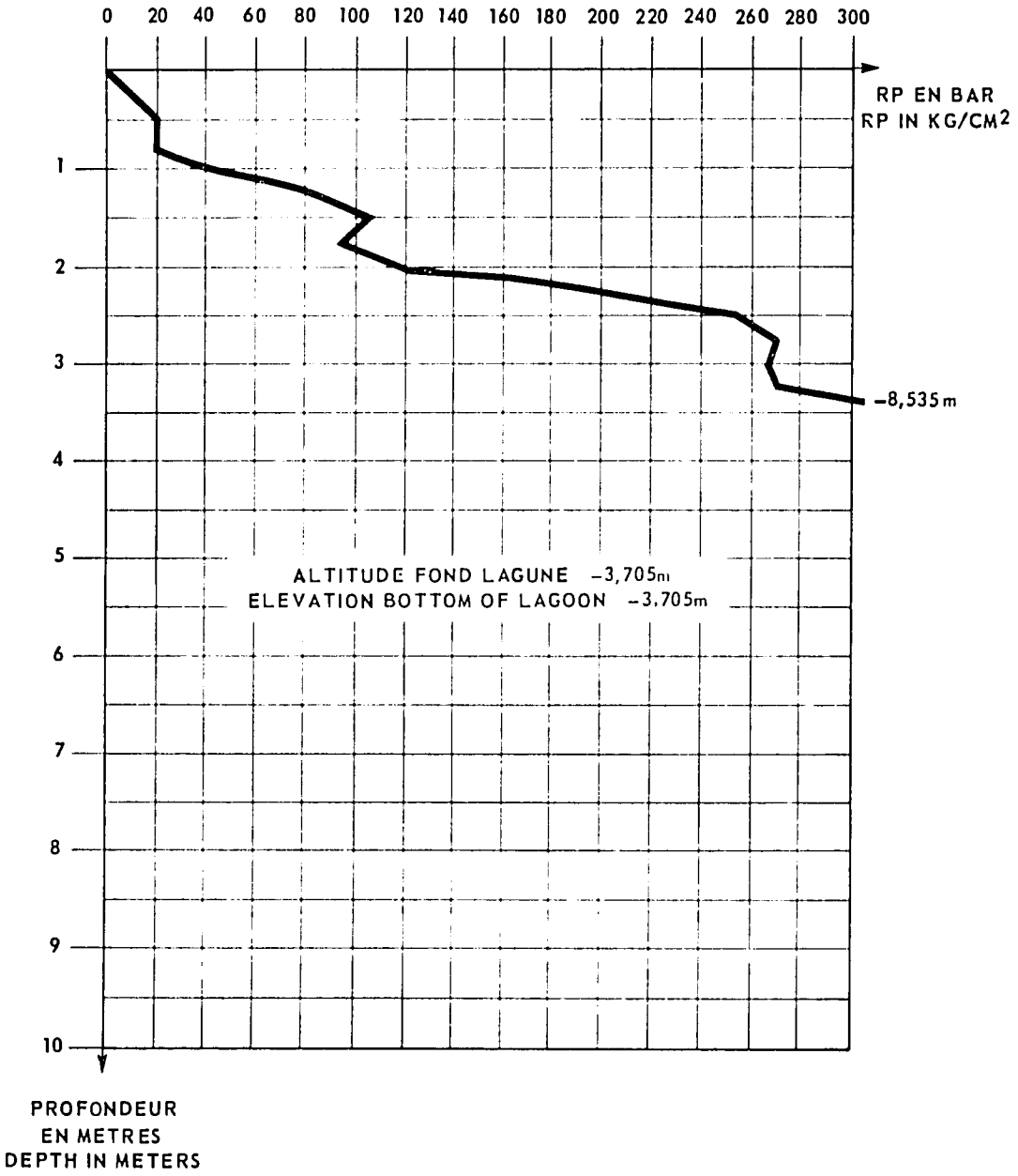

DIAGRAMME PENETROMETRIQUE DYNAMIQUE LOURD BORRO POINT DE SONDAGE: P5
DYNAMIC PENETROMETER GRAPH HEAVY PENETROMETER,
BORRO TYPE-TEST POINT: P5

FIG. 5-8

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SONDAGE ENTREE DU CANAL
PENETROMETER TEST AT LAGOON MOUTH

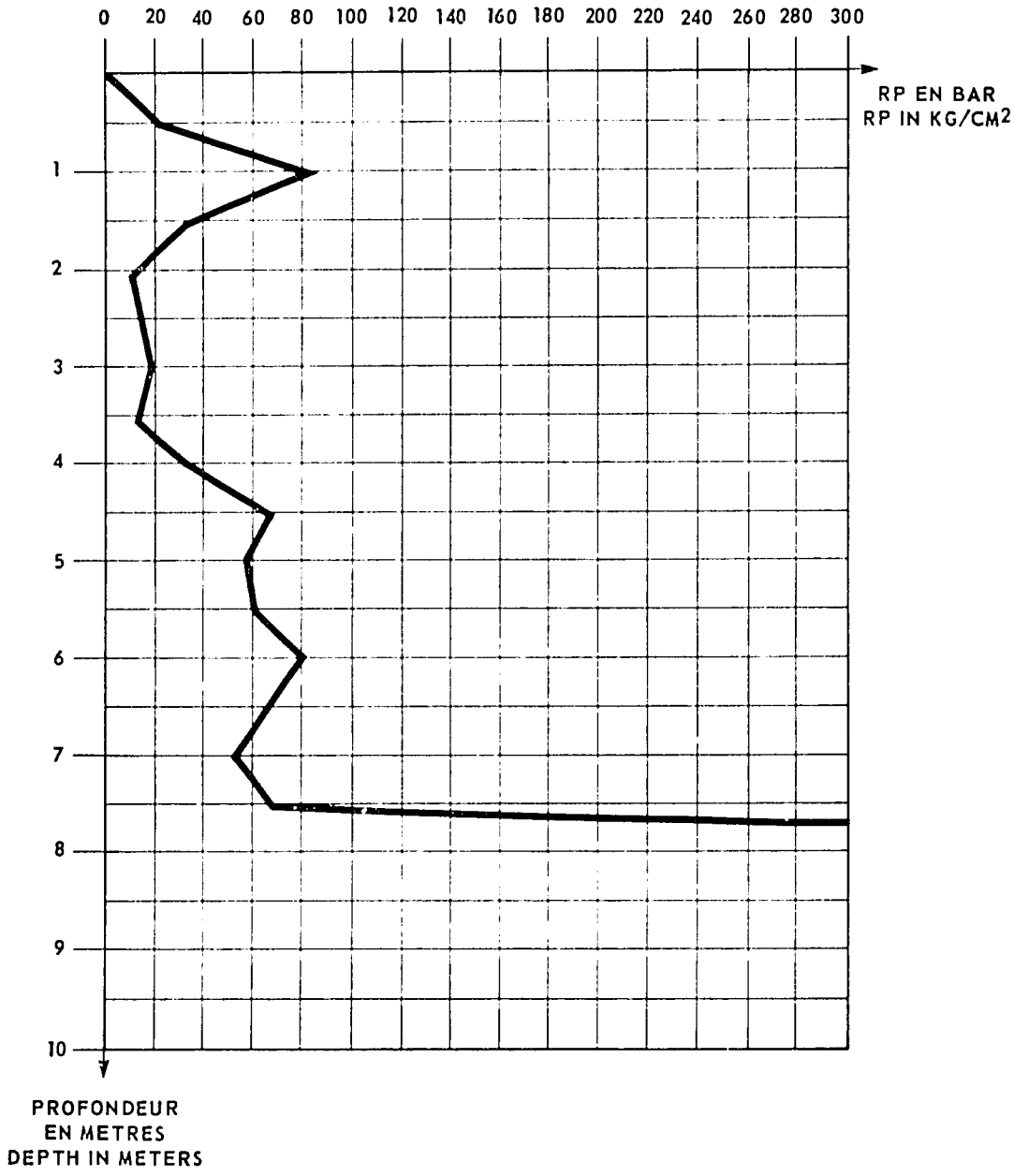

DIAGRAMME PENETROMETRIQUE DYNAMIQUE LOURD BORRO POINT DE SONDAGE
DYNAMIC PENETROMETER GRAPH HEAVY PENETROMETER, BORRO TYPE–TEST POINT

FIG. 5-9

The tests show refusal when the penetration resistance exceeds 300 kg/cm^2. In general, the penetrometer tests show that a resistance of 20 kg/cm^2 is encountered near the surface at the lagoon banks and at a depth of 3 meters in the middle of the lagoon. Below these depths the resistance increases up to refusal which is obtained at 3.5 meters depth at the banks and at 5.5 meters depth in the middle of the lagoon.

Also available were data from previous test borings and field pressure meter tests made by Bureau Central Equipments Outre-Mer (BCEOM) near the same location of the LNBTP tests.

C. LABORATORY TESTING

1. Subsoil Samples Obtained Near the Site of the Dam

The disturbed and undisturbed samples obtained by SASIF, have been tested by LNBTP which has also supervised the work of SASIF.

The laboratory testing included the following:

a. For the disturbed samples:

Sieve and Hydrometer Analysis
Sand Content
Relative Density
Shear Test (Remolded Sample)

b. For the undisturbed samples:

Specific Gravity
Sieve and Hydrometer Analysis
Atterberg Limits
Shear Tests
Consolidation Test

The results are shown in Figures 5-10 through 5-20.

L.N.B.T.P. COTONOU

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PONT-BARRAGE LAGUNE COTONOU
BRIDGE-DAM COTONOU LAGOON

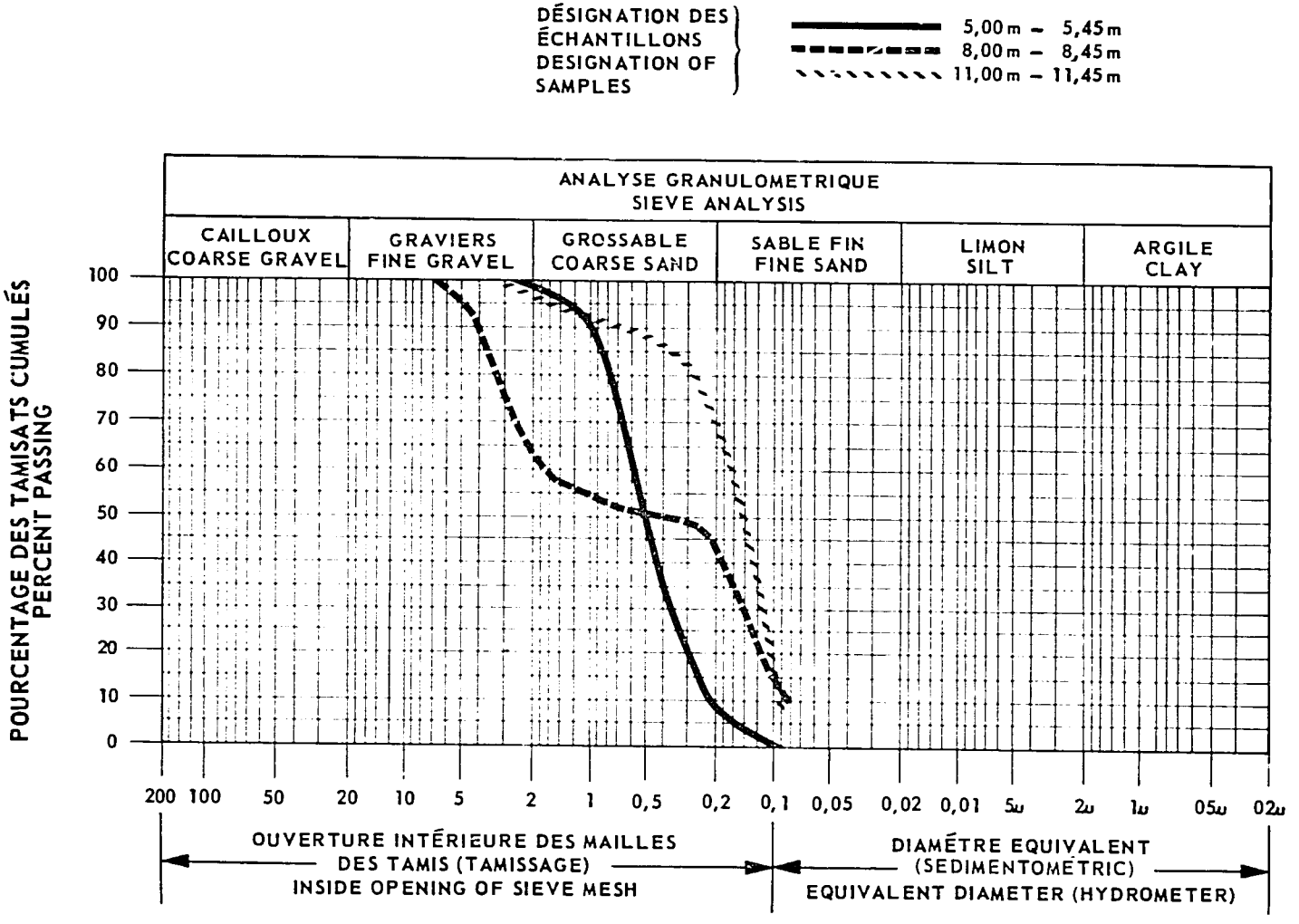

FIG. 5-10

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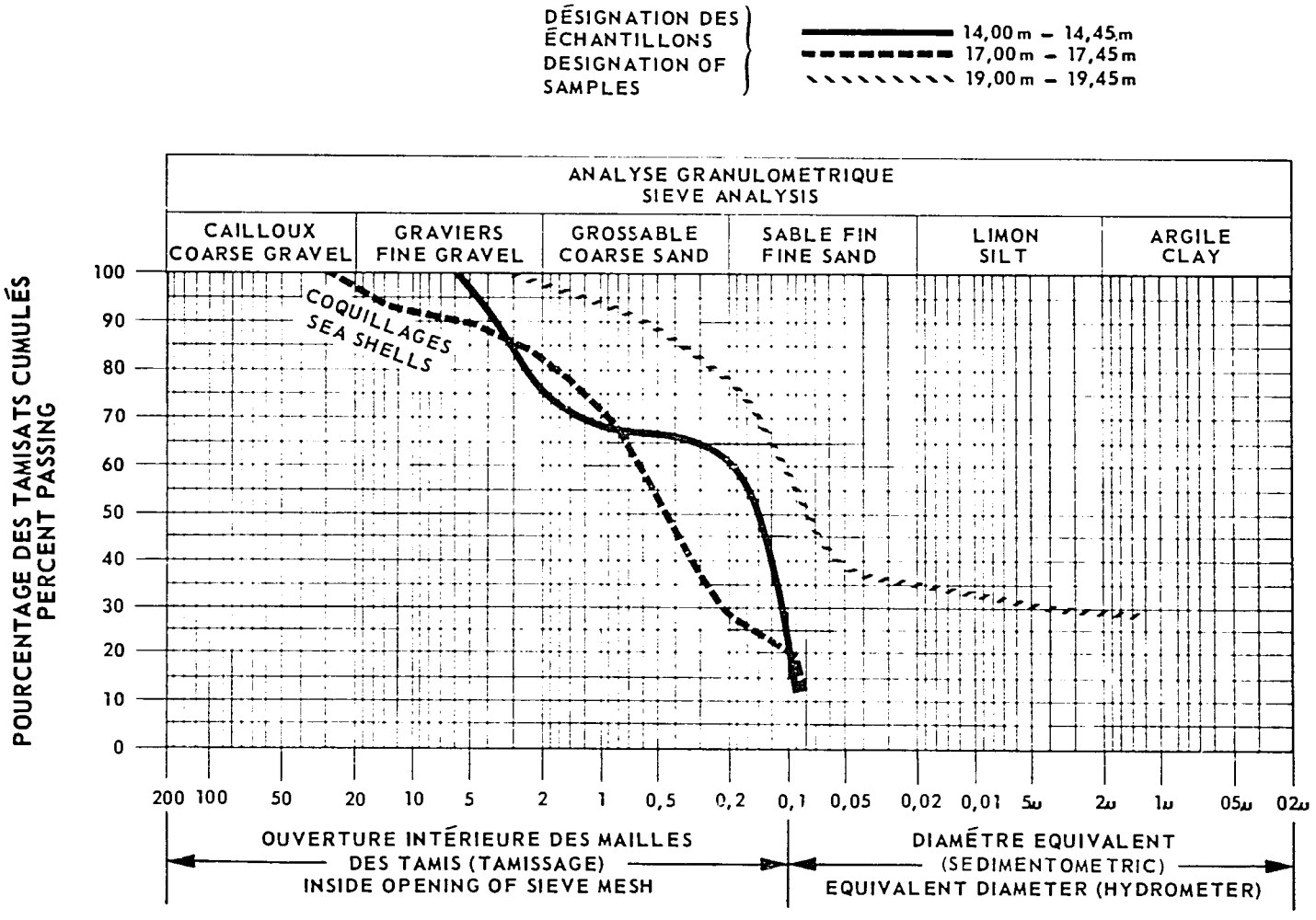
FIG. 5-11

L.N.B.T.P. COTONOU

PONT-BARRAGE LAGUNE COTONOU
BRIDGE-DAM COTONOU LAGOON



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L.N.B.T.P. COTONOU

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PONT-BARRAGE LAGUNE COTONOU
BRIDGE-DAM COTONOU LAGOON

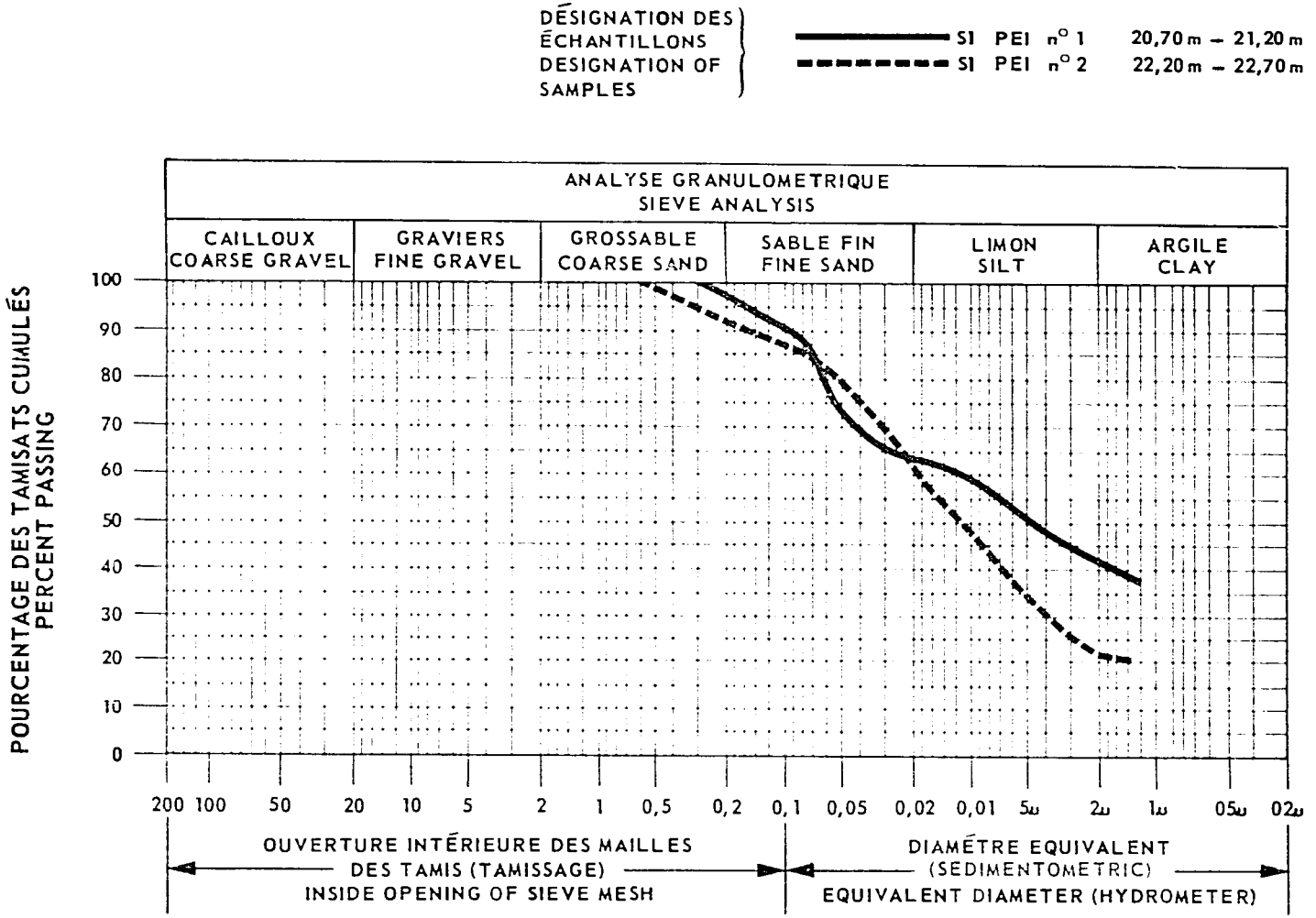
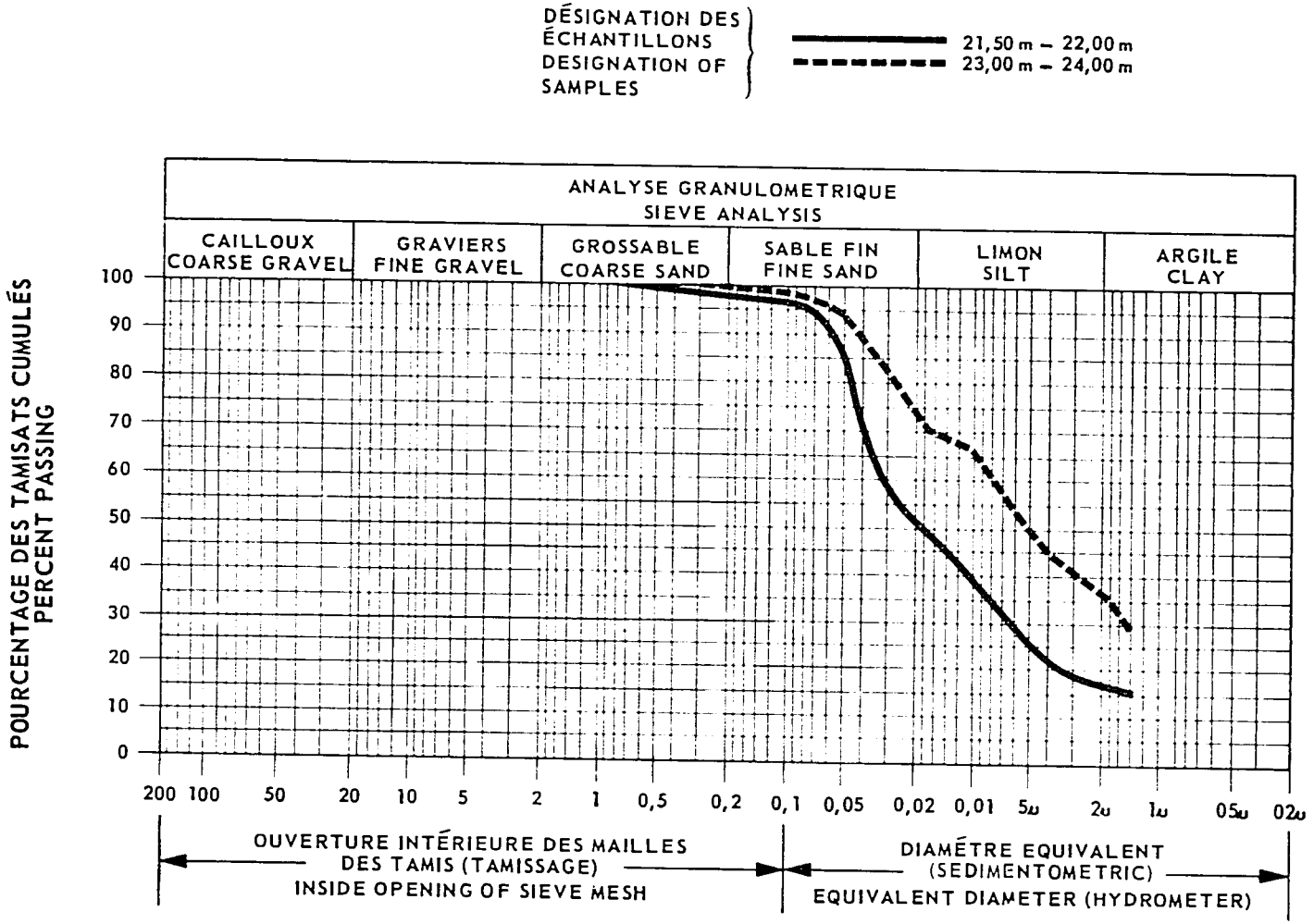


FIG. 5-13

FIG. 5-12

L.N.B.T.P. COTONOU

PONT–BARRAGE LAGUNE COTONOU
BRIDGE–DAM COTONOU LAGOON



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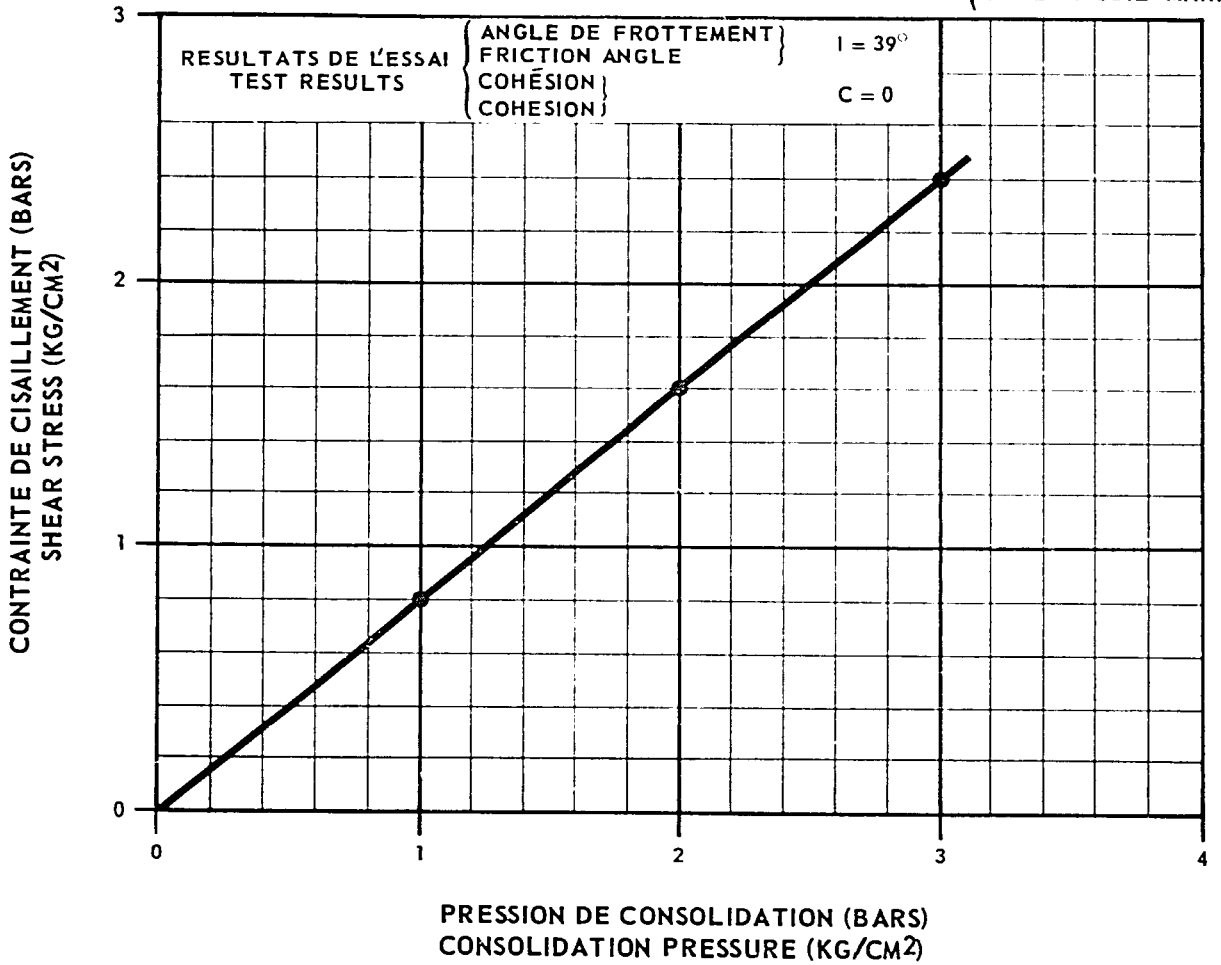
L.N.B.T.P. COTONOU

PONT-BARRAGE LAGUNE COTONOU
BRIDGE-DAM COTONOU LAGOON

(RAPIDE CONSOLIDÉ)
(QUICK-CONSOLIDATED)

ECHANTILLON
SAMPLE

SONDAGE / BORING } 1
PROF / DEPTH } 5,00-5,45m
NATURE DE TERRAIN-SABLE DE MER
TYPE OF SOIL-MARINE SAND



ESSAI DE CISAILLEMENT
SHEAR TEST

SANDERS & THOMAS INC.

FIG. 5-14

FIG. 5-15

L.N.B.T.P. COTONOU

PONT-BARRAGE LAGUNE COTONOU
BRIDGE-DAM COTONOU LAGOON

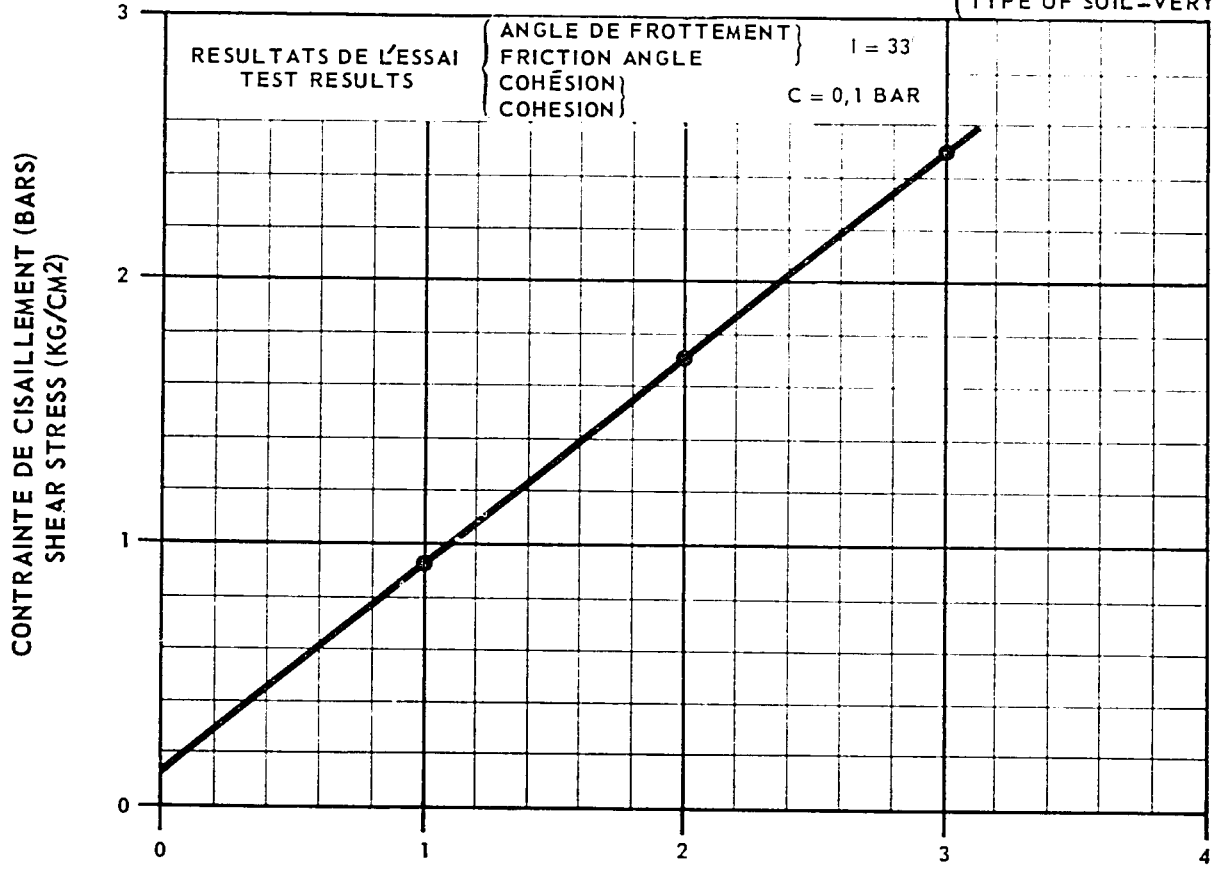
(RAPIDE CONSOLIDÉ)
(QUICK-CONSOLIDATED)

ECHANTILLON
SAMPLE

SONDAGE / BORING } 1

PROF / DEPTH } 14-14,45 m

NATURE DE TERRAIN-SABLE TRÉS FIN
TYPE OF SOIL-VERY FINE SAND



ESSAI DE CISAILLEMENT
SHEAR TEST

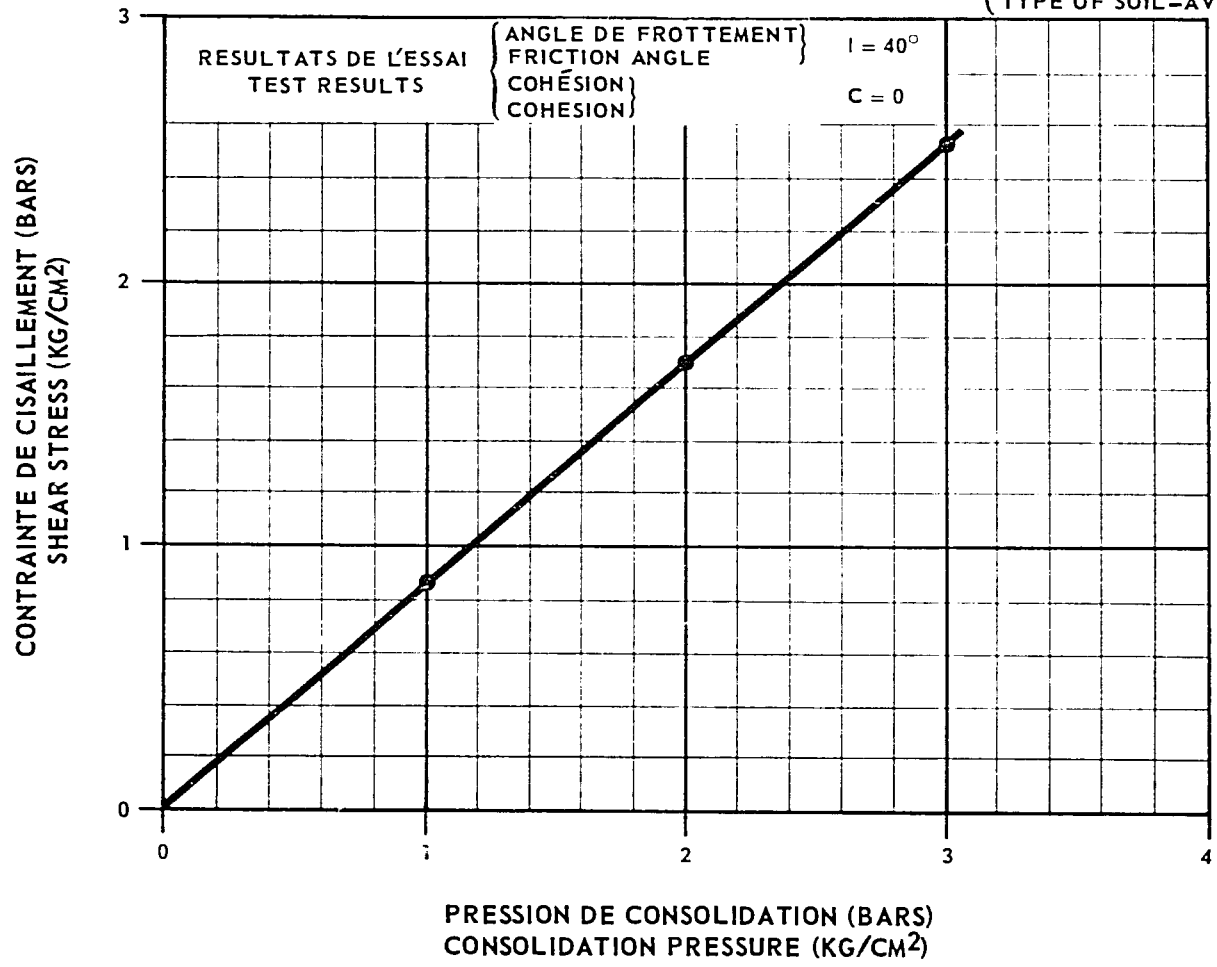
SANDERS & THOMAS INC.

L.N.B.T.P. COTONOU

PONT-BARRAGE LAGUNE COTONOU
BRIDGE-DAM COTONOU LAGOON

(RAPIDE CONSOLIDÉ)
(QUICK-CONSOLIDATED)

ECHANTILLON / SAMPLE
- SONDAGE / BORING: 1
- PROF / DEPTH: 19-19,45 m
- NATURE DE TERRAIN-SABLE MOYEN / TYPE OF SOIL-AVERAGE SAND



ESSAI DE CISAILLEMENT
SHEAR TEST

SANDERS & THOMAS INC.

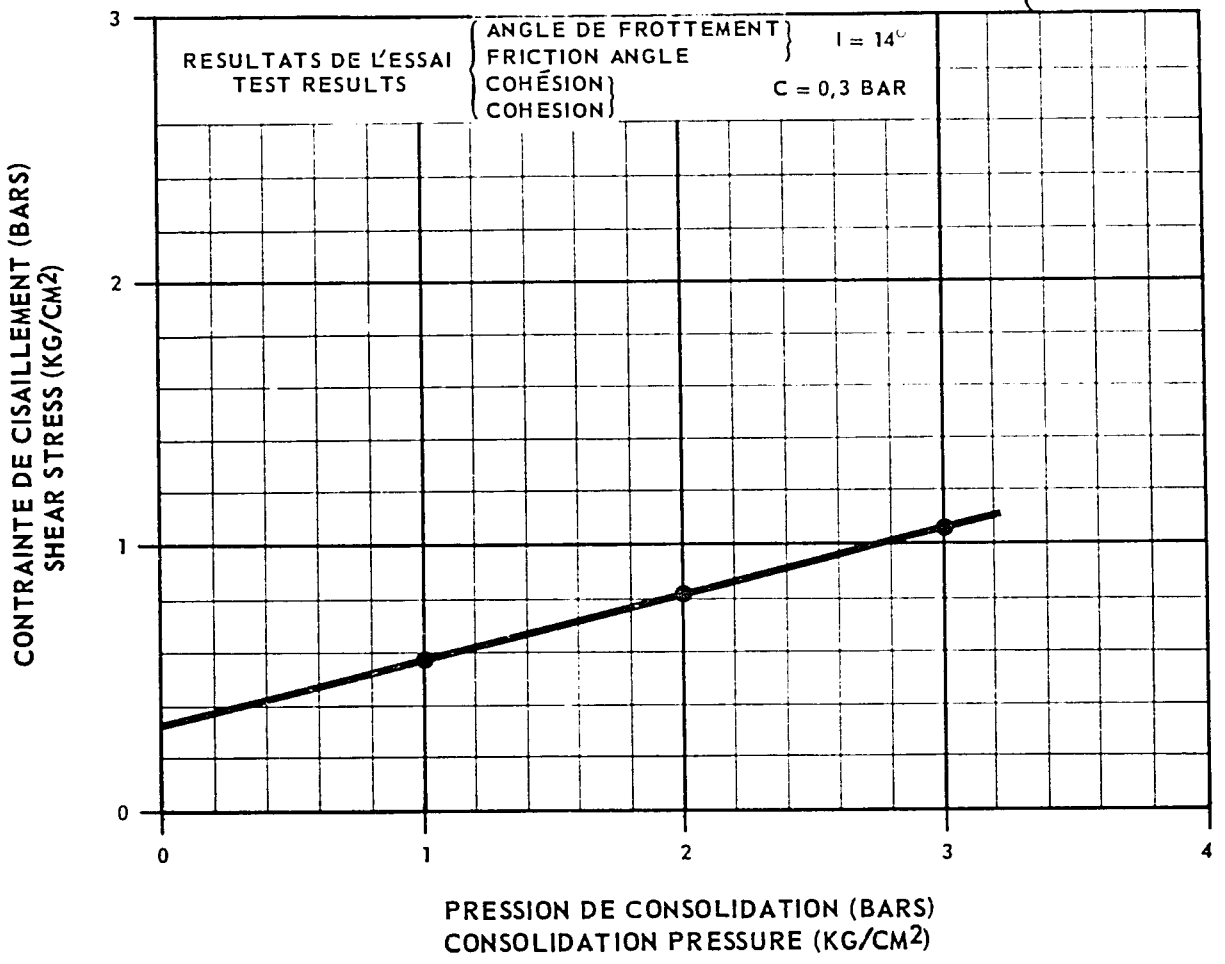
FIG. 5-16

L.N.B.T.P. COTONOU

PONT-BARRAGE LAGUNE COTONOU
BRIDGE-DAM COTONOU LAGOON

(RAPIDE CONSOLIDÉ)
(QUICK-CONSOLIDATED)

ECHANTILLON / SAMPLE
- SONDAGE / BORING: 1
- PROF / DEPTH: 20,70-21,20
- NATURE DE TERRAIN-P.E.I. n° 1
- TYPE OF SOIL-P.E.I. n° 1



ESSAI DE CISAILLEMENT
SHEAR TEST

SANDERS & THOMAS INC.

FIG. 5-17

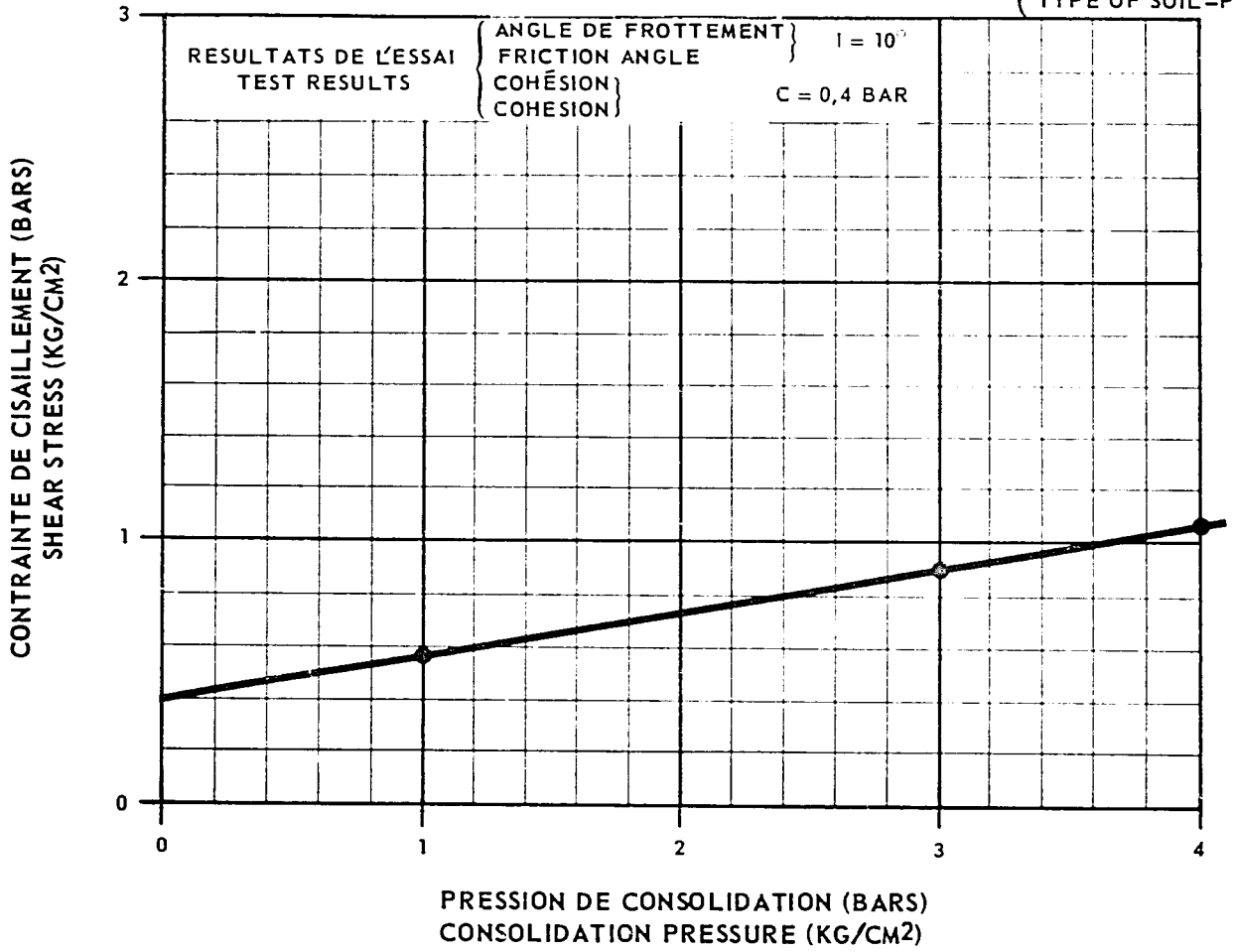
L.N.B.T.P. COTONOU

PONT-BARRAGE LAGUNE COTONOU
BRIDGE-DAM COTONOU LAGOON

(RAPIDE CONSOLIDÉ)
(QUICK-CONSOLIDATED)

ECHANTILLON / SAMPLE
SONDAGE / BORING 1
PROF / DEPTH 22,20-22,70
NATURE DE TERRAIN-P.E.I. n° 2
TYPE OF SOIL-P.E.I. n° 2

SANDERS & THOMAS INC.



ESSAI DE CISAILLEMENT
SHEAR TEST

FIG. 5-18

SANDERS & THOMAS INC.

L.N.B.T.P. COTONOU

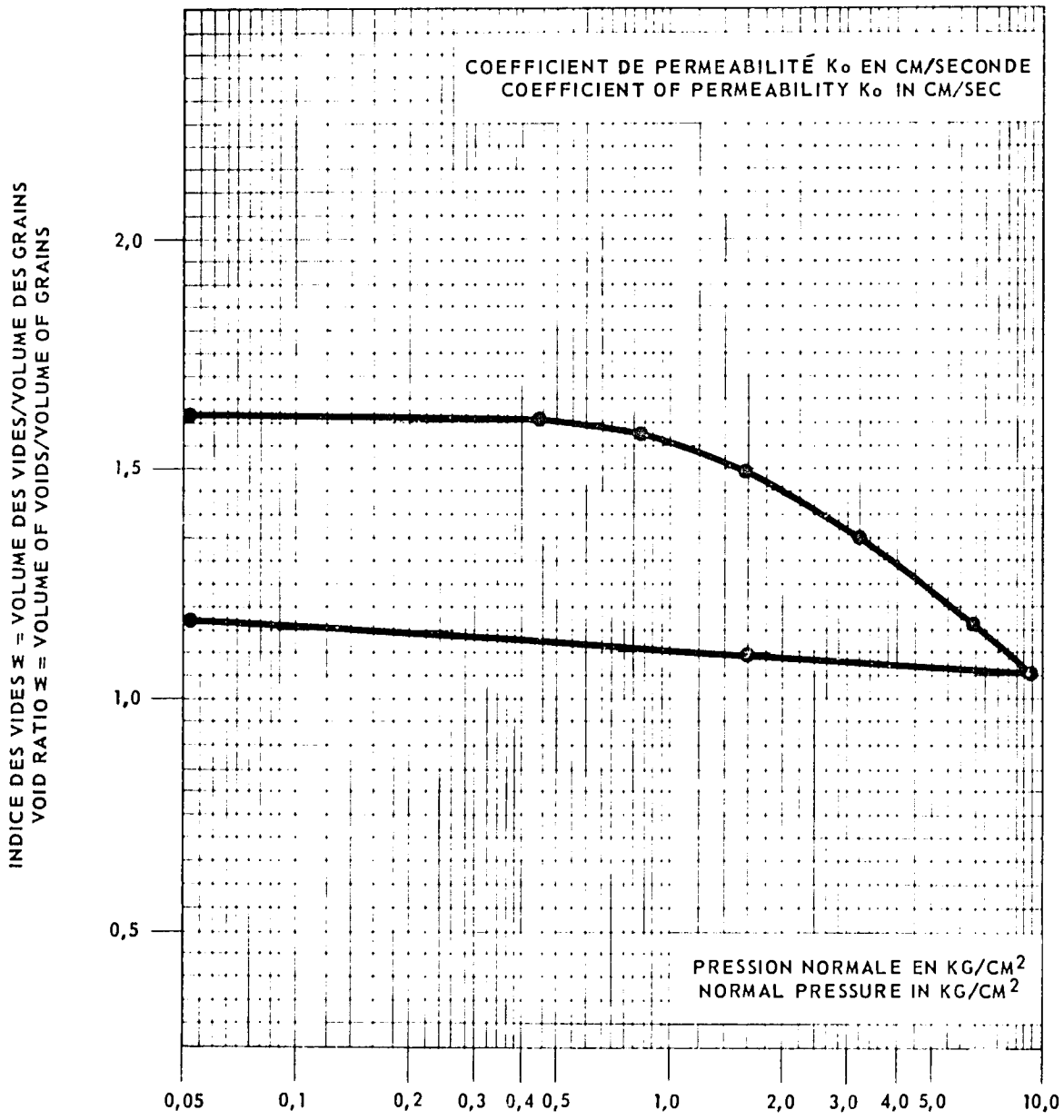
SONDAGE S1
BORING S1

ECHANTILLON P.E.I n° 1
SAMPLE P.E.I n°1

PROFONDEUR 20,70-21,20
DEPTH 20,70-21,20

3,16 KG/CM^2 K = 0,9 X 10^{-6}

9,45 KG/CM^2 K = 0,7 X 10^{-6}



ESSAI DE COMPRESSIBILITÉ PERMEABILITÉ
CONSOLIDATION TEST

FIG. 5-19

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SANDERS & THOMAS INC.

L.N.B.T.P. COTONOU

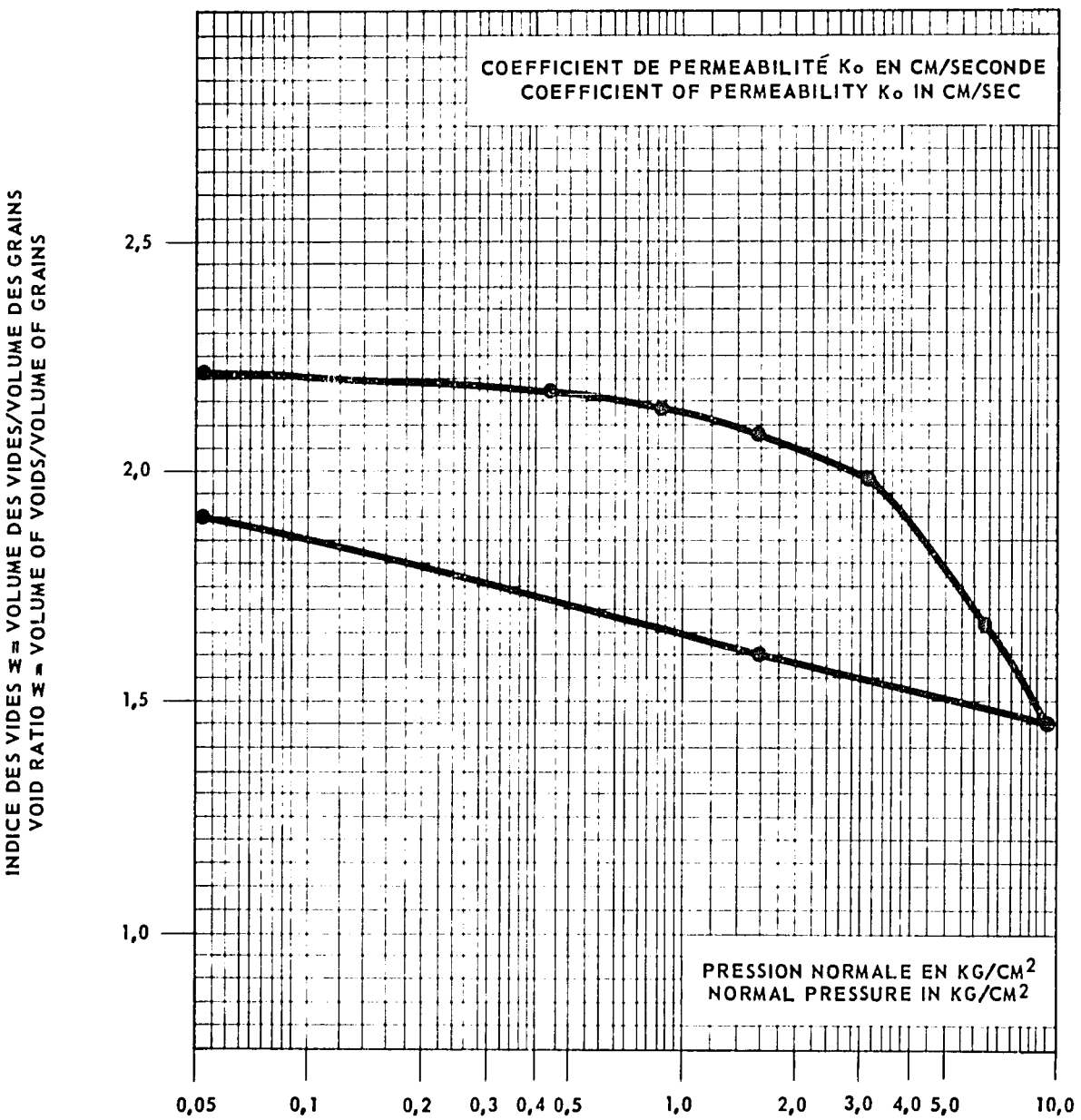
SONDAGE S 1
BORING S 1

ECHANTILLON P.E.I. n° 2
SAMPLE P.E.I. n° 2

PROFONDEUR 22,20–22,70
DEPTH 22,20–22,70

3,16 KG/CM2 K = 0,9 X 10–7

9,45 KG/CM2 K = 0,7 X 10–7



ESSAI DE COMPRESSIBILITÉ PERMEABILITÉ
CONSOLIDATION TEST

FIG. 5-20

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D. SUBSURFACE CONDITIONS

1. At the Site of the Proposed Dam

The subsoils, as encountered in the test borings by SASIF generally consist of four strata:

Stratum	Depth in Meters	Description and Condition
A	0 to 7	yellow and grey sand and silty sand with shell debris - loose
B	7 to 16	black sand and silty sand with small gravel and occasional shell debris - dense to very dense
C	16 to 20	black silt and clay with slight trace of fine sand - very soft to soft
D	20 to 25	black clay with organic matter - soft

Stratum A consists of fine sea-bottom sand with about 98% finer than 2 mm and virtually no silt. The angle of internal friction as determined from a remolded shear test was 39° with no cohesion.

Stratum B consists of black sand 62% to 96% finer than 2 mm with up to 11% silt. The angle of internal friction was about 40° with little cohesion.

Stratum C consists of loose black silt with 67% to 89% passing the #200 sieve. The Atterberg limits indicate that this soil is predominantly clay. Undisturbed shear tests indicate an angle of internal friction between 10 and 14°, with a cohesion of 0.3% to 0.4 g/cm^3.

Consolidation tests show that Stratum C has a compressibility index which varies from 63% with a preconsolidation pressure of 1.6 kg/cm^2 to 107% with a preconsolidation pressure of 2.2 kg/cm^2.

Stratum D consists of black highly plastic clay with organic contents varying from 15% to 25%.

2. At the Site of the Proposed Bridge Near Boulevard Saint Michel

The soil profile, as determined from previous and recent data, consists of two strata:

Stratum	Depth in Meters	Description and Condition
—	0 to 3	Water
A	3 to 13	Sand - Dense to very dense with the upper two meters and lower one meter somewhat less dense and mixed with silt
B	13 to 20-30	Clay and silt - medium dense

Based on the laboratory testing by LNBTP and previous data from BCEOM [1] following soil parameters were assumed for use in preliminary foundation analysis:

Stratum	Submerged Weight	Cohesion	Friction Angle
A	0.83 (g/cm^3)	0.02 (t/m^2)	33°
B	0.63 (g/cm^3)	4.70 (t/m^2)	14°

E. PRELIMINARY RECOMMENDATIONS FOR FOUNDATION DESIGN AND CONSTRUCTION

The foundation conditions were analyzed based on both the previous and new laboratory test data. The probable load-carrying capacity for piles and expected amounts of settlement have been evaluated in a conservative manner.

1. Proposed Dam

Settlement of the clay stratum under the dam will be substantial. A total settlement of 30% to 50 centimeters may be expected over a relatively long period of years. Half of the maximum settlement will probably occur within the first four years. In order to accelerate the time in which the consolidation of the compressible strata occurs, the dam foundation should be preloaded, if at all possible.

Prior to final design, additional investigations in the area of the dam should be made to determine the extent to which the soil substrata vary and to more accurately establish the compressibility characteristics of the underlying clay.

2. Proposed Bridge

Pile foundation bearing on the dense sand is feasible. The following formula was used for the determination of preliminary point bearing capacity for precast concrete

[1] Contained in BCEOM reports entitled Etude du Debouche Lagunaire de Cotonou (1963) and Ouvrage de Regularisation et de Franchissenent du Debouche Lagunaire de Cotonou (1968).

piles (with soil cohesion assumed equal to zero):

$$Qult = \pi R^2 \ (\delta D N_q + 0.6 \delta R N_\delta) + 2\pi R h \delta (D - h/2) \ \tan \phi$$

where:

Qult is the ultimate bearing capacity of a single pile
R is the radius of the pile tip
D is the penetration of pile, from ground surface to pile tip
F is the submerged unit weight of soil
N_q, N_δ are the bearing capacity factors (both assumed = 30)
h is the depth of penetration of pile tip in the dense granular coil
ϕ is the angle of internal friction of the supporting soil

It was calculated that a capacity of 25 to 50 tons per pile can be obtained with total pile embedment of 5 to 8 meters with a pile having a 24-inch diameter using a factor of safety of three. Piles should be kept as high above the clay stratum in order to minimize the settlement. The calculations[2] indicate that settlement should not exceed 3 centimeters under the anticipated loads. As piles are driven into the sand, local densification will occur increasing the bearing capacity of the soil under and adjacent to the driven pile.

Additional subsoil investigations at the bridge site should be made prior to final design to more accurately determine the profile of the subsoil and its strength and consolidation characteristics. Foundation investigation work should also include pile load tests and static cone penetrometer tests.

[2] Based on soil exploration and laboratory testing data contained in the BECOM reports of 1963 and 1968.

SECTION VI

HYDRAULIC STUDIES

A. OBJECTIVES

1. Prevention of Erosion in the Cotonou Lagoon

The erosion of the Cotonou Lagoon began in 1959 after the completion of the construction of the new deep-sea port. During the last ten years considerable damage has resulted to the lagoon banks and to the pile foundation of the existing bridge. Although the rate of erosion seems to have slowed down in some areas of the lagoon during the last few years, there is no guarantee that the erosion will stop altogether in the future.

In order to prevent the eventual collapse of the existing bridge and future undermining of the lagoon banks and the new bridge, a dam has been proposed to be constructed at the mouth of the lagoon near the ocean. A dam provides an effective erosion protection by reducing the velocity of flow in the lagoon. A dam also helps to reduce the salinity of Lake Nokoue.

2. Reduction of Salinity in Lake Nokoue

The change of salinity in Lake Nokoue began after the Cotonou Lagoon became permanently open to the sea in 1959. It was noted that the salinity cycles changed and that certain parts of Lake Nokoue continued to have high salinity for longer periods than before. This change has helped to invite the invasion of the terredos into the lake with the consequent destruction of the akadja fish traps and reduction of the lake fishing harvest.

In order to be able to evaluate the potential usefulness of the proposed dam with respect to salinity reduction, it was necessary first to evaluate and understand how the salinity changes had occurred in the lake. It was only then that the contribution of the proposed dam towards salinity reduction could properly be assessed. The proposed dam achieves the reduction of salinity by eliminating a substantial amount of the tidal sea water inflow into the lagoon. The maximum amount of the tidal inflow that the dam can block, however, is limited by other important requirements.

3. Maximum Allowable Flood Levels and Silting in the Cotonou Lagoon

In the past, when the Cotonou Lagoon was completely closed by a sand bar, the level of Lake Nokoue would rise during the flood peaks of the Oueme River and the City

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of Cotonou would become flooded. Since the dam will permanently obstruct the lagoon, one important requirement for the design of the dam is that its weir should have sufficient size to allow the flood waters to escape to the sea. Another important requirement for the weir of the dam is that the levels of the flood backwater must remain sufficiently low so that the City of Cotonou does not become flooded. Both of these goals could easily be achieved by constructing a low weir. This, however, would have been in direct opposition to the goal of maximum reduction of salinity, which requires that the weir be constructed at a level high enough to block the inflow of most if not all of the tidal waters. Thus, the problem was to determine the highest possible level for the weir which, at the same time, satisfies the flood and backwater requirements.

Another aspect that needs consideration is the potential problem of silting in the Cotonou Lagoon. The proposed dam will effectively prevent erosion in the lagoon by reducing the flow velocities. Reduced velocities, however, may cause the silting of the lagoon channel.

B. PREVIOUS AVAILABLE STUDIES AND STATISTICAL DATA

1. Monography of the Oueme River Delta [1]

This publication contains a collection of hydrologic and hydrographic data relative to the Oueme River delta. The data were collected and organized by the Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM).

From this source, data were obtained on the following:

a. Maximum recorded flood levels in the Porto-Novo Lagoon and Lake Nokoue.

b. Comparative levels of Lake Nokoue, the Atlantic Ocean and Porto-Novo Lagoon during the periods of opening or closing of the Cotonou Lagoon during the years 1952 to 1953.

c. Other useful information relative to the flood records in the Oueme delta.

2. Hydrographic Surveys by BCEOM

These surveys were performed by Bureau Central d'Etudes pour les Equipments d'Outre-Mer (BCEOM) and the results were included in their reports of 1963[2] and 1966[3]. The hydrographic surveys provided information relative to channel cross sections,

[1] ORSTOM, Monographie du Delta de l'Oueme, Edition Provisoire, 1964.

[2] BCEOM, Etude du Debouche Lagunaire de Cotonou, 1963.

[3] BCEOM, Ouvrage de Regularisation de Franchisement du Debouche Lagunaire de Cotonou, 1968.

topography, flow velocities and tidal records for the Cotonou Lagoon as well as salinity records for Lake Nokoue.

3. Tidal Records

Tidal records provided by the BCEOM reports contained daily tidal data for the periods of July 1, 1962 to March 31, 1963 and March 1, 1966 to November 30, 1966. The records show the tidal amplitudes at two locations in the lagoon: Cotonou bridge and Agbato. From these records, it was possible to determine the average variation of the levels of mean tide as well as the variation of the tidal amplitudes at each location. This information was useful in the determination of the probable reduction of the tidal inflow after the construction of the proposed dam.

4. Salinity Records

The salinity records were also obtained from the BCEOM reports. The records provided salinity measurements at the selected stations in Lake Nokoue and Porto-Novo Lagoon. The records include the periods of January, 1957 to December, 1959 and January, 1964 to July, 1966. The records for the years 1957 to 1959 were particularly valuable because they made possible the comparison of the salinity with the volume of flow of the Oueme River during the time when the Cotonou Lagoon changed from being open to being closed.

5. Mathematical Model Studies by SOGREAH

The hydraulic laboratory SOGREAH of Grenoble has performed very detailed mathematical model studies of the system consisting of Lake Nokoue and the Cotonou Porto-Novo Lagoons. The mathematical model was established by using basic hydraulic principles and by deriving certain coefficients in the mathematical formulas by conformance to known field measurements in the actual conditions. Thus, the adjusted mathematical formulas of the model allowed the investigation of many diverse conditions of channel flow, tidal amplitudes, etc., and the calculation of the expected consequences from the proposed construction of a dam in the lagoon.

The results of the SOGREAH studies have been very helpful in the hydraulic studies of Sanders & Thomas, Inc. Although the dam proposed by Sanders & Thomas, Inc. differed considerably from the one proposed by BCEOM, it was nevertheless possible to use the SOGREAH results. By appropriate substitution of the calculated flow characteristics for the type of dam proposed by Sanders & Thomas, Inc., one could relate to the rest of the model which remained unchanged.

C. HYDROGRAPHIC SURVEY BY SANDERS & THOMAS, INC.

1. Objectives

The objectives of the hydrographic surveys by Sanders & Thomas, Inc. were intentionally modest. One could not hope, in the short time available, to improve upon the rather exhaustive data already obtained in the previous studies. The extent of the survey was therefore limited to investigating a few key items to determine the latest and most up-to-date conditions in the Cotonou Lagoon. The items that were deemed important to check included channel cross sections at the proposed bridge locations, channel soundings to determine the best location for the dam near the mouth of the lagoon, and current velocity measurements at selected points in the lagoon. The cross section data were useful to establish more precise dimensions for the calculation of construction costs of the bridge and the dam. At the same time, they provided an indication of whether or not there were any changes in the rate of erosion of the lagoon channel. The flow velocity measurements helped to provide another indication of the future erosion risk. The location of the channel cross sections that were surveyed by Sanders and Thomas, Inc. is shown in Figure 6-1.

2. Channel Soundings at the Existing Bridge

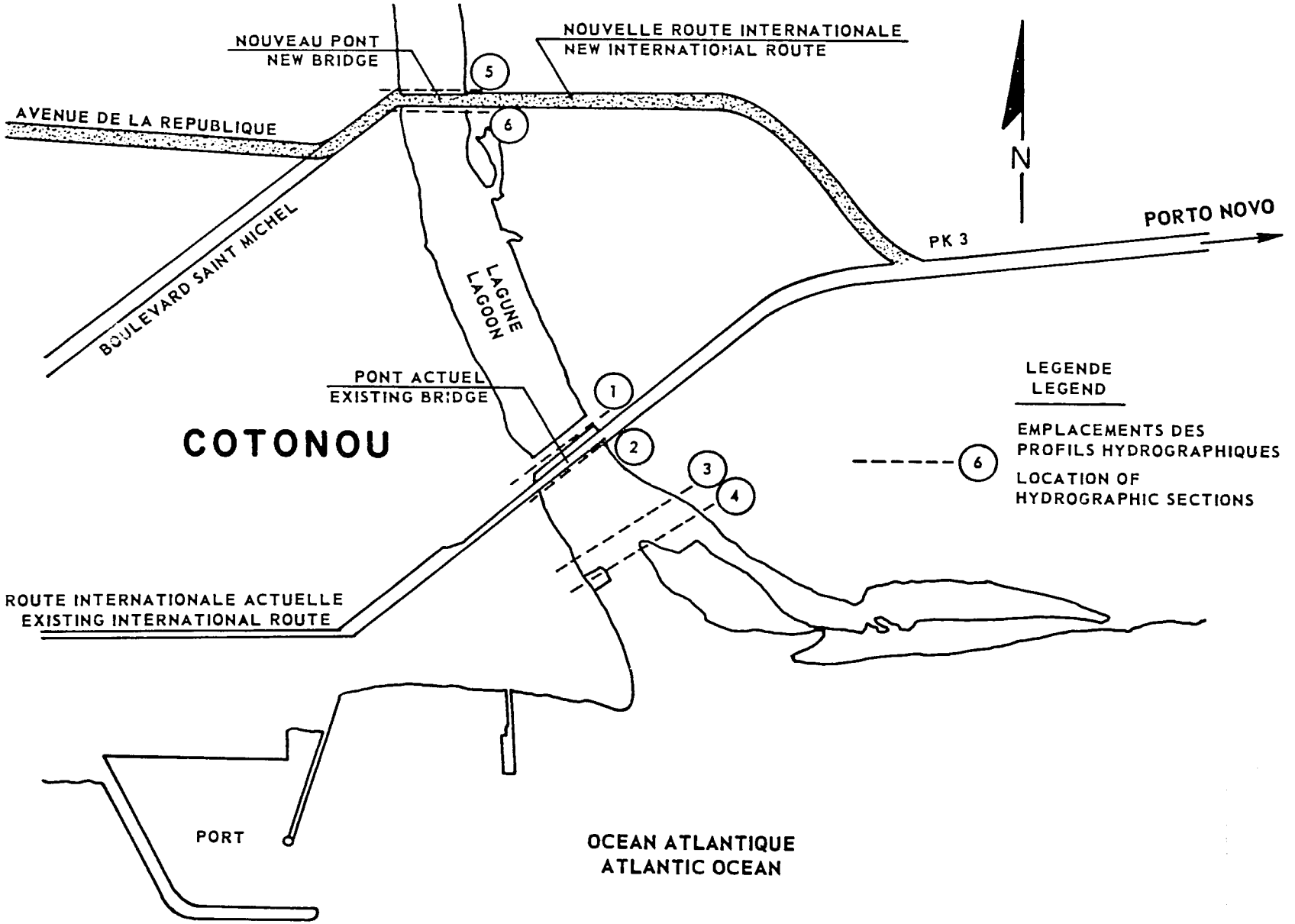
Channel soundings at the existing bridge were performed to determine whether there was any further undermining of its foundations since the last measurements were made by BCEOM in March of 1970.

The measurements of channel depth were made using a graduated rope with a weight attached to it. The sounding work was done during approximately a two-hour period at the time when the tides were changing, and the velocity of flow was relatively low. The results of these soundings show that the erosion under the existing bridge is still progressing, although at a slower rate than in the years past, (See Figures 6-2 and 7-1).

3. Channel Soundings Near the Lagoon Mouth

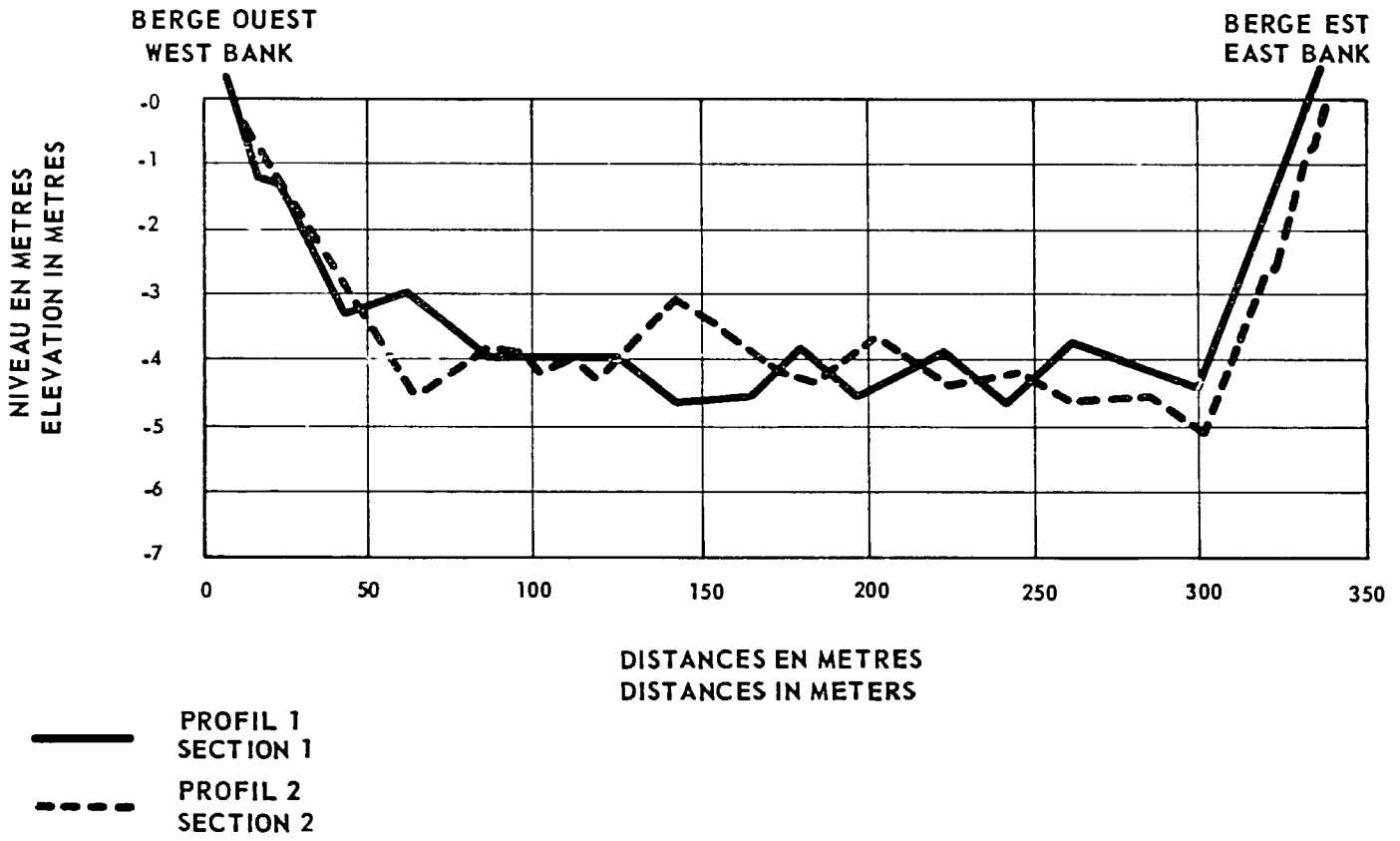
In order to determine the most advantageous location for the proposed dam, two cross sections were taken near the mouth of the lagoon. The sections were obtained using a boat equipped with sonar. The apparatus was EIAC-Electroaccoustic GBH of West German manufacture. It was powered by four 6-volt batteries. The boat, the crew, and the sonar equipment was provided by the Service de l'Hydraulique of Cotonou.

While the sonar work was in progress, two survey teams of the Service Topographique, Cotonou, were triangulating the boat position. The plotted cross sections are shown in Figures 6-3 and 6-4.



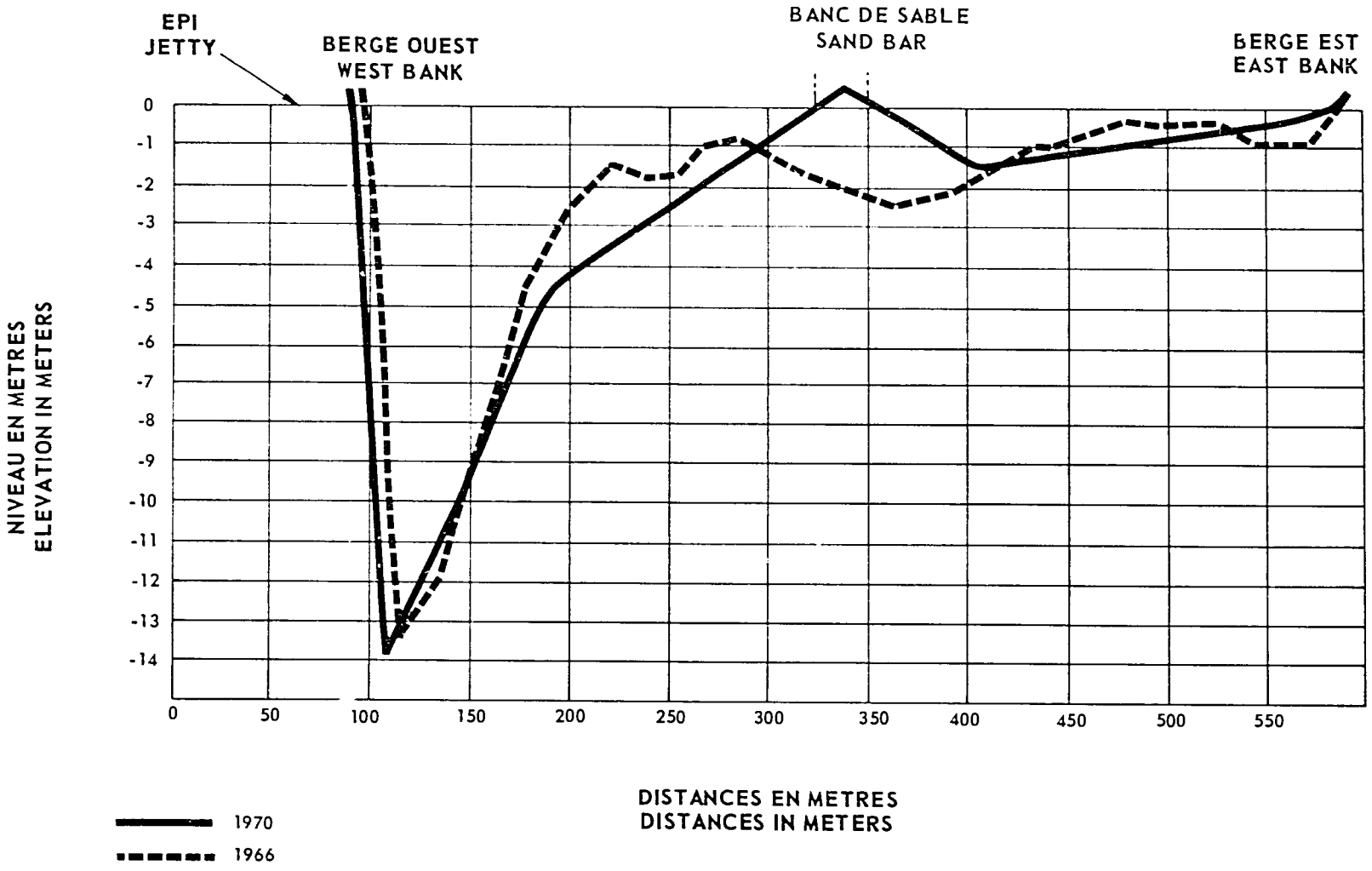
SANDERS & THOMAS INC.

FIG. 6-1



PROFILS EN TRAVERS NO. 1 ET 2
CROSS SECTIONS NO. 1 AND 2

SANDERS & THOMAS INC.

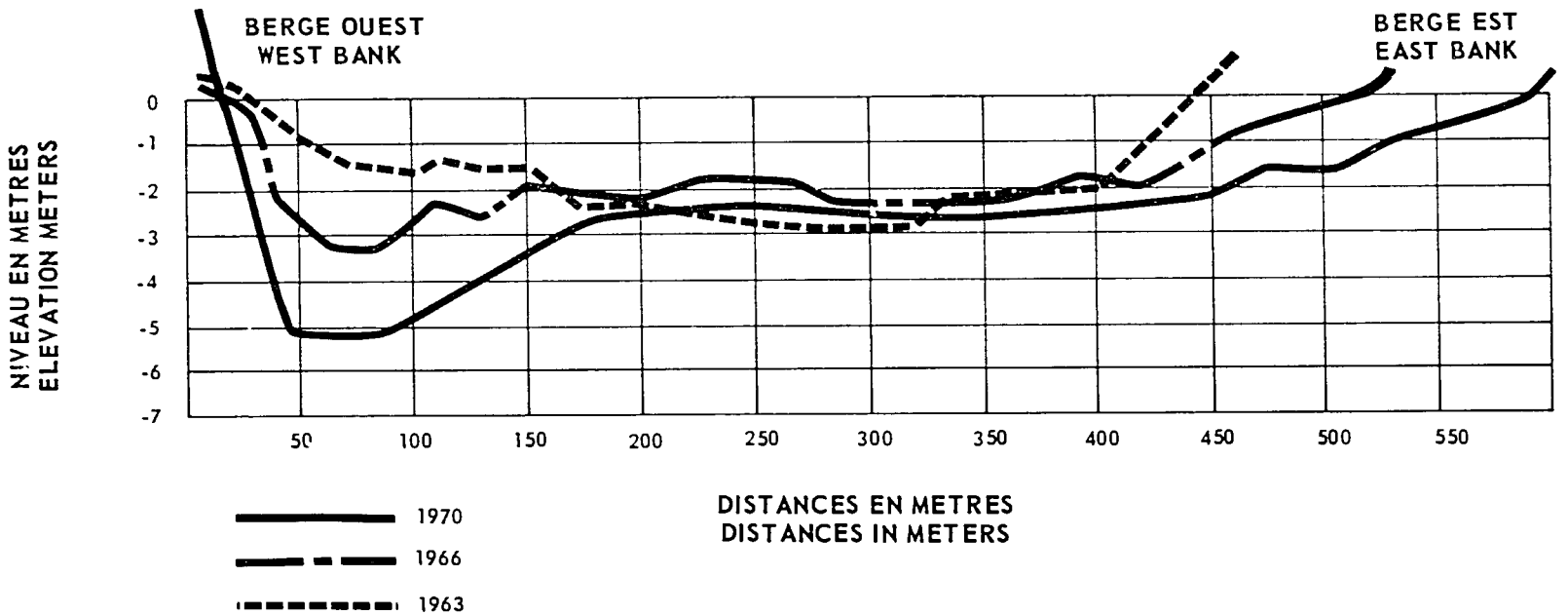


PROFIL À TRAVERS NO. 4
CROSS SECTION NO. 4

FIG. 6-3

SANDERS & THOMAS INC.

FIG. 6-4



PROFIL À TRAVERS NO. 3
CROSS SECTION NO. 3

4. Channel Soundings at the Boulevard Saint Michel Site

At this site, the soundings were made by using the graduated rope. Here it was also necessary to use a boat and two survey teams to triangulate the position of the soundings as they were made. The results of the soundings by graduated rope were later checked with sonar equipment.

The cross section of the channel at the Boulevard Saint Michel site was compared to the cross sections obtained at the same location by BCEOM in 1963 and 1966 (See Figure 6-5). At this location, it is evident that the erosion is continuing and that its rate does not seem to be subsiding.

5. Flow Velocity Measurements

The flow velocity measurements have been made at the location of the proposed bridge near Boulevard Saint Michel and near the existing bridge.

All velocity measurements were made using an inflatable rubber boat equipped with an OTT meter. The boat, its crew, and the OTT meter were provided by the Cotonou Office of ORSTOM. [1]

At the Boulevard Saint Michel site, velocity and depth measurements were made at intervals across the lagoon. The location of each measurement was established by means of a tagged cable stretched from one bank of the lagoon to the other. Thus, it was possible to determine the cross section of the channel as well as the flow velocities and the volume of flow. The calculated volume of flow was 800 cubic meters per second. The velocity readings were averaged over the depth in which they were measured. Higher average velocities were found in the more shallow depths. The highest average velocity was 0.76 meters per second (See Figure 6-6).

The velocity measurement at the existing bridge was made at only one point. The flow velocity variation was measured through a depth of 4.73 meters. The maximum velocity of 1.25 meters per second was recorded at the surface. At the bottom the velocity reduced to 0.45 meters per second (See Figure 6-7). This is comparable to the average flow velocities found at the Boulevard Saint Michel site. All of these velocity measurements indicate that the erosion of the lagoon channel is continuing.

The velocity measurements at both sites were made approximately one hour before or after the low tide. The velocities therefore were close to the maximum ones that exist at low tide. However, it is probable that during a peak flood the flow velocities in the lagoon would be even greater.

