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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.1 SUMMARY

MARCH 1998

PACIFIC CONSULTANTS INTERNATIONAL

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FOREIGN EXCHANGE RATE

1 US Dollar (US$) = 99.85 Japanese Yen (J¥)

= 0.86 Real Dollar (R$)

1 R$ = 116 J¥

(Average rate of September, 1994)

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 summary of the Main Report for 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.

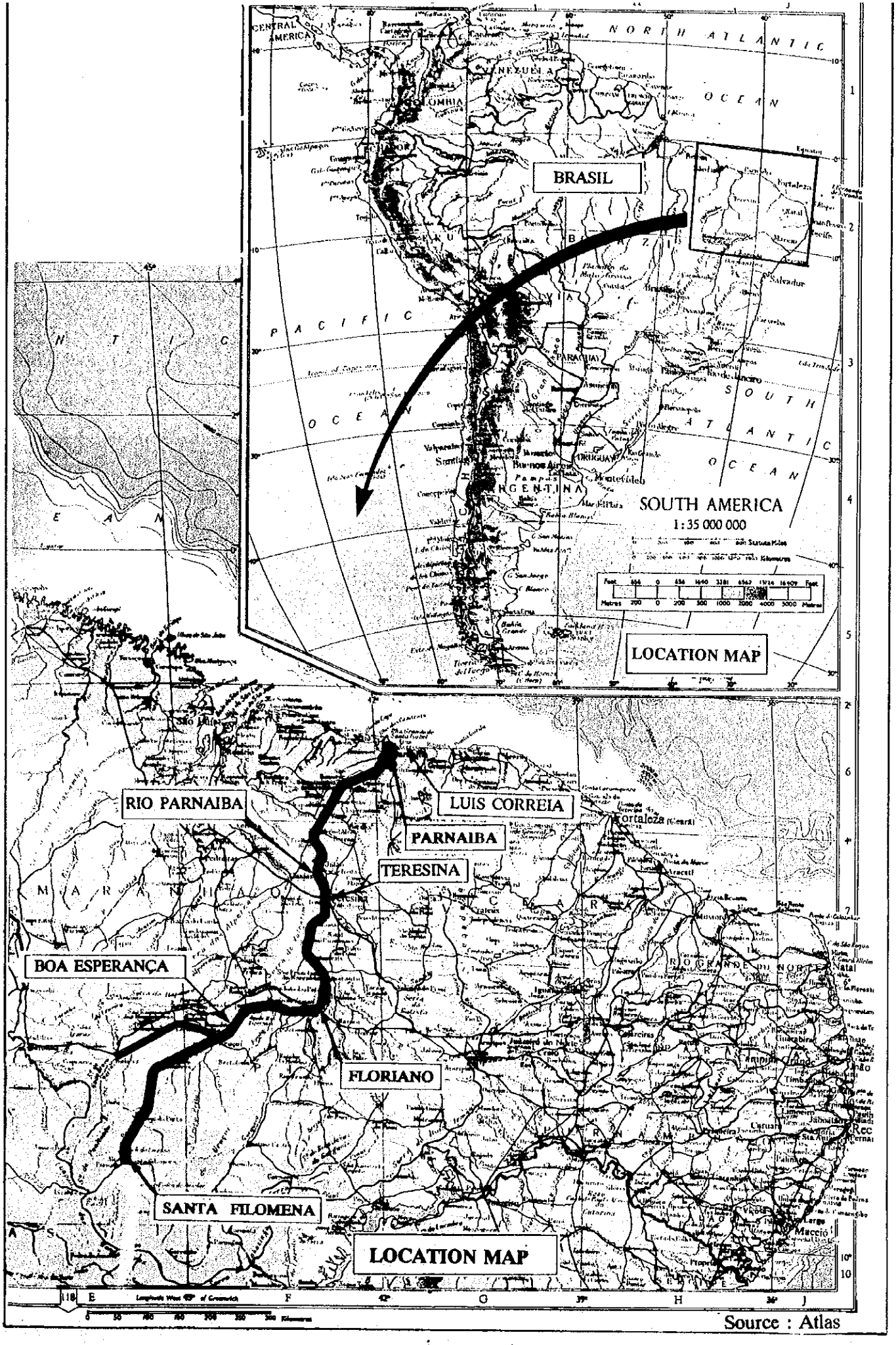
The study results show that river navigation is hardly possible all the way through to the river mouth since the efficiency of river transportation is restricted by the particulars of the river, i.e. the water depth in sand bar area and the Boa Esperança Locks for which construction was suspended due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

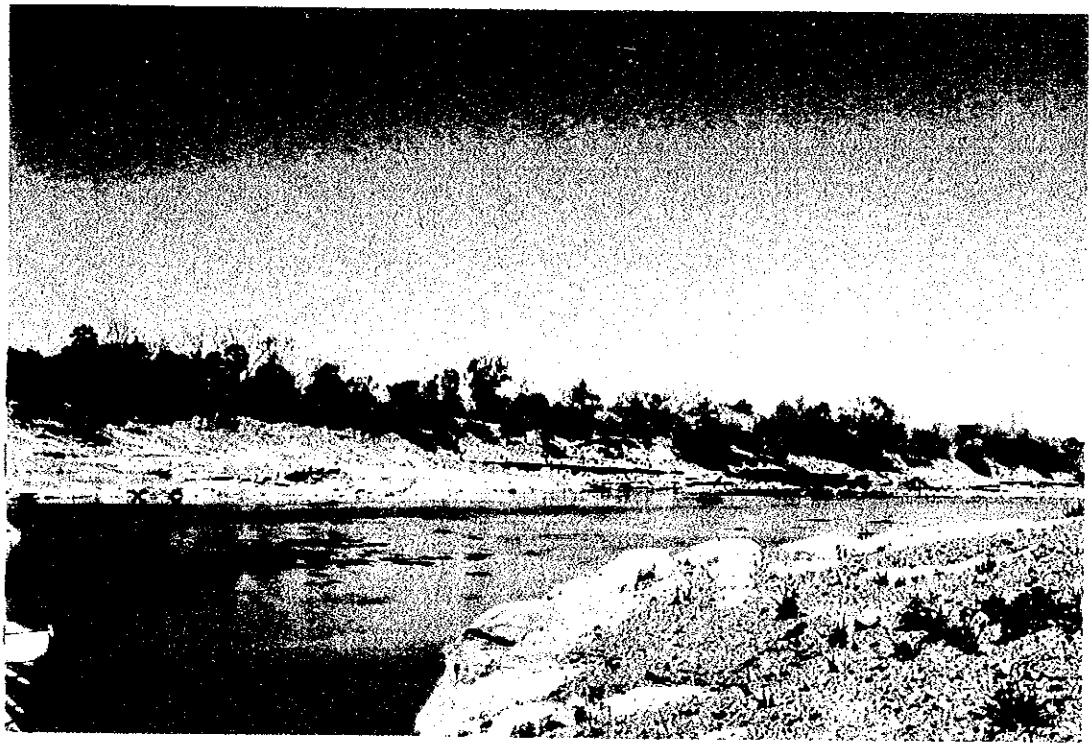
Makoto TANAKA
Team Leader
Feasibility Study on the Navigation of the Parnaíba River Basin
Pacific Consultants International


BRASIL
SOUTH AMERICA
1:35 000 000
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)	Parnaíba	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 Parnaíba 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.

TABLE OF CONTENTS

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 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 a river navigation system, for it will make the products much more competitive in the market by providing lower transporting cost compared with other agricultural production areas.

As a part of their activities, the State of Piauí started the construction of the Luiz Correia Port and the Boa Esperança Lock in the early 1970's. However both construction works were suspended in 1980's, because of financial difficulties.

