BASIC DESIGN STUDY REPORT
ON
FUEL TRANSPORTATION PROJECT
FOR
THE POWER PROJECTS
IN
THE DEMOCRATIC REPUBLIC OF THE SUDAN

JANUARY 1986

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to the request of the Government of the Democratic Republic of the Sudan, the Government of Japan decided to conduct a Basic Design Study on the Project of Fuel Transportation for the Power Projects and entrusted the study to the Japan International Cooperation Agency (JICA). JICA sent to the Sudan a study team headed by Mr. Tetsuya Yamagata of Japanese National Railways from 26th September to 17th October, 1985.

The team had discussions on the Project with the officials concerned of the Government of Sudan and conducted a field survey. After the team returned to Japan, further studies were made and the present report has been prepared.

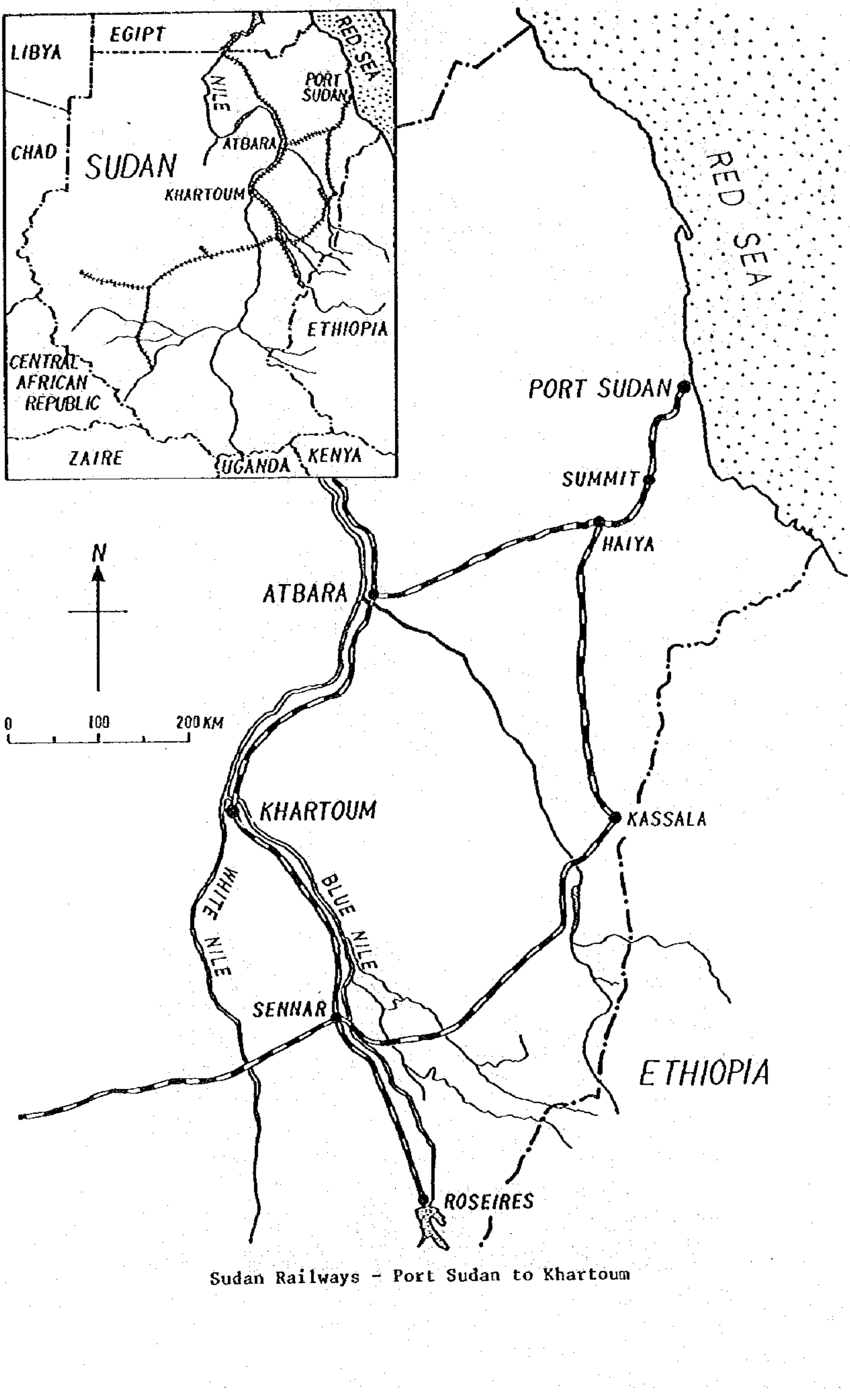
I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the Democratic Republic of the Sudan for their close cooperation extended to the team.