[1] Office de la Recherche Scientifique et Technique Outre-Mer

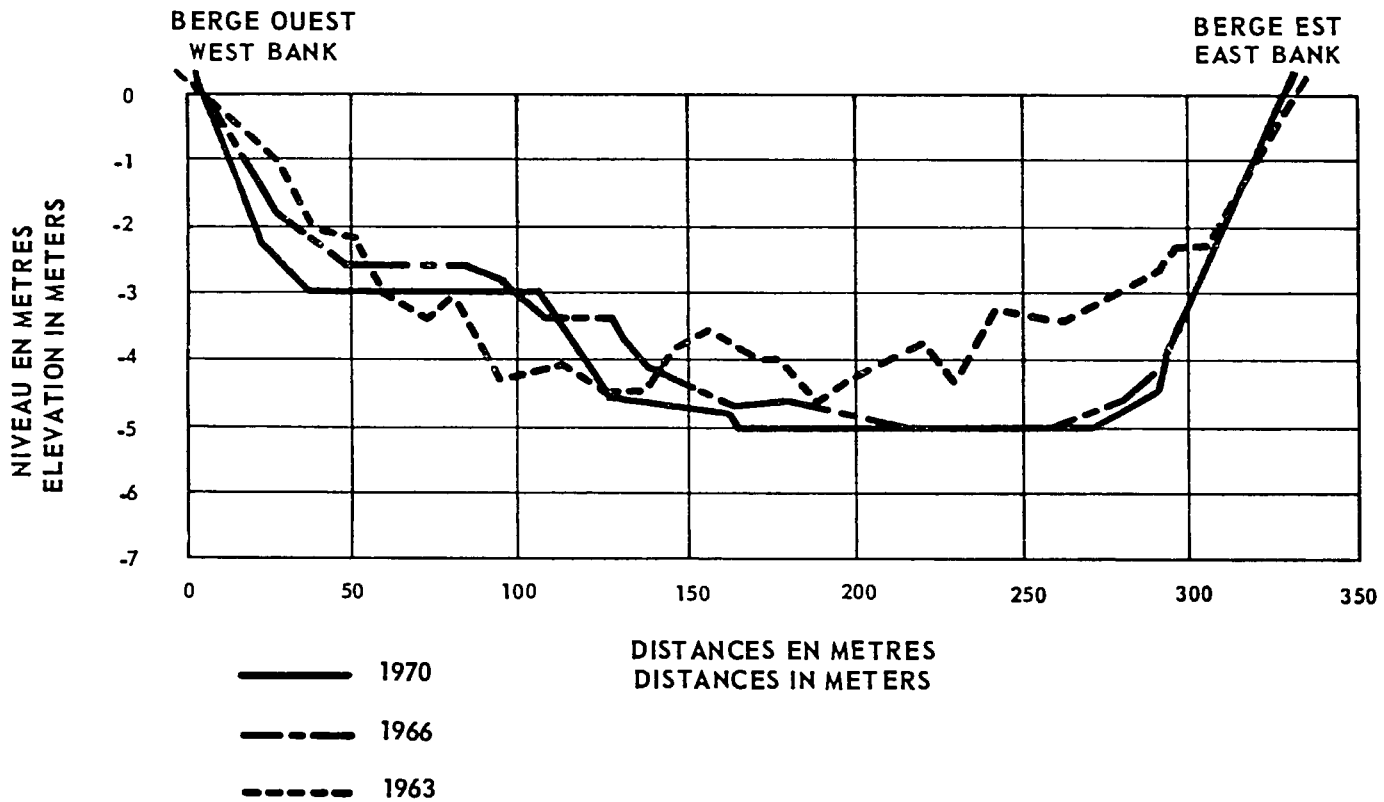
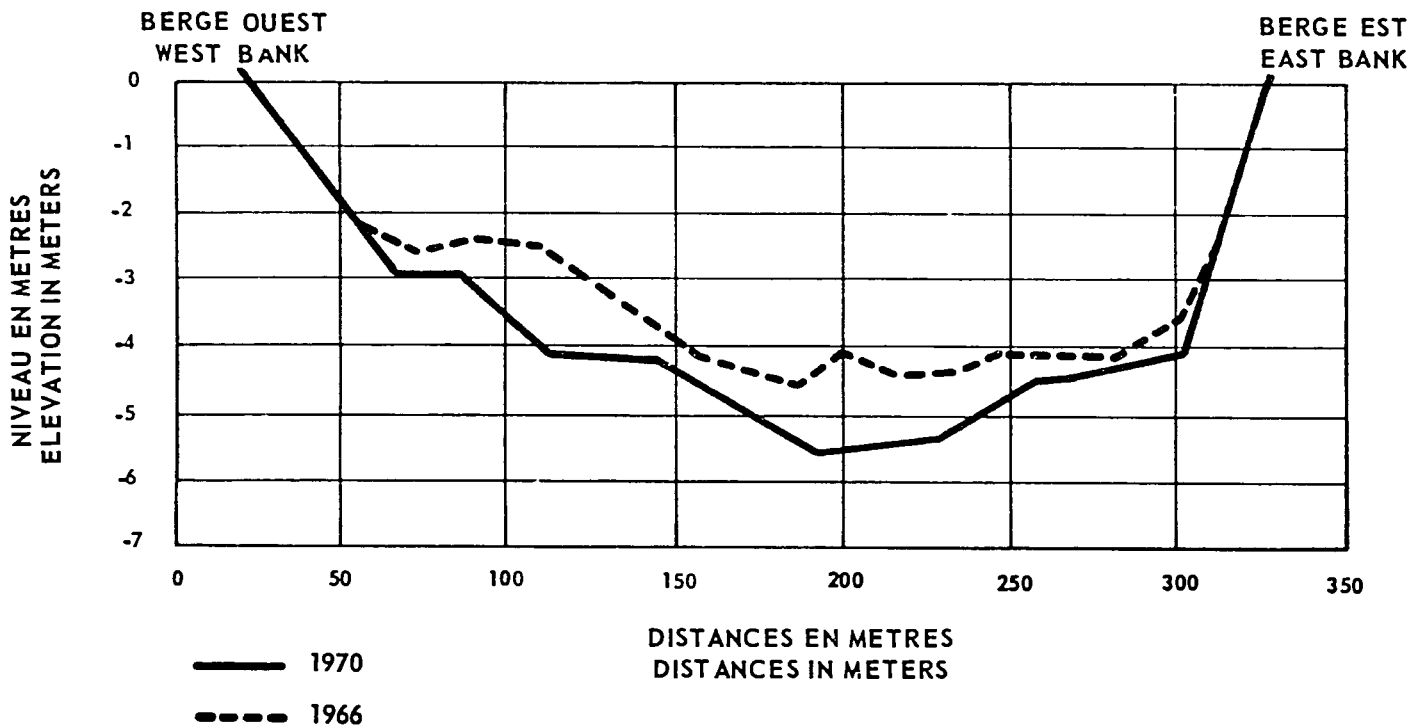


FIG. 6-5

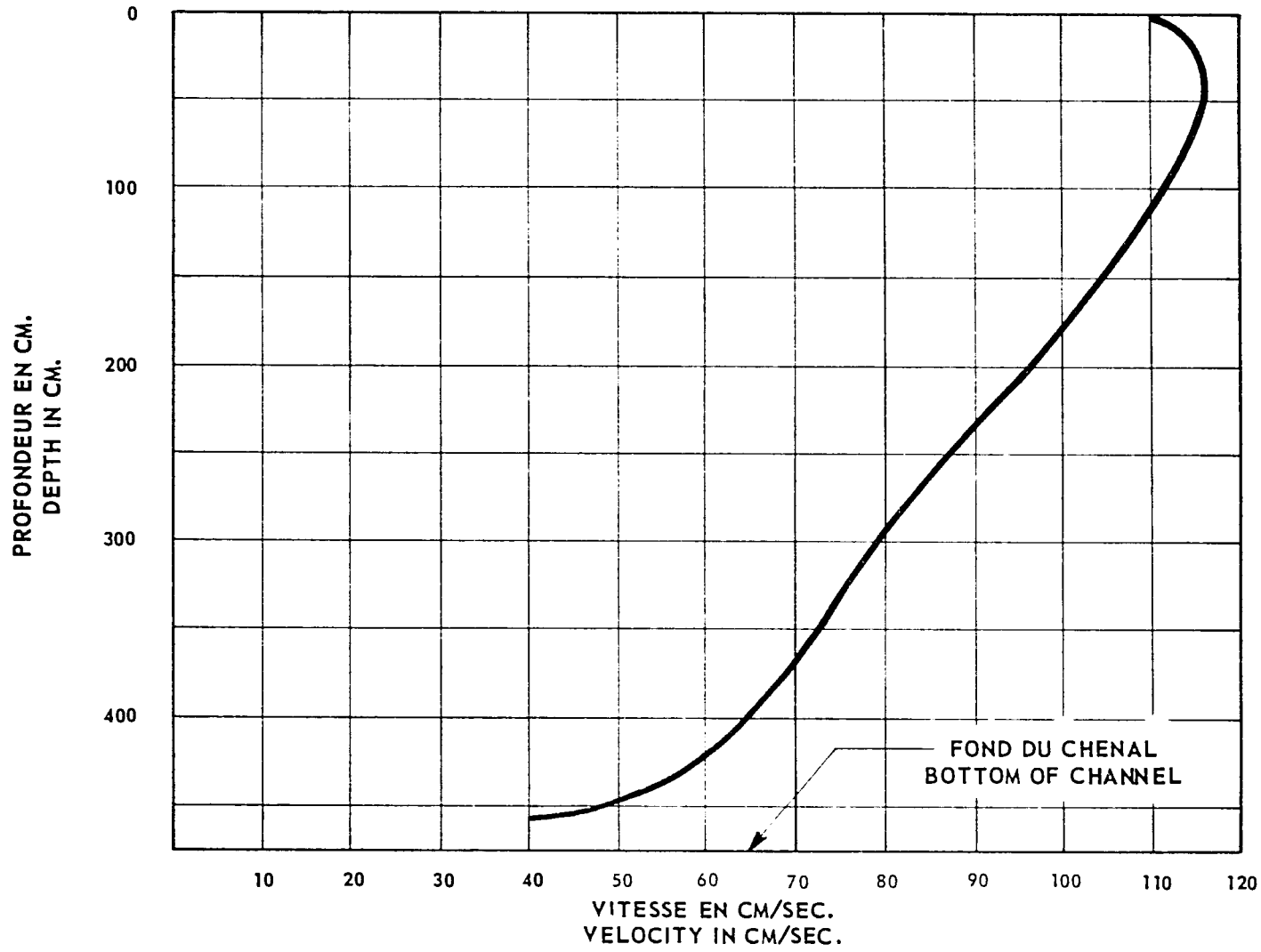
PROFIL À TRAVERS NO. 5 (BLVD. SAINT MICHEL)
CROSS SECTION NO. 5 (ST. MICHEL BLVD.)



PROFIL À TRAVERS NO. 6
CROSS SECTION NO. 6

SANDERS & THOMAS INC.

FIG. 6-6



VITESSE DE DEBIT AU PONT ACTUEL (NOV. 1970)
WATER VELOCITY AT EXISTING BRIDGE (NOV. 1970)

FIG. 6-7

D. ESTUARIAL CHARACTERISTICS OF THE COTONOU LAGOON

1. Physical and Hydraulic Characteristics

The Cotonou Lagoon is approximately 4 kilometers long and, on the average, 300 to 350 meters wide. It connects Lake Nokoue to the Atlantic Ocean and forms part of a system of lagoons through which the Oueme and So Rivers flow to the ocean. The Oueme River, the largest one in Dahomey, reaches the Atlantic Ocean through two channels. The first channel, known as the lagoon of Porto-Novo, is the longest one and extends for approximately 100 kilometers eastward to Lagos, Nigeria. The second channel, extends westward for approximately 20 kilometers and consists of two portions. The first portion is Lake Nokoue itself, and the second portion is the Cotonou Lagoon (See Figure 6-8). The So River flows southward, first through Lake Nokoue and then through the Cotonou Lagoon. Oueme and So, although being two separate rivers, share a common flood plain. During the flood season, they overflow their channels and submerge a huge area which at times is larger than Lake Nokoue itself.

In the past, prior to the construction of the Port of Cotonou, the Cotonou Lagoon was periodically closed by the action of the littoral drift which would create a sand bar and completely block the lagoon. During a flood, with the Cotonou Lagoon closed, all of the flow passed through the Porto-Novo Lagoon. As the Lake Nokoue level rose and the flood force increased, the sand bar would burst open and the Cotonou Lagoon would share part of the total flood flow. After the construction of the Port of Cotonou the lagoon became permanently open. As the erosion began to deepen the lagoon channel, the Cotonou Lagoon's share of the total flood flow increased. Thus, the hydraulic regime of the area changed. The effects of this change are discussed in the subsections that follow.

2. The Tidal Effects in the Lagoon

The deepening of the lagoon channel resulted in increased tidal inflow. The evidence of this is shown through the increased amplitude of the tides in various reaches of the Cotonou Lagoon. The measurements performed in 1963 by BCEOM show that the tidal amplitude in the lagoon has increased almost four times as compared to the amplitude that was measured in the years prior to the permanent opening of the lagoon.[5] The tidal amplitude is directly related to the volume of tidal inflow and is therefore also related to salinity.

In the past, when the lagoon was open, its mouth was relatively small. It never had a chance to increase to a large size because the action of the littoral drift would soon close it completely. Consequently, the effects of tidal amplitude in the lagoon were rather small. After 1959, when the port jetty deflected the action of the littoral drift,

[5] SOGREAH, Grenoble, Etude Theorique Preliminaire du Regime Hydraulique de Chenal de Cotonou et du Lac Nokoue. (1963)

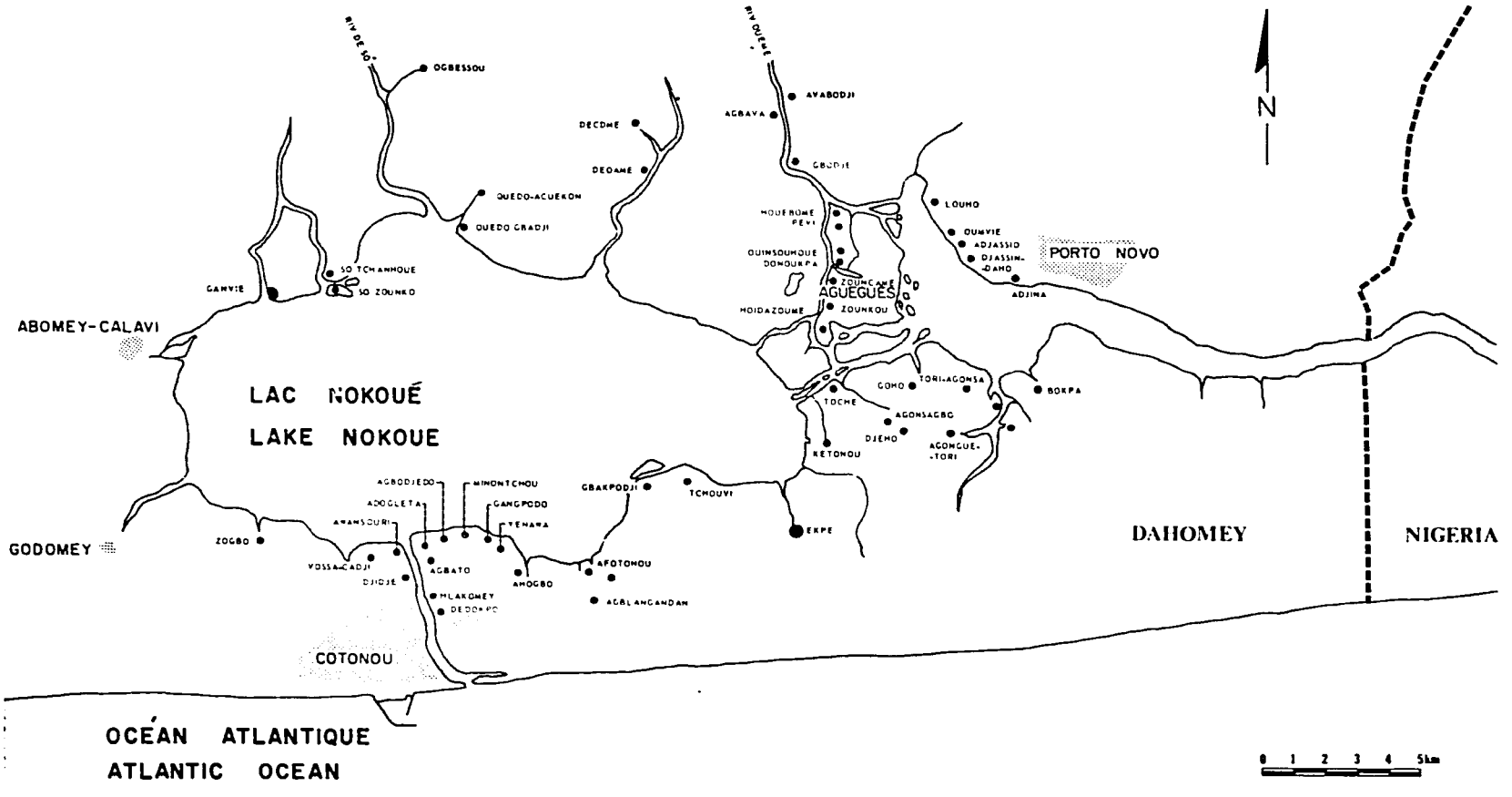

RIV DE SO
OGBESSOU
DEDOME
DEOAME
QUEDO-ACUEKON
QUEDO GRADJI
SO TCHANHOUE
SO ZOUNKO
GANVIE
ABOMEY-CALAVI
LAC NOKOUÉ
LAKE NOKOUE
GODOMEY
ZOGBO
AGBODJEDO
MINONTCHOU
ADOCLETA
GANGPODO
AHANSOURI
TENAWA
VOSSA-CADJI
DJIDJE
AGBATO
MLAKOMEY
DEDOKPO
AMOGBO
AFOTOHOU
ADBLANGANDAN
GBAKPODJI
TCHOUVI
COTONOU
OCÉAN ATLANTIQUE
ATLANTIC OCEAN
RIV OUÉMÉ
AVABODJI
AGBAVA
GBODJE
HOUEBOME PEVI
QUINSOUHOUE DONOUKPA
ZOUNCAME
AGUEGUES
ZOUNKOU
HOIDAZOUME
LOUHO
OUMVIE
ADJASSIO
DJASSIN-DAMO
ADJINA
PORTO NOVO
GOMO
TORI-AGONSA
BOKPA
TOCHE
AGONSAGBO
DJEMO
AGONGUE-TORI
KETONOU
EKPE
DAHOMEY
NIGERIA
N
0 1 2 3 4 5km

FIG. 6-8

133A

the lagoon mouth became permanently open. In the following years, as the opening continued to increase in size due to erosion, the tidal effects in the lagoon also increased.

The increased tidal inflow has brought with it increased periods of salinity in Lake Nokoue. The tidal inflow has also had a profound effect on the channel erosion. This is evidenced by considerably increased depths of the channel near the lagoon mouth.[6]

The erosion and the salinity penetration due to tidal inflow can best be understood by considering the action of density currents in a typical estuary.

3. Density Currents

Density currents are caused when waters with differing densities begin to mix. This occurs in estuaries where sea water and fresh water mix during high and low tides. At high tide the sea penetrates into the estuary due to a difference in both the static and velocity pressures. As the sea water progresses into the estuary, the difference in pressure and density causes circulatory motion in the vertical sense. The sea water has higher density and tends to drop to the bottom of the channel. Thus, a salinity wedge is formed. As the sea water continues to move into the fresh water region, the difference in pressures and density diminishes gradually. Eventually a point of equilibrium is reached. This point is defined as the "nul" point. During the low tide the reverse process takes place, and the salinity wedge retreats towards the sea.

The distance of sea water penetration depends on many factors. The most important ones are (a) the average difference between the fresh water level and that of the high tide, and (b) the width and depth of the mouth of the estuary.

In the Cotonou Lagoon, two situations exist presently, each developing different density currents and having different nul points:

a. Low Tide - (sea water level is lower than the lagoon level):

In this case the main flow is towards the sea. The fresh water is on top and little conflict exists in areas of tidal mixing. Therefore, circulatory flow is slight. The salt water edge is retreating towards the sea with the help of low tide and the pressure from the increasing flow of fresh water towards the sea.

b. High Tide - (sea water level is higher than the lagoon level):

In this case the sea water initially is at the top, but due to its greater density slowly moves towards the bottom. Thus, a salt water wedge begins to form and progresses towards Lake Nokoue. The greatest amount of circulatory motion occurs at the mouth of the lagoon where the largest difference in pressures exists. It is here, therefore, that most of the erosion is produced.

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[6] BCEOM. Rapport (1966) - Ouvrage de Regularisation et de Franchissement du Debouche Lagunaire de Cotonou, Annexe I, Lever Hydrographique du Debouche en Mer.

Prior to 1959, the nul point of the density current was probably somewhere near the middle of Lake Nokoue. It was only during the dry season when the flow of the Oueme and So rivers was rather low, that the salinity wedge probably penetrated as far as the Porto-Novo Lagoon. Today, however, the tidal inflow is much larger. The nul point therefore must be much farther in the lake. The salinity levels also tend to be higher in most areas of the lake and remain high for longer periods of time.

4. Effect of the Proposed Dam on Tidal Inflow and Density Currents

The proposed dam should greatly reduce the tidal flow in the lagoon. The top of the dam weir will be at an elevation slightly above that of the normal lagoon waters. Thus, a large outflow to the sea will occur only during the flood season when the lagoon level will exceed that of the weir. The tidal inflow will occur only during the high tides and then only during the time that the elevation of tide exceeds that of the weir.

Due to the variation of tidal amplitudes during the year, the total amount of sea water penetrating the lagoon will vary and will depend on the length of time that the high tide remains above the top of the weir. The volume of tidal inflow after the construction of the dam is discussed in more detail in subsection E.

Since the dam will cut off a great proportion of the tidal inflow, it is logical to expect that the salinity wedge will remain in the lagoon and that it will never penetrate beyond Agbato.

The circulatory movement on the upstream side of the dam (north side) will be slight and no erosion is expected to result there. On the downstream side, however, during the flood season, sizable energies are expected to be generated at low tide. For this reason it is recommended that protective measures be taken to dissipate the energy of the water flowing over the weir in order to prevent the undermining of the dam.

E. HYDRAULIC REGIME OF LAKE NOKOUE

1. Maximum Lake Levels During Flood Season

Before the permanent opening of the Cotonou Lagoon, the highest level in Lake Nokoue (recorded during the flood of October, 1952) was 2.20 meters (Hydraulic Zero Datum)*. After the opening, the highest level (recorded during the flood of September, 1968) was 1.93 meters. Besides the elevation of the lake during the floods, it would have been very useful to know the combined total volume of flow of the rivers Oueme and So, which flow through the lake. However, due to the fact that these rivers overflow their channels in the flood stage and form a huge flood delta, it was impossible to make any kind of field measurements of flow during a flood. The best available records made

* Hydraulic Zero Datum is defined as the lowest elevation attained by the lowest tide ever registered by the sea gauge located at the old wharf of Cotonou.

B5

at various measuring stations along the Oueme and the So indicate that the total combined flow should not exceed 1500 cubic meters per second.

One fact that has been well determined, however, is that conditions in the mouth of the Cotonou Lagoon have a strong influence on the lake level. When the lagoon was closed, in the years prior to 1959, the lake level would rise very high and all the flow would be forced through the Porto-Novo Lagoon. When the Cotonou Lagoon became permanently opened, the flow was shared by both lagoons and consequently the lake level was lower.

With the proposed dam, the level of Lake Nokoue during the flood season will be somewhat higher than under present conditions. The weir of the proposed dam, therefore, will need to be designed in such a way as not to create an excessively high lake level and, as a result, flood the City of Cotonou.

2. Effect of Closure of the Cotonou Lagoon on Lake Nokoue and Porto Novo Lagoons

The Oueme and So rivers discharge their waters into Lake Nokoue during the flood season, and the lake behaves as a reservoir which continues to fill and rise in level until the flow into the lake begins to be exceeded by the flow out through the lagoons of Porto-Novo and Cotonou. When the Cotonou Lagoon was closed, the level of the lake would rise much higher than when it was open. With both lagoons open, the flow into the lake was exceeded much sooner by the flow out because there were two lagoons available for the flood to escape to the ocean.

ORSTOM has measured the sea and lake levels during 1952 and has related them by means of a graph. The ORSTOM graph, replotted on the Hydraulic Zero Datum, is shown in Figure 6-9. The graph shows the following:

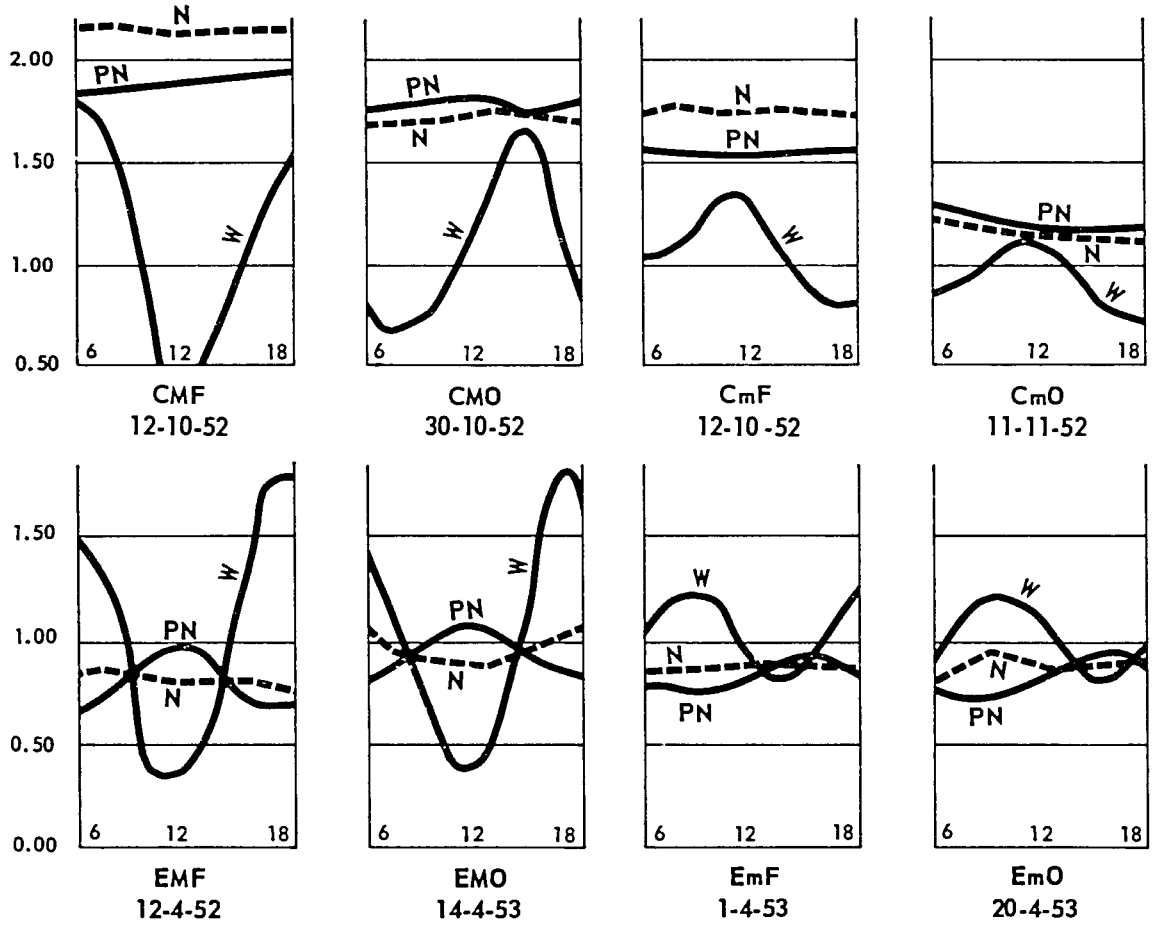
a. With Cotonou Lagoon closed (October 25, 1952): The highest level is at the Cotonou bridge. The level at the Porto-Novo Lagoon is lower, but quite high.

b. With Cotonou Lagoon open (October 30, 1952 - only five days later): The levels of both the Cotonou and Porto-Novo Lagoons is almost the same, but both are lower than in (a).

In case (a) the level of Lake Nokoue was probably slightly lower than that at the Cotonou bridge. In case (b) the level of the lake was probably slightly higher than that in both lagoons.

3. Flow Relationship Between the Cotonou and Porto-Novo Lagoons

The manner in which the two lagoons share the total flow of the Oueme and So Rivers has



LEGENDE
LEGEND

C	Crue Maximum flow
E	Etiage Minimum flow
M	Grande Marée High tide
m	Petite marée Low tide
F	Lagune fermeé Lagoon closed
O	Lagune ouverte Lagoon open
N	Lac Nokoué Lake Nokoue
PN	Lagune de Porto Novo Lagoon of Porto Novo
W	Marégraphe de wharf Sea Gauge at wharf

NIVEAUX DE LOCEAN, LAC NOKOUE ET LAGUNE DE PORTO NOVO EN FONCTION DE OUVERTURE OU FERMETURE DE LA LAGUNE DE COTONOU

LEVELS OF: OCEAN, LAKE NOKOUE, & PORTO NOVO LAGOON AS FUNCTION OF THE OPENING OR CLOSURE OF COTONOU LAGOON

been determined by field measurements and their relationship has been calculated and shown in a graphical form by SOGREAH in their report.[8] This graph has been modified in this report by the addition of the flow conditions that will exist when the dam proposed by Sanders and Thomas, Inc. is constructed (See Figure 6-10). Curves have been calculated for different elevations of the dam weir to determine the maximum backwater levels in the Cotonou Lagoon and also the resulting maximum levels of Lake Nokoue. Thus, for example, from Figure 6-10 it is seen that for a maximum expected discharge of 1500 cubic meters per second approximately 575 m^3/s will flow through the Cotonou Lagoon, 925 m^3/s will flow through the Porto-Novo Lagoon and the elevation of Lake Nokoue will be +1.97 meters.

It is generally considered that the level of +2.00 meters is the highest acceptable level before the city of Cotonou begins to be flooded. Most of the presently settled areas of the city are above that level. However, in the northern sections near Lake Nokoue there are many areas whose elevation is below the +2.00 meters level. These areas will continue to be flooded as the back water level approaches +2.00 meters.

In general, the +2.00 meter level will be reached only in extreme floods. The maximum total volume of flood waters will rarely reach 1500 cubic meters per second; therefore, the lake level should never exceed an elevation of approximately +1.90 meters (assuming a total volume of 1400 m^3/s).

4. Effect of Cotonou Lagoon on Outflow Currents in Lake Nokoue

The records of salinity in Lake Nokoue, prior to the permanent opening of the Cotonou Lagoon in 1959, shows that high salinity existed in certain areas of the Lake during the flood season while the lagoon was closed. With the lagoon closed, it would be logical to expect that the flood waters of the Oueme River would dilute and wash away any salinity that may have penetrated the lake while the Cotonou Lagoon was open. This seemingly contradictory situation needed an explanation. It was therefore essential to compare and analyze all available data on salinity, floods, openings, and closures of the lagoon in order to arrive, if possible, at a logical conclusion relative to what was happening in Lake Nokoue. The answer was provided by consideration of the outflow currents of the two rivers, the Oueme and the So through the lake.

The available salinity records for the years 1957 and 1958 (see Figure 6-11) have provided a good comparison between salinity trends in Lake Nokoue and the Cotonou Lagoon during the period of change from an open to a closed lagoon by action of the littoral drift. This is shown in Figures 6-12 through 6-16. In each, the approximate contours of salinity have been plotted as indicated by the available records for six locations: one in the Cotonou Lagoon, one in the Porto-Novo Lagoon and four in various parts of Lake Nokoue.

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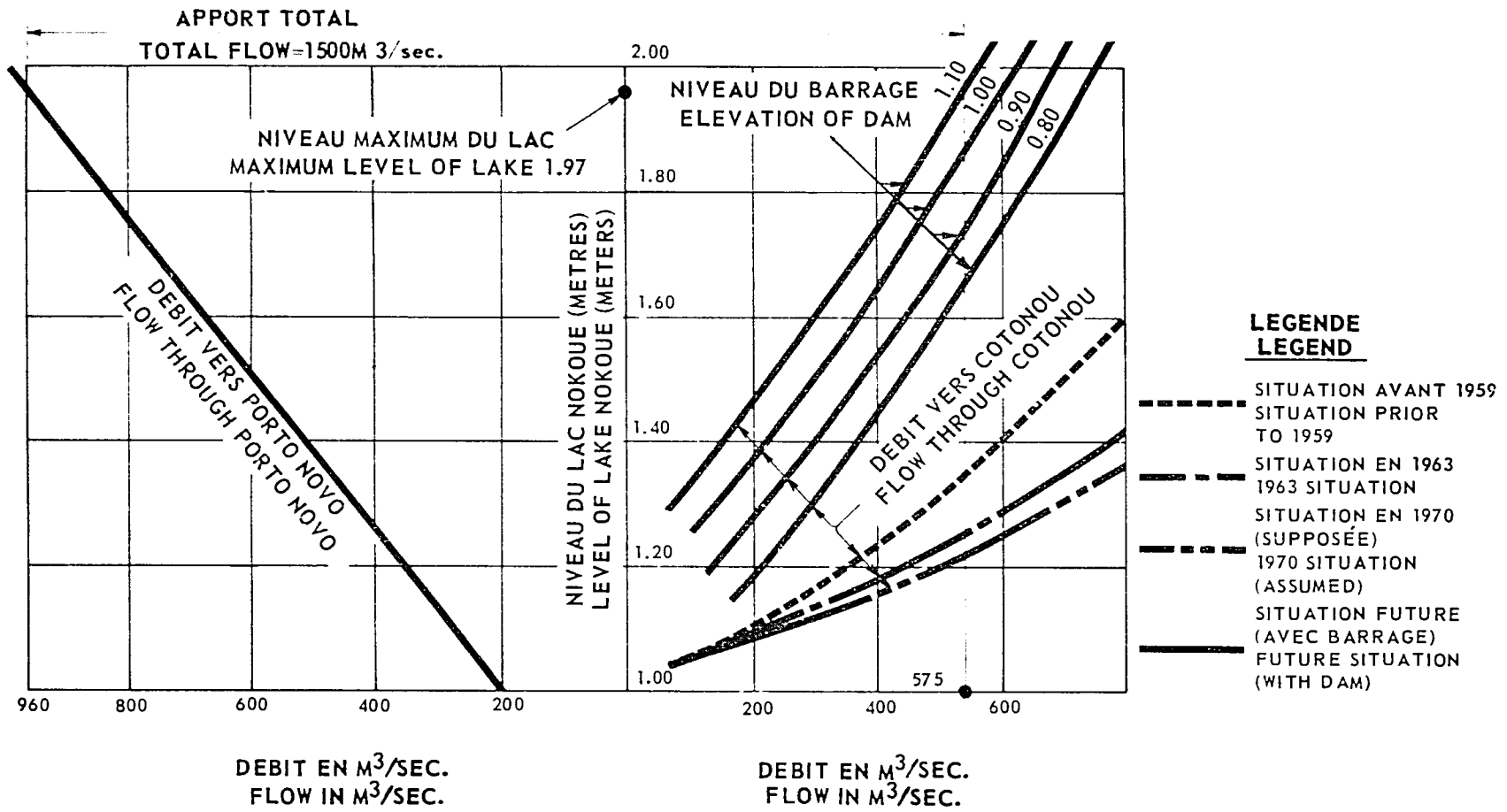
[8] SOGREAH, Grenoble - Etude Theorique Preliminaire du Regime Hydraulique du Chenal de Cotonou et du Lac Nokoue. (1963)

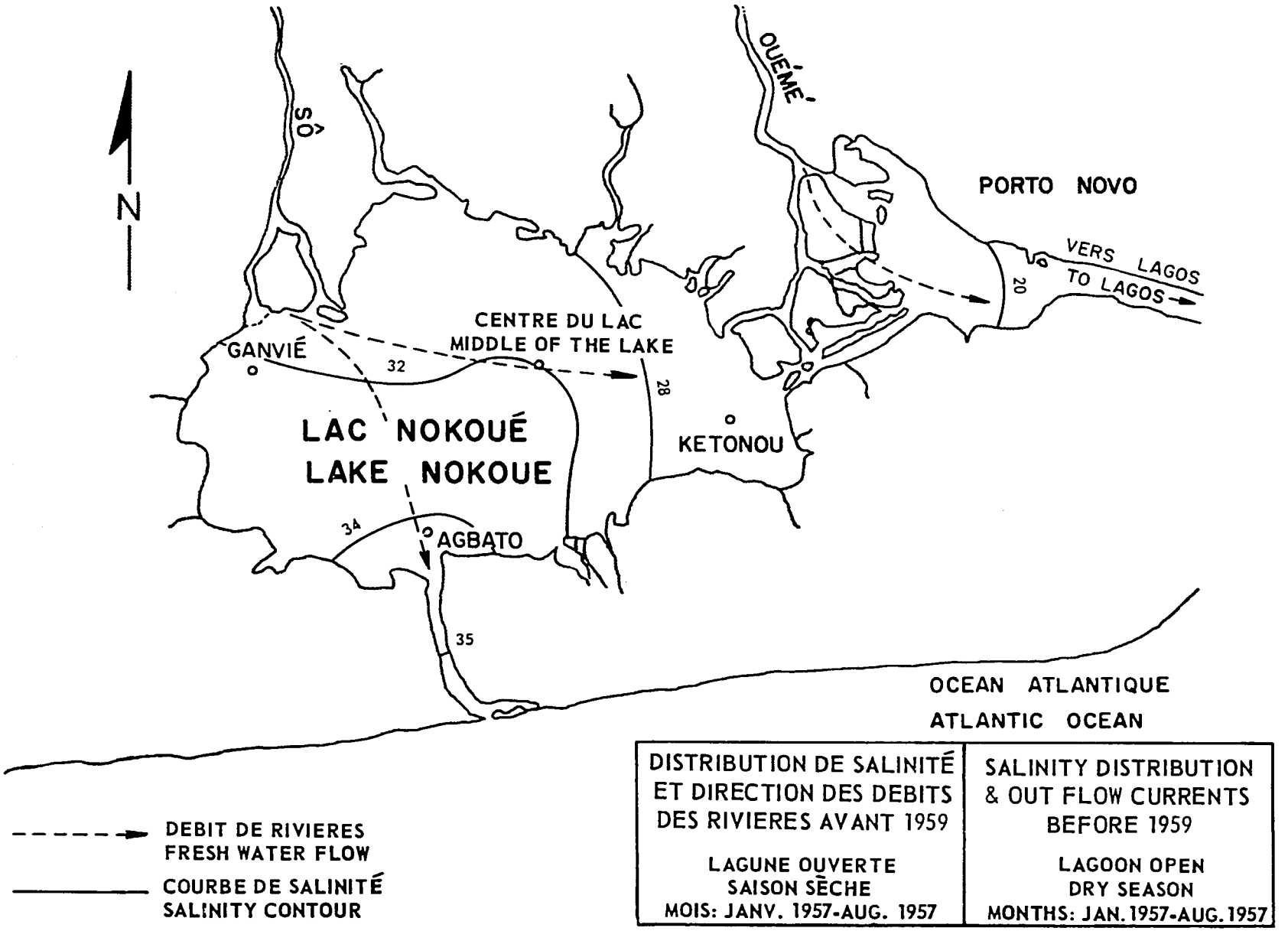
FIG. 6-10



DEBITS VERS COTONOU ET PORTO NOVO
EN FONCTION DU NIVEAU DE BARRAGE

FLOWS THROUGH COTONOU AND PORTO NOVO
BASED ON DIFFERENT HEIGHTS OF DAM

SANDERS & THOMAS INC.



DISTRIBUTION DE SALINITÉ ET DIRECTION DES DEBITS DES RIVIERES AVANT 1959	SALINITY DISTRIBUTION & OUT FLOW CURRENTS BEFORE 1959
LAGUNE OUVERTE SAISON SÈCHE MOIS: JANV. 1957-AUG. 1957	LAGOON OPEN DRY SEASON MONTHS: JAN. 1957-AUG. 1957

SANDERS & THOMAS INC.

FIG. 6-12

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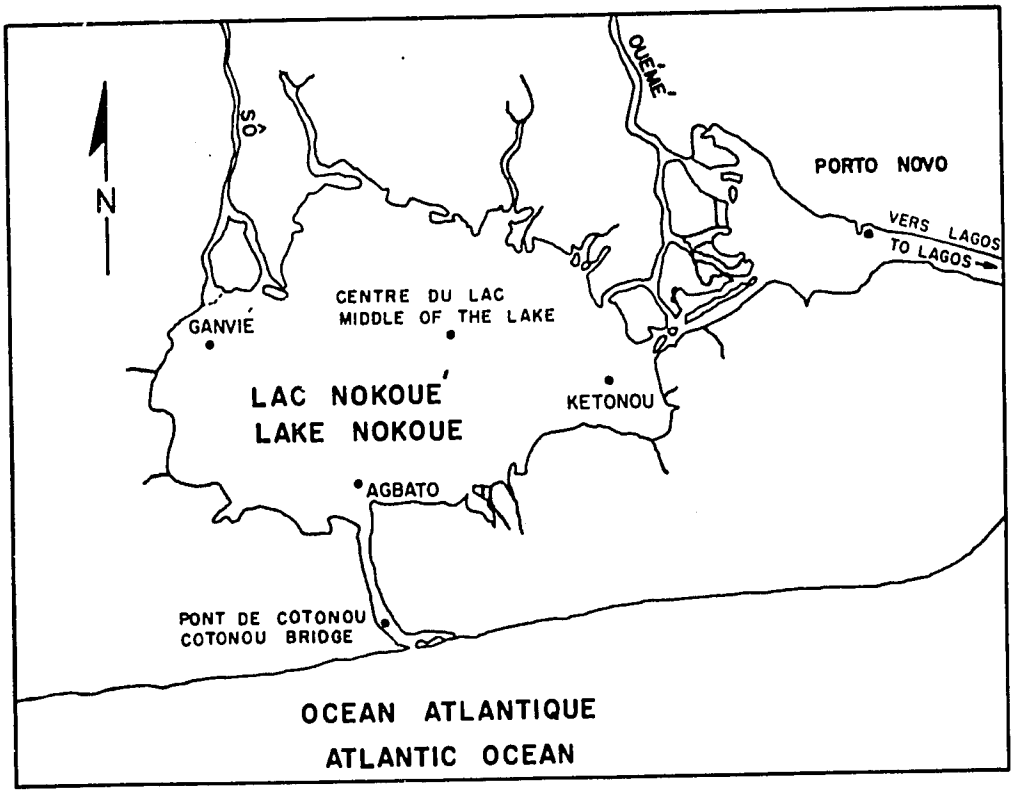
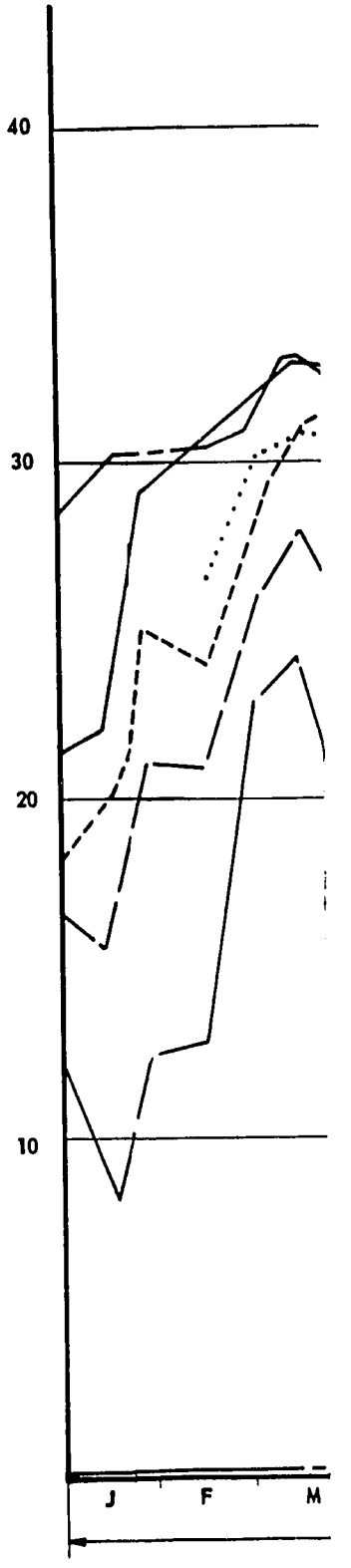
SANDERS & THOMAS INC.

PORTO NOVO
CENTRE DU LAC–MIDDLE OF LAKE
GANVIÉ
KETONOU
PONT DE COTONOU – COTONOU BRIDGE
AGBATO





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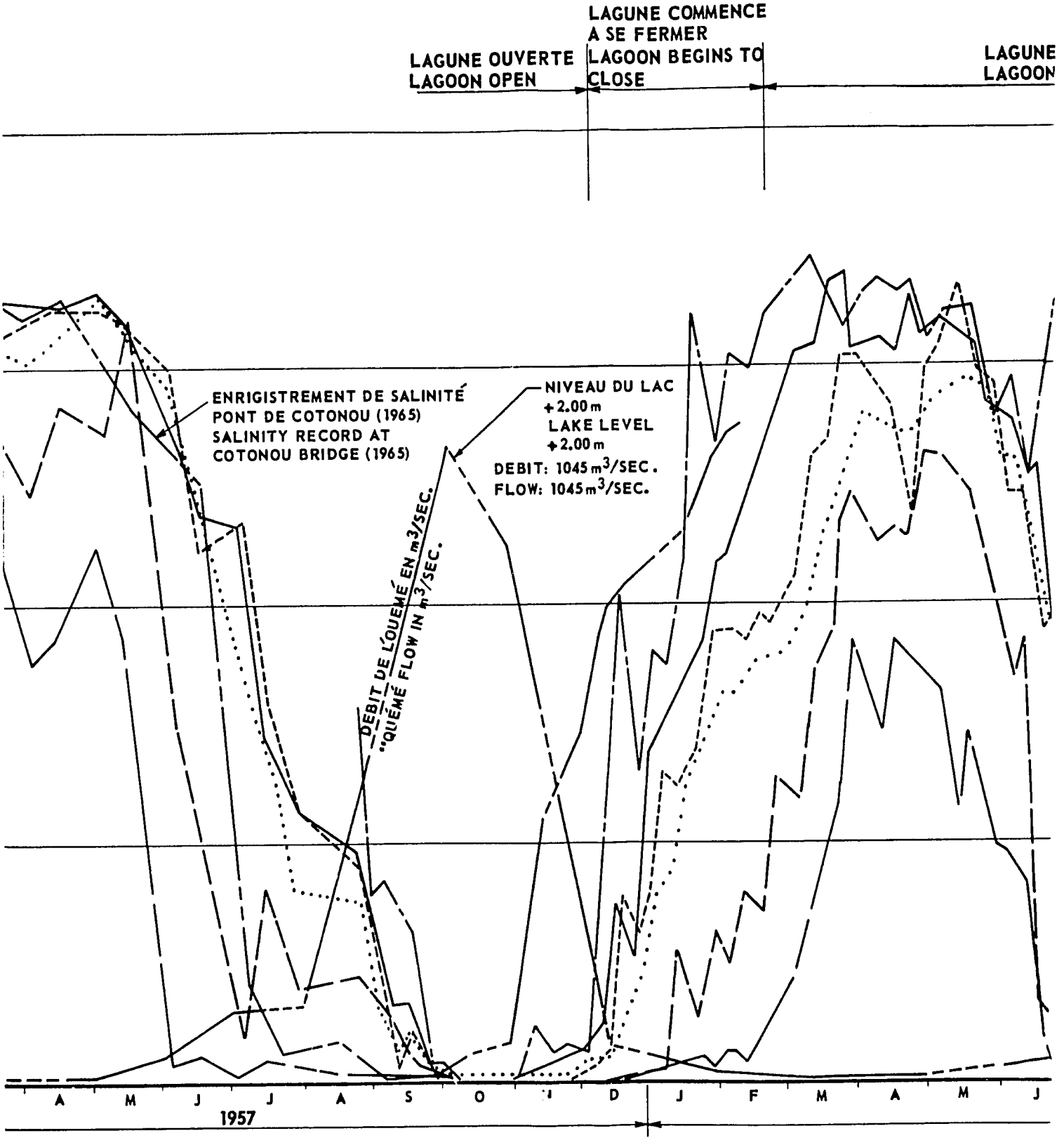
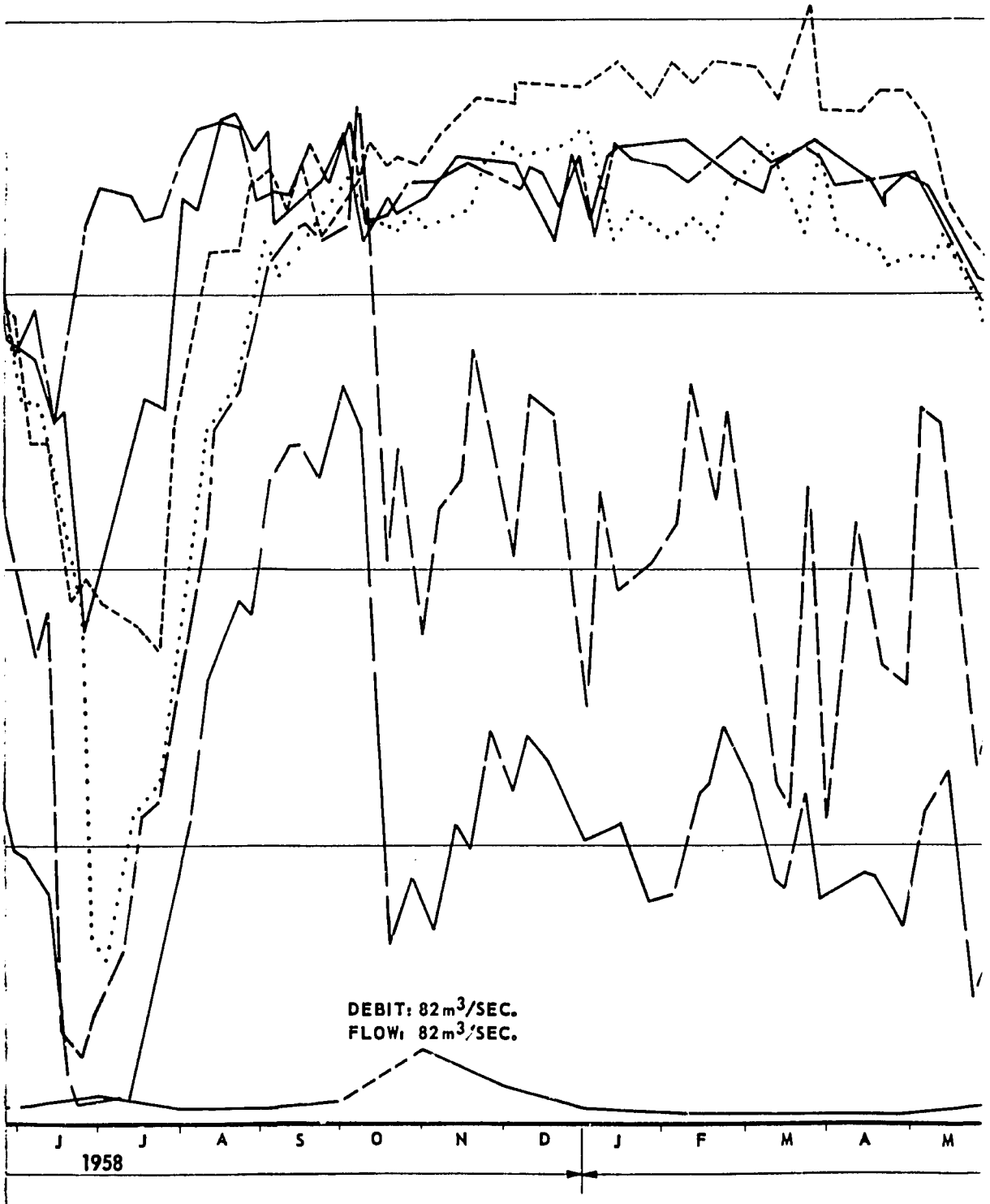


DEBIT ET ENREGISTREMENTS DE SALI
DISCHARGE AND SALINITY RECORDS

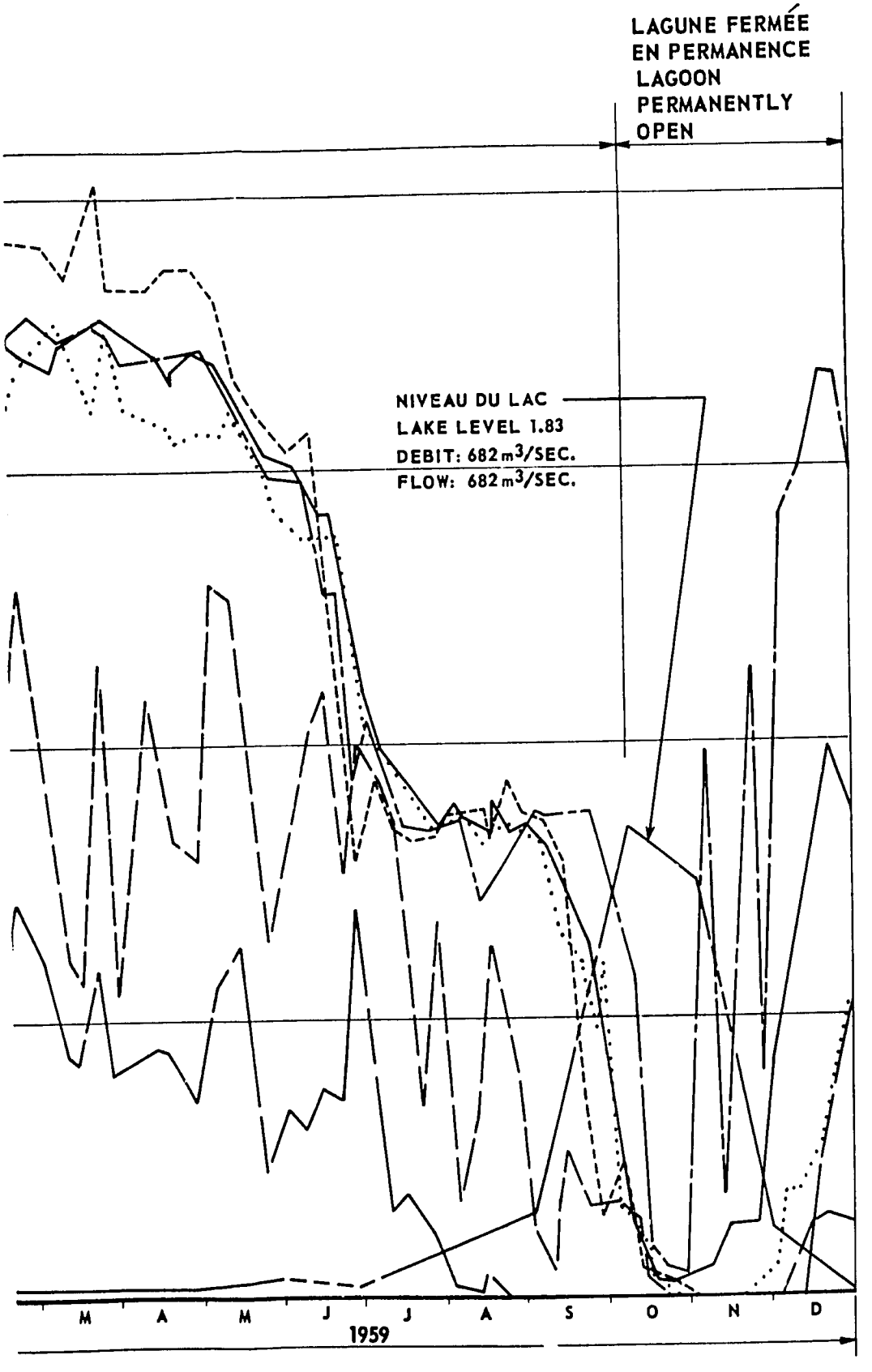
1402

LAGUNE FERMÉE
LAGOON CLOSED



E SALINITÉ
CORDS

14DC


LAGUNE FERMÉE
EN PERMANENCE
LAGOON
PERMANENTLY
OPEN
NIVEAU DU LAC
LAKE LEVEL 1.83
DEBIT: 682 m3/SEC.
FLOW: 682 m3/SEC.
M
A
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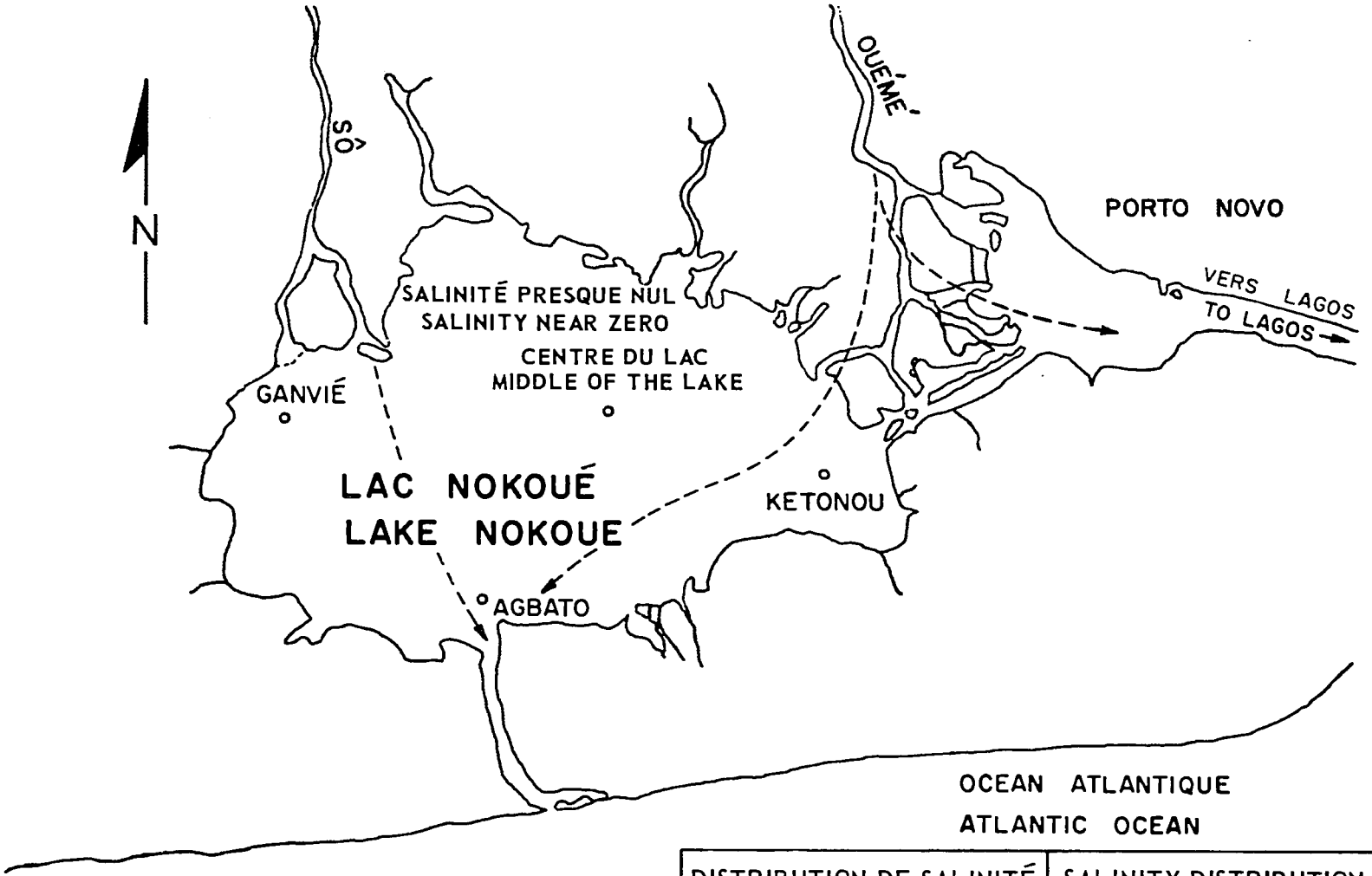
1959

FIG. 6-11

140d

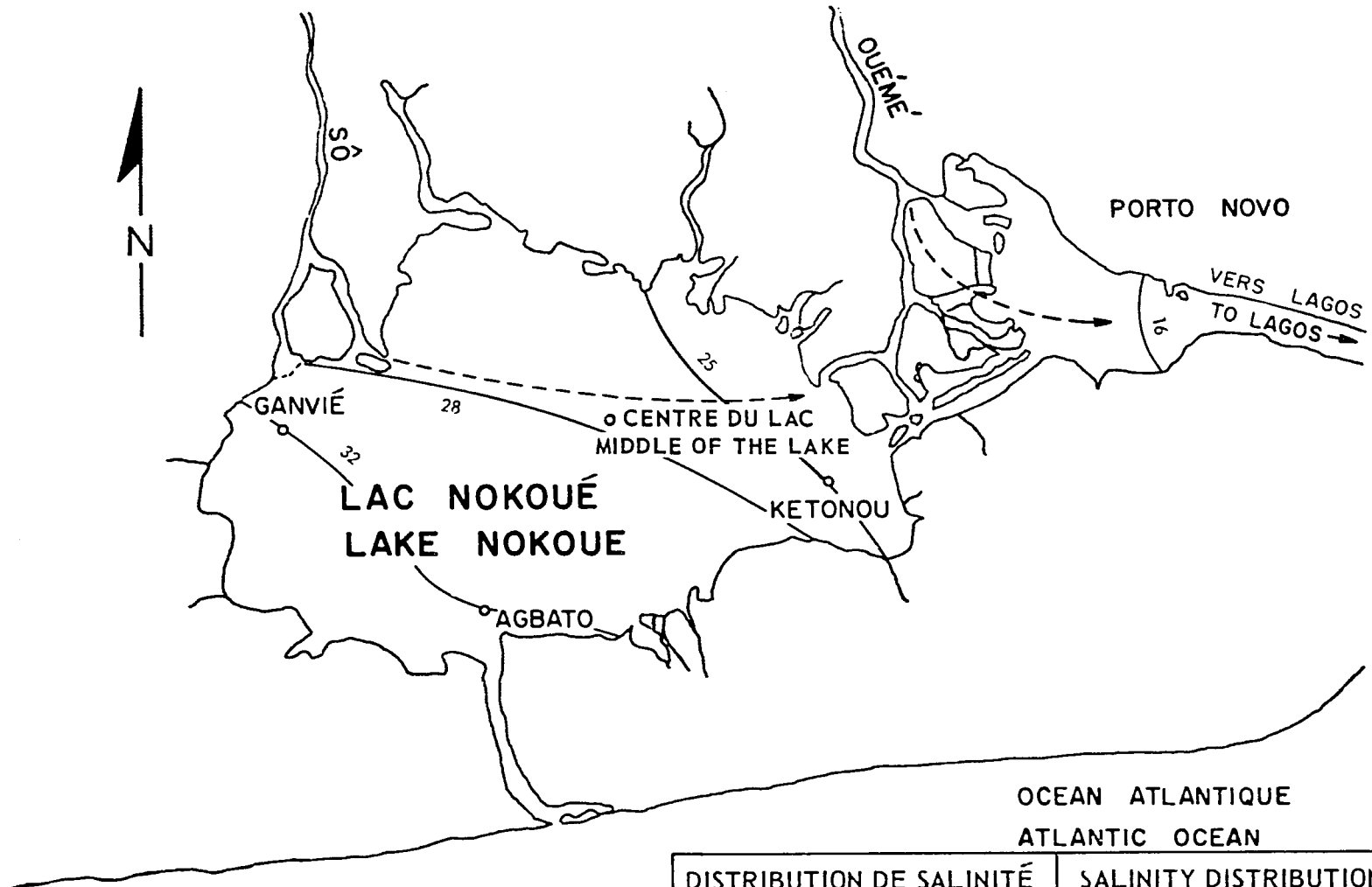


DISTRIBUTION DE SALINITÉ ET DIRECTION DES DEBITS DES RIVIERES AVANT 1959 LAGUNE OUVERTE SAISON DES PLUIES MOIS: SEPT. 1957-NOV. 1957	SALINITY DISTRIBUTION & OUT FLOW CURRENTS BEFORE 1959 LAGOON OPEN WET SEASON MONTHS: SEPT. 1957-NOV. 1957

DEBIT DE RIVIERES
FRESH WATER FLOW

FIG. 6-13

SANDERS & THOMAS INC.



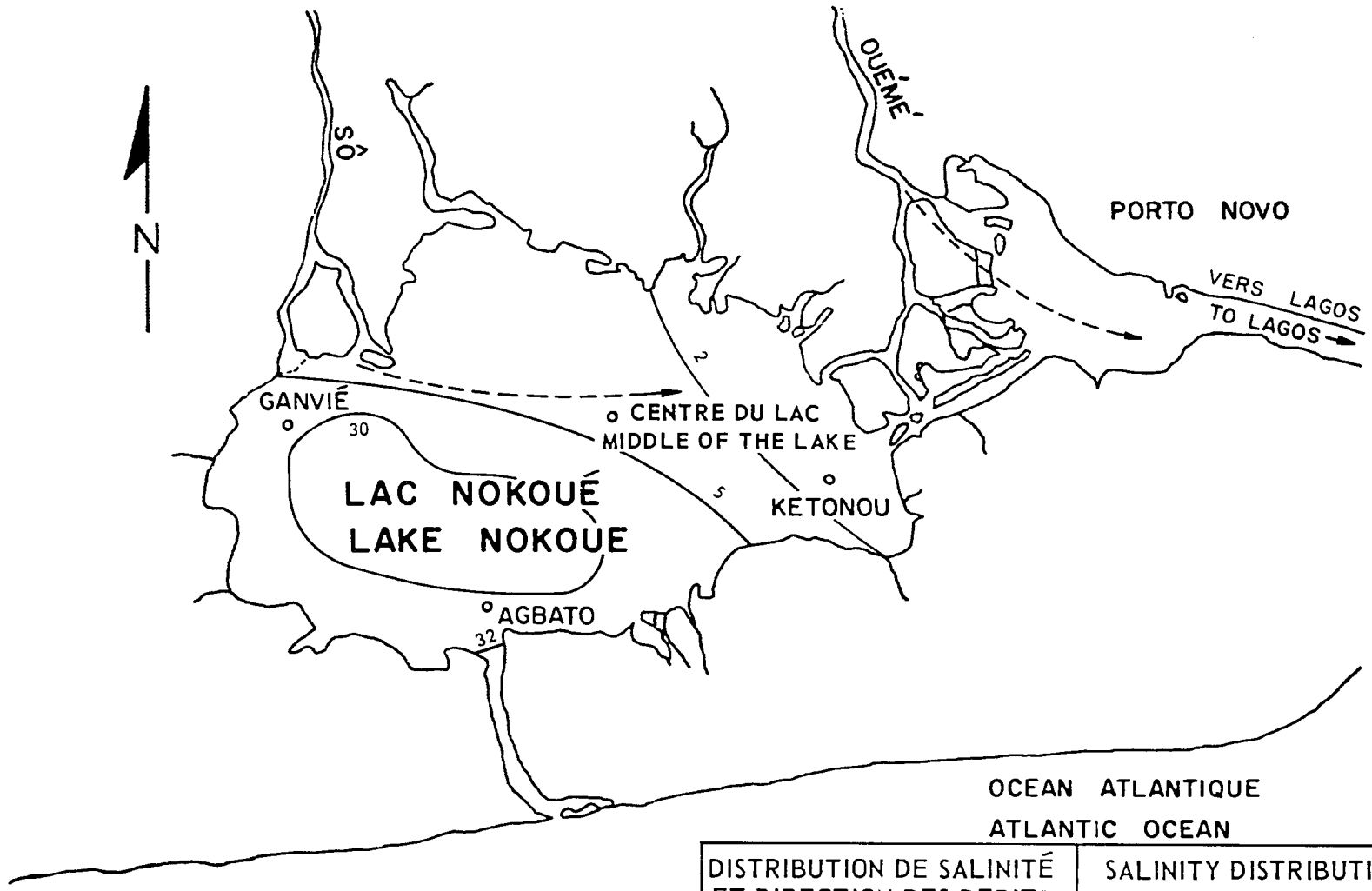
DEBIT DE RIVIERES
FRESH WATER FLOW

COURBE DE SALINITÉ
SALINITY CONTOUR

DISTRIBUTION DE SALINITÉ ET DIRECTION DES DEBITS DES RIVIERES AVANT 1959	SALINITY DISTRIBUTION & OUT FLOW CURRENTS BEFORE 1959
LAGUNE FERMÉE SAISON SÈCHE MOIS: DEC. 1957-FÉV. 1958	LAGOON CLOSED DRY SEASON MONTHS: DEC. 1957-FEB. 1958

FIG. 6-14

142



DEBIT DE RIVIERES
FRESH WATER FLOW

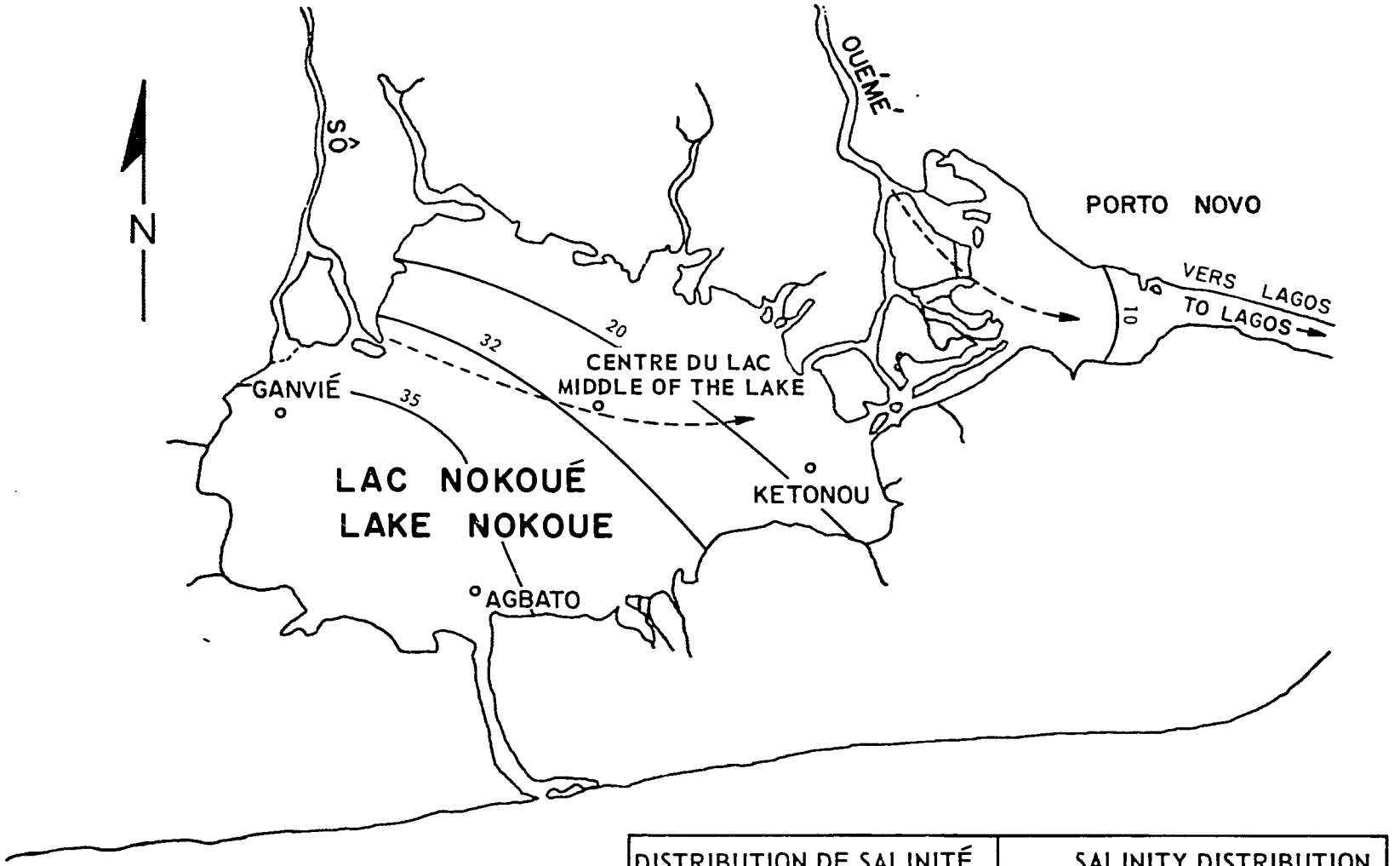
COURBE DE SALINITÉ
SALINITY CONTOUR

DISTRIBUTION DE SALINITÉ ET DIRECTION DES DEBITS DES RIVIERES AVANT 1959	SALINITY DISTRIBUTION & OUT FLOW CURRENTS BEFORE 1959
LAGUNE FERMÉE SAISON DES PLUIES MOIS: MARS. 1958-OCT. 1958	LAGOON CLOSED WET SEASON MARCH 1958-OCT 1958

FIG. 6-15

SANDERS & THOMAS INC.

142



DEBIT DE RIVIERES
FRESH WATER FLOW

COURBE DE SALINITÉ
SALINITY CONTOUR

DISTRIBUTION DE SALINITÉ ET DIRECTION DES DEBITS DES RIVIERES AVANT 1959 LAGUNE FERMÉE SAISON SÈCHE MOIS: NOV. 1958-AVRIL. 1959	SALINITY DISTRIBUTION & OUT FLOW CURRENTS BEFORE 1959 LAGOON CLOSED DRY SEASON MONTHS: NOV. 1958–APRIL 1959

FIG. 6-16

In Figure 6-12 the Cotonou Lagoon is open. Salinity contours show that the salinity decreases progressively from Agbato to Porto-Novo. The period of the year is generally the dry season, during which the rivers Oueme and So have minimum flow. Thus, we can see that most of the flow from both rivers would go towards Porto-Novo with possibly only a portion of the River So flowing towards the Cotonou Lagoon. (This is also shown by the graphs in Figure 6-11.) Thus, the diluting effect of the flow from the rivers made itself felt in the easterly direction only.

In Figure 6-13, the Cotonou Lagoon is open but the period is during the flood season. This time the recorded salinites in the entire Lake Nokoue were close to zero. The flow of the two rivers is large. Approximately 55% of the total flow goes towards Cotonou Lagoon and 45% towards Porto-Novo; thus, the salinity is completely diluted by the fresh water flow.

In Figure 6-14, the Cotonou Lagoon is closed. The period is mostly dry season. The salinities in Lake Nokoue are again high. They have been brought into the lake by the tidal inflow from December, 1957 to February, 1958, during the period when the lagoon was still open but began to slowly close under the action of the littoral drift. After March, 1958, the lagoon was totally closed. The flow of the So and the Oueme are again very low, and are directed entirely towards Porto-Novo. The region of highest salinity is in the western portion of the lake where there was little or no chance for dilution by the flow of the River So (See Figure 6-15).

In Figure 6-16, the Cotonou Lagoon is also closed but the period is from the beginning of the flood season in October of 1958 through the middle of the dry season in April, 1959. Figure 6-11 shows that during the flood months of October and November, 1958, hardly any flow was measured in the Cotonou Lagoon (only 82 m^3/s). This was due to the fact that the lake level was rising, the lagoon was closed, and the water from the lake was just filling up the lagoon. The entire lake was acting as a reservoir until the flow towards Porto-Novo began to prevail. Thus, once more the main direction of the flood waters was easterly while the western part of the Lake and the Cotonou Lagoon were almost stagnant.

The concept of Lake Nokoue outflow currents is important in order to arrive at the factors which influence the amount of salinity. These factors are:

(a) The size of the opening and the length of time that the Cotonou Lagoon remains open.

(b) The volume of flow from the Oueme and So Rivers.

(c) The direction of flow of the two rivers.

If there is moderate tidal inflow when the flow of the Oueme and the So is low (dry season), there will be little dilution; therefore the salinity will remain high. On the

other hand, when the tidal inflow is large and the volume of flow of the two rivers is also large, but is directed mainly towards Porto-Novo, the salinity again will be high. Therefore, the key item is the ratio of fresh water to salt water. In order to reduce salinity it is important to reduce drastically the tidal inflow so that at all times the ratio of fresh water to salt water is very high. The proposed dam does exactly that. As explained in the next subsection, the tidal inflow will be reduced by 90%. Thus, at all times (except in a very exceptional dry season), the salinity in Lake Nokoue should remain low.

5. Effect of the Proposed Dam on the Salinity in Lake Nokoue

The proposed dam reduces the tidal inflow by taking advantage of the following:

(a) Elimination of all tidal inflow during low tides.

(b) Elimination of all tidal inflow during high tides whose peak is lower than elevation +1.10 meters.

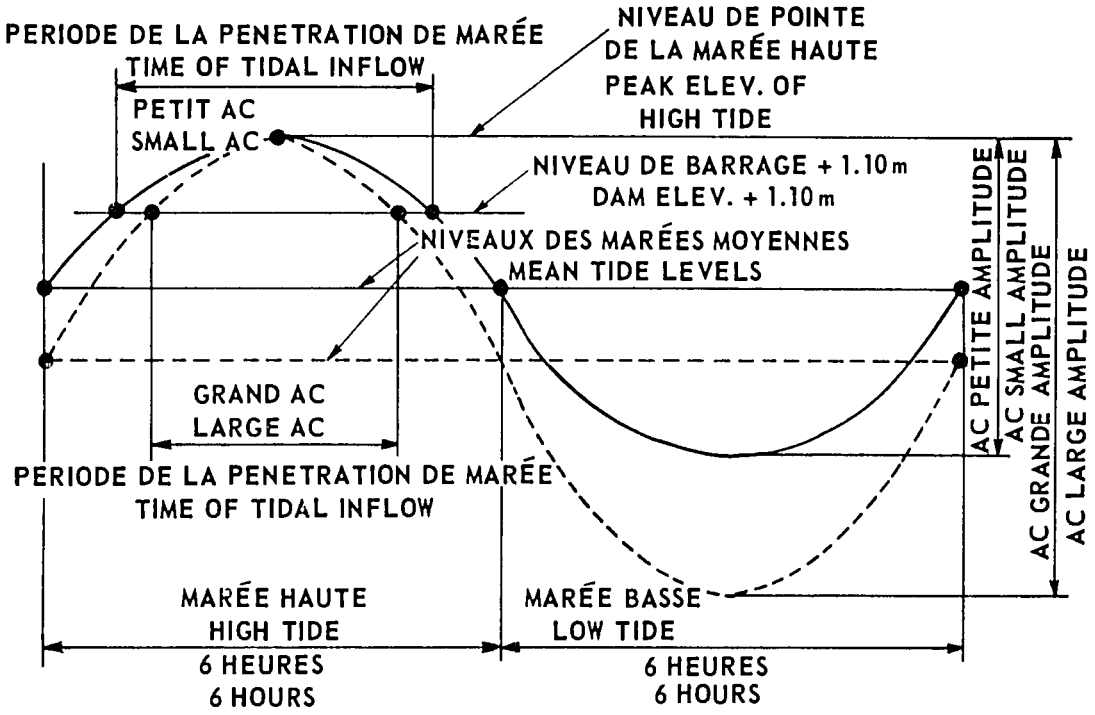
(c) Reduction in the length of time during which the high tides with peaks higher than elevation +1.10 meters flow into the lagoon of Cotonou.

In order to evaluate the amount of reduction in the tidal inflow by the proposed dam, a month to month record of tides, as measured in the Port of Cotonou, was used. Although the tides vary from year to year, usually on a 19-year cycle, it was deemed sufficiently accurate to regard the tidal records of 1970 as being typical. In this year, the highest peak of the tide did not exceed elevation +1.70 meters.

In Figure 6-17 a table is given showing the number of times that a certain elevation is exceeded by the high tide in each month. This table also shows that the peaks of the high tide in Cotonou vary considerably and that some of the very high peaks occur only a few times each month. The highest tides occur generally between August and November; this is also the period of the floods.

If one takes a look at the typical tidal curve diagram (shown in Figure 6-17), one can see how the length of time during which the tidal inflow enters the lagoon over the weir of the proposed dam varies with the tidal amplitude. For example, if two high tides have the same peak elevation but different amplitude, the tide with a bigger amplitude will penetrate the lagoon for a shorter time than the tide with a smaller amplitude. Figure 6-18 shows the relationship between the tidal amplitude, the peak elevation of the tide, and the number of hours that the tide will enter over the weir into the lagoon.

Next, Figures 6-19 and 6-20 show that there are two basic conditions of the tidal inflow over the weir of the dam. One condition (Figure 6-19), generally during the dry season, shows that all of the portion of the high tide above the weir will enter the lagoon. The second condition is in the flood season when the levels of both the lagoon and Lake Nokoue rise above the level of the weir. Generally, the peak levels of most floods are



COURBE TYPIQUE DES MARÉES
TYPICAL TIDAL CURVE

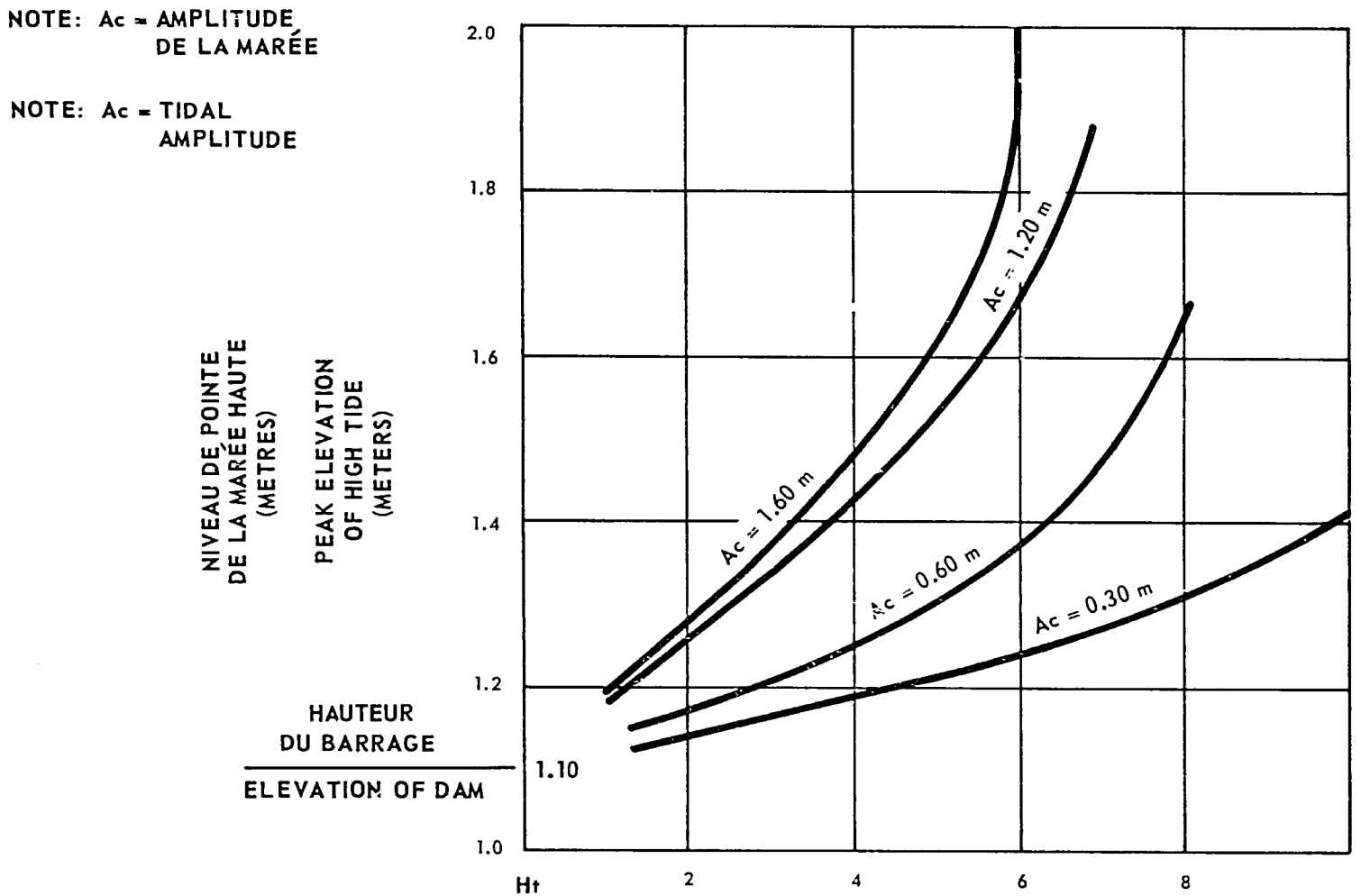
NOMBRE DES TEMPS AU DESSUS DU NIVEAU DE POINTE / NUMBER OF TIMES PEAK IS EXCEEDED	MOIS-MONTHS												
NIVEAU DE POINTE PEAK ELEV.	JANV. JAN.	FEV. FEB.	MARS MARCH	AVRIL APRIL	MAI MAY	JUIN JUNE	JUILLET JULY	AUG. AUG.	SEPT. SEPT.	OCT. OCT.	NOV. NOV.	DEC. DEC.
1.7	-	-	-	-	-	-	-	-	3	3	6	-
1.6	-	-	2	-	-	-	-	6	7	5	5	-
1.5	3	9	5	3	1	-	5	7	8	10	5	4
1.4	12	7	9	8	3	3	5	12	12	10	4	3
1.3	18	13	9	7	10	13	16	14	8	8	7	15
1.2	14	7	6	10	14	10	16	9	7	9	15	11
1.1	2	6	8	9	10	19	5	3	6	7	2	10

*STATISTIQUE DE 1962 (MANQUE D'INFORMATIONS EN 1970)
* 1962 DATA USED, (1970 DATA NOT AVAILABLE)

MARÉES EN 1970
TIDES IN 1970

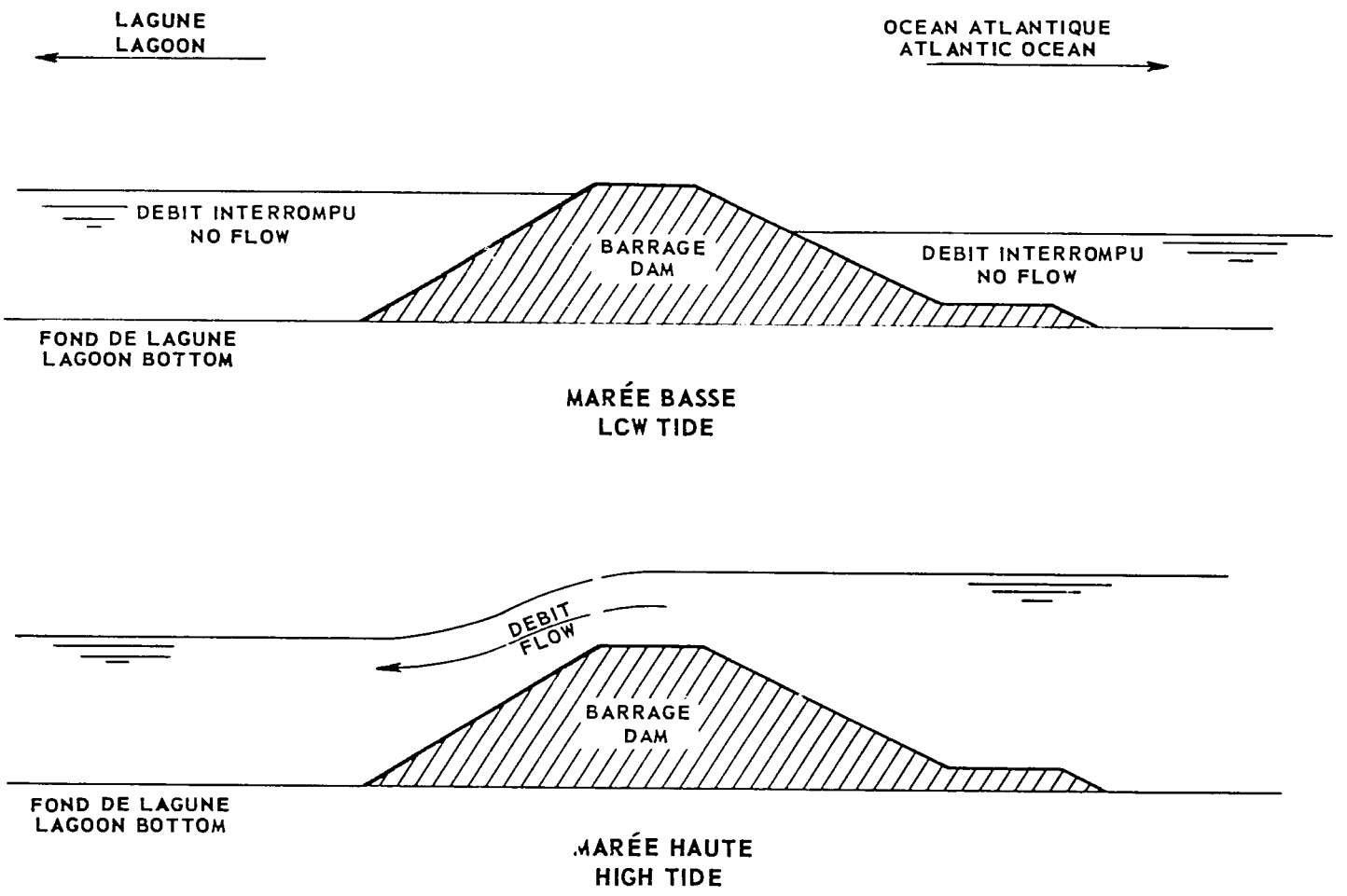
FIG. 6-17

141



NUMERO DES HEURES DE PENETRATION DE LA MARÉE DANS LA LAGUNE
EN FONCTION DAMPLITUDE DE LA MAREE
NUMBER OF HOURS OF TIDAL PENETRATION INTO THE LAGOON
AS A FUNCTION OF TIDAL AMPLITUDE

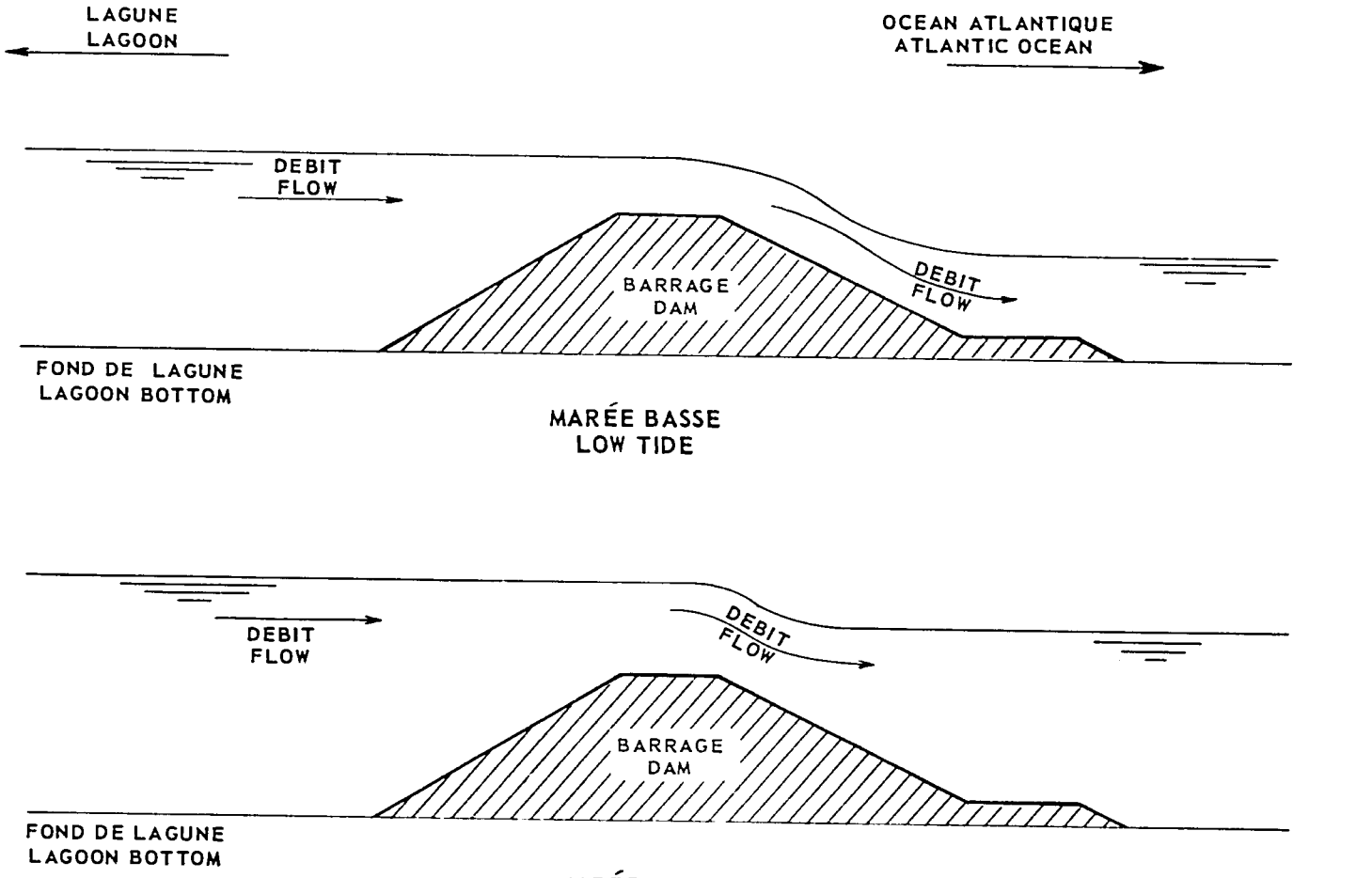
SANDERS & THOMAS INC.



