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JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

THE STATE SECRETARY OF PLANNING
THE STATE OF PIAUÍ
THE FEDERATIVE REPUBLIC OF BRAZIL

FINAL REPORT

THE FEASIBILITY STUDY ON THE NAVIGATION OF THE PARNAÍBA RIVER BASIN

VOL.2 MAIN REPORT

MARCH 1995

PACIFIC CONSULTANTS INTERNATIONAL (PCI)

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PREFACE

In response to a request from the Government of the Federative Republic of Brazil, the Government of Japan decided to conduct a feasibility study on the Navigation of the Parnaíba River Basin and entrusted the study to the Japan International Cooperation Agency (JICA).

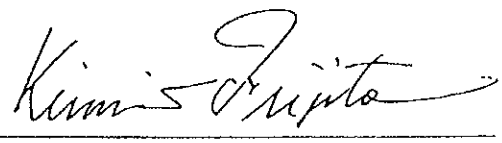
JICA sent to Brazil a study team headed by Mr. Makoto Tanaka, Pacific Consultants International, six (6) times between December 1992 and March 1995.

The team held discussions with the officials concerned of the Government of Brazil and conducted field surveys at the survey area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials of the Government of the Federative Republic of Brazil for their close cooperation they extended to the team.

March, 1995



Kimio Fujita
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

March, 1995

Mr. Kimio Fujita
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Mr. Fujita

We are pleased to submit to you the feasibility study report on the Navigation of the Parnaíba river basin in the State of Piauí, the Federative Republic of Brazil. The report contains the advice and suggestions of the authorities concerned from the Government of Japan and your Agency as well as the results of the Study. Also included are comments made by the State Secretary of Planning of the State of Piauí during technical discussions on the draft report which were held in Teresina on January, 1995.

This report presents the results of the feasibility study on the navigation of the Parnaíba river basin, in the State of Piauí in Brazil. Until 1960's, the Parnaíba river basin was utilized for the river transportation of agricultural products, but the river navigation dwindled after the construction of the Boa Esperança Dam which is located in the mid-stream region of the Parnaíba river basin.

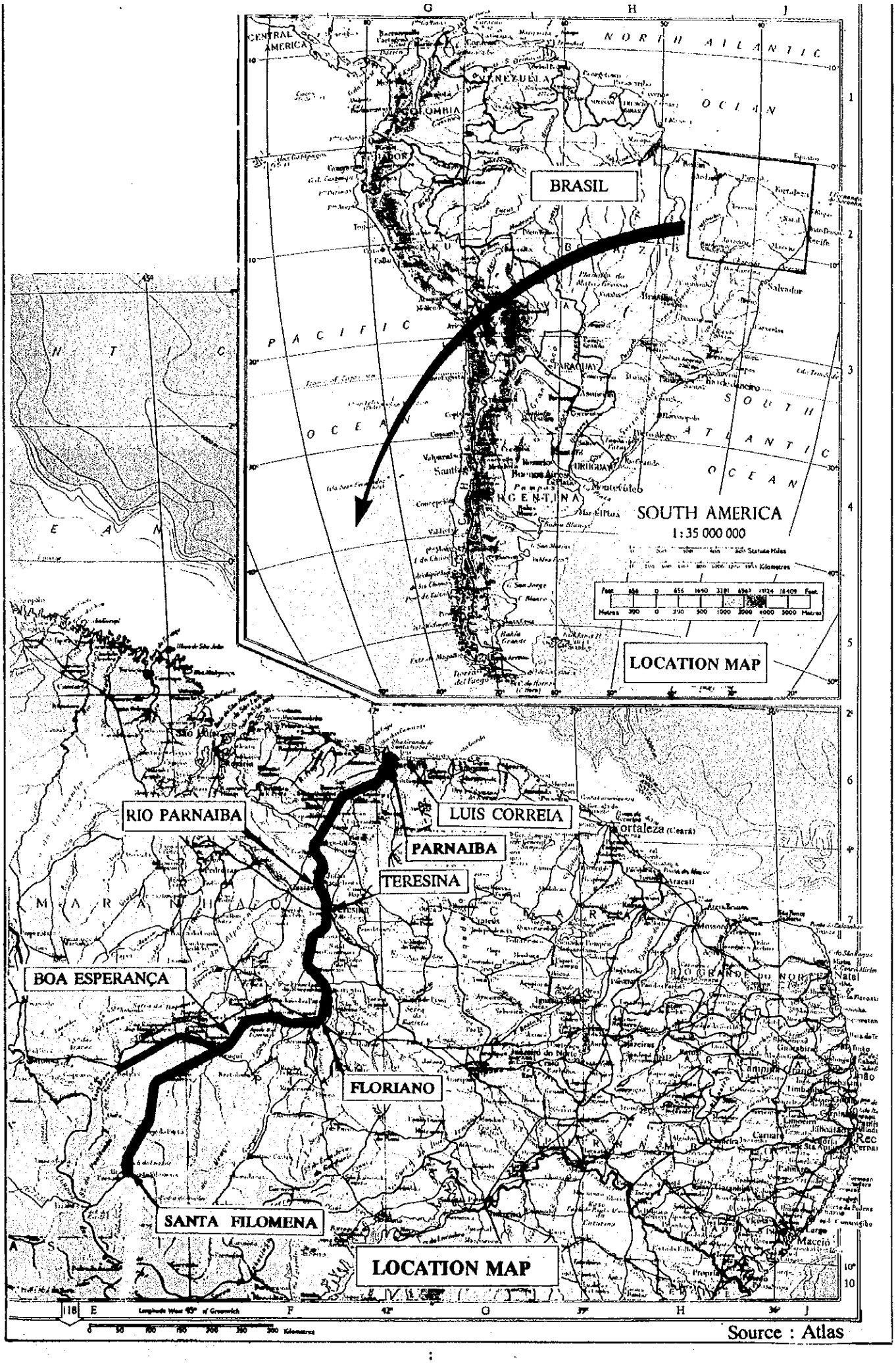
The study results show that river navigation is hardly possible all the way through to the river mouth since the efficiency of river transportation is restricted by the particulars of the river, i.e. the water depth in sand bar area and the Boa Esperança Locks for which construction was suspended due to financial problems.

A feasible scenario of river navigation is proposed in view of the socio-economic situation around the Parnaíba river basin, where the navigation is limited to the area upstream of Floriano in dry season, and to that of Teresina in rainy season. Despite such conditions, however, the feasibility from a financial point of view is discouraging. As a result, we recommend that a policy formulation with careful consideration of financial matters is imperative in determining whether to execute this project or not.

We wish to take this opportunity to express our sincere gratitude to your Agency, the Ministry of Foreign Affairs, and the Ministry of Transport. We also wish to express our deep gratitude to the officials concerned of the State Secretary of Planning of the State of Piauí and counterpart personnel for the close cooperation and assistance extended to us during our investigations and study.

Very truly yours,

Makoto TANAKA
Team Leader
Feasibility Study on the Navigation of the Parnaíba River Basin
Pacific Consultants International


BRASIL
SOUTH AMERICA
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LOCATION MAP
RIO PARNAIBA
LUIS CORREIA
PARNAIBA
TERESINA
BOA ESPERANÇA
FLORIANO
SANTA FILOMENA
LOCATION MAP
Source : Atlas

View of Luiz Correia Port. The Construction of the port was suspended due to the financial problems of PORTOBRAS.

View of Boa Esperança Dam and Locks. Until 1960's, the Parnaíba river was utilized for river navigation between Santa Filomena and Parnaíba cities mainly for transportation of the agricultural products. However, the river navigation dwindled, after the construction of Boa Esperança Dam since the construction of Boa Esperança Locks was suspended due to also the financial problems. The rehabilitation of the Locks is definitely required for the river navigation.

View of the Parnaíba river. There are many sand bars, especially down below Amarante. The water depths at this area are quite shallow during the dry seasons. The draft of the vessel is restricted by this depth.

The rock materials are observed at the river banks between Floriano and Guadalupe. Some precautionary measures of ship's maneuvering are required.

EXECUTIVE SUMMARY

1. The State of Piauí is located in the northeastern region of Brazil with an area of 250,934 km^2, and a population of 2.6 million. Although the land itself is relatively rich in natural resources, the southern part of the state is underdeveloped due to insufficient infrastructures. To promote the development around the area, the State of Piauí is implementing various projects, including transportation projects and agricultural development projects. Among them, the State of Piauí is interested in the development of navigation systems, as it would make their products much more competitive in the market by providing lower transporting costs comparing with other agricultural production areas. The State Government requested a feasibility study on the implementation of the above navigation project to Japanese Government.