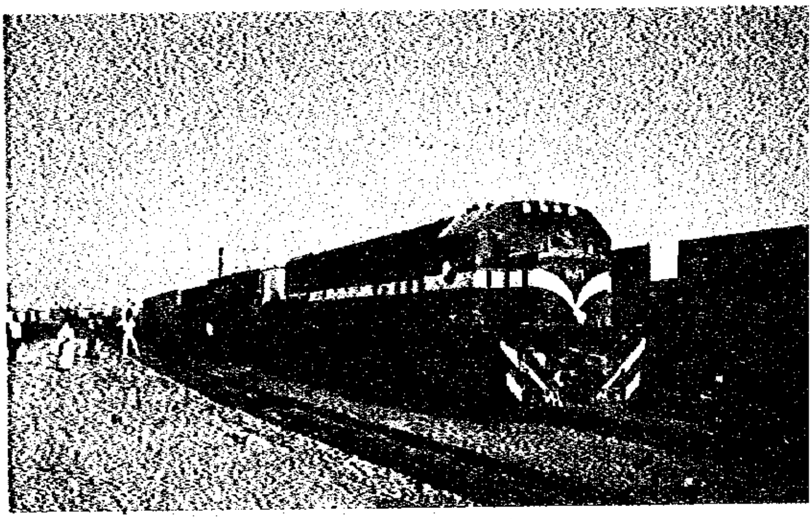
January , 1986

Keisuke Arita

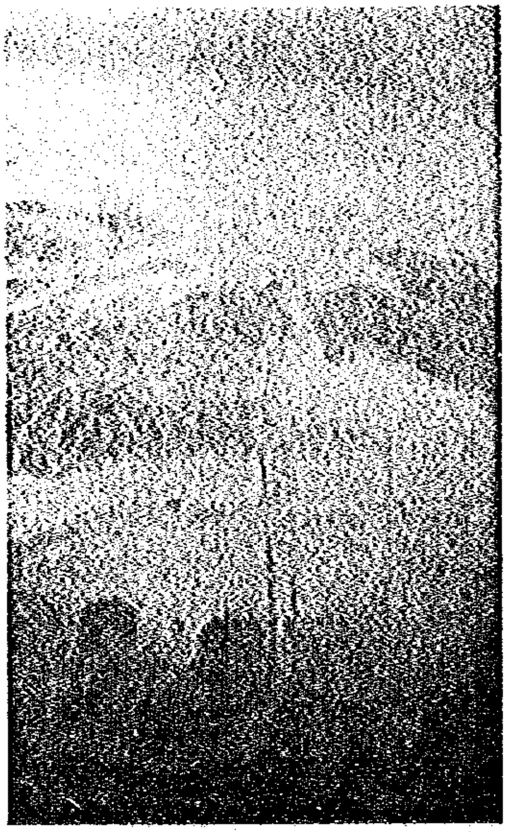
Keisuke ARITA
President
Japan International Cooperation Agency



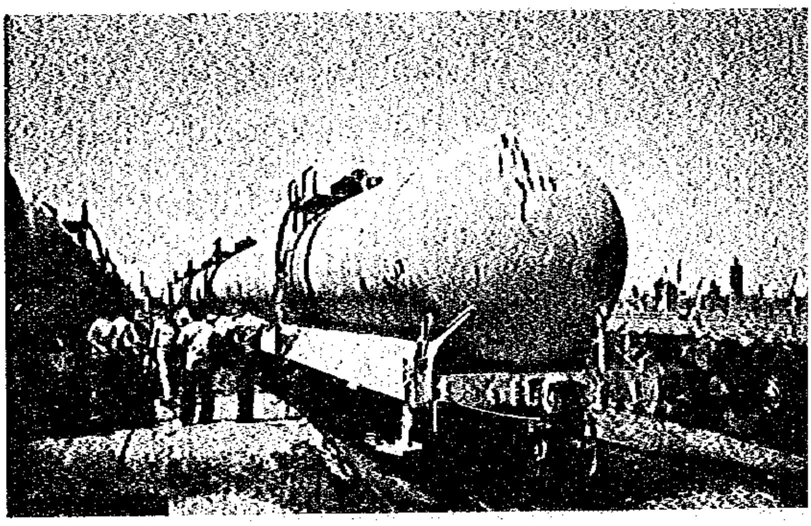
Sudan Railways - Port Sudan to Khartoum



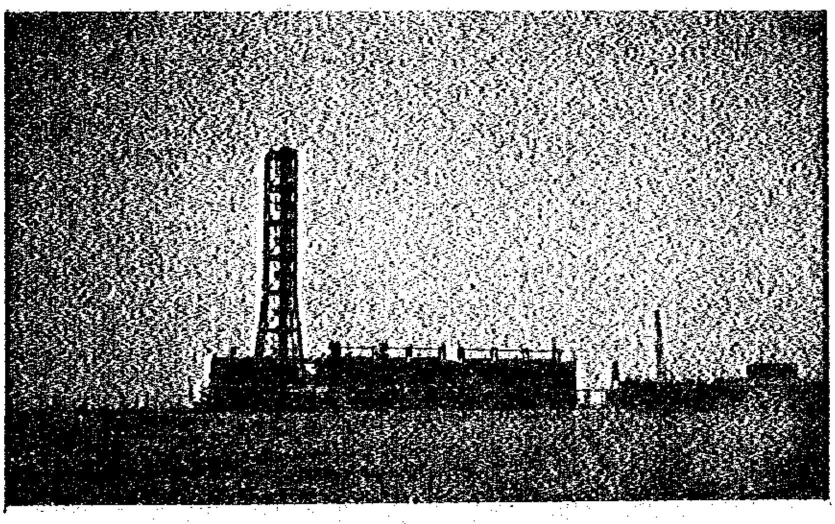
Fuel transport train (mixed)



Railway passing a desert
(Port Sudan - Summit)



Tank wagons



Khartoum North Power Station

Abbreviations

SRC	(Sudan Railways Corporation)
NEC	(National Electricity Corporation)
GPC	(General Petroleum Corporation)
STC	(Sudan Telecommunications Corporation)

The FTS Report

The Democratic Republic of the Sudan
National Electricity Corporation
"Fuel Transportation Study"
Final Report June 1984
SIR ALEXANDER GIBB & PARTNERS MERZ AND McLELLAN

SUMMARY

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The Democratic Republic of the Sudan has planned medium and long-term projects for agriculture, manufacturing, transportation, education, etc., and has been making efforts to promote the actualization of these projects. Electricity reinforcement is one of the most important projects in this country. Energy source which is supplying electric power to Khartoum, and the Blue Nile River side area (Blue Nile Grid) depends on hydrological power.