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 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 to the Federative Republic of Brazil for the purpose of the realization of the Feasibility Study on the Navigation of the Parnaíba River Basin in the Federative Republic of Brazil (hereinafter referred to as "the Study"). This was followed by a preparatory study team as the S/W Mission for the discussions on the Scope of Work held on August 12, 1992 (see Appendix 1-2 in Main Report for the Minutes of Meeting on Scope of Work of S/W Mission and the Appendix 1-1 for the Minutes of Meeting of the Contact Mission, respectively).

1.3 Study Area

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

1.4 Objective

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

1.5 Study Phases

The Study consisting of five phases has been carried out in due steps. Table 1.5.1 shows the outline of the Study. All the study items in each phase are listed hereunder (see Appendix 1-3 to 1-7 in the Main Report for the Minutes of Meetings exchanged by the JICA Study Team).

(1) Phase I Study (from Dec.1992 to Mar.1993)

- 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 (from May 1993 to Aug.1993)

- Aerial photography
- Preparation of mosaic photos
- 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 (from Sep.1993 to Mar.1994)

- 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

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	
		9				
		10				
		11				
		12				
	1994	1				Progress Report
		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	
		5				
		6				
		7				
		8				
		9				Interim Report (II)
Phase V		10			Facility planning Construction schedule Operation and maintenance planning Project cost estimation Project evaluation Environmental consideration Project implementation program	
		11				
		12				
		1				Draft Final Report
		2				
		3				

Work in Piaui State

Work in Japan

(4) Phase IV Study (from Jun.1994 to Sep.1994)

- 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 (from Sep.1994 to Mar.1995)

- 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 as follows.

(1) Japanese Advisory Committee Members

Hiroichi Tsuruya	Chairman
Masayuki Watanabe	Member (River Hydraulics)
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)
Eizaburo Yoshitaka	Member (Cargo Transportation System)
Youichi Takasugi	Member (Inland Waterway Transportation Planning)
Kazuhiro Watanabe	Member (Navigation Aids)

Kentaro Yoshida	Member (Port Design/Cost Estimation)
Hideo Kurokawa	Member (Lock Facilities)
Yutaka Nakata	Member (Aerial-photographic Survey)

(3) Counterparts to the JICA Study Team

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Seiji Nakayama	Coordinator
Jose Oscar Frazao Frota	Port Facilities
Julio Emilio	River Study
Antonio Alexandre	Natural Condition Study

1.7 Outline of the Reports

The report consists of the following three volumes;

- Summary report, available both in English and in Japanese versions,
- Report on F/S in English and
- Supplementary report on pilot spur dikes.

Of the above, the summary volume in Japanese was submitted as the main report summarizing important extracts from the F/S volume. The detailed contents of the F/S volume in English are summarized as follows:

Chapter 1 describes general information of the study, i.e., the background, the schematic procedure, the scope, the participants, etc.

In Chapter 2, natural and socio-economic conditions of the State of Piauí are presented as a basis of the successive studies.

Chapter 3 also deals with natural conditions, such as water depths observed by Companihia Hidro Eletrica do Sao Francisco (CHESF) and the investigations conducted by the Study Team, in order to determine the particulars of vessels which can maneuver in the Parnaíba river.

Chapter 4 explains the present transport conditions in the State of Piauí, the results of the logistics survey, and the introduction of zoning in the Parnaíba river for planning of the navigation system with consideration the natural conditions and the present transport network. The zoning comprises three zones; that is zone 1, downstream from Teresina where the navigation competes with transport by roads and railways, zone 2, in between Teresina and Floriano and zone 3, upstream from Floriano where the navigation is independent from the other transporting measures.

In Chapter 5, the agriculture conditions in the State of Piauí is presented as well as its future projection, for such agricultural products are the main cargo transported by the navigation. The forecast adopted here is the estimation by the Agro-Industrial Center of Piauí State.

Chapter 6 develops a scenario in the case of restarting the river navigation. It is based on the predicted product volumes from the previous Chapter 5. The prediction is also extended to the potential transporting demands of agricultural products, commodities, etc.

In relation to Chapter 3 of the natural conditions and Chapter 4 of the transport conditons, Chapter 7 describes the results of the study on the particular of vessels applicable to each zone, the restrictions imposed and the allowable maximum transport volumes.

By reflecting the study results from Chapter 6 of the potential transporting demands and from Chapter 7 of the allowable maximum cargo volumes, the cargo volumes in each scenario are presented in Chapter 8. Four scenarios are assumed here. The first assumes the navigation over the whole Parnaíba river. The second and the third are cases for the navigation upstream from Teresina and from Floriano, respectively. The fourth assumes the navigation up to Teresina during rainy season and to Floriano during dry season.

The operating plan for the river navigation is proposed as a result of the study on the channel planning and on the required number of vessels in each scenario. In terms of safe maneuvering, navigation in daytime has a principal importance, whereas the operating hours upstream amounts to 18 hrs., due to the limitations on the transporting capacity at the locks.

Chapters from 10 to 12 concern planning of the facilities to be provided for the navigation, such as the resumption of locks at Boa Esperança, river ports, navigation aids, etc. The relating issues on the administration, management and maintenance can be found in Chapter 13.

Financial and economical aspects of the project are studied in Chapter 15 for each of the scenarios. It concludes that the EIRR for scenario 4, that is for river navigation to be operated from the upstream to Teresina during rainy season, will be the most superior. Its FIRR is, however, estimated relatively lower, implying the necessity of public investment for the basic infrastructures, such as resumption of the locks, construction of river ports and navigation aids.

All the environmental impacts to be considered in the project are described in Chapter 16. The last Chapter 17 is the conclusion of the study and includes additional recommendations to be stressed for the successful implementation of the project.

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. About 82% of the land area is below 600 m in altitude, forming a relatively flat terrain. The territorial border with the State of Ceará, Pernambuco, Bahia, Tocantins and Maranhão is 3,114 km in total length. 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). Fig. 2.1.1 shows the location of the regions.

(2) Climate

The average temperature ranges from 18° C to 39° C, and the average humidity is 72 %. The annual rainfall ranges from 1,000 mm in the southeastern region, to 1,800 mm in the Lower Parnaíba region (see Fig. 2.1.3).

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 in urban areas is estimated about 49 % of the total in 1990. The average population density in the State is 10.5 inhabitants/km2 in 1990 and the corresponding total population is 2,643 thousand by estimation. Table 2.2.1 shows the population increase from 1940 to 1990.