SAISON SÈCHE
DRY SEASON

FIG. 6-19

SANDERS & THOMAS INC.



NOTE: NIVEAU DES CRUES TOUJOURS AU DESSUS DE MARÉE HAUTE

NOTE: FLOOD ALWAYS ABOVE HIGH TIDE

SAISON DES CRUES
FLOOD SEASON

FIG. 6-20

higher than the level of the high tide. Therefore, the penetration of the tide is further reduced during the flood season because the tide will enter the lagoon only during the time when the flood level is below its peak.

Using these relationships, the total inflow into the lagoon has been computed for each month of the year. Based on volumetric considerations, the salinity level for each month was computed next. Volumetric approach to salinity determination is admittedly approximate, but it should give a good indication of the expected results. Figure 6-21 shows the calculated volumes of tidal inflow and salinity in Lake Nokoue under present conditions and after the proposed dam is constructed. From it, one can see that during the dry season the total volume of the tidal inflow has been reduced almost 90% and that the salinity is estimated at less than 10 grams per liter.

6 Effect of the Proposed Dam on the Outflow Currents in Lake Nokoue

An attempt has been made to indicate the probable trend of salinity and outflow currents in Lake Nokoue after the construction of the dam. Based upon average monthly flow volumes of the rivers Oueme and So, and the volumes of reduced tidal inflow over the proposed dam, contours of salinity and river flow arrows have been shown in Figures 6-22 through 6-26. They show that (a) the nul point of the salt wedge will not progress much beyond Agbato, and (b) that the river outflow currents will be mostly directed towards Porto-Novo in all months of the dry season and (c) that during this period the salinities in excess of 10 grams per liter will exist only in the Cotonou Lagoon and in the immediate vicinity of Agbato. During the four months of the flood season (August through November), the outflow currents will be directed towards both Cotonou and Porto-Novo and Cotonou will have salinities less than 5 grams per liter. As mentioned before, in an exceptionally dry season (say when the combined flow of both rivers is under 200 cubic meters per second) it is possible that higher salinities than 10 grams per liter will exist in the northern and eastern portions of the lake. This, however, will be a rare occurrence.

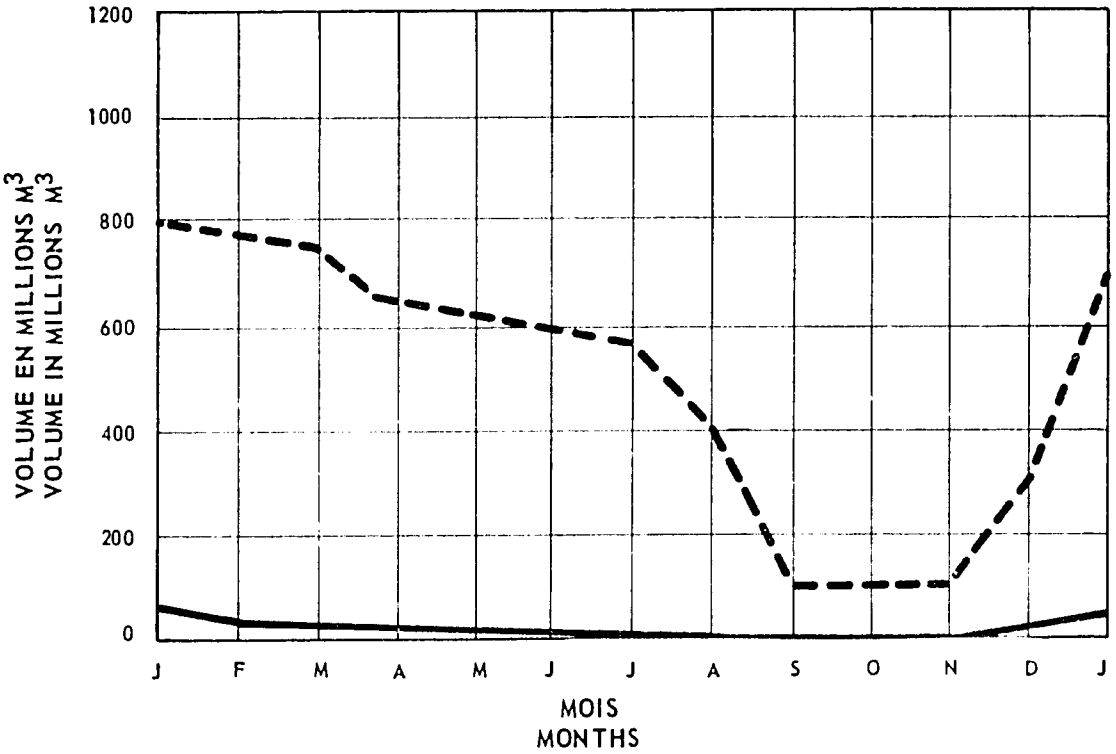
F CONTROLS AND DESIGN REQUIREMENTS FOR THE PROPOSED DAM

1 Maximum Expected Flood

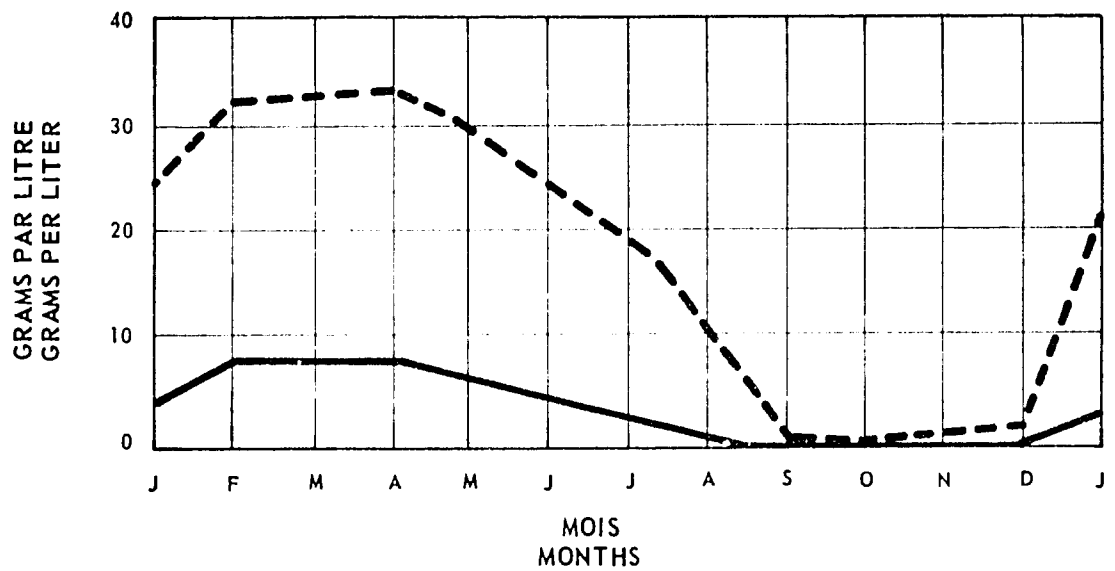
The maximum design flood from combined flow of the two rivers, Oueme and So, is assumed to be 1500 cubic meters per second. Based on the known relationship of how the lagoons of Cotonou and Porto-Novo share the flow, the maximum expected flood flow, through the Cotonou Lagoon is less than 600 cubic meters per second.

2. Requirements and Dimensions for Weir Design

The weir dimensions are controlled by the following requirements (Levels based upon Hydraulic Zero Datum):



PENETRATION DES MARÉES (EAUX DE MER)
PENETRATION OF TIDES (SEAWATER)

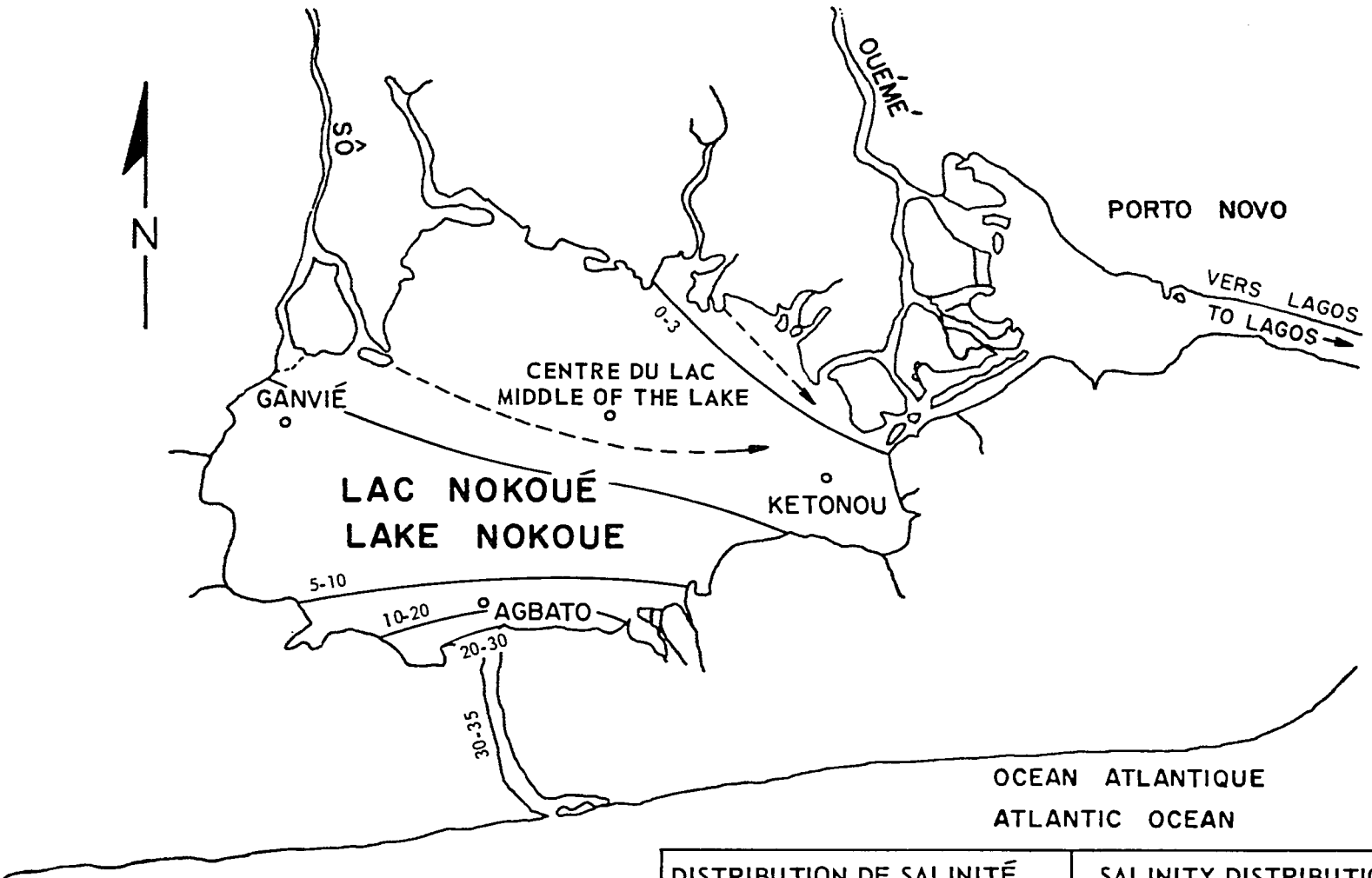


SALINITÉ
SALINITY

SANS BARRAGE
WITHOUT DAM

AVEC BARRAGE
WITH DAM

FIG. 6-21

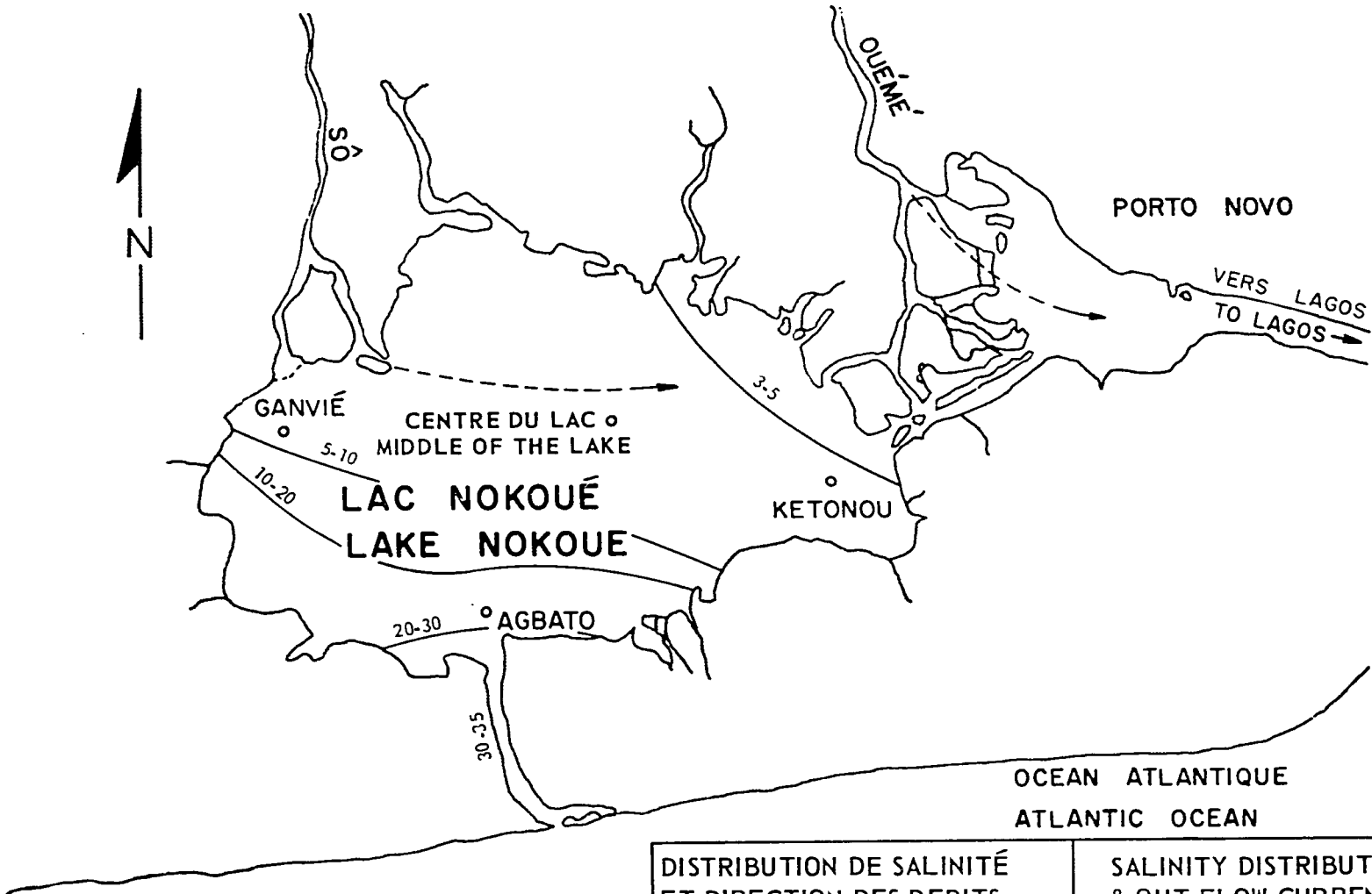


DEBIT DE RIVIERES
FRESH WATER FLOW

COURBE DE SALINITÉ
SALINITY CONTOUR

DISTRIBUTION DE SALINITÉ ET DIRECTION DES DEBITS DES RIVIERES AVEC BARRAGE	SALINITY DISTRIBUTION & OUT FLOW CURRENTS WITH DAM
SAISON SÈCHE MOIS: DEC.–JANV. NIVEAU DU LAC: 1.20 m ±	DRY SEASON MONTHS: DEC.–JAN. LAKE LEVEL 1.20 m ±

FIG. 6-22

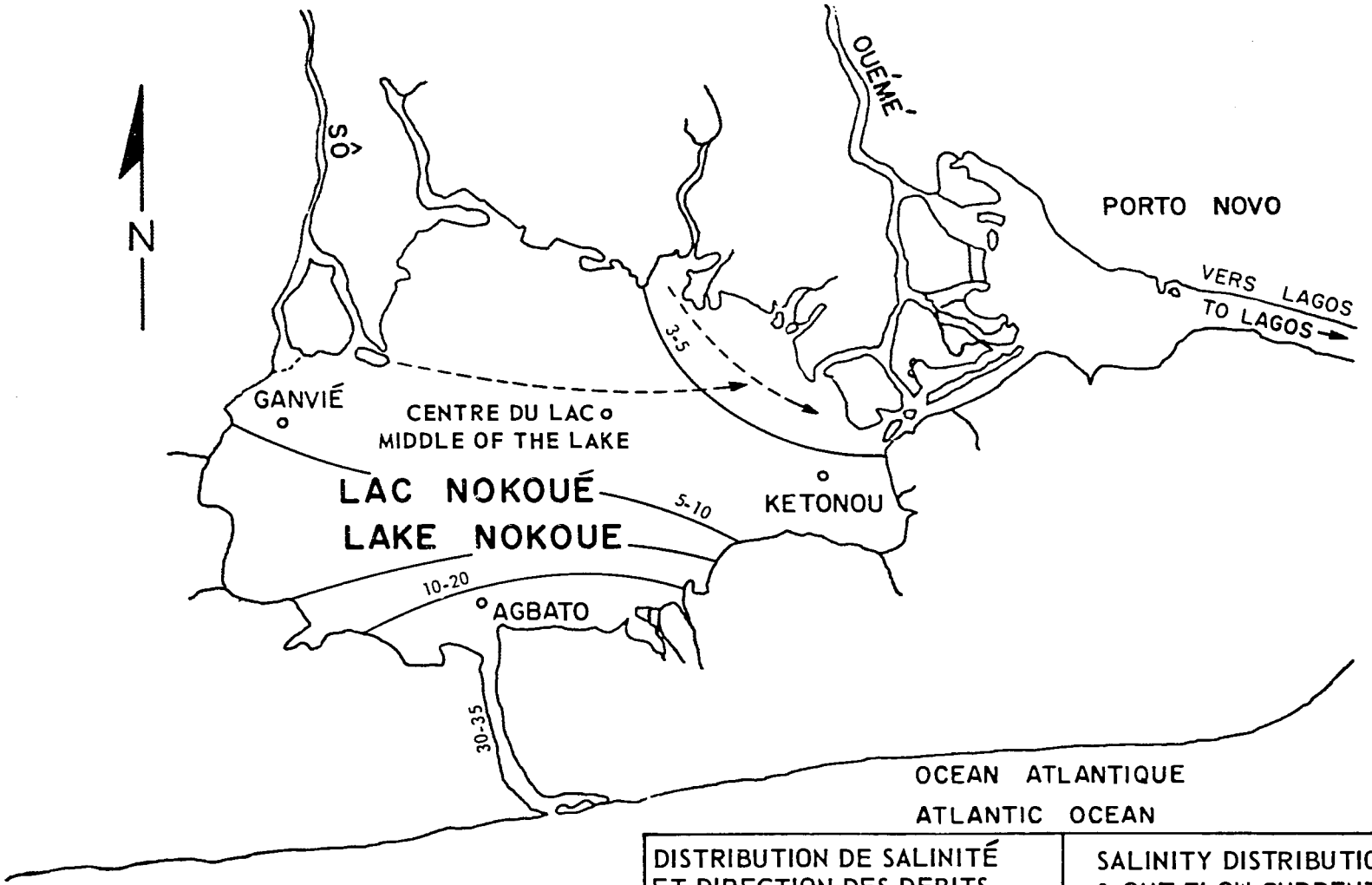


DEBIT DE RIVIERES
FRESH WATER FLOW

COURBE DE SALINITÉ
SALINITY CONTOUR

DISTRIBUTION DE SALINITÉ ET DIRECTION DES DEBITS DES RIVIERES AVEC BARRAGE	SALINITY DISTRIBUTION & OUT FLOW CURRENTS WITH DAM
SAISON SÈCHE MOIS: FÉV.–MARS. NIVEAU DU LAC: 1.20 m ±	DRY SEASON MONTHS: FEB.–MARCH LAKE LEVEL 1.20 m ±

FIG. 6-23

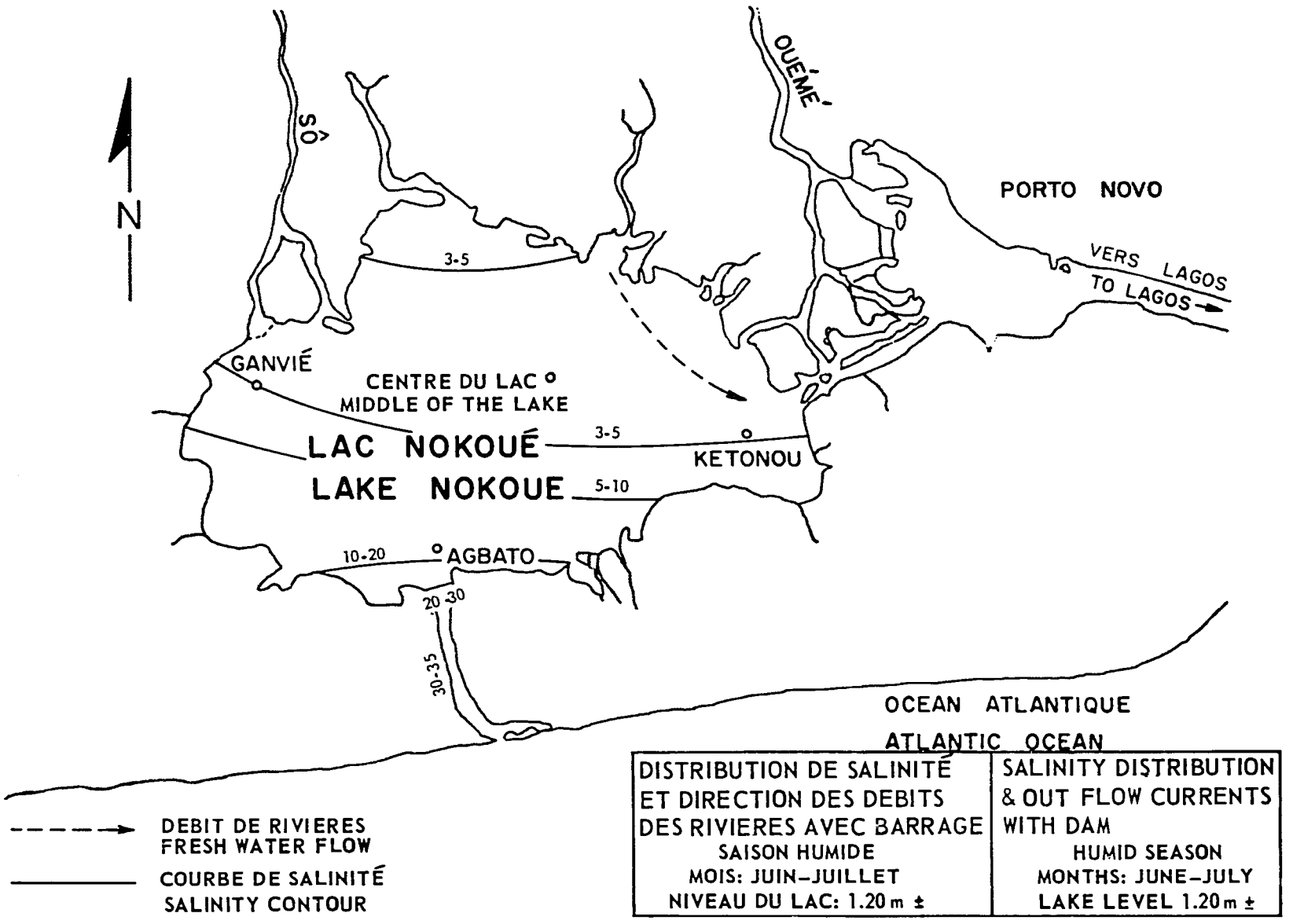


DISTRIBUTION DE SALINITÉ ET DIRECTION DES DEBITS DES RIVIERES AVEC BARRAGE	SALINITY DISTRIBUTION & OUT FLOW CURRENTS WITH DAM
SAISON HUMIDE MOIS: AVRIL–MAI NIVEAU DU LAC: 1.20 m ±	HUMID SEASON MONTHS: APRIL–MAY LAKE LEVEL 1.20 m ±

- - - - - → DEBIT DE RIVIERES
FRESH WATER FLOW

——— COURBE DE SALINITÉ
SALINITY CONTOUR

FIG. 6-24



DISTRIBUTION DE SALINITÉ ET DIRECTION DES DEBITS DES RIVIERES AVEC BARRAGE	SALINITY DISTRIBUTION & OUT FLOW CURRENTS WITH DAM
SAISON HUMIDE	HUMID SEASON
MOIS: JUIN–JUILLET	MONTHS: JUNE–JULY
NIVEAU DU LAC: 1.20 m ±	LAKE LEVEL 1.20 m ±

FIG. 6-25

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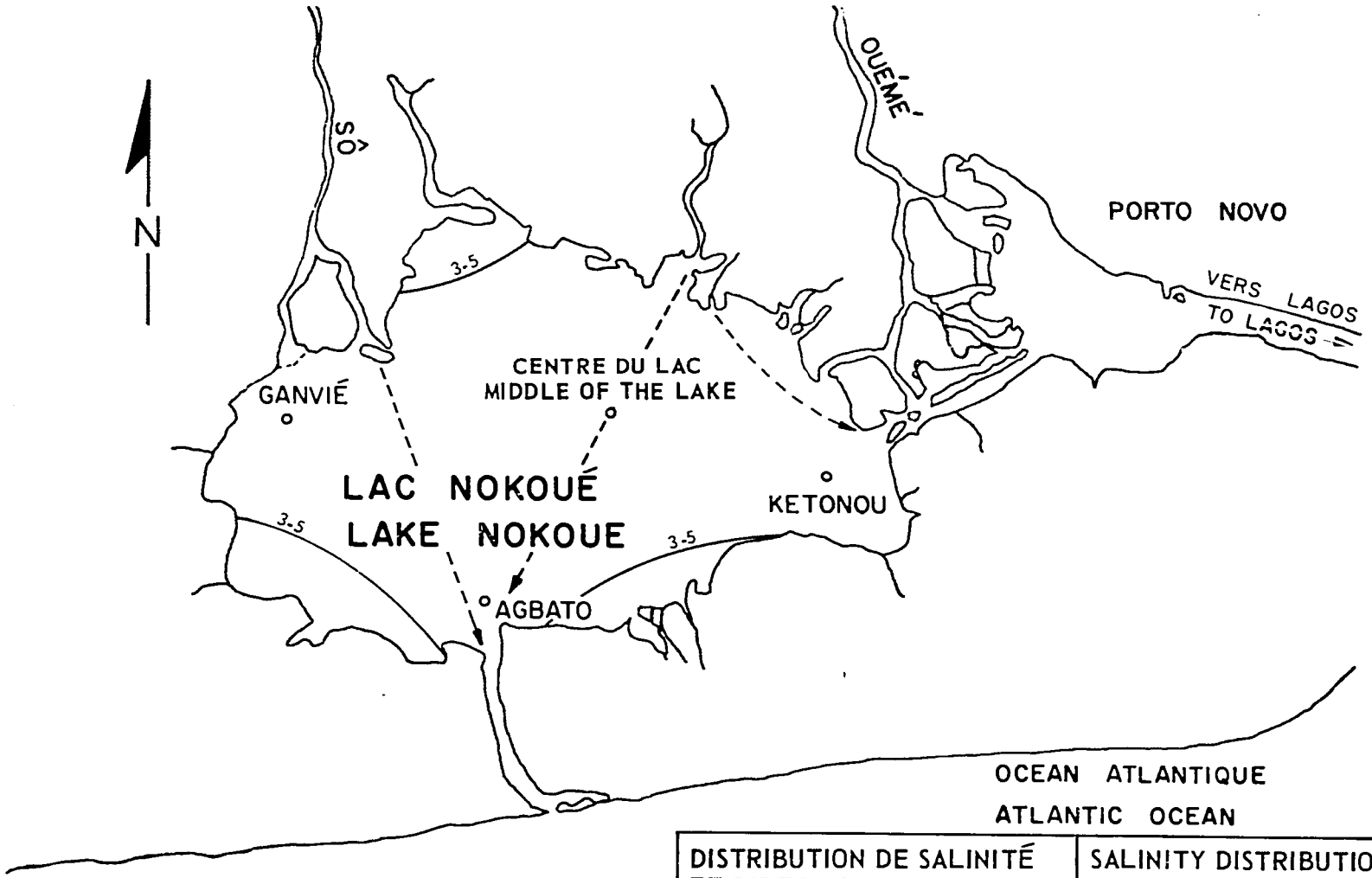


DISTRIBUTION DE SALINITÉ ET DIRECTION DES DEBITS DES RIVIERES AVEC BARRAGE	SALINITY DISTRIBUTION & OUT FLOW CURRENTS WITH DAM
SAISON DES PLUIES	WET SEASON
MOIS: AUG.–NOV.	MONTHS: AUG.–NOV.
NIVEAU DU LAC: 1.80 m ± MOYEN	LAKE LEVEL 1.80 m ± AVER.
1.95 m ± MAX.	1.95 m ± MAX.

- - - - - → DEBIT DE RIVIERES
FRESH WATER FLOW

——— COURBE DE SALINITÉ
SALINITY CONTOUR

FIG. 6-26

(a) Maximum allowable backwater elevation of +2.00 meters.

(b) Weir elevation at +1.10 meters.

(c) Top of the dam adjacent to the weir, of +2.80 meters.

(d) Capacity to discharge 600 cubic meters per second.

With the maximum backwater level of +2.00 meters and in order to be able to allow a flow of 600 cubic meters per second the required width of the weir is 520 meters. Thus during the maximum flood of 600 cubic meters per second the velocity of flow over the weir will be 1.3 meters per second.

The width of the weir should be sufficient to permit ease of construction and to allow access for construction equipment during low tide. A width of 3 meters would be sufficient for this purpose.

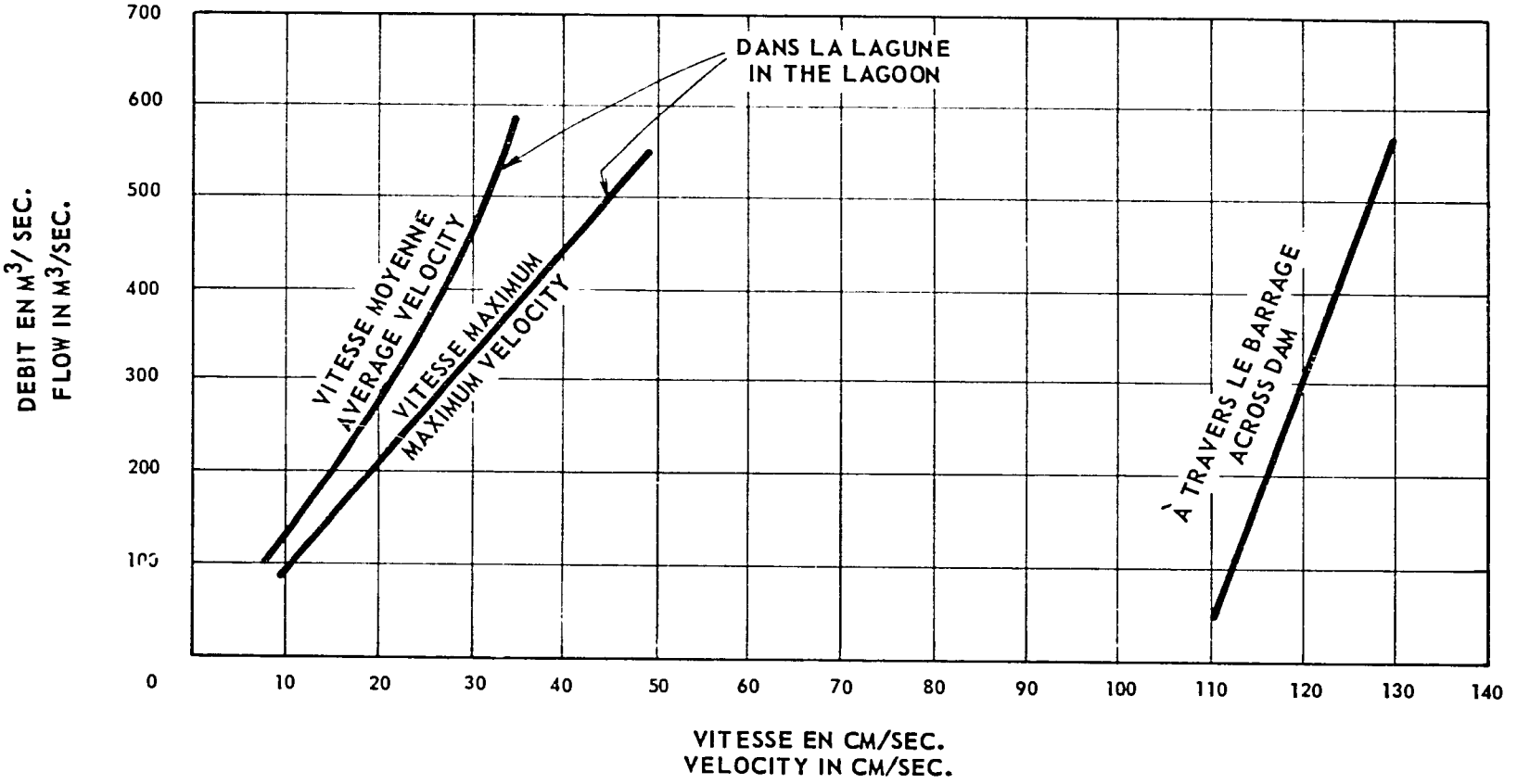
3. Effect of Future Expansion of Port of Cotonou on Littoral Drift and Tidal Forces on the Dam

The future expansion of the Port of Cotonou will cause the littoral drift to be deflected further to the east. This may cause the present sand bar in front of the Cotonou Lagoon to be eroded away. The disappearance of the sand bar may have a result in a slight increase in the tidal amplitude at the dam. This change, however, will have a negligible effect on the salinity levels due to the fact that higher tidal amplitudes tend to decrease the length of time during which salt water penetrates the lagoon.

G. BENEFITS AND DISADVANTAGES FROM DAM CONSTRUCTION

1. Reduction of Erosion in the Cotonou Lagoon

The proposed dam will greatly reduce the velocities of flow in the Cotonou Lagoon. During the dry season the flow velocities will be minimal. During the flood season they will be faster but will not exceed 1.3 meters per second at the weir. Elsewhere in the lagoon the velocity of flow will be much slower. Figure 6-27 shows the expected maximum and average velocities of flow as a function of quantity of flow through the Cotonou Lagoon. The present channel has already been eroded and has carried much larger flow than the expected maximum of 600 cubic meters per second. Thus the combination of less volume of flow coupled with slower velocities should definitely prevent any further erosion in the lagoon. The benefit of this will reflect itself in the reduced construction costs for the proposed future West Bank Boulevard which will not require any rock protection of its embankment along the lagoon. The seriousness of the erosion under the existing bridge is discussed in Section VII. The dam will eliminate also the need to provide special protection for the foundation of the new bridge. This should result in additional savings in the construction costs.



DEBIT A TRAVERS LAGUNE DE COTONOU-CONDITION FUTURE
FLOW THROUGH COTONOU LAGOON-FUTURE CONDITION

FIG. 6-27

SANDERS & THOMAS INC.

2. Reduction of Salinity in Lake Nokoue

The reduction of salinity in Lake Nokoue should help eliminate the problem of the terredos and the consequent loss of "akadja" fish traps and reduction in the fish harvest. This problem is discussed in detail in the report prepared by Dr. R. Thompson of the NMFS Laboratory.[9] The probable monetary benefits from the elimination of the terredo problem as evaluated by Dr. Thompson has been included in the benefit/cost analysis in this report.

The backwater levels in Lake Nokoue and Cotonou Lagoon will reach elevation +2.0 meters during the maximum flood conditions. When this happens many of the presently vacant low lying areas, in the northern portions of Cotonou near Lake Nokoue, will be subject to flooding. These areas, however, at some future date will need to be filled in to provide additional usable room for expansion of the City of Cotonou. At present there are some settlements that have been established in areas whose elevation is +1.5 meters or lower. Some damage may result there during the peak floods. The peak floods will particularly affect portions of areas known as Awansouri Ague, Ladji, Djidje and Hinde Village. However, the peak floods do not occur frequently. Little damage should result, therefore, during the "normal" flood season.

3. Silt Deposits

The problem of silting in the Cotonou Lagoon is difficult to evaluate. In the past, when Cotonou Lagoon was closed for several years at a time, no serious silting occurred. The dam at the mouth of the lagoon will constitute a permanent barrier and silting may become a problem over a long period of years. The rate of silting, however, should be extremely slow. The silt is brought in mostly by Oueme River. The flow of the river in its northern reaches is relatively fast and thus it is able to carry the silt downstream towards Lake Nokoue and Porto-Novo Lagoon. As soon as it reaches the lake, however, the speed of flow is drastically reduced. Thus any silt kept in suspension in the river water will be deposited in the northern portions of Lake Nokoue[10]. If there is any silt left in suspension when the flow reaches the Cotonou Lagoon, it will be in negligible quantities. Thus, it is not expected that silting will become a problem except perhaps after a long period of time, say 20 or more years.

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[9] Richard B. Thompson - Report of the Fishery Reconnaissance to Lake Nokoue, Dahomey, and George K. Tanonaka - Economic Evaluation of Expected Fishery Benefits. National Marine Fisheries Service, Biological Laboratory, Seattle, Washington, July 1971. A copy of Dr. Thompson's report is included in Appendix B.

[10] Some benefit to the fishing in Lake Nokoue may result from the silt depositing in Lake Nokoue since the silt is also rich in organic nutrients which are beneficial to the fish growth.

4. Loss of Shrimp in the Lagoon

The construction of the dam may totally eliminate the shrimp fishing in the Cotonou Lagoon and Lake Nokoue. The monetary loss, however, will not be large since to date the shrimp harvest in the lake has never exceeded 400 metric tons per year.

5. Sanitary Effluent

Presently all sanitary effluent in Cotonou is discharged into the ground where it mixes with the rainstorm effluent and eventually seeps into the lagoon and the lake. Fears have been expressed that the proposed dam will create stagnant conditions in the lagoon and therefore aggravate the pollution from the sanitary effluent. In effect, the dam will be a very pervious dam. Therefore, even in the dry season, there will always be some movement of water towards the sea during low tides. In flood season, the entire lagoon will continue to be flushed clean not only of any sanitary effluent accumulations, but also of salinity caused by the intermittent penetration during high tides. Therefore, no adverse conditions are anticipated from the construction of the proposed dam with respect to the accumulation of sanitary effluent in the lagoon. This however, should not preclude the fact that there will be a pressing need to construct a sanitary sewer system in Cotonou as the city continues to grow in size as well as in population. BCEOM has already made a study in 1963 for a sanitary sewer collection system in Cotonou, which would suffice until 1990, at a total cost (in 1963), of 243 million Fr. CFA.

SECTION VII

EXISTING BRIDGE

A. CAUSES OF BRIDGE DETERIORATION

1. Channel Erosion

The channel bottom at the existing Cotonou bridge has been subject to changes since the time of the bridge construction in 1928. These changes were caused by the scour of the bottom during the flood season and by deposition of materials during the dry season. As indicated by the measurements made by OCDN Railroad staff in the years prior to 1959, the changes in the lagoon bottom were relatively small. Therefore, there was no significant net loss of embedment of the piles supporting the bridge. Since 1959, however, the lagoon erosion began to acquire a faster rate. The most significant increase in the erosion rate occurred between 1959 and 1966. During this period the channel area has increased by 50% at an average rate of 7% per year. Since 1966 the rate of erosion has slowed down considerably. Based on the November 1970 measurements made by Sanders & Thomas, Inc. the rate of erosion, since 1966, is approximately 1% per year with loss of pile embedment progressing at 2% per year. (See Figure 7-1).

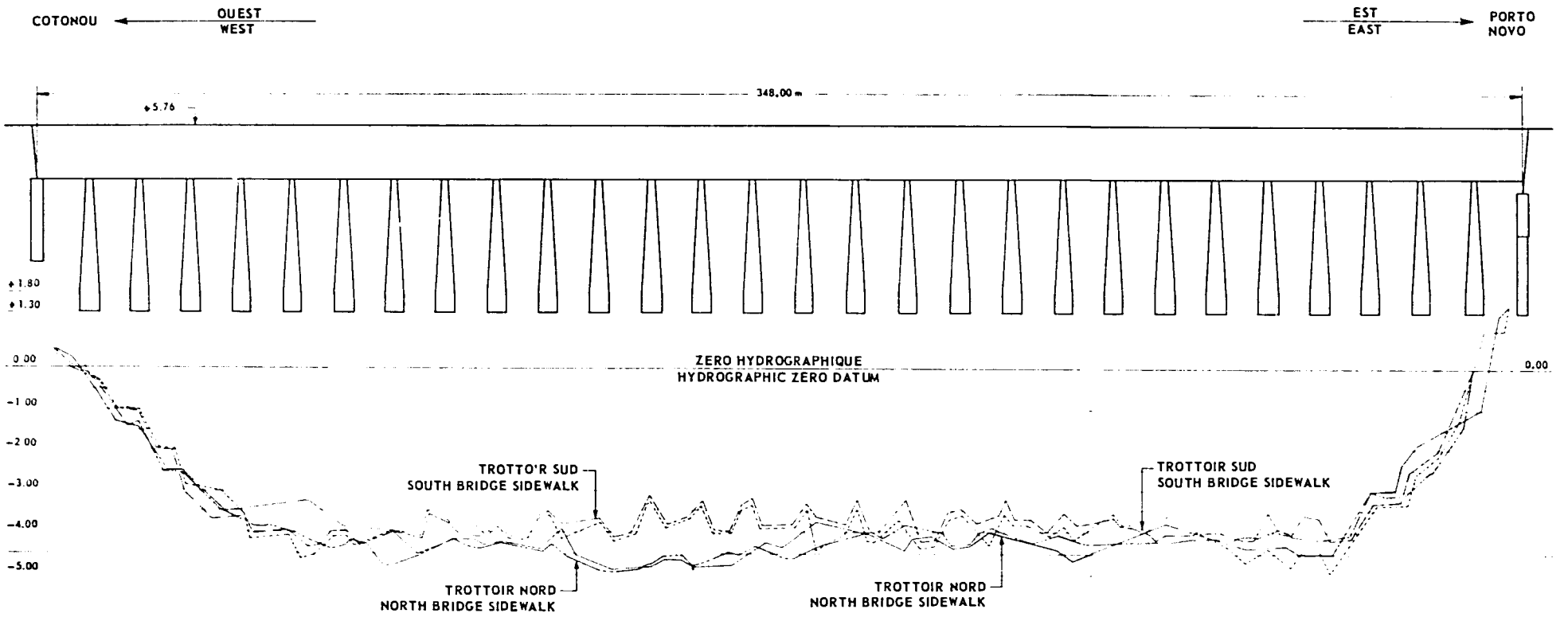
2. Traffic

The Cotonou bridge has been intended to function primarily as a railroad bridge. In the years prior to 1960, the volume of vehicular traffic which used the bridge was relatively small. Since 1960, however, the growth of the vehicular traffic has been rapid and paralleled the growth of the city. The effect of greatly-increased vehicular traffic on the bridge increased the rate of wear of its deck. In addition to that, the impact and vibrational loads on the bridge were made more serious by the concurrent loss of pile embedment. Presently, the vibration of the bridge superstructure and the sway of its piers is particularly noticeable when heavy traffic such as the trucks and the train cross the bridge. The vibration of the superstructure is also agravated by loose bearings of the bridge girders. Wearing of the deck is evidenced by the deterioration of the concrete and metal expansion joints.

3. Lack of Periodic Maintenance

The bridge deterioration has been increased by the lack of periodic maintenance. It is doubtful, in fact, that the bridge had received any maintenance at all until 1970. The bridge steel girders need a coat of paint, and their bearing seats have been loosened by corrosion. The metal deck joints also show evidence of

SANDERS & THOMAS INC.



— — — — MESURE BCEOM, JANV.–MARS 1970
- - — - - — BCEOM MEASUREMENT, JAN.–MARCH 1970
- - - - - - - - MESURE SANDERS & THOMAS INC., NOVEMBRE 1970
- - - - - - - - MEASUREMENT BY SANDERS & THOMAS INC., NOVEMBER 1970

PROFILS A TRAVERS NO. 1 & 2
CROSS SECTIONS NO. 1 & 2

FIG. 7-1

corrosion and spalling of adjacent concrete. The sidewalks have failed completely in several locations forcing pedestrians to step into the path of vehicular traffic to avoid these areas. The bridge lighting has been inoperative for several years making the use of sidewalks particularly hazardous at night.

B. CONDITION OF BRIDGE IN 1970

1. Superstructure

The superstructure of the bridge shows many signs of an incipient loss of structural integrity. Although there is no immediate danger to the bridge, continued lack of repairs will aggravate and accelerate the deterioration of the bridge deck. Since the last inspection of the bridge by Sanders & Thomas, Inc., in January, 1970, no repairs were made to the bridge superstructure. The sidewalk deck points and lighting system continue to need repairs and the steel girders need cleaning and painting.

2. Substructure

The piers of the bridge were repaired during the first half of 1970 and are presently in excellent condition. The only weakness remains in the piles which have lost a large portion of their embedment.

The abutments, however, have received no repairs and continue to be threatened by erosion and loss of stone facing.

C. BRIDGE REHABILITATION

1. Recent Repairs

Major repair work of the bridge piers and piles was completed during 1970 at a cost of 50 million Fr. CFA (approximately $182,000). The financing of the repairs was provided by Fonds d'Aide et de Cooperation (FAC). The work consisted of reconstructing the deteriorated concrete in piers and piles and application of an epoxy coating to protect against salt damage.

2. Proposed Immediate Additional Repairs

In order to protect the piles of the bridge against further erosion and loss of embedment, BCEOM has prepared plans to provide a rock mat under the bridge. The rock mat will consist of a 0.75 meter thick layer of medium size rock fragments (weighing 10 - 60 kg each). The project will be financed by FAC and is estimated to cost 45 million Fr. CFA (in 1971).

3. Required Additional Future Repairs

An additional program of repairs is being studied by BCEOM in cooperation with Ministry of Public Works. Included in this program are repairs to the abutments, complete replacement of the bridge deck (including repair of the metal joints and sidewalk) and rehabilitation of the lighting system. Estimated year of completion for various repairs is shown in Table VII-1. It should be pointed out that when the deck of the existing bridge is replaced, it should be constructed with much wider sidewalks than the presently existing in order to be adequate for future large pedestrian traffic. Sidewalks having a width of at least 2.0 meters each should be provided at that time. (See Figure 7-2).

TABLE VII-1

SUMMARY OF COSTS

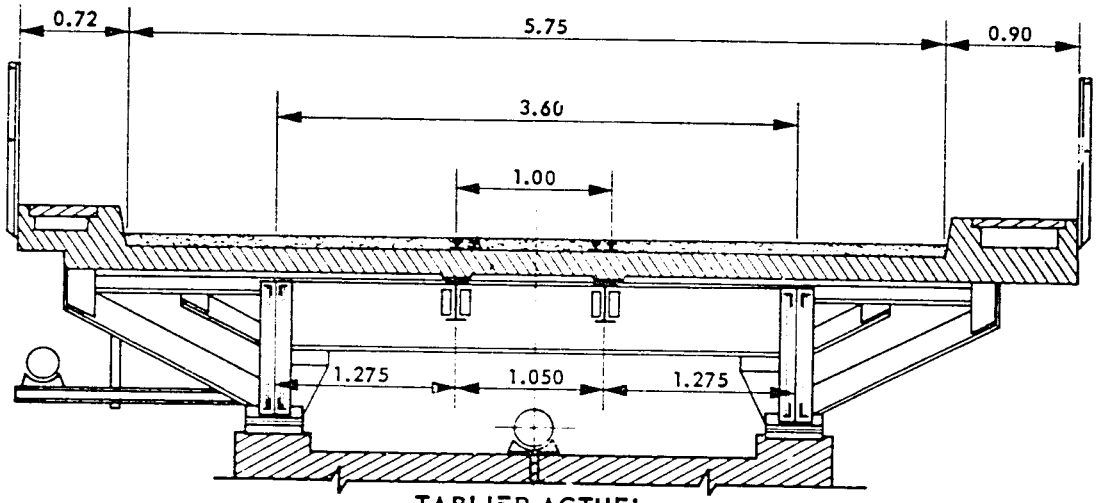
FOR REHABILITATION OF THE EXISTING COTONOU BRIDGE

Year Completed	Description of Work	Cost Millions Fr. CFA
1972	Place rock mat for erosion protection	45
1974	Repair abutments, place embankment and rock protection on lagoon banks adjacent to abutments	15
1978	Repair deck, repair sidewalks, restore lighting, clean and paint steel girders	150
1996	Replace rock mat for erosion protection	80

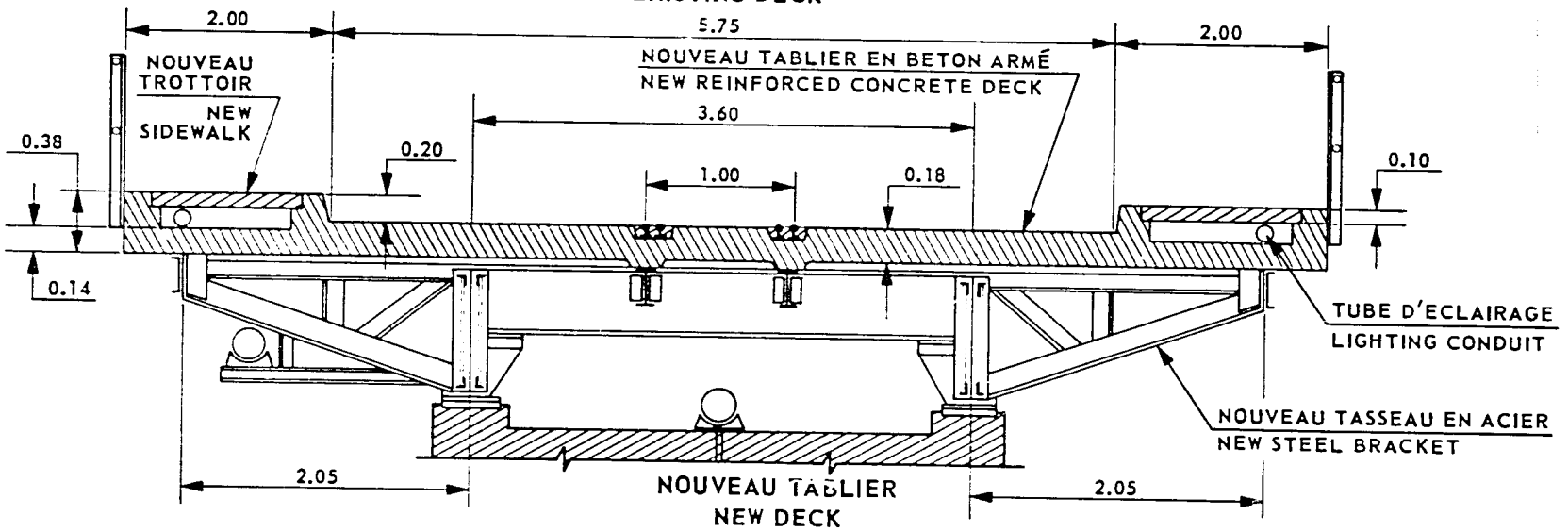
4. Feasibility of Maintenance of Traffic During Rehabilitation

Presently the Cotonou bridge carries heavy traffic during all but a few daylight hours. The traffic using the bridge is almost entirely of local origin. Any interruption of the bridge traffic, therefore, would have grave economic consequences for the City of Cotonou. All rehabilitation work, when undertaken, will have to be accomplished during the night hours, mostly between midnight and 5:00 AM. This would represent too short a working period to accomplish reasonably productive results.

It would certainly be impossible to do any kind of repairs on the bridge deck in a way to allow full use of it during the day. The width of the bridge is too narrow to allow the shutting down of one lane of traffic. If this were done, almost complete disruption of traffic would result.



TABLIER ACTUEL
EXISTING DECK



AMELIORATION DU TABLIER ET ELARGISSEMENT DES TROTTOIRS
DECK IMPROVEMENTS AND WIDENING OF SIDEWALKS

PONT ACTUEL – EXISTING BRIDGE

FIG. 7-2

The proposed construction of a rock mat under the bridge will also need to be done mostly at night. During this time rock material is proposed to be brought to the bridge site by rail and then transferred to a barge. The rock will then be placed under the bridge by dumping and by manual piece by piece placement in between the piles.

The repair of bridge abutments, once the stone material is brought to the site, will not create too much disruption to the traffic. The repair of sidewalks and lighting will necessitate that the pedestrian traffic be confined to one side only while the work is in progress on the other side. Due to the fact that the sidewalks are very narrow, interference to vehicular traffic will inevitably result.

In view of the fact that the present (1970) traffic is already quite congested, any repair work will be very difficult at best and therefore quite costly. The traffic congestion, at the same time, will become seriously aggravated causing considerable losses to the economic life of the city.

All of these problems could be avoided, however, if a new bridge is constructed first. In this case the traffic flow could be transferred to the new bridge while repairs are being made to the existing one. The only traffic which will need to be maintained will be the OCDN railroad traffic. This should not prove difficult.

5. Cost of Additional Bridge Repairs

The required rehabilitation work for the existing bridge is listed in Table VII-1 in chronological order of priority. The year shown for each item of work is the latest date by which the listed work should be completed. The cost shown for the work after 1977 assumes that a second bridge will be available for traffic maintenance. The repairs without the help of a second bridge will be extremely difficult. The costs for the work prior to 1977 reflects this. It is assumed that all work listed to be completed prior to 1975 will be financed by either FAC or FED. A detailed cost estimate for replacement of bridge deck (including wider sidewalks), repair of lighting and painting of steel girders is shown in Appendix A, pages A-6 and A-13.

D. EXPECTED REMAINING BRIDGE LIFE

1. Expected Life Without Additional Rehabilitation Work

Without any rehabilitation work, it is estimated that the remaining useful life of the existing bridge will not exceed ten years. The existing bridge was constructed in 1928. Since then it has had minimal maintenance and only recently have its piers and piles been repaired after undergoing serious deterioration. In general, bridges with adequate maintenance, have a useful life of 40 years. By 1970, the Cotonou bridge has become 42 years old. With the increased vehicular traffic one of the controlling factors in the remaining bridge life will be its concrete deck. The deck already shows signs of serious deterioration. In the next five years the failure of the deck will begin to accelerate, and eventually the deck will become unusable. Although the piers and

the piles have been repaired the problem of erosion remains. The erosion rate has slowed down, particularly in the center of the channel. Near the banks, however, the erosion continues. If nothing is done to stop it the bridge abutments may suffer serious damage. Some damage to the abutments has already occurred. Thus, erosion is the second most influential factor which limits the remaining useful life of the bridge.

2. Expected Life with Additional Repairs and Adequate Maintenance

Assuming that adequate repairs are made, and particularly, that the bridge piles are protected against further loss of embedment, the useful life of the Cotonou bridge will be extended for another 40 years. If a dam is not constructed, the useful life of the rock mat under the bridge would be shorter. Due to scouring action of the flood waters the rock mat would probably need a complete replacement in about 25 years.

If a dam is constructed, however, the erosive action of the flood flow will be greatly diminished, and the useful life of the rock mat will be extended to at least 40 years.

SECTION VIII

PROPOSED NEW BRIDGE AND ROADWAY APPROACHES

A. PARALLEL BRIDGE NEAR THE EXISTING BRIDGE SITE

1. Preliminary Layout, Design and Construction

A parallel bridge would be located approximately 20 meters north of the existing bridge. It would have a total length of 350.75 meters and would consist of 23 spans of 15.25 meters each. The total deck width is 11.10 meters and provides for two traffic lanes with a 3.50 meters wide sidewalk on the north side of the bridge. This wide single sidewalk was located on the north side of the bridge in order to reduce to the minimum the need for the pedestrians to cross the vehicular traffic. The bridge would have multiple simple-span precast prestressed concrete superstructure which is supported on pile bents. The bents consist of precast concrete octagonal piles which are battered to resist longitudinal and transverse forces. The top of the piles is imbedded in a pile cap which serves as a bearing seat for the superstructure. The plan and elevation of the proposed bridge and typical sections of the bridge and roadway approaches are shown on page A-2 in Appendix A.

The construction of the bridge would be relatively easy. Pile driving from barges would proceed from both shores. Alternate pile groups would be driven first in order to help consolidate the bearing sand strata. The completed pile groups would be used as anchorage for the barges. After all pile driving is completed, the piles would be cut to required elevation and capped. The placement of prestressed beams would then proceed using a barge mounted crane. Finally the deck concrete would be placed by trucks traveling on completed spans.

The storing of construction equipment, materials and prestressed beams, however, would be difficult if not impossible near the construction site. Therefore it would be necessary to set up the construction yard at a more open and less crowded location. Such a location would be removed at least 2 kilometers from the construction site. This would tend to increase equipment and material hauling costs. Furthermore, due to the congested traffic conditions near the existing bridge the access and delivery of materials to the construction site would be subject to many delays.[1]

2. Requirements for Approaches

A parallel bridge would require very short approaches. However, the close proximity of the existing bridge and several cross streets, including the proposed west bank boulevard would afford, at best, difficult channeling of the traffic at the western

[1] In 1975 at least 5 hours of each day will have traffic conditions at level of service E.

end of the bridge. Even if the existing bridge were used for two-lane one-way (eastbound only) traffic and the new two-lane parallel bridge were used for the westbound traffic only the traffic flow at either end of the bridge would be subject to heavy cross movements. This situation, plus the train crossings on the existing bridge, would reduce the effectiveness of the new bridge in handling increased traffic loads in the future. The western approaches to the parallel bridge are particularly limited since they pass through a crowded business section. The available space for the roadway is limited and in part occupied by the tracks of the OCDN railroad. The western approaches, therefore, would be restricted, to function at best as a four-lane roadway, even if widened and improved. For this reason it would not make sense to build a parallel bridge of more than two lanes width.

B. BRIDGE AT BOULEVARD SAINT MICHEL

1. Preliminary Layout, Design and Construction Aspects

The proposed new bridge at the Boulevard Saint Michel site would have the same layout and design as the parallel bridge described previously. The total length of the bridge would consist of 22 spans of 15.25 meters each for a total length of 335.50 meters. The total width of the bridge deck would be 19.00 meters and would provide for four traffic lanes and two sidewalks, each 2.50 meters wide.

The plan and elevation of the proposed bridge and typical sections of the bridge and approaches are shown on page A-3 in Appendix A.

The construction of the bridge would also be similar to the parallel bridge. One big advantage of the site near Saint Michel Boulevard, however, is unlimited room at the east bank of the lagoon where a large construction yard could easily and conveniently be located. The construction operations, therefore, would not suffer any interference from existing traffic. This will greatly facilitate construction operations and hence reduce construction time and costs.

2. Requirements for Approaches

The approaches necessary to connect the new bridge at the Boulevard Saint Michel site to the existing International Route are quite long. The western approach has a length of 4 kilometers. Of this, approximately 1.5 kilometers are in swampy terrain, 2.2 kilometers are along Avenue de la Republique and 0.3 kilometers are along the eastern end of Boulevard Saint Michel. The eastern approach is 1.5 kilometers long. It joins the existing International Route just east of the sports stadium known as Stade Pleven. The entire length of the approach roads is proposed to be constructed as a two-lane roadway except in the vicinity of the bridge where four lanes would be maintained for a length of 0.4 kilometers on the western side and 1.3 kilometers on the eastern side. Only the four-lane portion of the west approach is recommended to be constructed under the bridge project. The remainder of the west approach (two-lane portion), has already been proposed to be constructed at a cost of 150 millions Fr. CFA, with FED financing.

This cost, however, is estimated to be 180 million Fr. CFA by 1975. The entire east approach (four and two-lane portions) are recommended to be constructed with the bridge project.

A special requirement exists near the western end of the bridge where the proposed future improvements to the Lagoon (or Saint Michel) Market are to be made. An access road passing under the bridge is needed in order to separate the market traffic from the bridge traffic. One extra span has been provided in the Saint Michel bridge for this purpose.

The plan, profile and typical section of the approach roads are shown on pages A-2, A-3, A-4 and A-5 in Appendix A.

C. CONSTRUCTION COSTS

1. Effect of the Proposed Dam on Bridge Costs

If a dam is constructed in the Cotonou Lagoon the velocity of flow will be reduced drastically and the possibility of erosions almost entirely eliminated. It will not be necessary, therefore, to provide any protection for the bridge foundation. In addition to this, a definite advantage will exist during the construction of the new bridge.

With the dam completed or almost completed it will not be necessary to interrupt bridge construction during the flood season. This will result in a shorter construction schedule for the entire project.

Without the dam, it will be necessary to interrupt the pile driving operations during the flood season. It will be hazardous and difficult to operate barge carrying construction equipment near the partially completed bridge since the drag of the flood force might hurl the barge against the already driven piles and destroy them. Furthermore, a rock mat under the bridge would be necessary to protect the bridge piles against erosion and loss of embedment. Thus a longer construction schedule would result and this would reflect itself in higher costs.

A dam, therefore, would reduce the bridge construction costs but the additional cost of the dam would greatly exceed any savings in the bridge costs. However, the construction of the dam would result in fishing benefits and reduction in overall construction time schedule. The relative merits of the construction of a dam have been included in the economic analysis and are discussed in Section XII.

2. Determination of Unit Prices

Unit prices for the Feasibility Study were determined by using the same sources and revisiting the same local contractors and agencies in Cotonou and in the United States as was done for the Reconnaissance Study. The previously obtained data on unit prices were thus updated and improved. The sources for the local materials in Dahomey were rechecked and where the source changed, new material and transportation costs were determined.

To the new unit cost data (See Table VIII-1) conservative inflation factors were applied to predict the probable costs in 1975, the year in which the bids for the proposed construction are expected to be received. Every effort was made to predict and ascertain all probable items of cost and influences on the prices in order to insure that the estimated total costs are sufficiently accurate.

It should be noted that the unit prices in this report show a considerable increase with respect to the prices given in the Reconnaissance Report. This is due to the recent accelerating rate of inflation in the construction industry which is particularly felt in the American procurement and, to a lesser degree, is also reflected in the Foreign procurement costs.

3. American Procurement

Costs on the basis of American procurement are provided in this report and are included in the economic analysis. It must be pointed out, however, that it is unlikely that more than a few bids will be received from American contractors. Recent experience for a bridge project in Niamey, Niger indicates that it was not possible to implement American procurement even on a partial basis. The recent large escalation of construction costs in United States, mainly caused by high labor costs will tend to make American bidders less competitive with Foreign bidders since most skilled American labor foremen and equipment operators would have to be paid higher wages that prevail in the United States. For this reason it is strongly recommended that the financing agency allow maximum freedom for subcontracts and local procurement if a sufficient number of competitive bids are to be received from American bidders. The breakdown of bridge construction costs for American Procurement are shown on pages A-7 through A-10 in Appendix A.

4. Foreign Procurement

Even if foreign procurement were not restricted only to contractors from underdeveloped countries, most likely, the low bidders will be local contractors with offices in Dahomey or other nearby West African countries. They are in general quite competent and are equipped to perform the necessary work. The quality of their workmanship is excellent. This is evidenced by the recently completed repairs of the piers of the existing Cotonou bridge. In order to encourage the submission of a large number of bids from foreign contractors, it may be wise for the design consultant to first solicit interest for the project among the qualified bidders in eligible countries. Once a list of interested qualified bidders is developed, the prospective bidders should be consulted in order to help develop a design which would include the types and methods of construction with which the prospective bidders are familiar. Thus it will be possible to receive bids on the same basis from all the bidders. This should help generate tight competitive prices and therefore lowest total cost. In this report the costs of foreign procurement have been developed following French and German construction methods as shown in the BCEOM and Holzman reports but adapted to conform to the type of bridge proposed

in this report. The breakdown of the estimated bridge construction costs with foreign procurement is shown on pages A-14 through A-17 in Appendix A.

D. MAINTENANCE COSTS

1. Bridge Maintenance

No data were available to evaluate the maintenance costs for bridge structures in Dahomey. Bridges in general do not need yearly maintenance. In the case of the existing bridge, once the recommended rehabilitation work is completed, only the steel girders will need repainting approximately every five years. In the case of the new bridge, which will be an all concrete bridge, practically no maintenance will be necessary for at least ten years. At that time, the deck of the bridge may need some maintenance with respect to possible wear of the deck concrete surface. The lighting system for both bridges is the only item that might require yearly maintenance, but the cost of it would be of minor importance. Since the total length of the bridge is relatively short (0.35 km) it was deemed sufficiently accurate to assume that the yearly maintenance costs used for roadway maintenance would be adequate (when accumulated for five years) to pay for bridge maintenance costs.

2. Roadway Maintenance

The source of data for the roadway maintenance costs were the two reports prepared by N.D. Lea Associates and Lamarre Valois International Limitee for the International Bank for Reconstruction and Development (1968 and 1969). Based on these reports, the maintenance costs are composed of two portions. One is a fixed cost for the deterioration of the road surface due to weather conditions. The other is a function of the volume of traffic using the road (see Table VIII-2). No data were available for four-lane roads. In this case, twice the cost for two-lane paved roads has been assumed.

Normal maintenance is defined as that which will allow the vehicles to operate most of the time under the best conditions that might be expected for paved roads in Cotonou.

The roadway maintenance costs have been evaluated by applying the total city traffic to approach roads only. These include International Route No. 11 for the existing and the new parallel bridges and for the bridge at Saint Michel Boulevard, the new approach road along Avenue de la Republique and Boulevard Saint Michel on the western side and the new road to PK. 3 and the International Route No. 11 on the eastern side of the lagoon. All of these roads are or will be paved roads.

For the remaining roads and streets in Cotonou, it was assumed the maintenance costs would be the same under all alternatives and therefore, these costs have not been calculated.

In applying the traffic volume to the maintenance cost calculations, only traffic due to cars, trucks and busses was included, and it was assumed that pedal and motor bicycles have negligible effect on maintenance costs. An inflation factor of 2% per year was used for the costs shown in Table VIII-I. The total maintenance costs, for the 20 year study period discounted to 1975 for each alternative are as follows:

Parallel Bridge Alternative	251	Millions Fr. CFA.
Saint Michel Bridge Alternative	297	Millions Fr. CFA.

TABLE VIII - 1

UNIT PRICES

The prices have been adjusted to year 1975 by Sanders & Thomas, Inc. The unit prices are for completed construction and include normal overhead, taxes and profit. Additional overhead due to contractor's administrative and supervisory personnel living in Dahomey for the duration of construction is included in the cost estimates, pages A-6 through A-19 in Appendix A.

It is assumed that local materials such as sand, gravel, rock, bituminous paving, etc., would be used by all types of procurement. It is also assumed that local skilled and unskilled labor would be used in all cases. The cement is assumed to be purchased locally and to be of either American or local origin. Equipment, forms, precasting and prestressing plant, reinforcing steel, structural steel, prestressing strands, etc., is assumed to be imported. In the case of American procurement the shipping costs are generally computed separately, whereas, for Foreign procurement they are included in the respective unit prices.

CONSTRUCTION ITEM	UNIT	COST Fr. CFA	SOURCE	
Shipping - USA to Cotonou including loading and unloading	Ton	10,000 (1)	Various shipping agencies in USA	A
Precast Concrete Piles (2) (3)	M^3	49,000 (1)	Various U.S. pile precasting yards	A
Precast Concrete Piles delivered to Cotonou	M^3	61,000	Entreprises du Benin - Cotonou	F
Driving Piles	M	25,000	Entreprises du Benin - Cotonou	A F
Placing and Cutting Piles	each	38,000	Travaux Publics Cotonou	A F

A = American Procurement
F = Foreign Procurement

Remarks: (1) average cost
(2) includes forms and reinforcing steel
(3) precast in Cotonou - precasting forms brought from USA.

TABLE VIII - 1 (Continued)

UNIT PRICES

CONSTRUCTION ITEM	UNIT	COST Fr. CFA	SOURCE	
Structural Excavation and Backfill (Bridge Abutments	M^3	1,000	Societe Colas Cotonou	A F
Reinforced Concrete Precast Pile Caps (2) (3)	M^3	80,000 (5)	Eastern Prestress Co. - Hatfield, Pa.	A
Reinforced Concrete (2) Precast Pile Caps	M^3	74,000	Entreprises du Benin	F
Reinforced Concrete (2) Abutments - cast in place	M^3	60,000	Eastern Prestress Co. BCEOM	A F
Reinforced Concrete (2) Bridge deck - cast in place	M^3	65,000	Eastern Prestress Co. BCEOM	A F
Prestressed Concrete Bridge Beams (2) (3)	M^3	126,000 (5)	Eastern Prestress Co.	A
Prestressed Concrete Bridge Beams (1)	M^3	118,000	BCEOM Holzman, A. G.	F
Neoprene Bearing Pads (1)	each	5,000	Eastern Prestress Co. BCEOM	A F
Removal of Existing Bridge Deck	M^3	8,500	Eastern Prestress Co. Entreprises du Benin	A F
Structural Steel Existing Bridge Brackets (4)	kg	400	BCEOM	A F

A = American Procurement
F = Foreign Procurement

Remarks:
(1) average cost
(2) includes forms and reinforcing steel
(3) precast in Cotonou - precasting forms brought from USA.
(4) includes removal of existing brackets
(5) includes shipping precasting forms and prestressing plant back to USA.

TABLE VIII - 1 (Continued)

UNIT PRICES

CONSTRUCTION ITEM	UNIT	COST Fr. CFA	SOURCE	
Embankment	M^3	1,300	Societe Colas Cotonou	F
Excavation, including placement in embankment	M^3	500	Societe Colas Cotonou	F
Sub-base (silty sand, 15 cm depth)	M^2	300	Societe Colas Cotonou	F
Base (Laterite material, 15 cm depth)	M^2	1,300	Societe Colas Cotonou	F
Bituminous Surface Course (Sheet Asphalt, 3 cm depth)	M^2	800	Societe Colas Cotonou	F
Shoulders (15 cm depth)	M^2	400	Societe Colas Cotonou	F
Drainage Pipe, incl. excavation and backfill	M	12,500	Societe Colas Cotonou	F
Embankment	M^3	1,000 (6)	Various U.S. Contractors	A
Excavation, including placement in embankment	M^3	600 (6)	Various U.S. Contractors	A
Sub-base (silty sand, 15 cm depth)	M^2	200 (6)	Various U.S. Contractors	A

A = American Procurement
F = Foreign Procurement

Remarks: (2) includes forms and reinforcing steel
(3) precast in Cotonou - precasting forms brought from USA.
(6) Cost includes labor, materials and equipment depreciation only. The expenses of shipping road construction equipment from USA to Dahomey and back to USA (after completion of project) is included in the shipping tonnage in the cost estimates for roadway approaches.

TABLE VIII - 1 (Continued)

UNIT PRICES

CONSTRUCTION ITEM	UNIT	COST Fr. CFA	SOURCE	
Base (laterite material, 15 cm depth)	M^2	1,000 (6)	Various U.S. Contractors	A
Bituminous Surface Course (Sheet Asphalt, 3 cm depth)	M^2	600 (6)	Various U.S. Contractors	A
Shoulders (15 cm depth)	M^2	300 (6)	Various U.S. Contractors	A
Drainage Pipe including excavation and backfill	M	12,000 (6)	Various U.S. Contractors	A
Rock - (20 to 80 kg) furnishing and loading on train	T	600	Travaux Publics and BCEOM, Cotonou	A F
Rock - (20 to 200 kg) (Phase 1 & 2) furnishing and loading on train	T	800	Travaux Publics and BCEOM, Cotonou	A F
Transportation to Cotonou to site of dam (by train)	T	800	OCDN Railroad	A F
Transport to Cotonou OCDN Station	T	760	OCDN Railroad	A F
Unload Rock at site of dam	T	400	Travaux Publics and BCEOM, Cotonou	A F

A = American Procurement
F = Foreign Procurement

Remarks: (2) includes forms and reinforcing steel
(6) Cost includes labor, materials and equipment depreciation only. The expenses of shipping road construction equipment from USA to Dahomey and back to USA (after completion of project) is included in the shipping tonnage in the cost estimates for roadway approaches.

TABLE VIII - 1 (Continued)

UNIT PRICES

CONSTRUCTION ITEM	UNIT	COST Fr. CFA	SOURCE	
Unload rock from train (OCDN station), load on truck, transport by truck and unload truck. (9)	T	1,240	Travaux Publics and BCEOM, Cotonou	A F
Place Rock between piles (7)	T	5,900	Travaux Publics and BCEOM, Cotonou	A F
Place Rock in Dam (Phase 1) (7)	T	2,700	Travaux Publics and BCEOM, Cotonou	A F
Sand for core material in dam (8)	M^3	2,500	Travaux Publics and BCEOM, Cotonou	A F
Place Rock in Dam (Phase 2) (10)	T	900	Travaux Publics and BCEOM, Cotonou	A
Dredging	M^3	1,000	BCEOM	A F
Embankment (sand) (11)	M^3	300	BCEOM	A F
Rock Protection for Lagoon Banks (12)	T	4,700	Travaux Publics Cotonou	A F
Excavation (at Lagoon banks) (12)	M^3	500	Travaux Publics Cotonou	A F

A = American Procurement
F = Foreign Procurement

Remarks:
(3) precast in Cotonou - precasting forms brought from USA.
(7) includes loading on barge
(8) includes excavation, placing in canvas bags, loading on barge and placement in dam.
(9) transport by truck to bridge site or to stockpiling site (Rock, Phase 2).
(10) loading of rock at stockpiling site, transport by truck and unloading in dam (see discussion in Section IX).
(11) sand material obtained by dredging and placed in embankment in the lagoon banks near the dam.
(12) required for erosion prevention (alternative without the dam)

TABLE VIII-2

YEARLY ROADWAY MAINTENANCE COSTS (1000 Fr. CFA)
ASSUMING NORMAL MAINTENANCE
Base Year 1970

Type of Road	Fixed Portion (with no traffic)	Variable Portion (based on traffic volume)
2 lanes paved	239/KM	46/KM/1000 vehicles/day
4 lanes paved	478/KM	92/KM/1000 vehicles/day

SECTION IX

PROPOSED DAM

A. PRELIMINARY DESIGN

1. Choice of Site

The proposed site for the dam has been recommended in July of 1970 in the Reconnaissance Report by Sanders & Thomas, Inc. It was pointed out that the primary requirement was to place the dam at a location where the entire lagoon and therefore also both the existing and the new proposed bridge may be protected against erosion. The selected site has been surveyed and more precisely determined during the recent field work by Sanders & Thomas, Inc. team in Cotonou, in November of 1970. The location and the plan of the dam are shown in Figure 9-1 and the dam cross section is shown in Figure 9-2.

2. Foundation Conditions

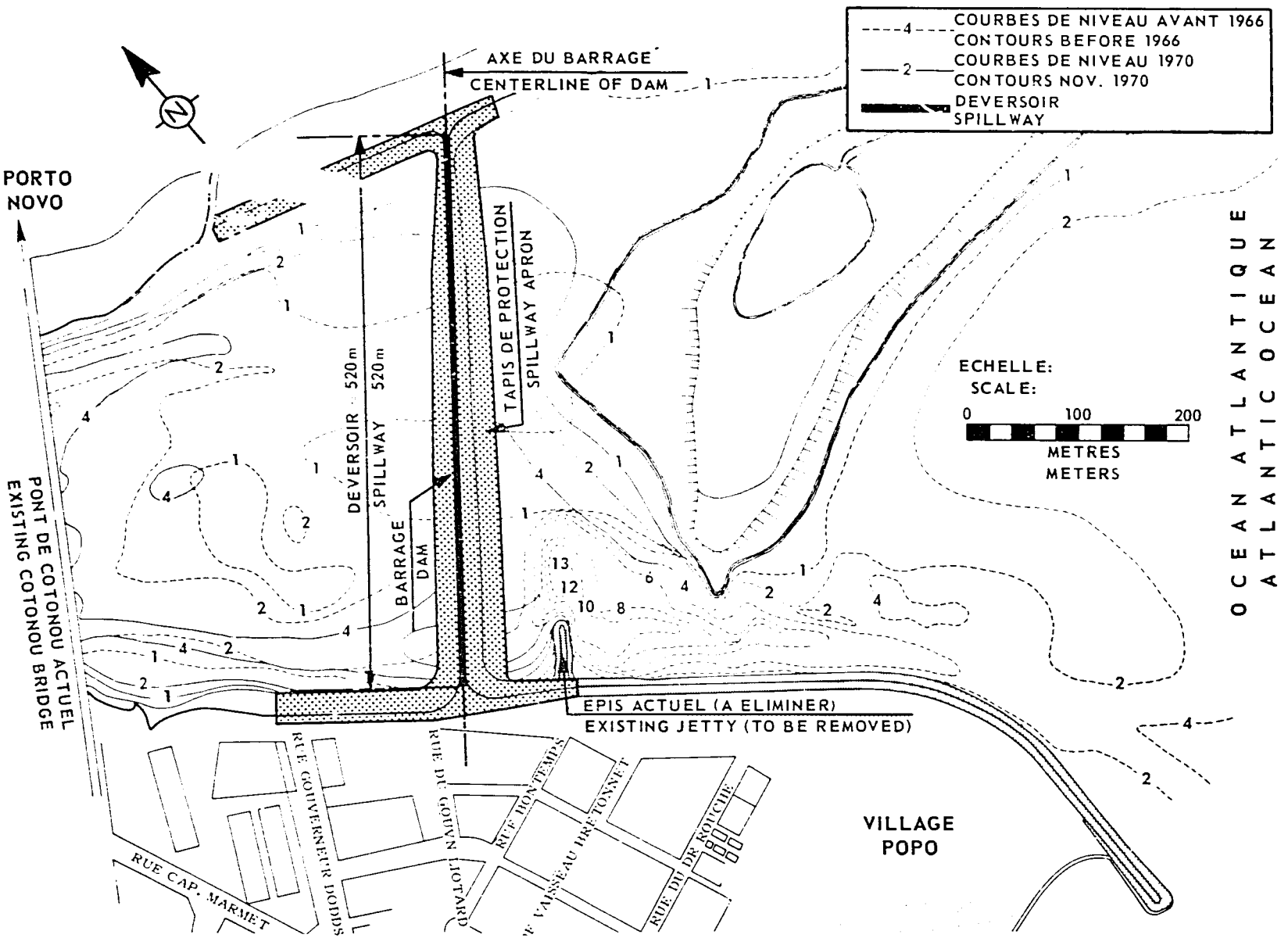
The limited exploratory information obtained for this report near the site of the proposed dam (see also Section V) indicates that a compressible clay stratum exists approximately 20 meters below the channel bottom. This will cause significant settlement under the dam over a period of at least the first six years. Beyond this time, the amount of settlement will be much smaller and of negligible importance. This is discussed additionally in subsection B.

3. Magnitude of Expected Flood and Tidal Forces on Dam

The expected flood forces on the dam are determined primarily by the velocities of flow over the dam during flood seasons. These will not exceed the velocities presently existing in the channel in the general area where the dam will be located. The largest energies will be generated by the flood waters during the low tide. For this reason a rock apron has been provided on the southern (ocean) side of the dam to absorb and dissipate the impact of the flood water spilling over the dam. The tidal impact on the dam and the velocities of the inflow during high tides will be considerably smaller than the velocities in the flood conditions.

4. Required Construction Materials

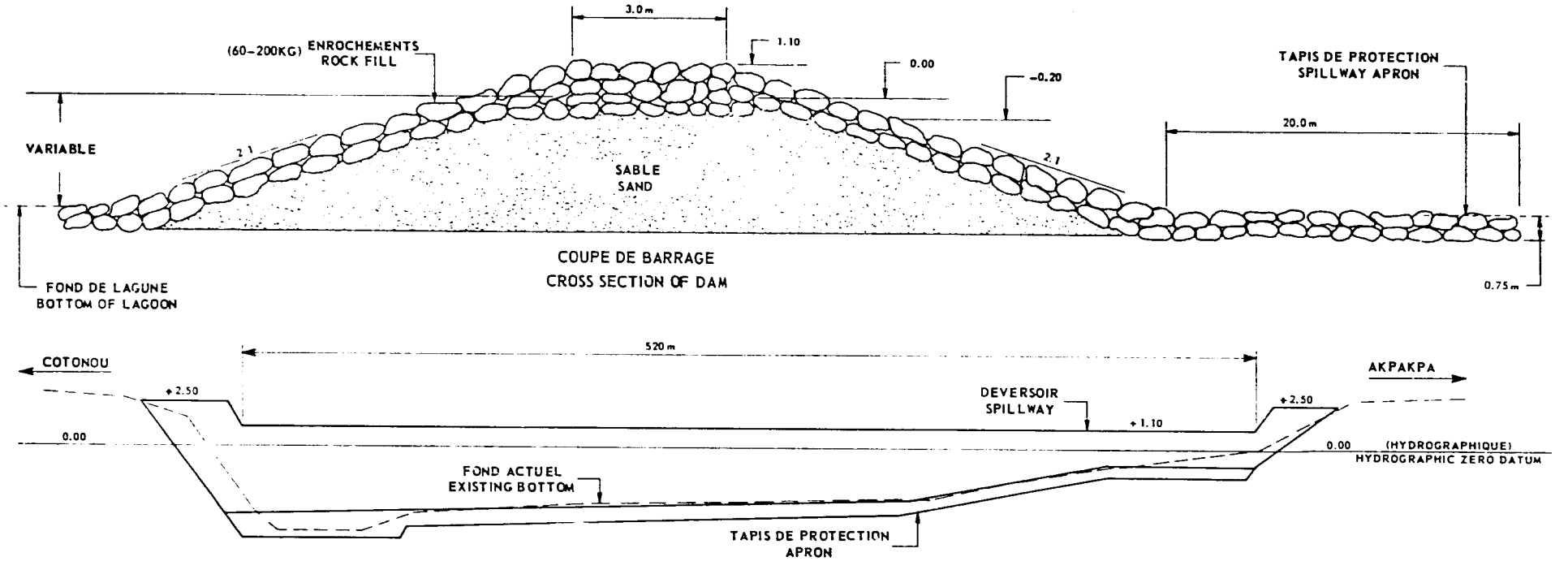
It is expected that maximum velocities of flow over the dam will not exceed 2 meters per second. Therefore, rock fragments of 20 to 200 kilograms are proposed to be used for the faces and the top of the dam. In the apron, the rock fragments of



PLAN DU BARRAGE
PLAN OF PROPOSED DAM

SANDERS & THOMAS INC.