However, it is not reliable due to water shortage during the dry season and its capacity is not sufficient to satisfy increasing demand in fast-growing urban areas. To cope with this situation, the Government of Sudan started to implement Power III Project in 1983 which was primarily designed to upgrade thermal power generation capacity, and which was mostly completed by June 1985. Right now, the Government is planning to implement Power IV Project.

The project is, however, hindered by insufficient capacity of fuel oil transport required for thermal power plants. To solve this problem, the Government planned a project for improving a fuel transport network between Port Sudan and Khartoum. In accordance with the project, 40 tank wagons will be provided by aid of the Government of France, and existing 40 tank wagons are being converted by Sudan herself. Also, negotiation is underway to procure 60 more tank wagons by aid of the French Government. On the other hand, there is no definite plan for procuring locomotives to haul fuel trains.

Under these circumstances, the Government of Sudan requested the Government of Japan to provide locomotives and communication equipment necessary for train operation under the grant-aid program.

The Japan International Cooperation Agency (JICA) sent a Basic Design Study Team to the country for the period between 26th September and 17th October, 1985. The Study Team held discussions with the competent authorities concerned in Sudan, carried out field investigations, collected and analyzed relevant data.

The results of the study, and an outline of the project are summarized as follows:

(a) It should be noted that this study set forth a target year of project completion in fiscal 1988/89 instead of 1987/88 planned by the Sudanese side so as to ensure more realistic procurement schedule.

(b) Power demand in 1988/89 is forecasted to be about 1,880 GWH. This figure is 1.5 times the actual consumption during 1984/85, but is 5% less than the 1987/88 amount (1,974 GWH) forecasted by the Sudanese side in its original plan.

(c) Fuel requirements, varied with hydropower production, are forecasted to be 258 kilo tons for a drought year, 198 kilo tons for an ordinary year. These will further increase by 20 - 30% if the Roseires Hydropower Plant (No. 7) is not completed in fiscal 1987/88 as planned.

(d) Daily fuel transport capacity should be 900 tons, i.e., 26 tank loads (35 t each), if the transport is made for 295 days each year.

(e) Among various possible methods of transportation, hauling by twin locomotives appears to be most suitable in consideration of local conditions such as high temperature and sand.

(f) Rolling stock requirements include 10 diesel locomotives (for hauling), 130 tank wagons, Manama, brake vans and shunting locomotives, which include spare equipment.

(g) 6 locomotives are to be procured for hauling 80 tank wagons the availability of which was confirmed at the time of field study. To make up for the shortage of locomotives, it is recommended to improve operation efficiency by reducing turn round time, to use existing equipment effectively, or to procure locomotives from other sources.

(h) As to communication equipment, on-board radio equipment of the same type as currently used should be furnished to new locomotives. On the other hand, communication equipment between related sections and organizations in and between wayside cities is not considered to be urgently needed.

(i) It will take about 22 months from E/N to complete this project.

(j) Fuel oil transport is essential in improving power generation capacities and maintaining stable power supply in the country. At the same time, transport by rail is expected to cost much less than by lorries and will generate new traffic for Sudanese railways, contributing greatly to its financial situation by bringing additional revenues.

Finally, the following recommendations are made to the Sudanese side in order to facilitate smooth project implementation.

To the Government of Sudan:

(a) To clearly define responsibilities of related organizations for major components of the fuel transport project, including fuel procurement, loading and discharge, reliable train operation, additional installation, operation and maintenance of the facilities, and to monitor their performance all the time and give necessary advice and guidance to them.

To NEC:

(a) To upgrade discharge facilities (station tracks, heating facilities, storage tanks) as planned.

(b) To provide exclusive shunting locomotives.

(c) To carry out efficient loading in consideration of the capacity of the oil companies, and thereby to minimize loading time.

To SRC:

(a) To establish adequate utilization plans for diesel locomotives and carry out their maintenance in planned manners.

(b) To secure the budget for spare parts and other costs required for efficient rolling stock maintenance, to upgrade workers' technique and carry out reliable inspection and maintenance.

(c) To provide shunting locomotives for efficient fuel loading and discharging through discussions with NEC.

(d) To review present train operation diagram and improve schedule speed. In particular, to reconsider the necessity of inspection of tank wagons and the stopping time at way stations.

CONTENTS

CHAPTER 1 INTRODUCTION

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At present, electric power consumed in Khartoum area, a capital of the Democratic Republic of the Sudan, is mainly supplied from hydropower stations. To cope with the shortage of electric power during the dry season and increasing power demand anticipated in the future, the Government of Sudan implemented Power III Project which included the increase of thermal power generation capacity, and planned to implement Power IV Project.

However, insufficient capacity of fuel transport as a vital means of fuel supply to thermal power stations is recognized as a major bottleneck to the implementation of the project, and the Government of Sudan laid out a plan for improving the fuel transport network between Port Sudan and Khartoum to cope with this problem.

Based on the plan, the Government of Sudan made a formal request to the Government of Japan to provide diesel locomotives and telecommunication equipment under the grant-aid program.

In response, the Government of Japan decided to conduct a basic design study on the fuel transport network improvement project and the Japan International Cooperation Agency (JICA) sent a Study Team headed by Mr. Tetsuya Yamagata (Department of Foreign Affairs, Japanese National Railways) to Sudan for a period between 26 September and 17 October, 1985.

The Study Team held discussions with the Government of Sudan (Ministry of Finance and Economic Planning), National Electricity Corporation (NEC) and Sudan Railways Corporation (SRC) and collected data and information on the following items as well as conducted field investigations on major facilities.