2. The Parnaíba river is located in the Northeastern part of Brazil, flowing along the border of the State of Piauí and Maranhão with the length of 1,344 km. Until 1960's, the Parnaíba river was utilized for river transportation between Santa Filomena and Parnaíba cities mainly for the transport of agricultural products. However, the river transportation along the Parnaíba river dwindled, especially after the construction of Boa Esperança Dam.

3. At present few navigation services are available in the Parnaíba river other than at the mouth of the delta zone or between Parnaíba and Luzilandia on a small scale, where the land transport system is insufficient.

4. The population in the State in 1990 was estimated at about 2.6 million, which comprises 1.8 % of the whole in Brazil. The Teresina area in the northern part of the state is densely populated, and is also downstream on the Parnaíba river. The major cities of the State are located along the Parnaíba river, where about one million people live in such urban zones. The annual growth rate in the decade from 1980 to 1990 was estimated as 2.1 % and the resulting forecast predicts its population to be about 4 million in 2010. The climate of the state is always hot throughout a year, though there is a distinct difference between dry and wet seasons. The annual rainfall along the Parnaíba river ranges from 1,000 mm to 1,800 mm, causing a remarkable change of the water depth in the river.

5. There are nine field stations along the Parnaíba river for monitoring the daily water level. The data from these records and from the investigation on the natural conditions newly conducted by the Study Team show the mean discharge in the river ranges from 80 to 90 ton/sec in the upper reaches, from 300 to 400 in the middle reaches and from 400 to 500 in the lower reaches. The difference of water depth between wet and dry seasons is about 1 m in the upper reaches, 1.5 m in the middle reaches and from 2 to 3 m in the lower reaches, increasing in difference the further lower reaches.

6. From Amarante, which located in the middle reaches of the Parnaíba river to the lower reaches many sand bars are located and the water becomes shallower. In particular, the maximum water depth in the sand bar areas around Luzilandia is estimated at 1.2 m and 1.5 m around Fazenda Veneza. They are limitations imposed on the drafts of the vessels to be maneuvered. In addition, flow velocity in the river is in the range from 1.3 to 1.8 m/s in the upper reaches and is 1.0 m/s in the lower reaches. The highest velocity of 2.2 m/s is evaluated near Guadalupe, downstream of the Dam.

7. Because of the suspended construction at the Port of Luiz Correia facing the Atlantic Ocean, only the ports at Fortaleza and at Itaqui in other states are terminals for the foreign trade in the State of Piauí. Almost all of the cargoes in the State are transported by land, mostly by trucks. The current network of roads in the state is developed mainly in the northern part around Teresina, namely in the lower reaches of the Parnaíba river. The present length is about 2,300 km in total. In the same manner, railway operations are only available around Teresina between Fortaleza and Itaqui, mainly transporting Oil products.

8. The Parnaíba river basin can be divided into three zones considering the present traffic conditions. The first zone, designated as "Zone 1", is from Luiz Correia to Teresina, the second designation of "Zone 2", is from Teresina to Floriano and the last zone, designated as "Zone 3", is from Floriano to Santa Filomena.

9. Zone 1 is one of the most developed areas and all kinds of transport modes are concentrated in this area. After the accomplishment of the river navigability, it will have to compete with other transport system, such as railways and roads. Zone 3 is still undeveloped, though there is a large scale development plan in the agricultural sector. The current population density is comparatively lower and there are no roads for transport by vehicles. Competition is hardly expected from other transport systems. Zone 2 is in the middle of Zone 1 and 3, where the river navigation will compete with land transport by vehicles.

10. For planning the river transport, agricultural products in the upstream region, namely rice, corn, soybean, fejon, fruits, nuts, etc., are considered as the main cargoes as well as commodities such as salt, fertilizer, sugar, wheat and oil products. A target year is set at 2010 for the potential cargo demand for river transport. The demand for agricultural products is depicted from the forecast by the State Secretary of Agriculture and that for other commodities is predicted based on the population and total agricultural production in the future.

11. The limitations on the river transport in the Parnaíba river are first the Boa Esperança Lock, in a state of suspended construction, and second the water depth around sand bars existing downstream of Amarante, especially in dry season. Passage of the Lock requires drafts less than 2.3 m satisfying the minimum water depth at the Lock of about 2.5 m. In the channel, the drafts have to satisfy the shallower water around Fazenda Veneza and Luzilandia, where many sand bars exist. For other limitations, the size of the vessels and the number of vessels to be maneuvered shall be considered with regard to the dimensional arrangement of the Lock and its operating hours.

12. A pusher and a barge system are both applicable in the Parnaíba river. However the barge system is not recommendable because of its piloting difficulties in winding areas, its steering sensitivity in shallower water and its principal instability under faster flow. The ships to be in service should be the self-propulsive type and be of lock passable size. The corresponding dimensions are 47 m in overall length, 11 m in breadth, 3.0 m in draft and 8 knots in servicing speed.

13. Considering the above limitations and assuming 18 hrs. operation at the Lock, the allowable maximum cargo volume is estimated for the above self-propelled cargo vessels. The evaluation is as follows:

Zone 1 : 593 thousand ton
Zone 2 : 737 thousand ton
Zone 3 : 1,095 thousand ton
Locks : 1,249 thousand ton

14. The following 4 scenarios are assumed for predicting the transport volume with considerations to the above allowable capacity and the inherent demand.

Scenario 1 : Transport between Santa Filomena and Parnaíba - The restrictions are imposed by the water depth at the locks in the rainy season and between Fazenda Veneza and Luzilandia in the dry season.
Scenario 2 : Transport between Ribeiro Goncalves and Teresina - The water depth is critical at the locks in the rainy season and also at Fazenda Veneza in the dry season.
Scenario 3 : Transport between Ribeiro Goncalves and Floriano - The water depth is critical at the locks in the rainy season and also at Urucui in the dry season.
Scenario 4 : Transport up to Teresina in the rainy season and to Floriano in the dry season - The same condition as in Scenario 3.

15. The required number of vessels, transporting volumes and corresponding costs in 2010 are summarized as shown below.

Outline of Each Scenario in 2010

Particulars	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Service Section (from St. Filomena to)	Parnaíba	Teresina	Floriano	Wet Season : Teresina Dry Season : Floriano
Required Nos. of Vessels (in 2010)	53 units	46 units	31 units	40 units
Transporting Volume (ton-km/vessel/year)	8,874,000	9,417,000	13,930,000	10,749,000
Transporting Cost (us$/ton-km) (including capital invest.)	0.0429	0.0388	0.0262	0.0272
Transporting Cost (us$/ton-km) (excluding capital invest.)	0.0281	0.0249	0.0168	0.0182

16. To facilitate the above navigation plan, the linking of activities upstream of the Boa Esperança Dam with these downstream have to be examined, for the lock splits the channel into two zones as an obstructive gate. As a result of the comparative study on such navigation all the way through the channel, the resumption of the Lock is recommendable.

17. The Boa Esperança Lock was planned to connect upstream and downstream sides by two locks with 47 m maximum difference in the water levels. The particulars for both the locks are 50 m effective chamber length, 12 m width, 26 m maximum water depth, with a minimum 2.5 m and a maximum difference in water level of 23.5 m. The suspended construction will be completed within 3 years with the installation of machinery, electrical equipment and controll systems.

18. According to the operational plan, river ports are planned at some of the major cities along the river. Navigation aids for safe maneuvering are also proposed at sharp curves or in the shallower zones of sand bars. The ports studied are classified into 4 types for planning. The navigation aids are planned basically assuming daytime maneuvering according to the regulations issued by the "Permanent International Association of Navigation Conference". The following number of ports and navigation aids are proposed:

Proposed Number of the River Ports and Navigation Aids of Each Scenario

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Service Section (from St. Filomena to)	Parnaiba	Teresina	Floriano	Wet Season : Teresina Dry Season : Floriano
Proposed Number of the River Ports	13	8	5	8
Proposed Number of the Navigation Aids	475	213	109	213

19. To maintain, manage and operate the facilities, management offices are proposed at the major cities along the river. They consist of four kinds according to their responsible facilities or operations, namely vessel operations, river port, channel and locks. In the State of Piauí, there should be a main office controlling the overall activities of the navigation and for its promotion.

20. Based on the previous plans on the operation of vessels, the resumption of the lock, the construction of the river ports, the installation of navigation aids and their maintenance/management/operation, an estimation of related costs for the project is conducted by using the relevant rates in September 1994. The evaluation is summarized as follows.