FIG. 9-1



PROFIL LONGITUDINAL DU BARRAGE
LONGITUDINAL SECTION OF THE DAM

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FIG. 9-2

the same size have also been selected. It is suggested that a sand fill be used for the dam core. The sand used will be of the coarse size. It will be placed in the dam in canvas bags weighing 40 to 60 kilograms. The sand core will not be used above elevation -0.2 meters in order to prevent loss of core by flushing through rock embankment during low tide. The dam will therefore remain pervious above elevation -0.2 meters. At low tide there will be a certain amount of leakage through the dam but this is considered beneficial with respect to the elimination of stagnant conditions in the Lagoon. Additionally, any silt that may tend to accumulate near the dam will probably be limited to an elevation below that of the lowest tide (elevation zero) due to cleaning action of the leakage through the dam. On the contrary, at high tide, the only movement of water will occur above elevation of approximately +1.0 meters therefore it is not necessary for the dam to be impervious with respect to salinity between elevations 0 and +1.10 meters.

5. Expected Future Maintenance

The dam will not require any maintenance on a periodic basis. It is expected that it will last at least 40 years without requiring any work. At worst, there may be some rearrangement of rock fragments as the dam settles through the first four or six years after its construction. This problem is discussed in subsection B. After the dam has settled, no further problems are expected and at the most, some minor repairs and additions of rock may be required after the dam has been subject to floods for a long number of years.

B. CONSTRUCTION REQUIREMENTS AND COSTS

1. Material Sources and Transportation to Cotonou

The nearest quarry where the necessary rock is available is located at Dassa-Zoume approximately 155 kilometers north of Cotonou. This quarry has been recently reactivated since the quarry of Dan, which was used for the construction of the Port of Cotonou, became exhausted. A railroad track is available near Dassa-Zoume. A railroad spur leading to the quarry also exists and can be easily reactivated for immediate use. Therefore transportation to Cotonou would be done by rail. The OCDN officials have confirmed the feasibility of transporting the rock from Dassa-Zoume and have given an estimate for the transportation costs to Cotonou.

The sand for the dam core can be obtained at the existing sand bar. Here it can be graded to coarser size and placed in bags. A barge can easily transport it to the construction site for placement in the dam.

2. Probable Construction Methods

One possible method of construction would be to dump the materials from the lagoon banks and gradually proceed to close the gap in the lagoon. This method, however, could create problems. As the gap between the two embankments begins to

narrow, high velocities through the partially completed dam would require heavy rock material and would make the placement extremely difficult.

For this reason, a different construction method is recommended. The method would consist of constructing the dam in approximately 0.5 meter lifts placed evenly across the full length of the dam. This would insure that the velocities of flow over the partially completed dam remain relatively low. In order to implement this procedure at least two good-sized barges will need to be employed, one transporting rock and the other transporting the sand in bags for the core. With two barges an efficient cycle of operations could be obtained so that one barge is placing the materials in the dam while the other is being loaded.

3. Dredging of the Dam Foundation and Protection of Banks

A certain amount of dredging will be required to remove the loose bottom materials and to excavate a trench in which the bottom of the dam can be anchored.

In order to protect against a possible damage of the lagoon banks in the immediate vicinity of the dam, it is proposed that the embankment be constructed and protected with rock rip-rap for approximately 50 meters on the ocean side, and 180 meters on the upstream side on both sides of the lagoon (See Figure 9-1).

The existing rock jetty should be removed in order to avoid constricting the flow in the immediate vicinity of the dam.

4. Expected Maximum Settlement of Dam

Due to compressible substrata, approximately 20 meters below the lagoon bottom a probable maximum settlement of 50 centimeters is anticipated. This will require the following procedure for the phasing of the construction of the dam:

Initially, the dam should be constructed to elevation of +1.10 meters. As the dam construction proceeds, some settlement will take place, and, with the top of the dam brought to +1.10 meters in height, the total settlement from the beginning of construction may already amount to 5 centimeters. This stage of construction should be completed in approximately six months, and just before the beginning of the flood season (approximately October 1975). The dam will continue to settle until the completion of the existing bridge repairs in January of 1978. By this time, it will have settled approximately an additional 10 centimeters, bringing the top of the dam below the required elevation of +1.10 meters. At this time, the top of the dam can be restored to elevation +1.15 meters in order to provide a slight excess to offset future additional settlement. The final adjustments in the top of the dam should be done approximately in 1982, but the measurements of the elevations in the top of the dam should be taken yearly, to chart the progress of the settlement.

It must be noted that a much more precise program and construction procedure can be developed in final design after detailed core borings are obtained and more laboratory testing has been made.

In order to provide for future adjustments in the top of the dam, it is suggested that sufficient rock be acquired at Dassa-Zoume as part of this project. The excess rock should be stockpiled, possibly in an area within the yard of Travaux Publics on the eastern side of Cotonou. It is proposed that later adjustment work for the dam be financed by the Dahomean Government. The cost should not be great, since the rock will be already available in Cotonou and could easily be trucked to the dam and placed. In fact, during dry seasons, the heavy trucks will be able to drive across the dam and dump the rock The cost of this work should not exceed 9 millions Fr. CFA in 1982.

5. Construction Quantities and Costs

The construction quantities and costs have been estimated to include the necessary work as explained in the foregoing subsections. The detailed breakdown for American and Foreign Procurement is shown in Appendix A, pages A-12 and A-19.

SECTION X

OTHER EROSION CONTROL ALTERNATIVES

A. LAGOON BANKS PROTECTION

1. Proposed Future West Bank Boulevard

As a consequence of the general erosion in the Cotonou Lagoon, the lagoon banks have suffered extensive damage. In 1966, BCEOM has made a detailed study, financed by FAC, for the improvement of the lagoon banks. [1]

The recommended work consisted of two phases. In the first phase, (Project A) it was decided to repair and place temporary protection on both the east and west banks. In the second phase (Project B) a permanent type of embankment with rock protection was proposed. The project included the construction of the West Bank Boulevard as recommended in the Cotonou Master Plan. Figure 10-1 shows the typical section for each project.

Project A was estimated to require seven months of construction time. It required 23,000 tons of rock, 4,000 cubic meters of sandstone and 25,000 cubic meters of embankment materials. The total cost, in 1966, was estimated at 75 millions Fr. CFA.

Project B was expected to require 10 months to complete and involved approximately twice the amount of the materials as project A. The total cost in 1966 of Project B was estimated at 125 millions of Fr. CFA.

To date none of this construction has been undertaken, probably due to the fact that other planning for a dam and a bridge in the Cotonou Lagoon may require extensive revisions to the proposed improvements for the lagoon banks.

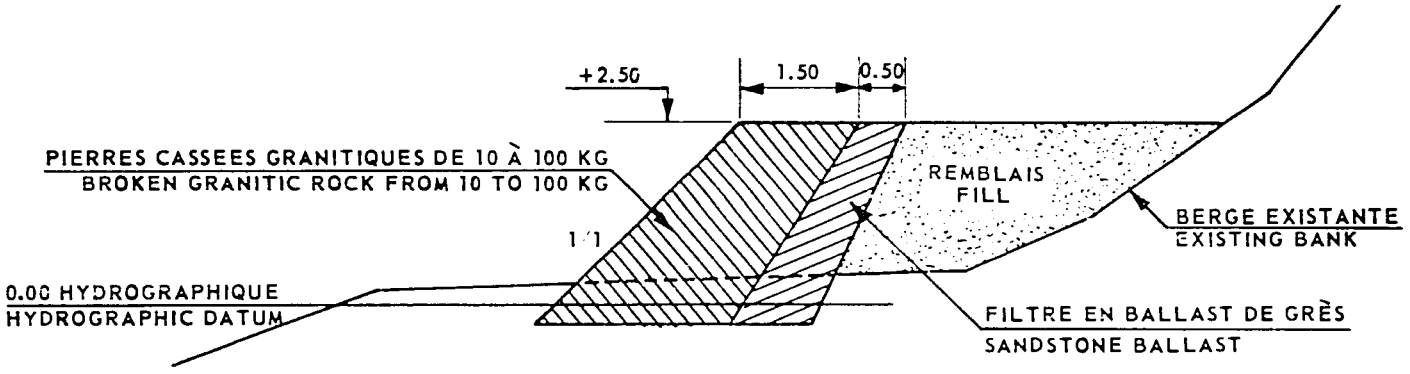
2. Estimated Cost of Required Rock Embankment

The following were the rock quantities and costs, estimated for Projects A and B by BCEOM in 1966:

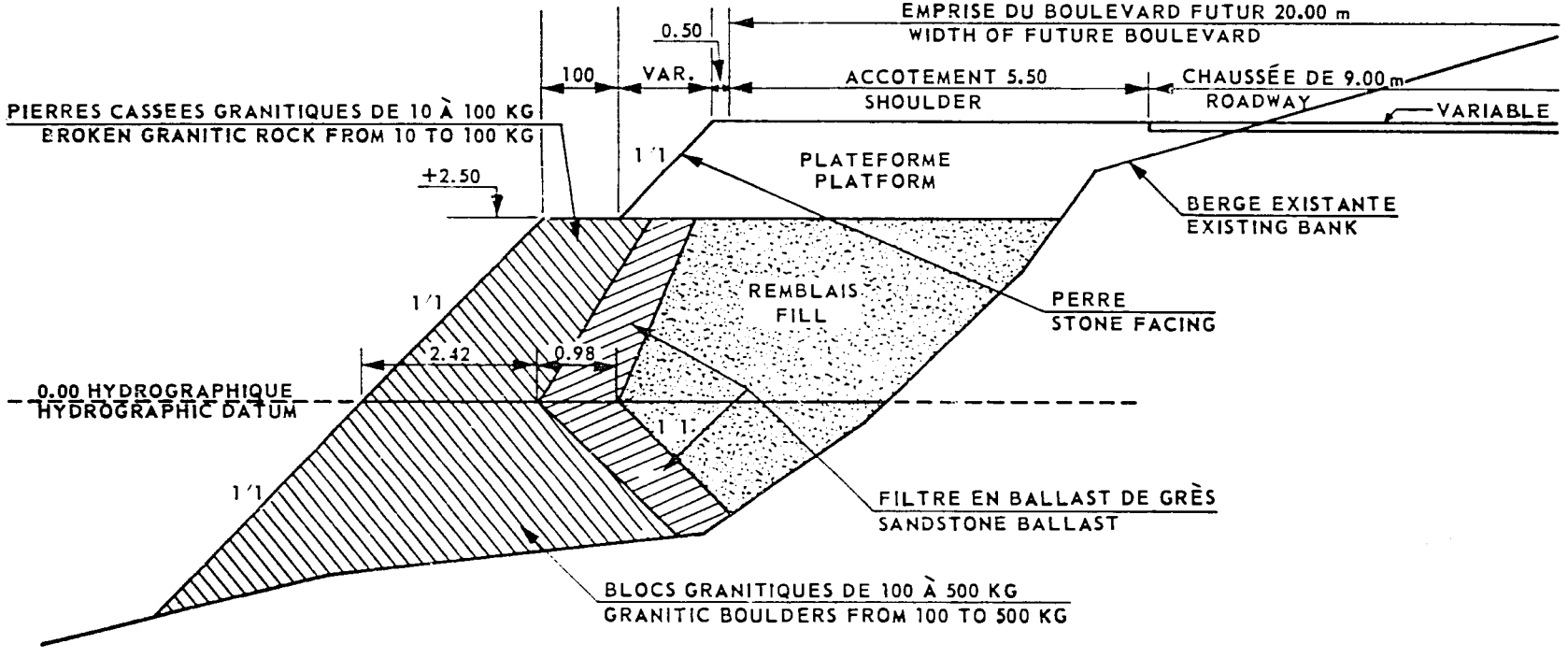
Project A	23,000 Tons	36.7 Millions Fr. CFA
Project B	43,000 Tons	64.5 Millions Fr. CFA
Total		100.2 Millions Fr. CFA

These costs, if escalated at 5% per year to 1975, would increase to 146.0 Millions Fr. CFA.

[1] Protection des Berges de la Lagune de Cotonou, Project No. 188, November 1966.



PROJET "A"
PROJECT "A"



PROJET "B"
PROJECT "B"

FIG. 10-1

It is safe to say that at least 50% of this cost or 73.0 Millions Fr. CFA. could be a saving attributed to the construction of the dam. However, this saving has not been included in the Benefit/Cost analysis for the dam.

B. PROTECTION OF BRIDGE FOUNDATION

1. Foundation Rock Mat

A dam at the lagoon mouth is an effective but costly erosion prevention structure. A substantially less expensive construction which would be equally effective against the erosion damage under the new bridge is a rock mat. It consists of rock fragments of sufficient size and weight to be able to resist the erosive forces, placed at the lagoon bottom under the bridge.

A rock mat has already been planned by BCEOM to be placed between the pilings under the existing bridge by 1972. The project has been financed by FAC and is expected to cost 45 million Fr. CFA. It is a tedious undertaking due to the necessity of confining the delivery of rock by train during off traffic hours (mostly during the night). After the transfer of the rock from the train to a barge, it will be necessary to place the rock partly by dumping and partly by hand between the piling. (See Figure 10-2).

In the case of the new bridge, it will be much easier to place the rock mat. The rock could be dumped between the piles as soon as they have been driven and before the pile cap and bridge beam construction is started.

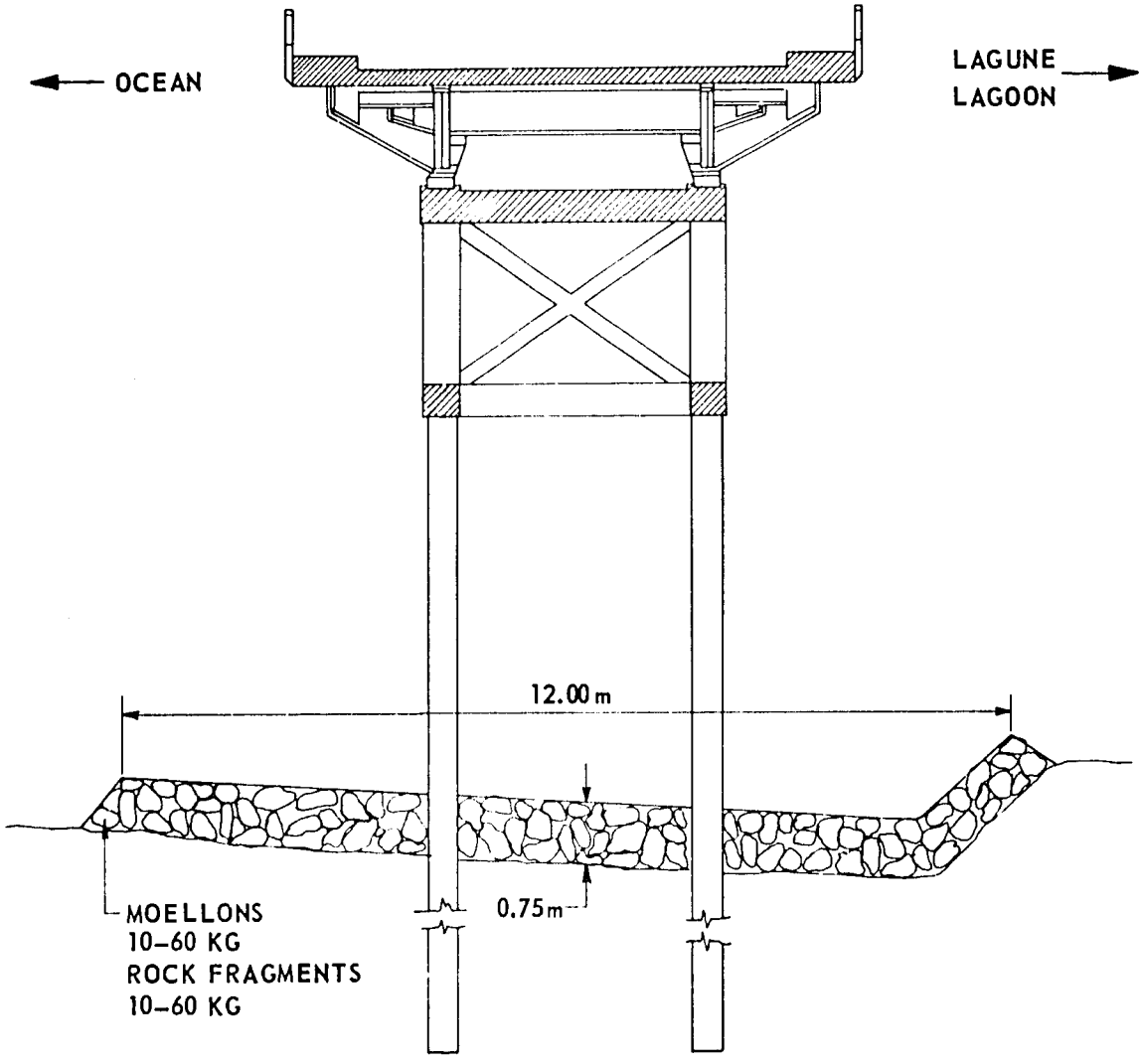
The rock mat should generally consist of rock fragments of 60 kg or less in size, forming a blanket of rock extending in width at least a few meters beyond the piling and having a total thickness of 0.75 meters.

2. Expected Life

Since the bridge piling in essence represents a constriction in the normal channel flow, there is a great deal of turbulence and high flow velocities around the pilings. Over a long period of time, some of the rock may begin to be scoured out. Thus, it is to be expected that a rock mat protection may need a total replacement after approximately 20 years.

3. Estimated Cost

The estimated quantities of rock and the construction cost for the rock mat are shown in detail in Appendix A, pages A-11 and A-18.



PROTECTION EN ENROCHEMENTS – PONT DE COTONOU ACTUEL
ROCK MAT PROTECTION – EXISTING COTONOU BRIDGE

FIG. 10-2

SECTION XI

CONSTRUCTION SCHEDULING

A. ESTIMATED COSTS AND TIME REQUIRED FOR FINAL DESIGN

1. Field Surveys, Core Borings and Testing

Updated detailed topographic and hydrographic surveys will be required for the final design of the bridge and the dam. Included in the surveys will be the establishing of control points for construction and elevation bench marks. In order to help determine the potential construction problems, updated flow velocity measurements should be made during both the flood season and the dry season of 1973. It is estimated that the required field work would take four months.

A program of core borings and standard penetration tests should be developed to obtain sufficient foundation data for final design. Included in the program for subsoil exploration should be one boring, penetrating 15 meters into the clay stratum, at each abutment and pier for the bridge and at least six borings for the dam. In addition, three bridge borings and three dam borings should have sufficient length to reach the bottom of the clay stratum, if it is within reasonable depth.

A laboratory program should include a sufficient number of tests on undisturbed samples to determine the consolidation characteristics of the clay stratum.

It would be extremely useful to perform at least one load test on a pile driven into the sand stratum at the location of the proposed Saint Michel bridge. In lieu of this, at the very minimum, static penetrometer tests should be made. The total cost of the core boring and testing program for final design is estimated at 24 million Fr. CFA. This cost is included in the bridge cost estimates under the contingencies item. The core boring and testing work could be completed in approximately eight months.

2. Hydraulic Model Studies

Hydraulic model studies would be very desirable in order to obtain more precise data on salinity reduction and backwater levels during flood with the proposed dam. Useful information could also be obtained on velocities of flow during various stages of construction of the dam. The overall cost of a hydraulic model, although substantial, would not be unreasonable in relation to the overall magnitude of investment. The design data that could be derived from a hydraulic model study would more than justify the expenditure through possible savings in the cost of the dam through more

economical design. The total cost of a hydraulic model is estimated not to exceed 16 million Fr. CFA. The necessary studies could be made and completed concurrently with the core boring and testing work.

3. Final Design and Contract Letting

The final design and preparation of contract bid documents should be started after the completion of the field surveys. It is estimated that this phase would require 12 months. The advertisement for bids, prequalification of prospective bidders, receipt of bids and the construction contract award will require a minimum of six months.

The total time from the beginning of final design to the beginning of construction is estimated to require 24 months. A scheduling network for this portion of the project is included in Figure 11-1.

B. ESTIMATED REQUIRED TIME FOR CONSTRUCTION

1. Procurement of Materials and Construction Equipment

In order to maintain an efficient and reasonably fast progress, it will be necessary to initially expedite the following:

a. Establish a construction yard and an area for stockpiling work materials near the site of the dam.

b. Bring the necessary construction and materials handling equipment to Cotonou.

c. Initiate the quarry operations at Dassa-Zoume and make arrangements with OCDN railroad for transportation of rock to Cotonou.

d. Initiate fabrication of precast elements and make arrangements for shipment to Cotonou, or

e. Acquire materials and equipment for establishing a prestressed concrete casting yard and arrange for their shipment to Cotonou.

f. Procure two construction barges either locally in Cotonou, or arrange for their shipment from abroad to Dahomey.

With the above listed priority items completed, the work can begin simultaneously on the grading and paving of bridge approach roads, quarry work and transportation of rock to Cotonou, and preparation of sandbags for placement in the dam.

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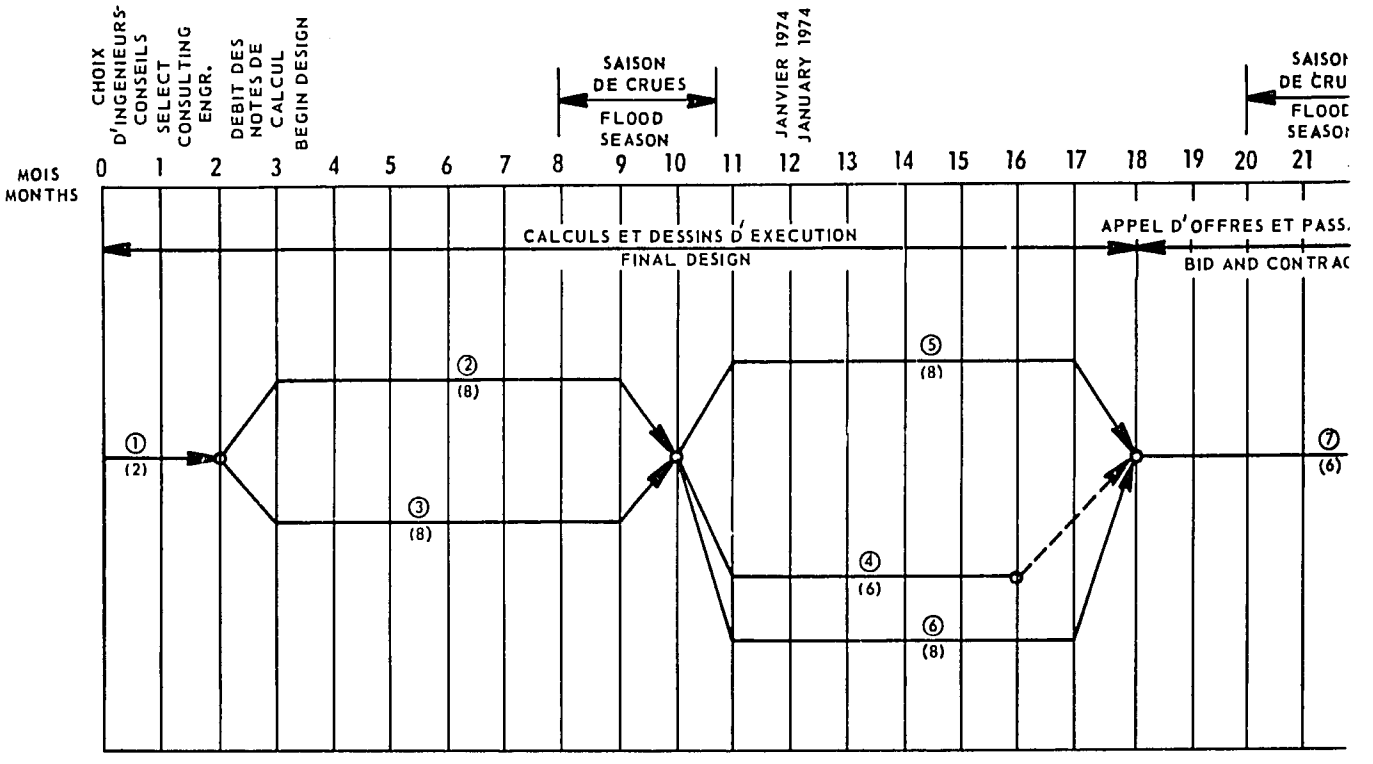

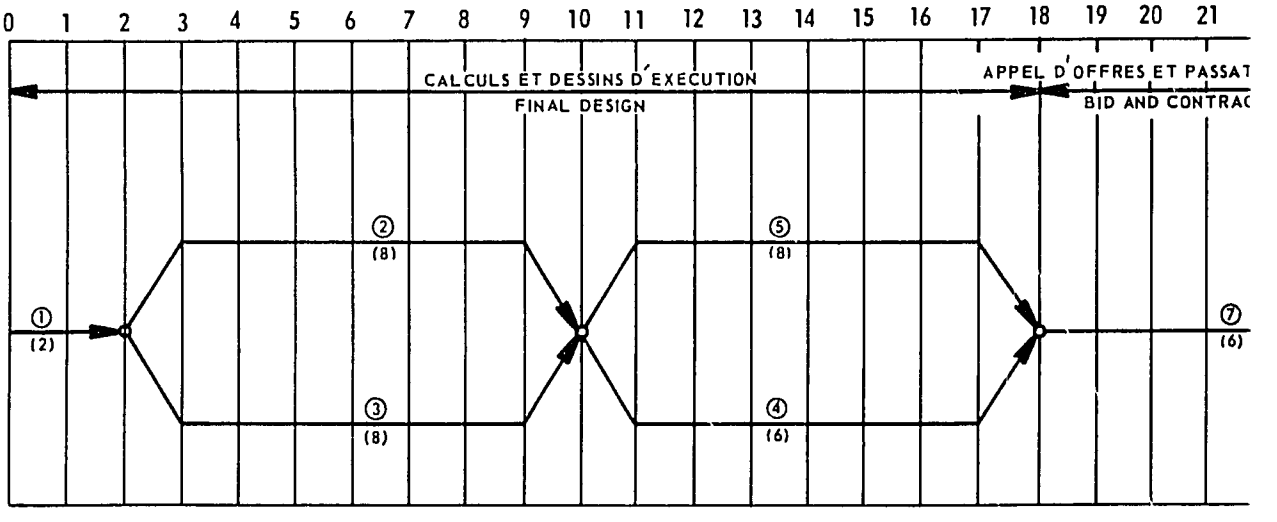

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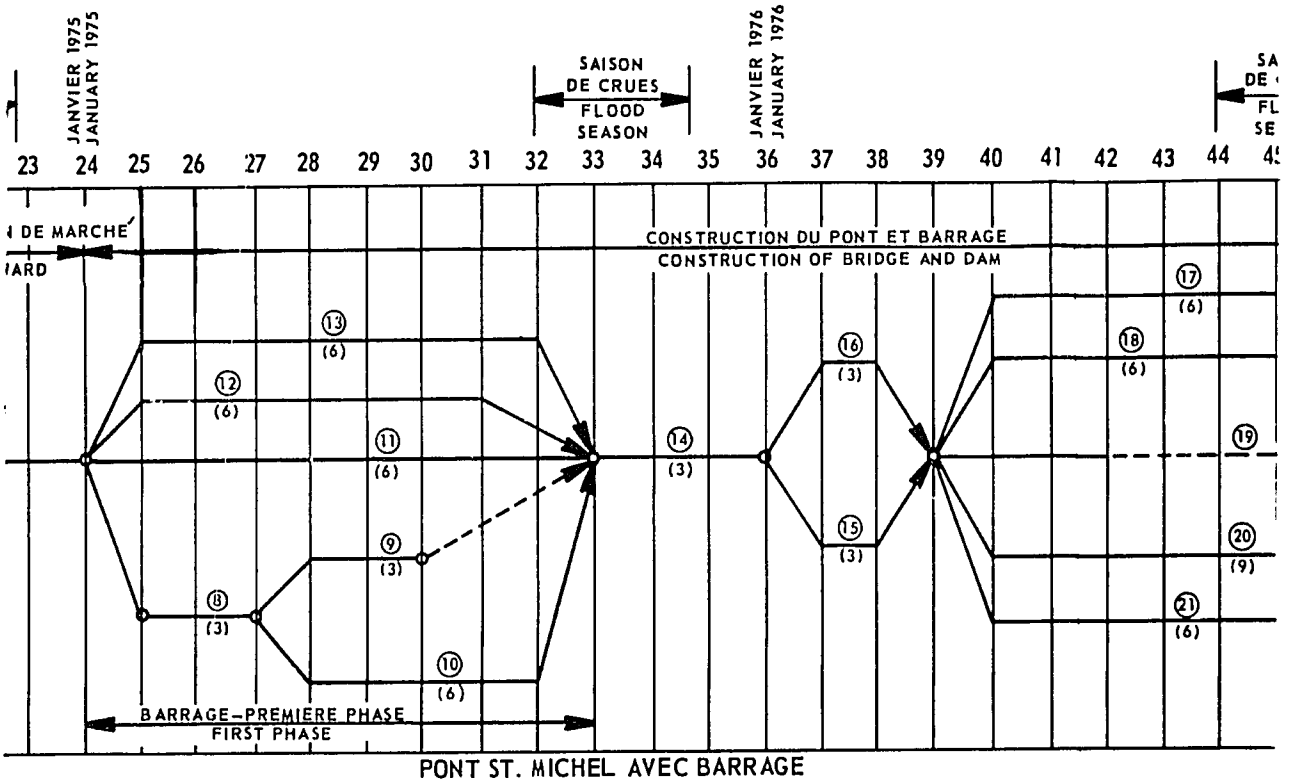
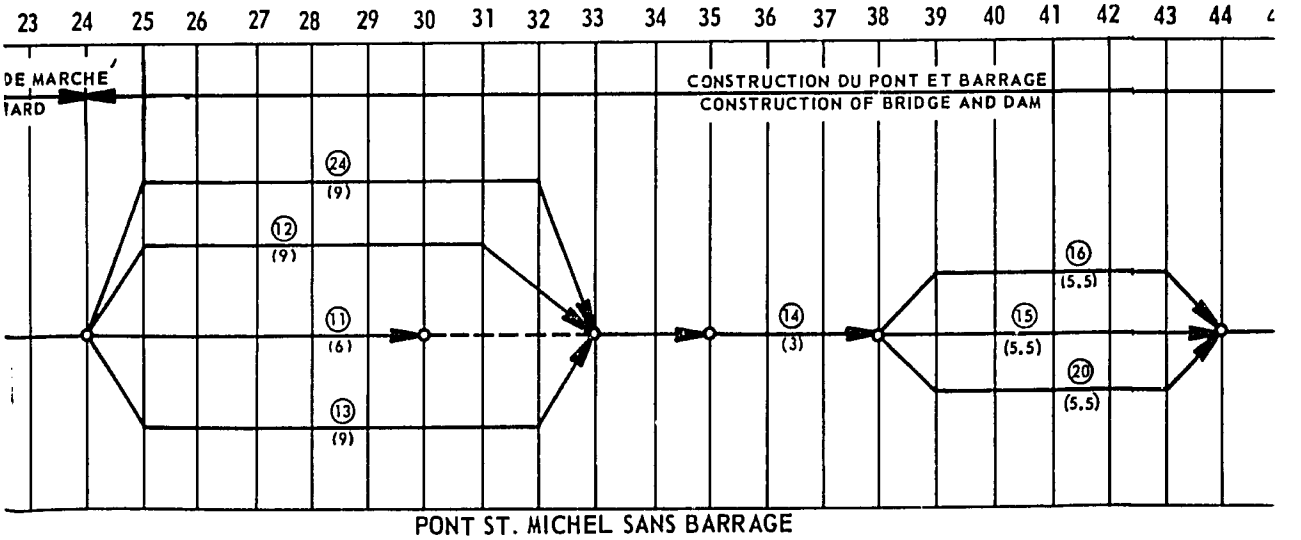


PONT ST. MICHEL AVEC BARRAGE
ST. MICHEL BRIDGE WITH DAM



PONT ST. MICHEL SANS BARRAGE
ST. MICHEL BRIDGE WITHOUT DAM

PROGRAMME D A
PROJECT

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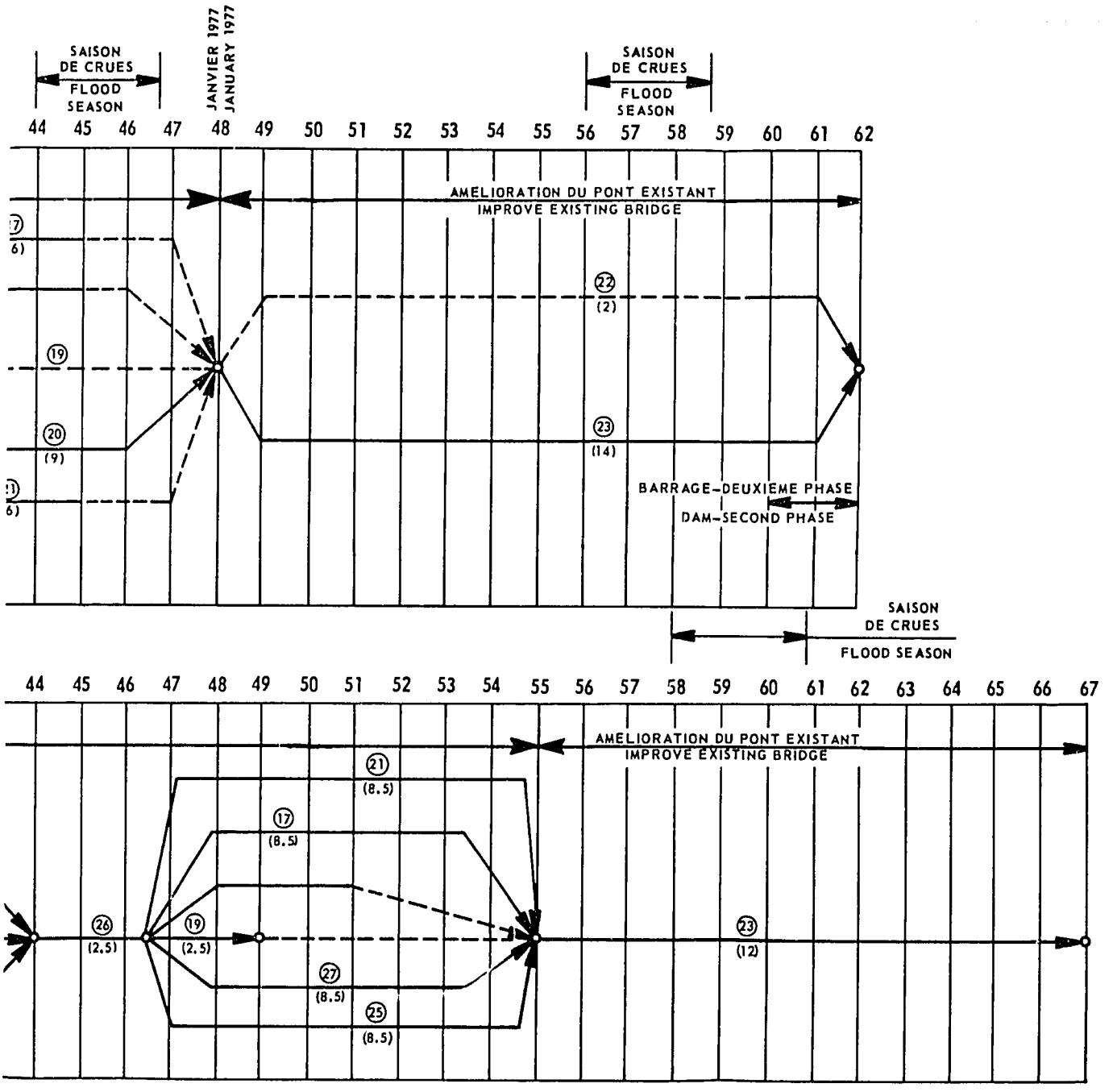

ME D ACTIVITES DU PROJET
OJECT SCHEDULING

193B

LEGEND

1	ETUDES INITIALLES AU SIEGE CENTRAL INITIAL HOME OFFICE STUDIES
2	FORAGES CORE BORINGS
3	RELEVES TOPOGRAPHIQUES ET HYDROGRAPHIQUES TOPOGRAPHIC AND HYDROGRAPHIC SURVEYS
4	CALCULS ET DESSINS D'EXECUTION (ACCES) ROADWAY DESIGN (APPROACHES)
5	CALCULS ET DESSINS D'EXECUTION (PONT) STRUCTURAL DESIGN (BRIDGE)
6	CALCULS ET DESSINS D'EXECUTION (BARRAGE) DESIGN OF DAM
7	APPEL D'OFFRES ET PASSATION DE MARCHE BIDS AND CONTRACT AWARD
8	TRANSPORT DES ENROCHMENTS TRANSPORTATION OF ROCK
9	TRANSPORT DES ENROCHEMENTS TRANSPORTATION OF ROCK
10	BARRAGE-PREMIERE PHASE DAM-FIRST PHASE
11	MISE EN CHANTIER ET TRANSPORT D'ENGINS DE CONSTRUCTION MOBILIZATION AND TRANSPORT OF CONSTRUCTION EQUIPMENT
12	TERRASSEMENT-ACCES OUEST GRADING-WEST APPROACH
13	TERRASSEMENT-ACCES EST GRADING-EAST APPROACH
14	BATTAGE DES PIEUX PILE DRIVING
15	BATTAGE DES PIEUX PILE DRIVING
16	CHAPEAUX DE PIEUX PILE CAPS
17	REVETMENT ROUTIER-ACCES OUEST PAVING-WEST APPROACH
18	CHAPEAUX DE PIEUX PILE CAPS
19	BATTAGE DES PIEUX PILE DRIVING
20	CONSTRUCTION DES POUTRES ET TABLIER SUPERSTRUCTURE CONSTRUCTION
21	REVETMENT ROUTIER-ACCES EST PAVING-EAST APPROACH
22	BARRAGE-SECONDE PHASE DAM-SECOND PHASE
23	AMELIORATION DU PONT EXISTANT EXISTING BRIDGE IMPROVEMENTS
24	PONT EXISTANT-AMELIORATION DES CULÉES EXISTING BRIDGE-ABUTMENTS REPAIR
25	PROTECTION DES PIEUX- RADIER EN ENROCHEMENTS PILE PROTECTION-ROCK MAT
26	CONSTRUCTION DES POUTRES ET TABLIER SUPERSTRUCTURE CONSTRUCTION
27	CONSTRUCTION DES POUTRES ET TABLIER SUPERSTRUCTURE CONSTRUCTION
28	ARRÊT DE TRAVAIL-SAISON DE CRUES NO WORK-FLOOD SEASON

(23) NOMBRE ASSIGNÉ A LA TÂCHE
ACTIVITY NUMBER

(14) DURÉE EN MOIS
DURATION IN MONTHS

FIG. 11-1

193C

2. Effect of Flood Season on Construction Progress

The dam must be constructed in time before the flood season of 1975 in order to facilitate the waterborne construction operation during the flood season. As mentioned earlier in this report, the construction of the dam will greatly reduce the flow velocities in the lagoon, even during the flood.

During the six months necessary to complete the first phase of the construction of the dam, the bridge beams and the piles can either be brought to Cotonou from abroad or precast in Cotonou. Therefore, as soon as the dam, Phase 1, has been completed, the pile driving operations can begin.

Without the construction of the dam, however, there can be no waterborne construction work during the flood season. If, instead of the dam, alternate erosion protection (rock mat) were to be constructed, the overall completion of construction would be delayed by at least five months, and the opening of the new bridge to traffic would be delayed by seven months (See Figures 11-1 and 11-2). This would result not only in increased construction costs, but also in loss of vehicle operating savings during the seven months of delay.

3. Construction of Bridge Approaches

The construction of the bridge approaches (for Saint Michel Bridge) will be done under two separate construction contracts. One will be financed by FED, and the other by the agency which will finance the bridge and the dam project.

It is to be noted that, in order to obtain maximum immediate vehicle operating savings, the full approach roads from the west to the east connection with the International Route No. 11 should be constructed and completed at the same time that the Saint Michel bridge is ready to be opened to traffic. To accomplish this, and assuming that the FED financed approach road project is begun in January of 1975, the following are the construction periods available for the completion of the approach roads (See pages A-4 and A-5 in Appendix A):

STA 0 to STA 4900 (FED project)	24 months
STA 4900 to Saint Michel bridge and Saint Michel Bridge to STA 8000	18 months [1]

It can be noted on the construction schedule network (Figure 11-1) that approach road construction has been planned in two stages. First the grading (nine months) and

[1] 18 months are required for construction; 24 months are available, since the approach roads need not be completed before the bridge construction is finished.

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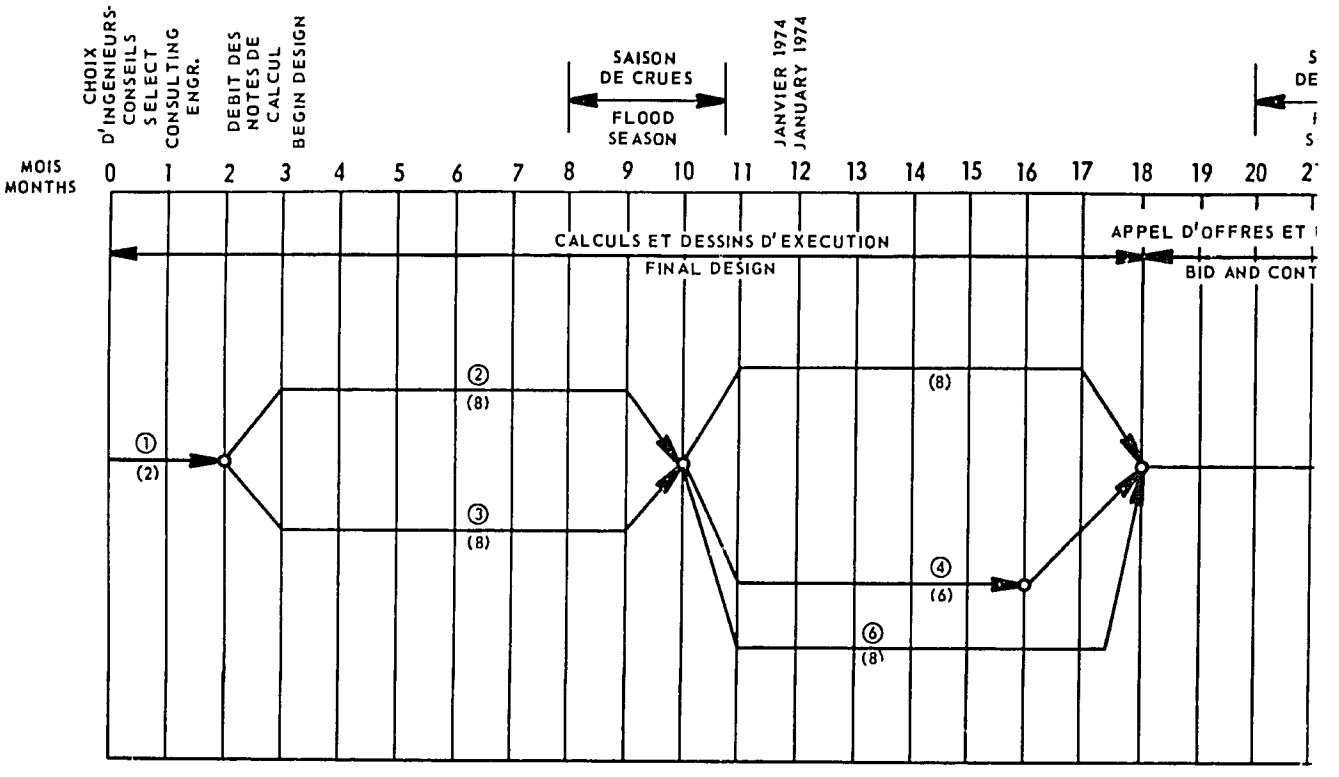

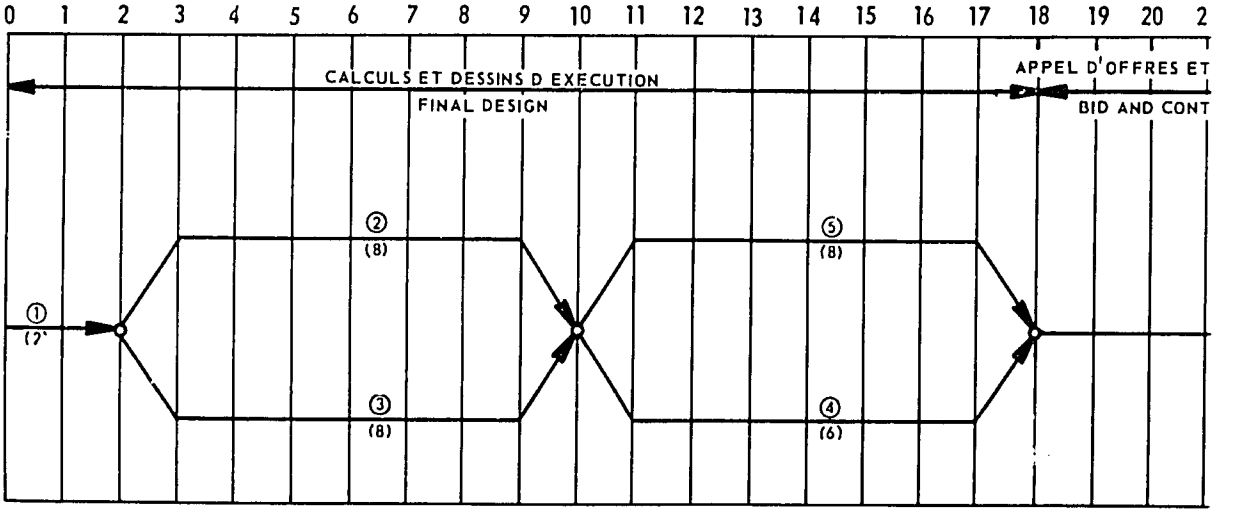

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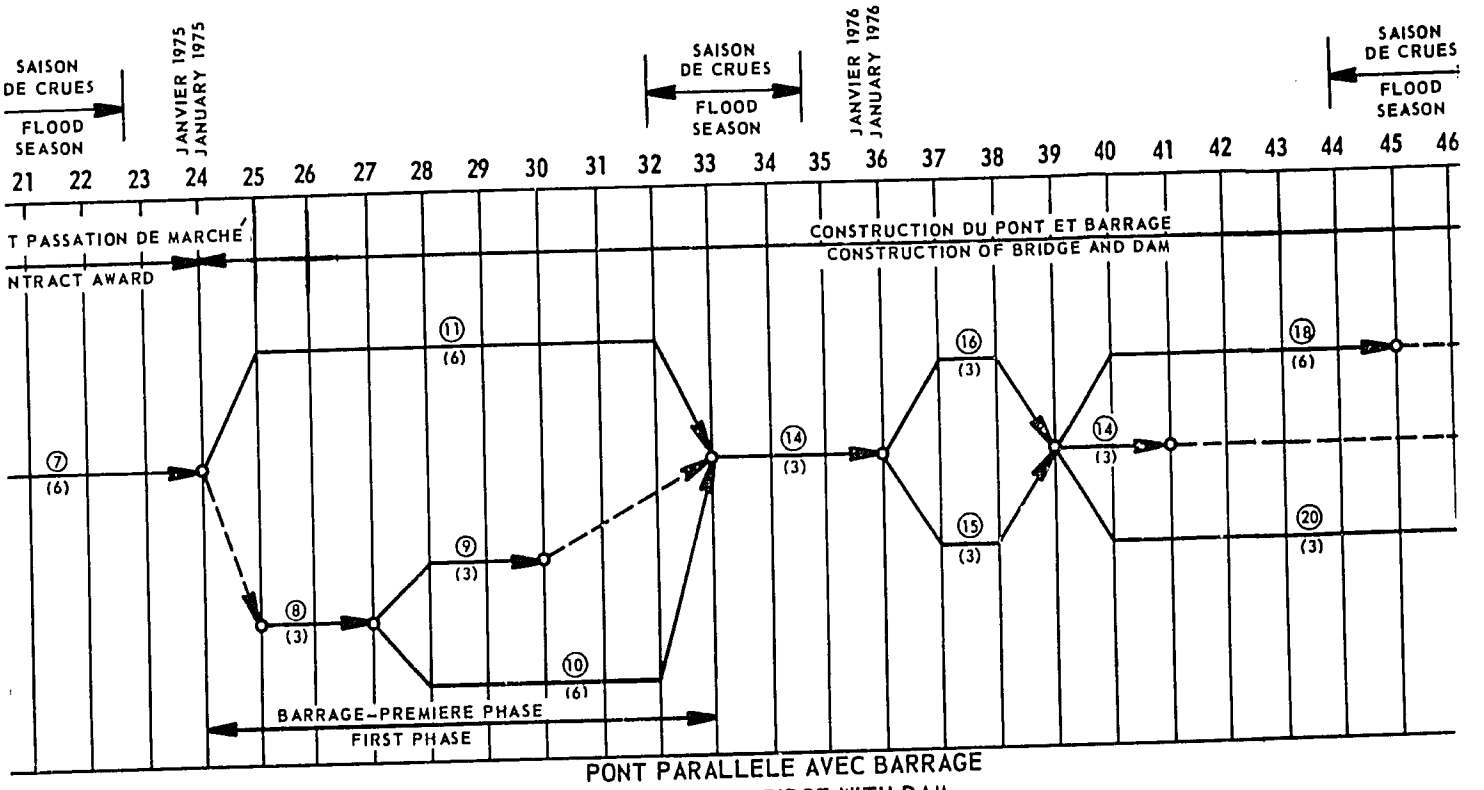
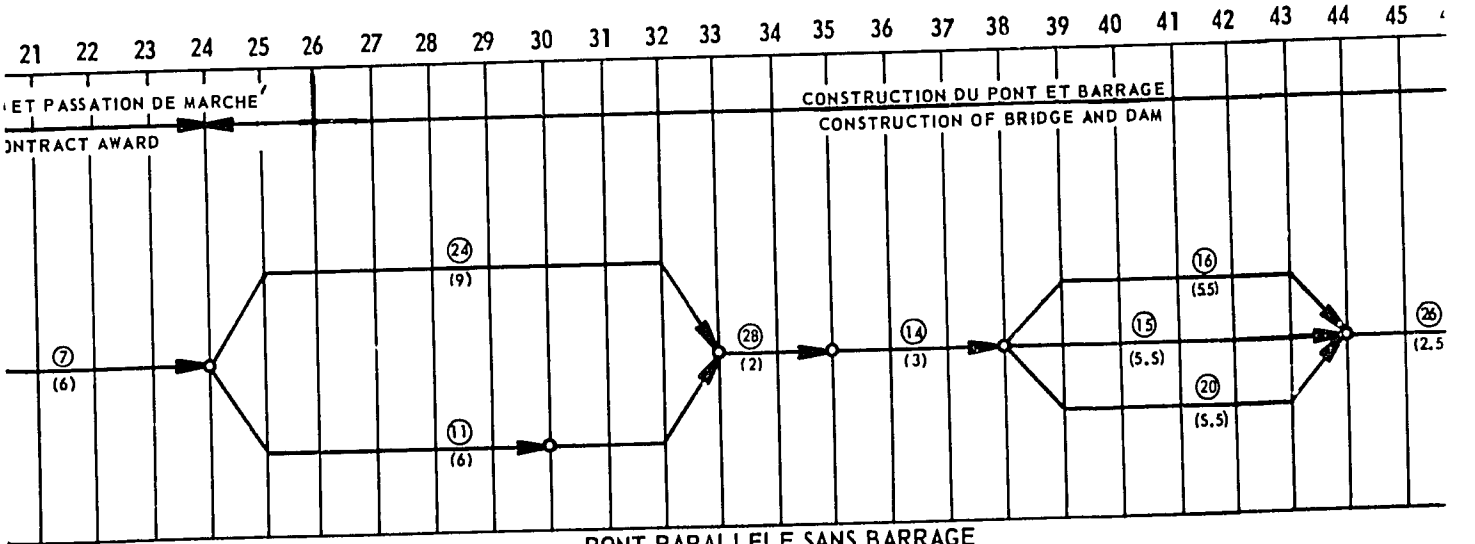


PONT PARALLELE AVEC BARRAGE
PARALLEL BRIDGE WITH DAM



PONT PARALLELE SANS BARRAGE
PARALLEL BRIDGE WITHOUT DAM

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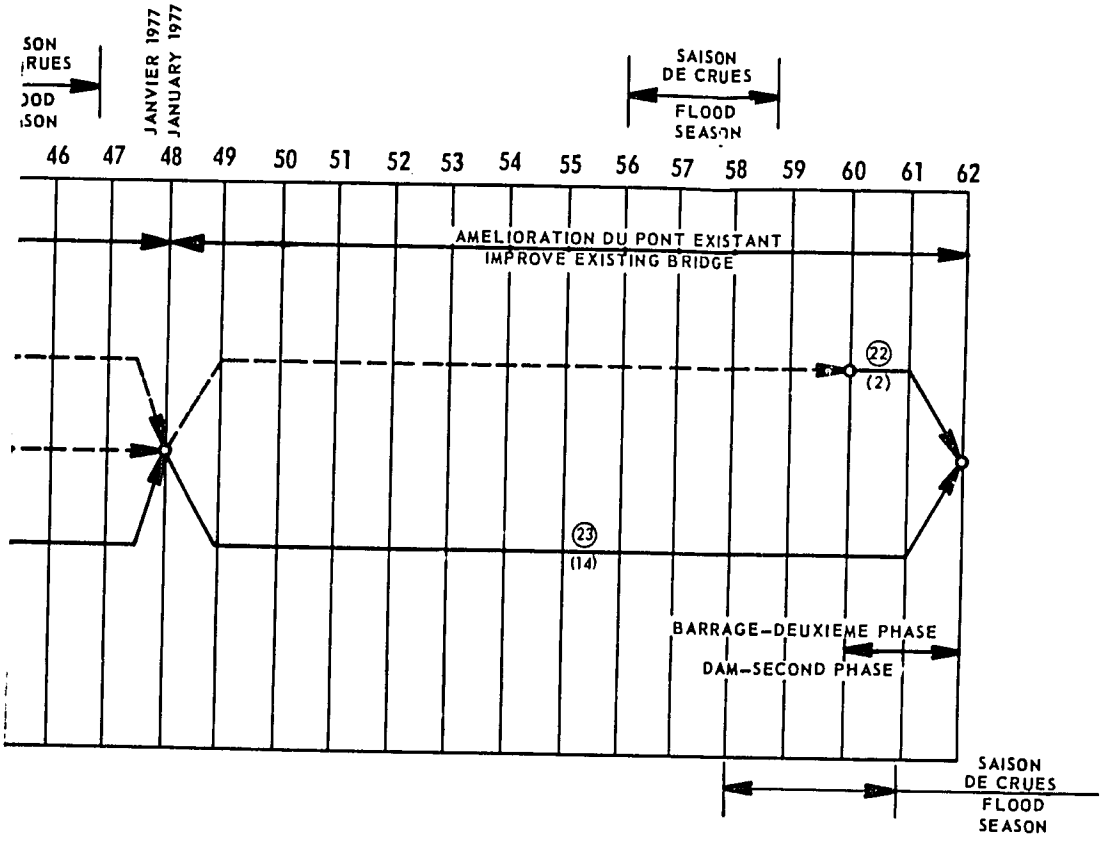

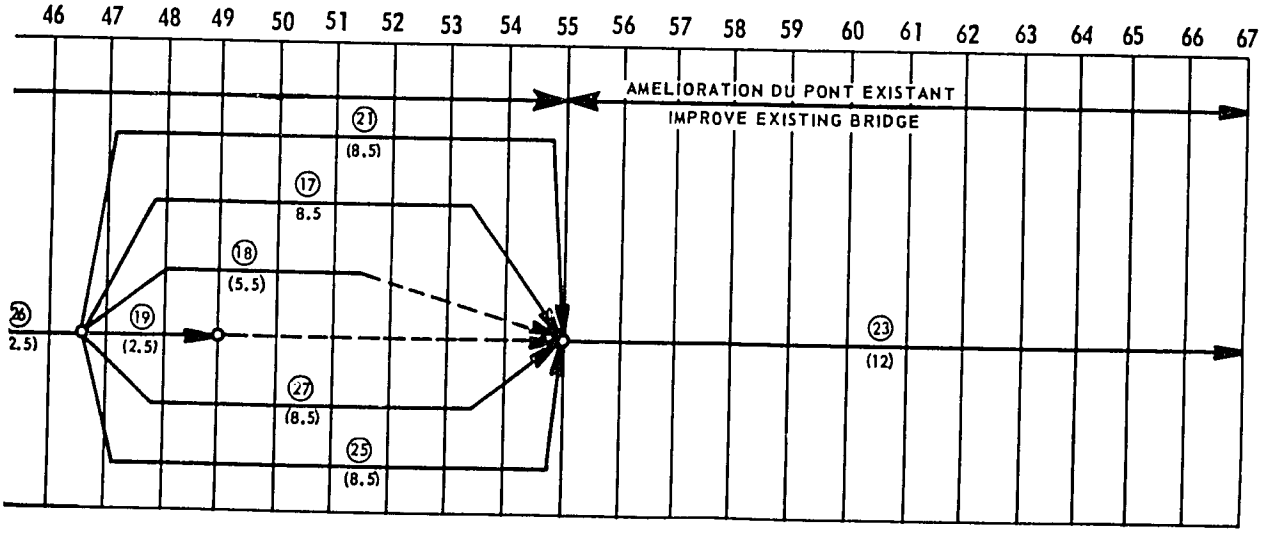

IVITES DU PROJET
HEDULING

1955

LEGEND

1 ETUDES INITIALLES AU SIEGE CENTRAL
INITIAL HOME OFFICE STUDIES

2 FORAGES
CORE BORINGS

3 RELEVES TOPOGRAPHIQUES ET HYDROGRAPHIQUES
TOPOGRAPHIC AND HYDROGRAPHIC SURVEYS

4 CALCULS ET DESSINS D'EXECUTION (ACCES)
ROADWAY DESIGN (APPROACHES)

5 CALCULS ET DESSINS D'EXECUTION (PONT)
STRUCTURAL DESIGN (BRIDGE)

6 CALCULS ET DESSINS D'EXECUTION (BARRAGE)
DESIGN OF DAM

7 APPEL D'OFFRES ET PASSATION DE MARCHÉ
BIDS AND CONTRACT AWARD

8 TRANSPORT DES ENROCHMENTS
TRANSPORTATION OF ROCK

9 TRANSPORT DES ENROCHEMENTS
TRANSPORTATION OF ROCK

10 BARRAGE-PREMIERE PHASE
DAM-FIRST PHASE

11 MISE EN CHANTIER ET TRANSPORT D'ENGINS DE CONSTRUCTION
MOBILIZATION AND TRANSPORT OF CONSTRUCTION EQUIPMENT

12 TERRASSEMENT-ACCES OUEST
GRADING-WEST APPROACH

13 TERRASSEMENT-ACCES EST
GRADING-EAST APPROACH

14 BATTAGE DES PIEUX
PILE DRIVING

15 BATTAGE DES PIEUX
PILE DRIVING

16 CHAPEAUX DE PIEUX
PILE CAPS

17 REVETMENT ROUTIER-ACCES OUEST
PAVING-WEST APPROACH

18 CHAPEAUX DE PIEUX
PILE CAPS

19 BATTAGE DES PIEUX
PILE DRIVING

20 CONSTRUCTION DES POUTRES ET TABLIER
SUPERSTRUCTURE CONSTRUCTION

21 REVETMENT ROUTIER-ACCES EST
PAVING-EAST APPROACH

22 BARRAGE-SECONDE PHASE
DAM-SECOND PHASE

23 AMELIORATION DU PONT EXISTANT
EXISTING BRIDGE IMPROVEMENTS

24 PONT EXISTANT-AMELIORATION DES CULÉES
EXISTING BRIDGE-ABUTMENTS REPAIR

25 PROTECTION DES PIEUX-RADIER EN ENROCHEMENTS
PILE PROTECTION-ROCK MAT

26 CONSTRUCTION DES POUTRES ET TABLIER
SUPERSTRUCTURE CONSTRUCTION

27 CONSTRUCTION DES POUTRES ET TABLIER
SUPERSTRUCTURE CONSTRUCTION

28 ARRÊT DE TRAVAIL-SAISON DE CRUES
NO WORK-FLOOD SEASON

(23) NOMBRE ASSIGNÉ A LA TÂCHE
ACTIVITY NUMBER

(14) DURÉE EN MOIS
DURATION IN MONTHS

FIG. 11-2

then the paving (three months) with an interval of six months without any work on the approaches. This was done in order to allow the roadway fill on the eastern approaches, which will be placed in swamping grounds, to stabilize itself prior to the paving operation. It will be desirable that, during the six months interval, the fill on the eastern approach be constructed higher than the required finished elevation in order to help faster consolidation of its foundation and then that it be adjusted to final grade just prior to the beginning of the paving work.

4. Construction of the New Bridge and Existing Bridge Repairs

The total time required for the construction of the bridge is 15 months. Of this time, pile driving and installation of pile caps need 12 months and the erection of bridge beams, bridge deck and lighting need nine months. The bridge superstructure construction will overlap by six months with the pile driving and pile caps construction.

The bridge abutments can be constructed during a six month period beginning in January of 1976, in parallel with pile driving and pile cap construction.

The overall bridge construction is scheduled to begin in October 1975 and be completed by January 1, 1977.

As soon as the new bridge with its approaches is completed and opened to traffic, the work on the existing bridge can begin. The entire lagoon crossing traffic will be shifted to Saint Michel bridge so that the repair work may proceed without interference. The existing bridge repairs are estimated to require 14 months with completion scheduled for March of 1978. This completion date would be delayed to October of 1978 if rock mat is constructed instead of the dam.

The construction schedule network for a parallel bridge alternative with or without the dam, is shown in Figure 11-2. The construction time for all items of work is basically the same, although the parallel bridge is less wide than that at Saint Michel, due to extremely congested traffic conditions which will exist in the immediate vicinity of the construction site. This will considerably slow down the movement of construction equipment and will make the delivery of construction materials and prestressed elements particularly difficult. Due to cramped conditions, the construction yard will be located a few kilometers away and this will cause delays in hauling and other complications.

SECTION XII

ECONOMIC FEASIBILITY STUDY

A. NATIONAL ECONOMIC SITUATION

1. Population Growth

The population of Dahomey in 1970 is estimated at nearly 2.7 million based upon projections from the last governmental counts in 1964 at an average growth rate of 2.8% per year, as shown in Table XII-1. The three coastal prefectures are the most densely populated and are growing more rapidly than the national average. The two prefectures nearest Cotonou, Oueme and Atlantique, with the city of Cotonou at their coastal boundary, contain about 40% of the national population and a much greater proportion of the urban population.

TABLE XII-1

DAHOMEY POPULATION DATA
(Thousands of Persons)

	Dahomey		Oueme Prefecture		Atlantique Prefecture	
Years	Total	Urban	Total	Urban	Total	Urban
1961	2106	200	464	64	309	95
1964	2291	340	516	93	366	146
1970 (est)	2682	417	603	114	446	184

Source: Ministry of the Interior headcounts in 1961 and 1964 as adjusted by the Institut National de la Statistique et des Etudes Economiques (INSEE) study are shown, projected to 1970 at 2.8% per year for the total population. The urban population is from the INSEE study for 1961 and, thereafter includes towns of more than 10,000 people.

Dahomey is still largely an agricultural society, as only slightly more than 15% of the estimated population live in towns of over 10,000 people. The two prefectures nearest Cotonou contain over 70% of the urban population, with the two largest cities, Cotonou and Porto-Novo, having about 50% of the urban total.[1] Of these two cities,

[1] Annuaire Statistique, Ministere du Plan et de la Prospective, 1967

Cotonou is considerably larger with an estimated 150,000 people living in the city and its suburbs in 1970. Although the available information on the larger cities in Dahomey is not sufficiently precise to calculate accurate growth rates, these two cities appear to be growing much more rapidly than the national average.

Although starting from a small base, Dahomey, like many other African countries, is becoming more urbanized. This trend is expected to continue, with the rate of urban growth dependent upon the employment opportunities available in each city or town. The relatively high rates of population growth and migration will probably continue in the near future, as the government has made no concentrated effort to discourage large families or migration to the urban areas.

2. Agriculture

Agriculture is the most important economic activity, accounting for about 40% of the gross domestic product in recent years. Crop production and animal husbandry occupy a great majority of the people's time with most farm families dependent upon subsistance production from such crops as maize, cassava, sorghum, millet, and yams. Subsistence agriculture is characterized by the sale or barter of any small excess family needs in the villages and towns.

Agricultural products constitute nearly all the exports from Dahomey and palm products, cotton, ground nuts, shea nuts and coffee are the important export crops. The bulk of these exports are marketed in the countries of the European economic community, and most are subsidized in price.[2] Once processed locally, export crops are shipped through the Port of Cotonou. The latest official data on the volume and value of the major export crops is shown in Table XII-2.

Animal production has remained relatively constant in recent years. There are approximately two million domestic animals in Dahomey, and per capita consumption of animal protein is low. However, the annual slaughter rate is relatively low.

Although nearly 40% of the country is in classified and protected forests, the annual harvest is insufficient for local needs, and lumber is imported from neighboring countries.

[2] Aspects Economiques 1968, Ministere de L'Economie et des Finances.

TABLE XII-2

DAHOMEY MAJOR EXPORT CROPS
(Volume in Thousands of Tons/Value in Millions of Fr. CFA)

	1965		1966		1967	
	Volume	Value	Volume	Value	Volume	Value
Palm products	62.7	2455.7	39.1	1369.5	51.1	1528.0
Cotton	1.3	431.1	2.3	271.9	2.6	331.7
Shelled ground nuts	2.3	95.8	3.3	113.3	5.5	223.1
Shea nuts	5.0	100.5	2.8	44.5	6.4	170.7
Coffee	0.9	108.9	1.2	107.5	1.1	139.4

Source: Annuaire Statistique 1967, Direction de la Statistique: Bulletin Statistique-Supplement Commerce Exterieur, No. 15, August 1968.

Production increases for most export crops are being supported by the government, other local agencies, external assistance, and by price subsidies: so prospects for future increases in volume are bright. As noted in Table XII-2, palm products are the most important export crop and additional plantings are being made according to schedule. However, cotton production has expanded most rapidly in recent years, rising from about 6,500 tons of seed cotton in 1966 to 23,000 tons in 1969, as a result of increased acreage and the introduction of improved varieties. Ground nut, shea nut, and coffee production have also risen, and other new export crops are being introduced.

Although the price of most agricultural exports will probably decline somewhat, ongoing programs for the expansion of production should increase the volume sufficiently to raise the value of agricultural exports by 5% to 7% annually for several years in the future.

3. Fishing

Up to 80,000 people living along the lakes, rivers, and ocean depend upon fishing for a livelihood and the catch is a primary source of animal protein for human consumption.

Lake fishing has been the most important, supporting some 60,000 people. During the last twelve years, however, yields have fallen sharply from an annual catch of about 16,000 metric tons in 1959 to about 4,500 metric tons in 1971. This is due to the problems in Lake Nokoue caused by the permanent opening of the estuary at Cotonou to

the ocean. These problems will be covered in detail in Subsection C.

Maritime fishing has been of lesser importance, with peak annual production of less than 5,000 tons; but improved facilities are being constructed at Cotonou to store and market greater quantities. The introduction of larger, refrigerated ships for offshore fishing should extend the range and depth of the catch areas.

4. Minerals

Mineral resources are not currently exploited to any significant extent, although several known deposits are under investigation.

The government is interested in developing a large limestone deposit at Onigblo, located 18 kilometers north of the railway terminus at Pobe. This limestone deposit would supply the newly-completed clinker plant at Cotonou, and a much larger integrated cement plant which is proposed to have sufficient capacity to supply local needs and exports to neighboring countries. Earlier studies have determined that over 13 million tons of limestone, suitable for cement production, are available at Onigblo and studies on the costs of extraction and on construction of a cement plant are continuing. However, other recently discovered deposits near Allada, Dahomey, and at Lome, Togo may prove cheaper to exploit. Togo and Dahomey have agreed to share whatever site proves the most feasible. If developed, the cement and clinker from Onigblo would probably be transported through Cotonou for distribution locally and for export.

A large deposit of quality marble is known to exist about 60 kilometers north of Kokoro, but the government has been unsuccessful in finding foreign firms to undertake development of the deposits. Large deposits of iron ore occur near Malanville, but the low ore content, (about 40-45%) and the distance from a seaport renders development uneconomical at the present time. Few other known mineral resources exist and the only current exploitation is a small amount of gold mined near Perma.

5. Petroleum

Exploration in waters offshore from Porto-Novo, done over the past several years by the Union Oil Company, has developed some promising wells; however, further drilling will be required to determine the extent of the field. Although the magnitude of the discovery is not definitely known, results to date are promising. If the reserves prove to be significant, Cotonou will certainly become a storage and trans-shipment center for crude oil and could become the site for a refinery.

6. Industry

Manufacturing and processing probably contribute only about 6% to 8% of the current gross domestic product, although the amount of local industry is increasing, and

much of the existing industry involves the processing of agricultural products. [3]

Five plants for processing palm products are operating in the major producing areas and three more are planned over the next few years. Six cotton granneries are in operation in the producing areas and more are planned, with IBRD and FAC financing, to handle the rapid expansion of output. In addition, a textile factory was being started in Cotonou in 1970 to help supply the domestic demand for piece goods from the local crop. A kenaf processing mill was completed in 1969 at Bohicon, but has had difficulty in securing enough raw material from nearby farms. Other agricultural processing plants are under consideration, including a groundnut crushing plant.

Except for the agricultural industries noted in the preceding paragraph, nearly all manufacturing activity is concentrated in Cotonou. These industries will be described in more detail in subsection B. 3.

7. Electric Power

A reduction in costs of electric power at Cotonou and other cities should follow completion of a transmission line from Ghana to Togo and Dahomey. Power in Cotonou and Porto Novo is presently generated at Cotonou by diesel engine and the cost is high (14 to 20 Fr. CFA per kilowatt hour). The new line should increase the demand, which has been growing at 10% annually, by reducing costs. It will also have sufficient capacity for anticipated demand until 1980.

8. Gross Domestic Product

Modest growth has apparently occurred in the gross domestic product over the past few years, although the increase in real terms in probably not significantly greater than the estimated 2.8% annual population growth. The latest official data[4] shows an average GDP growth over the years 1959-1966 of about 4.8% per year in current market prices. More recent information is not available, but the rates of increase do not appear to have risen in subsequent years and may have slipped slightly from the earlier levels. Although a comprehensive index of price changes is not maintained, wholesale prices are reported to have risen about 2% per year from 1964 to 1966[5], and similar rates of increase are assumed to have occurred in later years. Thus, real per capita GDP has

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[3] Comptes Nationaux 1964-1965-1966, Ministere de L'Economie et du Plan, June 1970, page IX.

[4] Comptes Nationaux 1964-1965-1966, ibid, page 96.

[5] As reported by officials of the Direction de la Statistique, from an unpublished index of selected goods. The index itself was not provided.

probably remained stable since the early 1960's. The average per capita GDP in 1966 was estimated at 19,670 Fr. CFA or approximately U.S. $70.[6]

9. Employment

The latest official data indicates that salaried employment has also been rising at modest levels, averaging 3.9% annually between 1959 and 1966.[7] However, in 1966 the number of salaried employees was quite low at 33,000 people from an economically active population of nearly 1.1 million.

As in most countries at similar stages of development, considerable unemployment appears to exist in the urban areas and even larger reservoirs of underemployment probably exist in the rural villages.

10. Public Sector Financing

The government has experienced continuing difficulty in financing public sector operations, largely due to the number and cost of public employees. Although some reductions have been achieved in recent years, the deficit in 1968 still represented over 15% of total public revenues. Most of the operating deficits have been covered by assistance from the French Government. As a result, the balance of payments shows that large negative balances on current account and a high proportion of domestic investment has been financed from external sources. With the volume of external financing that has been available, continuing public sector operating deficits have not had a significant impact upon prices, but have increased the foreign debt level until debt service has become a heavy burden.

France has contributed the majority of foreign assistance, consisting of technical, budget, and project aid. Founds Europeans de Development (FED) has also been a major contributor of project assistance and lending by the International Bank for Reconstruction and Development (IBRD) has expanded in the last three years.

The CFA franc was devalued by over 11% in November 1969 to a new official rate of CFAF 277.71 to the U.S. dollar, at the time similar action was taken in France. Thus, the CFA franc still is on a 50:1 ratio with the French franc.

B. FUTURE DEVELOPMENT OF COTONOU

1. Government Operations

Although Porto-Novo was the seat of government and still is officially recognized as the national capital, most governmental offices are located in Cotonou. These

[6] & [7] Comptes Nationaux 1964-1965-1966, page 96.

include the President's residence, the legislative assembly and most of the ministerial and other administrative offices. A token number of ministries and offices remain in Porto-Novo, such as the Ministry of Agriculture and the National Archives. The government has no plans to move these offices, at least within the near future, or to designate Cotonou as the official capital — even though it is the administrative seat of government.

Due to budgetary restrictions, governmental operations and employment are not likely to grow rapidly, at least for some years. The public sector budget has been expanding at an average rate of about 6% per year over the past few years, with about two-thirds of the budget currently devoted to salaries and other civil service costs. Employment has also increased about 5% per year, reaching a total of about 19,000 people, 75% of whom are employed by the central government. Revenues have also expanded but at a higher rate. Largely due to the size and increase in the civil service, expenditure has remained well above revenue, resulting in substantial operating deficits each year. Thus, future governmental operations will probably not expand more rapidly than in the past few years, if as fast. Nonetheless, the central government will undoubtedly remain, by far, the most important source of employment in Cotonou. The number of public sector employees in the city is estimated at about 15,000 persons.

2. Port Operations

Cotonou has the only seaport in Dahomey. Prior to construction of a new breakwater, dock, and shore facilities in 1960, ships anchored well offshore and cargo was transferred by lighters to and from an old steel-frame pier, east of the present harbor.

The new harbor has an enclosed surface area of 40 hectares and is capable of taking ships with 10-meter draft. Four parallel berths totaling 655 meters in length have been installed and additional berthing space can be developed as needed. The present port facilities have a rated capacity of approximately 700,000 tons per year.

Cargo traffic has been growing rapidly, averaging about 12% per year from 1965 to 1969, as shown in Table XII-3. However, a substantial part of the cargo traffic has been transhipped to or from Niger and northwestern Nigeria, estimated at 135,000 tons of imports and exports in 1969.

Palm products and groundnuts represented about the same volume of export cargo in 1969[8] and together accounted for nearly 56% of the total, with other agricultural exports making up the bulk of the balance. Cement and food stuffs each represented over 30% of imports by volume in 1969. Other important imports include construction materials, textiles, insecticides and vehicles. Passenger traffic through the port has been declining and is not an important factor.

[8] Transhipments for Niger and Nigeria are included in the data on imports and exports, and groundnuts are a major transhipment item.

TABLE XII-3

PORT OF COTONOU CARGO TRAFFIC: 1965-1969*
(Thousands of Metric Tons)

	1965	1966	1967	1968	1969
Exports	104	104	157	162	171
Merchandise Imports	174	178	189	188	260
Petroleum Imports	73	87	101	96	115
Total Traffic	351	369	447	446	546

* Includes items transhipped to other countries, particularly Niger.
Source: Port Autonome de Cotonou.

After the central government, the port is one of the most important employers in the city, hiring about 1,500 persons, even though employment was reduced following the separation of railway and port administrations.[9] Future operations will follow the trends of export and import cargo traffic. As noted previously, Dahomean exports are expected to increase in volume about 7% annually for the next few years[10] and imports should follow the trend of the growth of gross domestic product. Thus, the volume of cargo traffic for Dahomey is expected to increase between 4 and 5% per year for the next several years. Shifts in the transport routing of eastern Niger and Nigerian traffic, however, following the return of Nigeria to normal conditions, could cause a temporary decline in the port traffic.

3. Industrial Growth

Cotonou has a small but growing industrial establishment and a commercial sector which supplies Cotonou and, on a wholesale basis, the smaller cities and towns of Dahomey.

Existing industries will be described in summary form and further industrial prospects in somewhat more detail since light industry is likely to become a more important source of employment in the future.

[9] The port now operates as an independent agency.

[10] Assuming ± 2% overall annual decrease in agricultural export prices, a 5% rate of increase in value of agricultural exports would represent an increase in volume of 7% per year.

Most of the existing industry is located on the eastern side of the estuary between the ocean and Route 11, but several older firms were established on the western side, along the coast between the estuary and the new port, before new zoning regulations were enacted. The major service establishment and commercial houses are concentrated around Gouverneur Clozel Avenue on the west bank, with others scattered throughout the city.

The government's latest directory of industry[11] lists about 50 firms under construction or operating in Dahomey. Total employment by these firms exceeds 3,500 persons, with some 40 firms and over 2,100 employees located in Cotonou. Only the agricultural processing plants previously described and a small bakery and soap plant are located in other parts of the country. The more important manufacturing and processing industries in Cotonou include: bakeries, a brewery, wood and metal furniture manufacture, printing, coconut and palm oil processing, soap making, carpentry and construction, metal working, radio assembly, auto assembly, motorcycle assembly, bicycle assembly, electricity generation, air reduction, tanning, shoe manufacture, cement clinker crushing and tire recapping.

Many of the existing industries have been established since independence in 1960, and nearly all are financed by private capital, as the public sector has little capital to help finance private investment projects. The Dahomean Investment Code, however, encourages new local industry with tax incentives and embargoes or preferential duty rates on competing imports. The latest list of industrial proposals include 23 new projects which are licensed under the Investment Code, with a planned investment of over 2.5 billion Fr. CFA. All but one are to be located in Cotonou and total employment is forecast at nearly 1,900 persons. Private capital has been assured for each of these projects, most of which involve the use of local raw materials or represent import substitution. The proposed projects include: offshore trawlers and fish-freezing facilities, specialized printing, fruit and vegetable processing, shrimp freezing, paint manufacture, sponge and napkin manufacture, plastics manufacture, match manufacture, milling, and clothing manufacture. Not all of these projects will be implemented, but several should be initiated in the next few years. Other new projects are also under consideration by the private sector. All of the projects proposed for Cotonou would be located in the industrial zone east of the existing bridge. In addition, construction of a large textile factory was started in 1970 at Cotonou. The textile project will employ about 650 workers and involves an investment of nearly 1.8 billion Fr. CFA, with the capital to be supplied by the government and the private sector. Other public sector industrial projects are planned but would be located in other parts of the country.

Further industrial expansion also faces several problems. Local markets are limited and neighboring countries have not granted preferential tariff rates for Dahomean manufactured goods. European Economic Community regulations also require bidding to supply agricultural imports and restrict tariff protections for process agricultural goods.

[11] Industries Existantes, Ministere du Plan et de la Prospective; 1968.

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Even though private capital is available within Dahomey for investment projects, local entrepreneurs are not experienced and salaried managers are both expensive and scarce.

Thus some further expansion of industrial activity in Cotonou will undoubtedly occur, but is expected to be largely devoted to products that substitute for imported goods.

4. Employment Prospects

The rate of further migration to Cotonou is expected to turn largely on future employment opportunities in the city. Even without additional migration, the urban population would expand, but at rates closer to the national averages. Cotonou has been growing about 10% per year while the average urban growth has been only 6% annually. In the past, migration to the city from rural areas (and probably from other towns) undoubtedly contributed to the bulk of the higher population growth.

A large number of underemployed persons probably still exists in the rural areas surrounding Cotonou and these people would move to the city if jobs were available. For example, public notices of job openings in the government have caused thousands of applicants to rush to the city, only to return to their homes when the available jobs were filled.

Official data on employment in Cotonou are not available. Therefore, recent estimates by a labor advisor to the government are presented in Table XII-4 to give a rough idea of the employment situation in the city. Large numbers of unemployed also undoubtedly exist among the urban population.

TABLE XII-4

COTONOU ESTIMATED EMPLOYMENT AND EARNING LEVELS: 1970
(Thousands of Persons/Thousands of Fr. CFA)

Employer	Number Employed	Monthly Average Salary
Public sector[12]	15	30
Modern Firms	8	25
Artisans and Small Commerce[13]		
Male	12	7 to 8
Female	15	3 to 5
Unemployed	10	

[12] Includes independent public agencies.

[13] Includes estimated 15,000 people who are employed less than 100 days per year.
Source: Estimates by an advisor in the labor field.

Nearly 50% of the city's population is estimated to be less than 15 years old, and up to 3,000 persons are probably added to the employable ranks each year through maturation of young people. Up to 1966, the public sector and private firms absorbed up to 2,000 additional people each year. However, budget deficits have sharply curtailed additional public sector hiring and the rate of new job openings may have declined to around 500-1,000 openings per year. Near term employment prospects are not expected to rise significantly above this level so long as the government continues to restrict civil service expansion.

5. Urban Population Growth

With these constraints, the earlier rapid growth of population in Cotonou would certainly appear destined to slow considerably, barring unforeseen circumstances. Modest growth of the industrial and other sectors will probably not absorb the anticipated volume of urban youths seeking employment. As substantial increases in per capita income are not foreseen, the demand for services is not expected to increase much more rapidly than the rate of population growth. Thus, present levels of unemployment and underemployment will undoubtedly continue and may increase for some years. Under these circumstances, the rate of population growth is not expected to exceed 4.5% annually.

C. FISHING ON LAKE NOKOUE

1. Past Conditions

Up to 1960, Lake Nokoue and Porto-Novo Lagoon supported about 50,000 people, who were dependent upon an annual fish catch of about 15,000 metric tons. Most of the catch was of two species, which congregate in areas sheltered by branches. Although the open parts of the lakes were fished with nets and traps, yields were covered with branches and enclosed by stakes or poles. Several forms of "akadja" were used, depending upon the locale, and some extended over several hectares of shallow water. The annual yield per hectare varied with the type of akadja and the frequency of fishing but was generally much higher than open water. Although only about 25% of the total catch on the lakes was from akadja, they served as a shelter for the predominant species and probably contributed to increased catches in nearby open waters.

Prior to construction of the new harbor, the sand bar across the mouth of the Cotonou lagoon was broken open to the sea only by the pressure of the higher water level of Lake Nokoue during the most severe floods. On the average, the estuary was open once every three to five years but the littoral currents in the ocean drifted sufficient sand to close the opening within a few months after the flood waters subsided. Thus, Lake Nokoue and the smaller Porto-Novo lagoon remained relatively protected from terredo (marine borer) invasion, except during the shorter periods when the estuary was open.

2. Present Trend

After construction of the seawall for the new harbor, the sand-carrying ocean currents were shifted seaward, and the estuary channel remained open at all times. The constant intrusion of seawater and the consequential increase in the terredo infestation of Lake Nokoue has reduced the annual catch to an estimated 9,000 tons in 1967 and about 5,600 metric tons in 1970.

The most important effect of the multiplication in the lake waters of marine borers was that they attacked the wood used in akadja construction. Presently, the akadjas last about one-half the former time, as do canoes and other wooden objects immersed in water. The opening of the estuary also permits rapid outflow of mineral and sediment carried by flood waters, reducing the deposit of nutrients on the lake bottom. More importantly, tidal surges keep the water turbulent, scour the lake bottom, and reduce nutrient and mineral deposits.

The costs of akadja maintenance increased, at the same time that fish production was declining. Due to overcutting of nearby forests, the cost of branches and poles for akadja construction has doubled from 1960 levels. Consequently, several hundred hectares of the various forms of akadja in Lake Nokoue have not been replaced in the last few years. Thus, the total area of akadjas that have disappeared has increased as cost of replacement rose above the value of the fish produced.

3. Prospects for the Future

Dr. Thompson made the most recent survey of lake fishing[14] and concludes that fish production can be restored to former levels in about five years after the installation of the dam. During this period of time, Lake Nokoue would reach a stable condition with respect to salinity level and the silt and detritus deposition. Dr. Thompson found no other irreversible ecological changes and believes the reduction of salinity levels should effectively eliminate the marine borers or at least reduce their density sufficiently to eliminate the problem of akadja replacement.

Hydraulic calculations indicate that with the installation of the proposed rock dam, as described in Section IX, Dr. Thompson's criteria relative to salinity could be met, if not exceeded. In effect, the proposed dam could probably establish hydraulic and ecological conditions very similar to those that existed in the lake prior to 1960.

Under these circumstances, fishing would again become profitable through the increased use of akadjas after the initial restoration period. Although this form of fish culture represented only about 25% of the catch before the channel was opened, the use

[14] Report of the Fishing Reconnaissance of Lake Nokoue, Dahomey, by Richard B. Thompson and Economic Evaluation of Expected Fishery Benefits by George K. Tanonaka, National Marine Fisheries Service, Seattle, Washington. (July 1971). A complete copy of Dr. Thompson's report is included as Appendix B.

of akadjas is believed to add significantly to the total catch by sheltering the predominant species of fish. Costs of using akadjas are certainly higher than net casting, while production is also higher.

However, shrimp fishing in the lagoon would probably be lost with the construction of the dam, as the larvae are carried into the channel by tidal flows and the adults return to the deep continental shelf to breed. Production of shrimp has been averaging about 400 tons per year and prices are about 150 Fr. CFA per kilogram.