(a) Present state of power generation and future demand

(b) Implemented and planned power source improvement projects

(c) Operating system, rolling stock, track conditions, telecommunication/signalling facilities of SRC

(d) Locomotive depot and workshop of SRC and works carried out at these facilities

(e) Fuel loading and discharge facilities

(f) Diesel locomotives and telecommunication equipment requested under the grant-aid program

The Minutes of Discussions covering the study results were signed between the Study Team and the Sudanese side on 14th October 1985 at Khartoum.

The Minutes of Discussions, members of the Study Team, their itinerary and others are listed in Appendix of this report.

CHAPTER 2 BACKGROUND OF THE PROJECT

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2-1 Introduction

The Democratic Republic of the Sudan is located in the north-east of Africa between the equator and the Tropic of Cancer, having the largest land area in the continent (approximately 2.5 million km^2). It faces the Red Sea on the north-east and is bounded on the north by Egypt and Libya, on the west by Chad and Central African Republic, on the south by Kenya, Uganda and Zaire, and on the east by Ethiopia.

Topographically, Sudan is generally situated on a flat plateau with elevations of 300 - 500 m above the sea, except for Red Sea Hills in the north-east. It is made up of Nubian Desert in the north, irrigated farmland and grassland in the center, and vast swampland and tropical forest created by the meandering White Nile in the south.

The White Nile, originated in Lake Victoria and flowing in a north direction, joins the Blue Nile, originated in Lake Tana (Ethiopia), at Khartoum located in the center of Sudan to become the Nile which meanders into Egypt. In addition, tributaries of the Atbara and the Sobbat join the Nile in the country.

Sudan has a variety of climate types; from desert climate in the north to tropical climate in the south. The temperature is generally high throughout the year; the highest temperature is 52.2°C in the north, 47.7°C in the capital and 42.5°C in the south; the lowest is 16°C in the north and 29°C in the south. Rainy season also varies from region to region; June - September in the north and April - November in the south. The mean annual rainfall is 25 mm in the north and 1,400 mm in the south.

In Khartoum, the winter is between November and March and comprises the most comfortable season of the year with relatively low temperature (mean at 25°C). The mean temperature in April and May is about 36°C with relatively high temperature at night. The rainy season between June and August is subject to high temperature and humidity along with rain and sandstorms (habubs).

The sandstorms sometimes stop road traffic and put a few centimeters' lay of sand in a house. The period between September and October is called the second summer which is characterized by high temperature without wind or rains.

Table 2-1 Monthly Temperature of Khartoum City

Month		1	2	3	4	5	6	7	8	9	10	11	12
Temperature (°C)	Maximum	31.7	33.2	37.0	40.1	41.9	41.6	38.1	36.2	38.4	39.3	35.8	32.3
	Minimum	16.5	16.7	19.9	23.0	26.3	27.1	25.7	24.8	25.6	25.2	21.2	16.9
Precipitation (mm)		—	—	—	—	5.0	5.0	55.0	72.0	25.0	5.0	—	—

According to 1983 Sudan Yearbook, Sudan had a population of approximately 19.3 million in 1982 (about 1/6 of Japan), which has an annual increase average at 2.8% in recent years. The population increased by 90% from the year of independence. The population increase occurred predominantly in Khartoum; five times as much as the 23% in the south over the same period.

Sudan is an agricultural country and 76% of total labor force is engaged in agriculture. Major agricultural products include cotton, peanuts, durra (cereals), Arabian rubber and sesame. These products are major export items of the country, representing 70% of the total export in value in 1981/82. The export of durra, Arabian rubber and sesame have grown steadily while cotton export has decreased due to price decline in the world market; the export of cotton in 1981/82 decreased by half in comparison to 1977/78.

On the other hand, Sudan imports petroleum, industrial products, sugar and wheat the total amount of which has been increasing in recent years. In particular, the import of petroleum has increased rapidly; the import in 1981/82 was four times that in 1977/78.

As a result, the deficit in the balance of payment of the country has been increasing every year.

GNP per capita in 1981/82 was US$380.

2-2 Electric Energy Situation

Electric energy production and installed generating capacity in major developing countries (1982) are listed in Table 2-2. In terms of annual production and installed capacity per capita, Sudan is ranked among the lowest in Africa, 1/100 of annual production and 1/80 of installed capacity in Japan.

The electric energy is largely consumed in the central part around the Blue Nile and the White Nile, where farmland is widely irrigated using water from the Nile. Also, the area has Khartoum, the capital, where Government and company offices are concentrated.

Most of the electric power supplied to this area is generated at hydropower stations located along the Nile. Of the total annual discharge, the Blue Nile accounts for 59%, the White Nile 27% and the Atbara and other tributaries 14%. Since the White Nile has slow flowing speed and Atbara Tributary dries up all the year round except the rainy season from June to October, the Blue Nile with large discharge is used for hydropower generation.

Most of the hydropower is generated at Roseires dam at the upstream of the Blue Nile. During the summer, however, the riverhead area is in the rainy season and a large amount of sediment flowing into the dam blocks up the turbine entrance. As a result, power generation at the dam is cut by half and cannot meet power demand which reaches its peak during the season.

At the same time, power demand in the area is increasing year after year, exceeding installed generating capacity of existing facilities (including thermal power stations).