Project Cost in Each Scenario

Unit : US$

Project	Scenario 1	Scenario 2	Scenario 3	Scenario 4
A. Construction and Procurement Cost				
1 Lock Resumption	15,480,000	15,480,000	15,480,000	15,480,000
2 Port Construction	57,130,000	46,200,000	33,920,000	46,200,000
3 Vessel Procurement	60,420,000	52,440,000	35,340,000	45,600,000
4 Navigation Aids	830,000	360,000	200,000	360,000
sub-total	133,860,000	114,480,000	84,940,000	107,640,000
B. Engineering Fee	13,380,000	11,442,000	8,490,000	10,760,000
C. Physical Contingency	6,760,000	5,778,000	4,370,000	5,400,000
Total	154,000,000	131,700,000	97,800,000	123,800,000

Running Cost in each Scenario

Unit : US$

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
1 Vessel Operation Cost	13,207,600	10,777,800	7,263,300	7,812,000
2 Office Administration Cost				
1) Vessel Operation Office	2,802,000	1,809,600	1,148,400	1,589,200
2) Port Operation Office	4,131,600	2,776,800	1,820,400	2,458,000
3) River Management Office	2,961,600	1,736,400	1,574,400	1,682,400
Subtotal	9,895,200	6,322,800	4,574,400	5,729,600
Total	23,102,800	17,100,600	11,837,700	13,541,600

21. In the economic evaluation, two main benefits are considered. They are the cost saving effect of the transporting measures expressed as the difference between the river navigation and land transport, and the benefit from agricultural production also expressed as the difference between the market price and cost for production of soybeans. The resulting economic internal rate of return, conventionally termed as EIRR, is calculated for 30 years of the project period. The result for each scenario is shown below. It concludes that only the feasibility of scenario 4 can be confirmed.

Estimated EIRR in Each Scenario

EIRR %	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Including the benefit from production	Minus	6.56	8.54	11.02
Excluding the benefit from production	Minus	2.64	8.54	7.86
Discounting 5 % of the construction cost	-	-	-	11.59

22. Successive examination of the net present value (NPV), and of benefit and cost ratio (B/C), is proceeded only for Scenario 4, for its relative superiority among other scenarios. As shown in the above table, sensitivity analysis reducing 5 % of the construction cost was also tried for IRR, NPV and B/C. The result is shown in the following table. Note that all the computations are conducted with the national parameter of 0.1 in Brazil.

EIRR, NPV, and B/C in Scenario 4

	Original Case in Scenario 4	5 % Reduction in Construction cost of Scenario 4
EIRR	11.02%	11.59%
NPV	US$ 7,807,152	US$ 11,725,641
B/C Ratio	1.05	1.08

23 Scenario 4, which was previously considered feasible in view of economics, was subject to further financial evaluations in detail. For calculation of the financial internal rate of return (FIRR), the transport cost of the river navigation including capital cost applicable to Scenario 4 is 0.0272 US$/ton-km. According to the calculation in the case of all the project costs to be repaid, the corresponding figure indicates a negative value, meaning a lack of feasibility in the project. To sort out the difficulty in the project implementation and to find a more feasible solution, attempts were made by asking the following four questions.

Case 1 : How high is the unit transport charge (per ton-km) to be so as to repay the total project cost including its operation?

Case 2 : How much will the FIRR be, if the transport revenue from competitive charges against trucks can cover the cost of ship building and O&M?

Case 3 : How much is an appropriate charge just to cover the cost of ship building and associated O&M costs?

Case 4 : If the competitive charge against transport by trucks, i.e., 0.0272 US$/ton-km, is applied, how many subsidies for ship building would be needed?

24. The following table shows the results and solutions found through the above examination. It shows that unless the cost by trucks is increased to 0.10 US$/ton-km or more, the feasibility of the project cannot be achieved. Consequently, if it is decided to execute the project under the present conditions, all the costs for the resumption of Boa Esperança Lock, construction of the river ports and cost for the installation of navigation aids must be borne by public expenditure that does not require repayment. In addition, 50 % of the cost for ship building should be provided as a subsidy from the government.

FIRR in Scenario 4 in Each Case

Case	FIRR	Possible Solution
Original Case in Scenario 4	Minus	
Case 1	11.26 %	Charge per ton km is to be US$ 0.0816
Case 2	2.91 %	Impossible to repay
Case 3	11.89 %	Charge per ton km is to be US$ 0.0354
Case 4	11.78 %	50 % of the cost for ship building is to be subsidized

25. Summarizing the above solution and considering various positive effects counted as indirect benefits in qualitative examination, such as development promotion or an increase in the employment opportunities for undeveloped areas, it concludes that

1) only Scenario 4 is economically viable and
2) public investments requiring no redemption are essential for the project accomplishment without financial difficulties.

26. The analysis of the environmental study for the development of river transportation on the Parnaíba river basin shows that no serious damage will be imposed on the environment, although there are expected to be various kinds of influence from the restart of river navigation activities.

27. Throughout the course of the studies so far conducted, the applicability, the feasibility and the possibility of river navigation on the Parnaíba river have been investigated as a transporting method for agricultural products promoting the sectorial development in the South-west region of the State. The main conclusions derived from the study are summarized below.

1) River navigation along the whole of the Parnaíba river is at present very difficult because of the following reasons:

- The cargo volume transported downstream of Teresina will decrease greatly during the dry season, because only smaller vessels of 0.9 m or less in draft can safely manoeuvre in the channel. The outcomes of such a limitation are lower efficiency in the transport and the resulting higher transporting cost expressed in a unit per ton-km. The possible solution would be regular dredging work or construction of effective groins to provide sufficient water depth in the channel, though the required investment would be great, and thus it could no longer be payable only from the transporting revenues.

- The particulars of vessels traveling in the channel will be affected by the existing locks at Boa Esperança, particularly in their size. In terms of safe maneuvering, self-propelled vessels shall be assigned rather than barges without propellers. Subsequent transporting cost per ton-km for such vessels will be comparatively higher and less competitive than for transport by barges, typically practised in the river Tiete.

2) The development of a port at Luiz Correia located at the mouth of the Igaraçu river has a potential prospects for its future, though the necessity of its urgent implementation has

not been yet confirmed for the project period until 2010. For the time being, the ports of Fortaleza and Itaqui will preferably be utilized as a substitution.

3) A feasible scenario can possibly be proposed in view of the socio-economic situation around the Parnaiba river, where the river navigation is limited to the upstream region of Floriano in dry season and to that of Teresina in the dry season. Despite such conditions, the project still requires a great deal of investment. The feasibility from a financial aspect for a prolonged period will still be discouraging.

4) The essential implications stated above serve as a significant warning about the project implementation. Deliberate and obstinate determination shall be required in the implementation program covering aspects on the possible funding resources, the commencement schedules, etc.

28. To extend the above conclusions, some recommendations shall be stressed as below:

1) As a life-line of transporting agricultural products from the south-west region of the State, a state-wide study on the facilities supporting the State infrastructure will be a possible room for the development plan. It is worth studying overall transport activities, perhaps constituting a linking network in the state.

2) Despite relatively low feasibility for the river navigation, any countermeasures shall be adopted sooner or later in order to offer an effective transport service for the future demand of agricultural products, because no such transporting system is currently available in the southwest region of the State. If the program is implemented, backed up by an adequate financial policy, a pilot program on a smaller scale, using much smaller vessels, shall firstly be planned and examined. Based on such trials, the actual project will be continued by solving the problems experienced in the prototype.

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1. INTRODUCTION

1. INTRODUCTION

1.1 Project Background

The Parnaíba river is located in the Northeastern part of Brazil, flowing along the border of the State of Piauí and Maranhão with a length of 1,344 km. Until 1960's, the Parnaíba river was utilized for river transportation between Santa Filomena and Parnaíba cities mainly for the transportation of agricultural products. However, river transportation along the Parnaíba river dwindled, especially after the construction of Boa Esperança Dam.

The upstream area of the Parnaíba river is underdeveloped, due to insufficient infrastructure. To resolve this problem and to develop this area, the State of Piauí is implementing various projects, including transportation projects and agricultural development projects. Especially, the State of Piauí is interested in the development of a river navigation system which can compete with other agricultural production areas with low transportation costs. The goods produced in the State of Piauí are transported through Fortaleza or Itaqui Ports at present. The competitiveness of produced goods in the State of Piauí is lessened due to the lack of a good transportation system with low costs.

In order to resolve the lack of a transportation system, the State of Piauí started the construction of the Luiz Correia Port in 1976 through the PORTOBRAS as well as the construction of the Boa Esperança Lock in 1974. However the construction of Luiz Correia Port and Boa Esperança Lock were suspended in 1989 and 1982 respectively, because of financial problems. To resume the suspended port and lock constructions, would mean that the State of Piauí would be able to transport agricultural products by means of river transportation and a marine port. However, the inland transportation system is not yet established.

In this regard, the State Government requested the Japanese Government for the realization of the Feasibility Study in order to examine the possibility of the river transportation of the Parnaíba River.

1.2 Contact and S/W Mission

In response to the request of the Government of the Federative Republic of Brazil, the Government of Japan decided to conduct the Feasibility Study on the Navigation of the Parnaíba River Basin in the Federative Republic of Brazil (hereinafter referred to as "the Study").