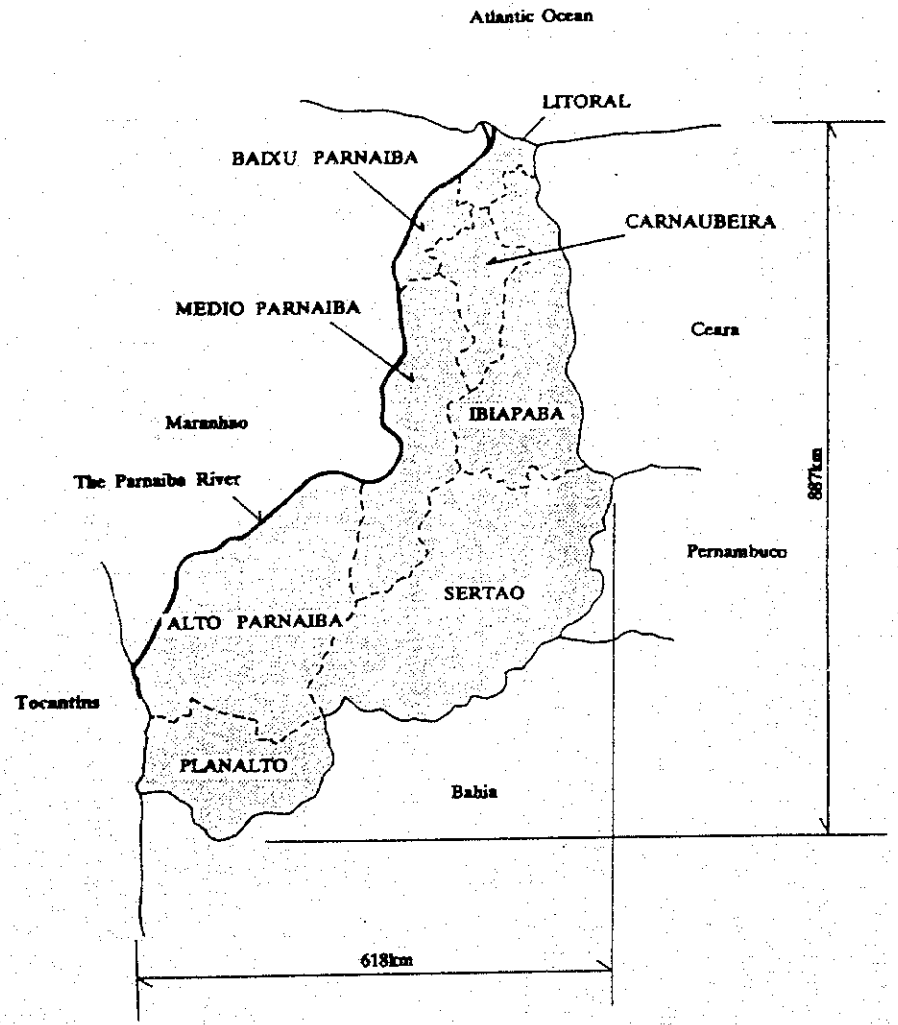
The major cities of the State are located along the Parnaíba river. Table 2.2.4 shows the population of the cities along the River. About one million people live in these cities, representing 38% of the total population in the State (see Fig. 2.2.1 for the location of these cities).

Table 2.2.1 Population of the State of Piauí

(Unit in thousand)

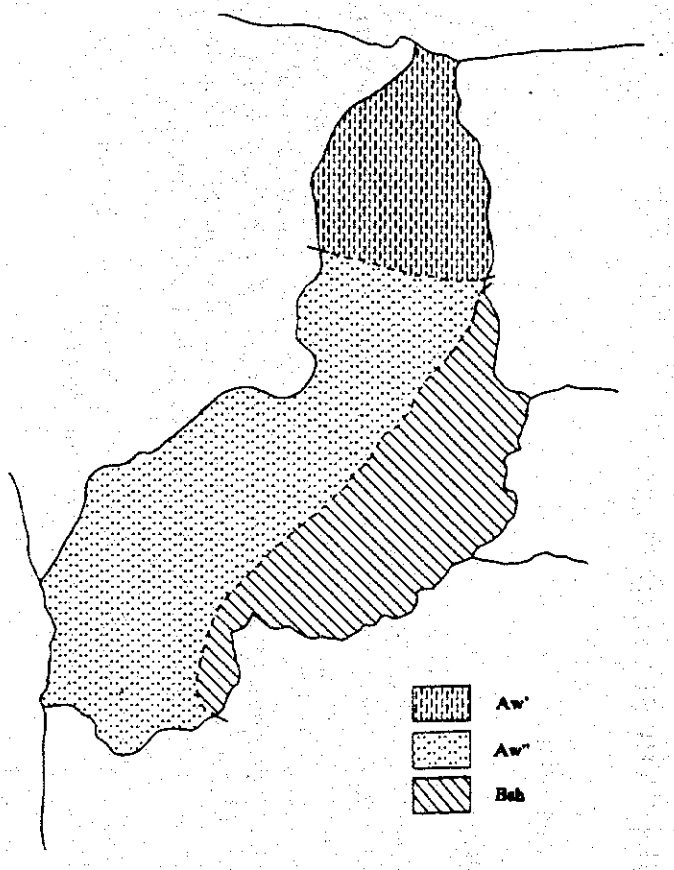
Year	Total Population	Urban Areas	Rural Areas
1940	817.6	124.2	693.4
1950	1,045.7	170.6	875.1
1960	1,242.1	285.6	956.6
1970	1,680.6	536.6	1,144.0
1980	2,139.0	898.0	1,241.0
1990	2,643.2	1,293.8	1,349.4

Source: JICA Study Report in September 1992.



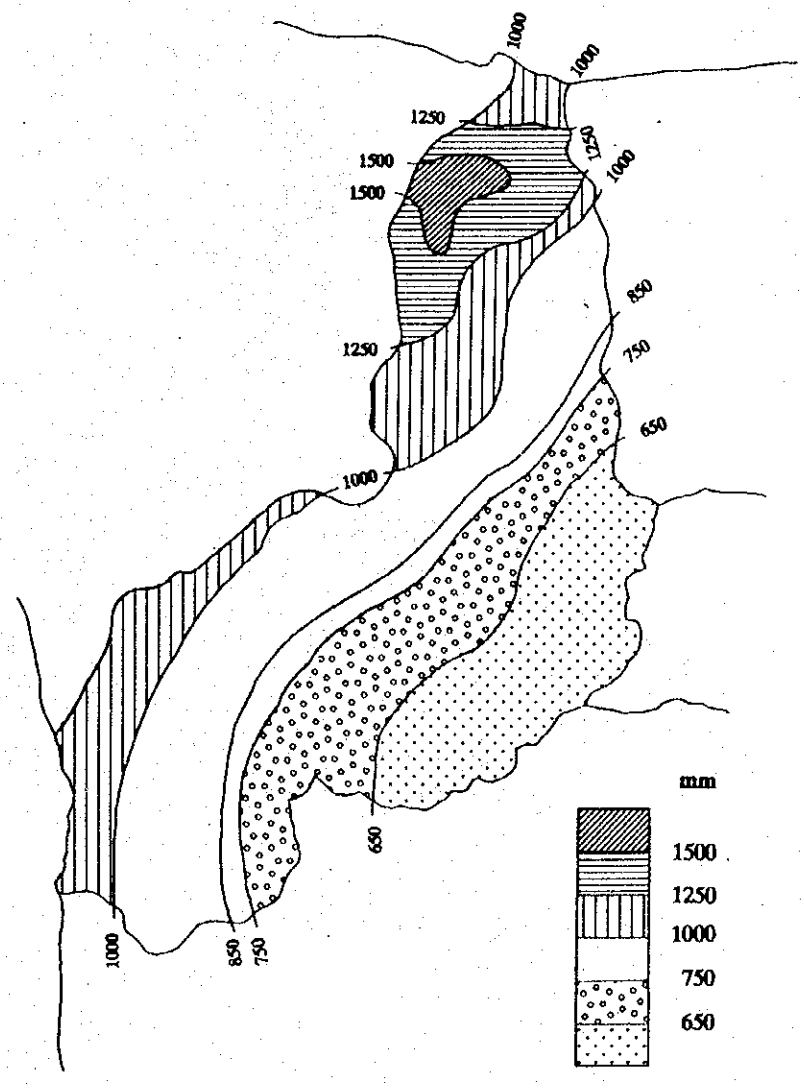
Source : Piaui, Caminhos da Industrializacao.