Table 2-2 Electric Energy Production Selected Developing Countries (1982)

Country	Population*	Annual production (GWH)	Installed generating capacity (MW)	Annual production per capita (KWH/person)	Installed generating capacity per capita (W/person)
Sudan	1,945	1,010	313	52	16
Egypt	4,467	17,720	3,782	397	85
Ethiopia	3,278	679	319	21	10
Kenya	1,786	1,806	556	101	31
Zaire	2,638	4,412	1,716	167	65
Nigeria	8,239	7,500	2,770	91	34
Ghana	1,224	4,981	1,060	407	87
Morocco	2,167	6,057	1,593	280	74
Algeria	2,029	7,180	2,006	354	99
Tunisia	667	3,088	929	463	139
Libya	322	6,000	1,180	1,863	366
Iran	4,024	17,500	5,300	433	131
Indonesia	15,303	7,365	2,860	48	19
Philippines	5,074	19,406	5,003	382	99
Thailand	4,849	17,220	4,935	352	101

* (Ten thousand persons)

(Reference)

Japan	11,869	618,100	159,232	5,208	1,342
USA	23,206	2,367,637	674,947	10,203	2,885
UK	5,578	232,162	69,191	4,162	1,240
France	5,422	281,589	83,958	5,193	1,548

Notes: 1. Annual production and installed capacity are obtained from 1985 Statistics of Overseas Electric Utilities (Japan Electric Power Information Center Incorporation).

2. Population data is based on UN estimates.

3. Annual production includes both private and public power generating plants.

According to some reports, shortage of electric power supply has become a very serious problem in the country; irrigation pumps for sugarcane fields stop operation and suspending sugar manufacture, and some leather factories suspend operations with anticipation of power failure.

To cope with this situation, NEC formulated three power source improvement projects (Power II, Power III, and Power IV) since 1982 and completed power II, and Power III project by June 1985, and at present it is implementing Power IV project.

These projects are summarized in Table 2-3.

Table 2-3 Electricity Expansion Projects

Project	Description
Power II	Installation of 40 MW hydropower generating facilities in Roseires Rehabilitation of Burri Power Station
Power III	Addition of 180 MW generating capacity to Roseires, Burri and Khartoum North stations
Power IV	Addition of 275 MW generating capacity (mainly thermal power generation) in the Blue Nile Grid area (planned to complete in 1989)

2-3 Increase in Generating Capacity and Future Plan

Under Power III Project, generating capacities in the Blue Nile Grid have been increased as shown in Table 2-4.

Table 2-4 Increase in Generating Capacities under Power III Project

Month completed		Facility	Added generating capacity
1983/84	July	Roseires (hydropower)	40 MW
	November	Burri III Set 1	10 MW
	February	Burri III Set 2	10 MW
	April	Burri III Set 3	10 MW
	June	Roseires (hydropower) (Damazine)	40 MW
1984/85	August	Burri III Set 4	10 MW
	January	Khartoum North Set 2	30 MW
	April	Khartoum North Set 1	30 MW

In addition, Power IV Project is planned to deal with future increase in power demand, as summarized in Table 2-5.

Table 2-5 Planned Increase in Generating Capacity under Power IV Project

No.	Location	Equipment	Generating capacity	Month to be completed
1	Khartoum North	Gas turbine	20 MW × 2	1986 June
2	Burri	Diesel	10 MW × 2	1988 February
3	Roseires	Hydro (No. 7)	40 MW	1988 June
4	Khartoum North	Steam turbine	30 or 60 MW	1989 March
5	Khartoum North	Steam turbine	30 or 60 MW	1989 June
6	Sennar	Hydro	15 MW × 2	1990 June
7	Khartoum North	Steam turbine	30 or 60 MW	1991 March
8	Khartoum North	Steam turbine	30 or 60 MW	1991 June

Of these equipment, the Khartoum North gas turbines, No. 1 are being manufactured and the Burri diesel generators, No. 2 are under tendering.

As a result, the total generating capacity is estimated to increase as shown in Table 2-6.

Table 2-6 Estimated Annual Generating Capacities

Year	Hydropower (mean conditions)		Thermal power		Production
	Generating capacity (MW)	Production (GWH)	Generating capacity (MW)	Production (GWH)	Total (GWH)
1984/85	225	1,102	30	162	1,264
1985/86	"	"	100	540	1,642
1986/87	"	"	"	"	1,642
1987/88	"	"	140	756	1,858
1988/89	(225) 265	(1,102) 1,293	160	864	(1,966) 2,157

* ( ) shows the figure when hydropower project at Roseires No. 7 (project cost is not determined) is not completed.

It should be noted that the above table lists only new thermal power generating equipment to be installed after Power III Project, not including existing equipment of 165 MW at Burri Power Station.

2-4 Present State of Sudan Railways Corporation

Sudan Railways Corporation (SRC) is one of the oldest railways in Africa and started the operation in 1875. It was first operated between Wadi Halfa and Saras near Egyptian border at the downstream of the Nile and was gradually extended to cover most of the present sections by 1928.

1) Passenger/freight carried and operating revenues/expenses

Passenger and freight carried by SRC is shown in Table 2-7.

Table 2-7 Passenger/Freight Carried by SRC

Year	Passenger transport		Freight transport	
	Passenger carried (Persons)	Passenger-kilo (Thousand person km)	Tonnage carried (Tons)	Ton-kilo (Thousand ton-kilo)
1979/80	2,310,293	1,061,058	2,135,743	2,003,207
1980/81	2,041,017	1,169,580	1,720,400	1,594,306
1981/82	2,675,016	1,148,646	1,690,874	1,608,389
1982/83	2,212,941	1,031,025	1,353,842	1,215,183
1983/84	1,524,380	729,899	895,292	836,000

As seen from Table 2-7, both passenger and freight carried by SRC have been decreasing gradually; especially, they decreased to 70% of the previous year in 1983/84. This is probably due to insufficient transport capacity caused by shortage of locomotives in working condition, rather than decrease in traffic demand.

The revenues/expenses of SRC is shown in Table 2-8. SRC has been operated in deficit in most of the years, except for fiscal 1981/82 when the profit was realized as a result of rate increase.