(1) Contact Mission

In March 1992, the Japan International Cooperation Agency (hereinafter referred to as "JICA"), the official agency responsible for the implementation of the technical cooperation programs of the Government of Japan, dispatched a Contact Mission headed by Dr. Tadahiko Yagyu to the Federative Republic of Brazil for the purpose of clarifying the contents of the Feasibility Study on the Navigation of the Parnaíba River Basin and agreed on the Minutes of the Meeting of Contact Mission with the State Secretary of Planning of the State of Piauí (hereinafter referred to as "SEPLAN").

See Appendix 1-1 for the Minutes of Meeting of the Contact Mission.

(2) S/W Mission

In July 1992, JICA dispatched a preparatory study team headed by Dr. Hiroichi Tsuruya to the Federative Republic of Brazil for the preparatory study and for the discussions on the Scope of Work which was agreed on between the State Government of Piauí and the Preparatory Study Mission on August 12, 1992 (see Appendix 1-2 for the Minutes of Meeting on Scope of Work of S/W Mission).

1.3 Study Area

The Study area covers the Parnaíba river, from Santa Filomena to Luiz Correia, for a distance of 1,180 km and the Balsas river, from the Balsas to the Uruçui for a distance of 220 km.

1.4 Objective

The purpose of the study is to examine the feasibility of river transportation on the Parnaíba and Balsas rivers, to formulate a river transport development plan and to transfer relevant technologies to the counterparts through the Study.

1.5 Study Phases

The Study divided into five phases. Fig. 1.5.1 and Table 1.5.1 show the flow chart and outline of the Study respectively. During these phases, especially at the time of explanation of the study reports, the minutes of meeting were exchanged between the parties (see Appendix 1-3 to 1-6 for the minutes of meetings exchanged by the JICA Study Team).

(1) Phase I Study

The Phase I study was conducted from December 1992 to March 1993. During the Phase I study, the following works were done.

- Explanation and discussion of the Inception Report
- Collection of data/information and field reconnaissance survey
- Water level observation and installation of water level monitoring stations
- Preparation of the Field Report
- Explanation and discussion of the Field Report

(2) Phase II Study

The Phase II study was carried out from May to August 1993. During the Phase II study, the following works were done.

- Aerial photography
- Preparation of mosaic photos

Table 1.5.1 Outline of the Study

	Y	M	Activity	Main Activity: Piaui State	Main Activity: Japan	Report
Phase I	1993	12		Field Reconnaissance Survey Installation of water level observation site Preparation of the Field Report		Inception Report Field Report
		1				
		2				
		3				
Phase II		4		Preparation of aerial photos Study on river conditions Washout Volume Study	Preparation of mosaic photos Preparation of the sand bar inventory Preparation of the Interim Report(I)	Interim Report (I)
		5				
		6				
		7				
Phase III		8		Observation of the river bed movement Natural conditions survey Washout volume study Transportation system study Environmental Study	Preparation of the Progress Report	Progress Report
		9				
		10				
		11				
		12				
	1994	1				
		2				
		3				
Phase IV		4		Additional data collection of river bed movement	Study of transportation system Study of navigability Formulation of socio-economic frame work Prediction of transportation demands Transportation system planning Planning of cargo transportation system Transportation facilities planning	Interim Report (II)
		5				
		6				
		7				
		8				
		9				
Phase V		10			Facility planning Construction schedule Operation and maintenance planning Project cost estimation Project evaluation Environmental consideration Project implementation program	Draft Final Report
		11				
		12				
		1				
		2				
		3				