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

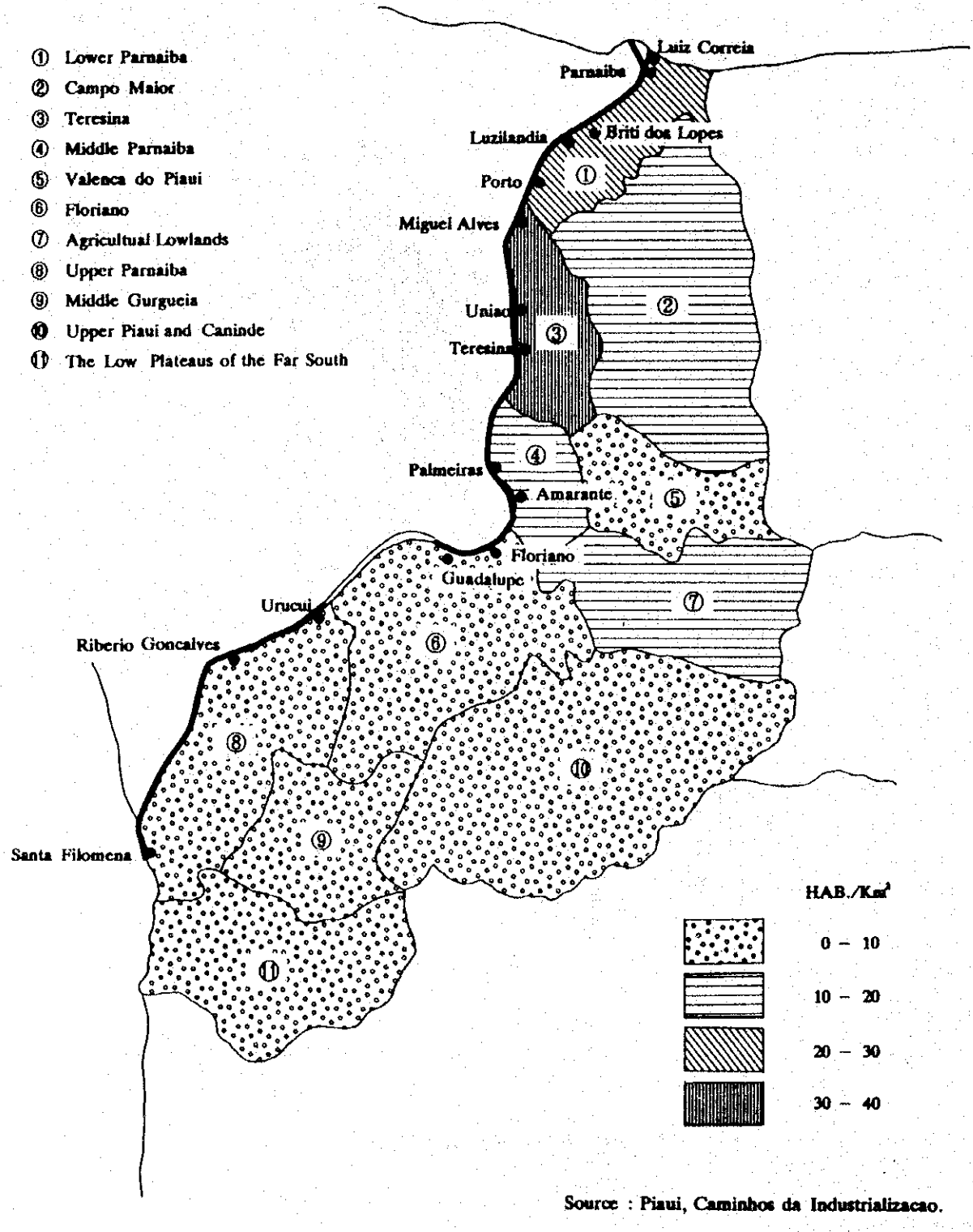


Fig. 2.2.1. Major Cities along the Parnaiba River and Regions in the States of Piauí

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

The northeastern region concerned in this study, where the state of Piauí is located, is ranked as one of the poorest and the most undeveloped regions in Brazil. A remarkable economic gap among regions is generally observed in Brazil and the southern province exhibits a typical prosperity in the country.

Only 0.47 % of the Gross Domestic Product is produced in the state of Piauí.

A reference index called IDS representing the social development rate of regions in Brazil is introduced. The 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. The IDS level by region is shown in Table 2.3.3. It can be seen that the value for the northeastern region is the lowest at 0.34.

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

Source : Published by Rodrigues, Maria Cecilia Prates, "Indice de Desenvolvimento Social), Conjuntura Economica, Vol. 45, No. 1 (January, 1991).

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 flows along the border of the states of Piauí and Maranhâo for the length of 1,344 km. The longitudinal gradient of the river is approximately 1/6,000 for the downstream portion of the Parnaíba river, while that for the upstream portion is 1/3,700. The rainy season of the Parnaíba river, creating High Water Condition, is from October to May. The dry season is from June to September, where the Low Water levels are identified.

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

(2) Balsas River

The Balsas river has an overall length of 525 kilometers and runs through the state of Maranhão, and merges into the Parnaíba river at Urucui. The water level of the Balsas river is at its peak from October to April and is at the lowest from June to September. The portion of the channel that allows the navigation of vessels is between the cities of Balsas and Urucui, and its overall length is approximately 255 kilometers. The river bed gradient is approximately 1/3,100.

3.2 Water Depth and Discharge Volumes at Monitoring Stations

(1) Location and Elevation

There are nine field stations along the Parnaíba river for monitoring the water level (see Fig.3.2.1). The monitoring is carried out by Companhia Hidro Eletrica do Sao Francisco (CHESF). Datum altitudes of these stations were measured using the global positioning system (GPS) during the Phase I study period by the JICA Study Team. Furthermore, two additional such stations were newly constructed at Parnaíba and Amarante (see Table 3.2.1).