Table 2-8 Operating Revenues/Expenses

Item \ Year		1979/80 *	1980/81 *	1981/82 *	1982/83 *
Revenue	Passenger	1,014	962	1,319	1,783
	Freight	4,270	4,645	7,363	6,582
	Other	19	18	19	13
	Total	5,303	5,625	8,701	8,378
Expense	Labor cost	3,602	4,459	4,764	5,091
	Fuel cost	552	564	809	913
	Other	1,412	1,407	1,726	2,413
	Total	5,566	6,430	7,299	8,417

* ($\times 10^4$ LS)

2) Organization and manpower

Organization and manpower of SRC are summarized in Fig. 2-1 and Table 2-9 respectively.

SRC has its head office in Atbara and five regional offices.

- Board of Director
  - General Manager – Deputy General Manager
    - Chief Mechanical Engineer
    - Chief Civil Engineer
    - Signalling and Telecommunication Engineer
    - Personal and Training Director
      - Personnel Director
      - Training Director
    - Traffic Manager
    - Chief Accountant
    - Planning and Economic Reserch Director
    - Controller of Stores
    - Eastern Regional Manager
    - Nothern Regional Manager
    - Central Regional Manager
    - Western Regional Manager
    - Southern Regional Manager
    - Fire Brigade Office
    - Social Services Director
    - Chief Police Office
    - Public Relation Director
  - Internal Auditor

Fig. 2-1 Organization of SRC

Table 2-9 Manpower of SRC

Section	Number of employees (Persons)
Head office	816
Mechanical/electrical	11,455
Facility	8,231
Transportation	7,226
Storage	1,047
Security	2,003
Accounting	929
Total	31,707

3) Tracks

Track length and rail type in each section are shown in Table 2-10.

Table 2-10 Track Length and Rail Type by Section

Section	Length (km)	Rail type (lb/yard)
Port Sudan - Atbara	475	90
Atbara - Khartoum	313	90
Haiya - Kassala	347	75
Kassala - Sennar	455	75
Khartoum - El Obeid	689	75
Er Rahad - Babanusas	363	75
Atbara - St No. 10	270	75
St No. 10 - Wadi Halfa	341	50
St No. 10 - Karima	222	50
Babanusa - Nyala	335	50
Babanusa - Wau	444	50
Sennar - Ed Damazin	227	50
Total	4,481	805

90 lb/yd (45 kg/m) rails are laid in 18% of the total track length, 75 lb/yd (37 kg/m) rails 50%, and 50 lb/yd (25 kg/m) rails the remaining percentage. A section between Port Sudan - atbara - Khartoum to be used for fuel oil transport in the project is the most important section and thus uses 90 lb/yd (45 kg/m) rails. On the other hand, an alternative route of Haiya - Kassala - Khartoum uses 75 lb/yd rails which have also permissible axle load of 16.5 tons.

Most of the tracks are unballasted and not well maintained, thus limiting maximum train speed to around 60 km/h.

4) Rolling stock

Rolling stock owned by SRC is listed in Table 2-11 and the number of locomotives (by type) and their operating status are summarized in Table 2-12.

Table 2-11 Rolling Stock Owned by SRC

Type	Use	Number
Steam locomotive	Main line	89
	Shunting	10
Diesel locomotive	Main line	169
	Shunting	76
Passenger carriage	For passenger	491
	For business use	606
Freight wagon	For passenger	5,613
	Tank wagon	746

Table 2-12 Number of Locomotives by Type and Their Operating Status

Type	Class use	Number	First year in service	Number operated	Number suspended from operation	Number unable to recover or abandoned
SL	Main line	89	—	6	71	12
	Shunting	10	—	—	—	
DL	1000	62	1960 - 69	9	42	11
	1500	20	1969	0	17	3
	1600	10	1982	4	4	2
	1700	10	1975 - 81	6	2	2
	1800	30	1976	15	3	12
	1850	10	1985	7	2	1
	1900	20	1975	3	12	5
	1950	10	1981 - 85	4	0	6
	(Sub-total)	172		48	82	42
	Shunting	76	—	26	41	9

Most of the diesel locomotives for main lines are out of service due to unfavorable environment (sand and high temperatue) as well as shortage of spare parts; only 48 locomotives (28%) are in working condition as of 1 October, 1985. Although 10 locomotives were procured by aid of the US Government in August 1985, three of them are under repair due to failure in a compressor or an accident.

Since locomotives in working condition are constantly in short supply, the utilization plan cannot be established. As a result, lack of locomotive utilization schedule makes operations unreliable.

As to shunting locomotives, only one-third (26 locomotives) is in working condition.

5) Operation

(1) Operation control

Operation control is done from six dispatch offices listed in Table 2-13.

Table 2-13 Dispatch Offices and Control Sections

Dispatch office	Control section	
	From	To
Port Sudan	Port Sudan	Haiya
Atbara	Haiya	Atbara
	Atbara	Khartoum
Khartoum	Khartoum	Sennar
Sennar	Sennar	Gedare
Kassala	Gedare	Kassala
Kosti	Sennar	Kosti
	Kosti	El Obeid

Note: Other sections are not controlled from dispatch office.

(2) Timetabling

Although a standard train timetable (one train per 1 - 2 hours in one direction) is established for the section between Khartoum and Port Sudan, actual train operations are carried out in accordance with weekly timetables.

Average number of runs each day is 5 round trips for the section between Khartoum and Atbara and 3 - 4 round trips for the section between Atbara and Port Sudan (1984/85).

(3) Locomotive depots

Locations of locomotive depots and their responsible sections are shown in Table 2-14.