Work in Piaui State

Work in Japan

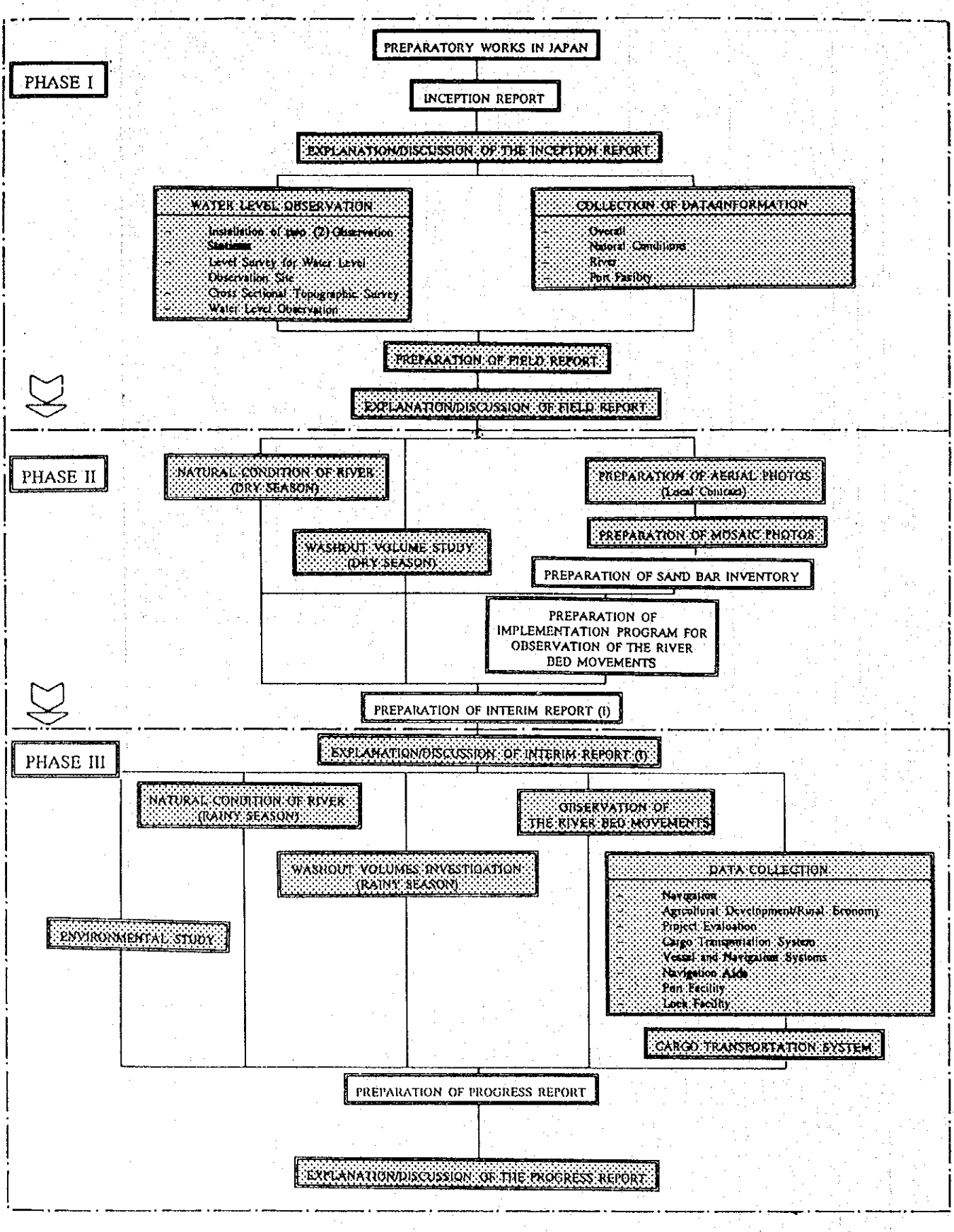

Fig. 1.5.1 (1) Flow Chart of the Study

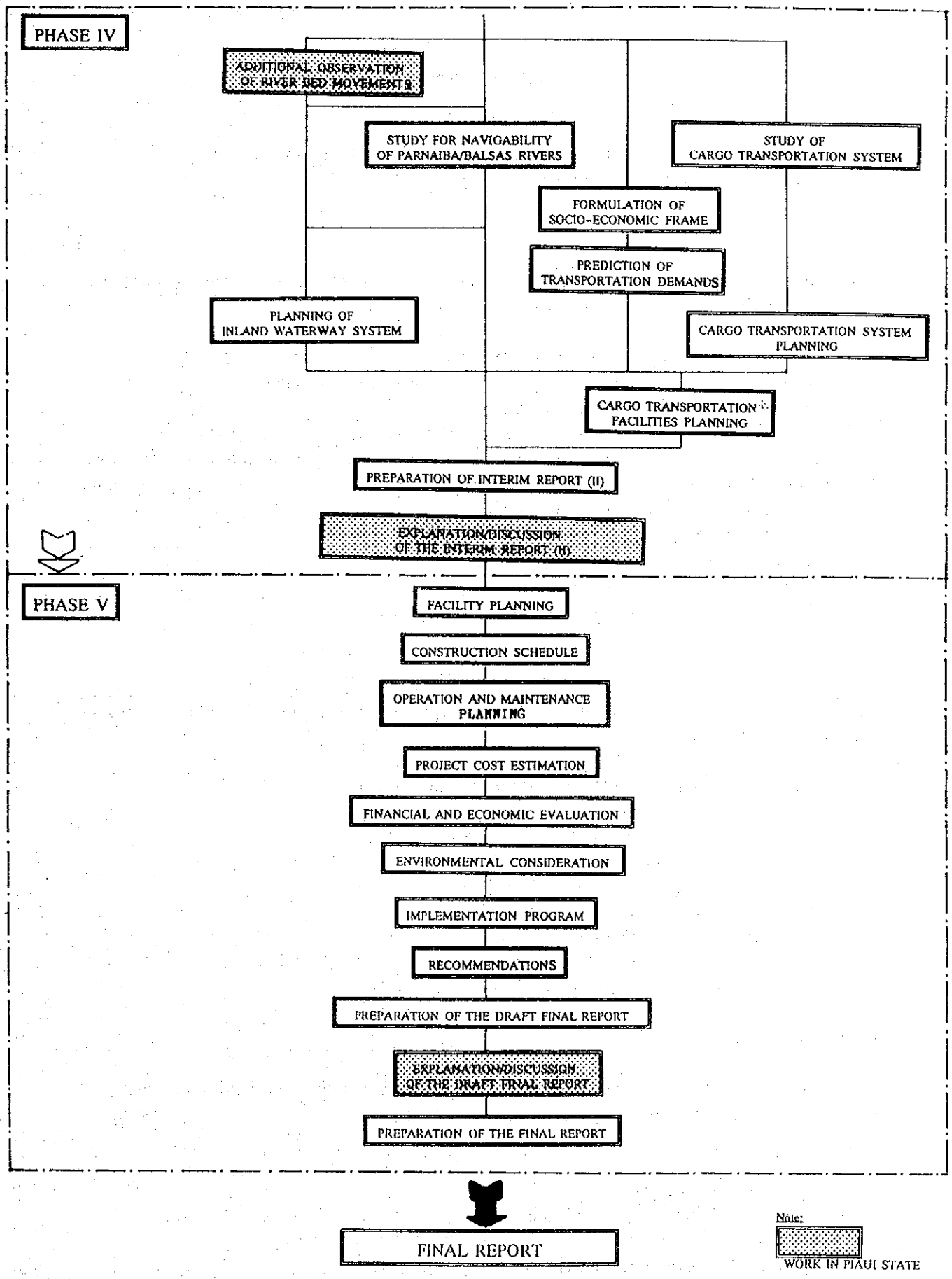

Fig. 1.5.1 (2) Flow Chart of the Study

- Field reconnaissance survey for the construction of spur dikes
- Preparation of sand bar inventories
- Natural condition survey for dry season
- Washout volume study in the Caninde and Poti rivers during dry season
- Preparation of the Interim Report (I)

(3) Phase III Study

The Phase III study was conducted from September 1993 to March 1994. During the Phase III study, the following works were done.

- Explanation and discussions of the Interim Report (I)
- Construction of spur dike and observation of river bed movement
- Natural condition survey for rainy season
- Washout volume study in the Caninde and Poti rivers during rainy season
- Data collection and field reconnaissance survey for social and economical conditions, agricultural conditions, vessel maneuvering and navigation system, navigation aids and river transportation system, lock and port facilities
- Cargo transportation system survey
- Environmental impact survey
- Preparation of the Progress Report
- Explanation and discussion of the Progress Report

(4) Phase IV Study

The Phase IV study was carried out from June to September 1994. During the Phase IV study, the following works were done.

- Additional observation of river bed movement
- Study of cargo transportation system
- Study of navigability of the Parnaíba and the Balsas rivers
- Prediction of transportation demand
- Cargo transportation system planning
- Planning of river transportation system
- Cargo transportation facilities planning
- Preparation of the Interim Report (II)
- Explanation and discussion of the interim Report (II)

(5) Phase V Study

The Phase V study was conducted from September 1994 to March 1995. During the Phase V, the following works were done.

- Facilities planning
- Construction schedule
- Operation and maintenance planning
- Project cost estimation
- Financial and economic analysis
- Preparation of the Draft Final Report

- Explanation and discussion of the Draft Final Report
- Preparation of the Final Report

1.6 Participants of the Study

Participants of the study are (1) Japanese Advisory Committee members, (2) The JICA Study Team, and (3) Counterparts to the JICA Study Team.

(1) Japanese Advisory Committee members

Hiroichi Tsuruya	Chairman
Masayuki Watanabe	Member (River Hydraulic)
Masataka Shiozaki	Member (Channel Planning)
Yoshikazu Takino	Member (Channel Planning)
Isao Tobiki	Member (Port Planning)
Seiji Matsumoto	Member (Port Planning)

(2) The JICA Study Team

Makoto Tanaka	Team Leader/Port Planning/Environment
Masakazu Ikehara	Member (Natural Condition)
Tsutomu Kameyama	Member (River)
Asushi Kishi	Member (Sabo)
Akira Watanabe	Member (Vessel Maneuvering)
Masayuki Honjyo	Member (Agricultural Development/Rural Economy)
Motoyoshi Yamada	Member (Demand Prediction/Project Evaluation)
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Kazuhiro Watanabe	Member (Navigation Aids)
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Antonio Alexandre	Natural Condition Study

2. OUTLINE OF THE STATE OF PIAUÍ

2. OUTLINE OF THE STATE OF PIAUÍ

2.1 Natural Conditions

(1) Topography

The State of Piauí is located in the western part of the Northeastern region of Brazil with an area of 250,934 km2 (representing 2.95 % of the total Brazilian territory). The linear distances are 887 km from the far North to the far South, and 618 km from the far East to the far West. The highest point is registered on the Mangabeiras Plateau at 880 m above sea level, located on the border of the State of Tocantins. About 82% of the land area is below 600 m altitude, and 53 % is below 300 m. The territorial borders with the States of Ceará, Pernambuco, Bahia, Tocantins and Maranhão is 3,114 km long. The north coast of the State faces the Atlantic Ocean with 66 km of coastline (representing 0.89 % of the Brazilian coast).

The State is divided into 8 regions by the Comissao Estadual de Planejamento Agricola do Piauí (CEPA). Table 2.1.1 shows the area of each region and Fig. 2.1.1 shows the location of the regions.

Table 2.1.1 Area of Each Region of the State

No.	Region	Area (Km2)	Share (%)
1	ALTO PARNAÍBA	59,199	23.59
2	PLANALTO	27,743	11.06
3	LITORAL	5,145	2.05
4	SERTAO	76,863	30.63
5	IBIAPABA	36,644	14.60
6	CARNAUBEIRA	12,433	4.95
7	BAIXU PARNAÍBA	5,111	2.04
8	MEDIO PARNAÍBA	27,796	11.08
	TOTAL	250,934	100.00

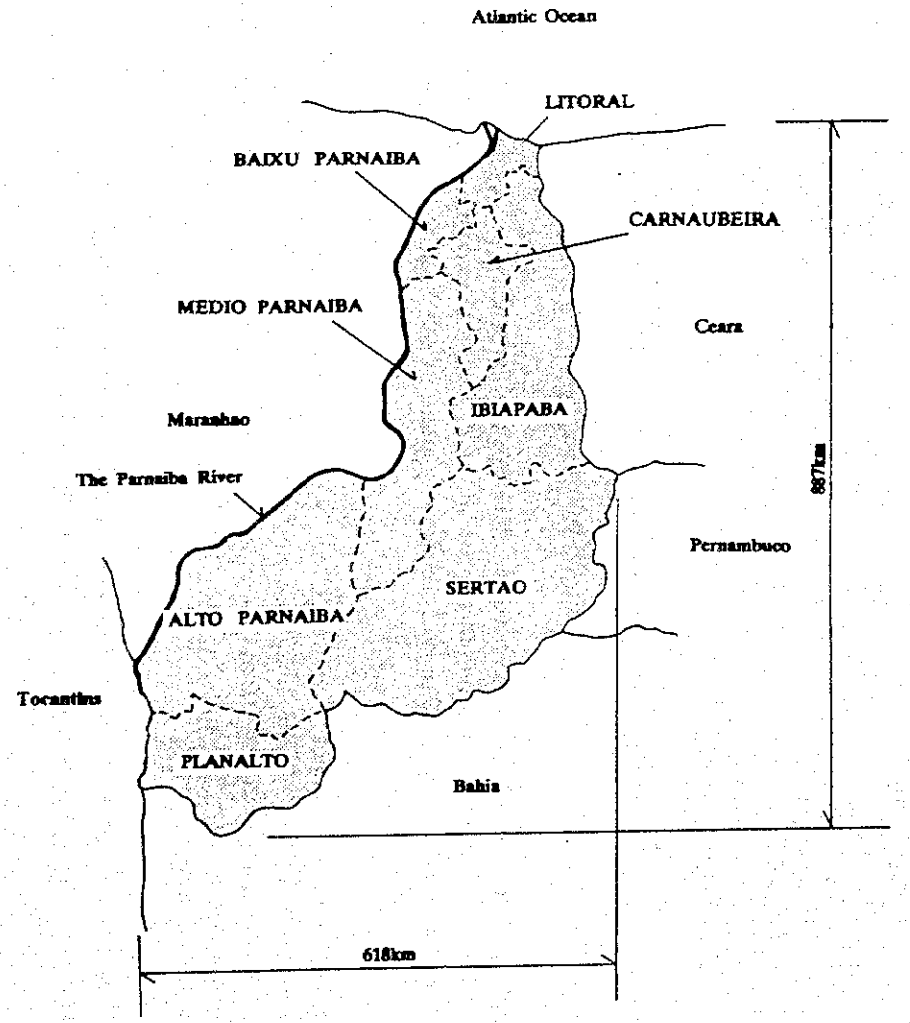
Source: COMMISSAO ESTADUAL DE PLANEJAMENTO AGRICOLA DO PIAUÍ(CEPA)