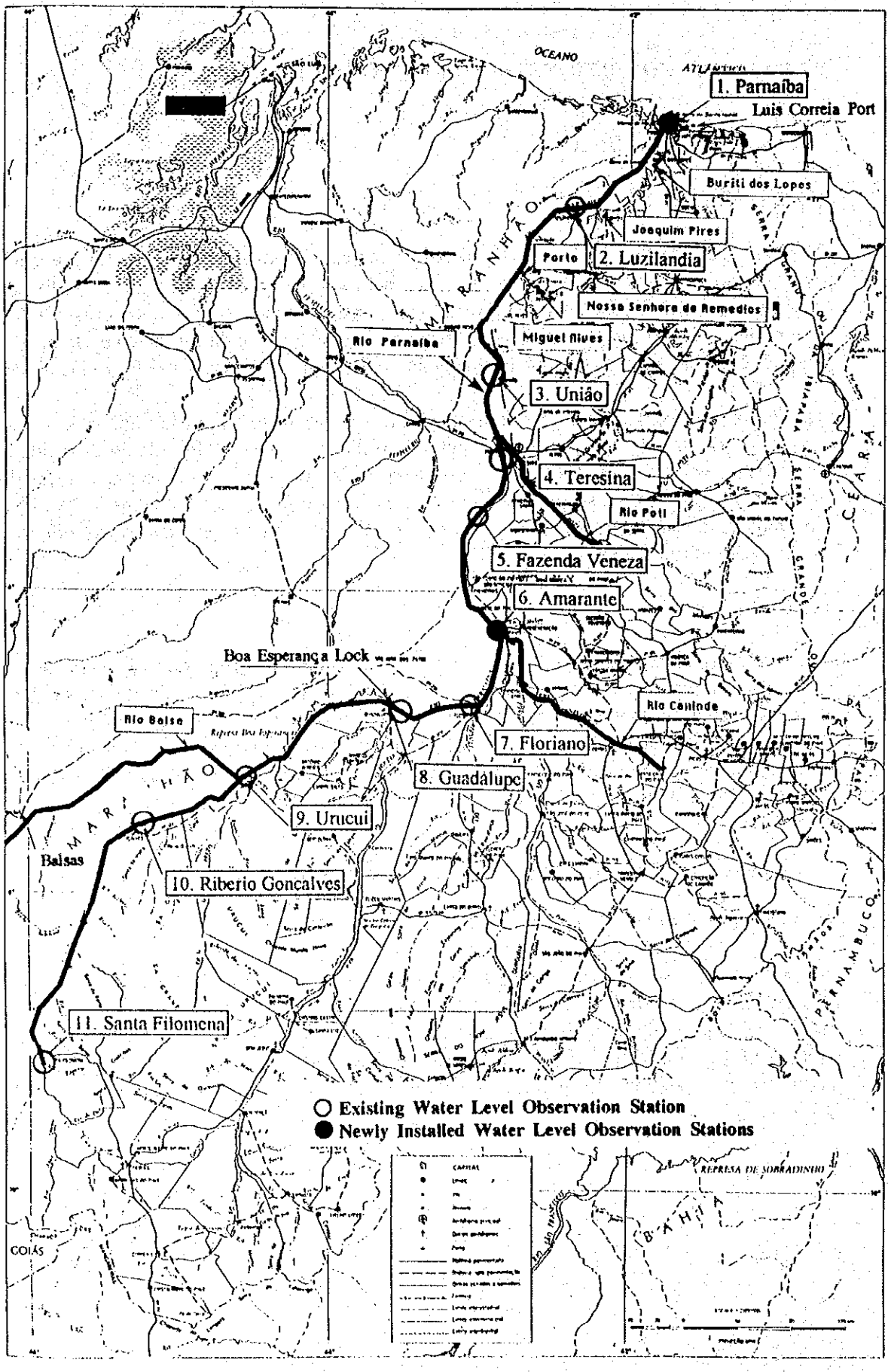


Fig. 3.2.1 Water Level Monitoring Stations

Table 3.2.1 Zero Gauging Level for 11 Monitoring Stations

Station Name	Survey Date	Zero Gauging Level (E.L. m)	Water Level in Altitude (m)
1. Parnaiba	'93. 1.22	0.2	
2. Luzilandia	'93. 1.22	13.6	16.0
3. Uniao	'93. 1.16	40.1	43.4
4. Teresina	'93. 1.13	52.4	55.8
5. Fazenda Veneza	'93. 1.14	62.7	67.5
6. Amarante	'93. 1.28	86.0	86.4
7. Floriano	'93. 1.29	97.1	100.9
8. Guadalupe	'93. 2.1	122.1	113.5
9. Urucui	'93. 2.2	157.1	159.4
10. Ribeiro Goncalves	'93. 2.3	186.7	189.7
11. Santa Filomena	'93. 2.5	263.8	267.6

Source: JICA Study Team

(2) Water Depth and Discharge Volume

Based on the water depth records at the monitoring stations of CHESF for a 23 year period, the average and minimum water depth throughout the year are evaluated. From the evaluation and the successive studies, the particulars of the Parnaíba river are identified as follows:

- The water level of the river Parnaíba varies seasonally. The rainy season is from November to April and the dry season is from May to October.
- The water depth below the Boa Esperança Dam is affected by the discharging volume of the Dam ranging from 300 to 350 m^3/sec for power generation.
- The difference in water depth between the dry and rainy seasons is about 1.0 meter for the upstream portion and 2.0 to 3.0 meters for the downstream portion. The deviation is smaller for the upstream portion.
- Water depths below 1.0 meter are recorded at Fazenda Veneza and Luzilandia during the dry seasons.
- An average discharge volume during the dry season is about 80 to 190 m^3/s for the upstream portion, 300 to 400 m^3/s for the midstream portion, and 400 to 500 m^3/s for the downstream portion (see Fig.3.2.12).

3.3 Water Depth in the Topographic Survey Area

As the result of a topographic survey and river flow observations conducted at twenty one (21) locations along the Parnaíba river basin, the following characteristics were recognized (see Fig. 3.3.1 for the location and Tables 3.3.1 & 3.3.2 for the results).

- The water depth in Miguel Alves is the shallowest. The estimated average water depth during dry seasons is 1.6 meters.
- The difference in water depth between dry and rainy seasons is about 0.5 meters for the upstream portion, and 1.1 to 3.0 meters for the midstream and the downstream portions.
- The velocity in the river ranges from 0.70 to 1.30 m/s for dry seasons, and 0.80 to 1.80 m/s for rainy seasons.
- The width of the river at Guadalupe is the minimum at about 36 meters.

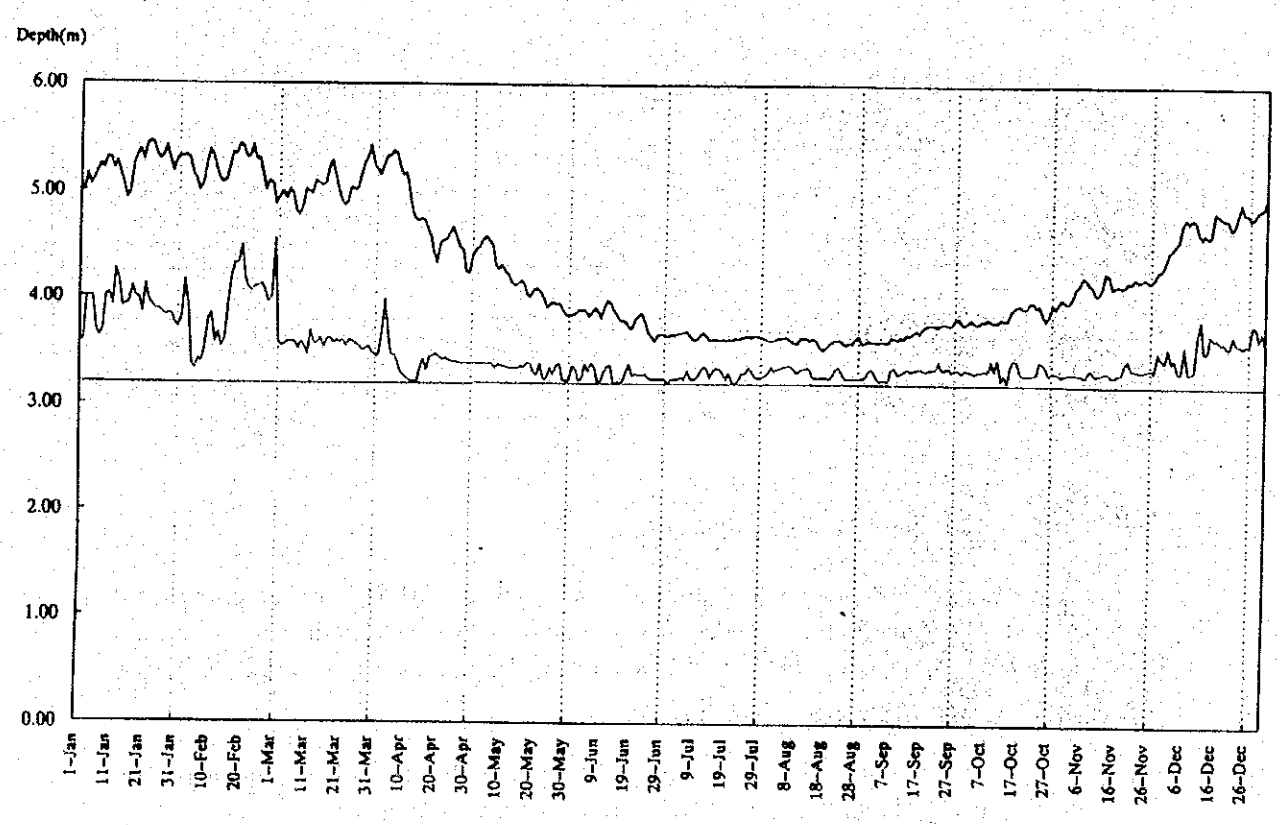


Fig. 3.2.7 Average and Minimum Water Depth at Floriano (1981 - 1993)
Source : JICA Study Team