Table 2-14 Locomotive Depots and Responsible Sections

Locomotive depot	Responsible section
Atbara	Khartoum - Atbara - Port Sudan Atbara - Karima, Atbara - Wadi Halfa
Khartoum	Khartoum - Sennar Junction
Kassala	Old Sennar Junction - Haiya Junction, Haiya - Port Sudan
Sennar Junction	Sennar Junction - Ed Damazine
Kosti	Senner Junction - El Obeid
Babanusa	Babanusa - Er Rahad, Babanusa - Nyala, Babanusa - Wau

(4) Operating record

Operating record in 1984/85 is shown in Table 2-15.

Table 2-15 Operating Record (1984/85)

Unit: Number of trains

Section / Operating record	Khartoum - Atbara		Atbara - Port Sudan	
On-time operation (Delay within 30 minutes)	1,892	52.3%	1,334	50.9%
Delay	1,723	47.7	1,287	49.1
Over 30 min.	103	2.9	20	0.8
Over 1 hour	449	12.4	130	5.0
Over 3 hours	363	10.1	143	5.5
Over 5 hours	478	13.2	395	15.0
Over 10 hours	330	9.1	599	22.8

As seen from the table, about 50% of trains operated in the Khartoum - Port Sudan section was delayed 30 minutes or longer. Of delayed trains, delays of 30 minutes - 5 hours account for 20% and those of more than 5 hours 30%, indicating a high percentage of long time delay. In the Atbara - Port Sudan section, in particular, delays of more than 5 hours account for 40%, much higher than 10% for delays of 30 minutes - 5 hours.

This is because the section is relatively long with steep and poorly maintained track on the Port Sudan side, which requires long hours to send a rescue locomotive from Atbara when a locomotive fails on the way.

Thus, to maintain reliable fuel oil transport, an adequate back-up system for locomotive failure (multi-hauling or appropriate positioning of rescue locomotives) should be provided.

6) Rolling stock maintenance

Maintenance of diesel locomotives is carried out at the locomotive depot and workshop in Atbara. These facilities are equipped with necessary machines, equipment and building, and the employees appear to work efficiently.

Nevertheless, prompt repairs cannot be done due to high rate of failure by severe operating conditions (sand and high temperature) and shortage of spare parts owing to financial condition, resulting in extremely low rate of operation. For instance, 20 diesel locomotives procured from Japan in 1969 are in failure and cannot be repaired due to lack of spare parts. To avoid such situation in this project, continuous provision of spare parts and technical guidance will be needed.

7) Signalling and communications equipment

(1) Signalling equipment

Major signalling equipment owned by SRC is listed in Table 2-16. Since all of SRC lines are single tracks, operation is controlled by tablet block system. All the points are manually operated, except for spring loaded points in some stations.

Signalling is done by semaphores and interlocking devices are of mechanical type.

Table 2-16 Major Signalling Equipment Operated by SRC

Item	Equipment	Remarks
Block device	Tablet block device	Key-token
Signal	Semaphore	
Interlocking device	Mechanical interlocking device	

(2) Communication equipment

A) Transmission lines

Short-wave radio is used for long distance communications between dispatch offices, and overhead bare wires are used for short distance communications between a dispatch office and each station as well as between neighboring stations (See Table 2-17).

Table 2-17 Transmission Lines by Type of Communication

Type of communication	Transmission medium	Remarks
Long distance	Short-wave radio and overhead bare wire	Used for telegraph (Morse) and call
Short distance	Overhead bare wire	Owned by STC, 5 lines leased to SRC

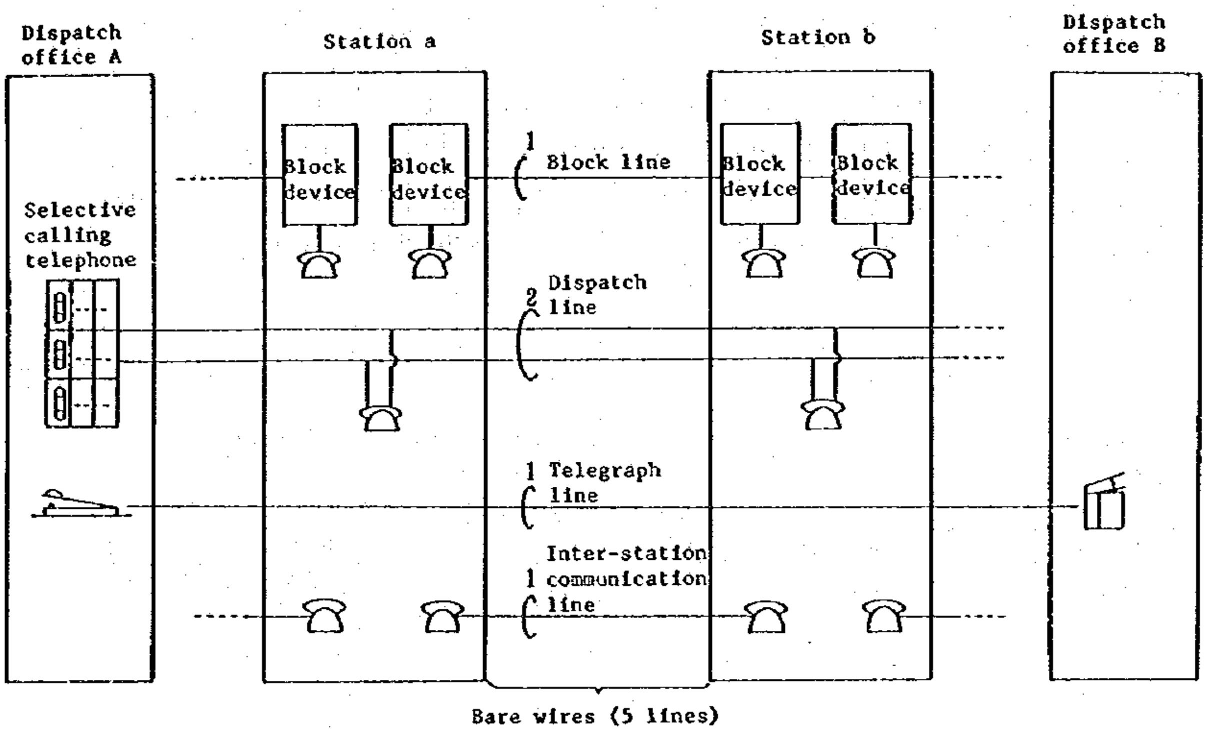
Note: STC - Sudan Telecommunications Corporation