D. TRANSPORT IN DAHOMEY AND COTONOU

1. Regional and International Traffic

The bulk of the traffic across the lagoon in late 1970 was generated within the city, with about 69% of passenger vehicle and 49% of truck and bus trips occurring inside the city limits. As noted in Section IV international traffic was a small proportion of the total for all vehicle categories, averaging about 1.5% of all vehicle trips, but reaching 8.8% of bus traffic.

As would be expected, Cotonou is the focus of regional traffic because it is the largest city, the seat of government, the only seaport, and contains the only concentration of industry. Less than 2% of passenger vehicles and 9% of trucks and busses pass through the city on trips between points outside the city limits.

Due largely to the short distances between the centers of population and agricultural production in the coastal area, nearly all cargo and passenger traffic moves by highway. The largest traffic volume occurs between the city and the population centers of Oueme prefecture, lying east and northeast of Cotonou, particularly Porto-Novo - the second largest city in the country. Large volumes also move between the city and southwestern population centers around Ouidah, as well as to centers as far north as Dassa-Zoume in south-central Dahomey. Traffic further north decreases significantly, particularly among the route parallel to the OCDN railway line north to Parakou. Traffic volumes in 1967 and projections to 1975 on the major feeder roads to Cotonou are shown in Table XII-5.

2. Railway Operations

The Dahomean railway network consists of an east-west and a north-south line. One railway line extends east from Cotonou to Porto-Novo and then north to Pobe. Another line extends west from Cotonou to Segboroue, west of Ouidah. At Pahou, 25 kilometers west of Cotonou, the west line branches, and becomes the north line which continues to Bohicon, Save and Parakou, in north-central Dahomey.

The great majority of railway traffic currently is carried between Cotonou and Parakou on the north line. About one-half of this traffic represents export or import

transfer cargo for Niger and northwestern Nigeria.[15] Cargo is carried by trucks, also operated under contract by the OCDN between Parakou and the northern border of Dahomey. Prior to the Nigerian hostilities, cargo from eastern Niger and northwestern Nigeria moved via Lagos and Port Harcout. With the disruption of Nigerian transport facilities following the outbreak of hostilities, a part of the cargo was shifted to the OCDN route. Now that Nigerian transport facilities are returning to normal, a good possibility exists that cargo to and from eastern Niger and northwestern Nigeria will revert to the Nigerian routing when the contracts signed under emergency conditions terminate. In addition, improvements of navigation facilities on the Niger River are under consideration, which would permit extended and more efficient barge service into Nigeria from western Niger. If most of the transfer traffic is diverted from the OCDN railroad the Lea Report suggests that rail operations on the northern line will incur financial losses and may have to be closed, with truck transport carrying the balance of the domestic and foreign cargo.

The eastern and western OCDN lines from Cotonou carry such small volumes of cargo and passengers that the Lea Report recommends immediate closure of operations. To date, the government has taken no definite steps to stop operations on either line. However, if the recommended action is followed, rail movements on the existing bridge over the Lake Nokoue estuary, now averaging about eight per day with some occurring at peak traffic hours, would terminate and the railway lines could be lifted to provide a smoother bridge surface for vehicular traffic.

TABLE XII-5

DAHOMEY TRAFFIC ON MAJOR FEEDER ROADS INTO COTONOU: 1967-1975
(Daily Two-Way Volumes)

	Actual Traffic 1967	Projected Traffic 1975[16]	Annual Growth Rates
Cotonou east toward Porto-Novo	2019	3133	5+ %
Cotonou west to Godomey	1465	2228	5 %
Godomey west toward Ouidah	803	1170	5- %
Godomey north toward Allada	737	1379	8 %

[15] Dahomey Land Transport, N.D. Lea Associates and Lamarre Valois International Limitee, July 1969.

[16] Data is taken from the "do nothing condition" in the source. Projected traffic does not change significantly under other hypotheses, except for the last feeder road on which the growth rate would be reduced to 6% if the recommended improvements are carried out. Source: Dahomey Land Transport, N.D. Lea Associates and Lamarre Valois International Limitee, July 1969.

3. Air Transportation

The airport on the western edge of Cotonou is the only international airport in the country and is used by international air carriers for scheduled flights several times per week. The balance of the airports in the country are small, many having earth surfaces, and are served only by light-twin aircraft of the local airlines.

The government is considering an extension of the present runway, which would require the relocation of Route 11 in the western part of Cotonou, or complete relocation of the airport at a spot near Abomey-Calavi. According to the airport manager the present runway is capable of continued handling of present traffic, including four-engine jets, without improvement. Three-engine "jumbo" jets could also be accommodated by strengthening the surface of the runway in the touch-down zones. Thus, the runway extension would only be required for four-engine "jumbo" and supersonic jets. Due to the financial constraints facing the government and the remote possibility of "747" type or supersonic jets calling at Cotonou in the near future, an extension of the runway does not appear likely or necessary for some time.

E. FUTURE TRAFFIC GROWTH IN COTONOU

1. Past Traffic Growth in Cotonou

The best information on traffic across the lagoon in previous years is provided by a series of traffic counts at the existing bridge by the Department of Public Works. These counts have been performed once or twice each year since 1960, with each count lasting a week and traffic divided into five vehicle categories. Although considerable variations in volume occur between counts[17] the overall trend is upward for all types of vehicles. Time series plotting of the counts is shown in Figures 12-1 through 12-4 and the resulting growth trends are summarized in Table XII-6.

Other possible sources of information on past traffic growth were investigated but the data are not maintained in such a way as to give usable indications about traffic volumes and trends in Cotonou.

Sales of gasoline and light diesel fuel in the city would indicate the amount and trends of vehicle usage in the area. However, only two of the six major distributors provided information on annual sales over the past several years. The others were either unwilling to divulge the information or personnel authorized to release it were unavailable at the time of field investigations for this report. Although changes in the share of the local market among distributors would affect the sales of any distributor, both of the firms which provided information indicated that gasoline sales in the city rose since 1967

[17] A cross check is available on the accuracy of each count since considerable variations occur among the counts without apparent cause. Errors undoubtedly exist in some of the counts

about 6-10% per year, while light diesel fuel sales were up 5-9% annually. Between 1965 and 1969, national sales of gasoline and light diesel fuel rose nearly 7% annually and are projected, by the association of fuel importers, to rise about 6% per year from 1969 to 1972.

TABLE XII-6

COTONOU GROWTH OF TRAFFIC CROSSING THE EXISTING BRIDGE: 1960-1970

	Increase Per Year
Passenger Cars	6 %
Light Trucks (less than two tons capacity)	6+ %
Medium Trucks (between two and ten tons capacity)	6+ %
Heavy Trucks (over 10 tons capacity)	7- %
Motor Bikes	19 %
All vehicles (very conservative estimate, see also Figure 12-4.)	4.5 %

Source: Department of Public Works, semi-annual traffic from 1960-1970.

The growth rate of the national vehicle fleet has declined steadily to about 3.2% per year in 1968 and appears to have decreased even further in subsequent years, according to data on vehicle registrations. Vehicle registration data are published currently by the Ministry of Finance. Vehicles are registered only when new and retired vehicles are not removed from the list. The Dahomey Land Transport study estimates that the average age of the vehicle fleet is about four years. Deducting all vehicles older than twice that age, the annual fleet growth in 1967 and 1968 was estimated at 3.2% per year (see pages 5p, 14 and 15). The same method of calculation shows that annual growth rates have declined further in subsequent years with the total fleet containing just over 11,000 vehicles of all types at the end of 1969. The system of vehicle registration is scheduled to be changed to annual registration in the near future. The only breakdown of registration data indicating the location of the vehicle is the domicile of the owner. According to the latest registration reports, 53% of all owners reside in Cotonou, but this may greatly exaggerate the proportion of vehicles actually in use in and around the city.

2. Traffic Growth Assumptions and Rate

Based upon the various economic and employment prospects outlined previously in subsections A and B, and the probable urban population growth described in Section III, expected annual growth rates for four types of traffic within the city were developed. These rates assume the urban population increases about 4.5% per year and that new employment

opportunities will be sufficient to boost urban employment proportionately with population increases. However, significant increases in average per capita income for the urban population are not assumed. The expected traffic growth rates are shown in Table XII-7 and are below the rates indicated by available evidence for prior years, in all cases (See Figures 12-1 through 12-4 and Table XII-6).

TABLE XII-7

COTONOU FORECAST TRAFFIC GROWTH RATES: 1971-1997

Vehicle Category	Annual Growth
Passenger Vehicles	6.0 %
Trucks and Busses	5.0 %
Motorcycles and Bicycles	8.0 %
Pedestrians	4.5 %

The growth rate has been reduced to 3/4 of the initial rate from 1987 on, in order to reflect the growing congestion which will begin to spread towards the end of the study period throughout Cotonou. Additionally, for sensitivity testing, the base 1970 average daily traffic is reduced 10% and then the future is calculated by using growth rates reduced by 20%. The projected volumes by categories of traffic for each year from 1970 to 1996 are shown in Appendix A, pages A-29 through A-31.

3. Zonal Traffic Projections

Using growth rates shown in Table XII-7, traffic growth was estimated for each O/D zone, using 1970 volumes, as a basis from which the expected relative volume of total traffic by vehicle category at the end of the study period was calculated.[18] The expected future character of each zone has been described in Section III and their relative importance in future traffic generation is described below. Some zones, which are expected to be important in the future, have practically no traffic at present. Therefore, present traffic was arbitrarily raised to a minimal proportion (0.1%), in order to provide a base for the projection of future traffic. Thus, all zones which had very low traffic volumes in 1970 would grow rapidly to reach expected levels at the end of the study period.

[18] Due to the manner of calculating traffic growth by zone, the overall growth rates do not match the target exactly. The resulting overall growth rates are: passenger vehicles, 5.82%; trucks and busses, 5.05%; motorcycles and bicycles, 7.71%; and pedestrians, 4.54%. This method of projecting traffic assumes linear growth for each zone, which may not be the case for those outlying zones some distance from the center of the city. In fact, those zones within the city limits may increase before the outlying ones.

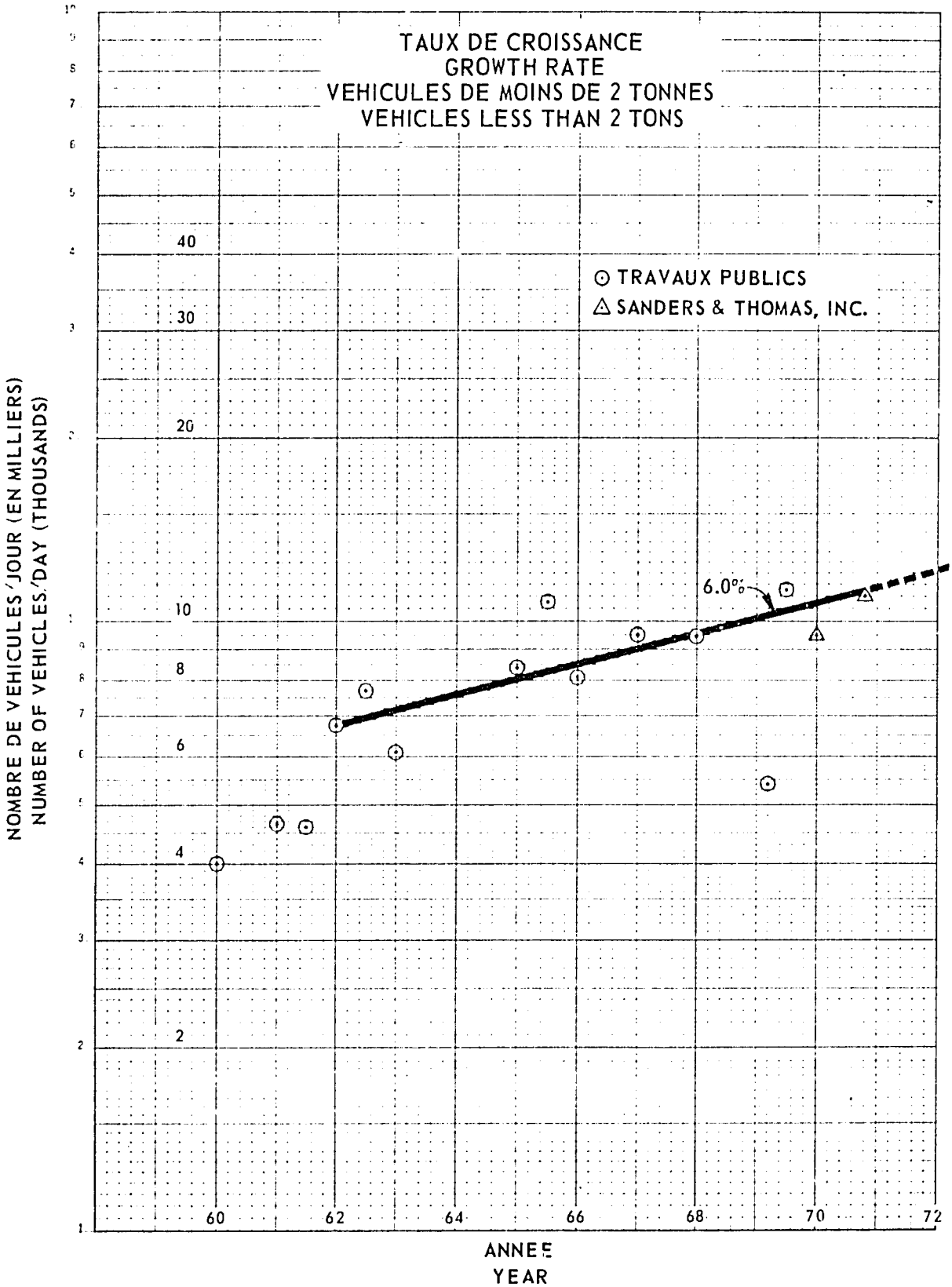
TAUX DE CROISSANCE
GROWTH RATE
VEHICULES DE MOINS DE 2 TONNES
VEHICLES LESS THAN 2 TONS
⊙ TRAVAUX PUBLICS
△ SANDERS & THOMAS, INC.
6.0%
NOMBRE DE VEHICULES/JOUR (EN MILLIERS)
NUMBER OF VEHICLES/DAY (THOUSANDS)
40
30
20
10
8
6
4
2
60
62
64
66
68
70
72
ANNEE
YEAR

FIG. 12-1

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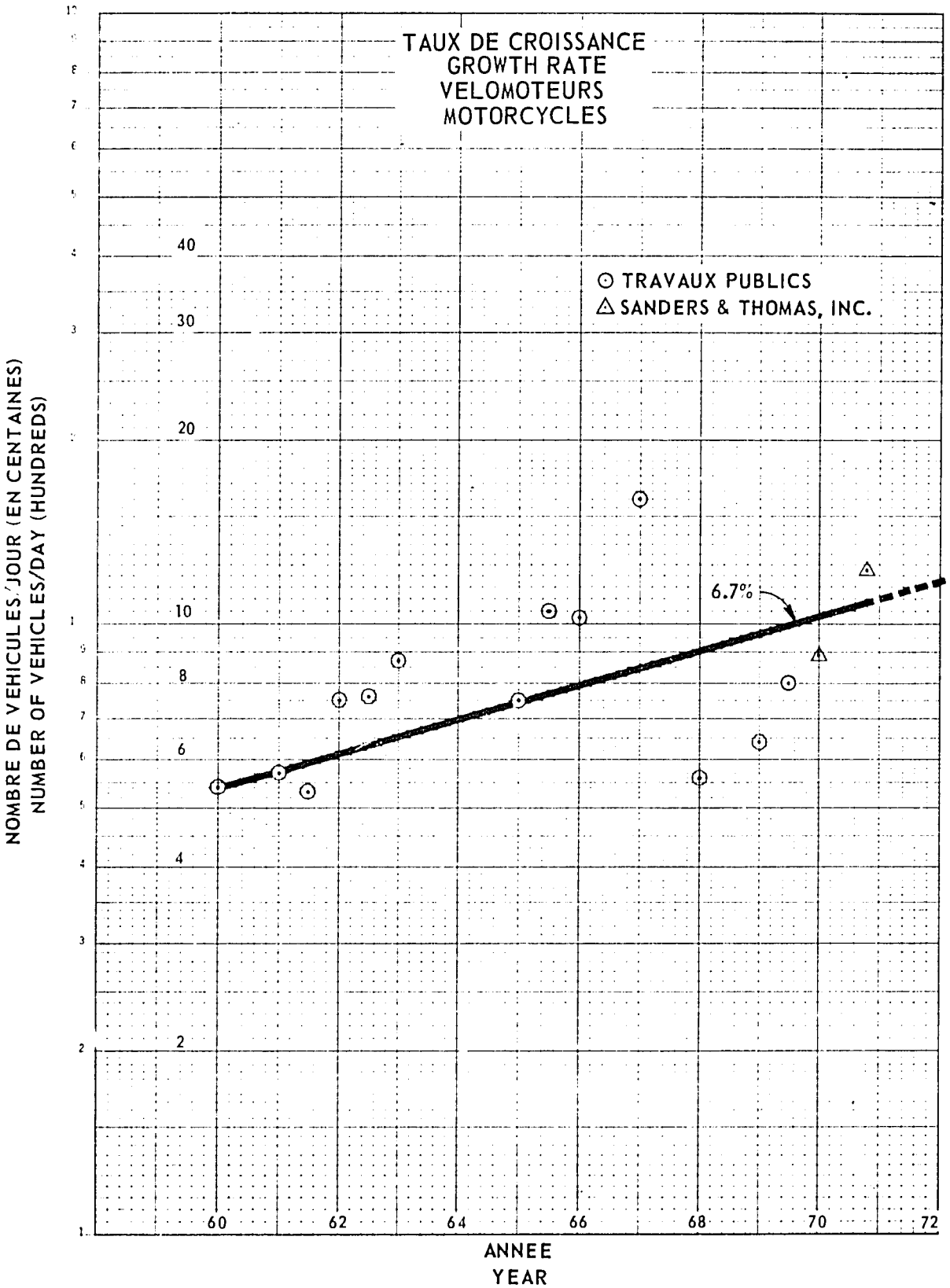
TAUX DE CROISSANCE
GROWTH RATE
VELOMOTEURS
MOTORCYCLES
⊙ TRAVAUX PUBLICS
△ SANDERS & THOMAS, INC.
6.7%
NOMBRE DE VEHICULES/JOUR (EN CENTAINES)
NUMBER OF VEHICLES/DAY (HUNDREDS)
40
30
20
10
8
6
4
2
60
62
64
66
68
70
72
ANNEE
YEAR

FIG. 12-2

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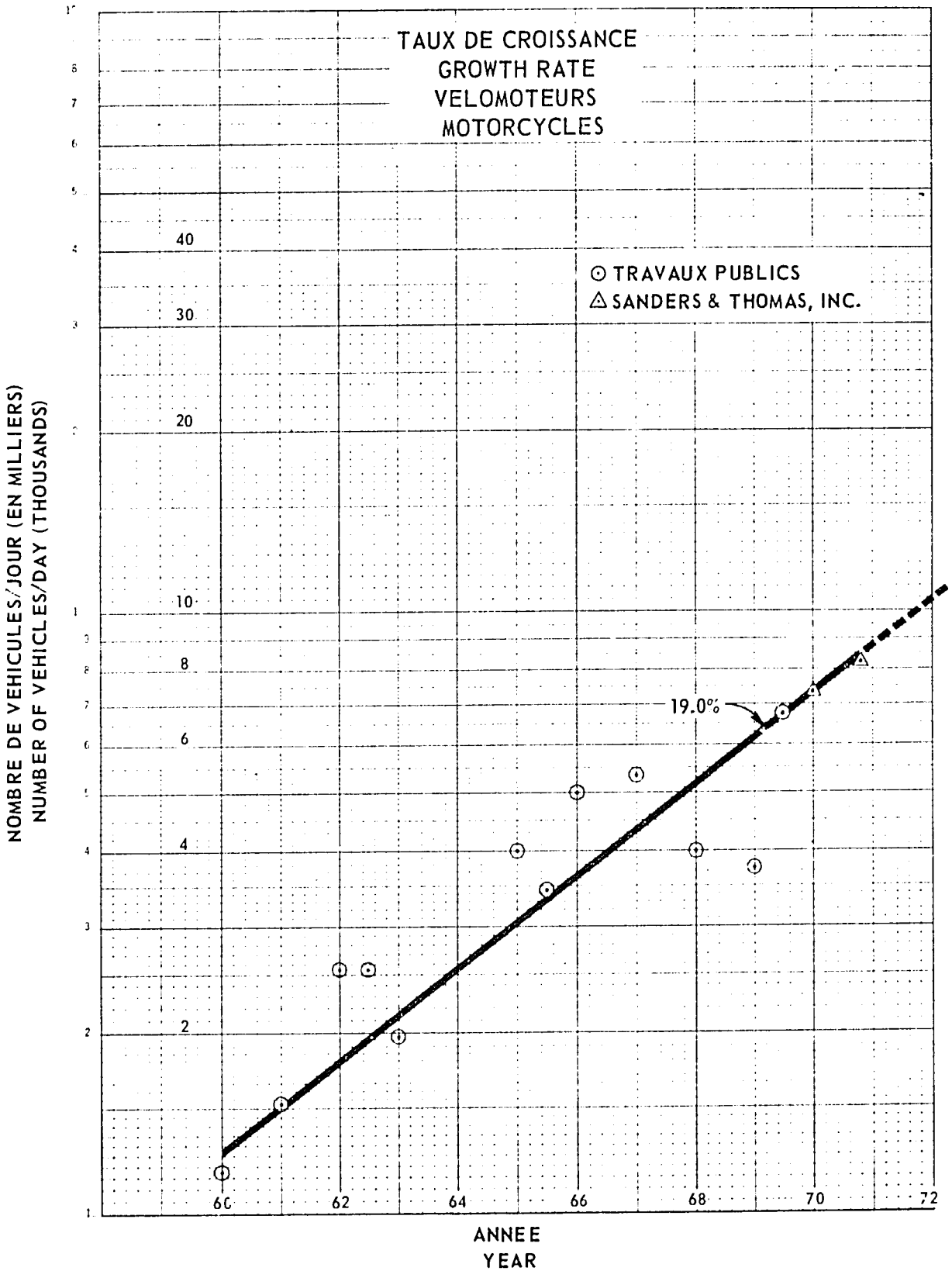
TAUX DE CROISSANCE
GROWTH RATE
VELOMOTEURS
MOTORCYCLES
⊙ TRAVAUX PUBLICS
△ SANDERS & THOMAS, INC.
19.0%
NOMBRE DE VEHICULES/JOUR (EN MILLIERS)
NUMBER OF VEHICLES/DAY (THOUSANDS)
40
30
20
10
8
6
4
2
60
62
64
66
68
70
72
ANNEE
YEAR

FIG. 12-3

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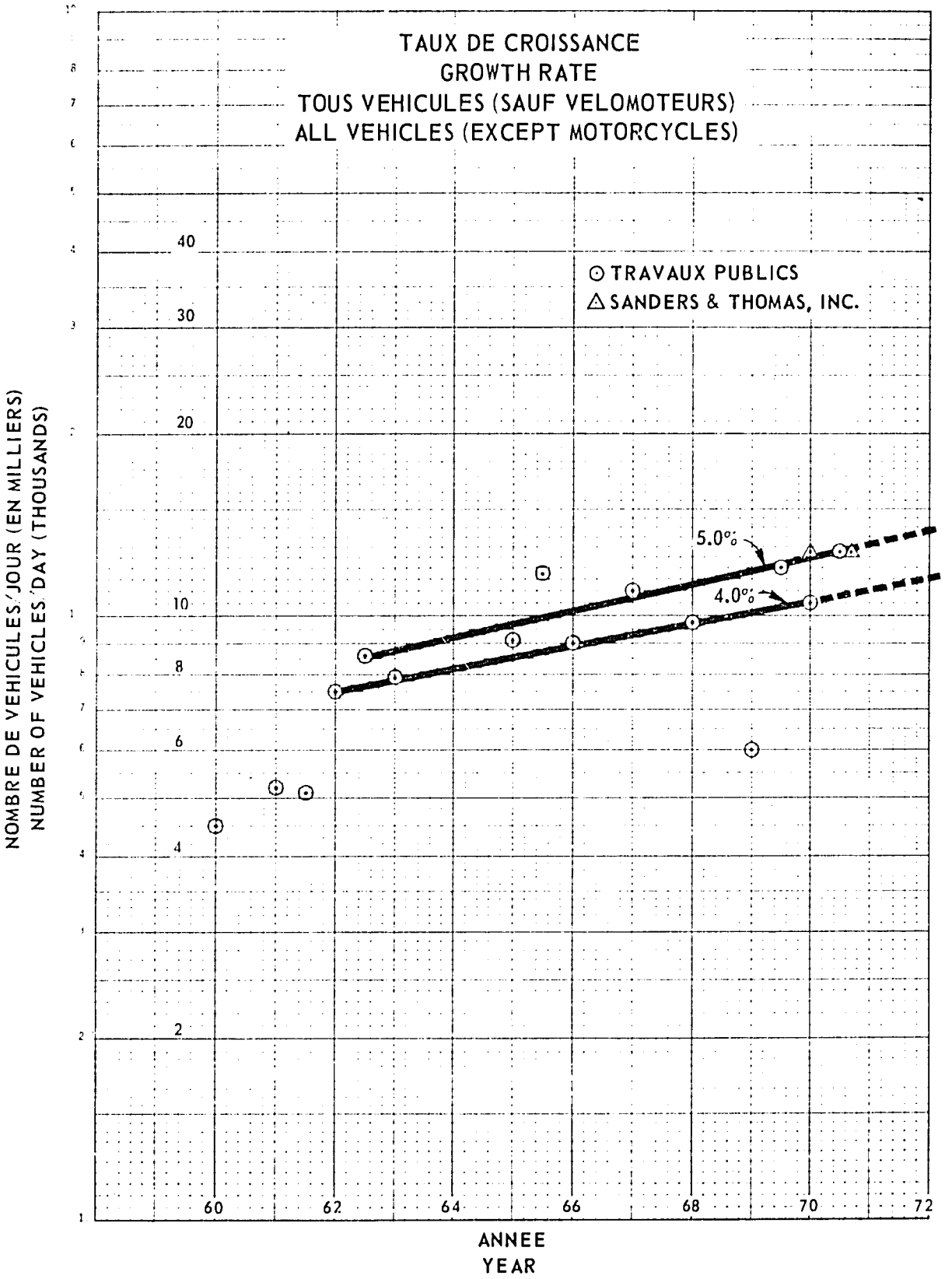
TAUX DE CROISSANCE
GROWTH RATE
TOUS VEHICULES (SAUF VELOMOTEURS)
ALL VEHICLES (EXCEPT MOTORCYCLES)
⊙ TRAVAUX PUBLICS
△ SANDERS & THOMAS, INC.
5.0%
4.0%
NOMBRE DE VEHICULES/JOUR (EN MILLIERS)
NUMBER OF VEHICLES/DAY (THOUSANDS)
40
30
20
10
8
6
4
2
60
62
64
66
68
70
72
ANNEE
YEAR

FIG. 12-4

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The proportion of present traffic, the expected growth rates and the probable diversion of traffic to the Saint Michel bridge for each O/D zonal pair are shown in Table XII-8 for passenger vehicles, in Table XII-9, for trucks and busses, in Table XII-10 for motorcycles and bicycles and in Table XII-11, for pedestrains. The estimated proportion of traffic diverted to the Saint Michel Bridge is judgmentally determined by relative distance and convenience and represents an average proportion over the 20-year study period after the bridge is opened.

TABLE XII-8

COTONOU BRIDGE PASSENGER VEHICLE TRAFFIC

Percentage of Traffic Between Zones in 1970[19]

O/D Zone	5	6	7	8	9	Total
1	17.7	4.6	0.8	10.4	17.1	50.6
2	5.2	1.2	0.1	2.6	2.3	11.4
3	10.1	3.5	1.0	5.1	4.7	24.4
4	3.8	1.4	0.4	2.7	1.4	9.7
10	1.0	0.5	0.0	0.5	1.9	3.9
Total	37.8	11.2	2.3	21.3	27.4	100.0

Projected Annual Growth Rates: 1971-1997[20]

O/D Zone	5	6	7	8	9
1	0.06	0.03	0.10	0.08	0.08
2	0.03	0.03	0.06	0.04	0.06
3	0.03	0.04	0.12	0.04	0.06
4	0.04	0.04	0.14	0.06	0.07
10	0.06	0.05	0.09	0.09	0.05

Proportion of Traffic Diverted to Saint Michel[21]

O/D Zone	5		6		7		8		9	
	A	B	A	B	A	B	A	B	A	B
1	0.00	0.40	0.25	0.60	0.70	1.00	0.15	0.50	0.20	0.60
2	0.10	0.60	0.70	1.00	1.00	1.00	0.50	0.90	0.70	1.00
3	0.30	1.00	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10	0.30	1.00	0.75	1.00	1.00	1.00	1.00	1.00	1.00	1.00

[19] Average daily traffic in 1970 was 10,400 cars. The O/D zones showing no traffic have been elevated to 0.1% of total traffic for purposes of traffic projection. Source: Origin-Destination Traffic Survey, by Sanders and Thomas, Inc. November 1970.

[20] The weighted average growth for all zones is 5.82% per year.

[21] Diverted traffic would represent 39.2% of total car traffic in 1977 (A) when the bridge opens, rising to 53.3% in 1997 (B).

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TABLE XII-9

COTONOU BRIDGE TRUCK & BUS TRAFFIC

Percentage of Traffic Between Zones in 1970[22]

O/D Zones	5	6	7	8	9	Total
1	17.5	0.7	0.0	25.2	15.8	59.2
2	3.5	0.0	0.1	2.1	1.7	7.4
3	2.6	0.3	0.0	3.3	5.9	12.1
4	1.2	0.0	0.0	0.9	0.1	2.2
10	2.7	0.1	0.3	7.2	8.8	19.1
Total	27.5	1.1	0.4	39.7	32.3	100.0

Projected Annual Growth Rates: 1971-1997[23]

O/D Zones	5	6	7	8	9
1	0.03	0.03	0.14	0.05	0.05
2	0.03	0.03	0.07	0.03	0.04
3	0.03	0.05	0.19	0.05	0.07
4	0.04	0.05	0.19	0.05	0.08
10	0.03	0.03	0.07	0.06	0.04

Proportion of Traffic Diverted to Saint Michel[24]

O/D Zone	5		6		7		8		9	
	A	B	A	B	A	B	A	B	A	B
1	0.05	0.40	0.30	0.70	0.70	1.00	0.20	0.80	0.30	0.70
2	0.10	0.60	0.70	1.00	1.00	1.00	0.50	0.90	0.70	1.00
3	0.30	1.00	0.90	1.00	1.00	1.00	0.70	1.00	0.80	1.00
4	0.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10	0.03	1.00	0.90	1.00	1.00	1.00	0.90	1.00	1.00	1.00

[22] Average daily traffic in 1970 was 2,290 vehicles, composed of 1,650 trucks and 640 busses. The O/D zones showing no traffic have been elevated to 0.1% of total traffic for purposes of traffic projections.
Source: Origin-Destination Traffic Survey, by Sanders and Thomas, Inc. November 1970.

[23] The weighted average growth for all zones is 5.05% per year.

[24] Diverted traffic would represent 41.4% of total car traffic in 1977 (A) when the bridge opens, rising to 62.3% in 1997 (B).

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TABLE XII-10

COTONOU BRIDGE MOTORCYCLE & BICYCLE TRAFFIC

Percentage of Traffic Between Zones in 1970[25]

O/D Zones	5	6	7	8	9	Total
1	18.9	8.0	4.2	11.0	1.2	43.3
2	3.2	2.0	0.8	1.2	0.2	7.4
3	16.0	5.9	1.6	10.7	0.9	35.1
4	6.9	1.5	0.2	4.6	0.2	13.4
10	0.3	0.2	0.0	0.3	0.0	0.8
Total	45.3	17.6	6.8	27.8	2.5	100.0

Projected Annual Growth Rates: 1971-1997[26]

O/D Zones	5	6	7	8	9
1	0.06	0.06	0.12	0.09	0.16
2	0.05	0.05	0.10	0.07	0.08
3	0.06	0.04	0.12	0.08	0.16
4	0.06	0.06	0.25	0.14	0.20
10	0.12	0.05	0.16	0.20	0.16

Proportion of Traffic Diverted to Saint Michel[27]

O/D Zone	5		6		7		8		9	
	A	B	A	B	A	B	A	B	A	B
1	0.00	0.10	0.10	0.60	0.50	0.60	0.10	0.20	0.10	0.20
2	0.00	0.20	0.30	1.00	1.00	1.00	0.20	0.60	0.20	0.80
3	0.30	0.80	0.80	1.00	1.00	1.00	0.80	1.00	0.90	1.00
4	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10	0.50	1.00	0.70	1.00	1.00	1.00	1.00	1.00	1.00	1.00

[25] Average daily traffic in 1970 was 17,200 bikes, composed of 8,200 motorbikes, and 9,000 pedal bicycles. The O/D zones showing no traffic have been elevated to 0.1% of total traffic for purposes of traffic projection.
Source: Origin-Destination Traffic Survey, By Sanders and Thomas, Inc. November 1970.

[26] The weighted average growth for all zones is 7.71% per year.

[27] Diverted traffic would represent 38.3% of total bicycle traffic in 1977 (A), when the bridge opens, rising to 63.5% in 1997 (B).

TABLE XII-11

COTONOU BRIDGE PEDESTRIAN TRAFFIC

Percentage of Traffic Between Zones in 1970[28]

O/D Zones	5	6	7	8	9	Total
1	22.0	18.8	6.6	5.1	0.6	53.1
2	3.2	1.5	0.8	1.6	0.1	7.2
3	14.4	10.5	2.9	3.5	0.9	32.2
4	2.7	0.9	0.6	1.7	0.0	5.9
10	1.1	0.2	0.2	0.0	0.1	1.6
Total	43.4	31.9	11.1	11.9	1.7	100.0

Projected Annual Growth Rates: 1971-1997[29]

O/D Zones	5	6	7	8	9
1	0.04	0.02	0.07	0.09	0.14
2	0.03	0.03	0.10	0.07	0.09
3	0.02	0.02	0.10	0.08	0.14
4	0.05	0.05	0.15	0.11	0.25
10	0.03	0.01	0.09	0.10	0.05

Proportion of Traffic Diverted to Saint Michel[30]

O/D Zones	5	6	7	8	9
1	0.00	0.10	0.30	0.00	0.00
2	0.00	0.40	0.70	0.20	0.30
3	0.30	0.80	1.00	0.70	0.80
4	0.50	1.00	1.00	1.00	1.00
10	0.10	0.80	1.00	1.00	1.00

[28] Average daily volumes of pedestrians over the existing bridge was 11,400 in 1970. In addition, boats carried an estimated 5,500 people across the estuary to the market area at Saint Michel. The O/D zones showing no traffic have been elevated to 0.1% of total traffic for purposes of traffic projections.
Source: Origin-Destination Traffic Survey, By Sanders and Thomas, Inc. November 1970.

[29] The weighted average growth for all zones is 4.5% per year, excluding existing boat traffic.

[30] Pedestrians diverting to Saint Michel would represent 30.6% of the total crossing the existing bridge in 1977, rising to 47.2% in 1997. Boat passengers would all use the new bridge and would probably increase at similar rates.

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4. Future Traffic Patterns

Most of the present traffic across the estuary occurs between a few of the zones. For passenger vehicles, Zones No. 1, 5, 3 and 8 are the most important. For trucks and busses, Zones No. 1, 8, 9 and 5 are the most important. For other traffic, Zones No. 1, 5, 3, 6 and 8 are the major generators of traffic across the estuary. Thus, Zones No. 1, 5 and 8 are important for all traffic categories.

The relative importance of all zones should change as time progresses and the city and suburban areas grow. Population expansion will probably be the most important factor in changing present traffic patterns. The proportion of the estimated population in each zone in 1970 and 1995 and the expected population growth rate for each zone is shown in Table XII-12.

Using a growth rate of 4.5% per year, the population of the city and suburban areas would increase threefold (150,000 to 450,000) from 1970 to 1995. Most of this increase should occur in the northern zones on each side of the estuary nearest Lake Nokoue (Zones No. 4 and 7) and in the two areas to the east and west of the present city boundaries (Zones No. 9 and 10), assuming that the character of housing and residential development within the city does not change markedly from present patterns.

Nearly one-half of the 1995 population would live outside the present city limits in the larger part of Zone No. 7 and in Zones No. 9 and 10. For traffic projections, each of these three zones has been assumed to contain one-third of the present suburban population and to absorb one-third of the population growth expected to occur outside the present city limits. If each zone now contains about 11,700 people, each of these three zones would grow over 7% per year and would contain over 70,000 people by 1995.

The population zones within the city are also expected to grow but at varying and much lower rates, as shown in Table XII-12. Zones No. 4, 8 and 3 are expected to absorb nearly 70% of the growth and contain about 65% of the 1995 population within the present city limits.

The relative importance of each residential zone in traffic generation should bear approximately a direct relationship to the number of inhabitants, unless other facilities exist within the zone which cause additional traffic. Zones No. 4, 6, 7, 9 and 10 are expected to remain largely residential in character, while Zones No. 2, 3, 5 and 8 will probably continue to be mixed with residential and commercial, governmental or industrial sections within the zone. Zone No. 1 is expected to continue to be largely devoted to industrial and commercial purposes.

Average income levels of the population in residential zones will also affect the type of traffic generated. Lower income areas, such as Zones No. 4 and 7, will undoubtedly generate more pedestrian, bicycle and motorcycle traffic than higher income areas such as Zone No. 2. However, this pattern could change somewhat over

time, particularly in the newly-settled areas. Zones 4, 7, 8, 9 and 10 are presently being developed and the normal pattern for new families appears to be to construct temporary shelter and, as family income rises, to construct permanent shelter and then to adopt more costly forms of transport.

TABLE XII-12

COTONOU AND SUBURBS
PRESENT AND FORECAST POPULATION BY O/D ZONES: 1970-1997

O/D Zones Within City Limits	Estimates 1970	Percentage of Total Population 1970	Forecast 1970	Percentage of Total Population 1995	Annual Growth
1	20,500	14	22,500	5	0.5%
2	11,000	7	27,000	6	3.7%
3	36,000	24	55,500	12	1.8%
4	25,250	17	61,000	14	3.7%
5	7,500	4	14,000	3	2.5%
6	6,750	4	11,300	2	2.2%
7 [31]	4,000	3	10,300	2	3.8%
8 [31]	5,000	3	37,400	8	8.3%
Outside City Limits [32]					
7 [31]	11,600	8	70,300	16	7 %
9	11,700	8	70,300	16	7 %
10	11,700	8	70,400	16	7 %
Totals	150,000	100	450,000	100	

Average Annual Growth rate about 4.5%

The relative importance of Zone No. 8 for traffic generation is expected to remain about the same over the study period, largely because of industrial expansion, but also because this zone is expected to increase more rapidly in population than any other within the city limits. Zone No. 5 also contains industrial establishments but the space

[31] O/D Zones No. 7 and 8 include areas within and outside the present city limits.

[32] The total estimated population outside the city has been arbitrarily divided equally into each zone, as the existing population is not known. This also provides a reasonable forecast of relative growth in each zone. Source: Section III, City of Cotonou-Planning Analysis, Tables III-2 and III-5.

available for additional industry is limited and the bulk of future expansion is likely to occur in Zone No. 8. Thus, Zone No. 5 is expected to decline in relative importance. In time, a shortage of space in Zone No. 8 may occur and additional industrial zones in outlying areas may be required. However, the amount of space available in Zone No. 8 is probably sufficient for several years and the location of additional zones has not been planned. In addition, some light and service industries are presently scattered throughout the city and this practice will probably continue as the city grows.

Zone No. 1 includes the port, the central business district, some older industries and several government offices. For these reasons, it is the most important zone for traffic generation at the present time. Although this zone will remain relatively important, the proportion of total traffic traveling to and from this zone is expected to decline over the study period. In part, the decline will probably occur as other business districts are developed in outlying areas. As high density housing is not anticipated to develop in any area of the city, population growth will produce a nearly proportionate increase in distances to the central part of the city. Under these circumstances, it seems reasonable to predict that shopping centers will develop in other parts of the city within a few years. The opening of the Saint Michel bridge and the improvement of the approach roads should hasten this trend, particularly for further development of the small businesses along Saint Michel Boulevard into a second shopping district.

The importance of the open market at the end of Boulevard Saint Michel would be heightened by the increased ease of access following bridge construction. Thus, traffic across the estuary to Zones No. 3 and 4 should increase more than the population increase in each would indicate - since the Saint Michel open market is located in both zones. Zone No. 4 should also become the most populous area within the present city limits, containing about 14% of the projected population in 1995, and zone No. 3 should become the second largest, containing nearly 12% of the urban population. As more of the open market is located in Zone No. 3, traffic to that zone should be even greater than to Zone No. 4.

Although the number is much higher on market days, which occur every fourth day, an average of some 5,500 people travel daily to this open market by boat. A sizeable volume of produce is also transported to the market by boat from Lake Nokoue and various points along the estuary. Most of the boat passenger traffic and much of the produce traffic will shift to vehicular conveyance or become pedestrians across the new bridge.

As the city grows, the need for more open markets will also grow as greater numbers of people settle in distant areas, particularly Zones No. 9 and 10. Thus, smaller versions of the Saint Michel Market are very likely to develop in these outlying areas to serve the lower-income inhabitants.

As traffic on the International Route No. 11 traverses Zones No. 9 and 10, all

traffic to or from points beyond these zones is regarded as attributable to the respective zone. Thus, the proportion of projected traffic attributed to each zone will be substantially greater than the population of each of these residential zones would justify.

Three residential zones contain no special facilities which would occasion additional traffic. Thus, Zones No. 2, 6 and 7 are expected to generate traffic in approximate proportion to their projected population. Traffic from Zones No. 2 and 6 should decline substantially as a proportion of the projected total, but that from Zone No. 7 would rise sharply from present levels.

The relative importance of traffic between each zonal pair should shift over the 20-year study period because of these expected changes in the structure of the city. The proportion of total traffic by vehicle category between each zone in 1977, 1987 and 1996 is shown in Table XII-13.

For the passenger cars and taxis the zonal pairs 1-5, 1-9 and 3-5 will continue to generate the largest traffic volumes although only zonal pair 1-9 shows the largest and an increasing proportion of the total traffic.

For the trucks and busses zonal pairs 1-5, 1-8 and 1-9 have the largest volumes but all have declining proportions of the total traffic. Zonal pairs 3-9 and 10-8, have lesser but still substantial volumes, and show an increasing proportion of the total traffic. This would indicate that in the future years truck and bus traffic originating in or going to areas outside Cotonou city limits will assume an increasing importance.

For the pedal and motor bicycle traffic, the zonal 1-5, 1-8, 3-5 and 3-8, have the largest volumes but all show a declining proportion of the total traffic. On the other hand, zonal pairs 4-7 and 4-8, show the largest growth in the proportion of the total traffic thus reflecting the expected great increase in the population of Zones 4, 7 and 8.

For the pedestrian traffic, the zonal pairs 1-5, 1-6, 3-5 and 3-6 contain the largest volumes but all show approximately 50 percent decline in their proportion of the total traffic in the future years. Zonal pairs 1-7, 1-8, 3-7 and 3-8 have lesser volumes but show an increasing proportion of the total pedestrian traffic. This again reflects the expected large increase in population in Zones 7 and 8 and shows also that Zones 1 and 3 will continue to be important sources of pedestrian traffic.

5. The Effect of Bridge Location upon Traffic Flow

The location of the existing bridge has had no apparent significant effects upon the development of the city up to the present time. Unimproved roads and poor access routes to the northern part of the city may have held back the settlement of these areas in relation to other parts of the city. However, the effects of congestion at the existing site, and the lack of a crossing at Boulevard Saint Michel, will have a much more important effect upon future development. Drivers are already beginning to complain

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TABLE XII-13

PROPORTION OF TOTAL TRAFFIC BY TRAFFIC CATEGORY BETWEEN CITY ZONES (1977-1996)

Zonal O - D	Cars 1977	Cars 1987	Cars 1996	Trucks/Buses 1977	Trucks/Buses 1987	Trucks/Buses 1996	Motor/Bikes 1977	Motor/Bikes 1987	Motor/Bikes 1996	Pedestrians 1977	Pedestrians 1987	Pedestrians 1996
1 - 5	17.7	17.2	16.4	15.6	13.0	11.1	16.4	12.2	8.8	20.7	17.2	12.3
1 - 6	3.7	2.7	2.1	0.6	0.5	0.4	7.0	5.2	3.7	15.5	10.6	7.1
1 - 7	1.0	1.5	1.9	0.1	0.4	0.8	5.6	7.5	8.1	7.7	8.6	8.1
1 - 8	12.0	14.2	15.5	25.3	25.7	25.1	11.9	11.8	10.4	6.8	9.3	10.1
1 - 9	19.8	23.4	25.6	16.2	16.4	16.0	2.1	4.1	5.9	1.1	2.5	3.8
2 - 5	4.2	3.0	2.4	3.1	2.6	2.2	2.6	1.7	1.1	2.8	2.1	1.5
2 - 6	0.9	0.7	0.5	0.0	0.0	0.0	1.6	1.1	0.7	1.3	1.0	0.7
2 - 7	0.1	0.0	0.0	0.1	0.1	0.1	0.9	1.0	0.9	1.1	1.7	2.0
2 - 8	2.2	1.8	1.5	1.8	1.5	1.3	1.1	0.9	0.7	1.8	2.0	1.9
2 - 9	2.3	2.2	2.1	1.6	1.4	1.3	0.2	0.1	0.1	0.1	0.1	0.1
3 - 5	8.2	6.0	4.6	2.3	1.9	1.6	14.0	10.4	7.5	11.9	8.1	5.5
3 - 6	3.0	2.4	2.0	0.3	0.3	0.3	4.5	2.7	1.7	8.6	5.9	4.0
3 - 7	1.5	2.6	3.8	0.2	1.0	2.7	2.1	2.8	3.0	4.2	6.2	7.2
3 - 8	4.4	3.5	2.9	3.3	3.4	3.3	10.8	9.7	8.0	4.4	5.4	5.4
3 - 9	4.7	4.6	4.4	6.9	8.5	9.6	1.5	3.1	4.4	1.7	3.8	5.7
4 - 5	3.3	2.6	2.2	1.1	1.0	0.9	6.0	4.5	3.2	2.7	2.5	2.0
4 - 6	1.2	0.9	0.8	0.1	0.1	0.1	1.3	0.9	0.7	0.9	0.8	0.6
4 - 7	0.7	1.5	2.4	0.2	1.0	2.7	0.6	3.1	8.1	1.2	2.9	4.8
4 - 8	2.7	2.6	2.5	0.9	0.9	0.9	7.0	11.4	14.1	2.6	4.3	5.3
4 - 9	1.5	1.6	1.6	0.1	0.1	0.2	0.4	1.3	2.5	0.4	2.6	8.5
10 - 5	1.0	0.9	0.9	2.4	2.0	1.7	0.4	0.5	0.5	0.9	0.7	0.5
10 - 6	0.4	0.4	0.3	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.0	0.0
10 - 7	0.1	0.1	0.1	0.3	0.4	0.4	0.1	0.3	0.4	0.2	0.3	0.3
10 - 8	0.6	0.8	0.9	7.9	8.8	9.2	0.7	2.0	3.7	0.1	0.2	0.2
10 - 9	1.7	1.5	1.4	8.4	7.7	7.0	0.1	0.3	0.4	0.1	0.0	0.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

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about delays at the bridge and the absence of improved roads, and a northern crossing will throw more and more traffic into the already crowded central business district.

The discussion of levels of service with alternate bridge locations are given in Section IV. In the same Section, it was shown that much less congestion will exist with a bridge at Boulevard Saint Michel, although additional traffic will be forced to divert from the existing bridge in the years from 1984 on. In Section IV, it was also pointed out that a total of six lanes of traffic across the lagoon will be needed to serve the traffic adequately, through 1996. Due to lack of physical room in the central business district, just west of the existing bridge, it is not possible to provide a six-lane approach at that spot. Thus a two lane parallel bridge would not junction adequately after 1988, and a four-lane bridge would not help, since the approaches are too narrow and subject to cross traffic and train crossings, and would also become overcongested in 1988.

It seems, therefore, desirable to provide a new crossing at Boulevard Saint Michel. As soon as the new bridge is open to traffic, a certain amount of drivers will immediately use this bridge.[33] As the conditions at the existing bridge begin to be excessively congested, in 1984, more traffic will divert to the Saint Michel bridge. Initially, only those vehicles for whom the trip is not much longer (by distance) will divert and will cross the lagoon via the Saint Michel bridge. As the traffic volumes grow and the congestion increases again at the existing bridge, more cars will divert to the Saint Michel bridge even if the travelled distance becomes substantially longer for them.

Eventually, the distribution of traffic will be such that approximately 60% of the total lagoon crossing traffic will use the Saint Michel bridge. This is logical, since it will be a centrally located bridge which is, in essence, convenient to almost all traffic, except that which travels between Zones 1 and 5.

In 1996, both the existing and the Saint Michel bridge will become congested, and therefore, a third bridge across the lagoon, possibly at Agbato, will become necessary.

F. EXPECTED BENEFITS FROM PROPOSED CONSTRUCTION

1. Types of Benefits

The most important benefit resulting from construction of an additional bridge would be a reduction in anticipated congestion for future traffic across the estuary. Thus, vehicle operating costs and the time required to make a trip across the estuary should be substantially less with two bridges. In addition, the traveling distance between the northern zones of the city would be reduced significantly by construction of the new bridge at the Boulevard Saint Michel site.

Construction of the proposed dam should increase the fish catch markedly on

[33] See the diversion factors shown in Tables XII-8 through XII-11.

Lake Nokoue and the smaller Porto-Novo Lagoon. In addition, the need to construct a rock mat to protect the foundation of the new bridge against erosion is eliminated and therefore the total cost of the new bridge construction is reduced.

2. Estimation of Vehicle Operating Costs in Cotonou

Although some research has been done on operating costs for rural conditions in other African countries, [34] no information is available on operating costs for urban conditions in Africa, particularly for congested urban conditions. Therefore, research data from other continents has been applied to the best available information on rural operating costs in Dahomey, to develop cost approximations at lower urban speeds and for congested traffic conditions.

In the N.D. Lea and Lamarre Valois study, basic costs and usage factors for vehicles operating in Dahomey, have been determined through field investigations. Methods of calculating operating costs on various types of roads at a range of speeds are also outlined.[35] The methodology is based upon that presented in an earlier report [36] and is designed for free running conditions, at the average speeds normally achieved in rural areas. These factors and methodology have been used to calculate operating costs, by major component, for the two surface types prevalent in Cotonou, at an average speed of 32 kilometers per hour. The results are shown in Table V-1 on page A-20 in Appendix A.

Although designed for rural conditions, these bench mark costs have been assumed to approximate operating costs in relatively free running conditions at the same average speed in Cotonou. Any errors introduced by this assumption would probably underestimate costs in urban areas. In the absence of better information on costs at lower speeds, estimated relationships in the U.S.A. have been applied to the Lea benchmark costs.

In his "Economic Analysis for highways", Robley Winfrey presents cost relationships and coefficients for a wide range of speeds and for congested conditions. [37] The ratio for each cost component at lower speeds to the 20 mph. benchmark speed in

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[34] Vehicle Operating Costs on Bituminous, Gravel and Earth Roads in East and Central Africa, R.S.P. Bonney and N.F. Stevens, Her Majesty's Stationery Office, Road Research Technical Paper No. 76, London 1967.

[35] Dahomey Land Transport, ibid., Chapter 6 and Appendix E.

[36] Quantification of Road User Savings, Jan de Weille, International Bank for Reconstruction & Development, 1966.

[37] Economic Analysis for Highways, Robley Winfrey, International Textbook Company, 1969, Appendix A.

Winfrey has been multiplied by the estimated/cost for the same component at 32 mph. in Dahomey, to derive relative costs at 4 k.p.h. intervals down to a speed of 8 k.p.h. The results are presented in Table V-2 through V-7 in Appendix A.

As these estimates represent approximations of running costs at uniform speeds, the costs of repeated stops and of vehicle standing time under congested traffic conditions would be additional. Vehicle standing time increases over the study period and becomes a major part of total operating costs of the existing bridge in later years. Therefore, careful attention has been given to each component of standing costs in Table V-8 in Appendix A which is based upon the usage and basic cost factors presented in the Lea report.

The additional stopping costs, due to congestion, are calculated in a similar manner to running costs at lower speeds, by applying ratios from the Winfrey data to bench mark costs derived from the Lea report. The resulting costs of stopping and a further explanation on methods are shown in Table V-9 in Appendix A.

The absence of reliable information on vehicle operating costs under congested urban conditions in Cotonou necessitates use of this method of approximation. As traffic conditions in Cotonou do not appear significantly different from those in a U.S. city of similar size, the cost relationships presented by Winfrey should be reasonably close to those encountered in Cotonou. The resulting costs of vehicle operation at all selected speeds and the standing and stopping costs are shown in Table XII-14, for two categories of vehicles on two roadway surfaces.

The three vehicle types used in the tables V-1 through V-7 are defined the same as classes 2, 4 and 5 of the Lea report[38]. Observation during the traffic counts confirmed that these classes are also representative of the traffic crossing the estuary. A typical or representative car would be a medium sedan of European manufacture, such as a Peugeot 404. Most of the busses are especially designed "mammy wagons", constructed similar to a 1-ton panel van, with four tires and a capacity of ten passengers. The truck class covers all cargo vehicles from light trucks to heavy semi-trailer units. Most are general purpose vehicles, with dual tires on a single rear axle and a capacity of about 5 tons.

Truck and bus costs are combined on Table XII-14 although not in the tables V-1 through V-7 in Appendix A, because future traffic in each category is expected to grow at the same rate. Thus, the combined operating costs are weighted in proportion to the volume of present traffic in each category (28% busses and 72% trucks). This may somewhat underestimate future costs as larger busses, with truck operating characteristics, should supplant some of the "mammy wagons" currently in use, as distances and the number of bus passengers increase with the growth of the city.

[38] Dahomey Land Transport, ibid., pages 5p 12 to 14.

TABLE XII-14

COTONOU BRIDGE
VEHICLE OPERATING COSTS AT SLECTED SPEEDS
(per kilometer)

	Car Costs		Combined Truck and Bus Costs	
Speeds-kph	Paved	Earth	Paved	Earth
8	37.646	44.544	82.157	98.802
12	27.836	34.035	60.063	76.426
16	22.825	28.819	48.742	65.353
20	19.772	25.713	41.970	59.330
24	17.650	23.504	37.438	55.711
28	16.166	22.166	34.231	53.372
32	15.002	21.082	31.893	52.289
COST OF STOP CYCLES (per cycle)				
Speeds				
8	.164	.164	.800	.800
12	.256	.256	1.378	1.378
COST OF VEHICLE STANDING TIME (per minute)				
	5.017	5.017	10.2	10.2

No attempt has been made to estimate the relative costs of operating motorcycles, motorized bicycles or pedal bicycles at different speeds and under conditions of congestion, as no cost information exists for this type of transport. Presumably, the cost differentials per vehicle would be small for this low cost form of transport even though the current and projected volume of traffic is high.

The terrain in Cotonou is flat and the two road types shown in Table XII-14 and in Tables V-1 through V-7 in Appendix A are typical of present street conditions. Paved roads are two-lane bituminous surfaced roadways and the balance of the streets are earthen roads, usually containing two usable lanes with a natural sand surface, even though the roadway is much wider. A few earthen roads have select material surfaces but many others are in poor condition. For vehicle operating cost calculations, these two types are regarded as equivalent to Classes 2 and 5 of the Lea report.[39]

[39] Dahomey Land Transport, ibid., Chapter 6 and Appendix E.

3. Alternative Improvement Assumptions

In order to compare the benefits of constructing a new bridge at the Saint Michel site with those of a parallel bridge, vehicle operating costs were estimated for three different cases. Case one assumes that no improvements are made and that all traffic across the estuary continues to use the existing bridge. Case two presumes that a new bridge, as described in Section VIII, is completed at Boulevard Saint Michel by the beginning of 1977, and that vehicles, thereafter, can use either the new or the existing bridge at the driver's option. Case three presumes that a new bridge, parallel to the existing structure, is completed by early 1977, with vehicular traffic using both structures in accordance with the best means of traffic regulation and flow. It is also assumed, under both cases two and three, that the approach roads to the respective sites are improved, as described in Section VIII and that all roads are adequately maintained during the study period (including the roads for case one).

4. Calculation of Vehicle Operating Savings

The amount of congestion which will confront drivers in future years will obviously be different under each of the three cases and will also differ for the two alternative routes under case two. Method of calculation of vehicle delays, standing time and congested distances has been described in Section IV. The results are shown in Tables XII-15 through XII-17. In the calculation of delay costs the following assumptions were made:

a. After the year in which delays begin to exceed 60 minutes, the drivers will begin to avoid making the trip across the estuary. Eventually, the extreme congestion will deter additional traffic growth. However, the value of the loss in business, trade and production due to the refusal of drivers to make the trip, is assumed equal to the actual number of cars wanting to cross the estuary, times the costs of a delay which remains constant and equal to 60 minutes. Thus the delay costs will continue to rise each year in proportion to the increased number of vehicles. In lieu of attempting to estimate production and dislocation losses in future years, traffic has been assumed to continue to grow after 1986 at the rate of 75% of the former rates for the benefit/cost computations.

b. As the congestion becomes excessive at the existing bridge, drivers will shift to Saint Michel bridge. The proportion of drivers shifting to Saint Michel bridge is assumed to vary linearly and to be determined by proportion from factors given in Tables XII-8 through XII-11.

c. The normal growth of traffic in the downtown business area, but not necessarily crossing the bridge, will increase the congestion for all vehicles in the area. This factor is taken into account by limiting the approach road capacity in relation to overall daily traffic volume.[40]

[40] See Section IV, Effect of Traffic Composition and Number of Lanes on Levels of Service.

Included in the delay calculations are those estimated distances where traffic moves bumper-to-bumper, with frequent stops and waiting periods. These conditions are expected to prevail on the bridge and particularly in the approach areas where traffic from several streets meld together to gain access to the bridge. The delay time shown in Tables XII-15 through XII-17 are averages to be applied to all traffic, as some vehicles crossing the bridge at peak hours will encounter much greater congestion, while vehicles crossing at other times should encounter less delay, or perhaps, none at all, if traveling during night hours. In calculating trip costs, the congested distances are subtracted from total trip distances to determine the distance traveled at the speeds shown on Table XII-18.[41] Total trip costs are the sum of the congested and "free running" costs between each origin-destination (O/D) zonal pair.

As the city grows and traffic volumes increase, the amount of congestion under each case should increase and the average speeds in non-congested areas are expected to decline due to greater interference from other vehicles and pedestrians and to more traffic regulatory measures. However, the average speeds in non-congested conditions, shown on Table XII-18 will also vary between O/D zones depending upon the route used to cross the estuary. As the areas along the route to the San Michel crossing are likely to remain less developed than the central business district, through which all traffic must pass to the present bridge site, average speeds between zones are expected to be higher on the San Michel route. Thus, operating costs and travel time would be less via this route for the non-congested distances, without considering the effect of full congestion at the present crossing.

Congestion under case one (no improvement case), where all traffic continues to use the existing bridge is expected to be far worse than in the other two cases. All traffic will funnel through the central business district and waiting times to gain access to the bridge increase rapidly over time.[42] Thus, most of the business district should be filled with bumper-to-bumper, stop-and-go traffic for several hours a day by 1983. Before that time, drivers will begin to avoid crossing during hours of heavy traffic because of the inconvenience and delay. At some point, traffic growth might stop entirely. As most of the vehicular traffic across the estuary travels for business purposes, such as shopping, employment, cargo and passenger transfer, general economic activity is bound to suffer. Instead of attempting to estimate the losses and dislocations to trade, production and business or the crossing costs by other modes of transport, traffic had been assumed to continue growing at 75% of previous rates to the end of the study period. This assumes the high operating costs for the additional traffic would approximate the losses in general economic activity or the travel costs by other modes. The 25% reduction in traffic growth is applied also to the other two cases, although delays are substantially less and occur only in later years.

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[41] As the approach roads are paved, the congested distances are subtracted first from the paved surface and then from the earth distances between each set of zones.

[42] See Table XII-15

TABLE XII-15

CALCULATED DELAYS AND CONGESTED DISTANCES
No Improvement Alternative

Year	EVU	EVU delayed more than 60 minutes	EVU delayed less than 60 minutes	Number of hours bridge capacity exceeded	Applicable to Total ADT**	
					Average EVU waiting time (min)	Average congestion distance (meters)
1971	20419	0	0	0	0.0	0.0
1972	21665	0	1841	0	0.0	0.0
1973	23002	0	5672	0	0.1 **	0.0
1974	24437	0	6027	0	0.2 **	0.0
1975	25979	0	12104	0	0.5 **	0.0
1976	27639	0	22225	0	0.9 **	0.0
1977	29427	0	23659	0	1.4	0.0
1978	31356	337	25205	3	3.0	727.6
1979	33439	1114	26874	5	6.7	1918.4
1980	35692	2765	30554	10	18.3	3720.8
1981	38132	5372	32639	11	54.7	12028.0
1982	40779	8221	34900	11	101.5 *	24438.2
1983	43656	11454	38934	12	149.6 *	35661.2
1984	46789	15069	43243	12	195.2 *	50097.2
1985	50206	19012	46394	12	238.5 *	65844.9
1986	53942	23366	49837	13	279.5 *	76670.9
1987	56977	27076	54102	14	308.9 *	83178.4
1988	60231	31213	57192	14	337.1 *	96029.8
1989	63725	35658	61840	15	364.1 *	102516.7
1990	67484	40637	65488	15	393.3 *	117335.8
1991	71534	46032	69418	16	421.2 *	124971.9
1992	75903	52020	73659	16	448.0 *	141128.7
1993	80626	58493	79282	16	473.7 *	158597.5
1994	85740	65503	84312	16	498.4 *	177519.3
1995	91289	73317	89769	17	522.0 *	186404.2
1996	97322	81814	95702	17	544.6 *	207421.6

* 60 minutes average delay assumed for cost computation
** Delay not included in vehicle operating cost computations

TABLE XII-16

CALCULATED DELAYS AND CONGESTED DISTANCES
Parallel Bridge Alternative

Year	EVU	EVU delayed more than 60 minutes	EVU delayed less than 60 minutes	Number of hours bridge capacity exceeded	Applicable to Total ADT **	
					Average EVU waiting time (min)	Average congestion distance (meters)
1977	29427	0	0	0	0.0	0.0
1978	31356	0	0	0	0.0	0.0
1979	33439	0	0	0	0.0	0.0
1980	35692	0	0	0	0.0	0.0
1981	38132	0	0	0	0.0	0.0
1982	40779	0	0	0	0.0	0.0
1983	43656	0	0	0	0.0	0.0
1984	46789	0	0	0	0.0	0.0
1985	50206	0	0	0	0.0	0.0
1986	53942	0	0	0	0.0	0.0
1987	56977	0	9687	0	0.0	0.0
1988	60231	0	19578	0	0.2	0.0
1989	63725	0	34186	0	0.5	0.0
1990	67484	1164	54147	3	2.5	1112.1
1991	71534	3965	57390	6	10.5	3628.0
1992	75903	10124	64880	11	48.9	10929.2
1993	80626	17647	68909	11	115.0 *	27775.4
1994	85740	26391	73271	12	183.3 *	43369.6
1995	91289	35918	84227	12	248.8 *	62799.6
1996	97322	46758	92420	14	311.4 *	71933.4

* 60 minutes average delay assumed for cost computation

Under case two, new four-lane bridge at Boulevard Saint Michel, the distances between the northern zones of the city will be substantially shorter via the Saint Michel crossing, and most traffic between these zones is expected to divert to a new bridge. The distances between all zones, as shown on Table XII-19, is calculated by using an estimated center of traffic generation within each zone, and the roadway surface distances assume that improvements recommended in each case are made.

Because of the factors previously described,[43] serious congestion is not

[43] See Section IV.

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TABLE XII-17

CALCULATED DELAYS AND CONGESTED DISTANCES
AT EXISTING BRIDGE **
Saint Michel Bridge Alternative

Year	EVU	EVU delayed more than 60 minutes	EVU delayed less than 60 minutes	Number of hours bridge capacity exceeded	Applicable to Total ADT **	
					Average EVU waiting time (min)	Average congestion distance (meters)
1977	17836	0	0	0	0.0	0.0
1978	18421	0	0	0	0.0	0.0
1979	19024	0	0	0	0.0	0.0
1980	19646	0	0	0	0.0	0.0
1981	20287	0	0	0	0.0	0.0
1982	20948	0	0	0	0.0	0.0
1983	21629	0	3646	0	0.0	0.0
1984	22331	0	3770	0	0.0	0.0
1985	23053	0	3898	0	0.1	0.0
1986	23797	0	7695	0	0.2	0.0
1987	25019	0	8095	0	0.3	0.0
1988	26312	0	12294	0	0.6	0.0
1989	27683	0	20394	0	0.9	0.0
1990	29135	0	23331	0	1.3	0.0
1991	30676	250	24561	2	2.4	697.2
1992	32311	722	25867	4	4.0	1036.0
1993	34047	1531	29079	6	8.7	2351.8
1994	35891	2910	30651	10	19.3	3997.3
1995	37850	4948	32321	11	49.1	10649.9
1996	39935	7185	34098	11	84.9 *	19907.4

* 60 minutes average delay assumed for cost computation

expected to occur at the Saint Michel bridge before the end of the study period. As noted, however, average speeds on this route should decline over time due to further development in the approach areas and the general growth of traffic throughout the city. The balance of traffic which continues to use the existing bridge would, however, encounter growing congestion in the approach areas. As congestion increases, additional traffic will divert to the Saint Michel route to avoid these congestion delays and inconvenience.

TABLE XII-18

COTONOU BRIDGE
FREE RUNNING SPEED ASSUMPTIONS: ALTERNATE CASES[44]
(Kilometers Per Hour)

ALL CASES: TRAFFIC USING EXISTING BRIDGE

Years 1970 to 1976

O/D Zones	5	6	7	8	9
1	24	22	17	32	40
2	27	24	22	34	42
3	26	24	21	32	37
4	24	22	21	29	34
10	37	32	27	39	45

Years 1977 to 1981

O/D Zones	5	6	7	8	9
1	16	16	12	24	28
2	20	20	16	24	32
3	20	16	12	20	28
4	16	16	12	20	24
10	24	20	16	28	32

Years 1982 on

O/D Zones	5	6	7	8	9
1	8	8	12	20	24
2	16	16	16	20	28
3	16	16	12	20	28
4	16	16	12	20	24
10	24	20	16	28	32

CASE II: TRAFFIC USING SAINT MICHEL BRIDGE

Years 1977 to 1981

O/D Zones	5	6	7	8	9
1	24	24	24	28	28
2	28	28	28	28	28
3	28	28	28	28	28
4	24	24	24	28	28
10	32	32	28	32	32

[44] See Origin/Destination Map, Page A-1 in Appendix A, for the location of each zone.

TABLE XII-18 (Continued)

CASE II: TRAFFIC USING SAINT MICHEL BRIDGE (Continued)

O/D Zones	Years 1982 on 5	6	7	8	9
1	20	20	20	24	24
2	24	24	24	24	24
3	24	24	24	24	24
4	24	24	24	28	28
10	28	28	28	32	32

TABLE XII-19

COTONOU BRIDGE
DISTANCES BY SURFACE TYPE: ALTERNATE ASUMPTIONS[45]
(Kilometers on Paved (P) and Earth (E) Roads)

PRESENT BRIDGE AND PARALLEL BRIDGE

Origin-Destination Zones

	5		6		7		8		9	
Zones	P	E	P	E	P	E	P	E	P	E
1	1.7	0.3	1.1	1.3	1.1	2.2	3.3	0.3	6.9	0.3
2	4.9	0.0	4.3	1.1	4.3	1.9	6.5	0.0	10.1	0.0
3	3.3	0.2	2.7	1.3	2.7	2.1	4.9	0.2	8.4	0.2
4	3.9	0.1	3.4	1.2	3.4	2.0	5.5	0.1	9.1	0.1
10	8.4	0.0	7.9	1.1	7.9	1.9	10.1	0.0	13.6	0.0

PROPOSED BRIDGE AT SAINT MICHEL

Origin-Destination Zones

	5		6		7		8		9	
Zones	P	E	P	E	P	E	P	E	P	E
1	5.1	0.2	2.8	0.6	3.5	0.5	5.5	0.2	9.0	0.2
2	6.9	0.0	4.8	0.5	5.4	0.3	7.4	0.0	10.8	0.0
3	4.0	0.2	1.9	0.7	2.5	0.5	4.5	0.2	8.0	0.2
4	4.3	0.1	2.3	0.6	2.8	0.4	4.8	0.1	8.3	0.1
10	8.1	0.0	6.0	0.5	6.6	0.3	8.6	0.0	12.1	0.0

[45] See Origin-Destination Map in the Appendix for the location of each zone.

Total operating costs for all traffic under case two, is the sum of the costs for that portion of the traffic crossing at Saint Michel, and for the balance of the traffic crossing the existing bridge. These annual costs for each year of the study period are subtracted from the total annual costs under case one, with the remainder representing the estimated vehicle operating savings due to construction of a new bridge at Saint Michel.

Under case three, (parallel two-lane bridge next to the existing one), the construction of an additional bridge and improved approach roads would reduce congestion considerably at the crossing site in the early years. However, all traffic would still have to move through the central business district and congestion in the business area during the later years of the study period would become excessive. Again, the total annual operating costs under this case are subtracted from annual costs under the no improvement case to calculate vehicle operating savings resulting from construction of a parallel bridge and improvement of the approaches.

5. Time Savings

It is obvious, from the foregoing, that travel time for vehicle passengers would be reduced in future years by the construction of an additional bridge at either location. The delay time shown in Tables XII-15 through XII-17 would apply to passengers in all types of vehicles and to motorcycles and bicycle riders. Although the same delay is unlikely to be encountered by pedestrians, a new bridge at Boulevard Saint Michel would save both distance and time for pedestrians.

However, the probable extent of partial and complete unemployment in Cotonou and in the surrounding villages and rural areas tends to reduce the economic value of time and, therefore, of time savings toward zero. As additional personnel are available, economic activities are not likely to suffer because of a labor shortage due to the time lost in crossing the estuary. Therefore, no value has been attributed to the time savings of vehicle passengers, motor and bicycle riders or of pedestrians. However, time savings would be high after 1984 and should be seriously considered in the final decision on construction of an additional bridge.

In contrast, the extra time required for vehicles to cross the estuary with the expected future congestion levels does have economic value. The cost of extra transport vehicles to carry an equivalent volume of goods and the additional inventory of goods and material necessitated by increasing delays in crossing the estuary, could be calculated in order to derive an additional savings. Although quantification of this item might prove difficult, as cargo vehicles could be scheduled to cross the existing bridge at night or during periods of low traffic, the calculation of these savings has not been necessary, because the reduction in vehicle operating costs alone provides high rates of return on the construction of an additional bridge.

6. Effects Upon Urban Development

The absence of an additional bridge will lead to much greater congestion overtime which will deter normal traffic growth and undoubtedly will affect the pattern of urban growth on both sides of the estuary. Attempts will be made by people, institutions and firms to locate or move to areas which minimize the necessity of crossing the estuary. The end result will probably be to emphasize development in the western half of Cotonou, while growth in the areas east of the estuary would suffer.

Although dislocations would certainly result, it is difficult to predict, with any degree of accuracy, to what extent the absence of an additional bridge and the resulting congestion would inhibit urban development (including further industrialization and expansion of the commercial sector). As all new industrial projects are planned to be located in Cotonou (which will undoubtedly remain the commercial center of Dahomey), the construction of an additional bridge is not expected to constitute immediately a significant attraction for further industrialization. However, in the later years, an additional bridge will be essential for a continued economic growth. Thus, it could, indirectly, help to increase governmental tax revenues in a long run. On the other hand, reductions in vehicle operating costs, some components of which are taxed fairly heavily, may reduce tax revenue in earlier years.

Assuming that a new bridge is constructed, the Saint Michel location appears to be the preferable location for a variety of reasons, aside from high returns on the investment. As described in Section III, the northern areas on both sides of the estuary are being settled at the present time, and are capable of absorbing substantial increases in population. As these are nearest to the center of the city, further northward expansion is both natural and desirable, and will probably occur before outlying areas are occupied by large numbers of people.

By diverting local traffic away from the central business district and opening a new and shorter east-west route through the northern part of the city, a bridge at Saint Michel will probably hasten the development of a second commercial district in the area near the open market on both sides of the estuary. This expansion would probably not represent a net developmental benefit attributable to the new bridge, as business would largely be attracted away from the central business district.

Some additional traffic would be attracted to this area as commercial activity develops. However, neither location for an additional bridge is likely to generate much new traffic, as the traffic attracted to the Saint Michel area, for commercial purposes, would otherwise have traveled to the central business district.

7. Benefits of Dam Construction

The construction of the proposed dam has been included in the benefit/cost and IRR calculations for both new bridge alternatives considering only the benefits towards

erosion protection in the lagoon. Erosion benefits occur because of reductions in foundation requirements for both the new and existing bridge and in bank protection near the abutments.

A major result expected to follow construction of the proposed dam is the restoration of fishing yields in Lake Nokoue. A benefit/cost and IRR calculation has, therefore, also been made considering only the cost of the dam and fishing benefits. The expected production impact upon fishing is described in Dr. Thompson's report.[48] The calculations of the net benefits attributable to the dam in the Thompson report, Appendix Table 3, have been used in comparing benefits and costs. However, the increases in fish yields beyond the levels prevailing in 1960 have not been assumed[46], and the year in which the benefits are first obtained has been changed to 1977.[47] A summary of the benefit estimates is reproduced in Table XII-20.

TABLE XII-20

DAM CONSTRUCTION
BENEFITS DERIVING FROM ADDITIONAL FISH PRODUCTION[49]
(Thousands Fr. CFA, except where noted)

Year	Total Production	Incremental Fish Production (metric tons)	Gross Value	Material Costs	Net Benefits
1976	2,200	-	-	-	-
1977	3,600	1,400	127,750	28,119	99,631
1978	8,000	5,800	432,950	112,203	320,747
1979	13,800	11,600	539,750	128,310	411,440
1980 on	16,700	14,500	643,750	212,667	431,083

[46] Further increases in fishing yields would only result from better and more intensive fishing practices.

[47] It is anticipated that the dam would be completed in 1976 and therefore, the first effects of reduction in salinity would not be felt until 1977.

[48] Report of the Fishery Reconnaissance to Lake Nokoue, Dahomey, Richard Thompson, and Economic Evaluation of Expected Fishery Benefits, George Tanonaka, National Marine Fisheries Service, Biological Laboratory, Seattle, Washington, July 1971.

[49] All data are the same as shown in Appendix Table 3 of the source, except that amounts are shown in CFAF and production increases are not assumed after 1980. Source: Report of the Fishery Reconnaissance to Lake Nokoue, Dahomey.

The net benefits in Table XII-20 must be reduced each year by the value of the shrimp harvest which will be lost in the lagoon and the lake after the dam has been constructed. Shrimp fishing in these two areas is estimated at about 400 tons per year. At an average value of 150 Fr. CFA per kilogram of shrimp, the yearly loss would amount to 60 million Fr. CFA. The calculation of net benefits to fishing reduced by the losses of the shrimp catch are shown in Appendix C.

G. SUMMARY OF CONSTRUCTION AND MAINTENANCE COSTS

1. No Improvement Alternative

In this alternative, existing bridge repairs must be made and the roadway approaches must be maintained in order to insure that they will continue to be usable until the end of the study period. The repairs of the existing bridge will be extremely difficult and costly, since the traffic flow through the bridge must be maintained and there will be no other bridges to serve as a bypass during the repair work. It is assumed, therefore, that the cost of repairs would be 30% higher than in the other alternatives. This is a conservative assumption, since the actual costs would be much higher due to the fact that the bridge deck replacement work could only be done at night and high early strength (quick setting) concrete would need to be used.

Item	COST (Millions Fr. CFA) American Procurement	Foreign Procurement
Existing Bridge Repairs - Construction	129.3	126.9
Design and Construction Supervision	19.4	15.3
Total	148.7	142.2
Approach Roads - Maintenance (1977 to 1996) (Discounted to 1975 at 10%)	251.0	251.0
Total	399.7	393.2

2. Parallel Bridge Alternative

a. Without Dam:

Item	COST (Millions Fr. CFA) American Procurement	Foreign Procurement
Parallel Bridge - Construction	621.8	503.6
Alternate Erosion Protection - Construction	130.5	128.1
Design and Construction Supervision	112.9	75.8
Total	865.2	707.5
Approach Roads - Construction	33.5	37.4
Design and Construction Supervision	5.1	4.5
Total	38.5	41.9
Existing Bridge Repairs - Construction	129.3	126.9
Design and Construction Supervision	19.4	15.3
Total	148.7	142.2
Approach Roads - Maintenance (1977 to 1996) (Discounted to 1975 at 10%)	251.0	251.0

b. With Dam:

Parallel Bridge - Construction	621.8	503.6
Design and Construction Supervision	93.3	60.4
Total	715.1	564.0
Dam - Construction	430.0	454.3
Design and Construction - Supervision	96.0	54.5
Total	576.0	508.8

Costs for Existing Bridge Repairs, Approach Roads Construction and Maintenance are same as in 2. a.

3. Saint Michel Bridge Alternative

a. Without Dam:

Item	COST (Millions Fr. CFA) American Procurement	Foreign Procurement
Saint Michel Bridge - Construction	869.7	758.4
Alternate Erosion Protection - Construction	130.5	128.1
Design and Construction Supervision	150.1	106.4
Total	1150.3	992.9
Approach Roads - Construction [50]	150.4	181.3
Design and Construction Supervision	22.6	21.8
Sub Total	173.0	203.1
Approaches funded by F.E.D.	180.0	180.0
Approach Roads - Maintenance (1977 to 1996) [51] (Discounted to 1975 at 10%)	353.0	383.1

Existing Bridge Repairs - Same as in Parallel Bridge Alternative.

b. With Dam:

Saint Michel Bridge - Construction	869.7	758.4
Design and Construction Supervision	130.5	91.0
Total	1000.2	849.4

Costs for Approach Roads Construction and Maintenance are same as in 3. a. above. Costs for Dam and Existing Bridge Repairs are same as in 2.b. and 2.a. respectively, in the parallel bridge alternative.

4. Dam

As explained in Section IX, the costs for the proposed dam include the initial construction and subsequent adjustments needed to restore the weir to elevation +1.1 meters. Although some of the costs for the dam will be incurred in the years 1978 and possibly 1980, all costs are assumed in the benefit/cost calculations to be incurred in 1975, the year in which the construction of the project will commence. The costs for the dam are as shown above for the bridge alternatives.

[50] This cost includes only the immediate necessary approaches for the Saint Michel Bridge. The remainder of approaches connecting to the International Route will cost 180 millions Fr. CFA and will be funded by FED (see also page 8-2 in Section VIII).

[51] The maintenance costs include the portion of approach roads to be constructed under FED financing.

H. SUMMARY OF BENEFITS

The benefits consist of the difference in the vehicle operating and construction costs between the no-improvement and the new bridge alternative. The net benefit is computed as follows:

1. Parallel Bridge Alternative

a. Without Dam:

	(Millions Fr. CFA) American Procurement	Foreign Procurement
No improvement Alternate -		
Vehicle Operating Costs [52]	+ 36,897.0	+ 36,897.0
Existing Bridge Repairs	+ 148.7	+ 142.2
Maintenance of Approach Roads	+ 251.0	+ 251.0
Parallel Bridge Alternative -		
Vehicle Operating Costs [53]	- 16,413.0	- 16,413.0
Existing Bridge Repairs	- 148.7	- 142.2
New Bridge Construction and Approaches	- 753.7	- 605.9
Alternate Erosion Protection	- 150.1	- 143.4
Maintenance of Approach Roads	- 251.0	- 251.0
Net Benefit	+ 19,580.2	+ 19,734.7

b. With Dam:

Net Benefit from 1.a.	+ 19,580.2	+ 19,734.7
Dam	- 576.0	- 508.8
Alternate Erosion Protection	+ 150.1	+ 143.4
Net Benefit	+ 19,154.3	+ 19,369.3

2. Saint Michel Bridge Alternative

a. Without Dam:

No Improvement Alternate (All costs)	+ 37,296.7	+ 37,290.2
Saint Michel Bridge Alternate:		
Vehicle Operating Costs [54]	- 9,869.0	- 9,869.0
Existing Bridge Repairs	- 148.7	- 142.2
New Bridge Construction and Approaches *	- 1,353.2	- 1,232.5
Alternate Erosion Protection	- 150.1	- 143.4
Maintenance of Approach Roads	- 297.0	- 297.0
Net Benefit	+ 25,478.7	+ 25,606.1

* Includes 180 millions Fr. CFA funded by F.E.D.

[52], [53], [54] Discounted at 10 percent rate to 1975.

b. With Dam:

	(Millions Fr. CFA) American Procurement	Foreign Procurement
Net Benefit from 2. a.	+ 25,478.7	+ 25,606.1
Dam	- 576.0	- 508.8
Alternate Erosion Protection	+ 150.1	+ 143.4
Net Benefit.	+ 25,052.8	+ 25,240.7

3. Value of Increased Fish Production Due to Construction of the Dam

The fish benefits as described in Dr. Thompson's report and as modified in this study, over the period of 1975 to 1996 and discounted to 1975 at 10% rate amount to 2310 Millions Fr. CFA. This sum assumes that without any improvements the annual fish catch in Lake Nokoue would not deteriorate below 2200 tons/year through 1996.

In the sensitivity analysis it is assumed that the fish benefits would be reduced to 50 percent of those expected in each year. In this case the total 20 year benefits, again discounted at 10% rate to 1975, would amount to 943 Millions Fr. CFA.

In both cases the lost revenue from shrimp harvest in the lagoon and the lake are deducted from the net benefits.

4. Other Benefits

There are other substantial benefits to be obtained from the construction of both the new bridge as well as the dam. Some of the additional benefits could have been quantified and included in the benefit/cost computations. This was not done since sufficiently high B/C ratios are obtained without them. Among these is the substantial reduction in the costs of construction for the proposed West Bank Boulevard which would result from reduced requirements for erosion protection of the lagoon banks after the dam is constructed.[55] Other benefits will undoubtedly accrue from the value of drivers' time which would be saved with reduced congestion.

Among the non-quantifiable benefits are the improvement of conditions for a better urban development of Cotonou. These are discussed in detail in Section III.

I. BENEFIT/COST ANALYSIS AND INTERNAL RATES OF RETURN

1. Comparison of Various Alternatives

The net costs and benefits as well as internal rates of return are summarized in Tables XII-21 and XII-22.

[55] See also Section X.

2. Sensitivity to Changes in Traffic Growth Rates and Value of Benefits

The following changes have been included in order to minimize the benefits and maximize the costs for the purpose of sensitivity analysis:

Description	Decreased By
1970 Average Daily Traffic	10%
Traffic Growth Rates	20%
Vehicle Operating Savings	15%
Diverted Traffic to Saint Michel Bridge	15%
Fish Benefits	50%

All the changes are applied simultaneously, and the results are shown in Tables XII-23 and XII-24.

TABLE XII-21

BENEFIT/COST ANALYSIS AND INTERNAL RATES OF RETURN
AMERICAN PROCUREMENT

Alternative	Millions Fr. CFA		B/C at 10% Interest Rate	Internal Rate of Return
	Benefits	Costs *		
a. No Improvement	-	400	-	-
b. Parallel Bridge without Dam	19,580	1,304	15.05	44%
c. Parallel Bridge with Dam **	19,154	1,730	11.09	38%
d. Saint Michel Bridge without Dam	25,479	1,947	13.10	38%
e. Saint Michel Bridge with Dam **	25,052	2,373	10.57	34%
f. Dam ***	2,310	576	4.00	29%
g. Saint Michel Alternative Compared to the Parallel Bridge Alternative	6,078	2,373	2.57	-

* Includes both the construction and maintenance costs. All are discounted to 1975.
** Not including the fish benefits.
*** Only fish benefits and shrimp losses considered.

SANDERS & THOMAS INC.

TABLE XII-22

BENEFIT/COST ANALYSIS AND INTERNAL RATES OF RETURN
FOREIGN PROCUREMENT

Alternative	Millions Fr. CFA		B/C at 10% Interest Rate	Internal Rate of Return
	Benefits	Costs *		
a. No Improvement	-	393	-	-
b. Parallel Bridge without Dam	19,735	1,143	17.31	48%
c. Parallel Bridge with Dam **	19,369	1,508	12.86	41%
d. Saint Michel Bridge without Dam	25,606	1,813	14.14	39%
e. Saint Michel Bridge with Dam **	25,241	2,178	11.60	35%
f. Dam ***	2,310	509	4.50	30%
g. Saint Michel Alternative Compared to the Parallel Bridge Alternative	6,051	2,178	2.78	-

* Includes both the construction and maintenance costs. All are discounted to 1975.
** Not including the fish benefits.
*** Only fish benefits and shrimp losses considered.

SANDERS & THOMAS INC.

TABLE XII-23

SENSITIVITY ANALYSIS ****
BENEFIT/COST AND INTERNAL RATES OF RETURN
AMERICAN PROCUREMENT

Alternative	Millions Fr. CFA		B/C at 10% Interest Rate	Internal Rate of Return
	Benefits	Costs *		
a. No Improvement	–	365	–	–
b. Parallel Bridge without Dam	13,769	1,269	10.85	30%
c. Parallel Bridge with Dam **	13,343	1,695	7.87	26%
d. Saint Michel Bridge without Dam	14,036	1,912	7.30	26%
e. Saint Michel Bridge with Dam **	13,610	2,338	5.79	23%
f. Dam ***	943	576	1.60	16%

* Includes both the construction and maintenance costs. All are discounted to 1975.
** Not including the fish benefits.
*** Only fish benefits and shrimp losses considered.
**** Includes the following: Reduced: 1970 ADT by 10%, Traffic Growth Rates by 20%, Vehicle Operating Savings by 15%, Diverted Traffic to Saint Michel Bridge by 15%, Fishing Benefits by 50%.