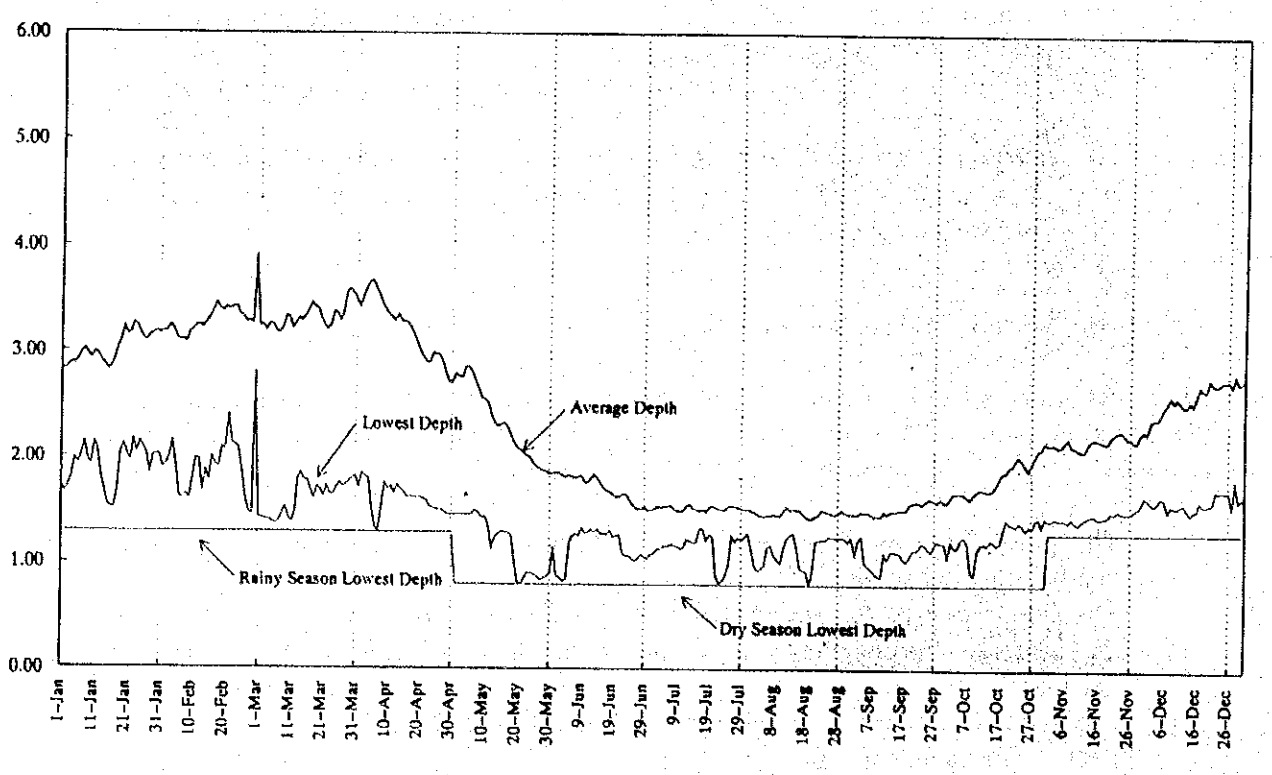


Fig. 3.2.8 Average and Minimum Water Depth at Fazenda Veneza (1973 - 1993)
Source : JICA Study Team

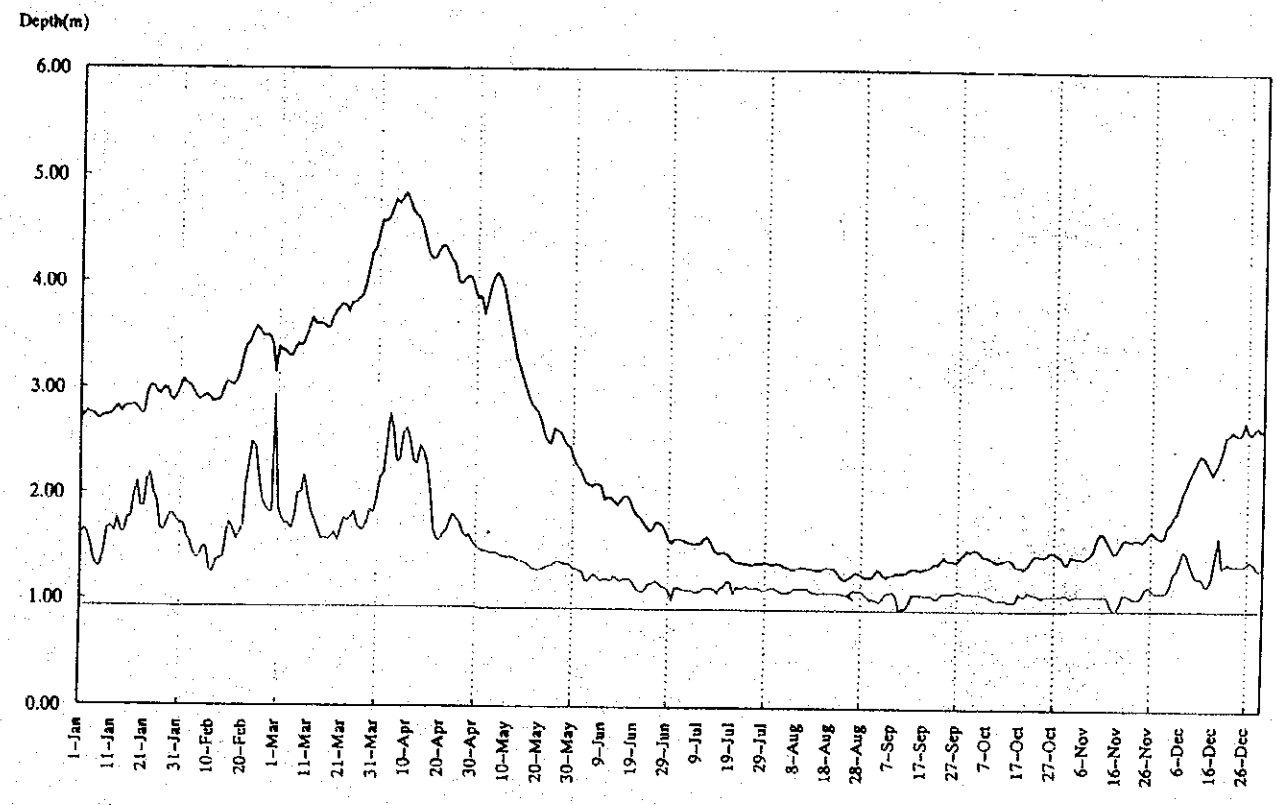


Fig. 3.2.11 Average and Minimum Water Depth at Luzilandia (1983 - 1993)
Source : JICA Study Team