(2) Climate

On account of being a transition zone between the semi-arid Northeast and Amazon region, Piauí has a hot and humid or semi-humid climate in the North (the coastal area) and on the banks of the Parnaíba river and a hot and semi-arid climate in the Southeastern part of the State.

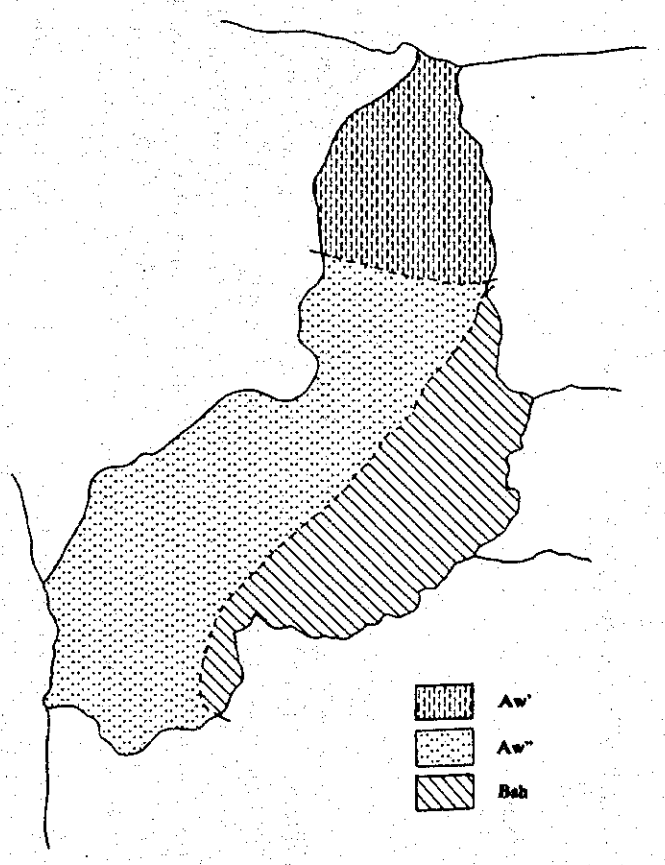
The average temperature ranges from 18° C to 39° C, and the average humidity is 72 %, ranging from 60 % to 84 %. The annual rainfall ranges from 1,000 mm in the southeastern region, to 1,800 mm in the Lower Parnaíba region. Table 2.1.2 shows climate type and rainfall in each region (see Figs. 2.1.2 and 2.1.3 for the location of each climate type and annual rainfall map of the State).

Table 2.1.3 shows a records of temperature and rainfall at Teresina in 1987. According to the record, the average temperature is about 27° C and the annual rainfall is about 1,500 mm.



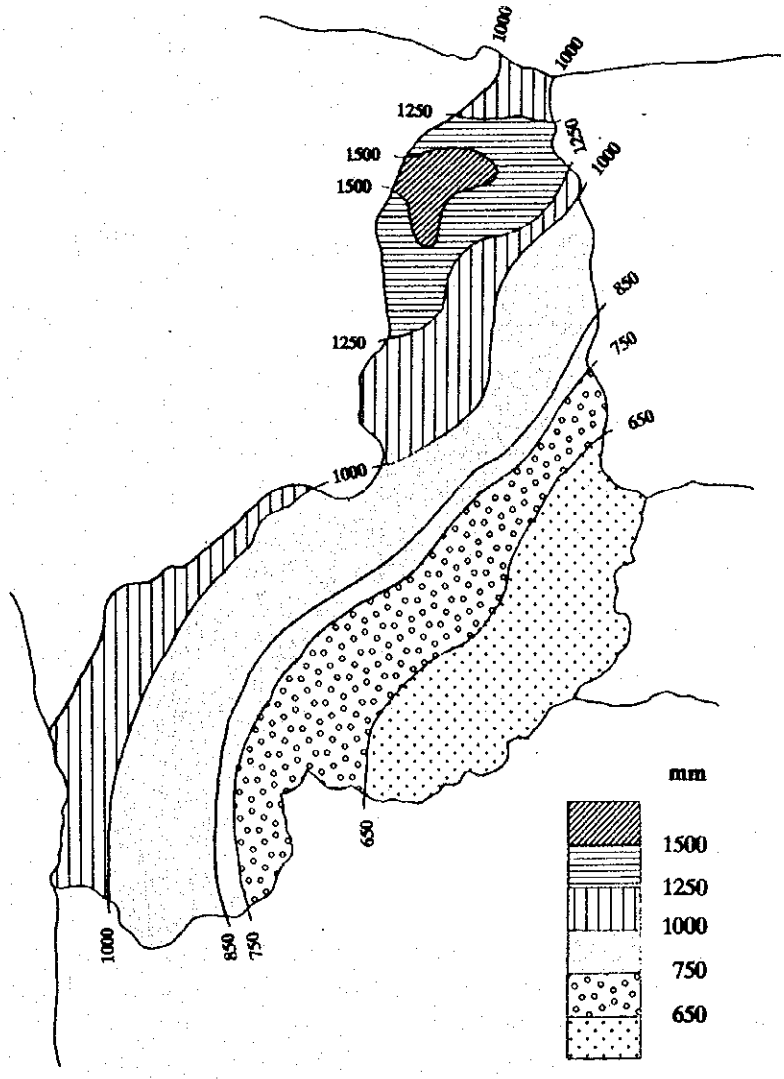
Source : Piaui, Caminhos da Industrializacao.

Fig. 2.1.1. Region of the State of Piaui by CEPA



Source : Piaui, Caminhos da Industrializacao.

Fig. 2.1.2. Climate Type



Source : Piaui, Caminhos da Industrializacao.

Fig. 2.1.3. Rainfall Map

Table 2.1.2 Type of Climate and Rainfall by Region

Region	Type of Climate	Rainfall per Year (mm)	Min. Rainfall in Month (mm)	
ALTO PARNAÍBA	AW, Bsh	1,072.5	July,	0.2
PLANALTO	AW, Bsh	1,071.7	July to Aug.,	0.2
LITORAL	AW'	1,188.0	Sep.,	1.0
SERTAO	AW, Bsh	676.7	July,	1.0
IBIAPABA	AW, AW', Bsh	1,209.3	Aug.,	3.6
CARNAUBEIRA	AW, AW'	1,462.8	Aug.,	9.8
BAIXO PARNAÍBA	AW	1,606.2	Aug.,	3.4
MEDIO PARNAÍBA	AW, AW'	1,327.7	Aug.,	5.5

Source : JICA Study Report, September 1992.

Table 2.1.3 Weather Records in Teresina (1987)

Month	Temperature (° C)			Rainfall (mm)
	Max.	Min.	Ave.	
Jan.	34.8	20.1	26.4	302.0
Feb.	36.1	19.2	26.6	230.0
Mar.	34.1	20.2	25.6	564.5
Apr.	34.6	20.0	26.7	248.2
May	33.8	20.1	26.7	54.1
June	33.9	18.8	26.3	28.4
Jul.	35.2	18.3	26.4	-
Aug.	37.2	17.1	27.5	0.9
Sep.	38.1	16.6	28.3	-
Oct.	38.7	18.8	28.7	49.2
Nov.	39.6	19.4	29.1	26.3
Dec.	NA	NA	NA	NA

Note: NA: data is not available.
Source: IBGE

2.2 Population

According to the census in 1980, the population of the State of Piauí is 2,139 thousand (representing 1.8 % of the total population of Brazil). The population of the State in 1990 is estimated at about 2,643 thousand with an average annual growth rate of 2.1%. The population in urban areas is estimated at about 49 % of the total in 1990. The average population density in the State is 10.5 inhabitants/km2 in 1990. Table 2.2.1 shows the population increase between 1940 and 1990.