TABLE XII-24

SENSITIVITY ANALYSIS ****
BENEFIT/COST AND INTERNAL RATES OF RETURN
FOREIGN PROCUREMENT

Alternative	Millions Fr. CFA		B/C at 10% Interest Rate	Internal Rate of Return
	Benefits	Costs *		
a. No Improvement	-	358	-	-
b. Parallel Bridge without Dam	13,924	1,108	12.57	32%
c. Parallel Bridge with Dam **	13,558	1,473	9.20	28%
d. Saint Michel Bridge without Dam	14,163	1,778	7.92	27%
e. Saint Michel Bridge with Dam **	13,798	2,143	6.40	24%
f. Dam ***	943	509	1.85	17%

* Includes both the construction and maintenance costs. All are discounted to 1975.
** Not including the fish benefits.
*** Only fish benefits and shrimp losses considered.
**** Includes the following: Reduced: 1970 ADT by 10%, Traffic Growth Rates by 20%, Vehicle Operating Savings by 15%, Diverted Traffic to Saint Michel Bridge by 15%, Fishing Benefits by 50%.

SECTION XIII

RECOMMENDATIONS

A. PROPOSED NEW CONSTRUCTION

1. Bridge

It is recommended that a new bridge be constructed at the site near Boulevard Saint Michel. The bridge should have four roadway lanes 3.5 meters wide with two 2.5 meters wide sidewalks. The overall bridge width will, therefore, be 19.0 meters.

The approaches to the bridge should have the following widths and lengths:

On the west side:	0.4 kilometers (4 lanes)
On the east side:	1.3 kilometers (4 lanes) and
	0.8 kilometers (2 lanes)

These lengths are considered essential to make the bridge usable without the additional approaches to be financed with FED funds.

A detailed description of the bridge and approaches is given in Section VIII and plans with details of proposed construction are shown in the Appendix, pages A-2, A-3, A-4, and A-5.

2. Dam

It is recommended that a rock and sandfill dam be constructed at the mouth of the lagoon. If the benefits to the fishing in Lake Nokoue are disregarded, the returns on the investment for the project (bridge with dam), are still high (based on vehicle operating savings and erosion benefits only). The cost of the dam is amply justified even when its entire cost is compared to fish benefits only. The details and description of the proposed dam construction are included in Section IX.

B. ADDITIONAL REPAIRS OF THE EXISTING BRIDGE

1. Substructure

The repairs of the existing bridge substructure were started in 1970 with FAC financing, and are still in progress. It is expected that the remaining needed repairs, as listed below, will be completed prior to the beginning of the new bridge project.

Bridge Piers:	Repaired in 1970
Rock mat for erosion protection:	Expected to be completed in 1972
Repair of Abutments and adjacent lagoon banks:	Expected to be completed in 1974

2. Superstructure

It is recommended that the existing bridge concrete deck be removed and entirely reconstructed in this project with wider sidewalks. It is also recommended that the existing bridge steel girders be cleaned and painted and that the lighting system be repaired. The details of the deck with widened sidewalks is shown in Section VII, Figure 7-2.

C. CONSTRUCTION SCHEDULING

1. Procurement and Timing of Contract Award

It is recommended that maximum possible latitude be afforded the prospective bidders with respect to subcontracts. Too many restrictive conditions will discourage bidding and will also tend to result in higher project costs.

One of the following schedules should be adopted by the funding Agency:

Activity	Schedule	
	Normal	Accelerated
a. Select final design consultant	by January 1973	by July 1972
b. Complete final design, advertisement and prequalification of prospective bidders	by July 1974	by July 1973
c. Award construction contract	by December 1974	by December 1973

2. Construction Sequence

The most efficient and expeditious construction schedule will require that the dam be constructed before any of the bridge construction is started. Completion of the first phase of the dam prior to the flood season (October to December) will therefore be essential. The establishment of a construction yard for the dam and procurement of rock materials will be the most critical items in the early stages of construction.

APPENDIX A

City of Cotonou - General Plan A-1
Parallel Bridge and Approaches A-2
Saint Michel Bridge A-3
Saint Michel Bridge Approaches - Sta. 200 to Sta. 4000 A-4
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- Parallel Bridge A-7
- Parallel Bridge Approaches A-8
- Saint Michel Bridge A-9
- Saint Michel Bridge Approaches A-10
- Foundation Protection A-11
- Dam A-12

Cost Estimate (Foreign Procurement)
- Existing Bridge Repairs A-13
- Parallel Bridge A-14
- Parallel Bridge Approaches A-15
- Saint Michel Bridge A-16
- Saint Michel Bridge Approaches A-17
- Foundation Protection A-18
- Dam A-19

Table V-1, Vehicle Operating Costs at 32 kph A-20
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Projected Average Daily Traffic Volumes
- No Bridge Improvement Hypothesis A-29

Projected Average Daily Traffic Volumes
- Saint Michel Bridge Alternative
  - Traffic at New Bridge A-30

Projected Average Daily Traffic Volumes
- Saint Michel Bridge Alternative
  - Traffic at Existing Bridge A-31

LEGENDE
LEGEND

LIMITE DE LA VILLE DE COTONOU
COTONOU CITY LIMITS

LIMITES DES ZONES
ZONE LIMITS

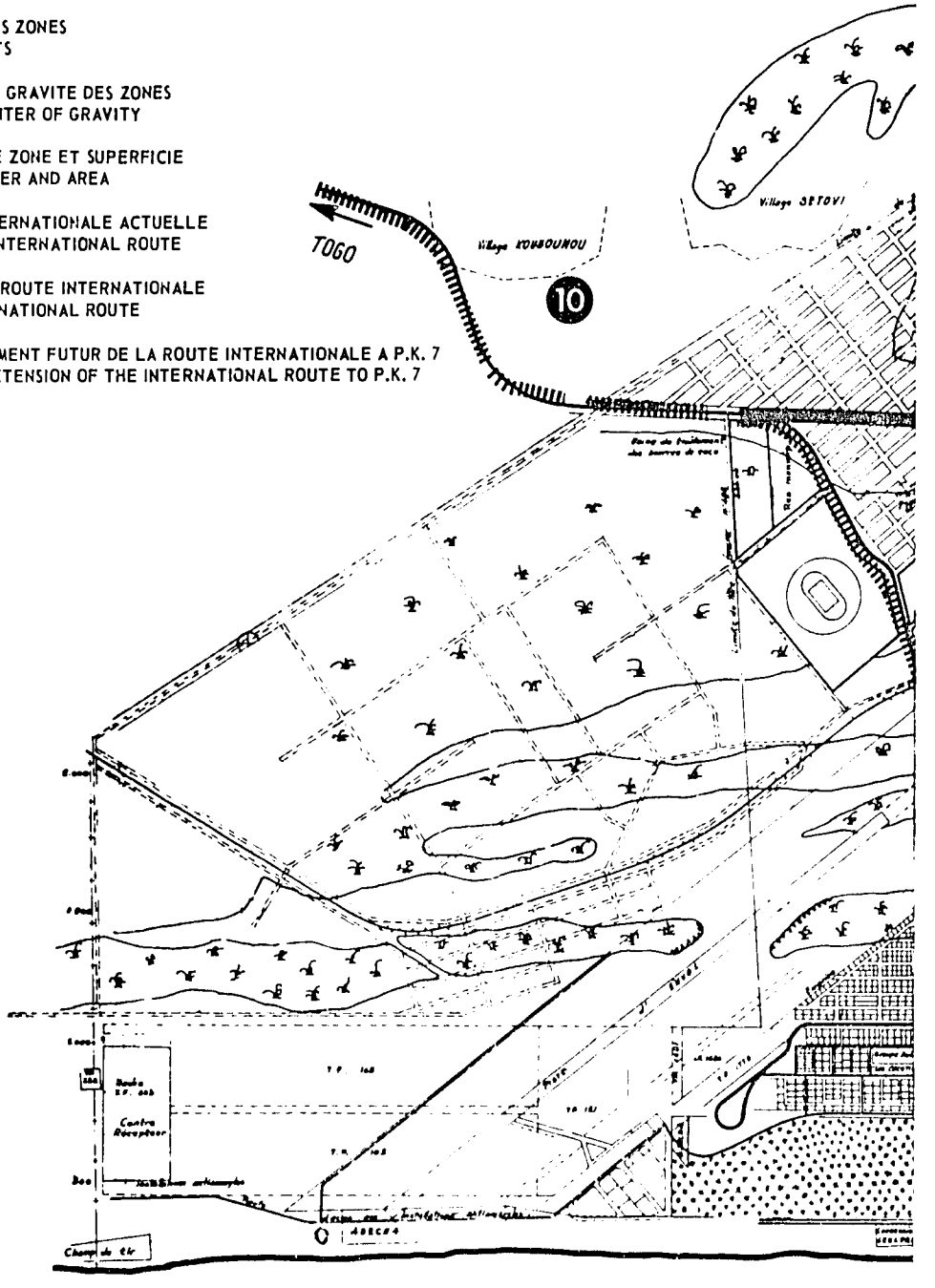
CENTRE DE GRAVITE DES ZONES
ZONAL CENTER OF GRAVITY

3
9.1 KM²
NUMERO DE ZONE ET SUPERFICIE
ZONE NUMBER AND AREA

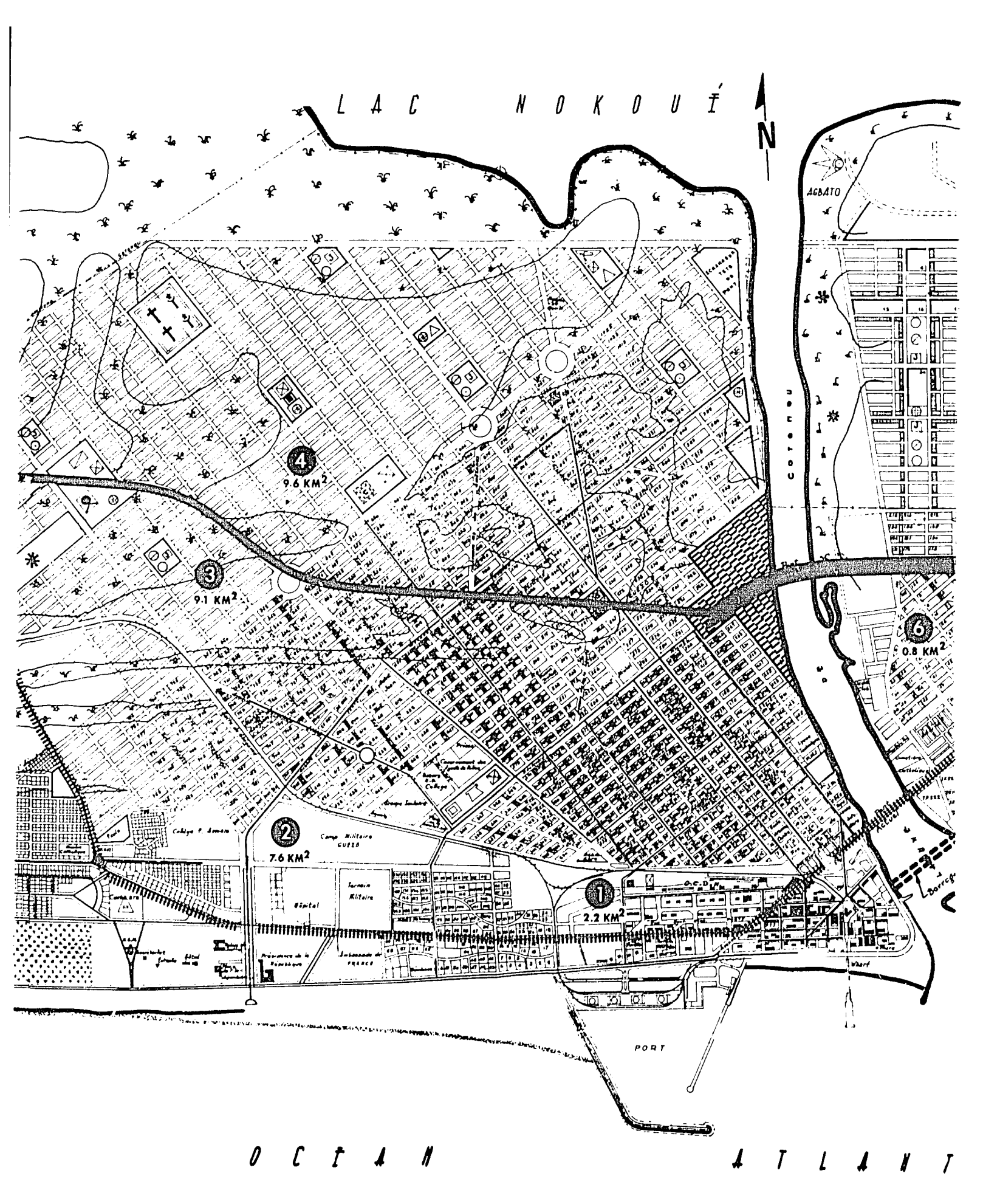
ROUTE INTERNATIONALE ACTUELLE
EXISTING INTERNATIONAL ROUTE

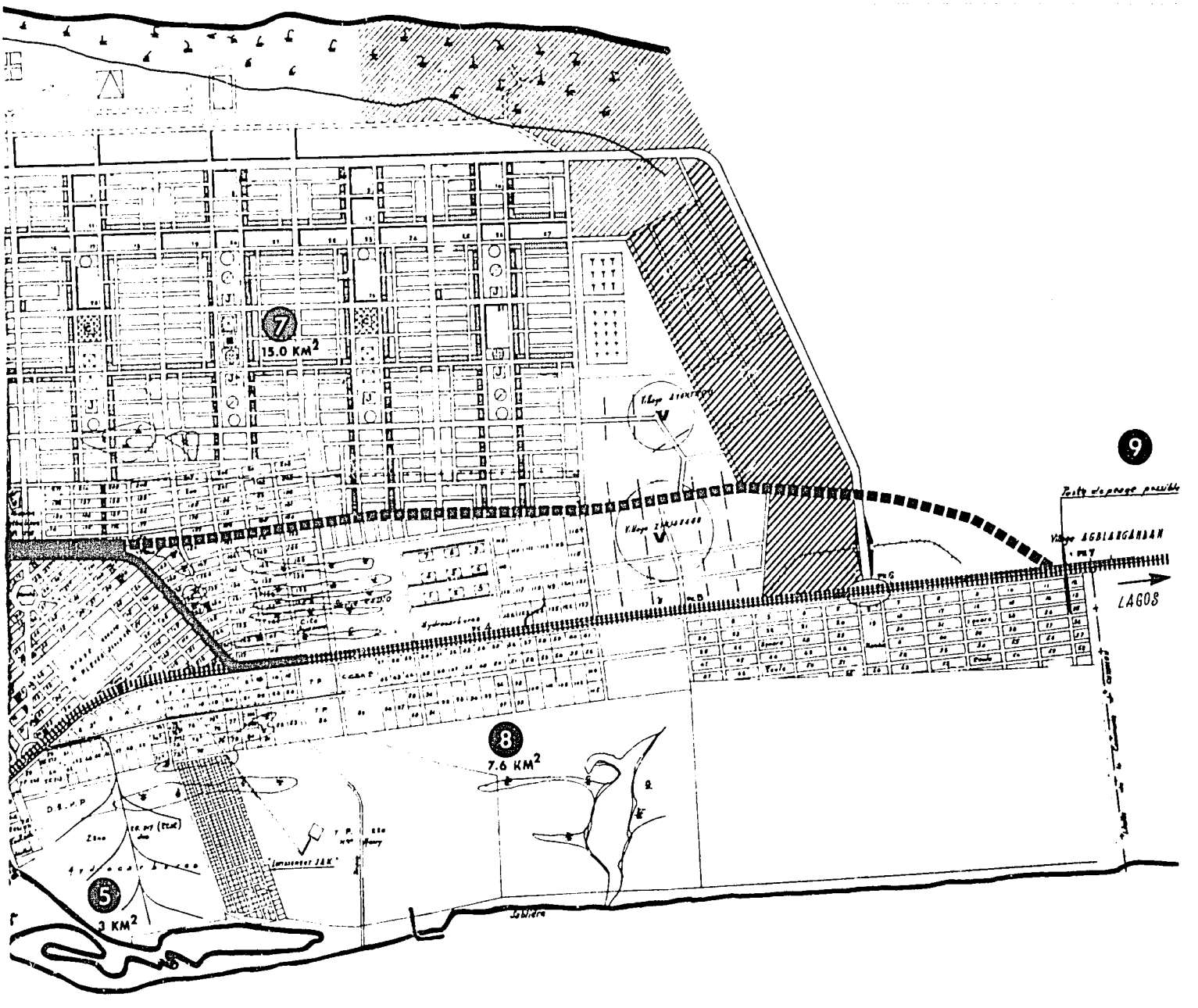
NOUVELLE ROUTE INTERNATIONALE
NEW INTERNATIONAL ROUTE

PROLONGEMENT FUTUR DE LA ROUTE INTERNATIONALE A P.K. 7
FUTURE EXTENSION OF THE INTERNATIONAL ROUTE TO P.K. 7



VILLE OF COTONOU
CITY OF COTONOU

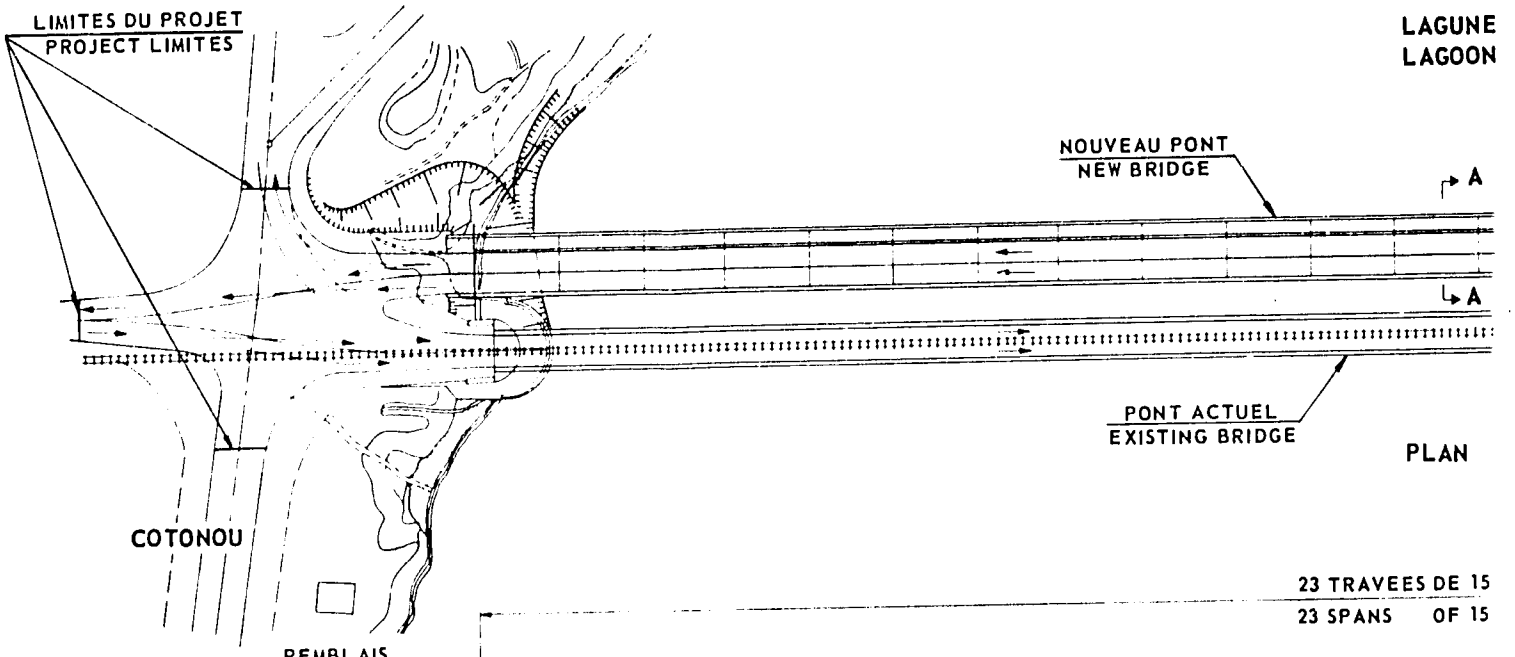

LAC NOKOUÉ
N
AGBATO
COTONOU
4
9.6 KM²
3
9.1 KM²
6
0.8 KM²
2
7.6 KM²
Camp Militaire
GUEZO
Hôpital
Terrain Militaire
Ambassade de FRANCE
1
2.2 KM²
PORT
OCEAN ATLANT

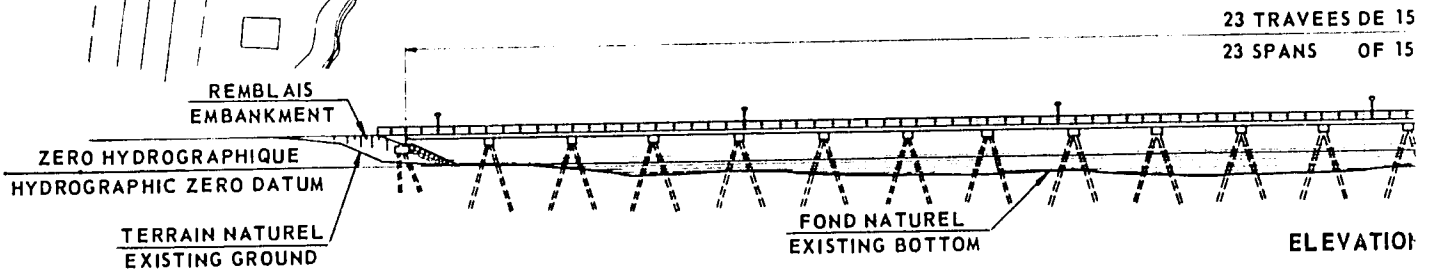


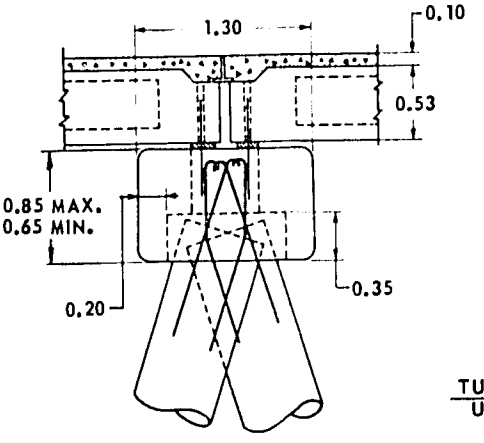
PLAN DE VILLE AVEC LIMITES DES ZONES
CITY PLAN WITH ZONE BOUNDARIES

T I Q U T

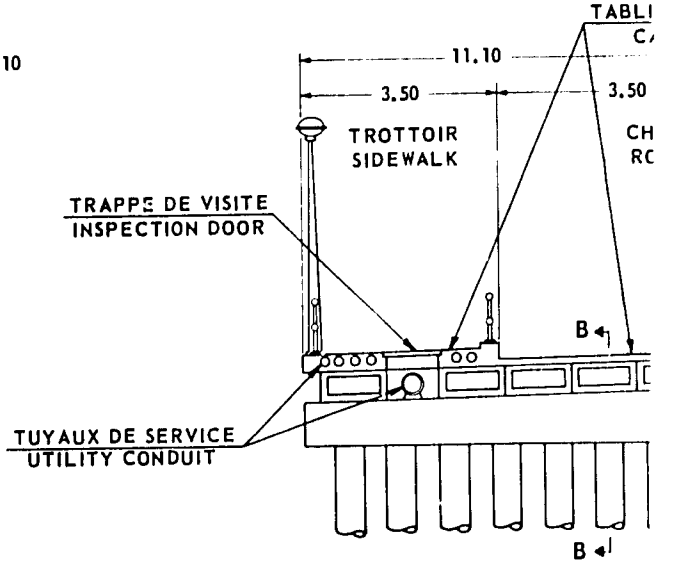
2546





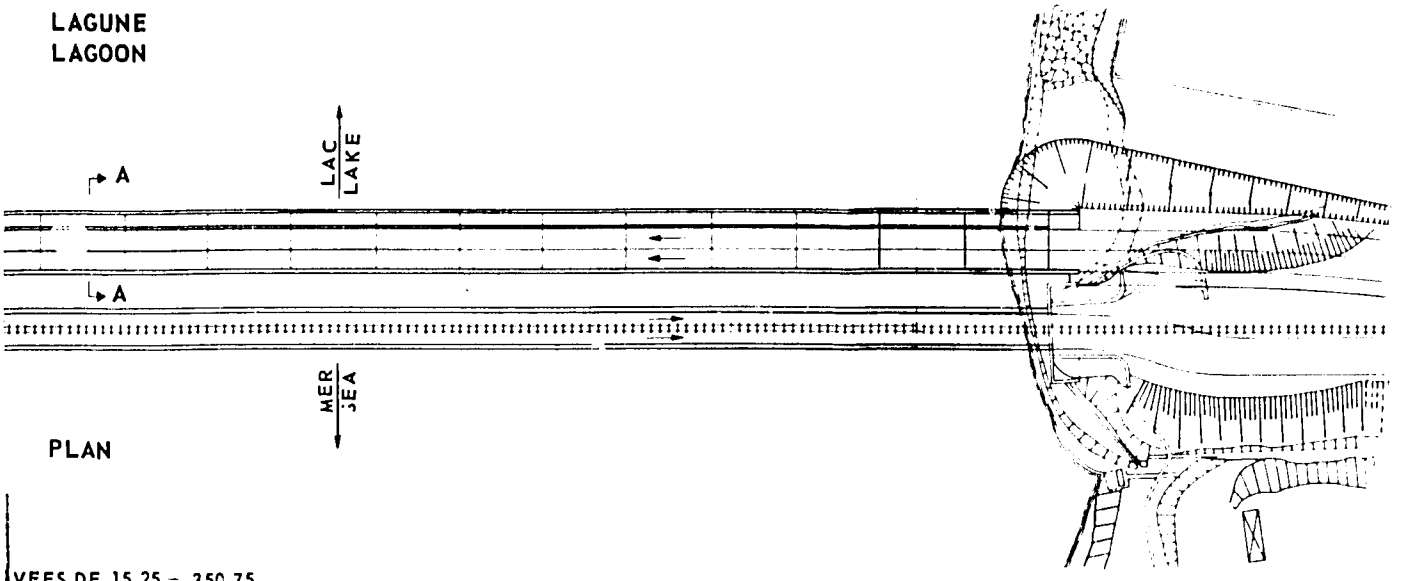


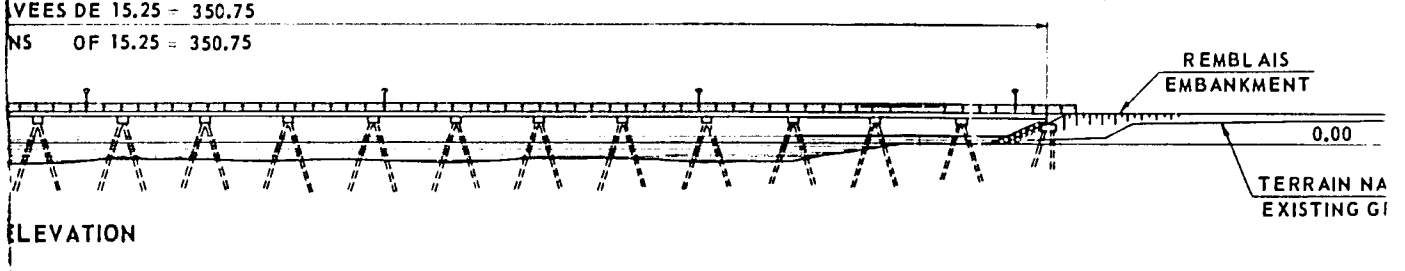
COUPE B-B
SECTION B-B

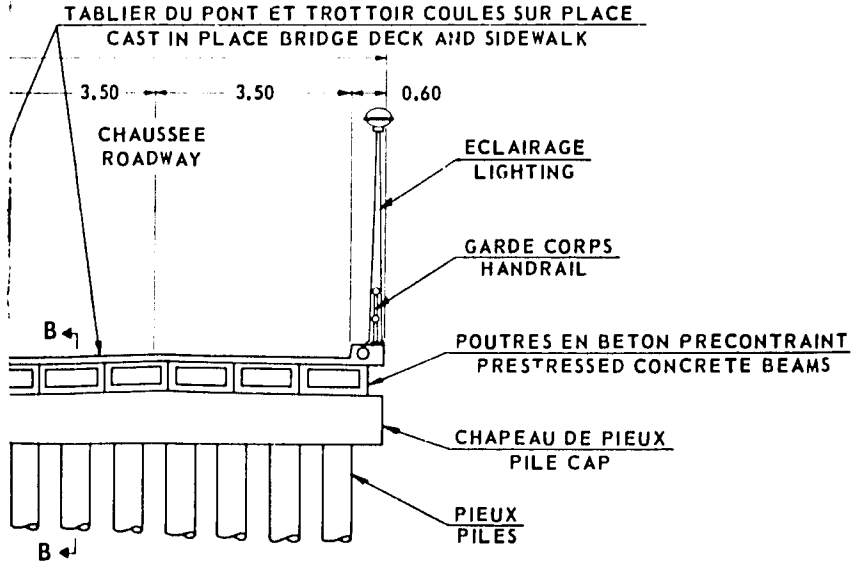


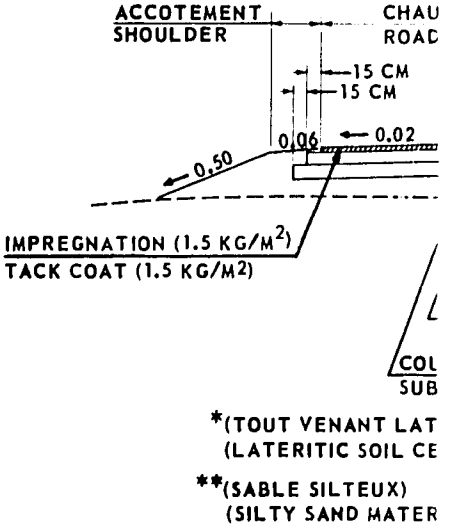
COUPE
SECTION

25

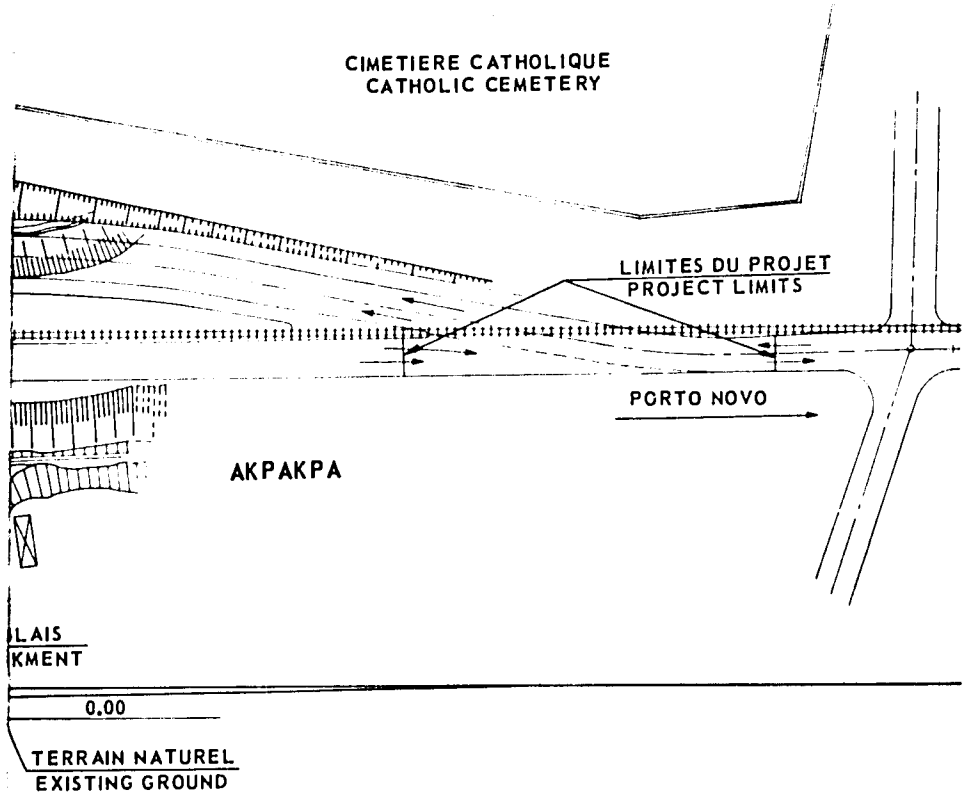


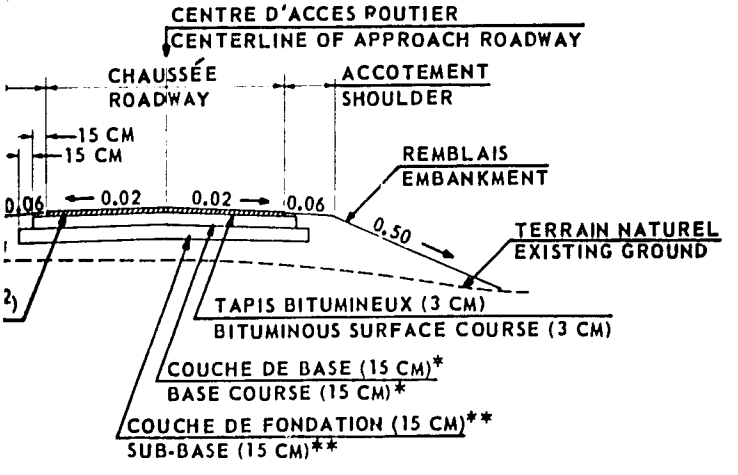






PONT PARALLELE ET ACCES
PARALLEL BRIDGE AND APPROACHES



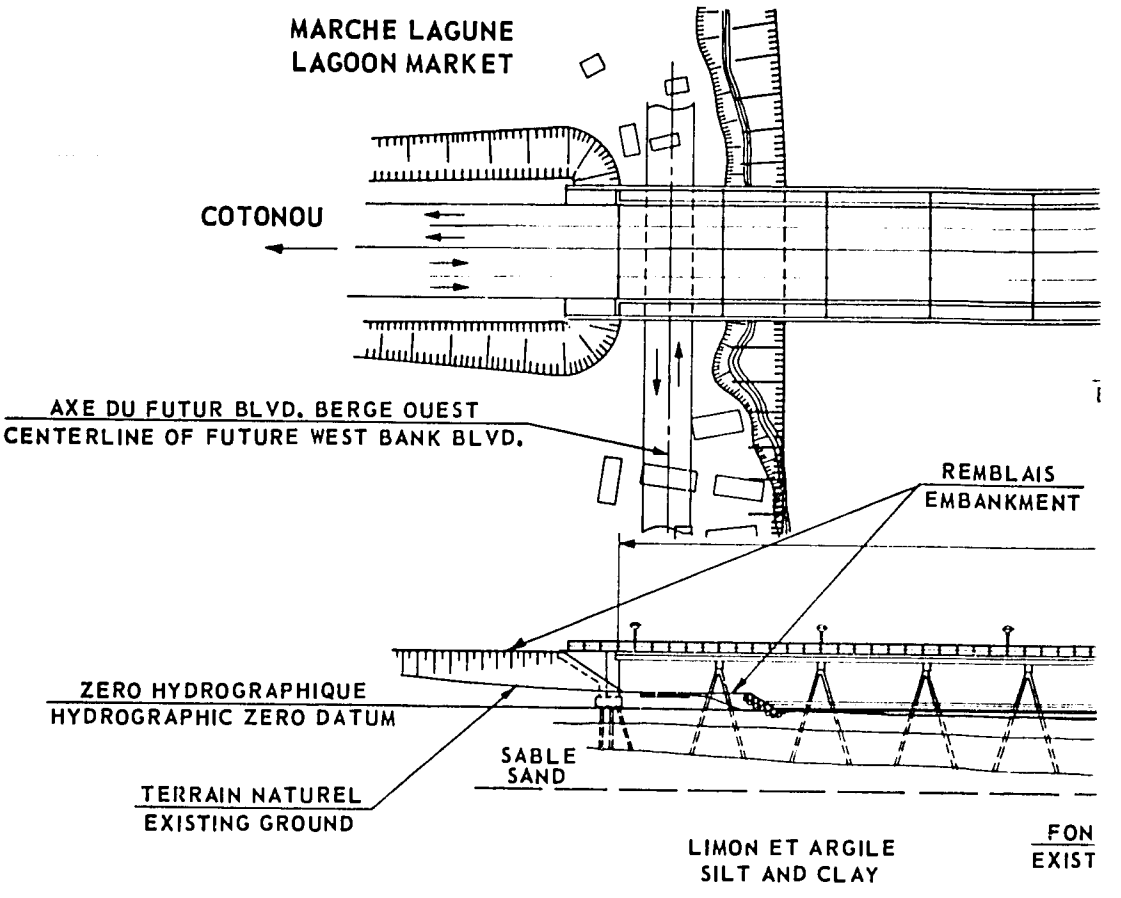


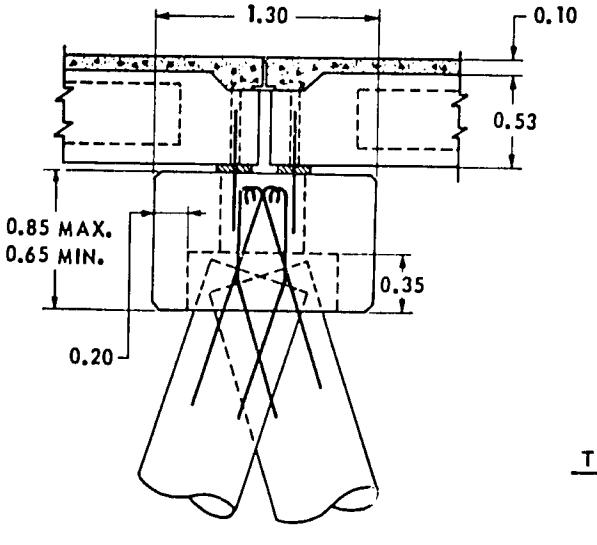
IT VENANT LATERITIQUE – 3% CIMENT)
'ERITIC SOIL CEMENT – 3% CEMENT CONTENT)

LE SILTEUX)
TY SAND MATERIAL)

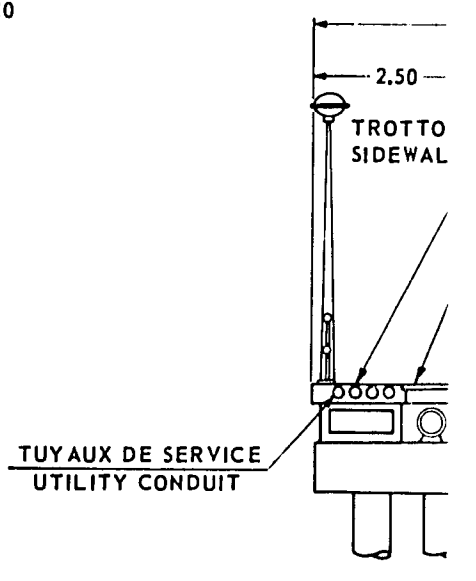
COUPE TYPIQUE – ACCES ROUTIER
PICAL SECTION – ROADWAY APPROACHES

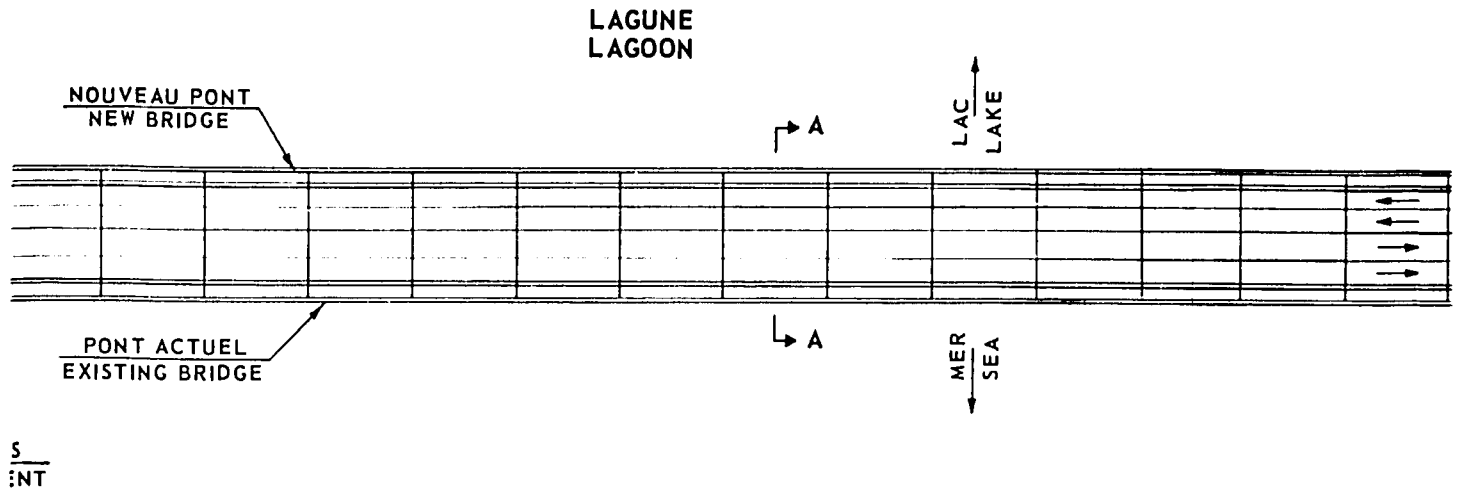
255B

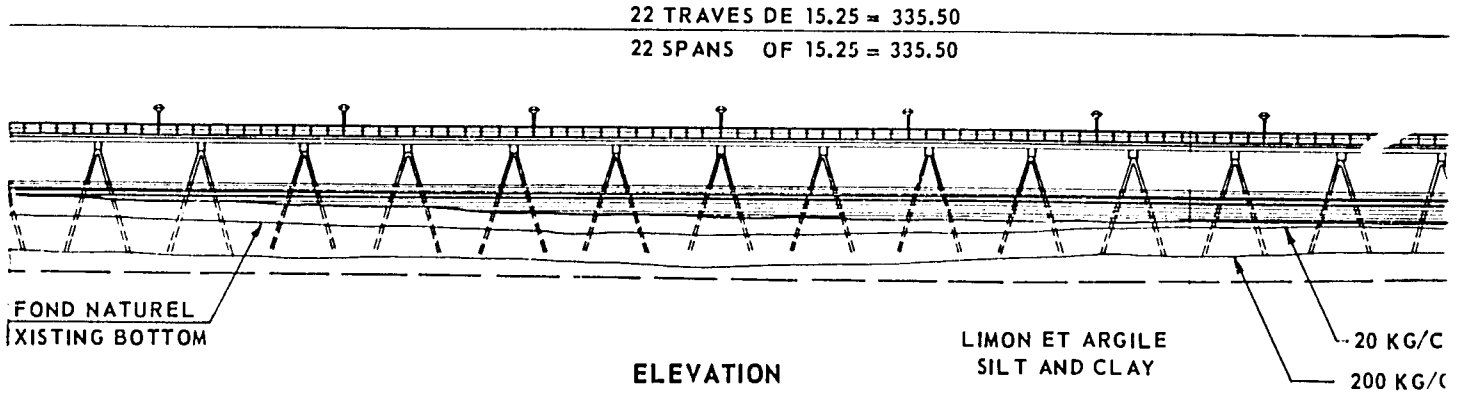




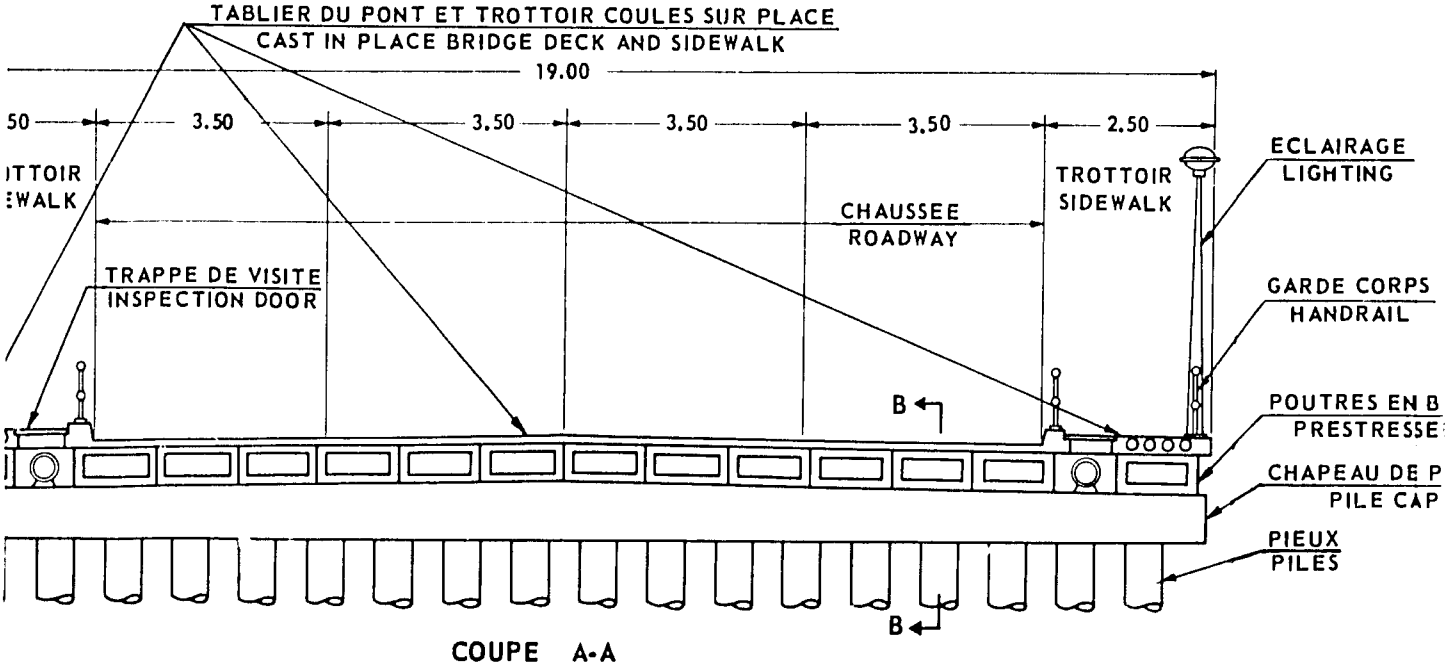
COUPE B-B
SECTION B-B







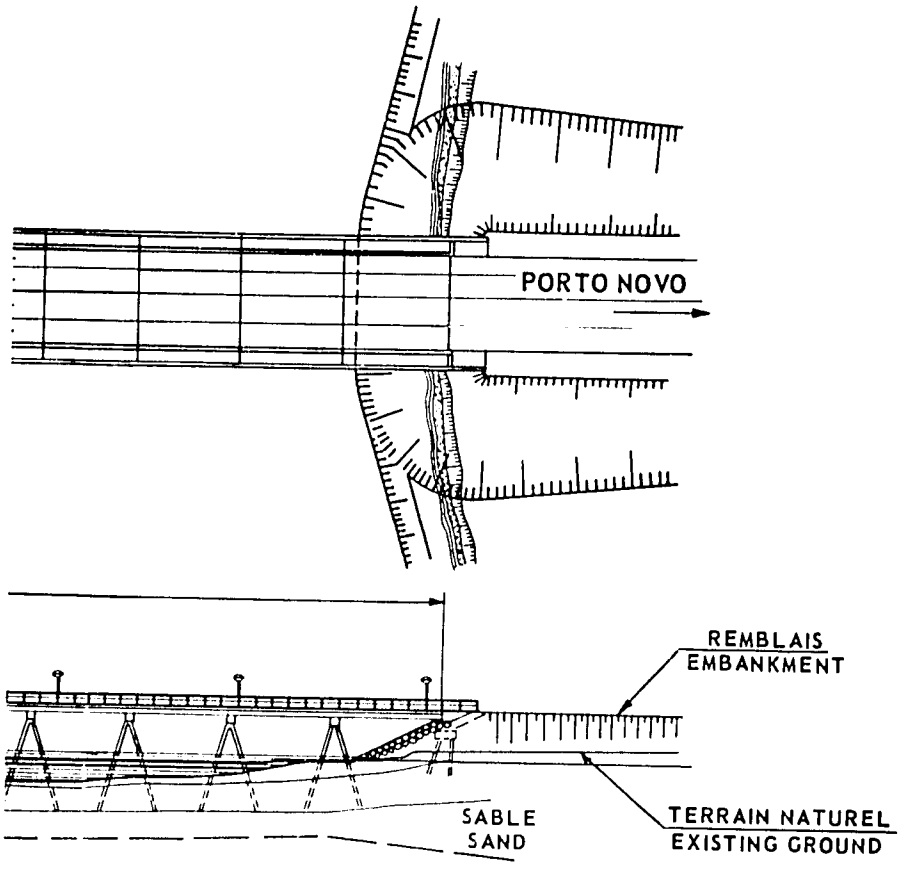
ELEVATION



COUPE A-A
SECTION A-A

PONT SAINT MICHEL ET ACCÈS
SAINT MICHEL BRIDGE AND APPROACHES

256A



/CM² } RESISTANCE AU PENETROMETRE DYNAMIQUE
;/CM² } RESISTANCE TO DYNAMIC PENETROMETER

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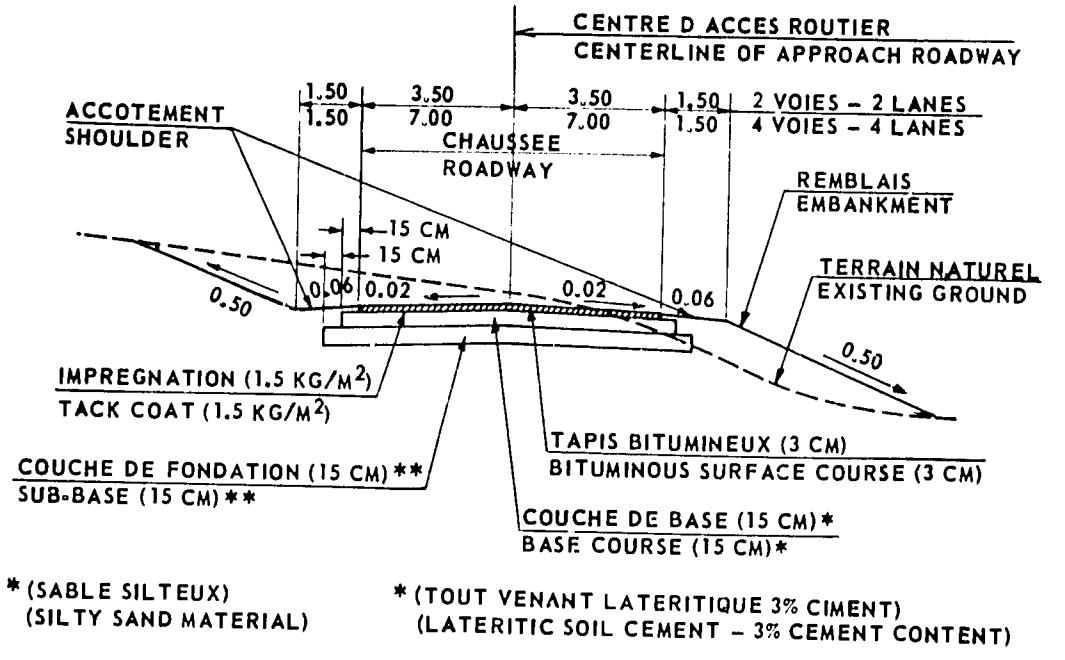
BETON PRECONTRAINT
SED CONCRETE BEAMS

PIEUX
P

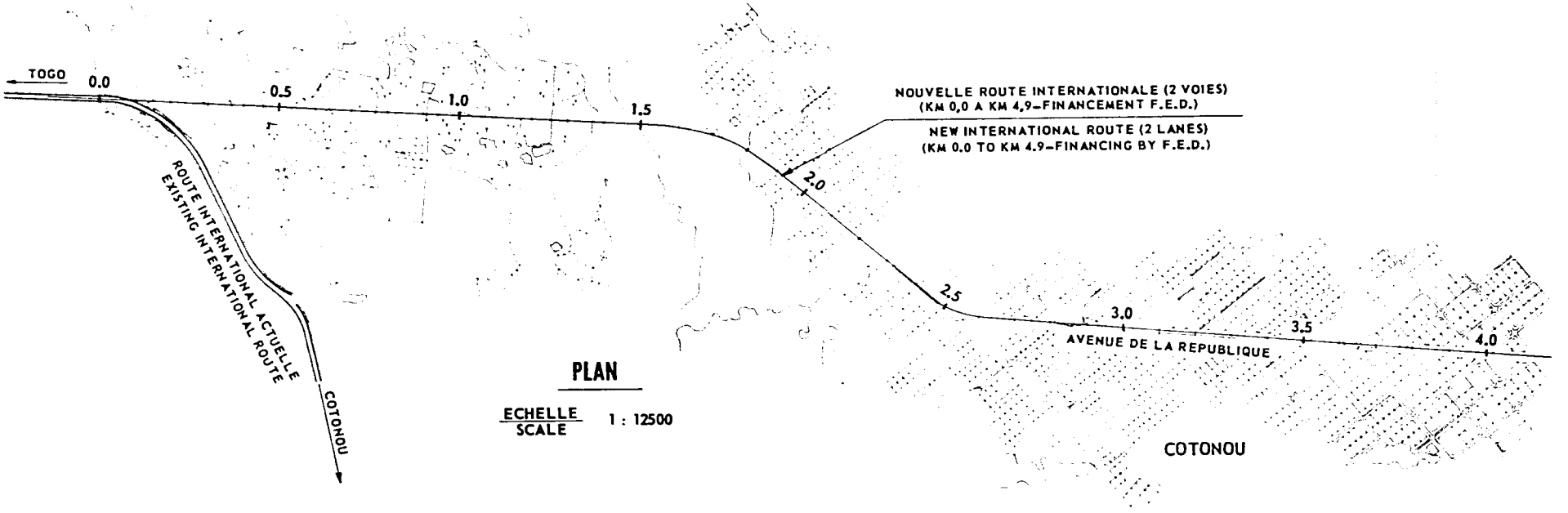


** (SABLE SILTEUX)
(SILTY SAND MATERIAL)

* (TOUT VENANT LATERITIQUE 3% CIMENT)
(LATERITIC SOIL CEMENT - 3% CEMENT CONTENT)

COUPE TYPIQUE - ACCES ROUTIER
TYPICAL SECTION - ROADWAY APPROACHES

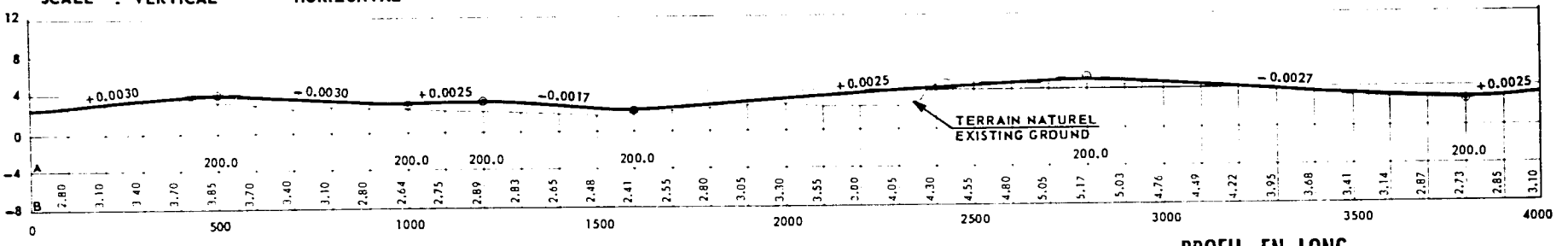
256B



PLAN

ECHELLE / SCALE 1 : 12500

ECHELLES : SCALE : HAUTEUR / VERTICAL 1 : 500 LONGUEUR / HORIZONTAL 1 : 12500



PROFIL EN LONG

PROFILE

+0.0030 = PENTE / SLOPE

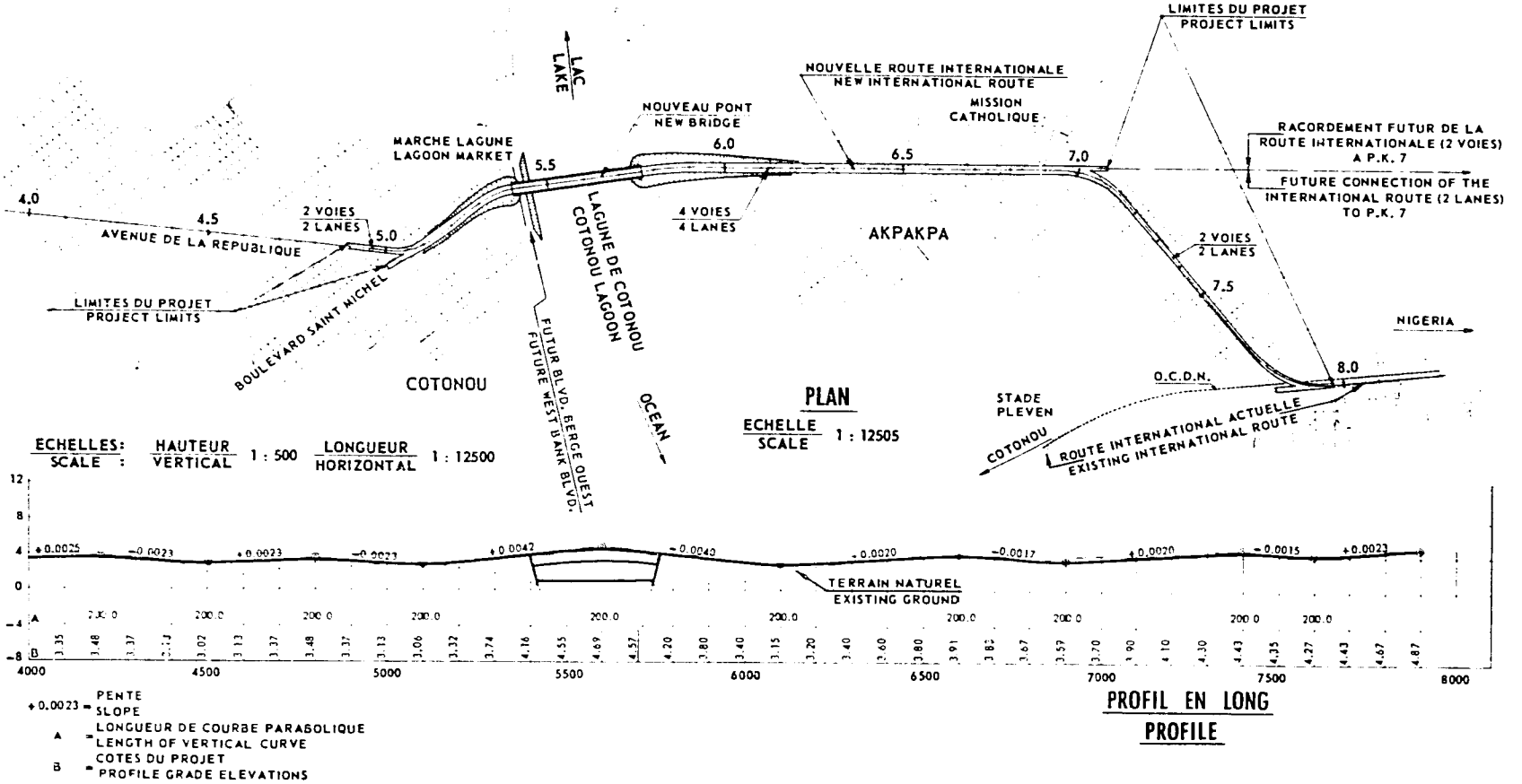
A = LONGUEUR DE COURBE PARABOLIQUE / LENGTH OF VERTICAL CURVE

B = COTES DU PROJET / PROFILE GRADE ELEVATIONS

ACCES EST – PLAN ET PROFIL
(FINANCEMENT F.E.D.)

EAST APPROACHES – PLAN AND PROFILE
(FINANCING BY F.E.D.)

259



ACCES EST ET OUEST – PLAN ET PROFIL
(INCLUS DANS PROJET PONT SAINT MICHEL)

EAST AND WEST APPROACHES – PLAN AND PROFILE
(INCLUDED IN SAINT MICHEL BRIDGE PROJECT)

EXISTING BRIDGE REPAIRS
AMERICAN PROCUREMENT
(COSTS IN FR. CFA)

ITEMS	QUANTS.	UNITS	UNIT PRICE	FOREIGN CURRENCY	TAXES	LOCAL CURRENCY	TOTAL
REMOVE EXISTING CONCRETE DECK	LUMP SUM	L.S.	5,000,000	472,500	3,177,500	1,350,000	5,000,000
MAINTAIN RAILROAD TRAFFIC	LUMP SUM	L.S.	5,000,000		3,500,000	1,500,000	5,000,000
REINFORCED CONCRETE (NEW DECK*)	745	M3	90,000	8,917,650	32,653,350	25,479,000	67,050,000
BRIDGE LIGHTING & MISCELLANEOUS	LUMP SUM	L.S.	4,100,000	932,750	502,250	2,665,000	4,100,000
CLEAN & PAINT STEEL GIRDERS	LUMP SUM	L.S.	2,000,000	240,000	960,000	800,000	2,000,000
OVERHEAD				2,543,520	845,032	3,263,448	6,652,000
CONSTRUCTION YARD				6,867,505	2,281,586	8,811,309	17,960,400
SUBTOTAL (1)				41,205,025	13,689,518	52,867,857	107,762,400
CONTINGENCIES (20 PERCENT)				8,241,006	2,737,903	10,573,571	21,552,480
SUBTOTAL (2)				49,446,031	16,427,421	63,441,428	129,314,880
DESIGN & CONSTRUCTION SUPERVISION				13,578,062		5,819,170	19,397,232
			T O T A L	63,024,093	16,427,421	69,260,598	148,712,112

*(INCLUDES EXTENDING STEEL BRACKETS TO SUPPORT WIDER SIDEWALKS)

PARALLEL BRIDGE
AMERICAN PROCUREMENT
(COSTS IN FR. CFA)

ITEMS	QUANTS.	UNITS	UNIT PRICE	FOREIGN CURRENCY	TAXES	LOCAL CURRENCY	TOTAL
SHIPPING **	7,000	TONS	10,000		15,400,000	54,600,000	70,000,000
PILES - DELIVERED TO JOB	1,036	M3	49,000	8,680,644	13,147,876	28,935,480	50,764,000
DRIVING PILES	2,100	M	25,000	8,085,000	21,315,000	23,100,000	52,500,000
PLACING & CUTTING PILES	264	EA	38,000	1,299,144	5,021,016	3,711,840	10,032,000
STRUCTURAL EXCAVATION	75	M3	1,000	5,250	54,750	15,000	75,000
REINFORCED CONCRETE							
-PIER CAPS	238	M3	80,000	3,617,600	5,902,400	9,520,000	19,040,000
-ABUTMENTS	70	M3	60,000	602,700	1,875,300	1,722,000	4,200,000
-BRIDGE DECK	663	M3	65,000	4,826,640	24,477,960	13,790,400	43,095,000
-BRIDGE BEAMS	1,010	M3	126,000	26,470,080	34,614,720	65,175,200	127,260,000
BEARING PADS	368	EA	5,000	450,800	101,200	1,288,000	1,840,000
BRIDGE LIGHTING & MISCELLANEOUS	LUMP SUM	L.S.	5,000,000	1,137,500	612,500	3,250,000	5,000,000
OVERHEAD				16,488,635	4,414,028	9,801,817	30,704,480
CONSTRUCTION YARD ***				55,649,140	14,897,346	33,081,134	103,627,620
SUBTOTAL (1)				278,245,695	74,486,732	155,405,673	518,138,100
CONTINGENCIES (20 PERCENT)				55,649,140	14,897,346	33,081,134	103,627,620
SUBTOTAL (2)				333,894,835	89,384,078	198,486,807	621,765,720
DESIGN & CONSTRUCTION SUPERVISION				65,285,400		27,979,458	93,264,858
			T O T A L	399,180,235	89,384,078	226,466,265	715,030,578

**(TONNAGE INCLUDES CONSTRUCTION EQUIPMENT, PRESTRESSED PLANT, AND PILES)
***(INCLUDES ALLOWANCE FOR INCREASED COSTS DUE TO LONGER HAUL AND TRAFFIC CONGESTION NEAR THE CONSTRUCTION SITE)

PARALLEL BRIDGE APPROACHES
AMERICAN PROCUREMENT
(COSTS IN F.F. CFA)

ITEMS	QUANTS.	UNITS	UNIT PRICE	FOREIGN CURRENCY	TAXES	LOCAL CURRENCY	TOTAL
SHIPPING **	300	TONS	10,000		660,000	2,340,000	3,000,000
EMBANKMENT	6,000	M3	1,500	675,000	6,075,000	2,250,000	9,000,000
EXCAVATION *	100	M3	900	6,750	60,750	22,500	90,000
SUBBASE	800	M2	300	18,000	162,000	60,000	240,000
BASE	4,200	M2	1,500	472,500	4,252,500	1,575,000	6,300,000
BITUMINOUS SURFACE COURSE	4,000	M2	900	270,000	2,430,000	900,000	3,600,000
SHOULDERS	800	M2	450	27,000	243,000	90,000	360,000
OVERHEAD				579,000	117,540	1,110,660	1,807,200
CONSTRUCTION YARD ***				1,954,126	396,697	3,748,477	6,099,300
SUBTOTAL (1)				9,770,626	1,983,487	18,742,387	30,496,500
CONTINGENCIES (10 PERCENT)				977,064	198,348	1,874,238	3,049,650
SUBTOTAL (2)				10,747,690	2,181,835	20,616,625	33,546,150
DESIGN & CONSTRUCTION SUPERVISION				3,522,345		1,509,577	5,031,922
			T O T A L	14,270,035	2,181,835	22,126,202	38,578,072

*(INCLUDES PLACING IN EMBANKMENT)
**(TONNAGE INCLUDES ROADWAY CONSTRUCTION EQUIPMENT)
***(INCLUDES ALLOWANCE FOR INCREASED COSTS DUE TO LONGER HAUL AND TRAFFIC CONGESTION NEAR THE CONSTRUCTION SITE)

SAINT MICHEL BRIDGE
AMERICAN PROCUREMENT
(COSTS IN FR. CFA)

ITEMS	QUANTS.	UNITS	UNIT PRICE	FOREIGN CURRENCY	TAXES	LOCAL CURRENCY	TOTAL
SHIPPING **	7,000	TONS	10,000		15,400,000	54,600,000	70,000,000
PILES - DELIVERED TO JOB	1,730	M3	49,000	14,495,670	21,955,430	48,318,900	84,770,000
DRIVING PILES	3,350	M	25,000	12,897,500	34,002,500	36,550,000	83,750,000
PLACING & CUTTING PILES	414	EA	38,000	2,037,294	7,873,866	5,520,840	15,732,000
STRUCTURAL EXCAVATION	150	M3	1,000	10,500	109,500	30,000	150,000
REINFORCED CONCRETE							
-PIER CAPS	389	M3	80,000	5,912,800	9,647,200	15,560,000	31,120,000
-ABUTMENTS	240	M3	60,000	2,066,400	6,429,600	5,904,000	14,400,000
-BRIDGE DECK	938	M3	65,000	6,828,640	34,630,960	19,510,400	60,970,000
-BRIDGE BEAMS	1,687	M3	126,000	44,212,896	57,816,864	110,532,240	212,562,000
BEARING PADS	616	EA	5,000	754,600	169,400	2,156,000	3,080,000
BRIDGE LIGHTING & MISCELLANEOUS	LUMP SUM	L.S.	7,000,000	1,592,500	857,500	4,550,000	7,000,000
OVERHEAD				24,306,591	7,264,704	15,111,425	46,682,720
CONSTRUCTION YARD				49,220,847	14,711,025	30,600,636	94,532,508
SUBTOTAL (1)				377,359,818	112,764,529	234,604,681	724,749,228
CONTINGENCIES (20 PERCENT)				75,471,964	22,556,905	46,920,976	144,949,845
SUBTOTAL (2)				452,831,782	135,341,434	281,525,857	869,699,073
DESIGN & CONSTRUCTION SUPERVISION				91,318,402		39,136,458	130,454,860
			T O T A L	544,150,184	135,341,434	320,662,315	1,000,153,933

**(TONNAGE INCLUDES CONSTRUCTION EQUIPMENT, PRESTRESSED PLANT, AND PILES)

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SAINT MICHEL BRIDGE APPROACHES
AMERICAN PROCUREMENT
(COSTS IN FR. CFA)

ITEMS	QUANTS.	UNITS	UNIT PRICE	FOREIGN CURRENCY	TAXES	LOCAL CURRENCY	TOTAL
SHIPPING **	500	TONS	10,000		1,100,000	3,900,000	5,000,000
CLEARING & DEMOLITION	LUMP SUM	L.S.	2,000,000	210,000	1,090,000	700,000	2,000,000
EMBANKMENT	32,000	M3	1,000	2,400,000	21,600,000	8,000,000	32,000,000
EXCAVATION *	8,000	M3	600	360,000	3,240,000	1,200,000	4,800,000
SUBBASE	20,700	M2	200	310,500	2,794,500	1,035,000	4,140,000
BASE	31,700	M2	1,000	2,377,500	21,397,500	7,925,000	31,700,000
BITUMINOUS SURFACE COURSE	30,800	M2	600	1,386,000	12,474,000	4,620,000	18,480,000
SHOULDERS	7,800	M2	300	175,500	1,579,500	585,000	2,340,000
DRAINAGE PIPE (INCL. EXCAV.)	800	M	12,000	720,000	6,480,000	2,400,000	9,600,000
OVERHEAD				2,429,200	635,160	5,740,440	8,804,800
CONSTRUCTION YARD				4,919,130	1,286,199	11,624,391	17,829,720
SUBTOTAL (1)				37,713,330	9,860,859	89,120,331	136,694,520
CONTINGENCIES (10 PERCENT)				3,771,334	986,085	8,912,033	13,669,452
SUBTOTAL (2)				41,484,664	10,846,944	98,032,364	150,363,972
DESIGN & CONSTRUCTION SUPERVISION				15,788,216		6,766,379	22,554,595
			T O T A L	57,272,880	10,846,944	104,798,743	172,918,567

*(INCLUDES PLACING IN EMBANKMENT)
**(TONNAGE INCLUDES ROADWAY CONSTRUCTION EQUIPMENT)

FOUNDATION PROTECTION
AMERICAN PROCUREMENT
(COSTS IN FR. CFA)

ITEMS	QUANTS.	UNITS	UNIT PRICE	FOREIGN CURRENCY	TAXES	LOCAL CURRENCY	TOTAL
ROCK MAT (20 TO 80 KG)	8,500	T	8,500	3,251,250	58,161,250	10,837,500	72,250,000
ROCK EMBANKMENT PROTECTION	1,800	T	4,700	380,700	6,810,300	1,269,000	8,460,000
EMBANKMENT	9,000	M3	300	202,500	1,822,500	675,000	2,700,000
EXCAVATION	1,000	M3	500	37,500	337,500	125,000	500,000
OVERHEAD				1,032,520	309,756	5,370,524	6,712,800
CONSTRUCTION YARD				2,787,805	836,341	14,500,414	18,124,560
SUBTOTAL (1)				16,726,825	5,018,047	87,002,488	108,747,360
CONTINGENCIES (20 PERCENT)				3,345,366	1,003,609	17,400,497	21,749,472
SUBTOTAL (2)				20,072,191	6,021,656	104,402,985	130,496,832
DESIGN & CONSTRUCTION SUPERVISION				13,702,166		5,872,358	19,574,524
			T O T A L	33,774,357	6,021,656	110,275,343	150,071,356

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DAM
AMERICAN PROCUREMENT
(COSTS IN FR. CFA)

ITEMS	QUANTS.	UNITS	UNIT PRICE	FOREIGN CURRENCY	TAXES	LOCAL CURRENCY	TOTAL
CORE MATERIAL	26,000	M3	2,500	2,275,000	56,225,000	6,500,000	65,000,000
ROCK (PHASE 1) (20 KG TO 200 KG)	44,625	T	2,000	4,685,625	71,176,875	13,387,500	89,250,000
ROCK (PHASE 1) (20 KG TO 200 KG)	44,625	T	2,700	6,325,593	96,088,782	18,073,125	120,487,500
PLACING IN DAM							
EXCAVATION	1,000	M3	500	17,500	432,500	50,000	500,000
DREDGING	3,000	M3	1,000	105,000	2,595,000	300,000	3,000,000
EMBANKMENT (SAND)	15,000	M3	300	157,500	3,892,500	450,000	4,500,000
ROCK (PHASE 2) (20 KG TO 200 KG)	800	T	3,700	155,400	2,360,600	444,000	2,960,000
OVER-HEAD				4,704,556	1,546,594	27,932,550	34,283,700
CONSTRUCTION YARD				8,781,837	3,073,642	52,140,761	63,996,240
SUBTOTAL (1)				52,691,018	18,441,854	312,844,568	383,977,440
CONTINGENCIES (25 PERCENT)				13,172,755	4,610,463	78,211,142	95,994,360
SUBTOTAL (2)				65,863,773	23,052,317	391,055,710	479,971,800
DESIGN & CONSTRUCTION SUPERVISION				67,196,052		28,798,308	95,994,360
			TOTAL	133,059,825	23,052,317	419,854,018	575,966,160

EXISTING BRIDGE REPAIRS
FOREIGN PROCUREMENT
(COSTS IN FR. CFA)

ITEMS	QUANTS.	UNITS	UNIT PRICE**	FOREIGN CURRENCY	TAXES	LOCAL CURRENCY	TOTAL
REMOVE EXISTING CONCRETE DECK	LUMP SUM	L.S.	5,000,000	472,500	3,177,500	1,350,000	5,000,000
MAINTAIN RAILROAD TRAFFIC	LUMP SUM	L.S.	5,000,000		3,500,000	1,500,000	5,000,000
REINFORCED CONCRETE (NEW DECK*)	745	M3	90,000	8,917,650	32,653,350	25,479,000	67,050,000
BRIDGE LIGHTING & MISCELLANEOUS	LUMP SUM	L.S.	4,100,000	932,750	502,250	2,665,000	4,100,000
CLEAN & PAINT STEEL GIRDERS	LUMP SUM	L.S.	2,000,000	240,000	960,000	800,000	2,000,000
OVERHEAD				1,907,640	633,774	2,447,586	4,989,000
CONSTRUCTION YARD				6,740,329	2,239,334	8,648,137	17,627,800
SUBTOTAL(1)				40,441,969	13,436,008	51,888,823	105,766,800
CONTINGENCIES (20 PERCENT)				8,088,395	2,687,201	10,377,764	21,153,360
SUBTOTAL (2)				48,530,364	16,123,209	62,266,587	126,920,160
DESIGN + CONSTRUCTION SUPERVISION				10,661,293		4,569,126	15,230,419
			TOTAL	59,191,657	16,123,209	66,835,713	142,150,579

*(INCLUDES EXTENDING STEEL BRACKETS TO SUPPORT WIDER SIDEWALK)
**(UNIT PRICES INCLUDE THE COST OF TRANSPORTING CONSTRUCTION EQUIPMENT TO THE CONSTRUCTION SITE)

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PARALLEL BRIDGE
FOREIGN PROCUREMENT
(COSTS IN FR. CFA)

ITEMS	QUANTS.	UNITS	UNIT PRICE**	FOREIGN CURRENCY	TAXES	LOCAL CURRENCY	TOTAL
PILES	1,036	M3	61,000	10,806,516	16,367,764	36,021,720	63,196,000
DRIVING PILES	2,100	M	25,000	8,085,000	21,315,000	23,100,000	52,500,000
PLACING & CUTTING PILES	264	EA	38,000	1,299,144	5,021,016	3,711,840	10,032,000
STRUCTURAL EXCAVATION	75	M3	1,000	5,250	54,750	15,000	75,000
REINFORCED CONCRETE							
-PIER CAPS	238	M3	74,000	3,346,280	5,459,720	8,806,000	17,612,000
-ABUTMENTS	70	M3	60,000	602,700	1,875,300	1,722,000	4,200,000
-BRIDGE DECK	663	M3	65,000	4,826,640	24,477,960	13,790,400	43,095,000
-BRIDGE BEAMS	1,010	M3	118,000	24,789,440	32,416,960	61,973,600	119,180,000
BEARING PADS	368	EA	5,000	450,800	101,200	1,288,000	1,840,000
BRIDGE LIGHTING & MISCELLANEOUS	LUMP SUM	L.S.	5,000,000	1,137,500	612,500	3,250,000	5,000,000
OVERHEAD				9,220,714	3,320,956	6,462,130	19,003,800
CONSTRUCTION YARD ***				40,724,819	14,667,556	28,541,075	83,933,450
SUBTOTAL (1)				203,624,093	73,337,782	142,705,375	419,667,250
CONTINGENCIES (20 PERCENT)				40,724,819	14,667,556	28,541,075	83,933,450
SUBTOTAL (2)				244,348,912	88,005,338	171,246,450	503,600,700
DESIGN & CONSTRUCTION SUPERVISION				43,511,100		16,920,984	60,432,084
			TOTAL	287,860,012	88,005,338	188,167,434	564,032,784

**(UNIT PRICES INCLUDE THE COST OF TRANSPORTING CONSTRUCTION EQUIPMENT TO THE CONSTRUCTION SITE)
***(INCLUDES ALLOWANCE FOR INCREASED COSTS DUE TO LONGER HAUL AND TRAFFIC CONGESTION NEAR THE CONSTRUCTION SITE)

PARALLEL BRIDGE APPROACHES
FOREIGN PROCUREMENT
(COSTS IN FR. CFA)

ITEMS	QUANTS.	UNITS	UNIT PRICE**	FOREIGN CURRENCY	TAXES	LOCAL CURRENCY	TOTAL
EMBANKMENT	6,000	M3	1,950	877,500	7,897,500	2,925,000	11,700,000
EXCAVATION *	100	M3	1,200	9,000	81,000	30,000	120,000
SUBBASE	800	M2	450	27,000	243,000	90,000	360,000
BASE	4,200	M2	1,950	614,250	5,528,250	2,047,500	8,190,000
BITUMINOUS SURFACE COURSE	4,000	M2	1,200	360,000	3,240,000	1,200,000	4,800,000
SHOULDERS	800	M2	600	36,000	324,000	120,000	480,000
OVERHEAD				384,750	115,425	1,038,825	1,539,000
CONSTRUCTION YARD ***				1,699,314	509,793	4,588,143	6,797,250
SUBTOTAL (1)				8,496,564	2,548,968	22,940,718	33,986,250
CONTINGENCIES (10 PERCENT)				849,658	254,896	2,294,071	3,398,625
SUBTOTAL (2)				9,346,222	2,803,864	25,234,789	37,384,875
DESIGN & CONSTRUCTION SUPERVISION				3,230,053		1,256,132	4,486,185
			TOTAL	12,576,275	2,803,864	26,490,921	41,871,060

*(INCLUDES PLACING IN EMBANKMENT)
**(UNIT PRICES INCLUDE THE COST OF TRANSPORTING CONSTRUCTION EQUIPMENT TO THE CONSTRUCTION SITE)
***(INCLUDES ALLOWANCE FOR INCREASED COSTS DUE TO LONGER HAUL AND TRAFFIC CONGESTION NEAR THE CONSTRUCTION SITE)

SAINT MICHEL BRIDGE
FOREIGN PROCUREMENT
(COSTS IN FR. CFA)

ITEMS	QUANTS.	UNITS	UNIT PRICE**	FOREIGN CURRENCY	TAXES	LOCAL CURRENCY	TOTAL
PILES	1,730	M3	61,000	18,045,630	27,332,270	60,152,100	105,530,000
DRIVING PILES	3,350	M	25,000	12,897,500	34,002,500	36,850,000	83,750,000
PLACING & CUTTING PILES	414	EA	38,000	2,037,294	7,873,866	5,820,840	15,732,000
STRUCTURAL EXCAVATION	150	M3	1,000	10,500	109,500	30,000	150,000
REINFORCED CONCRETE							
-PIER CAPS	389	M3	74,000	5,469,340	8,923,660	14,393,000	28,786,000
-ABUTMENTS	240	M3	60,000	2,066,400	6,429,600	5,904,000	14,400,000
-BRIDGE DECK	938	M3	65,000	6,828,640	34,630,960	19,510,400	60,970,000
-BRIDGE BEAMS	1,687	M3	118,000	41,405,728	54,145,952	103,514,320	199,066,000
BEARING PADS	616	EA	5,000	754,600	169,400	2,156,000	3,080,000
BRIDGE LIGHTING & MISCELLANEOUS	LUMP SUM	L.S.	7,000,000	1,592,500	857,500	4,550,000	7,000,000
OVERHEAD				15,172,841	5,466,487	10,468,512	31,107,840
CONSTRUCTION YARD				40,208,026	14,486,192	27,741,558	82,435,776
SUBTOTAL (1)				308,261,527	111,060,811	212,685,278	632,007,616
CONTINGENCIES (20 PERCENT)				61,652,306	22,212,162	42,537,055	126,401,523
SUBTOTAL (2)				369,913,833	133,272,973	255,222,333	758,409,139
DESIGN & CONSTRUCTION SUPERVISION				65,526,549		25,482,547	91,009,096
			T O T A L	435,440,382	133,272,973	280,704,880	849,418,235

**(UNIT PRICES INCLUDE THE COST OF TRANSPORTING CONSTRUCTION EQUIPMENT TO THE CONSTRUCTION SITE)

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SAINT MICHEL BRIDGE APPROACHES
FOREIGN PROCUREMENT
(COSTS IN FR. CFA)

ITEMS	QUANTS.	UNITS	UNIT PRICE**	FOREIGN CURRENCY	TAXES	LOCAL CURRENCY	TOTAL
CLEARING & DEMOLITION	LUMP SUM	L.S.	2,000,000	210,000	1,090,000	700,000	2,000,000
EMBANKMENT	32,000	M3	1,300	3,120,000	28,080,000	10,400,000	41,600,000
EXCAVATION *	8,000	M3	800	480,000	4,320,000	1,600,000	6,400,000
SUBBASE	20,700	M2	300	465,750	4,191,750	1,552,500	6,210,000
BASE	31,700	M2	1,300	3,090,750	27,816,750	10,302,500	41,210,000
BITUMINOUS SURFACE COURSE	30,800	M2	800	1,848,000	16,632,000	6,160,000	24,640,000
SHOULDERS	7,800	M2	400	234,000	2,106,000	780,000	3,120,000
DRAINAGE PIPE (INCL. EXCAV.)	800	M	12,500	750,000	6,750,000	2,500,000	10,000,000
OVERHEAD				2,039,700	611,910	5,459,190	8,110,800
CONSTRUCTION YARD				5,405,206	1,621,561	14,466,853	21,493,620
SUBTOTAL (1)				41,439,906	12,431,971	110,912,543	164,784,420
CONTINGENCIES (10 PERCENT)				4,143,991	1,243,197	11,091,254	16,478,442
SUBTOTAL (2)				45,583,897	13,675,168	122,003,797	181,262,862
DESIGN & CONSTRUCTION SUPERVISION				15,661,110		6,090,433	21,751,543
			TOTAL	61,245,007	13,675,168	128,094,230	203,014,405

*(INCLUDES PLACING IN EMBANKMENT)
**(UNIT PRICES INCLUDE THE COST OF TRANSPORTING CONSTRUCTION EQUIPMENT TO THE CONSTRUCTION SITE)

FOUNDATION PROTECTION
FOREIGN PROCUREMENT
(COSTS IN FR. CFA)

ITEMS	QUANTS.	UNITS	UNIT PRICE**	FOREIGN CURRENCY	TAXES	LOCAL CURRENCY	TOTAL
ROCK MAT (20 TO 80 KG)	8,500	T	8,500	3,251,250	58,161,250	10,837,500	72,250,000
ROCK EMBANKMENT PROTECTION	1,800	T	4,700	380,700	6,810,300	1,269,000	8,460,000
EMBANKMENT	9,000	M3	300	202,500	1,822,500	675,000	2,700,000
EXCAVATION	1,000	M3	500	37,500	337,500	125,000	500,000
OVERHEAD				774,390	232,317	4,027,893	5,034,600
CONSTRUCTION YARD				2,736,179	820,853	14,231,888	17,788,920
SUBTOTAL (1)				16,417,069	4,925,120	85,391,331	106,733,520
CONTINGENCIES (20 PERCENT)				3,283,414	985,024	17,078,266	21,346,704
SUBTOTAL (2)				19,700,483	5,910,144	102,469,597	128,080,224
DESIGN & CONSTRUCTION SUPERVISION				11,066,130		4,303,496	15,369,626
			T O T A L	30,766,613	5,910,144	106,773,093	143,449,850

**(UNIT PRICES INCLUDE THE COST OF TRANSPORTING CONSTRUCTION EQUIPMENT TO THE CONSTRUCTION SITE)

DAM
FOREIGN PROCUREMENT
(COSTS IN FR. CFA)

ITEMS	QUANTS.	UNITS	UNIT PRICE**	FOREIGN CURRENCY	TAXES	LOCAL CURRENCY	TOTAL
CORE MATERIAL	26,000	M3	2,500	2,275,000	56,225,000	6,500,000	65,000,000
ROCK (PHASE 1) (20 KG TO 200 KG)	44,625	T	2,000	3,123,750	77,201,250	8,925,000	89,250,000
ROCK (PHASE 1) (20 KG TO 200 KG)	44,625	T	2,700	6,325,593	96,088,782	18,073,125	120,487,500
PLACING IN DAM							
EXCAVATION	1,000	M3	500	17,500	432,500	50,000	500,000
DREDGING	3,000	M3	1,000	105,000	2,595,000	300,000	3,000,000
EMBANKMENT (SAND)	15,000	M3	300	157,500	3,892,500	450,000	4,500,000
ROCK (PHASE 2) (20 KG TO 200 KG)	800	T	3,700	155,400	2,360,600	444,000	2,960,000
OVERHEAD				2,084,529	729,584	14,327,737	17,141,850
CONSTRUCTION YARD				7,365,332	2,577,865	50,624,673	60,567,870
SUBTOTAL (1)				44,191,986	15,467,192	303,748,042	363,407,220
CONTINGENCIES (25 PERCENT)				11,047,997	3,866,798	75,937,010	90,851,805
SUBTOTAL (2)				55,239,983	19,333,990	379,685,052	454,259,025
DESIGN & CONSTRUCTION SUPERVISION				39,247,979		15,263,104	54,511,083
			TOTAL	94,487,962	19,333,990	394,948,156	508,770,108

**(UNIT PRICES INCLUDE THE COST OF TRANSPORTING CONSTRUCTION EQUIPMENT TO THE CONSTRUCTION SITE)

TABLE V-1

COTONOU BRIDGE
VEHICLE OPERATING COSTS AT 32 k.p.h.[1]
UNIFORM SPEEDS ON LEVEL TANGENT ROADS IN GOOD CONDITION
(Fr. CFA per kilometer)

Paved Road	Car	Bus	Truck
Fuel	1.080	1.943	3.254
Tires	0.297	0.539	2.326
Depreciation & Interest	6.534	5.189	9.042
Oil	0.154	0.231	1.078
Crew	2.790	5.580	4.960
Spares	0.462	0.734	4.125
Main Labor	0.300	0.375	1.100
Fixed Costs	3.385	4.625	10.938
Total	15.002	19.216	36.823
Earth Road			
Fuel	1.490	2.565	4.555
Tires	1.782	3.232	13.953
Depreciation & Interest	9.423	7.405	12.656
Oil	0.231	.347	1.617
Crew	2.790	5.580	4.960
Spares	1.201	1.909	10.725
Labor	0.780	0.975	2.860
Fixed Costs	3.385	4.625	10.938
Total	21.082	26.638	62.264

[1] Based upon cost data collected by N. D. Lea Assoc. in Dahomey during 1967. See Dahomey Land Transport, ibid. Free running is assumed, as typical of operations in rural areas. Costs have not been increased for the estimated 2% annual inflation factor to 1970.