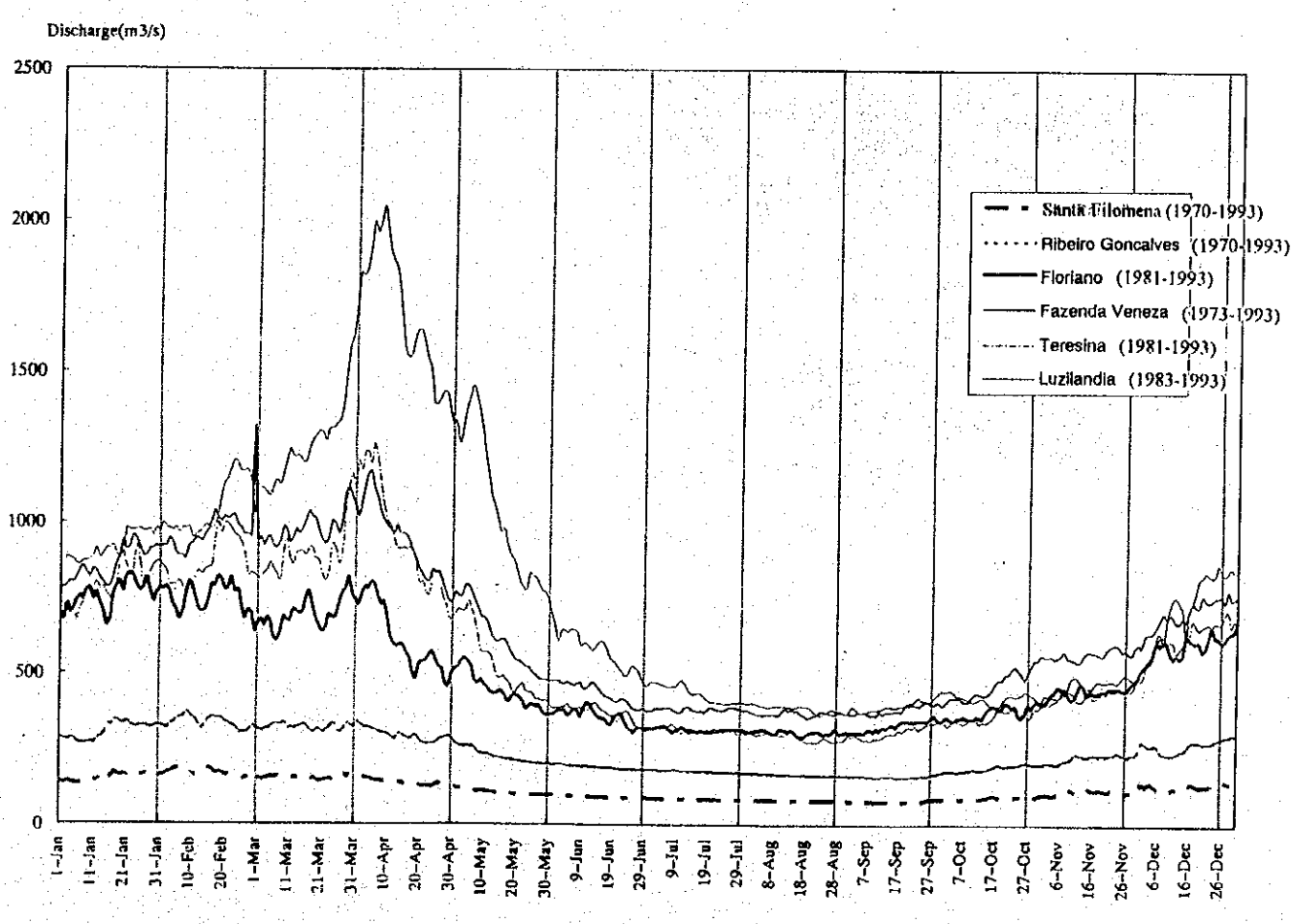


Fig. 3.2.12 Discharge Volume at Monitoring Stations **Source : JICA Study Team**

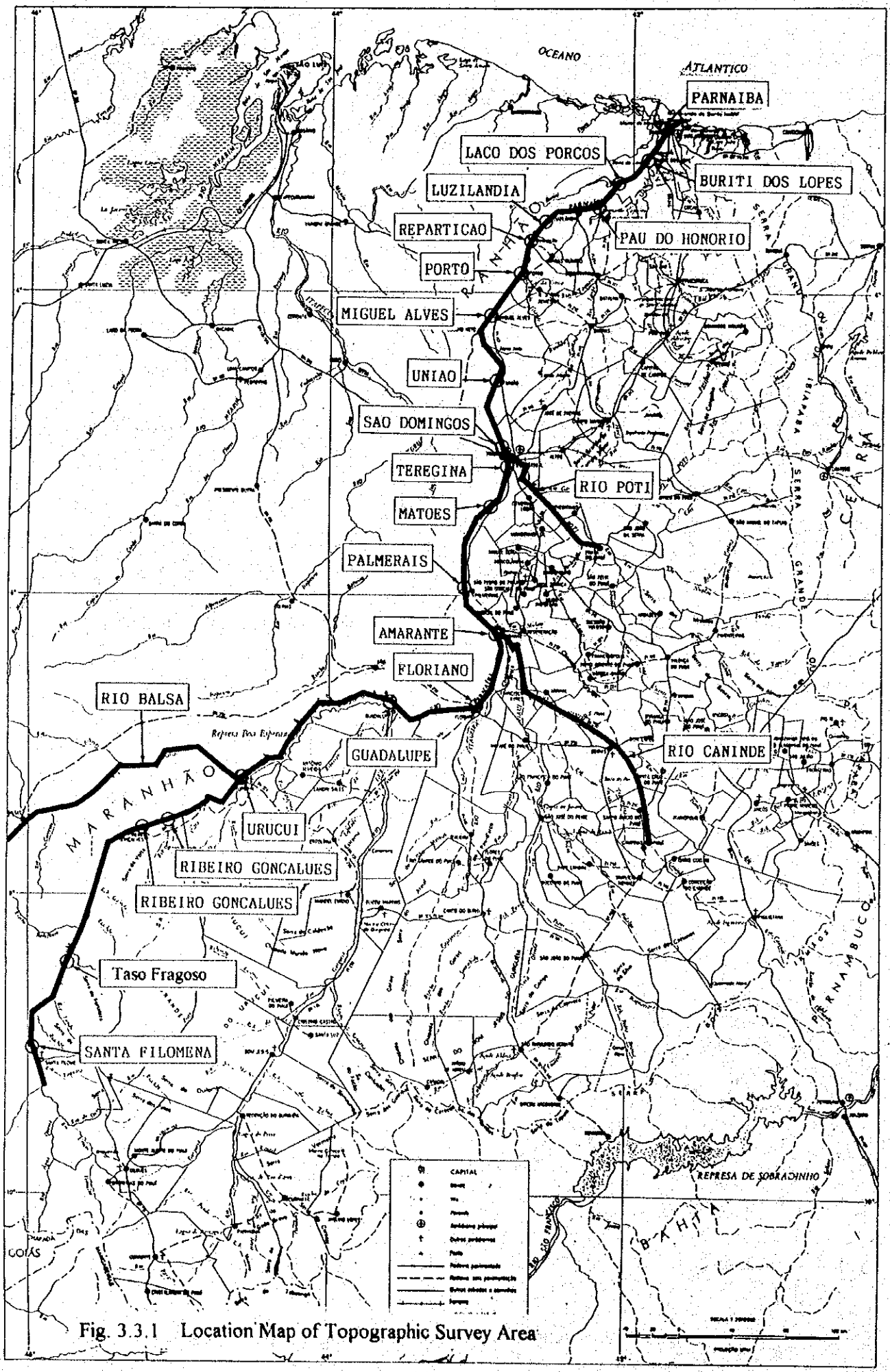


Fig. 3.3.1 Location Map of Topographic Survey Area

Table 3.3.1 Summary of the Topographic Survey

No.	Name	Location	Water Level (EL. m)	River Width (m)	Water Depth (m)
1	Parnaíba	S 2°53'43", W 41°46'36"	1.85 (0.64)	64 - 114 (48 - 98)	4.0 - 8.3 (2.7 - 7.0)
2	Buriti dos Lopes	S 3°08'53", W 41°55'39"	7.2 (5.50)	412 - 706 (285 - 690)	4.0 - 5.5 (3.1 - 4.5)
3	Lago dos Porcos	S 3°05'45", W 42°07'05"	11.6 (10.50)	475 - 495 (472 - 490)	3.5 - 4.4 (1.5 - 2.9)
4	Magaidas de Aimeida (Pau do Honorio)	S 3°24'10", W 42°12'10"	15.1 (14.0)	552 - 560 (52 - 539)	5.8 - 7.0 (3.1 - 5.5)
5	Santa Quiteria do Marabhao (Luzilandia)	S 3°32'02", W 42°32'49"	22.80 (21.7)	472 - 516 (511 - 637)	5.0 - 5.1 (2.4 - 4.0)
6	Brejo (Reparticao)	S 3°40'55", W42°40'55"	26.60 (25.40)	272 - 280 (255 - 258)	4.0 - 4.6 (2.9 - 3.4)
7	Porto	S 3°53'39", W 42°43'15"	29.70 (28.50)	370 - 400 (350 - 393)	4.0 - 4.5 (2.9 - 3.2)
8	Miguel Alves	S 4°09'28", W 42°53'39"	34.40 (32.90)	645 - 693 (642 - 688)	3.3 - 5.3 (1.0 - 2.0)
9	União	S 4°35'05", W 42°52'17"	44.10 (42.5)	340 - 600 (330 - 516)	3.9 - 5.0 (1.5 - 2.3)
10	Sao Domingos	S 4°57'52", W 42°51'38"	52.40 (51.2)	500 - 555 (95 - 200)	6.2 - 7.0 (5.3 - 6.3)
11	Teresina	S 5°06'21", W 42°48'53"	56.00 (54.79)	370 - 420 (363 - 412)	2.5 - 4.2 (1.9 - 2.8)
12	Parnarama (Matoes)	S 5°40'58", W 43°05'11"	71.30 (70.09)	252 - 288 (223 - 246)	4.0 - 5.1 (2.5 - 3.8)
13	Palmerais	S 5°58'47", W 43°03'45"	78.10 (76.90)	212 - 244 (203 - 239)	4.2 - 6.6 (5.3 - 3.4)
14	Amarante	S 6°14'45", W 42°51'19"	87.34 (85.80)	284 - 328 (172 - 217)	4.2 - 6.0 (2.0 - 4.4)
15	Floriano	S 6°45'38", W 43°00'52"	101.70 (100.20)	216 - 224 (200 - 208)	4.0 - 4.3 (2.5 - 2.9)
16	Guadalupe	S 6°46'21", W 43°32'43"	115.22 (113.34)	76 - 104 (36 - 84)	11.1 - 11.6 (9.2 - 9.8)
17	Urucui	S 7°13'35", W 44°33'32"	160.10 (160.40)	116 - 228 (122 - 231)	3.3 - 5.2 (3.5 - 5.6)
18	Ribeiro Gonçalves 1	S 7°33'05", W 45°14'15"	190.00 (189.32)	66 - 145 (55 - 140)	3.0 - 5.6 (2.5 - 5.0)
19	Ribeiro Gonçalves 2	S 7°33'16", W 45°14'36"	190.06 (189.32)	105 - 190 (107 - 190)	2.6 - 4.5 (1.7 - 3.8)
20	Taso Fragoso (Santa Filomena 1)	S 8°28'16", W 45°44'33"	228.85 (228.20)	79 - 88 (70 - 83)	2.5 - 3.0 (1.8 - 2.4)
21	Santa Filomena 2	S 9°06'46", W 45°55'30"	267.85 (267.23)	88 - 92 (88 - 91)	2.0 - 2.2 (1.4 - 1.5)

Source: JICA Study Team

Note that the numbers in parenthesis show the survey results of the Phase II study, during dry seasons.

Table 3.3.2 Results of the River Flow Observations

No.	Name	Location	Survey Date	River Flow (m/s)
1	Parnaiba	S 2°53'43", W 41°46'36"	Jan. 29, 94	0.78 (1.28)
2	Buriti dos Lopes	S 3°08'53", W 41°55'39"	Jan. 30, 94	0.89 - 1.12 (1.03)
3	Lago dos Porcos	S 3°05'45", W 42°07'05"	Feb. 1, 94	0.85 - 0.93 (0.91)
4	Magaidas de Aimeida (Pau do Honorio)	S 3°24'10", W 42°12'10"	Jan. 31, 94	0.87 - 0.91 (0.89)
5	Santa Quiteria do Marabhao (Luzilandia)	S 3°32'02", W 42°32'49"	Feb. 2, 94	1.08 (0.72)
6	Brejo (Reparticao)	S 3°40'55", W 42°40'55"	Feb. 3, 94	0.91 - 1.25 (0.69)