According to the regional classification adopted by IBGE, the State was divided into eleven (11) homogeneous micro regions. Table 2.2.3 shows the population in the regions (see Fig. 2.2.1 for the location of the regions).

In terms of residential area distribution, the population tends to concentrate in the urban areas rather than in the rural areas. It is believed that this could be an important issue in Piauí because its main industry is supposed to be agriculture.

The major cities of the State are located along the Parnaíba river. Table 2.2.4 shows the population of the cities along the River. About one million people live in these cities, representing 38% of the total population in the State (see Fig. 2.2.1 for the location of these cities).

Table 2.2.1 Population of the State of Piauí

(Unit in thousand)

Year	Total Population	Urban Areas	Rural Areas
1940	817.6	124.2	693.4
1950	1,045.7	170.6	875.1
1960	1,242.1	285.6	956.6
1970	1,680.6	536.6	1,144.0
1980	2,139.0	898.0	1,241.0
1990	2,643.2	1,293.8	1,349.4

Source: JICA Study Report in September 1992.

Table 2.2.2 Urbanization Trend of Piauí's Population

Unit: Persons

Year	Population	Breakdown	
		Urban Areas	Rural Areas
1980	2,139,000 (100)	898,000 (42.0)	1,241,000 (58.0)
1990	2,643,261 (100)	1,144,049 (43.3)	1,499,212 (56.7)

Source : IBGE

Table 2.2.3 Population in the Regions in the State of Piauí (1990)

(Unit in thousand)

Regions	Urban Area	Rural Area	Total Population
1) Lower Parnaíba	154.3	157.8	312.1
2) Campo Maior	149.4	282.2	431.6
3) Teresina	576.1	153.1	729.2
4) Middle Parnaíba	67.8	57.7	125.5
5) Valenca do Piauí	41.5	65.9	107.4
6) Floriano	84.9	73.0	157.9
7) Agricultural Lowlands	109.5	232.1	341.6
8) Upper Parnaíba	12.8	22.1	34.9
9) Middle Gurgucia	18.2	29.0	47.2
10) Upper Piauí and Caninde	53.6	205.4	259.0
11) The Low Plateaus of the Far South	25.7	71.1	96.8
Total	1,293.8	1,349.4	2,643.2

Source: JICA Study Report in September 1992

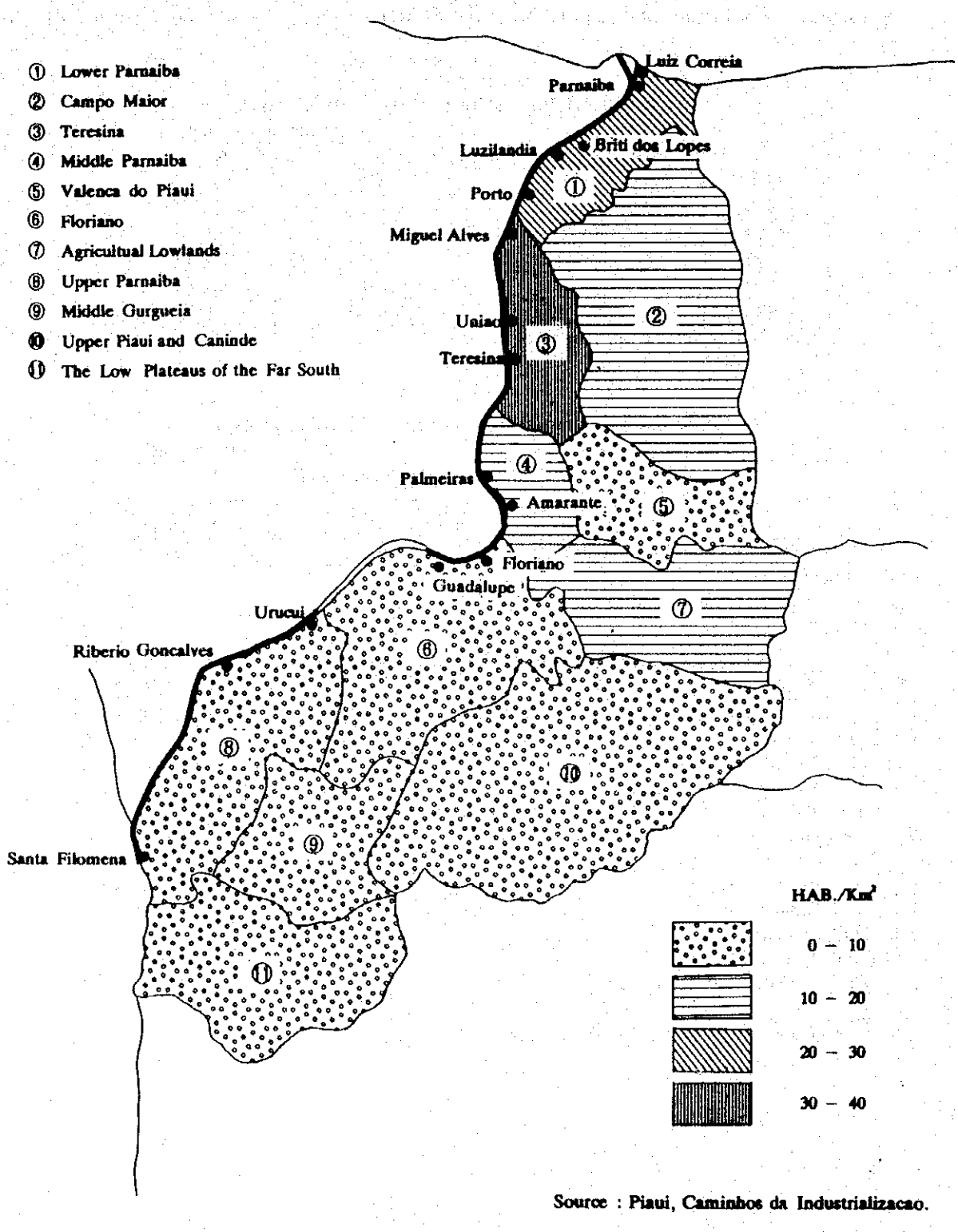


Fig. 2.2.1. Major Cities along the Parnaiba River and Regions in the States of Piauí

Table 2.2.4 Population in the Cities along the Parnaíba River (1991)

Cities	Population	Area (Km2)	Density (pop./km2)
1. Luiz Correia	28,828	1,607.2	17.94
2. Parnaíba	127,992	1,053.0	121.55
3. Briti dos Lopes	31,055	1,835.7	16.92
4. Luzilandia	36,030	1,108.6	32.50
5. Porto	14,296	752.1	19.01
6. Miguel Alves	27,672	1,493.0	18.53
7. União	41,090	1,822.9	22.54
8. Teresina	598,411	1,356.2	441.24
9. Palmeiras	11,597	1,501.0	7.73
10. Amarante	16,503	1,272.8	12.97
11. Floriano	51,445	3,650.9	14.09
12. Guadalupe	9,618	1,106.8	8.69
13. Urucuí	15,929	8,892.9	1.79
14. Ribeiro Gonçalves	11,925	11,891.1	1.00
15. Santa Filomena	5,613	5,640.2	1.00
Total	1,028,004	44,984.4	22.85

Source: Anuário Estatístico do Brasil 1992

2.3 Social and Economic Conditions

2.3.1 Social and Economic Conditions in the State of Piauí

As Brazil is a very large country, not only does the climate differ by region but regional economic gaps also exist because of the historical background of the country's development during the colonial days.

The undeveloped northern and northeastern regions of the country have an extremely symmetrical economic gap with the prosperous southern and southeastern regions. The subject of this study, Piauí (including a part of the state of Maranhão), is in the northeastern region (called Nordeste) and is ranked as one of the poorest and undeveloped regions in Brazil.

(1) Economic Gap

The following may be deduced by studying the above-mentioned gap using several economic indicators:

Table 2.3.1 shows the change in the share of Brazil's total GDP held by each region. Looking at the shares by region in 1985, the biggest share is held by the southeastern region (58.2%), consecutively followed by the southern region (17.7%), northeastern region (13.5%), mid-western region (6.2%), and northern region (4.3%).

Table 2.3.1 Distribution Percentage of the Gross Domestic Product by Region
1975 to 1985 (Unit: %)

	1970	1975	1980	1985
Brazil	100	100	100	100
Northern Region	2.2	2.2	3.5	4.3
Northeastern Region	12.0	11.5	12.1	13.5
Southeastern Region	65.0	63.7	62.1	58.2
Southern Region	17.1	18.3	17.2	17.7
Mid-western Region	3.7	4.3	5.1	6.2

Source : Published by IBGE, Anuario Estatistico do Brazil (Annual Statistics of Brazil), 1991

It may easily be inferred from the above table that the most economically prosperous region is the southeastern region. The 1985 Gross Domestic Product (GDP) figures by state show Sâo Paulo (34.1%) and Minas Gerais (9.7%), generally states in the southeastern region, to have a high share while those with a low share such as the states of Roraima (0.06%) and Tocantins (0.07%) are in the northern region; Piauí's productivity is merely 0.47%, the third lowest.