TABLE V-2

COTONOU BRIDGE
VEHICAL OPERATING COSTS AT 28 k.p.h.[1]
UNIFORM SPEEDS ON LEVEL TANGENT ROADS IN GOOD CONDITION
(Fr. CFA per kilometer)

Paved Road	Car	Bus	Truck
Fuel	1.129	2.026	3.369
Tires	0.257	0.467	2.014
Depreciation & Interest	6.816	5.414	9.643
Oil	0.164	0.245	1.125
Crew	3.188	6.377	5.668
Spares	0.451	0.717	4.024
Main Labor	0.293	0.366	1.073
Fixed Costs	3.868	5.285	12.500
Total	16.166	20.897	39.416
Earth Road			
Fuel	1.558	2.675	4.716
Tires	1.543	2.803	12.079
Depreciation & Interest	9.830	7.256	13.498
Oil	0.246	0.368	1.688
Crew	3.188	6.377	5.668
Spares	1.172	1.864	10.463
Labor	0.761	0.952	2.790
Fixed Costs	3.868	5.285	12.500
Total	22.166	27.580	63.402

[1] Costs at 28 k.p.h. are based upon Dahomey data from the Lea report, as shown in Table V-1. The ratio of increase by cost component for the lower speed is from Winfrey (Appendix A) except for crew and fixed costs, which are increased in proportion to speed reduction. Thus, this table shows an approximation of operating costs at the selected speed under free running conditions in Dahomey.

TABLE V-3

COTONOU BRIDGE
VEHICLE OPERATING COSTS AT 24 k. p. h.[1]
UNIFORM SPEEDS ON LEVEL TANGENT ROADS IN GOOD CONDITION
(Fr. CFA per kilometer)

Paved Road	Car	Bus	Truck
Fuel	1.199	2.157	3.547
Tires	0.205	0.393	1.698
Depreciation & Interest	7.122	5.656	10.398
Oil	0.179	0.266	1.207
Crew	3.711	7.421	6.597
Spares	0.444	0.705	3.960
Labor	0.288	0.360	1.056
Fixed Costs	4.502	6.151	14.548
Total	17.650	23.109	43.011
Earth Road			
Fuel	1.654	2.847	4.965
Tires	1.230	2.359	10.186
Depreciation & Interest	10.271	8.071	14.554
Oil	0.268	0.399	1.811
Crew	3.711	7.421	6.597
Spares	1.153	1.833	10.296
Labor	0.749	0.936	2.746
Fixed Costs	4.468	6.151	14.548
Total	23.504	30.017	65.703

[1] Costs at 24 k.p.h. are based upon Dahomey data from the Lea report, as shown in Table V-1. The ratio of increase by cost component for the lower speed is from Winfrey (Appendix A) except for crew and fixed costs, which are increased in proportion to speed reduction. Thus, this table shows an approximation of operating costs at the selected speed under free running conditions in Dahomey.

TABLE V-4

COTONOU BRIDGE
VEHICLE OPERATING COSTS AT 20 k.p.h.[1]
UNIFORM SPEEDS ON LEVEL TANGENT ROADS IN GOOD CONDITION
(Fr. CFA per kilometer)

Paved Road	Car	Bus	Truck
Fuel	1.312	2.352	3.797
Tires	0.177	0.324	1.389
Depreciation & Interest	7.487	5.947	11.188
Oil	0.200	0.196	1.321
Crew	4.464	8.928	7.936
Spares	0.434	0.690	3.897
Main Labor	0.282	0.353	1.039
Fixed Costs	5.416	7.400	17.501
Total	19.772	26.290	48.068
Earth Road			
Fuel	1.810	3.105	5.316
Tires	1.065	1.946	9.333
Depreciation & Interest	10.797	8.487	15.659
Oil	0.300	0.445	1.981
Crew	4.464	8.928	7.936
Spares	1.128	1.795	10.133
Labor	0.733	0.917	2.702
Fixed Costs	5.416	7.400	17.501
Total	25.713	33.023	69.561

[1] Costs at 20 k.p.h. are based upon Dahomey data from the Lea report, as shown in Table V-1. The ratio of increase by cost components for the lower speed is from Winfrey (Appendix A) except for crew and fixed costs, which are increased in proportion to speed reduction. Thus, this table shows an approximation of operating costs at the selected speed under free running conditions in Dahomey.

TABLE V-5

COTONOU BRIDGE
VEHICLE OPERATING COSTS AT 16 k.p.h.[1]
UNIFORM SPEEDS ON LEVEL TANGENT ROADS IN GOOD CONDITION
(Fr. CFA per kilometer)

Paved Road	Car	Bus	Truck
Fuel	1.490	2.662	4.198
Tires	0.137	0.253	1.070
Depreciation & Interest	7.906	6.279	12.207
Oil	0.233	0.344	1.466
Crew	5.580	11.160	9.920
Spares	0.430	0.683	3.878
Main Labor	0.279	0.349	1.034
Fixed Costs	6.770	9.250	21.876
Total	22.825	30.980	55.649
Earth Road			
Fuel	2.056	3.514	5.876
Tires	0.820	1.519	6.418
Depreciation & Interest	11.402	8.960	17.086
Oil	0.349	0.517	2.199
Crew	5.580	11.160	9.920
Spares	1.117	1.775	10.082
Labor	0.725	0.907	2.688
Fixed Costs	6.770	9.250	21.876
Total	28.819	37.250	76.145

[1] Costs at 16 k.p.h. are based upon Dahomey data from the Lea report, as shown in Table V-1. The ratio of increase by cost component for the lower speed is from Winfrey (Appendix A) except for crew and fixed costs, which are increased in proportion to speed reduction. Thus, this table shows an approximation of operating costs at the selected speed under free running conditions in Dahomey.

TABLE V-6

COTONOU BRIDGE
VEHICAL OPERATING COSTS AT 12 k.p.h.[1]
UNIFORM SPEEDS ON LEVEL TANGENT ROADS IN GOOD CONDITION
(Fr. CFA per kilometer)

Paved Road	Car	Bus	Truck
Fuel	1.790	3.202	4.877
Tires	0.101	0.187	0.797
Depreciation & Interest	8.498	6.750	13.544
Oil	0.282	0.414	1.799
Crew	7.440	14.880	13.226
Spares	0.423	0.672	3.891
Main Labor	0.275	0.343	1.038
Fixed Costs	9.027	12.333	29.167
Total	27.836	38.781	68.339
Earth Road			
Fuel	2.469	4.228	6.827
Tires	0.608	1.121	4.779
Depreciation & Interest	12.256	9.633	18.957
Oil	0.422	.622	2.698
Crew	7.440	14.880	13.226
Spares	1.100	1.748	10.117
Labor	0.713	0.893	2.698
Fixed Costs	9.027	12.333	29.167
Total	34.035	45.458	88.469

[1] Costs at 12 k.p.h. are based upon Dahomey data from the Lea report, as shown in Table V-1. The ratio of increase by cost component for the lower speed is from Winfrey (Appendix A) except for crew and fixed costs, which are increased in proportion to speed reduction. Thus, this table shows an approximation of operating costs at the selected speed under free running conditions in Dahomey.

TABLE V-7

COTONOU BRIDGE
VEHICLE OPERATING COSTS AT 8 k.p.h. [1]
UNIFORM SPEEDS ON LEVEL TANGENT ROADS IN GOOD CONDITION
(Fr. CFA per kilometer)

Paved Road	Car	Bus	Truck
Fuel	2.408	4.313	6.265
Tires	0.065	0.119	0.512
Depreciation & Interest	9.409	7.472	15.371
Oil	0.371	0.547	2.242
Crew	11.160	22.320	19.840
Spares	0.420	0.668	3.960
Main Labor	0.273	0.341	1.056
Fixed Costs	13.540	18.500	43.752
Total	37.646	54.280	92.998
Earth Road			
Fuel	3.323	5.694	8.791
Tires	0.392	0.711	3.070
Depreciation & Interest	13.569	10.663	21.515
Oil	0.557	0.822	3.363
Crew	11.160	22.320	19.840
Spares	1.093	1.737	10.296
Labor	0.710	0.887	2.746
Fixed Costs	13.540	18.500	43.752
Total	44.344	61.334	113.375

[1] Costs at 8 k.p.h. are based upon Dahomey data from the Lea report, as shown in Table V-1. The ratio of increase by cost component for the lower speed is from Winfrey (Appendix A) except for crew and fixed costs, which are increased in proportion to speed reduction. Thus, this table shows an approximation of operating costs at the selected speed under free running conditions in Dahomey.

TABLE V-8

COTONOU BRIDGE
COST OF VEHICLE STANDING TIME WITH ENGINE IDLING
(Fr. CFA Per Hour)

	Car	Bus	Truck
Engine Idling [1]	15	36	54
Depreciation [2]	67	53	82
Interest [3]	20	16	33
Crew [4]	90	180	160
Fixed Cost [5]	109	156	350
Total	301	441	679

[1] Idling costs are taken directly from Winfrey, with the car cost reduced 50% to adjust for the smaller car used in Dahomey.

[2] Depreciation is calculated by dividing 1/3 of the new vehicle cost by the total hours of use during the vehicle's life, as shown in the Lea report.

[3] Interest is calculated by dividing annual interest costs by the average hours of use during the year as shown in the Lea report.

[4] Crew costs are taken from the Lea report.

[5] Annual fixed costs are divided by hours of use per year, as shown in the Lea report.

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TABLE V-9

COTONOU BRIDGE
ADDITIONAL COST OF SPEED CHANGE CYCLES[1]
(Fr. CFA Per 1000 Cycles/Excess Hours Per 1000 Cycles)

Full Stop From	Car		Bus		Truck	
Speed Shown	Cost	Hours	Cost	Hours	Cost	Hours
8 k.p.h.	164	1.02	348	0.75	976	0.75
16 k.p.h.	348	1.51	754	1.12	2424	1.47
24 k.p.h.	625	2.00	1290	1.52	4242	2.20
32 k.p.h.	945	2.49	1972	1.93	6431	2.93

[1] Costs are calculated by using Winfrey's estimates of additional stopping costs in relation to his estimate of running costs at the selected speed for the same type of vehicle. The resulting ratio is multiplied by the running cost estimates from the preceding tables. Car costs are reduced 50% to adjust for the smaller average car used in Dahomey.

PROJECTED AVERAGE DAILY TRAFFIC VOLUMES
NO BRIDGE IMPROVEMENT HYPOTHESIS

Year	Cars	Trucks and Buses	Motor and Pedal Bikes	Pedestrians
1977	15,694	3,161	29,783	15,845
1978	16,675	3,314	32,365	16,687
1979	17,725	3,474	35,219	17,599
1980	18,851	3,644	38,381	18,588
1981	20,058	3,823	41,893	19,663
1982	21,353	4,012	45,802	20,835
1983	22,742	4,212	50,165	22,115
1984	24,234	4,425	55,045	23,518
1985	25,836	4,650	60,521	25,060
1986	27,558	4,889	66,682	26,760
1987	28,934	5,078	71,816	28,152
1988	30,388	5,276	77,447	29,657
1989	31,924	5,484	83,634	31,287
1990	33,547	5,703	90,445	33,056
1991	35,264	5,933	97,957	34,981
1992	37,079	6,175	106,258	37,081
1993	38,999	6,430	115,450	39,376
1994	41,032	6,699	125,648	41,893
1995	43,183	6,984	136,987	44,660
1996	45,461	7,285	149,621	47,710

PROJECTED AVERAGE DAILY TRAFFIC VOLUMES
SAINT MICHEL BRIDGE ALTERNATIVE
TRAFFIC AT NEW BRIDGE

Year	Cars	Trucks and Buses	Motor and Pedal Bikes	Pedestrians
1977	5,887	1,293	12,456	5,095
1978	6,550	1,430	14,090	5,451
1979	7,275	1,579	15,936	5,844
1980	8,068	1,739	18,026	6,281
1981	8,935	1,912	20,393	6,767
1982	9,883	2,098	23,081	7,310
1983	10,920	2,298	26,138	7,918
1984	12,054	2,515	29,620	8,601
1985	13,296	2,749	33,597	9,371
1986	14,655	3,001	38,148	10,243
1987	15,379	3,130	41,496	10,973
1988	16,145	3,266	45,211	11,779
1989	16,956	3,410	49,343	12,671
1990	17,815	3,562	53,947	13,658
1991	18,725	3,724	59,085	14,756
1992	19,690	3,895	64,834	15,979
1993	20,713	4,076	71,277	17,346
1994	21,799	4,270	78,513	18,876
1995	22,952	4,476	86,658	20,596
1996	24,176	4,696	95,845	22,533

PROJECTED AVERAGE DAILY TRAFFIC VOLUMES
SAINT MICHEL BRIDGE ALTERNATIVE
TRAFFIC AT EXISTING BRIDGE

Year	Cars	Trucks and Buses	Motor and Pedal Bikes	Pedestrians
1977	9,807	1,859	17,327	10,749
1978	10,124	1,874	18,274	11,236
1979	10,450	1,888	19,282	11,754
1980	10,783	1,898	20,355	12,306
1981	11,123	1,906	21,499	12,895
1982	11,469	1,911	22,721	13,524
1983	11,822	1,913	24,026	14,197
1984	12,179	1,911	24,425	14,917
1985	12,540	1,905	26,924	15,689
1986	12,903	1,894	28,534	16,517
1987	13,555	1,956	30,320	17,179
1988	14,242	2,021	32,235	17,877
1989	14,967	2,087	34,291	18,616
1990	15,731	2,157	36,498	19,397
1991	16,538	2,228	38,871	20,224
1992	17,388	2,302	41,424	21,101
1993	18,285	2,379	44,173	22,030
1994	19,232	2,458	41,134	23,016
1995	20,231	2,541	50,328	24,063
1996	21,285	2,626	53,776	25,176

APPENDIX B

REPORT OF THE FISHERY RECONNAISSANCE TO LAKE NOKOUE, DAHOMEY

Richard B. Thompson

and

ECONOMIC EVALUATION OF EXPECTED FISHERY BENEFITS

by

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July 1971

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REPORT OF THE FISHERY RECONNAISSANCE TO LAKE NOKOUE, DAHOMEY

Richard B. Thompson

Introduction

A brief survey was made in January and February of 1971 of the status of the fisheries of Lake Nokoue in the Republic of Dahomey and the associated physical and biological conditions that have influenced the yields of fish from the lake. This assignment was in response to a request from the Agency for International Development of the Department of State through the National Marine Fisheries Service Office of Technical Services.

The mission was a reconnaissance of the fishery aspects of the proposal to construct a bridge and dam across the Cotonou Channel for purposes of transportation, erosion control and possible fishery benefits. The results of the fishery survey would be included in the consideration of the feasibility of the over-all plan.

Arrival in Cotonou was on January 18, 1971. Valuable assistance and information were received from the American Embassy in Cotonou. Arrangements were made through Embassy staff to meet representatives of the Department of Fisheries of the Republic of Dahomey and of the Cotonou delegation of the United Nations Developmental Program. A flight over the lake was made on January 25 when observations and photographs were made of the many fishery installations and operations. Three trips by boat on the channel and lake were made on January 22, 27, and 29. Observations were made of the general geography and limnology of the lake, the construction and maintenance of the acadjas, the harvesting of fish from both small and large acadjas, and of other types of fishing operations. Discussions (through three languages) with fishermen were made of the various aspects of the fishery situation.

The survey, while restricted to two weeks and therefore limited in scope, did provide knowledge of the physical relations of the lake, the sea and the Cotonou Channel; the physical and biological problems created by the salinity intrusion; the methodology of the various types of fisheries; and the cultural and economic conditions of the fishermen. Descriptions of the local geography, the lake, and the various types of fishing operations have been adequately made elsewhere (Welcomme, 1969, 1970; CTFT, 1965, 1969; BCEOM, 1963, 1966, 1968 ; UNDP, 1970) and will only be summarized shortly here.

Description of the Fishery

Prior to 1959 the fishery of Lake Nokoue and the adjoining Porto-Novo lagoon was the most productive and important in Dahomey and provided income and subsistence for some 50,000 people. Before 1961, this area was producing about 15,000 metric tons of fish per year, but by 1967 the yearly production had decreased to about 9,000 tons, and in 1970 was estimated to be 5,600 tons (Fig. 1). This disastrous decrease in production has been a result of the changes in the ecology of the lake and the lagoon, due directly to the permanent opening of the Cotonou Channel, which in turn, was caused by the construction of the deep-water Port of Cotonou. Prior to the construction of the port, along-shore currents carried sand which was deposited at and closed the mouth of the Cotonou Channel. The Channel was opened frequently by flood waters, usually during the fall of the year (October-December), but was soon re-closed by sands deposited at the mouth. Thus, the channel remained open for inflow of tidewaters into the lake and lagoon for only a short time. The present situation, where the sand-bearing coastal currents are diverted offshore by the breakwater of the Port, has prevented the re-formation of the sand bar since 1959. Tide waters from the Atlantic Ocean have had direct access to the lake whenever the marine tide level exceeded about +1.0 m.

The main fish-production in Lake Nokoue has been from the various types of "acadja" installations, which are artificial fish-culturing or fish-farming operations. The fishermen implant large numbers of branches of wood or brush close together in the shallow water. These are in a variety of forms--from small circles 5 to 7 meters in diameter (acadjavis) to very large rectangular shapes of up to seven hectares in area (avas and hanoumekadjas). These parks are attraction and refuge areas for fishes which occur in low densities in the open water of the lake: the fish find the refuge of the acadjas and feed on organisms growing on and amongst the branches. Food and cover have been adequate in the past to support good fish growth, and the fish grow rapidly. Welcomme (1969) determined that the density of fish in the acadjas was approximately 100 times the density of the same species of fishes in the open water of the lake. It must be established, then, that the brush acadjas are necessary for the high production of fish that existed prior to 1959. The food and cover provided are necessary to entice and retain the fish in them, for there is no fish-tight fence around the acadjas and fish are not planted into them by the fishermen. If the brush is destroyed and the refuge and food source no longer exist, then the fish move until they find another similar refuge.

The acadjas are also contributing to the harvesting of the cast-netters. Many of the cast-netters observed on the lake were fishing in the immediate vicinity of large acadjas--fishing for fish which had temporarily wandered out of the acadja into the nearby open water.

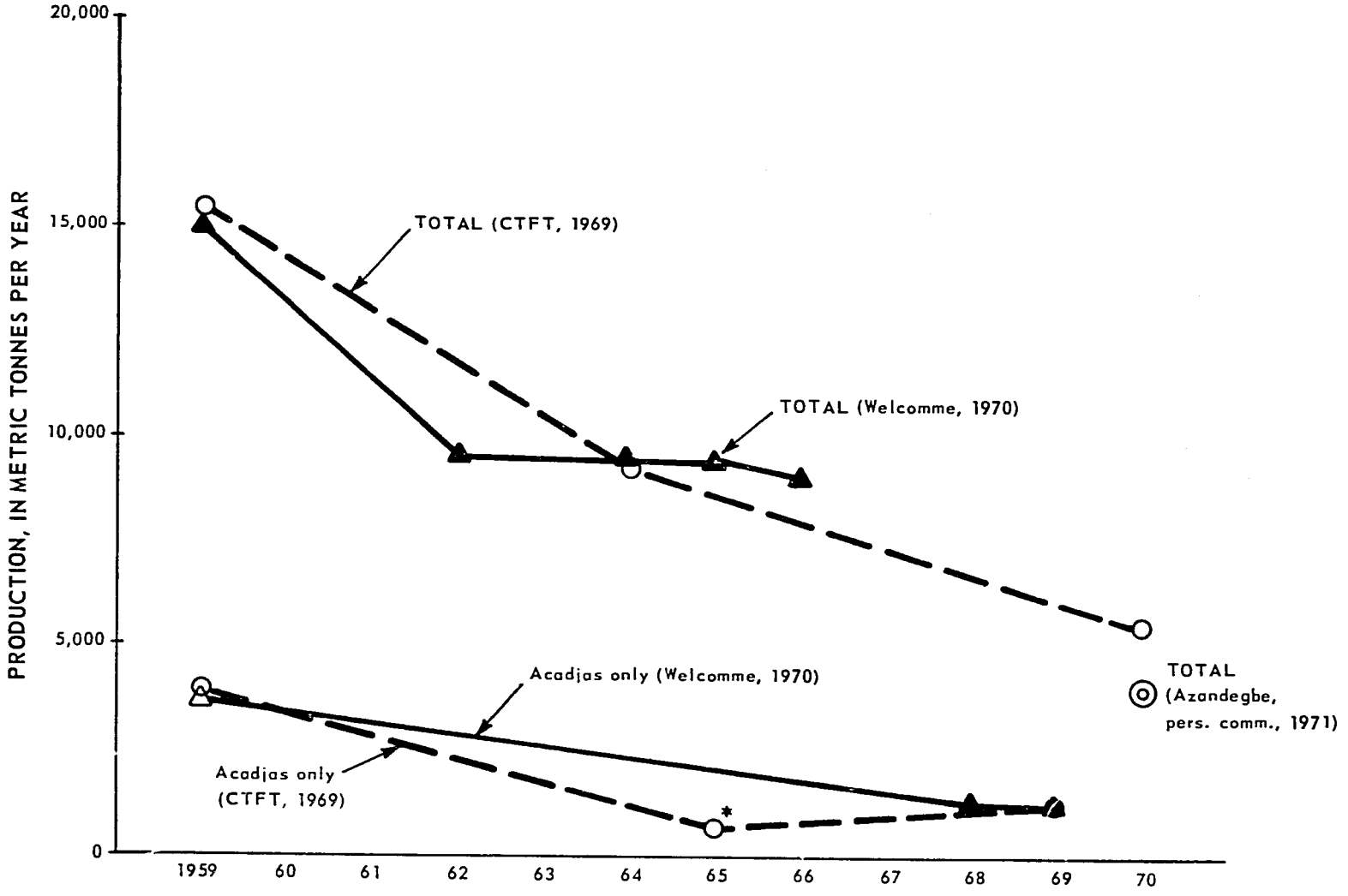

FIGURE 1. DECREASE IN PRODUCTION OF FISH IN LAKE NOKOUE, 1959 TO 1970
* "PROBABLY UNDERESTIMATED"

The main species of fish harvested from the acadjas are Tilapia heudelotii and Chrysichthys nigrodigitatus, which together comprise 90% of the yields by weight. These are basically freshwater forms which are especially tolerant to changes in salinity and are therefore found in estuarine and brackish waters. Tilapia is a rapidly-growing fish and attains sexual maturity in its first year. They are highly gregarious and live in dense aggregations where proper cover is available; in fact, they are seldom found outside of dense cover of branches or aquatic vegetation. The annual yield of Tilapia from the acadjas has approached nine metric tons per hectare (about 4 English tons per acre). The yield has been highest in those acadjas with the densest implantation of brush and branches.

Biological bases of productivity

Under the pre-1959 conditions, the mineral-rich silt delivered to the lake by the tributaries settled onto the lake bottom, providing a basis for excellent biological production, both within the lake bottom and in the waters of the lake. At the present situation the velocity of flood waters flowing through the lake and channel to the sea (at low tides) and the constant turbulence created by incoming and outgoing tides, have prevented the deposition of the silt and detritus on the lake bottom. There has thus been a considerable loss of basic biological productivity which has been a factor in reducing fish growth and yield from the lake.

The intrusion of tide water into the lake has, in addition to the physical scouring by turbulence, affected the ecology of the lake in many biological ways. The most serious biological change has been the introduction of and environmental enhancement for the marine borers, or shipworms, of Teredo and Bankia genera. These have been abundant enough and the damage created by them serious enough to jeopardize the acadja fishing operations in the lake and lagoon. They have bored into the wooden material of the acadjas and caused the rapid disintegration of these installations. The total area of acadja installations has been seriously reduced since 1959 (Fig. 2). In the less-saline areas of the lake, where the fishermen are still constructing and operating acadjas, the rapid rate of loss and the increase in cost of the branches has more than doubled the cost of their construction and maintenance. Information from fishermen on the lake indicated that prior to 1959 the brush in the acadjas was good for 1 year or more; after 1960 this durability began decreasing and the fishermen now report that the brush lasts only from 1 to 3 months. Because of this rapid destruction of the artificial environment required by the fish for optimum growth and reproduction, and to the need for more frequent addition of branches to the acadjas and to rising costs of the wood, the fishermen have been reluctant or financially unable to invest in the construction of new acadjas (cf. Fig. 2). The teredos are also damaging the houses constructed on stilts in the lake, and are attacking the small dugout canoes used by the fishermen and lake-dwellers. Houses which used to last for 12 to 14 years now collapse in 5 to 7 years; the pirogues previously had a life of 7 years and now last but two. Most lake residents have racks for raising the smaller canoes out of the water when they are not being used; the larger canoes cannot be lifted out of the water and are continuously at the mercy of the borers.

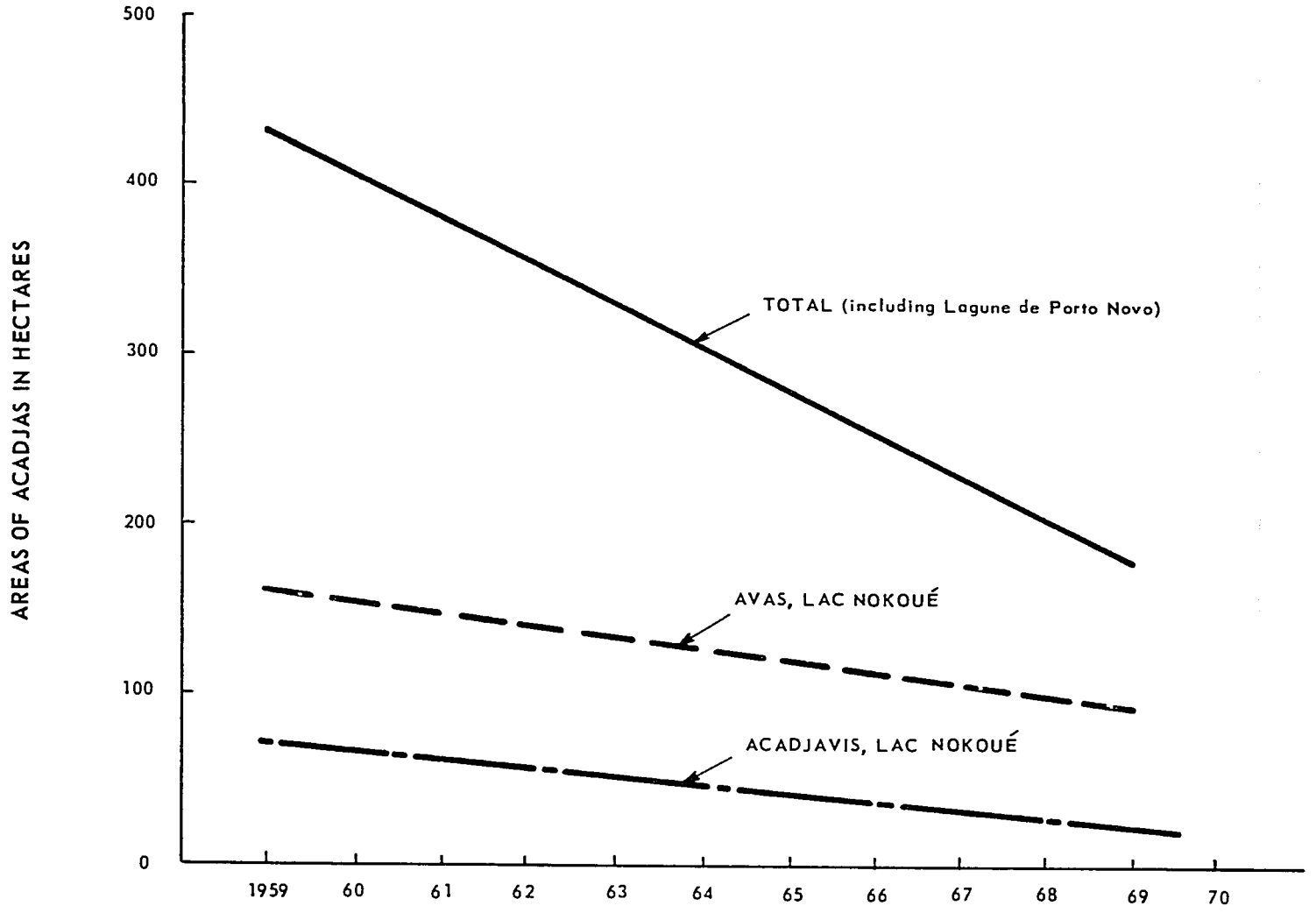

FIGURE 2. DECREASE IN AREA OF PREPARED ACADJAS IN LAKE NOKOUE AND ASSOCIATED AREAS, 1959 TO 1969 C.T.F.T., 1969

It is estimated that about one-half of the decrease in total fish production from the lake has been due to the too-rapid outflow of the nutritious flood waters. The other half of the decrease can be attributed to the effects of changes in the amount and schedules of salinity intrusion which has brought in additional teredos or has provided a more suitable environment within the lake for their development.

Evaluation of the Effects of the Proposed Dam

With the rock-fill weir type of dam with a crest of +1.1 meter as proposed by Sanders and Thomas, Inc., the initial benefit will be to reduce the rate of flow of water in both directions through the channel and in the outlet area of the lake. This reduction in velocity and total flow seaward during the flood season will permit the flood-borne silt and detritus to settle onto the lake bed. Reduction in current and turbulence in the outlet area of the lake (Agbato) will permit the silt to be deposited and to remain there. At present the current created by the in-rushing tides and the reverse outflows of tide water and lake water have scoured the lake bottom of all silt and detritus in the outlet area.

If no dam is built in the Cotonou Channel, it is obvious that, at best, the fish production of the lake will remain the same. It is more likely that the production of fish will continue to decline. Unless something is done to reduce the damaging effects of the teredos, the fishermen will not install the acadjas because of the financial constraints. Primary production within the lake will continue to decrease because of the loss of the biologically productive silt and other flood-borne nutritive material. Unless the salinity intrusion is reduced, the effects of the borers will continue to reduce the installation and maintenance of the acadjas and the production of fish from that type of fish culture. The effects of the borers on the stilt-houses and the dug-out canoes of the fishermen will continue to be a problem exclusive of the effects on fishery installations and productivity.

Any barrier to the flow of flood waters and tide waters in the channel can be expected to have beneficial effects on the fishery production of the lake. A barrier will reduce volume and rate of flows in both directions and reduce erosion and scouring. During flood periods the flow reduction will permit the settling of silt and detritus to the bottom of the lake and, to an unknown degree, restore some of the basic biological productivity that has been lost. The effects of reducing the salinity intrusion will depend upon the degree of reduction of the inflow of saline tidewaters. According to calculations by Sanders and Thomas, Inc. (Fig. 3), the +1.1 meter weir will reduce the amount of salt water flowing into the lake to approximately 1% of the present amount. Although calculations to determine the resultant salinity in the lake have not been completed, it is estimated that this will reduce the salinity level to less than 6 grams/liter or parts per thousand. The tolerance of Teredos of related species to different levels of salinity is shown in Fig. 4. The target for maximum salinity for the lake should be at 4 g/l. If this level could be attained for a period of 7 days every 3 months, the existence of Teredos should be almost completely controlled. Larvae have been found to be able to exist at 10 g/l, but not to be able to burrow into wood

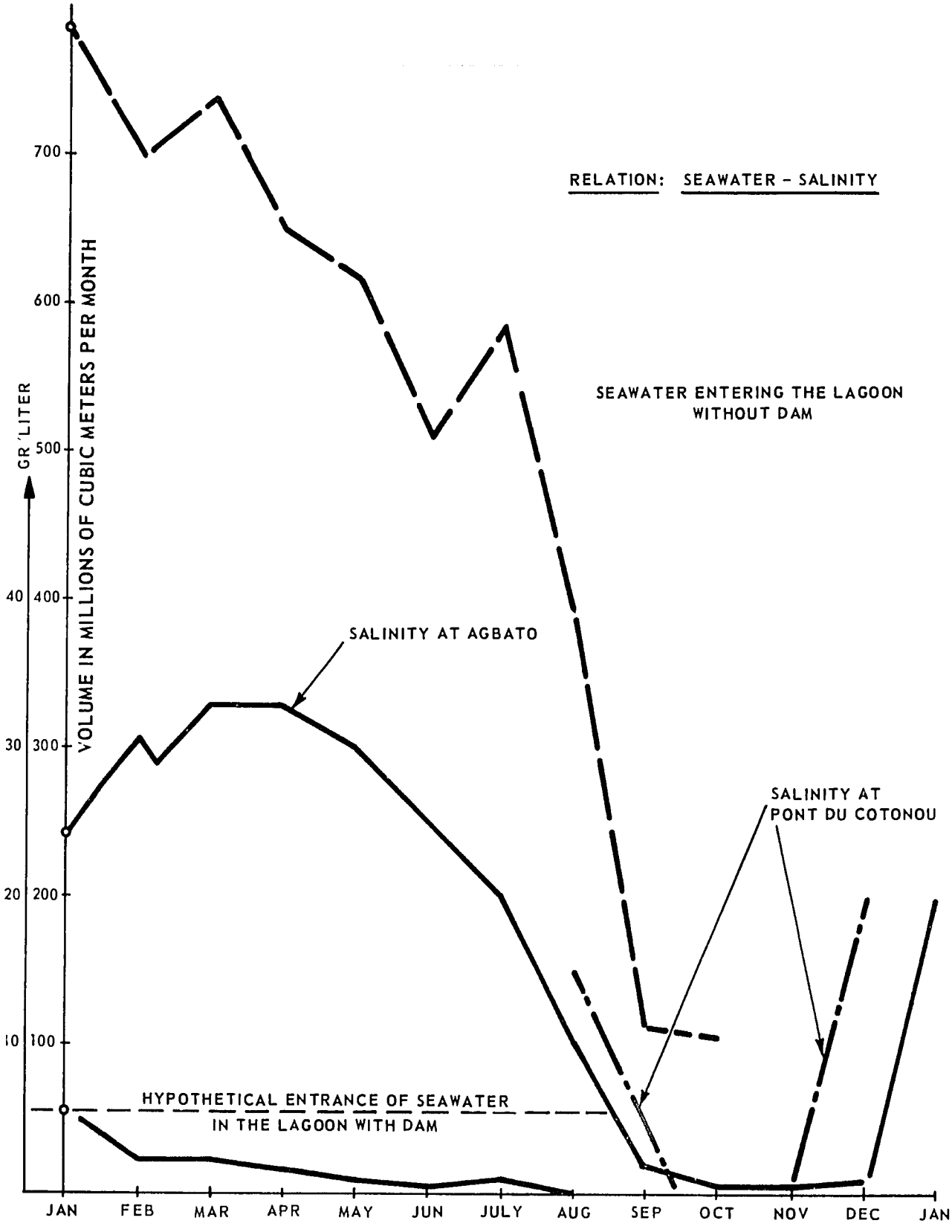

FIGURE 3. RELATION OF TIDAL FLOWS INTO THE COTONOU CHANNEL WITH SALINITY AT THE COTONOU BRIDGE AND THE CALCULATED FLOWS WITH THE +1.1 METER WEIR

at that level, hence they would soon die. The burrowing of adult Teredos is reduced below 10 g/l, and has been found to cease below 4 g/l (Kofoid, 1927). Salinities of 5 g/l and below have been found to be lethal to Teredos over a longer period of time. Thus, the primary target for maximum salinity of Lake Nokoue should be at 4 g/l for at least 7 days every 3 months. This level will, of course, eradicate the Bankia borers, which require salinities of greater than 12 g/l, and should also greatly reduce if not control the effects of the Teredo borers.

Accurate prediction and quantification of the effects of borer control cannot be made at the present time; the data needed for this type of analysis are not available from the Department of Fisheries or elsewhere. The financial constraints on the fishermen in maintaining the acadjas must also be considered. This involves the supply and demand for wood and the profit motives of the woodcutters. There will undoubtedly be better biological growth and production of fish in the lake but the effects of teredos have currently reduced the durability of the acadjas, forcing the fishermen to harvest at poorer productive schedules--due to the expected life of the acadja and not related to the prime biological harvesting time of the fish stock. The shorter life of the acadjas requires the fishermen to harvest more frequently, with resultant less production of fish on a per unit of time basis.

If the fishermen can be assured that salinities will be reduced and the effects of the borers eliminated, it should encourage them to invest in the construction of more and larger acadjas. With the restoration of the basic biological productivity to the level that existed in the lake prior to the permanent opening of the channel, there is no reason to believe that the fishery productivity of the lake would not be restored to its 1959 level. There is no indication available that the environmental changes have had an effect on anything but the quantitative aspects of the existing fish populations. No species of fish seems to have increased in numbers in response to the ecological changes of the lake. Restoration of original, or better, conditions by the construction of a barrier in the channel should provide for restoration of fish-cultural operations and the restoration of productivity levels to what they were before 1959. With the added information about the basic biology of the fish populations and the techniques of improving acadja installations and harvesting times and techniques (Welcomme, 1969 and 1970), there appears to be ample justification to support an hypothesis that fish productivity can be increased up to and perhaps beyond the 15,000 metric tons per year that existed prior to the permanent opening of the channel.

There should be no significant harmful effects to fishery enterprises or fish production if the dam is constructed as proposed. The only exception to this is the production of shrimp. These organisms come into the lake with the inflowing tides as pelagic larvae, grow in the lake for 1 to 3 years, and at the onset of sexual maturity migrate back out to sea for spawning. It is during the seaward migration that the fishermen harvest the shrimp with traps. With the installation of the +1.1 m weir, it can be expected that the shrimp fishery will be reduced greatly. If the calculations of the Sanders and Thomas engineers are accurate in

predicting that the inflow of tidewater will be reduced to 1% of its current amount (Fig. 3), it seems reasonable to expect that the abundance of shrimp larvae entering the lake will be reduced in the same proportion. The effect of reduced salinity on the survival and growth of these shrimp that do gain access to the lake is not predictable at the present time.

The only recognizable environmental factor, other than shifts in the salinity patterns, that is now or is likely in the future to affect the fishing yield for the principal fish varieties as well as for shrimp is the expected restoration of biological productivity to be derived from the added desposition of flood-borne silts and detritus on the lake bottom by the reduction in flows and turbulence. It is roughly estimated that one-half of the decrease in fish yields from Lake Nokoue has been due to the loss of this silt; it is therefore reasonable to expect that a minimum of this amount would be restored by the construction of the dam and the subsequent reduction in turbulence.

No other controllable environmental factor than the effects of turbulence and the effects of salinity intrusion were evident. These are the two prime causes of decrease in fish yields, as indicated in all previous reports obtained and the situation as surveyed by this investigator.

Most evident factors controlling fishing yields, with the exception of the two mentioned above, are not environmental, but are associated with the material needs of the fishermen to engage in fishing, the harvesting of the fish crops and the marketing and distribution of the product. The cost and the transportation of wood branches for the construction of the acadjas are two important factors in the determination of future fishing yields. The supply of branches to the fishermen by woodcutters may be a limiting factor in increasing future productivity. The use of artificial materials for acadja installations is a future possibility and is being investigated at the present time. Marketing and distribution systems for the yields of fish from the lake are quite primitive and should be a target for improvement by the various fishery management and development agencies in Dahomey. These factors, however, are independent from the basic problem of evaluating the fishery benefits to be derived from the construction of a bridge and dam in the channel.

The totality of these effects requires that something be done to block the channel. The rapid out-flow of nutrition-bearing flood waters must be stopped; the turbulence created by the incoming tides must be reduced; and the intrusion of salinity into the lake system must be controlled before any improvement in the yield of fish from the lake can be expected.

Forecasting Considerations

As discussed above, it is not possible to forecast definitively the increase in fish yields due to ecological conditions that will be changed by the proposed dam. At present the following factors must be considered:

1. Reduce turbulence; allow deposition of silt, detritus and minerals in the lake.

2. Limit salinity intrusion: reduce salinities in the lake to below the minimum tolerated by Teredo petiti (less than 4 g/l.) and thus restore conditions that will ensure durability of the acadjas. With the assurance to the fishermen that the effects of the Teredos are indeed reduced, the construction of more and possibly larger acadjas should follow, until the area provided for such fish-culture operations equals if not exceeds that which existed prior to 1959.

3. There does not appear to be any evident biological restriction on the amount of fish production that can be achieved in Lake Nokoue--at least evident from available information. The major restriction on yields is the existence and durability of the acadjas; the more there are and the longer they last the greater the yield will be. Of course, there is an upper limit to yields, but on the basis of past cultivation efforts and productivity, it is estimated that this level is far above those achieved in the past.

4. The increase in population of the area surrounding Lake Nokoue in the past 10 years now provides a greater market for fish from the lake which should provide further incentive for more intensive fish-cultural operations.

5. To take advantage of this expected increase in yield, efforts should be initiated by the Department of Fisheries to provide for better preservation, transportation and marketing facilities.

6. After the season of the floods, freshwater conditions were soon established in the lake. The local rainy season flushed the salt water from the lake, and it remained in essentially a freshwater condition through the late summer and early fall until the high fall tides (the highest of the year) flowed into the lake and made it saline again. Thus, if the intrusion of salt water during the high fall tides can be reduced or controlled, the lake should start toward a freshwater condition. Available records on the time of the opening of the channel, the height and frequency of the tides and the resultant salinity changes in the lake are not adequate to predict accurately future schedules and salinity changes. However, it is estimated that within three, or at most five, years after installation of the dam the lake should reach its post-dam stable condition, relative to salinity levels and to silt and detritus deposition.

The monetary evaluation of fishery benefits to be derived from the barrier dam is attached as an Appendix.

Other Recommendations

Another element related to the fishery situation in the lake is the improvement of the primitive and laborious system of harvesting fish from the acadjas. Estimates have been made that 160 man-days of labor per hectare of acadjas are required for the harvest (Welcomme, 1969). This is not in exact terms of "man-days" of work as usually defined in an industrial-technological society since many people involved in harvests were engaged in highly

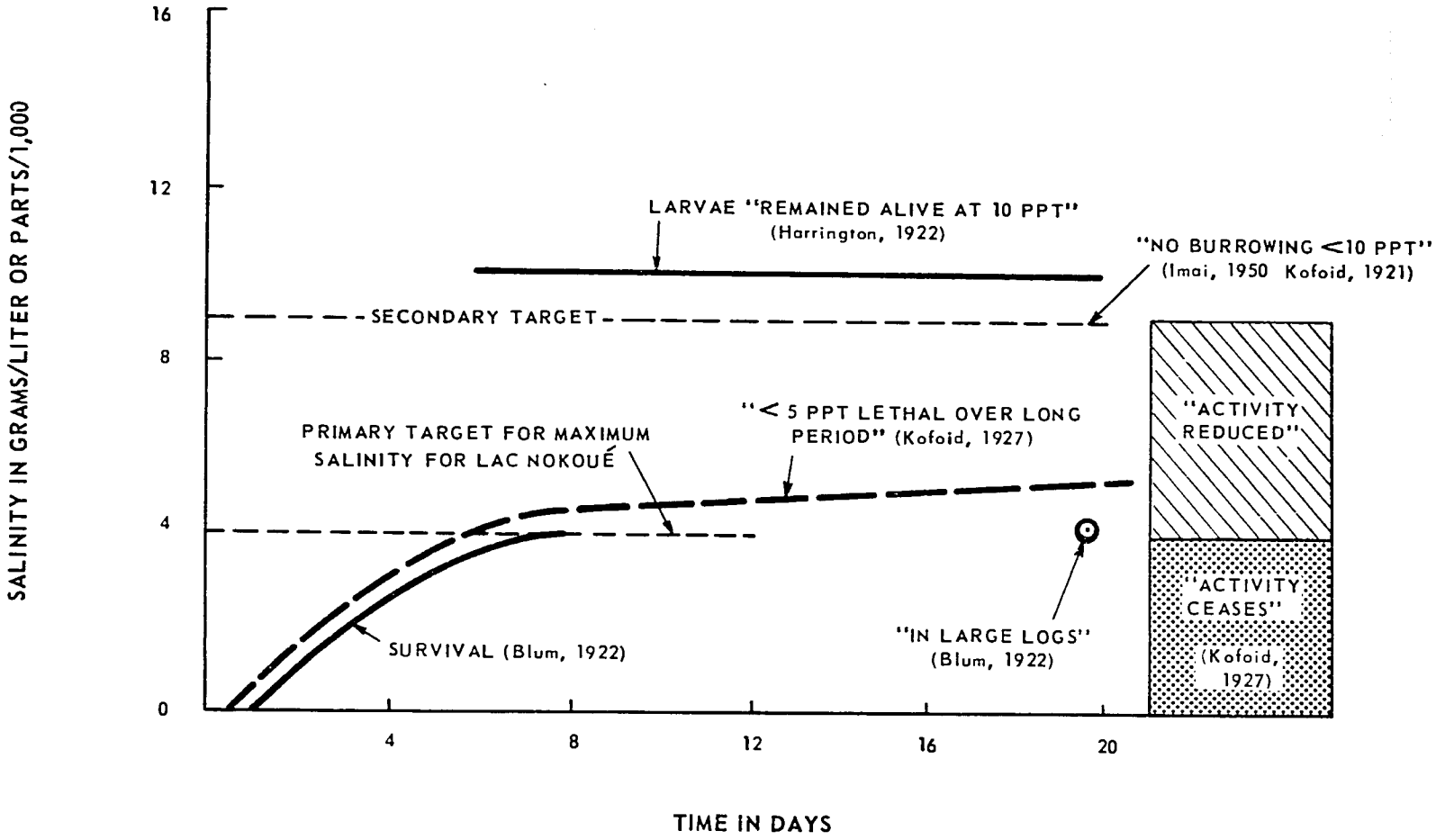

FIGURE 4. RELATIONSHIP OF SALINITY WITH ACTIVITY AND SURVIVAL OF TEREDO

unsupervised activities. Many observed in January did not appear to be working under supervision; participating observers and almost "picnickers" would seem to be more accurate descriptions.

It is not known if reduction in labor needs would be a benefit in a nation with the extremely high unemployment rate that Dahomey now has. However, if this is a valid objective, various innovations may be considered.

The first is the development and use of an electro-fishing harvesting system. When the lake is not highly saline and thus not too high in conductivity to operate electrofishing gear, such harvesting should provide for quicker and less expensive means of collecting fish. Pulsed direct current units could be used to great advantage during the harvest. This would permit the fishermen to have more time for the construction and maintenance of acadjas. The harvest could be selective for species and sizes of fish taken. Small fish could be returned unharmed to the acadjas and the sizes of fish harvested could be those at which productivity is maximized. The brush installations would not be disrupted by the need to move them during harvesting and this should provide greater long-range productivity. A fishermen's cooperative might be formed to provide a properly-equipped harvesting team, which could go from acadja to acadja at the proper schedule for maximum yields. Payment for this work could be in the form of a portion of the yield.

Another development that might be considered, even if the teredos are controlled immediately, is the use of artificial branches made of plastic materials in the acadjas. Preliminary efforts to gather information on the feasibility and availability of use of these materials have been made and forwarded to the American Embassy. Advantages in the use of this type of material might include:

1. Durability--the materials would last much longer than the softwoods now used. Even with reduced damage from teredos, the life expectancy of softwood branches in the lake would be not much more than 1 year, due to insect, bacteria and fungus effects.

2. Unit size: If the same harvesting techniques are used, the plastic materials could be joined in large units, say 10 clumps of brush per anchor unit. This would be moved, during harvesting, as one large unit. The removal of the artificial brush materials in larger groups would be much faster than having to remove each branch individually from the lake bottom.

3. Improvements in the physical nature of the brush must be possible; such as number, diameter and shape of the branches, twigs and leaves. The more cover for the fish and the more surface area there is available on which to grow algae and other fish-food organisms (attachment space is a limiting factor in productivity of sessile aquatic organisms), the greater the production and yield of fish should be. Plastic "trees" for ornaments and decoration are almost unlimited in types, sizes and shapes. These are imitations of natural plants and trees. If the demand was great enough, there should not be any serious problem in designing and producing such "trees" in sizes, shapes and forms that would be optimum for this

particular purpose - that of providing cover for the fish of the lake and maximum living space for the growth and production of the biological organisms on which these fish feed.

Conclusions

1. The basic productivity of Lake Nokoue has been reduced in the past 10 years, partially due to the loss and lack of replacement of nutritive silt and detritus on the lake bottom; caused by turbulent outflows of flood waters and inflows of tidal waters.

2. The fishery productivity has been reduced because of (1) above and because of the damaging effects of marine borers on the wooden fish-cultural installations, collectively called "acadjas". The effects of marine borers have increased in the past decade because of the intrusion of saline waters and the changes in the salinity characteristics of the lake.

3. Any reduction in turbulent flows out of or into the lake will help to replace the productive bottom materials.

4. A significant reduction in the amount of salt water reaching the lake will reduce the effects of the marine borers. The decrease in volume of salt water intrusion calculated by Sanders and Thomas appears to be sufficient to restrict, if not eliminate, the effects of the marine borers.

5. Correction of the two major causes of reduced fishery productivity should restore the lake's fisheries to or above their level of 1959.

6. The use of new plastic materials for acadja construction and the use of electrofishing devices in harvesting are suggested as improvements in fishery operations.

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Appendix

Fishery Benefits
Lake Nokoue, Dahomey

As a result of changes in the ecological characteristics of Lake Nokoue, fish production from the lake has dropped to 5,600 tons in 1970 from 15,000 tons in 1959 (see Text Figure 1). The social and economic well-being of approximately 50,000 people who depend directly on the fisheries of Lake Nokoue as a source of income and food are being threatened as are other sectors of the economy involved in fishery production and distribution. Consumers are also being affected by this decline in fishery production, as indicated by the doubling of fish prices at the harvesting level: Tilapia, 25 francs (CFA) per kg in 1959 and 50 francs per kg in 1971; mullet and shrimp, 70 francs per kg in 1959 and 150 francs per kg in 1971. Compounding these problems are the high unemployment in the fishery and region at this time and the need to import approximately 3,000 tons annually of fish products in recent years to offset the drastic decline in domestic production.

General benefits from the proposed dam:

The project (dam) is expected to result in the following general fishery benefits over time:

1. Increased production will contribute to food and higher nutritional needs of the region.

2. Increased employment and income in the harvesting and distribution sectors of the fishery.

3. Long-range stability that promotes maximum benefits from the fishery.

4. Stable and lower prices for these fish products.

5. Reduction in per unit production cost of fishing operations; especially material (wood) costs in the acadja fishery.

6. Permit alternative uses of national (Dahomey) monies (nearly U.S. $1 million per year) currently expended on import of fish products.

Fishery benefits from the proposed dam:

Economic benefits attributable to the fishery with the implementation of the project that will improve the fishery are reported here in terms of net economic benefits based on the following assumptions:

1. The low economic condition and high unemployment in the fishery specifically and in the region generally, permit evaluating benefits based on the assumption that net benefit can be represented by gross benefits less material costs only, due to lack of alternative employment for most resources currently employed in this fishery.

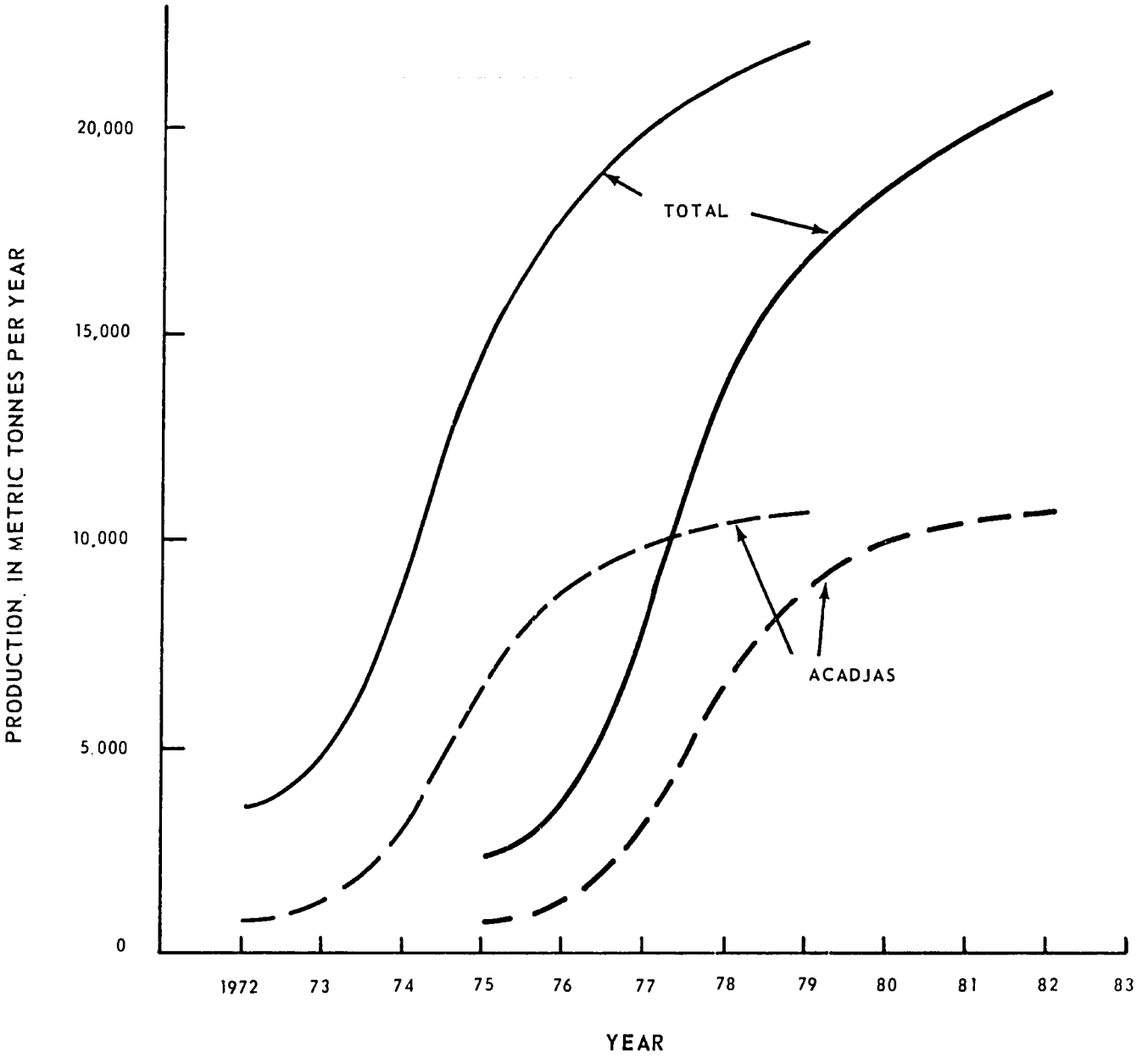
2. In the absence of adequate information on projected market prices at levels of increased productivity, an approximated decreasing price trend is used to value the increased fish production.

3. It will be assumed that the net value productivity of the fishery will return only to the 1959 level. This is considered a very conservative estimate as discussed elsewhere in this report.

Based on these assumptions, Appendix Table 1 summarizes the projected net economic benefits to the fishery from a dam constructed in 1972 or in 1975. In each case the planning period, or benefit stream, covers only seven years and is based on the production (or recovery) curves shown in Appendix Figure 1. These benefits are, however, expected to continue far beyond the planning period. Detailed analyses, by acadja and open lake fisheries, are given in Appendix Tables 2 and 3.

The total net economic benefit to the fishery during 1973-79 with the dam completed in 1972 is approximately U.S. $10.7 million. With the dam completed in 1975, the total net economic benefit during 1976-82 is U.S. $10.4 million. For informational purposes, discounted net benefits at four alternative interest rates are given in Appendix Tables 2 and 3. They show that the above stated net benefits when discounted to appropriate present values range from U.S. $8.6 to $4.8 million for the 1972 dam and U.S. $8.3 to $4.7 million for the 1975 dam.

Fishery benefits are expected beyond the planning period. As an example of net benefits that can be expected over a longer benefit stream, the total net economic benefit for a 20 year period (1973-92) discounted at the 20 percent rate would be U.S. $7.7 million with the dam completed in 1972.



APPENDIX FIGURE 1.

Estimated recovery of fish production from Lake Nokoue for acadjas (dashed lines) and total lake production (solid lines). The origins of the respective curves, at arbitrarily selected dates of 1972 and 1975, indicate the levels of fish production at those times and the curves the recovery estimated to occur if the dam is completed in those two years.

Appendix Table 1.--Projected increase in fishery production and net economic benefits from the proposed dam at Lake Nokoue, Dahomey.

Year	Fish production: Total	Fish production: Annual increment	Fish production: Cumulative	Gross revenue	Fishing cost	Net benefit
	metric tons			U.S. $1,000		
			(Dam completed in 1972)			
1972	3,700	-	-	-	-	-
1973	5,100	1,400	1,400	564	150	414
1974	9,300	4,200	5,600	1,574	418	1,156
1975	15,000	5,700	6,170	1,941	465	1,476
1976	18,200	3,200	9,370	2,383	787	1,596
1977	20,000	1,800	11,170	2,679	884	1,795
1978	21,400	1,400	12,570	2,956	975	1,981
1979	23,300	1,900	14,470	3,394	1,120	2,274
					Total	= $10,692
			(Dam completed in 1975)			
1975	2,200	-	-	-	-	-
1976	3,600	1,400	1,400	468	103	365
1977	8,000	4,400	5,800	1,586	411	1,175
1978	13,800	5,800	11,600	1,977	470	1,507
1979	16,700	2,900	14,500	2,359	779	1,580
1980	18,500	1,800	16,300	2,621	865	1,756
1981	19,800	1,300	17,600	2,873	949	1,924
1982	20,700	900	18,500	3,054	1,008	2,046
					Total	= $10,353

Appendix Table 2.--Projected benefits with enhancement project (dam) completed in 1972, Lake Nokoue fishery, Dahomey (1973-1979). 1/

Year	Fish production 2/ Total	Annual increment	Cumulative increase	Estimated price for fish 3/	Gross benefits 4/ CFA	U.S.$	Fishing cost 5/ (U.S.$)	Net benefit 6/ (U.S.$)	Net benefit (U.S.$) discounted at: 7/ 4 7/8%	6%	12%	20%
	metric tons			(CFA/kg)	thousands							
					(Acadja Fishery)							
1972	900	-	-	-	-	-	-	-	-	-	-	-
1973	1,500	600	600	50	30,000	110	0	110	105	104	98	92
1974	3,300	1,800	2,400	35	84,000	308	0	308	280	274	246	214
1975	6,700	3,400	5,800	25	145,000	531	0	531	460	446	378	307
1976	9,000	2,300	8,100	25	202,500	742	245	487	411	394	316	240
1977	10,000	1,000	9,100	25	227,500	838	275	558	440	417	317	224
1978	10,500	500	9,600	25	240,000	879	290	589	443	415	298	197
1979	10,800	300	9,900	25	247,500	907	299	608	436	404	275	170
							Total	= $3,201	2,575	2,454	1,928	1,444
					(Open Lake Fishery)							
1972	2,800	-	-	-	-	-	-	-	-	-	-	-
1973	3,600	800	800	155	124,000	454	150	304	290	287	272	253
1974	6,000	2,400	3,200	108	345,600	1,266	418	848	771	755	676	589
1975	8,300	2,300	5,500	70	385,000	1,410	465	945	819	793	673	547
1976	9,200	900	6,400	70	448,000	1,641	542	1,099	908	870	698	530
1977	10,000	800	7,200	70	504,000	1,846	609	1,237	975	924	701	497
1978	10,900	900	8,100	70	567,000	2,077	685	1,392	1,046	981	706	466
1979	12,500	1,600	9,700	70	679,000	2,487	821	1,666	1,194	1,108	754	465
							Total	= $7,491	6,003	5,718	4,480	3,347
					(Total Fishery)							
1972	3,700	-	-	-	-	-	-	-	-	-	-	-
1973	5,100	1,400	1,400	-	154,400	564	150	$ 414	395	391	370	345
1974	9,300	4,200	5,600	-	429,600	1,574	418	1,156	1,051	1,029	922	803
1975	15,000	5,700	6,170	-	530,000	1,941	465	1,476	1,280	1,239	1,051	854
1976	18,200	3,200	9,370	-	650,500	2,383	787	1,596	1,319	1,264	1,014	770
1977	20,000	1,800	11,170	-	731,500	2,679	884	1,795	1,415	1,341	1,018	721
1978	21,400	1,400	12,570	-	807,000	2,956	975	1,981	1,489	1,396	1,004	663
1979	23,300	1,900	14,470	-	926,500	3,394	1,120	2,274	1,630	1,512	1,029	635
							Total	= $10,692	8,578	8,172	6,408	4,791

1/ The planning period is 1973 through 1979 (7 years). The 1979 total net benefit of U.S. $2,274,000 may be extrapolated or kept as a constant estimate for each year beyond the planning period of 1979.

2/ Represents the projected recovery in fish production following the completion of the dam in 1972. The 1959 level of 15,000 tons is expected to be reached in 1975. The increased production (but at a declining rate of increase) thereafter is based on projected changes in fishery practices which will further enhance production.

3/ Reports indicate the following prices received by fishermen: Acadja fishery: 1959 = 25 francs per kg.
1969 = 35 francs per kg.
1971 = 50 francs per kg.
Open lake fishery: 1959 = no data
1969 = no data
1971 = 150 francs per kg. and up to 500 francs per kg. for large fish

In the absence of supply and demand relations, it will be assumed that market price will decline with increased production (supply) as approximated in the table. The use of a constant 25 francs for the Acadja fishery and 70 francs for the open lake fishery is considered to be extremely conservative.

4/ Gross benefit is the cumulative increase in production times price. Monetary conversion is 273 francs (CFA) = U.S. $1.

5/ In determining net benefits associated costs are limited to material costs of the fishery based on the rationale that labor and capital costs are omitted in view of the high unemployment and lack of alternative employment opportunities in the fishery region. All material costs, except for the Acadja fishery during 1973-75, are based on the 33 percent of gross revenues suggested in Welcomme (1968). The exception noted above is based on the fact that cost savings will be realized because less wood will need to be replaced with the reduction in the effects of marine borers on wood; i.e. the replacement rate of wood had increased over the 1959 normal by 75 to 100 percent by 1969 with an attending 100 percent increase also in wood prices.

6/ Net benefit is gross benefit (revenue) less the fishing cost, and represents the benefit to the fishery from the enhancement project.

7/ For informational purposes, net benefits are discounted at four alternative interest rates using 1973 as year 1.

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Appendix Table 3.--Projected benefits with enhancement project (dam) completed in 1975, Lake Nokoue fishery, Dahomey (1976-1982). 1/

Year	Fish production 2/ Total	Annual increment	Cumulative increase	Estimated price for fish 3/	Gross benefits 4/ CFA	U.S.$	Fishing cost 5/ U.S.$	Net benefit 6/ U.S.$	Net benefit (U.S.$) discounted at: 7/ 4 7/8%	6%	12%	20%
	metric tons			(CFA/kg)	thousands							
					(Acadja Fishery)							
1975	750	-	-	-	-	-	-	-	-	-	-	-
1976	1,600	850	850	50	42,500	156	0	156	149	147	139	130
1977	3,400	1,800	2,650	35	92,750	340	0	340	309	303	271	236
1978	6,800	3,400	6,050	25	151,250	554	0	554	480	465	394	321
1979	9,000	2,200	8,250	25	206,250	756	250	506	418	401	322	244
1980	10,200	1,200	9,450	25	236,250	865	285	580	457	433	329	233
1981	10,700	500	9,950	25	248,750	911	301	610	458	430	309	204
1982	11,000	300	10,250	25	256,250	939	310	629	451	418	284	175
							Total =	$3,375	2,722	2,597	2,048	1,544
					(Open Lake Fishery)							
1975	1,450	-	-	-	-	-	-	-	-	-	-	-
1976	2,000	550	550	155	85,250	312	103	209	199	197	187	174
1977	4,600	2,600	3,150	108	350,200	1,246	411	835	759	743	666	580
1978	7,000	2,400	5,550	70	388,500	1,423	470	953	826	800	679	551
1979	7,700	700	6,250	70	437,500	1,603	529	1,074	888	851	682	518
1980	8,300	600	6,850	70	479,500	1,756	580	1,176	927	879	667	473
1981	9,100	800	7,650	70	535,500	1,962	648	1,314	988	926	666	440
1982	9,700	600	8,250	70	577,500	2,115	698	1,417	1,015	943	642	395
							Total =	$6,978	5,602	5,339	4,189	3,131
					Total Fishery)							
1975	2,200	-	-	-	-	-	-	-	-	-	-	-
1976	3,600	1,400	1,400	-	127,750	468	103	365	348	344	326	304
1977	8,000	4,400	5,800	-	432,950	1,586	411	1,175	1,068	1,046	937	816
1978	13,800	5,800	11,600	-	539,750	1,977	470	1,507	1,306	1,265	1,073	872
1979	16,700	2,900	14,500	-	643,750	2,359	779	1,580	1,306	1,252	1,004	762
1980	18,500	1,800	16,300	-	715,750	2,621	865	1,756	1,384	1,312	996	706
1981	19,800	1,300	17,600	-	784,250	2,873	949	1,924	1,446	1,356	975	644
1982	20,700	900	18,500	-	833,750	3,054	1,008	2,046	1,466	1,361	926	571
							Total =	$10,353	8,324	7,936	6,237	4,675

1/ The planning period is 1976 through 1982 (7 years). The 1982 total net benefit of U.S. $2,046,000 may be extrapolated or kept as a constant estimate for each year beyond the planning period of 1982.

2/ Represents the projected recovery in fish production following the completion of the dam in 1975. The 1959 level of 15,000 tons is expected to be reached around 1979. The increased production (but at a declining rate of increase) thereafter is based on projected changes in fishery practices which will further enhance production.

3/ See same footnote in Appendix Table 2.

4/ See same footnote in Appendix Table 2.

5/ See same footnote in Appendix Table 2.

6/ See same footnote in Appendix Table 2.

7/ For informational purposes, net benefits are discounted at four alternative interest rates using 1976 as year 1.

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1. Q.: Will a dam at the mouth of the Lagune de Cotonou, together with continued sewage discharge, cause Lake Nokoue to become polluted to an extent that it would affect fishing in the lake or constitute a potential health problem?

A.: In general, the dam will be an artificial replacement of the naturally-formed sand bar that closed the lagoon outlets prior to 1959; therefore pollution from sewage, other conditions being equal, should be approximately the same as in pre-1959 years. I have no information on sewage or pollution conditions in those years. However, the bi-annual floods would probably flush out much of the accumulated sewage materials in the lagoon area. It is unlikely that domestic sewage, unless extremely heavy, -heavy enough to create de-oxygenated conditions in the lagoon, but not in the lake, would create conditions that would be deleterious to fish production, and these effects would probably be restricted to the lagoon area. The element of this question pertaining to a potential health problem is out of my area of knowledge and I cannot answer it.

2. Q.: What effects might the dam have on salinity, pollution, fishing, etc. in the Porto Novo area?

A.: The first two elements of this question are essentially sanitary engineering questions that I am unable to answer. If the Cotonou lagoon is blocked by the dam, as it was blocked before 1959 by the sand bar, the river waters flowing into the lake will have to exit the watershed through the Porto-Novo lagoon. These flows of fresh water, as opposed to salt, should restore aquatic conditions in the Porto Novo lagoon area to their pre-1959 levels. The incursion of salt water has apparently been the single most effective deterrent to fish production. Control of the inflow of saltwater, followed by reduction in abundance and effects of the marine borers, should restore the durability of the existing acadjas and encourage the fishermen to invest in the construction of additional ones. From these efforts, fish production should increase to the 1959 level, if not exceed it.

3. Q.: Would incorporation of a culvert or a by-pass permit the ingress-egress of the shrimp?

A.: At the time the larval shrimp move into coastal estuaries, they are being passively transported by currents and are not large enough to swim volitionally. Pink shrimp (Penaeus duorarum) life history investigations have shown that the greater the volume flow the more larvae and post-larval shrimp are transported into the coastal estuaries and lagoons. Thus, in the specific shrimp/tides/lagoon situation at Cotonou, it can be assumed that, other biotic factors being equal, the abundance of larval shrimp entering the lagoon-lake system is a lineal function of the volume of water entering. If this volume is reduced by the dam to 1% of the current amount, it follows that only 1% of the current amount of larval shrimp will be transported. Since the main achievement to increase total fishery production is to reduce the inflow of saltwater, a culvert or by-pass would not significantly enhance shrimp abundance in the lake, and would perhaps jeopardize much potential fishery production because of the saltwater intrusion. Further studies on timing and abundance of incoming larval shrimp, (as I suggested to Fisheries Director Azandegbe during my visit to Dahomey) might better define certain seasonal periods - e.g. certain nocturnal flood tides during spring half-moons - when it would be worthwhile to allow a little saltwater - bearing a significant density of larval shrimp - thru a culvert into the lagoon. If a

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closeable culvert, or culverts, can be included in initial construction without additional costs, it may be worthwhile to include them. However, much additional life history information on the pink shrimp needs gathering before it would be advantageous to undertake additional costs to provide for their movement into the lagoon. As stated elsewhere in the report, Dr. Azandegbe said that the shrimp fishery would be expendable if the acadja fisheries in Lake Nokoue could be restored.

It may be fruitful to consider installation of controllable-flow culverts in the dam for permitting seaward flows during low tides to help alleviate sewage concentrations in the lagoon, if such occurs. Then, on the basis of knowledge on the timing/density of larval shrimp movement with the tides, to permit a small amount of saltwater to flow inward at high tide levels. It may be that the peak abundance of larval shrimp coincides with the high tides that would flow over the +1.1 m. weir. Adequate information on shrimp larvae availability and transport by tidal flows is not available.

4. Q.: Alternate erosion control measures: effect on fisheries?

A.: No information at present on what, exactly, these control measures will be. If the inflow of the saltwater tides through the lagoon into the lake is not reduced by at least 95%, the resulting saline conditions in the lake will permit survival of marine borers, which will reduce the durability of acadjas and rate of construction of acadjas - hence, fishery production will remain at its present low level or be reduced even further.. To enhance the Lac Nokoue fishery production, the incursion of saltwater must be greatly reduced. If alternate measures do not include a weir or dam to halt tidal inflows, no improvement in fishery production can be expected.

5. Q.: Reasons for price differential

A.: In June, 1971, the Department of Fisheries of the Republic of Dahomey, through the American Embassy in Cotonou, gave the prices of fish received by the fishermen for Lake Nokoue fish as: Tilapia, 50 CFAF per kilo; mullet, 150 CFAF per kilo. Tilapia is the main species harvested from acadjas; mullet are not taken in great abundance in the acadja fisheries, but are taken mostly by the castnetters in open waters. A few large catfish, with a reported price to the fishermen of 500 CFAF per kilo, are taken both in acadjas and open waters, but estimates of numbers taken were very low and catfish production figures were not included in the economic evaluation.

APPENDIX C

APPENDIX C

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DAHOMEY INTERNATIONAL BRIDGE
FEASIBILITY STUDY

1970 ADT DATA - ORIGIN/DESTINATION SURVEY

O-D	CARS ADT	CARS PER CENT	TRUCKS/BUSES ADT	TRUCKS/BUSES PERCENT	MOTOR/BIKES ADT	MOTOR/BIKES PER CENT	PEDESTRIANS ADT	PEDESTRIANS PER CENT
1- 5	1830.	17.6	400.	17.5	3216.	18.7	2485.	21.8
1- 6	478.	4.6	16.	0.7	1376.	8.0	2143.	18.8
1- 7	83.	0.8	2.	0.1	722.	4.2	752.	6.6
1- 8	1081.	10.4	565.	24.7	1892.	11.0	581.	5.1
1- 9	1778.	17.1	361.	15.8	206.	1.2	68.	0.6
2- 5	540.	5.2	80.	3.5	550.	3.2	364.	3.2
2- 6	124.	1.2	2.	0.1	344.	2.0	171.	1.5
2- 7	10.	0.1	2.	0.1	137.	0.8	91.	0.8
2- 8	270.	2.6	48.	2.1	206.	1.2	182.	1.6
2- 9	239.	2.3	38.	1.7	34.	0.2	11.	0.1
3- 5	1050.	10.1	59.	2.6	2752.	16.0	1641.	14.4
3- 6	364.	3.5	6.	0.3	1014.	5.9	1197.	10.5
3- 7	104.	1.0	2.	0.1	275.	1.6	330.	2.9
3- 8	530.	5.1	75.	3.3	1840.	10.7	399.	3.5
3- 9	488.	4.7	135.	5.9	134.	0.9	102.	0.9
4- 5	395.	3.8	27.	1.2	1186.	6.9	307.	2.7
4- 6	145.	1.4	2.	0.1	258.	1.5	102.	0.9
4- 7	41.	0.4	2.	0.1	34.	0.2	68.	0.6
4- 8	280.	2.7	20.	0.9	791.	4.6	193.	1.7
4- 9	145.	1.4	2.	0.1	34.	0.2	11.	0.1
10- 5	104.	1.0	61.	2.7	51.	0.3	125.	1.1
10- 6	52.	0.5	2.	0.1	34.	0.2	22.	0.2
10- 7	10.	0.1	6.	0.3	17.	0.1	22.	0.2
10- 8	52.	0.5	164.	7.2	51.	0.3	11.	0.1
10- 9	197.	1.9	201.	8.8	17.	0.1	11.	0.1
	10399.	100.0	2289.	100.0	17199.	100.0	11399.	100.0

NO BRIDGE IMPROVEMENT HYPOTHESIS
AND PARALLEL BRIDGE ALTERNATIVE

ADT PROJECTIONS FOR 1972

O-D	CARS ADT	CARS PER CENT	TRUCKS/BUSES ADT	TRUCKS/BUSES PERCENT	MOTOR/BIKES ADT	MOTOR/BIKES PER CENT	PEDESTRIANS ADT	PEDESTRIANS PER CENT
1- 5	2063.	17.6	425.	16.9	3626.	18.1	2692.	21.6
1- 6	507.	4.3	17.	0.6	1551.	7.7	2230.	17.9
1- 7	101.	0.8	3.	0.1	918.	4.5	865.	6.9
1- 8	1269.	10.8	625.	24.9	2265.	11.3	696.	5.5
1- 9	2086.	17.8	399.	15.9	284.	1.4	90.	0.7
2- 5	574.	4.9	85.	3.3	608.	3.0	387.	3.1
2- 6	132.	1.1	2.	0.0	380.	1.8	181.	1.4
2- 7	11.	0.1	2.	0.1	168.	0.8	111.	0.8
2- 8	292.	2.5	51.	2.0	237.	1.1	209.	1.6
2- 9	269.	2.3	42.	1.6	40.	0.2	13.	0.1
3- 5	1115.	9.5	63.	2.5	3102.	15.5	1708.	13.7
3- 6	394.	3.3	7.	0.3	1099.	5.4	1245.	10.0
3- 7	132.	1.1	3.	0.1	349.	1.7	403.	3.2
3- 8	574.	4.9	83.	3.3	2159.	10.7	468.	3.7
3- 9	551.	4.7	155.	6.1	212.	1.0	135.	1.0
4- 5	428.	3.6	29.	1.1	1338.	6.6	340.	2.7
4- 6	157.	1.3	2.	0.1	290.	1.4	113.	0.9
4- 7	55.	0.4	3.	0.1	56.	0.2	92.	0.7
4- 8	316.	2.7	22.	0.9	1046.	5.2	241.	1.9
4- 9	167.	1.4	2.	0.1	51.	0.2	18.	0.1
10- 5	117.	1.0	65.	2.6	65.	0.3	133.	1.0
10- 6	57.	0.4	2.	0.0	38.	0.1	23.	0.1
10- 7	12.	0.1	7.	0.3	23.	0.1	27.	0.2
10- 8	62.	0.5	185.	7.4	76.	0.3	13.	0.1
10- 9	218.	1.8	218.	8.7	23.	0.1	12.	0.1

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DAHOMEY INTERNATIONAL BRIDGE
FEASIBILITY STUDY

PARALLEL BRIDGE ALTERNATIVE
AND NO IMPROVEMENT HYPOTHESIS

ADT PROJECTIONS FOR 1977

O-D	CARS ADT	CARS PER CENT	TRUCKS/BUSES ADT	TRUCKS/BUSES PERCENT	MOTOR/BIKES ADT	MOTOR/BIKES PER CENT	PEDESTRIANS ADT	PEDESTRIANS PER CENT
1- 5	2785.	17.7	494.	15.6	4895.	16.4	3288.	20.7
1- 6	590.	3.7	19.	0.6	2094.	7.0	2465.	15.5
1- 7	167.	1.0	6.	0.1	1573.	5.6	1228.	7.7
1- 8	1893.	12.0	802.	25.3	3552.	11.9	1091.	6.8
1- 9	3113.	19.8	513.	16.2	632.	2.1	182.	1.1
2- 5	667.	4.2	98.	3.1	781.	2.6	450.	2.8
2- 6	153.	0.9	2.	0.0	488.	1.6	210.	1.3
2- 7	15.	0.1	3.	0.1	277.	0.9	183.	1.1
2- 8	357.	2.2	59.	1.8	336.	1.1	297.	1.8
2- 9	364.	2.3	51.	1.6	60.	0.2	21.	0.1
3- 5	1295.	8.2	73.	2.3	4188.	14.0	1888.	11.9
3- 6	481.	3.0	9.	0.3	1342.	4.5	1376.	8.6
3- 7	240.	1.5	8.	0.2	637.	2.1	665.	4.2
3- 8	701.	4.4	107.	3.3	3221.	10.8	698.	4.4
3- 9	743.	4.7	220.	6.9	474.	1.5	273.	1.7
4- 5	522.	3.3	36.	1.1	1806.	6.0	436.	2.7
4- 6	192.	1.2	3.	0.1	392.	1.3	145.	0.9
4- 7	110.	0.7	8.	0.2	197.	0.6	195.	1.2
4- 8	427.	2.7	29.	0.9	2108.	7.0	418.	2.6
4- 9	237.	1.5	4.	0.1	139.	0.4	63.	0.4
10- 5	158.	1.0	76.	2.4	119.	0.4	154.	0.9
10- 6	73.	0.4	2.	0.0	48.	0.1	24.	0.1
10- 7	19.	0.1	11.	0.3	52.	0.1	42.	0.2
10- 8	97.	0.6	250.	7.9	209.	0.7	22.	0.1
10- 9	280.	1.7	268.	8.4	52.	0.1	16.	0.1
	15694.	100.0	3161.	100.0	29783.	100.0	15845.	100.0

PARALLEL BRIDGE ALTERNATIVE
AND NO IMPROVEMENT HYPOTHESIS

ADT PROJECTIONS FOR 1981

O-D	CARS ADT	CARS PER CENT	TRUCKS/BUSES ADT	TRUCKS/BUSES PERCENT	MOTOR/BIKES ADT	MOTOR/BIKES PER CENT	PEDESTRIANS ADT	PEDESTRIANS PER CENT
1- 5	3541.	17.6	557.	14.5	6223.	14.8	3858.	19.6
1- 6	465.	2.3	22.	0.5	2662.	6.3	2670.	13.5
1- 7	249.	1.2	10.	0.2	2704.	6.4	1625.	8.2
1- 8	2607.	12.9	983.	25.6	5091.	12.1	1564.	7.9
1- 9	4287.	21.3	627.	16.4	1199.	2.8	319.	1.6
2- 5	752.	3.7	111.	2.9	953.	2.2	507.	2.5
2- 6	173.	0.8	3.	0.0	596.	1.4	237.	1.2
2- 7	20	0.1	4.	0.1	413.	0.9	273.	1.3
2- 8	419.	2.0	66.	1.7	445.	1.0	393.	2.0
2- 9	462.	2.3	60.	1.5	82.	0.1	30.	0.1
3- 5	1461.	7.2	82.	2.1	5324.	12.7	2045.	10.4
3- 6	565.	2.8	11.	0.3	1575.	3.7	1491.	7.5
3- 7	389.	1.9	18.	0.4	1030.	2.4	993.	5.0
3- 8	823.	4.1	130.	3.4	4437.	10.5	961.	4.8
3- 9	945.	4.7	291.	7.6	899.	2.1	478.	2.4
4- 5	613.	3.0	42.	1.1	2296.	5.4	533.	2.7
4- 6	226.	1.1	3.	0.1	499.	1.1	177.	0.9
4- 7	194.	0.0	15.	0.4	539.	1.2	356.	1.8
4- 8	543.	2.7	35.	0.9	3692.	8.8	649.	3.3
4- 9	314.	1.5	5.	0.1	310.	0.7	178.	0.9
10- 5	201.	1.0	86.	2.2	193.	0.4	174.	0.8
10- 6	90.	0.4	3.	0.0	59.	0.1	25.	0.1
10- 7	27.	0.1	14.	0.3	99.	0.2	61.	0.3
10- 8	139.	0.6	319.	8.3	465.	1.1	34.	0.1
10- 9	342.	1.7	312.	8.1	99.	0.2	19.	0.1
	20058.	100.0	3823.	100.0	41893.	100.0	19663.	100.0

PARALLEL BRIDGE ALTERNATIVE
AND NO IMPROVEMENT HYPOTHESIS

ADT PROJECTIONS FOR 1986

O-D	CARS ADT	CARS PER CENT	TRUCKS/BUSES ADT	TRUCKS/BUSES PERCENT	MOTOR/BIKES ADT	MOTOR/BIKES PER CENT	PEDESTRIANS ADT	PEDESTRIANS PER CENT
1- 5	4780.	17.3	647.	13.2	8400.	12.5	4713.	17.6
1- 6	773.	2.8	25.	0.5	3593.	5.3	2951.	11.0
1- 7	412.	1.4	21.	0.4	4927.	7.3	2305.	8.6
1- 8	3890.	14.1	1258.	25.7	7988.	11.9	2453.	9.1
1- 9	6396.	23.2	805.	16.4	2669.	4.0	642.	2.4
2- 5	873.	3.1	129.	2.6	1224.	1.8	559.	2.2
2- 6	201.	0.7	3.	0.0	765.	1.1	276.	1.0
2- 7	27.	0.0	7.	0.1	681.	1.0	451.	1.6
2- 8	512.	1.8	77.	1.5	632.	0.9	559.	2.0
2- 9	624.	2.2	73.	1.5	123.	0.1	48.	0.1
3- 5	1697.	6.1	96.	1.9	7187.	10.7	2240.	8.4
3- 6	690.	2.5	15.	0.3	1924.	2.8	1646.	6.1
3- 7	709.	2.5	47.	0.9	1877.	2.8	1657.	6.1
3- 8	1005.	3.6	168.	3.4	6619.	9.9	1435.	5.3
3- 9	1276.	4.6	414.	8.4	2002.	3.0	953.	3.6
4- 5	749.	2.7	52.	1.0	3099.	4.6	685.	2.5
4- 6	276.	1.0	5.	0.1	673.	1.0	228.	0.8
4- 7	390.	1.4	47.	0.9	1878.	2.8	753.	2.8
4- 8	733.	2.6	45.	0.9	7432.	11.1	1126.	4.2
4- 9	446.	1.6	8.	0.1	843.	1.2	622.	2.3
10- 5	271.	0.9	99.	2.0	351.	0.5	202.	0.7
10- 6	115.	0.4	3.	0.0	76.	0.1	26.	0.0
10- 7	43.	0.1	21.	0.4	222.	0.3	96.	0.3
10- 8	219.	0.7	430.	8.8	1265.	1.8	56.	0.2
10- 9	439.	1.5	382.	7.8	227.	0.3	25.	0.0
	27558.	100.0	4899.	100.0	66682.	100.0	26760.	100.0