7	Porto	S 3°53'39", W 42°43'15"	Feb. 4, 94	0.90 - 1.11 (1.08)
8	Miguel Alves	S 4°09'28", W 42°53'39"	Jan. 23, 94	0.90 - 0.94 (0.86)
9	União	S 4°35'05", W 42°52'17"	Jan. 22, 94	0.88 - 1.62 (0.90)
10	Sao Domingos	S 4°57'52", W 42°51'38"	Jan. 20, 94	1.44 - 1.46 (0.71 - 1.43)
11	Teresina	S 5°06'21", W 42°48'53"	Jan. 19, 94	0.91 - 1.12 (1.03)
12	Parnarama (Matoes)	S 5°40'58", W 43°05'11"	Jan. 18, 94	0.91 - 1.33 (0.99)
13	Palmerais	S 5°58'47", W 43°03'45"	Jan. 21, 94	0.90 - 1.41 (0.54 - 1.09)
14	Amarante	S 6°14'45", W 42°51'19"	Jan. 26, 94	0.91 (1.19)
15	Floriano	S 6°45'38", W 43°00'52"	Jan. 27, 94	0.82 - 0.95 (0.93 - 1.03)
16	Guadalupe	S 6°46'21", W 43°32'43"	Feb. 23, 94	1.44 - 1.46 (1.08)
17	Urucui	S 7°13'35", W 44°33'32"	Feb. 22, 94	P:1.26, B:1.17 (P.1.77, B.0.72)
18	Ribeiro Gonçalves 1	S 7°33'05", W 45°14'15"	Feb. 21, 94	1.37 - 1.80 (1.03 - 1.26)
19	Ribeiro Gonçalves 2	S 7°33'16", W 45°14'36"	Feb. 21, 94	0.97 - 1.53 (1.13 - 1.29)
20	Tasso Fragoso (Santa Filomena 1)	S 8°28'16", W 45°44'33"	Feb. 20, 94	1.21 - 1.23 (1.18)
21	Santa Filomena 2	S 9°06'46", W 45°55'30"	Feb. 19, 94	0.96 - 0.97 (0.93)

Source: JICA Study Team

Note that the numbers in parenthesis show the survey results of the Phase II study, during dry seasons.

3.4 Characteristics of the Parnaíba River for the Navigation

The Parnaíba river is classified into three portions by means of their geographical features; they are 1) from Amarante to Luiz Correia, 2) from Amarante to Guadalupe and 3) from Guadalupe to Santa Filomena. Limitations on river navigation in each portion are summarized as follows.

(1) Amarante - Luiz Correia : The restrictive obstacles for river navigation are the sand bars. In particular, the maximum water depth in the sand bar areas during the dry season is estimated at 1.2 m for Luzilandia and 1.5 m for Fazenda Veneza. There is an S-shaped sharp curve upstream of the Igaracu near the confluence of the Parnaíba. The velocity in this area is about 2 knots (1.0 m/s), while near Luzilandia where a corrade exists, the observed flow velocity is about 4 knots (2 m/sec).

(2) Amarante - Guadalupe : The river shows relatively stable dimensions in this zone. However, there are some rocky outcrops along the river. The restricttion in this area for the navigation is the width of the river. The flow velocity is reported at 2.2 knots (1.1 m/sec) on average.

(3) Guadalupe - Santa Filomena : Boa Esperança Locks restricts navigable ship's dimension physically and affects the passing time as well. The velocity in this area is high on the whole, ranging from about 1.3 to 1.8 m/s. Near Santa Filomena, the river has some very shallow points of approximately 1.5 m in the dry season. Also a corrade exists in this area.

Note that the aerial photography works were carried out during the dry season in 1993 to obtain the basic data for the mosaic photo, sand bar inventory and the selection of the construction sites for the test spur dikes (See the Interim Report (I) and accompanied Supplemental Report for the details of the aerial photography works, mosaic photo, sand bar inventory and spur dikes construction, respectively.).