Even in terms of per capita GDP, the mid-western federal districts (Brasilia) have the highest figure while Tocantins has the lowest, followed by Piauí and Maranhâo, respectively.

However, from 1975 to 1985, the GDP of the southeastern region showed a rapid decrease compared to the other regions. This is due to the fact that during this period, a regional development plan for the poorly developed regions was undertaken and except for the southeastern region, economically strategic points were developed.

Later trends indicate that the dispersion of economic activities in Brazil is progressing but the economic gap among regions has become bigger than ever and the concentration of economic activities in the southeastern and southern regions has basically not changed.

Table 2.3.2 which shows the GDP by region and by industrial sector indicates again that the southeastern and southern regions are indeed tremendously predominant.

Table 2.3.2 Gross Domestic Product By Industrial Sector, 1985 (Unit: %)

	Brazil Region	Northern Region	Northeastern Region	Southeastern Region	Southern Region	Mid-Western Region
Primary Industry	100.0	6.6	19.0	39.1	27.2	8.1
Secondary Industry	100.0	4.1	12.1	65.7	15.7	2.4
Tertiary Industry	100.0	3.4	12.7	54.7	15.4	13.8

Source : Published by IBGE, Anuario Estatistico do Brazil, 1991

(2) Social Gap

According to a reference called IDS (see Table 2.3.3) which is an index of the social development rate of regions in Brazil (note that this index is similar to the UN standard HDI or Human Development Index), the IDS level by region indicates regional gaps which more or less match the economic level (i.e., per capita income) of the regions --- the southern region

on top followed by the southeastern, mid-western, northern, and northeastern regions, in that order. Needless to say, the northeastern region which is the subject of this study is the lowest.

Table 2.3.3 IDS Index

	Average Life Span (Age)	Literacy Rate (%)	Gini's Coefficient	IDS	Per Capita Income (in dollars)
Brazil	67	79	0.61	0.52	2,020
Southern Region	72	86	0.57	0.65	2,186
Southeastern Region	69	87	0.58	0.61	2,889
Mid-Western Region	69	81	0.63	0.54	1,642
Northern Region	69	86	0.66	0.53	1,324
Northeastern Region	55	60	0.62	0.34	841

Note: Average life span - The average life span of residents of each region in 1987
Literacy rate - the rate of adult literacy in 1985
Gini's coefficient - The lesser the value , the more the distribution among citizens.
Values are computed from 1967-1985 data.
Per capita income - The average figure for residents of each region in 1987.
Source : Published by Rodrigues, Maria Cecilia Prates, "Indice de Desenvolvimento Social), Conjuntura Economica, Vol. 45, No. 1 (January, 1991).

Note that the IDS index is a combination of Gini's coefficient that indicates average life span, rate of adult literacy, and fairness of income distribution. It is an index expressed in numerical values from 0 to 1; the closer the value is to 1, the higher the degree of social development.

One of the causes of this regional gap are the economic cycles that existed in Brazil. In each past economic cycle, export products that enriched a particular region existed. Together with export products, the economic center shifted geographically. This type of economy continued until the 1930's. The sugar cycle of the 16th and 17th centuries made the economy of the northeastern region prosperous; likewise for the present Minas Gerais state in the southeastern region owing to the gold cycle in the 18th century. The coffee cycle in the 19th century onward brought prosperity to Rio de Janeiro, and then to São Paulo. The southeastern region changed into an industrial center, along with its abundant export products. This is due to the fact that the capital accumulated from the coffee economy was invested in infrastructure facilities and industrialization. It can be said that industrialization hastened the regional gaps.

Presently, Brazil's regional gap consists of an industrialized southeastern region, an agricultural and industrial southern region, mid-western and northern regions with vast lands but a low population, and an economically and socially poor northeastern region.

2.3.2 Present Industrial Conditions in the State of Piauí

Analyzing several economic indicators for the State of Piauí, it is evident that its GDP has been growing steadily, although at a slow rate. For example, in 1970 Piauí's production accounted for 2.3% of Brazil's total, but by the late 1980's this figure had increased to 3.9%.

The highest rate of growth is recorded in early 1970's, which corresponds to the period when the Brazilian economy was at its most dynamic. This growth brought about an increase in disposable income as well as per-capita production in Piauí.

Piauí's GDP during this period also shows a substantial change in the percentages that each sector of its economy contributes to total production. All sectors grew in terms of the percentage of regional production they account for, with growth in the agricultural sector being particularly pronounced. The percentage that agriculture contributed to the states GDP increased from 3.5% to 5.6% during the period from 1970 to 1987, in contrast to the industrial sector whose share of the state's economy declined from 23.5% to 19.0% during the same period.

Manufacturing industries, whose percentage share of the state's total economic production moved in a similar manner to the industrial sector as a whole, exhibited a significant recovery in 1987.

Growth was most striking in the service industries, whose percentage of the total economic output exhibited a constant rising trend, growing from 50.7% to 57.6%. This marked increase was primarily due to the expansion of commerce and financial activities.

The agricultural sector of the State is the most important productive sector employing about 60 % of the working population of the State. The main agricultural products are maize, feijão, rice and casaba. The total cultivated area was estimated to be 1 million hectares. The main productive areas are concentrated in the lower reaches of the Parnaíba river.

The industries of Piauí at present are as follows: the picking industry (picking and processing of babuçu coconut) which occupies an important position as a local industry; there is also the agricultural industry which mainly produces corn, Feijão beans, rice and mandioca as well as the livestock farming industry with cattle and sheep as the primary products. It is believed that the future development of the said agricultural industry and agricultural product processing industry will have a big impact on the development of the state itself; related details are described in the following section.

As for the manufacturing industry, about 1,400 enterprises are concentrated mainly in the four cities of Teresina, Picos, Parnaíba and Floriano; 93.6% of these enterprises are small businesses --- the types of industry are mainly non-metal, food manufacturing, and textile which are nothing beyond cottage industries. Only in Teresina can be seen some movement towards the formation of an industrial complex which hopefully will invite many businesses.

3. NATURAL CONDITIONS OF THE PARNAÍBA RIVER

3. NATURAL CONDITIONS OF THE PARNAÍBA RIVER

3.1 Overview of the River

(1) Parnaíba River

The Parnaíba river is located in the Northeastern part of Brazil, flowing along the border of the State of Piauí and Maranhão with the length of 1,344 km. The main stream of the Parnaíba river originates in the Mangabeiras Tableland foothills with heights of about 700 m, located at 45 degrees west longitude and 10 degrees south latitude. The river runs through the lake Esperança (Esperança dam), merges with many tributaries, and finally reaches the Atlantic Ocean. The river's main tributaries consist of the Balsas river, Urucui Preto river, Gurgueia river, Caninde river, Poti river and Longa river.

The Parnaíba river shapes a large delta before flowing into the Atlantic Ocean with three river branches at the sea. The center one, with a north general direction, flows into Canárias bay. It forms the border between the State of Piauí and Maranhão. The eastern branch, called the Igaraçu river, flows into the ocean by Luiz Correia city. The west chnnel, called the Sant Rosa river is the longest one, being sub-divided in many branches, which forms several islands.

The longitudinal gradient of the river is approximately 1/6,000 for the downstream portion of the Parnaíba river (from Guadalupe to the estuary), while the upstream portion (from Santa Filomena to Urucui) is 1/3,700, which indicates that the gradient is much steeper for the upstream portion.

The rainy season of the Parnaíba river is from October to May, and the dry season is from June to September. Table 3.1.1 shows the maximum and minimum water levels of the Parnaíba and Balsas rivers.

The Parnaíba river was navigable from its estuary to the Santa Filomena until 1960' with small size of vessels mainly for the transportation of agricultural products. However, after the construction of Boa Esperança Dam in 1965, river navigation dwindled. The restrictions to river navigation are the suspended Boa Esperança Locks located at 669 km from the estuary, the sand bars mostly located downstream of the city of Amarante, and rocky outcrops downstream of the Boa Esperança Locks.

(2) Balsas River

The Balsas river has an overall length of 525 kilometers and runs through the state of Maranhâo, which merges into the Parnaíba river at Urucui. The gradient of the river bed is steep and the river is meandering.

The water levels of the Balsas river vary throughout the season similar to the Parnaíba river, with the water level at its peak in the period from October to April and the lowest water level in the period from June to September.