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DAHOMEY INTERNATIONAL BRIDGE
FEASIBILITY STUDY

PARALLEL BRIDGE ALTERNATIVE
AND NO IMPROVEMENT HYPOTHESIS

ADT PROJECTIONS FOR 1991

O-D	CARS ADT	CARS PER CENT	TRUCKS/BUSES ADT	TRUCKS/BUSES PERCENT	MOTOR/BIKES ADT	MOTOR/BIKES PER CENT	PEDESTRIANS ADT	PEDESTRIANS PER CENT
1- 5	5986.	14.9	724.	12.2	10519.	10.7	5475.	15.6
1- 6	865.	2.4	28.	0.4	4500.	4.5	3181.	9.0
1- 7	599.	1.7	36.	0.6	7727.	7.8	2998.	8.5
1- 8	5251.	14.8	1518.	25.5	11191.	11.4	3439.	9.8
1- 9	8634.	24.4	971.	16.3	4864.	4.9	1086.	3.1
2- 5	978.	2.7	144.	2.4	1477.	1.5	659.	1.8
2- 6	225.	0.6	4.	0.0	923.	0.9	309.	0.8
2- 7	34.	0.0	9.	0.1	991.	1.0	657.	1.8
2- 8	595.	1.6	86.	1.4	822.	0.8	726.	2.0
2- 9	782.	2.2	85.	1.4	167.	0.1	67.	0.1
3- 5	1899.	5.3	107.	1.8	9000.	9.1	2436.	6.9
3- 6	802.	2.2	18.	0.3	2236.	2.2	1776.	5.0
3- 7	1112.	3.1	97.	1.6	2943.	3.0	2382.	6.8
3- 8	1168.	3.3	202.	3.4	8935.	9.1	1937.	5.5
3- 9	1598.	4.5	538.	9.0	3648.	3.7	1629.	4.6
4- 5	870.	2.4	60.	1.0	3881.	3.9	826.	2.3
4- 6	320.	0.9	6.	0.1	843.	0.8	275.	0.7
4- 7	660.	1.8	97.	1.6	4796.	4.8	1323.	3.7
4- 8	918.	2.6	55.	0.9	12563.	12.8	1701.	4.8
4- 9	580.	1.6	11.	0.1	1786.	1.8	1589.	4.5
10- 5	340.	0.9	111.	1.8	551.	0.5	226.	0.6
10- 6	139.	0.3	4.	0.0	92.	0.0	27.	0.0
10- 7	61.	0.1	27.	0.4	405.	0.4	134.	0.3
10- 8	307.	0.8	539.	9.0	2679.	2.7	82.	0.2
10- 9	530.	1.5	444.	7.4	405.	0.4	30.	0.0
	35264.	100.0	5933.	100.0	97957.	100.0	34981.	100.0

PARALLEL BRIDGE ALTERNATIVE
AND NO IMPROVEMENT HYPOTHESIS

ADT PROJECTIONS FOR 1996

O-D	CARS ADT	CARS PER CENT	TRUCKS/BUSES ADT	TRUCKS/BUSES PERCENT	MOTOR/BIKES ADT	MOTOR/BIKES PER CENT	PEDESTRIANS ADT	PEDESTRIANS PER CENT
1- 5	7497.	16.4	811.	11.1	13174.	8.8	6362.	13.3
1- 6	968.	2.1	32.	0.4	5636.	3.7	3429.	7.1
1- 7	872.	1.9	61.	0.8	12119.	8.1	3898.	8.1
1- 8	7088.	15.5	1831.	25.1	15683.	10.4	4819.	10.1
1- 9	11654.	25.6	1171.	16.0	8864.	5.9	1836.	3.8
2- 5	1094.	2.4	162.	2.2	1782.	1.1	738.	1.5
2- 6	252.	0.5	4.	0.0	1113.	0.7	346.	0.7
2- 7	42.	0.0	11.	0.1	1442.	0.9	956.	2.0
2- 8	592.	1.5	97.	1.3	1069.	0.7	945.	1.9
2- 9	979.	2.1	99.	1.3	225.	0.1	94.	0.1
3- 5	2125.	4.6	120.	1.6	11272.	7.5	2626.	5.5
3- 6	931.	2.0	22.	0.3	2597.	1.7	1915.	4.0
3- 7	1744.	3.8	199.	2.7	4616.	3.0	3466.	7.2
3- 8	1357.	2.9	244.	3.3	12061.	8.0	2614.	5.4
3- 9	2002.	4.4	700.	9.6	6648.	4.4	2754.	5.7
4- 5	1011.	2.2	70.	0.9	4861.	3.2	996.	2.0
4- 6	372.	0.8	7.	0.1	1056.	0.7	332.	0.6
4- 7	1116.	2.4	199.	2.7	12247.	8.1	2322.	4.8
4- 8	1150.	2.5	66.	0.9	21238.	14.1	2570.	5.3
4- 9	754.	1.6	15.	0.2	3782.	2.5	4058.	8.5
10- 5	425.	0.9	125.	1.7	865.	0.5	253.	0.5
10- 6	168.	0.3	4.	0.0	111.	0.0	28.	0.0
10- 7	86.	0.1	35.	0.4	738.	0.4	189.	0.3
10- 8	431.	0.9	675.	9.2	5673.	3.7	119.	0.2
10- 9	639.	1.4	515.	7.0	738.	0.4	36.	0.0
	45461.	100.0	7285.	100.0	149621.	100.0	47710.	100.0

DAHOMEY INTERNATIONAL BRIDGE
FEASIBILITY STUDY

SAINT MICHEL BRIDGE ALTERNATIVE
TRAFFIC AT NEW BRIDGE

ADT PROJECTIONS FOR 1977

O-D	CARS ADT	CARS PER CENT	TRUCKS/BUSES ADT	TRUCKS/BUSES PERCENT	MOTOR/BIKES ADT	MOTOR/BIKES PER CENT	PEDESTRIANS ADT	PEDESTRIANS PER CENT
1- 5	0.	0.0	0.	0.0	0.	0.0	0.	0.0
1- 6	0.	0.0	0.	0.0	209.	1.6	246.	4.8
1- 7	117.	1.9	4.	0.3	836.	6.7	368.	7.2
1- 8	284.	4.8	120.	9.3	359.	2.8	0.	0.0
1- 9	622.	10.5	102.	7.9	63.	0.5	0.	0.0
2- 5	66.	1.1	9.	0.7	0.	0.0	0.	0.0
2- 6	107.	1.8	1.	0.1	244.	1.9	84.	1.6
2- 7	15.	0.2	3.	0.1	277.	2.2	128.	2.5
2- 8	178.	3.0	29.	2.2	67.	0.5	59.	1.1
2- 9	294.	4.[illegible]	36.	2.7	12.	0.0	6.	0.1
3- 5	388.	6.6	22.	1.7	1256.	10.0	566.	11.1
3- 6	433.	7.3	8.	0.6	1342.	10.7	1101.	21.6
3- 7	240.	4.0	8.	0.6	637.	5.1	665.	13.0
3- 8	79[illegible].	11.9	107.	8.2	2577.	20.6	488.	9.5
3- 9	743.	12.6	220.	17.0	426.	3.4	218.	4.2
4- 5	261.	4.4	18.	1.4	933.	7.2	218.	4.2
4- 6	192.	3.2	3.	0.2	392.	3.1	145.	2.8
4- 7	110.	1.8	8.	0.6	197.	1.5	195.	3.8
4- 8	427.	7.2	29.	2.2	2108.	16.9	418.	8.2
4- 9	237.	4.[illegible]	4.	0.3	139.	1.1	65.	1.2
10- 5	47.	0.8	22.	1.7	59.	0.4	15.	0.3
10- 6	55.	0.9	2.	0.1	34.	0.2	19.	0.3
10- 7	19.	0.3	11.	0.8	52.	0.4	42.	0.8
10- 8	97.	1.6	250.	19.4	209.	1.6	22.	0.4
10- 9	280.	4.7	266.	20.6	92.	0.4	16.	0.3
	5887.	100.0	1293.	100.0	12496.	100.0	5095.	100.0

SAINT MICHEL BRIDGE ALTERNATIVE
TRAFFIC AT NEW BRIDGE

ADT PROJECTIONS FOR 1981

O-D	CARS ADT	CARS PER CENT	TRUCKS/BUSES ADT	TRUCKS/BUSES PERCENT	MOTOR/BIKES ADT	MOTOR/BIKES PER CENT	PEDESTRIANS ADT	PEDESTRIANS PER CENT
1- 5	298.	3.3	46.	2.4	131.	0.6	0.	0.0
1- 6	84.	0.9	3.	0.1	546.	2.6	267.	3.9
1- 7	190.	2.1	8.	0.4	1409.	6.9	487.	7.2
1- 8	583.	6.5	270.	14.1	616.	3.0	0.	0.0
1- 9	1218.	13.6	178.	9.3	145.	0.7	0.	0.0
2- 5	154.	1.	22.	1.1	40.	0.1	0.	0.0
2- 6	132.	1.4	2.	0.1	360.	1.7	95.	1.4
2- [illegible]	20.	0.[illegible]	4.	0.2	413.	2.0	191.	2.8
2- 8	245.	2.7	39.	2.0	126.	0.6	78.	1.1
2- 9	353.	3.9	46.	2.4	27.	0.1	9.	0.1
3- 5	653.	7.3	37.	1.9	2157.	10.5	613.	9.0
3- 6	520.	5.8	10.	0.5	1575.	7.7	1193.	17.6
3- 7	389.	4.3	18.	0.9	1030.	5.0	993.	14.6
3- 8	823.	9.2	139.	7.2	3736.	18.3	673.	9.9
3- 9	945.	10.[illegible]	304.	15.9	828.	4.0	382.	5.6
4- 5	571.	6.1	23.	1.2	1389.	6.8	266.	3.9
4- 6	226.	2.5	3.	0.2	499.	2.4	177.	2.6
4- 7	194.	2.1	18.	0.9	938.	2.6	356.	5.2
4- 8	543.	6.0	35.	1.8	3690.	18.0	649.	9.6
4- 9	514.	5.5	5.	0.2	318.	1.5	178.	2.6
10- 5	90.	1.0	36.	1.9	116.	0.5	17.	0.2
10- 6	72.	0.8	2.	0.1	37.	0.1	20.	0.3
10- 7	27.	0.3	14.	0.7	99.	0.4	61.	0.9
10- 8	139.	1.5	325.	17.0	465.	2.2	34.	0.5
10- 9	342.	3.8	312.	16.3	99.	0.4	19.	0.2
	8935.	100.0	1912.	100.0	20393.	100.0	6767.	100.0

SAINT MICHEL BRIDGE ALTERNATIVE
TRAFFIC AT NEW BRIDGE

ADT PROJECTIONS FOR 1986

O-D	CARS ADT	CARS PER CENT	TRUCKS/BUSES ADT	TRUCKS/BUSES PERCENT	MOTOR/BIKES ADT	MOTOR/BIKES PER CENT	PEDESTRIANS ADT	PEDESTRIANS PER CENT
1- 5	905.	6.1	122.	4.0	397.	1.0	0.	0.0
1- 6	219.	1.4	8.	0.2	1210.	3.1	295.	2.8
1- 7	347.	2.3	18.	0.6	2697.	7.0	691.	6.7
1- 8	1228.	8.3	546.	18.2	1176.	3.0	0.	0.0
1- 9	2491.	16.9	313.	10.4	393.	1.0	0.	0.0
2- 5	294.	2.0	43.	1.4	118.	0.3	0.	0.0
2- 6	169.	1.1	3.	0.1	564.	1.4	110.	1.0
2- 7	27.	0.1	7.	0.2	681.	1.7	316.	3.0
2- 8	353.	2.4	53.	1.7	246.	0.6	111.	1.0
2- 9	526.	3.5	62.	2.0	59.	0.1	14.	0.1
3- 5	1072.	7.3	60.	2.0	3858.	10.1	678.	6.6
3- 6	653.	4.4	14.	0.4	1924.	5.0	1318.	12.8
3- 7	709.	4.8	47.	1.5	1877.	4.9	1637.	15.9
3- 8	1009.	6.8	192.	6.3	5922.	15.5	1004.	9.8
3- 9	1276.	8.7	453.	15.1	1897.	4.9	771.	7.5
4- 5	592.	3.7	30.	1.0	2283.	5.9	342.	3.3
4- 6	278.	1.8	9.	0.1	673.	1.7	228.	2.2
4- 7	390.	2.6	47.	1.5	1878.	4.9	753.	7.3
4- 8	733.	5.0	45.	1.5	7432.	19.4	1126.	10.9
4- 9	446.	3.0	8.	0.2	843.	2.2	622.	6.0
10- 5	171.	1.1	58.	1.9	259.	0.6	29.	0.1
10- 6	100.	0.6	2.	0.0	42.	0.1	21.	0.2
10- 7	43.	0.2	21.	0.7	222.	0.5	96.	0.9
10- 8	219.	1.4	451.	15.0	1265.	3.3	56.	0.5
10- 9	439.	3.0	382.	12.7	222.	0.5	29.	0.2
	14655.	100.0	3001.	100.0	38148.	100.0	10243.	100.0

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DAHOMEY INTERNATIONAL BRIDGE
FEASIBILITY STUDY

SAINT MICHEL BRIDGE ALTERNATIVE
TRAFFIC AT NEW BRIDGE

ADT PROJECTIONS FOR 1991

O-D	CARS		TRUCKS/BUSES		MOTOR/BIKES		PEDESTRIANS	
	ADT	PER CENT	ADT	PERCENT	ADT	PER CENT	ADT	PER CENT
1- 5	1134.	6.0	137.	3.6	498.	0.8	0.	0.0
1- 6	245.	1.3	9.	0.2	1515.	2.5	318.	2.1
1- 7	504.	2.6	30.	0.8	4229.	7.1	899.	6.0
1- 8	1658.	8.8	659.	17.7	1649.	2.7	0.	0.0
1- 9	3362.	17.9	378.	10.1	716.	1.2	0.	0.0
2- 5	329.	1.7	48.	1.3	139.	0.2	0.	0.0
2- 6	190.	1.0	3.	0.0	680.	1.1	123.	0.8
2- 7	34.	0.1	9.	0.2	991.	1.6	460.	3.1
2- 8	410.	2.1	59.	1.6	320.	0.5	145.	0.9
2- 9	658.	3.5	72.	1.9	80.	0.1	20.	0.1
3- 5	1199.	6.4	68.	1.8	4832.	8.1	731.	4.9
3- 6	759.	4.0	17.	0.4	2236.	3.7	1421.	9.6
3- 7	1112.	5.9	97.	2.6	2943.	4.9	2382.	16.1
3- 8	1168.	6.2	231.	6.2	7994.	13.5	1355.	9.1
3- 9	1598.	8.5	589.	15.8	3456.	5.8	1303.	8.8
4- 5	641.	3.4	36.	0.9	2860.	4.8	413.	2.7
4- 6	320.	1.7	6.	0.1	843.	1.4	275.	1.8
4- 7	660.	3.5	97.	2.6	4796.	8.1	1323.	8.9
4- 8	918.	4.9	55.	1.4	12563.	21.2	1701.	11.5
4- 9	580.	3.0	11.	0.2	1786.	3.0	1589.	10.7
10- 5	214.	1.1	65.	1.7	406.	0.6	22.	0.1
10- 6	121.	0.6	3.	0.0	51.	0.0	22.	0.1
10- 7	61.	0.3	27.	0.7	405.	0.6	134.	0.9
10- 8	307.	1.6	564.	15.1	2679.	4.5	82.	0.5
10- 9	530.	2.8	444.	11.9	405.	0.6	30.	0.2
	18725.	100.0	3724.	100.0	59085.	100.0	14756.	100.0

SAINT MICHEL BRIDGE ALTERNATIVE
TRAFFIC AT NEW BRIDGE

ADT PROJECTIONS FOR 1996

O-D	CARS		TRUCKS/BUSES		MOTOR/BIKES		PEDESTRIANS	
	ADT	PER CENT	ADT	PERCENT	ADT	PER CENT	ADT	PER CENT
1- 5	1420.	5.8	153.	3.2	624.	0.6	0.	0.0
1- 6	275.	1.1	10.	0.2	1898.	1.9	342.	1.5
1- 7	734.	3.0	51.	1.1	6633.	6.9	1169.	5.1
1- 8	2238.	9.2	795.	16.9	2311.	2.4	0.	0.0
1- 9	4539.	18.7	456.	9.7	1306.	1.3	0.	0.0
2- 5	368.	1.5	54.	1.1	168.	0.1	0.	0.0
2- 6	212.	0.8	3.	0.0	820.	0.8	138.	0.6
2- 7	42.	0.1	11.	0.2	1442.	1.5	669.	2.9
2- 8	477.	1.9	67.	1.4	416.	0.4	189.	0.8
2- 9	825.	3.4	83.	1.7	109.	0.1	28.	0.1
3- 5	1342.	5.5	76.	1.6	6051.	6.3	787.	3.4
3- 6	882.	3.6	21.	0.4	2597.	2.7	1532.	6.7
3- 7	1744.	7.2	199.	4.2	4616.	4.8	3466.	15.3
3- 8	1357.	5.6	279.	5.9	10791.	11.2	1830.	8.1
3- 9	2002.	8.2	766.	16.3	6298.	6.5	2203.	9.7
4- 5	745.	3.0	41.	0.8	3581.	3.7	498.	2.2
4- 6	372.	1.5	7.	0.1	1056.	1.1	332.	1.4
4- 7	1116.	4.6	199.	4.2	12247.	12.7	2322.	10.3
4- 8	1130.	4.7	66.	1.4	21238.	22.1	2570.	11.4
4- 9	754.	3.1	15.	0.3	3782.	3.9	4058.	18.0
10- 5	269.	1.1	73.	1.5	637.	0.6	25.	0.1
10- 6	146.	0.6	3.	0.0	62.	0.0	23.	0.1
10- 7	86.	0.3	35.	0.7	738.	0.7	189.	0.8
10- 8	431.	1.7	707.	15.0	5673.	5.9	119.	0.5
10- 9	639.	2.6	515.	10.9	738.	0.7	36.	0.1
	24176.	100.0	4696.	100.0	95845.	100.0	22533.	100.0

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DAHOMEY INTERNATIONAL BRIDGE
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SAINT MICHEL BRIDGE ALTERNATIVE
TRAFFIC AT EXISTING BRIDGE

ADT PROJECTIONS FOR 1977

O-D	CARS		TRUCKS/BUSES		MOTOR/BIKES		PEDESTRIANS	
	ADT	PER CENT	ADT	PERCENT	ADT	PER CENT	ADT	PER CENT
1- 5	2785.	28.4	494.	26.5	4895.	28.2	3288.	30.5
1- 6	590.	6.0	19.	1.0	1884.	10.8	2218.	20.6
1- 7	50.	0.5	1.	0.0	836.	4.8	859.	7.9
1- 8	1609.	16.4	642.	34.5	3197.	18.4	1091.	10.1
1- 9	2490.	25.3	359.	19.3	559.	3.2	182.	1.6
2- 5	600.	6.1	88.	4.7	781.	4.5	450.	4.1
2- 6	46.	0.4	0.	0.0	244.	1.4	126.	1.1
2- 7	0.	0.0	0.	0.0	0.	0.0	55.	0.5
2- 8	178.	1.8	29.	1.5	269.	1.5	238.	2.2
2- 9	109.	1.1	15.	0.8	48.	0.2	14.	0.1
3- 5	907.	9.2	51.	2.7	2931.	16.9	1321.	12.2
3- 6	48.	0.4	0.	0.0	0.	0.0	275.	2.5
3- 7	0.	0.0	0.	0.0	0.	0.0	0.	0.0
3- 8	0.	0.0	32.	1.7	644.	3.7	209.	1.9
3- 9	0.	0.0	44.	2.3	47.	0.2	54.	0.5
4- 5	261.	2.6	7.	0.3	903.	5.2	218.	2.0
4- 6	0.	0.0	0.	0.0	0.	0.0	0.	0.0
4- 7	0.	0.0	0.	0.0	0.	0.0	0.	0.0
4- 8	0.	0.0	0.	0.0	0.	0.0	0.	0.0
4- 9	0.	0.0	0.	0.0	0.	0.0	0.	0.0
10- 5	110.	1.1	45.	2.4	59.	0.3	139.	1.2
10- 6	18.	0.1	0.	0.0	14.	0.0	4.	0.0
10- 7	0.	0.0	0.	0.0	0.	0.0	0.	0.0
10- 8	0.	0.0	25.	1.3	0.	0.0	0.	0.0
10- 9	0.	0.0	0.	0.0	0.	0.0	0.	0.0
	9807.	100.0	1859.	100.0	17327.	100.0	10749.	100.0

SAINT MICHEL BRIDGE ALTERNATIVE
TRAFFIC AT EXISTING BRIDGE

ADT PROJECTIONS FOR 1981

O-D	CARS		TRUCKS/BUSES		MOTOR/BIKES		PEDESTRIANS	
	ADT	PER CENT	ADT	PERCENT	ADT	PER CENT	ADT	PER CENT
1- 5	3243.	29.1	510.	26.7	6092.	28.3	3858.	29.9
1- 6	581.	5.2	19.	0.9	2115.	9.8	2403.	18.6
1- 7	59.	0.5	2.	0.1	1295.	6.0	1137.	8.8
1- 8	2024.	18.1	660.	34.6	4475.	20.8	1564.	12.1
1- 9	3068.	27.5	386.	20.2	1054.	4.9	319.	2.4
2- 5	597.	5.3	88.	4.6	913.	4.2	507.	3.9
2- 6	41.	0.3	0.	0.0	235.	1.0	142.	1.1
2- 7	0.	0.0	0.	0.0	0.	0.0	82.	0.6
2- 8	174.	1.5	27.	1.4	319.	1.4	315.	2.4
2- 9	109.	0.9	14.	0.7	55.	0.2	21.	0.1
3- 5	807.	7.2	45.	2.4	3166.	14.7	1431.	11.1
3- 6	44.	0.4	0.	0.0	0.	0.0	298.	2.3
3- 7	0.	0.0	0.	0.0	0.	0.0	0.	0.0
3- 8	0.	0.0	31.	1.6	700.	3.2	288.	2.2
3- 9	0.	0.0	46.	2.4	71.	0.3	95.	0.7
4- 5	242.	2.1	6.	0.3	906.	4.2	266.	2.0
4- 6	0.	0.0	0.	0.0	0.	0.0	0.	0.0
4- 7	0.	0.0	0.	0.0	0.	0.0	0.	0.0
4- 8	0.	0.0	0.	0.0	0.	0.0	0.	0.0
4- 9	0.	0.0	0.	0.0	0.	0.0	0.	0.0
10- 5	111.	0.9	40.	2.1	76.	0.3	156.	1.2
10- 6	17.	0.1	0.	0.0	21.	0.1	5.	0.0
10- 7	0.	0.0	0.	0.0	0.	0.0	0.	0.0
10- 8	0.	0.0	25.	1.3	0.	0.0	0.	0.0
10- 9	0.	0.0	0.	0.0	0.	0.0	0.	0.0
	11123.	100.0	1906.	100.0	21499.	100.0	12895.	100.0

DAHOMEY INTERNATIONAL BRIDGE
FEASIBILITY STUDY

SAINT MICHEL BRIDGE ALTERNATIVE
TRAFFIC AT EXISTING BRIDGE

ADT PROJECTIONS FOR 1986

O-D	CARS ADT	CARS PER CENT	TRUCKS/BUSES ADT	TRUCKS/BUSES PERCENT	MOTOR/BIKES ADT	MOTOR/BIKES PER CENT	PEDESTRIANS ADT	PEDESTRIANS PER CENT
1- 5	3874.	30.0	524.	27.7	8002.	28.0	4713.	28.5
1- 6	553.	4.2	17.	0.9	2383.	8.3	2656.	16.0
1- 7	65.	0.5	3.	0.1	2230.	7.8	1614.	9.7
1- 8	2661.	20.6	649.	34.2	6808.	23.8	2453.	14.8
1- 9	3905.	30.2	411.	21.6	2276.	7.9	642.	3.8
2- 5	579.	4.4	85.	4.5	1108.	3.8	589.	3.5
2- 6	31.	0.2	0.	0.0	201.	0.7	165.	1.0
2- 7	0.	0.0	0.	0.0	0.	0.0	135.	0.8
2- 8	159.	1.2	24.	1.2	386.	1.3	447.	2.7
2- 9	98.	0.7	11.	0.6	65.	0.2	35.	0.2
3- 5	625.	4.8	35.	1.8	3328.	11.6	1582.	9.5
3- 6	36.	0.2	0.	0.0	0.	0.0	329.	1.9
3- 7	0.	0.0	0.	0.0	0.	0.0	0.	0.0
3- 8	0.	0.0	26.	1.4	696.	2.4	430.	2.6
3- 9	0.	0.0	43.	2.3	105.	0.3	192.	1.1
4- 5	197.	1.5	5.	0.2	815.	2.8	342.	2.0
4- 6	0.	0.0	0.	0.0	0.	0.0	0.	0.0
4- 7	0.	0.0	0.	0.0	0.	0.0	0.	0.0
4- 8	0.	0.0	0.	0.0	0.	0.0	0.	0.0
4- 9	0.	0.0	0.	0.0	0.	0.0	0.	0.0
10- 5	100.	0.7	31.	1.6	92.	0.3	182.	1.1
10- 6	15.	0.1	0.	0.0	35.	0.1	5.	0.0
10- 7	0.	0.0	0.	0.0	0.	0.0	0.	0.0
10- 8	6.	0.0	22.	1.1	0.	0.0	0.	0.0
10- 9	0.	0.0	0.	0.0	0.	0.0	0.	0.0
	12903.	100.0	1894.	100.0	28534.	100.0	16517.	100.0

DAHOMEY INTERNATIONAL BRIDGE
FEASIBILITY STUDY

SAINT MICHEL BRIDGE ALTERNATIVE
TRAFFIC AT EXISTING BRIDGE

ADT PROJECTIONS FOR 1991

O-D	CARS ADT	CARS PER CENT	TRUCKS/BUSES ADT	TRUCKS/BUSES PERCENT	MOTOR/BIKES ADT	MOTOR/BIKES PER CENT	PEDESTRIANS ADT	PEDESTRIANS PER CENT
1- 5	4852.	29.3	587.	26.3	10021.	25.7	5475.	27.0
1- 6	619.	3.7	19.	0.8	2984.	7.6	2863.	14.1
1- 7	94.	0.5	5.	0.2	3497.	8.9	2098.	10.3
1- 8	3592.	21.7	783.	35.1	9542.	24.5	3439.	17.0
1- 9	5271.	31.8	495.	22.2	4148.	10.6	1086.	5.3
2- 5	648.	3.9	96.	4.3	1337.	3.4	659.	3.2
2- 6	35.	0.2	0.	0.0	243.	0.6	185.	0.9
2- 7	0.	0.0	0.	0.0	0.	0.0	197.	0.9
2- 8	185.	1.1	27.	1.2	502.	1.2	581.	2.8
2- 9	123.	0.7	13.	0.6	86.	0.2	47.	0.2
3- 5	699.	4.2	39.	1.7	4168.	10.7	1705.	8.4
3- 6	42.	0.2	0.	0.0	0.	0.0	355.	1.7
3- 7	0.	0.0	0.	0.0	0.	0.0	0.	0.0
3- 8	0.	0.0	32.	1.4	940.	2.4	581.	2.8
3- 9	0.	0.0	56.	2.5	192.	0.4	325.	1.6
4- 5	229.	1.3	6.	0.2	1021.	2.6	413.	2.0
4- 6	0.	0.0	0.	0.0	0.	0.0	0.	0.0
4- 7	0.	0.0	0.	0.0	0.	0.0	0.	0.0
4- 8	0.	0.0	0.	0.0	0.	0.0	0.	0.0
4- 9	0.	0.0	0.	0.0	0.	0.0	0.	0.0
10- 5	125.	0.7	35.	1.5	145.	0.3	204.	1.0
10- 6	18.	0.1	0.	0.0	40.	0.1	5.	0.0
10- 7	0.	0.0	0.	0.0	0.	0.0	0.	0.0
10- 8	0.	0.0	28.	1.2	0.	0.0	0.	0.0
10- 9	0.	0.0	0.	0.0	0.	0.0	0.	0.0
	16338.	100.0	2228.	100.0	38871.	100.0	20224.	100.0

SAINT MICHEL BRIDGE ALTERNATIVE
TRAFFIC AT EXISTING BRIDGE

ADT PROJECTIONS FOR 1996

O-D	CARS ADT	CARS PER CENT	TRUCKS/BUSES ADT	TRUCKS/BUSES PERCENT	MOTOR/BIKES ADT	MOTOR/BIKES PER CENT	PEDESTRIANS ADT	PEDESTRIANS PER CENT
1- 5	6076.	28.5	657.	25.0	12550.	23.3	6362.	25.2
1- 6	693.	3.2	21.	0.8	3737.	6.9	3086.	12.2
1- 7	137.	0.6	9.	0.3	5485.	10.2	2728.	10.8
1- 8	4849.	22.7	944.	35.9	13372.	24.8	4819.	19.1
1- 9	7119.	33.4	598.	22.7	7558.	14.0	1836.	7.2
2- 5	725.	3.4	107.	4.0	1613.	3.0	738.	2.9
2- 6	39.	0.1	0.	0.0	293.	0.5	207.	0.8
2- 7	0.	0.0	0.	0.0	0.	0.0	296.	1.1
2- 8	214.	1.0	30.	1.1	652.	1.2	756.	3.0
2- 9	154.	0.7	13.	0.5	116.	0.2	66.	0.2
3- 5	783.	3.6	44.	1.6	3220.	6.7	1838.	7.3
3- 6	49.	0.2	1.	0.0	2.	0.0	383.	1.5
3- 7	0.	0.0	0.	0.0	0.	0.0	0.	0.0
3- 8	0.	0.0	38.	1.4	1269.	2.3	784.	3.1
3- 9	0.	0.0	73.	2.8	349.	0.6	550.	2.1
4- 5	266.	1.2	7.	0.2	1279.	2.3	498.	1.9
4- 6	0.	0.0	0.	0.0	0.	0.0	0.	0.0
4- 7	0.	0.0	0.	0.0	0.	0.0	0.	0.0
4- 8	0.	0.0	0.	0.0	0.	0.0	0.	0.0
4- 9	0.	0.0	0.	0.0	0.	0.0	0.	0.0
10- 5	156.	0.7	39.	1.5	227.	0.4	228.	0.9
10- 6	22.	0.1	0.	0.0	49.	0.0	5.	0.0
10- 7	0.	0.0	0.	0.0	0.	0.0	0.	0.0
10- 8	0.	0.0	39.	1.5	0.	0.0	0.	0.0
10- 9	0.	0.0	0.	0.0	0.	0.0	0.	0.0
	21285.	100.0	2626.	100.0	53776.	100.0	25176.	100.0

DAHOMEY INTERNATIONAL BRIDGE

TRAFFIC STUDIES

NO IMPROVEMENT HYPOTHESIS
AND PARALLEL BRIDGE ALTERNATIVE
YEAR 1971

TIME	CARS	TRUCKS + BUSES	BIKES + MOTORBIKES	EQUIVALENT VEHICLE UNITS
MIDNIGHT TO 1 AM	26.	3.	33.	41.
1 2	7.	1.	11.	12.
2 3	2.	0.	3.	4.
3 4	2.	0.	3.	4.
4 5	19.	6.	33.	41.
5 6	51.	18.	109.	115.
6 7	205.	50.	736.	491.
7 8	720.	114.	2103.	1475.
8 9	812.	167.	1305.	1474.
9 10	773.	183.	1090.	1412.
10 11	745.	189.	940.	1358.
11 12	854.	216.	927.	1519.
12 1 PM	737.	145.	1296.	1353.
1 2	368.	103.	665.	742.
2 3	673.	179.	1344.	1368.
3 4	757.	207.	1055.	1435.
4 5	851.	245.	1153.	1631.
5 6	855.	235.	1637.	1736.
6 7	880.	144.	1995.	1667.
7 8	688.	77.	888.	1066.
8 9	441.	46.	508.	662.
9 10	275.	28.	357.	420.
10 11	168.	17.	222.	260.
11 12	79.	8.	102.	122.
	11014.	2396.	18546.	20419.

DAHOMEY INTERNATIONAL BRIDGE

TRAFFIC STUDIES

NO IMPROVEMENT HYPOTHESIS

YEAR 1977

TIME	CARS	TRUCKS + BUSES	BIKES + MOTORBIKES	EQUIVALENT VEHICLE UNITS
MIDNIGHT TO 1 AM	37.	4.	53.	59.
1 2	10.	1.	17.	18.
2 3	3.	0.	5.	6.
3 4	3.	0.	5.	6.
4 5	28.	5.	53.	58.
5 6	73.	24.	175.	165.
6 7	293.	66.	1182.	722.
7 8	1026.	151.	3377.	2173.
8 9	1158.	221.	2095.	2124.
9 10	1101.	241.	1751.	2022.
10 11	1062.	249.	1510.	1938.
11 12	1217.	285.	1489.	2161.
12 1 PM	1051.	191.	2081.	1955.
1 2	525.	135.	1069.	1066.
2 3	958.	237.	2159.	1973.
3 4	1079.	273.	1694.	2049.
4 5	1213.	324.	1852.	2325.
5 6	1219.	310.	2629.	2498.
6 7	1253.	190.	3204.	2435.
7 8	980.	102.	1426.	1543.
8 9	629.	61.	816.	956.
9 10	392.	36.	574.	610.
10 11	240.	29.	357.	376.
11 12	112.	11.	163.	177.
	15694.	3141.	29783.	29427.

NO IMPROVEMENT HYPOTHESIS

YEAR 1981

TIME	CARS	TRUCKS + BUSES	BIKES + MOTORBIKES	EQUIVALENT VEHICLE UNITS
MIDNIGHT TO 1 AM	48.	4.	75.	76.
1 2	14.	1.	23.	24.
2 3	4.	1.	8.	8.
3 4	4.	1.	8.	8.
4 5	36.	10.	75.	75.
5 6	94.	29.	247.	214.
6 7	375.	80.	1663.	952.
7 8	1311.	182.	4750.	2865.
8 9	1480.	267.	2949.	2752.
9 10	1406.	292.	2463.	2608.
10 11	1397.	301.	2124.	2492.
11 12	1556.	345.	2094.	2771.
12 1 PM	1343.	232.	2928.	2340.
1 2	671.	165.	1503.	1379.
2 3	1223.	286.	3037.	2558.
3 4	1380.	330.	2383.	2636.
4 5	1550.	392.	2605.	2986.
5 6	1558.	375.	3699.	3235.
6 7	1602.	230.	4507.	3189.
7 8	1253.	124.	2006.	2003.
8 9	884.	74.	1147.	1240.
9 10	501.	44.	808.	793.
10 11	306.	28.	502.	489.
11 12	144.	14.	230.	230.
	20058.	3823.	41893.	38132.

NO IMPROVEMENT HYPOTHESIS

YEAR 1986

TIME	CARS	TRUCKS + BUSES	BIKES + MOTORBIKES	EQUIVALENT VEHICLE UNITS
MIDNIGHT TO 1 AM	66.	6.	120.	108.
1 2	19.	2.	40.	34.
2 3	5.	1.	13.	11.
3 4	5.	1.	13.	11.
4 5	49.	13.	120.	106.
5 6	129.	37.	393.	302.
6 7	515.	103.	2647.	1383.
7 8	1802.	233.	7561.	4160.
8 9	2033.	341.	4694.	3890.
9 10	1934.	373.	3920.	3661.
10 11	1865.	355.	3380.	3482.
11 12	2138.	441.	3334.	3556.
12 1 PM	1846.	296.	4661.	3605.
1 2	923.	211.	2393.	1945.
2 3	1683.	366.	4834.	3625.
3 4	1896.	422.	3794.	3489.
4 5	2130.	501.	4147.	4170.
5 6	2141.	480.	5888.	4574.
6 7	2201.	294.	7175.	4584.
7 8	1722.	158.	3194.	2838.
8 9	1105.	95.	1927.	1752.
9 10	688.	57.	1286.	1125.
10 11	421.	36.	800.	695.
11 12	198.	18.	366.	326.
	27558.	4889.	66682.	53942.

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DAHOMEY INTERNATIONAL BRIDGE

TRAFFIC STUDIES

NO IMPROVEMENT HYPOTHESIS
AND PARALLEL BRIDGE ALTERNATIVE
YEAR 1991

TIME	CARS	TRUCKS + BUSES	BIKES + MOTORBIKES	EQUIVALENT VEHICLE UNITS
MIDNIGHT TO 1 AM	84.	7.	176.	144.
1 2	24.	2.	58.	45.
2 3	7.	1.	19.	15.
3 4	7.	1.	19.	15.
4 5	63.	16.	176.	139.
5 6	165.	45.	577.	400.
6 7	659.	125.	3888.	1882.
7 8	2306.	283.	11108.	5650.
8 9	2602.	414.	6896.	5156.
9 10	2475.	453.	5759.	4822.
10 11	2387.	468.	4966.	4565.
11 12	2736.	536.	4897.	5033.
12 1 PM	2362.	360.	6847.	4794.
1 2	1181.	256.	3516.	2574.
2 3	2154.	444.	7101.	4820.
3 4	2426.	512.	5973.	4846.
4 5	2723.	608.	6092.	5466.
5 6	2740.	583.	8649.	6068.
6 7	2817.	357.	10540.	6167.
7 8	2204.	192.	4692.	3762.
8 9	1414.	115.	2684.	2316.
9 10	881.	69.	1980.	1493.
10 11	539.	44.	1175.	922.
11 12	253.	21.	538.	432.
	35264.	5939.	97957.	71534.

NO IMPROVEMENT HYPOTHESIS
AND PARALLEL BRIDGE ALTERNATIVE
YEAR 1996

TIME	CARS	TRUCKS + BUSES	BIKES + MOTORBIKES	EQUIVALENT VEHICLE UNITS
MIDNIGHT TO 1 AM	109.	9.	269.	195.
1 2	31.	3.	89.	61.
2 3	9.	2.	29.	20.
3 4	9.	2.	29.	20.
4 5	81.	19.	269.	188.
5 6	213.	55.	882.	545.
6 7	850.	153.	5939.	2642.
7 8	2973.	348.	16967.	7911.
8 9	3355.	509.	10533.	7006.
9 10	3191.	556.	8797.	6504.
10 11	3077.	574.	7585.	6123.
11 12	3527.	658.	7481.	6715.
12 1 PM	3045.	442.	10458.	6545.
1 2	1522.	315.	5371.	3496.
2 3	2777.	546.	10847.	6582.
3 4	3127.	629.	8513.	6515.
4 5	3514.	747.	9306.	7335.
5 6	3532.	716.	13211.	8267.
6 7	3632.	438.	16099.	8534.
7 8	2641.	236.	7166.	5106.
8 9	1823.	142.	4099.	3132.
9 10	1136.	85.	2887.	2028.
10 11	695.	54.	1795.	1253.
11 12	327.	26.	822.	586.
	45461.	7285.	149621.	97322.

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DAHOMEY INTERNATIONAL BRIDGE

TRAFFIC STUDIES

SAINT MICHEL BRIDGE SCHEME - NEW BRIDGE

YEAR 1977

TIME	CARS	TRUCKS + BUSES	BIKES + MOTORBIKES	EQUIVALENT VEHICLE UNITS
MIDNIGHT TO 1 AM	14.	1.	22.	23.
1 2	4.	0.	7.	7.
2 3	1.	0.	2.	2.
3 4	1.	0.	2.	2.
4 5	10.	3.	22.	23.
5 6	27.	9.	73.	65.
6 7	110.	27.	494.	288.
7 8	385.	61.	1412.	861.
8 9	434.	90.	876.	834.
9 10	413.	98.	732.	793.
10 11	398.	102.	631.	760.
11 12	456.	116.	622.	846.
12 1 PM	394.	78.	870.	769.
1 2	197.	55.	447.	420.
2 3	359.	96.	903.	779.
3 4	405.	111.	708.	805.
4 5	455.	132.	774.	914.
5 6	457.	127.	1099.	986.
6 7	470.	77.	1340.	961.
7 8	367.	42.	596.	601.
8 9	236.	25.	341.	371.
9 10	147.	15.	240.	237.
10 11	90.	9.	149.	146.
11 12	42.	4.	68.	69.
	5887.	1293.	12456.	11573.

SAINT MICHEL BRIDGE SCHEME - NEW BRIDGE

YEAR 1981

TIME	CARS	TRUCKS + BUSES	BIKES + MOTORBIKES	EQUIVALENT VEHICLE UNITS
MIDNIGHT TO 1 AM	21.	2.	36.	35.
1 2	8.	0.	12.	11.
2 3	1.	0.	4.	3.
3 4	1.	0.	4.	3.
4 5	18.	5.	38.	35.
5 6	41.	14.	120.	181.
6 7	167.	40.	809.	458.
7 8	584.	91.	2312.	1345.
8 9	659.	133.	1455.	1285.
9 10	627.	146.	1199.	1219.
10 11	604.	150.	1033.	1165.
11 12	693.	172.	1019.	1294.
12 1 PM	598.	116.	1425.	1187.
1 2	299.	82.	752.	647.
2 3	545.	143.	1478.	1202.
3 4	614.	165.	1160.	1235.
4 5	690.	196.	1268.	1400.
5 6	694.	187.	1800.	1320.
6 7	713.	115.	2194.	1492.
7 8	558.	62.	976.	926.
8 9	358.	37.	558.	572.
9 10	223.	22.	393.	364.
10 11	138.	14.	244.	226.
11 12	64.	7.	112.	106.
	8935.	1912.	20393.	17836.

SAINT MICHEL BRIDGE SCHEME - NEW BRIDGE

YEAR 1986

TIME	CARS	TRUCKS + BUSES	BIKES + MOTORBIKES	EQUIVALENT VEHICLE UNITS
MIDNIGHT TO 1 AM	35.	3.	68.	68.
1 2	10.	1.	22.	18.
2 3	2.	0.	7.	6.
3 4	2.	0.	7.	6.
4 5	26.	8.	68.	59.
5 6	68.	22.	225.	178.
6 7	274.	63.	1314.	779.
7 8	958.	143.	4326.	2326.
8 9	1081.	209.	2685.	2172.
9 10	1028.	229.	2243.	2048.
10 11	992.	236.	1934.	1949.
11 12	1137.	271.	1907.	2156.
12 1 PM	981.	182.	2466.	2012.
1 2	498.	129.	1389.	1093.
2 3	895.	225.	2785.	2037.
3 4	1008.	239.	2170.	2069.
4 5	1132.	307.	2372.	2341.
5 6	1138.	299.	3368.	2570.
6 7	1170.	180.	4104.	2558.
7 8	915.	97.	1827.	1567.
8 9	587.	58.	1045.	966.
9 10	366.	35.	736.	620.
10 11	224.	22.	457.	383.
11 12	109.	11.	209.	180.
	14659.	3001.	38148.	30158.

DAHOMEY INTERNATIONAL BRIDGE

TRAFFIC STUDIES

SAINT MICHEL BRIDGE SCHEME - NEW BRIDGE

YEAR 1991

TIME	CARS	TRUCKS + BUSES	BIKES + MOTORBIKES	EQUIVALENT VEHICLE UNITS
MIDNIGHT TO 1 AM	44.	4.	106.	81.
1 2	13.	1.	35.	25.
2 3	3.	1.	11.	8.
3 4	3.	1.	11.	8.
4 5	33.	10.	106.	80.
5 6	88.	28.	348.	231.
6 7	350.	78.	2345.	1093.
7 8	1224.	178.	6700.	3255.
8 9	1381.	260.	4159.	2942.
9 10	1314.	284.	3474.	2752.
10 11	1267.	293.	2995.	2604.
11 12	1453.	336.	2954.	2865.
12 1 PM	1254.	226.	4130.	2739.
1 2	627.	161.	2121.	1480.
2 3	1144.	279.	4283.	2773.
3 4	1288.	321.	3361.	2772.
4 5	1447.	382.	3675.	3130.
5 6	1455.	366.	5217.	3491.
6 7	1496.	224.	6357.	3533.
7 8	1170.	121.	2830.	2119.
8 9	750.	72.	1618.	1300.
9 10	468.	43.	1140.	840.
10 11	286.	27.	709.	519.
11 12	134.	13.	324.	243.
	18725.	3724.	59085.	40896.

SAINT MICHEL BRIDGE SCHEME - NEW BRIDGE

YEAR 1996

TIME	CARS	TRUCKS + BUSES	BIKES + MOTORBIKES	EQUIVALENT VEHICLE UNITS
MIDNIGHT TO 1 AM	58.	6.	172.	113.
1 2	16.	2.	57.	35.
2 3	4.	1.	19.	12.
3 4	4.	1.	19.	12.
4 5	43.	12.	172.	112.
5 6	113.	35.	565.	326.
6 7	452.	99.	3805.	1601.
7 8	1581.	224.	10868.	4747.
8 9	1784.	328.	6747.	4127.
9 10	1697.	358.	5635.	3823.
10 11	1636.	370.	4859.	3592.
11 12	1876.	424.	4792.	3923.
12 1 PM	1619.	285.	6699.	3864.
1 2	809.	203.	3440.	2076.
2 3	1477.	352.	6948.	3918.
3 4	1663.	405.	5453.	3838.
4 5	1868.	481.	5961.	4323.
5 6	1878.	461.	8463.	4917.
6 7	1931.	282.	10312.	5075.
7 8	1511.	192.	4590.	2964.
8 9	969.	91.	2626.	1809.
9 10	604.	54.	1849.	1176.
10 11	369.	35.	1150.	727.
11 12	174.	17.	527.	340.
	24176.	4696.	95845.	57462.

DAHOMEY INTERNATIONAL BRIDGE

TRAFFIC STUDIES

SAINT MICHEL BRIDGE SCHEME - EXISTING BRIDGE

YEAR 1977

TIME	CARS	TRUCKS + BUSES	BIKES + MOTORBIKES	EQUIVALENT VEHICLE UNITS
MIDNIGHT TO 1 AM	23.	2.	31.	36.
1 2	6.	0.	10.	11.
2 3	1.	0.	3.	3.
3 4	1.	0.	3.	3.
4 5	17.	5.	31.	35.
5 6	46.	14.	102.	99.
6 7	183.	39.	687.	433.
7 8	641.	88.	1964.	1310.
8 9	723.	129.	1219.	1288.
9 10	688.	142.	1018.	1227.
10 11	663.	146.	878.	1177.
11 12	761.	168.	866.	1313.
12 1 PM	657.	112.	1211.	1185.
1 2	328.	80.	622.	645.
2 3	599.	139.	1256.	1192.
3 4	674.	160.	985.	1242.
4 5	758.	190.	1077.	1409.
5 6	762.	182.	1530.	1510.
6 7	783.	111.	1864.	1473.
7 8	612.	60.	829.	941.
8 9	393.	56.	474.	584.
9 10	243.	21.	334.	372.
10 11	150.	13.	207.	229.
11 12	70.	6.	95.	108.
	9807.	1859.	17327.	17836.

SAINT MICHEL BRIDGE SCHEME - EXISTING BRIDGE

YEAR 1981

TIME	CARS	TRUCKS + BUSES	BIKES + MOTORBIKES	EQUIVALENT VEHICLE UNITS
MIDNIGHT TO 1 AM	26.	2.	38.	41.
1 2	7.	0.	12.	12.
2 3	2.	0.	4.	4.
3 4	2.	0.	4.	4.
4 5	20.	5.	38.	39.
5 6	52.	14.	126.	112.
6 7	208.	40.	853.	501.
7 8	727.	91.	2438.	1519.
8 9	820.	139.	1513.	1465.
9 10	783.	145.	1264.	1388.
10 11	753.	150.	1090.	1326.
11 12	863.	172.	1074.	1476.
12 1 PM	745.	115.	1502.	1352.
1 2	372.	82.	771.	730.
2 3	679.	145.	1558.	1355.
3 4	765.	166.	1223.	1400.
4 5	859.	195.	1557.	1585.
5 6	864.	187.	1898.	1713.
6 7	888.	114.	2313.	1496.
7 8	695.	61.	1029.	1076.
8 9	446.	57.	589.	667.
9 10	278.	22.	414.	426.
10 11	170.	14.	297.	263.
11 12	88.	7.	118.	123.
	11123.	1986.	21499.	20287.

SAINT MICHEL BRIDGE SCHEME - EXISTING BRIDGE

YEAR 1986

TIME	CARS	TRUCKS + BUSES	BIKES + MOTORBIKES	EQUIVALENT VEHICLE UNITS
MIDNIGHT TO 1 AM	30.	2.	51.	48.
1 2	9.	0.	17.	15.
2 3	2.	0.	5.	5.
3 4	2.	0.	5.	5.
4 5	23.	5.	51.	46.
5 6	60.	14.	168.	131.
6 7	241.	39.	1132.	604.
7 8	843.	98.	3235.	1833.
8 9	952.	132.	2088.	1719.
9 10	905.	144.	1677.	1614.
10 11	873.	149.	1446.	1534.
11 12	1001.	171.	1426.	1700.
12 1 PM	844.	115.	1994.	1593.
1 2	432.	82.	1024.	832.
2 3	788.	142.	2068.	1589.
3 4	887.	165.	1623.	1621.
4 5	997.	174.	1774.	1829.
5 6	1002.	186.	2519.	2004.
6 7	1030.	114.	3070.	2026.
7 8	806.	61.	1366.	1271.
8 9	517.	36.	781.	786.
9 10	322.	22.	550.	504.
10 11	197.	14.	342.	311.
11 12	92.	7.	156.	146.
	12909.	1894.	28534.	23797.

DAHOMEY INTERNATIONAL BRIDGE

TRAFFIC STUDIES

SAINT MICHEL BRIDGE SCHEME - EXISTING BRIDGE

YEAR 1991

TIME	CARS	TRUCKS + BUSES	BIKES + MOTORBIKES	EQUIVALENT VEHICLE UNITS
MIDNIGHT TO 1 AM	39.	2.	69.	62.
1 2	11.	1.	23.	19.
2 3	3.	0.	7.	6.
3 4	3.	0.	7.	6.
4 5	29.	6.	69.	59.
5 6	77.	16.	229.	168.
6 7	309.	47.	1543.	789.
7 8	1081.	106.	4408.	2396.
8 9	1220.	155.	2736.	2216.
9 10	1160.	170.	2285.	2072.
10 11	1119.	175.	1970.	1964.
11 12	1283.	201.	1943.	2172.
12 1 PM	1108.	135.	2717.	2057.
1 2	554.	96.	1395.	1095.
2 3	1010.	167.	2818.	2049.
3 4	1137.	192.	2211.	2075.
4 5	1278.	228.	2417.	2340.
5 6	1285.	219.	3432.	2581.
6 7	1321.	134.	4182.	2635.
7 8	1033.	72.	1861.	1643.
8 9	663.	43.	1065.	1016.
9 10	413.	26.	750.	653.
10 11	253.	16.	466.	403.
11 12	119.	8.	213.	189.
	16538.	2228.	38871.	30676.

SAINT MICHEL BRIDGE SCHEME - EXISTING BRIDGE

YEAR 1996

TIME	CARS	TRUCKS + BUSES	BIKES + MOTORBIKES	EQUIVALENT VEHICLE UNITS
MIDNIGHT TO 1 AM	51.	3.	96.	82.
1 2	14.	1.	32.	25.
2 3	4.	0.	10.	8.
3 4	4.	0.	10.	8.
4 5	38.	7.	96.	76.
5 6	100.	19.	317.	219.
6 7	398.	55.	2134.	1042.
7 8	1392.	125.	6098.	3167.
8 9	1570.	183.	3785.	2884.
9 10	1494.	200.	3162.	2686.
10 11	1441.	207.	2726.	2537.
11 12	1651.	237.	2688.	2798.
12 1 PM	1426.	159.	3758.	2684.
1 2	713.	113.	1930.	1423.
2 3	1300.	196.	3898.	2669.
3 4	1464.	226.	3059.	2683.
4 5	1645.	269.	3344.	3020.
5 6	1653.	258.	4748.	3357.
6 7	1700.	158.	5786.	3463.
7 8	1330.	85.	2575.	2145.
8 9	853.	51.	1473.	1324.
9 10	532.	30.	1037.	853.
10 11	325.	19.	645.	526.
11 12	153.	9.	295.	246.
	21285.	2626.	53776.	39935.

DAHOMEY INTERNATIONAL BRIDGE
FEASIBILITY STUDY

VEHICLE OPERATING COST IN CONGESTED AREA

PARALLEL BRIDGES ALTERNATIVE

NO. OF YEARS	STANDING TIME (MINUTES)	CAR STANDING COSTS (FR.CFA)	TRUCK/BUS STANDING COSTS (FR.CFA)	STOP CYCLES	SPEED CONGESTED AREA (KM/HR)	CONGESTED DISTANCE (KM)
1977	0.0	0.	0.	0.	12.	0.0
1978	0.0	0.	0.	0.	12.	0.0
1979	0.0	0.	0.	0.	12.	0.0
1980	0.0	0.	0.	0.	12.	0.0
1981	0.0	0.	0.	0.	12.	0.0
1982	0.0	0.	0.	0.	12.	0.0
1983	0.0	0.	0.	0.	12.	0.0
1984	0.0	0.	0.	0.	12.	0.0
1985	0.0	0.	0.	0.	12.	0.0
1986	0.0	0.	0.	0.	12.	0.0
1987	0.0	0.	0.	0.	12.	0.0
1988	0.0	0.	0.	0.	12.	0.0
1989	1.0	5.	10.	2.	12.	0.0
1990	3.0	15.	31.	6.	12.	1.1
1991	11.0	55.	115.	22.	12.	3.6
1992	49.0	245.	514.	98.	8.	10.9
1993	60.0	301.	630.	120.	8.	27.7
1994	60.0	301.	630.	120.	8.	43.3
1995	60.0	301.	630.	120.	8.	62.7
1996	60.0	301.	630.	120.	8.	71.9

VEHICLE OPERATING COST IN CONGESTED AREA

SAINT MICHEL ALTERNATIVE AT EXISTING BRIDGE
NO CONGESTION AT SAINT MICHEL BRIDGE

NO. OF YEARS	STANDING TIME (MINUTES)	CAR STANDING COSTS (FR.CFA)	TRUCK/BUS STANDING COSTS (FR.CFA)	STOP CYCLES	SPEED CONGESTED AREA (KM/HR)	CONGESTED DISTANCE (KM)
1977	0.0	0.	0.	0.	12.	0.0
1978	0.0	0.	0.	0.	12.	0.0
1979	0.0	0.	0.	0.	12.	0.0
1980	0.0	0.	0.	0.	12.	0.0
1981	0.0	0.	0.	0.	12.	0.0
1982	0.0	0.	0.	0.	12.	0.0
1983	0.0	0.	0.	0.	12.	0.0
1984	0.0	0.	0.	0.	12.	0.0
1985	0.0	0.	0.	0.	12.	0.0
1986	0.0	0.	0.	0.	12.	0.0
1987	0.0	0.	0.	0.	12.	0.0
1988	1.0	5.	10.	2.	12.	0.0
1989	1.0	5.	10.	2.	12.	0.0
1990	1.0	5.	10.	2.	12.	0.0
1991	2.0	10.	21.	4.	12.	0.6
1992	4.0	20.	42.	8.	12.	1.0
1993	9.0	45.	94.	18.	12.	2.3
1994	19.0	95.	199.	38.	8.	3.9
1995	49.0	245.	514.	98.	8.	10.6
1996	60.0	301.	630.	120.	8.	19.9

VEHICLE OPERATING COST IN CONGESTED AREA

NO BRIDGE IMPROVEMENT HYPOTHESIS

NO. OF YEARS	STANDING TIME (MINUTES)	CAR STANDING COSTS (FR.CFA)	TRUCK/BUS STANDING COSTS (FR.CFA)	STOP CYCLES	SPEED CONGESTED AREA (KM/HR)	CONGESTED DISTANCE (KM)
1977	1.0	5.	10.	2.	12.	0.0
1978	3.0	15.	31.	6.	12.	0.7
1979	7.0	35.	73.	14.	12.	1.9
1980	18.0	90.	189.	36.	8.	3.7
1981	55.0	275.	577.	110.	8.	12.0
1982	60.0	301.	630.	120.	8.	24.4
1983	60.0	301.	630.	120.	8.	35.6
1984	60.0	301.	630.	120.	8.	50.0
1985	60.0	301.	630.	120.	8.	65.8
1986	60.0	301.	630.	120.	8.	76.6
1987	60.0	301.	630.	120.	8.	83.1
1988	60.0	301.	630.	120.	8.	96.0
1989	60.0	301.	630.	120.	8.	102.5
1990	60.0	301.	630.	120.	8.	117.3
1991	60.0	301.	630.	120.	8.	124.9
1992	60.0	301.	630.	120.	8.	141.1
1993	60.0	301.	630.	120.	8.	158.5
1994	60.0	301.	630.	120.	8.	177.5
1995	60.0	301.	630.	120.	8.	186.4
1996	60.0	301.	630.	120.	8.	207.4

DAHOMEY INTERNATIONAL BRIDGE
FEASIBILITY STUDY

NO BRIDGE IMPROVEMENT HYPOTHESIS

(MILLIONS OF FR. CFA)

SUMMARY OF VEHICLE OPERATING COSTS

	MOVING PORTION	STOPPING + STANDING PORTION	TOTAL
1977	758.5	88.4	847.0
1978	903.8	187.2	1091.1
1979	1115.7	346.8	1462.6
1980	1109.2	1050.2	2159.5
1981	1330.5	3220.7	4551.3
1982	1420.2	3786.1	5206.3
1983	1511.2	4014.9	5526.1
1984	1608.7	4259.7	5868.5
1985	1713.4	4521.9	6235.3
1986	1825.8	4802.9	6628.7
1987	1915.5	5026.9	6942.4
1988	2010.2	5263.0	7273.3
1989	2110.2	5512.1	7622.4
1990	2215.9	5775.0	7991.0
1991	2327.6	6052.6	8380.2
1992	2445.6	6345.9	8791.5
1993	2570.5	6655.9	9226.4
1994	2702.6	6983.7	9686.4
1995	2842.5	7330.7	10173.2
1996	2990.6	7698.1	10688.7
	37429.1	88923.5	126352.7

SAINT MICHEL ALTERNATIVE NEW BRIDGE SITE

(MILLIONS OF FR. CFA)

SUMMARY OF VEHICLE OPERATING COSTS

	MOVING PORTION	STOPPING + STANDING PORTION	TOTAL
1977	314.3	0.0	314.3
1978	348.6	0.0	348.6
1979	385.9	0.0	385.9
1980	426.7	0.0	426.7
1981	471.2	0.0	471.2
1982	519.7	0.0	519.7
1983	572.7	0.0	572.7
1984	630.4	0.0	630.4
1985	693.5	0.0	693.5
1986	762.3	0.0	762.3
1987	798.7	0.0	798.7
1988	837.1	0.0	837.1
1989	935.7	0.0	935.7
1990	981.4	0.0	981.4
1991	1029.6	0.0	1029.6
1992	1080.5	0.0	1080.5
1993	1134.4	0.0	1134.4
1994	1191.3	0.0	1191.3
1995	1251.5	0.0	1251.5
1996	1315.2	0.0	1315.2
	15681.6	0.0	15681.6

SAINT MICHEL ALTERNATIVE AT EXISTING BRIDGE

(MILLIONS OF FR. CFA)

SUMMARY OF VEHICLE OPERATING COSTS

	MOVING PORTION	STOPPING + STANDING PORTION	TOTAL
1977	345.5	27.1	372.6
1978	355.5	27.8	383.4
1979	365.8	28.5	394.3
1980	376.1	29.2	405.3
1981	386.5	29.9	416.4
1982	397.0	30.6	427.6
1983	407.5	31.3	438.8
1984	418.0	31.9	450.0
1985	428.4	32.6	461.1
1986	438.7	33.3	472.0
1987	460.6	34.8	495.5
1988	483.7	36.4	520.2
1989	554.1	38.1	592.3
1990	582.2	79.9	662.1
1991	704.5	125.5	830.1
1992	787.6	219.2	1006.8
1993	983.5	413.3	1396.8
1994	924.4	1008.8	1933.2
1995	1057.3	2642.3	3699.6
1996	1112.8	3378.0	4490.8
	11570.8	8279.2	19850.0

PARALLEL BRIDGE ALTERNATE

(MILLIONS OF FR. CFA)

SUMMARY OF VEHICLE OPERATING COSTS

	MOVING PORTION	STOPPING + STANDING PORTION	TOTAL
1977	758.5	44.2	802.8
1978	805.5	46.8	852.3
1979	855.8	49.5	905.4
1980	909.8	52.4	962.3
1981	967.8	55.5	1023.4
1982	1030.1	58.9	1089.0
1983	1097.1	62.5	1159.6
1984	1305.8	66.3	1372.2
1985	1391.3	70.4	1461.7
1986	1483.4	74.8	1558.2
1987	1557.1	78.3	1635.4
1988	1635.1	82.0	1717.1
1989	1717.7	85.9	1803.6
1990	2039.6	270.0	2309.7
1991	2583.7	1037.8	3621.6
1992	2433.0	5097.5	7530.5
1993	2570.5	6655.9	9226.4
1994	2702.6	6983.7	9686.4
1995	2842.5	7330.7	10173.2
1996	2990.6	7698.1	10688.7
	33678.3	35901.8	69580.2

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DAHOMEY INTERNATIONAL BRIDGE
FEASIBILITY STUDY

MAINTENANCE COSTS OF BRIDGE ROADWAY APPROACHES

(MILLIONS OF FR. CFA)

YEAR	NO BRIDGE IMPROVEMENT HYPOTHESIS	SAINT MICHEL BRIDGE ALTERNATIVE	PARALLEL BRIDGE ALTERNATIVE
1977	15.	19.	15.
1978	17.	21.	17.
1979	19.	24.	19.
1980	21.	26.	21.
1981	23.	29.	23.
1982	25.	31.	25.
1983	28.	34.	28.
1984	31.	37.	31.
1985	34.	40.	34.
1986	37.	44.	37.
1987	41.	47.	41.
1988	44.	51.	44.
1989	47.	54.	47.
1990	51.	58.	51.
1991	55.	62.	55.
1992	60.	67.	60.
1993	64.	71.	64.
1994	69.	76.	69.
1995	74.	81.	74.
1996	80.	87.	80.
	845.	971.	845.

MAINTENANCE COSTS OF BRIDGE ROADWAY APPROACHES

(MILLIONS OF FR. CFA)

DISCOUNTED AT 10 PERCENT TO 1975

YEAR	NO BRIDGE IMPROVEMENT HYPOTHESIS	SAINT MICHEL BRIDGE ALTERNATIVE	PARALLEL BRIDGE ALTERNATIVE
1977	12.	16.	12.
1978	12.	16.	12.
1979	12.	16.	12.
1980	13.	16.	13.
1981	13.	16.	13.
1982	13.	16.	13.
1983	13.	16.	13.
1984	13.	16.	13.
1985	13.	15.	13.
1986	13.	15.	13.
1987	13.	15.	13.
1988	12.	14.	12.
1989	12.	14.	12.
1990	12.	14.	12.
1991	12.	13.	12.
1992	11.	13.	11.
1993	11.	12.	11.
1994	11.	12.	11.
1995	11.	12.	11.
1996	10.	11.	10.
	251.	297.	251.

DAHOMEY INTERNATIONAL BRIDGE
FEASIBILITY STUDY

TOTAL O-D TRIP COSTS
NOT DISCOUNTED

(MILLIONS OF FR. CFA)

YEAR	NO BRIDGE IMPROVEMENT HYPOTHESIS	SAINT MICHEL ALTERNATIVE EXISTING BRIDGE	NEW BRIDGE	TOTAL	PARALLEL BRIDGES ALTERNATIVE
1977	847.0	372.6	314.3	686.9	802.8
1978	1091.1	383.4	348.6	732.0	852.3
1979	1462.6	394.3	385.9	780.2	905.4
1980	2159.5	405.3	426.7	832.0	962.3
1981	4551.3	416.4	471.2	887.5	1023.4
1982	5206.3	427.6	519.7	947.3	1089.0
1983	5526.1	438.8	572.7	1011.5	1159.6
1984	5868.5	450.0	630.4	1080.4	1372.2
1985	6235.3	461.1	693.5	1154.6	1461.7
1986	6628.7	472.0	762.3	1234.3	1558.2
1987	6942.4	495.5	798.7	1294.2	1635.4
1988	7273.3	520.2	837.1	1357.3	1717.1
1989	7622.4	592.3	935.7	1528.0	1803.6
1990	7991.0	662.1	981.4	1643.5	2309.7
1991	8380.2	830.1	1029.6	1859.6	3621.6
1992	8791.5	1006.8	1080.5	2087.3	7530.5
1993	9226.4	1396.8	1134.4	2531.2	9226.4
1994	9686.4	1933.2	1191.3	3124.5	9686.4
1995	10173.2	3699.5	1251.5	4951.1	10173.2
1996	10688.7	4490.8	1315.2	5806.0	10688.7

TOTAL O-D TRIP SAVING

10 PERCENT RATE OF RETURN

(MILLIONS OF FR. CFA)

YEAR	NO IMPROVEMENT MINUS SAN MICHEL BRIDGE	NO IMPROVEMENT MINUS PARALLEL BRIDGES	NO IMPROVEMENT MINUS SAN MICHEL BRIDGE DISCOUNTED 1975	NO IMPROVEMENT MINUS PARALLEL BRIDGES DISCOUNTED 1975
1977	160.1	44.2	132.3	36.5
1978	359.1	238.7	269.7	179.4
1979	682.4	557.2	466.0	380.5
1980	1327.5	1197.2	824.2	743.3
1981	3663.7	3527.9	2068.0	1991.4
1982	4259.0	4117.3	2185.5	2112.8
1983	4514.6	4366.5	2106.0	2037.0
1984	4788.1	4496.3	2030.6	1906.8
1985	5080.7	4773.6	1958.8	1840.4
1986	5394.4	5070.5	1890.7	1777.1
1987	5648.2	5307.0	1799.6	1690.9
1988	5916.0	5556.2	1713.6	1609.4
1989	6094.4	5818.7	1604.8	1532.2
1990	6347.5	5681.3	1519.5	1360.0
1991	6520.5	4758.6	1419.0	1035.6
1992	6704.2	1261.0	1326.3	249.4
1993	6695.1	0.0	1204.1	0.0
1994	6561.8	0.0	1072.9	0.0
1995	5222.1	0.0	776.2	0.0
1996	4882.7	0.0	659.8	0.0
			27028.6	20483.4

TOTAL FISH BENEFITS
LESS SHRIMP LOSSES
10 PERCENT RATE OF RETURN

YEAR	TOTAL FISH PRODUCTION (METRIC TONS)	ADDITIONAL FISH PRODUCTION DUE TO DAM (METRIC TONS)	GROSS REVENUE FISH PRODUCTION DUE TO DAM CONST. (MILLIONS FR. CFA)	GROSS REVENUE FISH PRODUCTION DUE TO DAM CONST. (MILLIONS FR. CFA) DISCOUNTED
1977	2200.	0.	0.	0.
1978	3600.	1400.	40.	30.
1979	8000.	5800.	263.	179.
1980	13800.	11600.	354.	220.
1981	15000.	12800.	362.	204.
1982	15000.	12800.	362.	186.
1983	15000.	12800.	362.	169.
1984	15000.	12800.	362.	153.
1985	15000.	12800.	362.	139.
1986	15000.	12800.	362.	127.
1987	15000.	12800.	362.	115.
1988	15000.	12800.	362.	105.
1989	15000.	12800.	362.	95.
1990	15000.	12800.	362.	86.
1991	15000.	12800.	362.	78.
1992	15000.	12800.	362.	71.
1993	15000.	12800.	362.	65.
1994	15000.	12800.	362.	59.
1995	15000.	12800.	362.	53.
1996	15000.	12800.	362.	49.
			6460.	2191.

DAHOMEY INTERNATIONAL BRIDGE
FEASIBILITY STUDY

CONSTRUCTION AND MAINTENANCE COSTS
(MILLIONS FR. CFA)
10 PER CENT RATE OF RETURN

NO BRIDGE IMPROVEMENT HYPOTHESIS

	AMERICAN PROCUREMENT	FOREIGN PROCUREMENT	AMERICAN PROCUREMENT DISCOUNTED 1975	FOREIGN PROCUREMENT DISCOUNTED 1975
EXISTING BRIDGE REPAIRS	148.7	142.2	148.7	142.2
APPROACH MAINT. (20 YRS)	835.0	835.0	248.1	248.1
			396.	390.

SAINT MICHEL ALTERNATIVE

	AMERICAN PROCUREMENT	FOREIGN PROCUREMENT	AMERICAN PROCUREMENT DISCOUNTED 1975	FOREIGN PROCUREMENT DISCOUNTED 1975
EXISTING BRIDGE REPAIRS	148.7	142.2	148.7	142.2
SAINT MICHEL BRIDGE CONST.	1000.2	849.4	1000.2	849.4
SAINT MICHEL APPROACH CONST. INCLUDES 180 MILLIONS FR. CFA. FUNDED BY F.E.D.	352.9	383.0	352.9	383.0
EROSION PROTECTION CONST.	150.1	143.4	150.1	143.4
APPROACH MAINT. (20 YRS)	959.0	959.0	292.2	292.2
			1944.	1810.

PARALLEL BRIDGES ALTERNATIVE

	AMERICAN PROCUREMENT	FOREIGN PROCUREMENT	AMERICAN PROCUREMENT DISCOUNTED 1975	FOREIGN PROCUREMENT DISCOUNTED 1975
EXISTING BRIDGE REPAIRS	148.7	142.2	148.7	142.2
NEW BRIDGE PARALLEL CONST. INCLUDING APPROACHES	753.6	605.9	753.6	605.9
EROSION PROTECTION CONST.	150.1	143.4	150.1	143.4
APPROACH MAINT. (20 YRS)	835.0	835.0	248.1	248.1
			1300.	1139.

NET CONSTRUCTION COSTS FOR BENEFIT/COST TABULATION

SAINT MICHEL BRIDGE MINUS NO BRIDGE IMPROVEMENT (DISCOUNTED)		PARALLEL BRIDGE MINUS NO BRIDGE IMPROVEMENT (DISCOUNTED)	
AMERICAN PROCUREMENT	FOREIGN PROCUREMENT	AMERICAN PROCUREMENT	FOREIGN PROCUREMENT
1547.36	1419.96	903.70	749.29

BENEFIT/COST RATIO AT 10 PERCENT RATE OF RETURN

SAINT MICHEL BRIDGE ALTERNATIVE		PARALLEL BRIDGE ALTERNATIVE	
AMERICAN PROCUREMENT	FOREIGN PROCUREMENT	AMERICAN PROCUREMENT	FOREIGN PROCUREMENT
13.10	14.14	15.05	17.31

DAHOMEY INTERNATIONAL BRIDGE
FEASIBILITY STUDY

CONSTRUCTION AND MAINTENANCE COSTS
(MILLIONS FR. CFA)
10 PER CENT RATE OF RETURN

NO BRIDGE IMPROVEMENT HYPOTHESIS

	AMERICAN PROCUREMENT	FOREIGN PROCUREMENT	AMERICAN PROCUREMENT DISCOUNTED 1975	FOREIGN PROCUREMENT DISCOUNTED 1975
EXISTING BRIDGE REPAIRS	148.7	142.2	148.7	142.2
APPROACH MAINT. (20 YRS)	835.0	835.0	248.1	248.1
			396.	390.

SAINT MICHEL ALTERNATIVE

	AMERICAN PROCUREMENT	FOREIGN PROCUREMENT	AMERICAN PROCUREMENT DISCOUNTED 1975	FOREIGN PROCUREMENT DISCOUNTED 1975
EXISTING BRIDGE REPAIRS	148.7	142.2	148.7	142.2
SAINT MICHEL BRIDGE CONST.	1000.2	849.4	1000.2	849.4
SAINT MICHEL APPROACH CONST. INCLUDES 180 MILLIONS FR. CFA. FUNDED BY F.E.D.	352.9	383.0	352.9	383.0
DAM CONST.	576.0	508.8	576.0	508.8
APPROACH MAINT. (20 YRS)	959.0	959.0	292.2	292.2
			2370.	2175.

PARALLEL BRIDGES ALTERNATIVE

	AMERICAN PROCUREMENT	FOREIGN PROCUREMENT	AMERICAN PROCUREMENT DISCOUNTED 1975	FOREIGN PROCUREMENT DISCOUNTED 1975
EXISTING BRIDGE REPAIRS	148.7	142.2	148.7	142.2
NEW BRIDGE PARALLEL CONST. INCLUDING APPROACHES	753.6	605.9	753.6	605.9
DAM CONST.	576.0	508.8	576.0	508.8
APPROACH MAINT. (20 YRS)	835.0	835.0	248.1	248.1
			1726.	1505.

NET CONSTRUCTION COSTS FOR BENEFIT/COST TABULATION

SAINT MICHEL BRIDGE MINUS NO BRIDGE IMPROVEMENT (DISCOUNTED)		PARALLEL BRIDGE MINUS NO BRIDGE IMPROVEMENT (DISCOUNTED)	
AMERICAN PROCUREMENT	FOREIGN PROCUREMENT	AMERICAN PROCUREMENT	FOREIGN PROCUREMENT
1973.26	1785.36	1329.60	1114.69

BENEFIT/COST RATIO AT 10 PERCENT RATE OF RETURN

SAINT MICHEL BRIDGE ALTERNATIVE		PARALLEL BRIDGE ALTERNATIVE	
AMERICAN PROCUREMENT	FOREIGN PROCUREMENT	AMERICAN PROCUREMENT	FOREIGN PROCUREMENT
10.57	11.60	11.09	12.86

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DAHOMEY INTERNATIONAL BRIDGE
FEASIBILITY STUDY

TOTAL O-D TRIP COSTS
NOT DISCOUNTED

(MILLIONS OF FR. CFA)

YEAR	NO BRIDGE IMPROVEMENT HYPOTHESIS	SAINT MICHEL ALTERNATIVE EXISTING BRIDGE	NEW BRIDGE	TOTAL	PARALLEL BRIDGES ALTERNATIVE
1977	738.9	390.9	246.3	637.2	738.9
1978	817.4	400.4	269.9	670.3	774.7
1979	872.7	410.0	295.2	705.2	812.4
1980	1091.1	419.8	322.3	742.1	852.3
1981	1385.1	429.7	351.5	781.2	894.5
1982	1928.8	439.7	382.7	822.4	939.0
1983	2974.8	449.9	416.3	866.2	986.2
1984	4965.7	460.1	452.4	912.5	1153.3
1985	5206.3	470.5	491.0	961.5	1211.4
1986	5460.4	480.9	532.6	1013.5	1272.9
1987	5660.2	499.5	552.3	1051.8	1321.5
1988	5868.5	518.9	572.9	1091.8	1372.2
1989	6085.5	581.5	633.4	1214.9	1425.1
1990	6311.4	604.3	657.3	1261.6	1480.5
1991	6547.8	667.1	682.2	1349.3	1538.3
1992	6793.9	693.4	708.1	1401.5	1598.8
1993	7050.7	824.4	735.1	1559.5	1662.1
1994	7318.7	1016.8	763.4	1780.1	1728.3
1995	7598.5	1211.4	792.8	2004.1	1797.7
1996	7890.7	1616.2	823.6	2439.8	2187.3

TOTAL O-D TRIP SAVING

10 PERCENT RATE OF RETURN

(MILLIONS OF FR. CFA)

YEAR	NO IMPROVEMENT MINUS SAN MICHEL BRIDGE	NO IMPROVEMENT MINUS PARALLEL BRIDGES	NO IMPROVEMENT MINUS SAN MICHEL BRIDGE DISCOUNTED 1975	NO IMPROVEMENT MINUS PARALLEL BRIDGES DISCOUNTED 1975
1977	86.4	0.0	71.4	0.0
1978	125.0	36.2	93.9	27.2
1979	142.3	51.2	97.2	35.0
1980	296.6	202.9	184.1	126.0
1981	513.3	417.0	289.7	235.3
1982	940.4	841.3	482.5	431.7
1983	1792.3	1690.3	835.1	788.5
1984	3445.2	3240.5	1461.1	1374.3
1985	3608.0	3395.6	1391.0	1309.1
1986	3779.8	3559.3	1324.8	1247.5
1987	3917.1	3687.8	1248.1	1175.0
1988	4060.1	3821.8	1176.0	1107.0
1989	4140.0	3961.3	1090.1	1043.1
1990	4292.6	4106.6	1027.6	983.0
1991	4418.7	4258.0	961.6	926.6
1992	4583.5	4415.8	906.8	873.6
1993	4667.5	4580.3	839.4	823.8
1994	4707.7	4751.8	769.7	776.9
1995	4755.1	4930.6	706.8	732.9
1996	4633.2	4847.8	626.0	655.1
			15584.9	14672.5

TOTAL FISH BENEFITS

10 PERCENT RATE OF RETURN

YEAR	TOTAL FISH PRODUCTION (METRIC TONS)	ADDITIONAL FISH PRODUCTION DUE TO DAM (METRIC TONS)	GROSS REVENUE FISH PRODUCTION DUE TO DAM CONST. (MILLIONS FR. CFA)	GROSS REVENUE FISH PRODUCTION DUE TO DAM CONST. (MILLIONS FR. CFA) DISCOUNTED
1977	2200.	0.	0.	0.
1978	3600.	1400.	0.	0.
1979	8000.	5800.	101.	69.
1980	13800.	11600.	147.	91.
1981	15000.	12800.	151.	85.
1982	15000.	12800.	151.	77.
1983	15000.	12800.	151.	70.
1984	15000.	12800.	151.	64.
1985	15000.	12800.	151.	58.
1986	15000.	12800.	151.	53.
1987	15000.	12800.	151.	48.
1988	15000.	12800.	151.	43.
1989	15000.	12800.	151.	39.
1990	15000.	12800.	151.	36.
1991	15000.	12800.	151.	32.
1992	15000.	12800.	151.	29.
1993	15000.	12800.	151.	27.
1994	15000.	12800.	151.	24.
1995	15000.	12800.	151.	22.
1996	15000.	12800.	151.	20.
			2670.	895.

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DAHOMEY INTERNATIONAL BRIDGE
FEASIBILITY STUDY

CONSTRUCTION AND MAINTENANCE COSTS
(MILLIONS FR. CFA)
10 PER CENT RATE OF RETURN

NO BRIDGE IMPROVEMENT HYPOTHESIS

	AMERICAN PROCUREMENT	FOREIGN PROCUREMENT	AMERICAN PROCUREMENT DISCOUNTED 1975	FOREIGN PROCUREMENT DISCOUNTED 1975
EXISTING BRIDGE REPAIRS	148.7	142.2	148.7	142.2
APPROACH MAINT. (20 YRS)	707.0	707.0	215.8	215.8
			364.	358.

SAINT MICHEL ALTERNATIVE

	AMERICAN PROCUREMENT	FOREIGN PROCUREMENT	AMERICAN PROCUREMENT DISCOUNTED 1975	FOREIGN PROCUREMENT DISCOUNTED 1975
EXISTING BRIDGE REPAIRS	148.7	142.2	148.7	142.2
SAINT MICHEL BRIDGE CONST.	1000.2	849.4	1000.2	849.4
SAINT MICHEL APPROACH CONST. INCLUDES 180 MILLIONS FR. CFA. FUNDED BY F.E.D.	352.9	383.0	352.9	383.0
EROSION PROTECTION CONST.	150.1	143.4	150.1	143.4
APPROACH MAINT. (20 YRS)	857.0	857.0	268.1	268.1
			1920.	1786.

PARALLEL BRIDGES ALTERNATIVE

	AMERICAN PROCUREMENT	FOREIGN PROCUREMENT	AMERICAN PROCUREMENT DISCOUNTED 1975	FOREIGN PROCUREMENT DISCOUNTED 1975
EXISTING BRIDGE REPAIRS	148.7	142.2	148.7	142.2
NEW BRIDGE PARALLEL CONST. INCLUDING APPROACHES	753.6	605.9	753.6	605.9
EROSION PROTECTION CONST.	150.1	143.4	150.1	143.4
APPROACH MAINT. (20 YRS)	707.0	707.0	215.8	215.8
			1268.	1107.

NET CONSTRUCTION COSTS FOR BENEFIT/COST TABULATION

SAINT MICHEL BRIDGE MINUS NO BRIDGE IMPROVEMENT (DISCOUNTED)		PARALLEL BRIDGE MINUS NO BRIDGE IMPROVEMENT (DISCOUNTED)	
AMERICAN PROCUREMENT	FOREIGN PROCUREMENT	AMERICAN PROCUREMENT	FOREIGN PROCUREMENT
1555.54	1428.14	903.69	749.29

BENEFIT/COST RATIO AT 10 PERCENT RATE OF RETURN

SAINT MICHEL BRIDGE ALTERNATIVE		PARALLEL BRIDGE ALTERNATIVE	
AMERICAN PROCUREMENT	FOREIGN PROCUREMENT	AMERICAN PROCUREMENT	FOREIGN PROCUREMENT
7.30	7.92	10.85	12.57

SENSITIVITY ANALYSIS

1970 BASE ADT REDUCED BY 10 PERCENT
TRAFFIC GROWTH RATE REDUCED BY 20 PERCENT
VEHICLE OPERATING SAVINGS REDUCED BY 15 PERCENT
DIVERTED TRAFFIC TO SAINT MICHEL BRIDGE REDUCED BY 15 PERCENT

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DAHOMEY INTERNATIONAL BRIDGE
FEASIBILITY STUDY

CONSTRUCTION AND MAINTENANCE COSTS
(MILLIONS FR. CFA)
10 PER CENT RATE OF RETURN

NO BRIDGE IMPROVEMENT HYPOTHESIS

	AMERICAN PROCUREMENT	FOREIGN PROCUREMENT	AMERICAN PROCUREMENT DISCOUNTED 1975	FOREIGN PROCUREMENT DISCOUNTED 1975
EXISTING BRIDGE REPAIRS	148.7	142.2	148.7	142.2
APPROACH MAINT. (20 YRS)	707.0	707.0	215.8	215.8
			364.	358.

SAINT MICHEL ALTERNATIVE

	AMERICAN PROCUREMENT	FOREIGN PROCUREMENT	AMERICAN PROCUREMENT DISCOUNTED 1975	FOREIGN PROCUREMEN DISCOUNTED 1975
EXISTING BRIDGE REPAIRS	148.7	142.2	148.7	142.2
SAINT MICHEL BRIDGE CONST.	1000.2	849.4	1000.2	849.4
SAINT MICHEL APPROACH CONST. INCLUDES 180 MILLIONS FR. CFA. FUNDED BY F.E.D.	352.9	383.0	352.9	383.0
DAM CONST.	576.0	508.8	576.0	508.8
APPROACH MAINT. (20 YRS)	857.0	857.0	268.1	268.1
			2345.	2151.

PARALLEL BRIDGES ALTERNATIVE

	AMERICAN PROCUREMENT	FOREIGN PROCUREMENT	AMERICAN PROCUREMENT DISCOUNTED 1975	FOREIGN PROCUREMENT DISCOUNTED 1975
EXISTING BRIDGE REPAIRS	148.7	142.2	148.7	142.2
NEW BRIDGE PARALLEL CONST. INCLUDING APPROACHES	753.6	605.9	753.6	605.9
DAM CONST.	576.0	508.8	576.0	508.8
APPROACH MAINT. (20 YRS)	707.0	707.0	215.8	215.8
			1694.	1472.

NET CONSTRUCTION COSTS FOR BENEFIT/COST TABULATION

SAINT MICHEL BRIDGE MINUS NO BRIDGE IMPROVEMENT (DISCOUNTED)		PARALLEL BRIDGE MINUS NO BRIDGE IMPROVEMENT (DISCOUNTED)	
AMERICAN PROCUREMENT	FOREIGN PROCUREMENT	AMERICAN PROCUREMENT	FOREIGN PROCUREMENT
1981.44	1793.54	1329.60	1114.69

BENEFIT/COST RATIO AT 10 PERCENT RATE OF RETURN

SAINT MICHEL BRIDGE ALTERNATIVE		PARALLEL BRIDGE ALTERNATIVE	
AMERICAN PROCUREMENT	FOREIGN PROCUREMENT	AMERICAN PROCUREMENT	FOREIGN PROCUREMENT
5.79	6.40	7.87	9.20

SENSITIVITY ANALYSIS

1970 BASE ADT REDUCED BY 10 PERCENT
TRAFFIC GROWTH RATE REDUCED BY 20 PERCENT
VEHICLE OPERATING SAVINGS REDUCED BY 15 PERCENT
DIVERTED TRAFFIC TO SAINT MICHEL BRIDGE REDUCED BY 15 PERCENT

FISH BENEFITS REDUCED BY 50 PERCENT

DAHOMEY INTERNATIONAL BRIDGE
DAM BENEFIT/COST ANALYSIS

DAM CONSTRUCTION COSTS (MILLIONS OF FR. CFA)	AMERICAN PROCUREMENT	FOREIGN PROCUREMENT
	576.	508.

FISH BENEFITS LESS SHRIMP LOSSES
(MILLIONS OF FR. CFA)

YEAR	MARKET VALUE	MARKET VALUE DISCOUNTED TO 1975
1975	0.	0.
1976	40.	33.
1977	263.	194.
1978	354.	237.
1979	362.	219.
1980	362.	199.
1981	362.	180.
1982	362.	162.
1983	362.	147.
1984	362.	133.
1985	362.	120.
1986	362.	109.
1987	362.	98.
1988	362.	89.
1989	362.	80.
1990	362.	73.
1991	362.	66.
1992	362.	59.
1993	362.	54.
1994	362.	49.
		2310.

DISCOUNT RATE = 10 PERCENT

B/C = 4.0 AMERICAN PROCUREMENT

B/C = 4.5 FOREIGN PROCUREMENT

SENSITIVITY ANALYSIS

FISH MARKET VALUE REDUCED BY 50 PER CENT

DAM CONSTRUCTION COSTS (MILLIONS OF FR. CFA)	AMERICAN PROCUREMENT	FOREIGN PROCUREMENT
	576.	508.

FISH BENEFITS LESS SHRIMP LOSSES
(MILLIONS OF FR. CFA)

YEAR	MARKET VALUE	MARKET VALUE DISCOUNTED TO 1975
1975	0.	0.
1976	0.	0.
1977	101.	75.
1978	147.	98.
1979	151.	91.
1980	151.	83.
1981	151.	75.
1982	151.	68.
1983	151.	61.
1984	151.	55.
1985	151.	50.
1986	151.	45.
1987	151.	41.
1988	151.	37.
1989	151.	33.
1990	151.	30.
1991	151.	27.
1992	151.	25.
1993	151.	22.
1994	151.	20.
		943.

DISCOUNT RATE = 10 PERCENT

B/C = 1.5 AMERICAN PROCUREMENT

B/C = 1.8 FOREIGN PROCUREMENT