In the section between Khartoum - Port Sudan, there are three dispatch offices in Khartoum, Atbara and Port Sudan to control train operations systematically. These dispatch offices are far away from each other; 313 km between Khartoum and Atbara and 474 km between Atbara and Port Sudan. Communications between them are made by means of short-wave radio or through overhead bare wires leased from STC.

The overhead lines are used for short distance blocking, telephone communications between neighboring stations and dispatch telephones. Also they are used for long distance telegraph communications between dispatch offices. However, they break down frequently (800 - 1,000 cases each year in the entire sections) to make communications unreliable, and their repairs are always delayed since STC who is responsible for maintenance operates its own microwave network; once, communications were interrupted for 50 days because of failure in an overhead line.

The overhead lines are used in the following manner.

Fig. 2-2 Use of Overhead Lines



Each dispatch office is equipped with one short-wave equipment. 10 frequencies (Table 2-18) are used in the radio communications since reaching distance of short waves varies with time.

Table 2-18 Frequencies Used in SRC's Short-wave Radio Communications

No.	Frequency (MHz)
1	4,570
2	4,770
3	5,073
4	5,220
5	6,780
6	9,086
7	9,790
8	9,914
9	10,153
10	11,011

B) Train - nearby station radio

This is used for communications between train crew and nearby stations and is installed in the section between Khartoum - Port Sudan and Haiya - Kassala. Radio equipment is installed at 32 stations (24 stations between Khartoum and Port Sudan), with two units each including a stand-by unit. Antennas are installed at the top of 35 - 40 m high steel tower.

Stations having the radio equipment are listed in Table 2-19.

Table 2-19 Stations with Radio Equipment

Port Sudan - Khartoum

Location	Spacing (km)
Port Sudan	29
Sallom	37
Kamob Sanha	39
Gebeit	24
Summit	19
Barameiyu	20
Erheib	35
Haiya Jn	26
Kas	27
Talquhari	30
Musmar	25
Sigadeit	43
Siyateb	43
Hadiga	46
Hudi	31
Atbara	33
Ezzeidab	41
Mahmiya	30
Kabushiya	37
Shendi	40
W. Ban Naga	49
J. Ouerri	36
El Geili	43
Khartoum N.	

Haiya - Kassala

Location	Spacing (km)
(Haiya Jn.)	43
Imasa	41
Tehella	39
Delai	52
Ungwatiri	56
Amadam	46
Mitatib	37
Akala	33
Kassala	

On the other hand, on-board radio equipment (fixed type) is installed in operator's cabins (both sides) of locomotives; one unit is used while the other serves as stand-by equipment. At present 70 units of on-board radio equipment are installed on 35 locomotives.

The radio communication system, made by Storno in Denmark, is used for communications at the time of engine trouble or accident.

C) Other communication equipment

SRC owns 4 telephone exchanges shown in Table 2-20, which are interconnected with STC lines.

Table 2-20 Telephone Exchanges Owned by SRC

Line Capacity	Number	Location
400 lines	1	Atbara
50 lines	3	Port Sudan, Kassala, Kosti

2-5 Present State of Terminal Facilities

1) Fuel loading facilities

Fuel oil is loaded at oil company's facilities in Port Sudan. Marshalling of empty or loaded wagons is carried out at New South Station near the oil companies. When loading is finished, wagons are assembled to a train and taken to Town Station where Manama and brake van are added to make up one fuel train (See Fig. 2-3).

New South Station has five tracks of 326 - 535 m and plans to add five more tracks. The tracks use 75 lb/yd rails with permissible axle load of 16.5 tons.

Relevant data on fuel loading facilities owned by AGIP, who supplies 70% of NEC's fuel requirements, is as follows:

o Shipping capacity (maximum)	Tank wagon: 900 tons/day Tank lorry: 500 - 700 tons/day
o Filling point	2 for 1,500 sec. 1 for 3,500 sec. Two more points will be added in 1986.
o Oil pump	2 units (40 tons/hour each)
o Storage tank	1 unit (850 tons, 1,500 sec.) 1 unit (950 tons, 3,500 sec.) Installation of a new tank is planned.
o Heating facilities	Installation is planned (schedule not decided). There is no loading problem, since fuel oil from the refineries is loaded before being cooled. Loading time of 3,500 sec. fuel oil during the winter takes twice as much as that in the other seasons.
o Shunting	Manual shunting (using wires and winches)

According to the FTS Report*, other oil companies own similar facilities, with storage capacities as follows:

Total	1,350 t
Mobil	910 t
Shell	3,210 t

Also, SHELL has a steam raising plant and the best equipped loading facilities.

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* The Democratic Republic of the Sudan
National Electricity Corporation
"Fuel Transportation Study"
Final Report June 1984
SIR ALEXANDAR GIBB & PARTNERS MERZ AND MCLELLAN

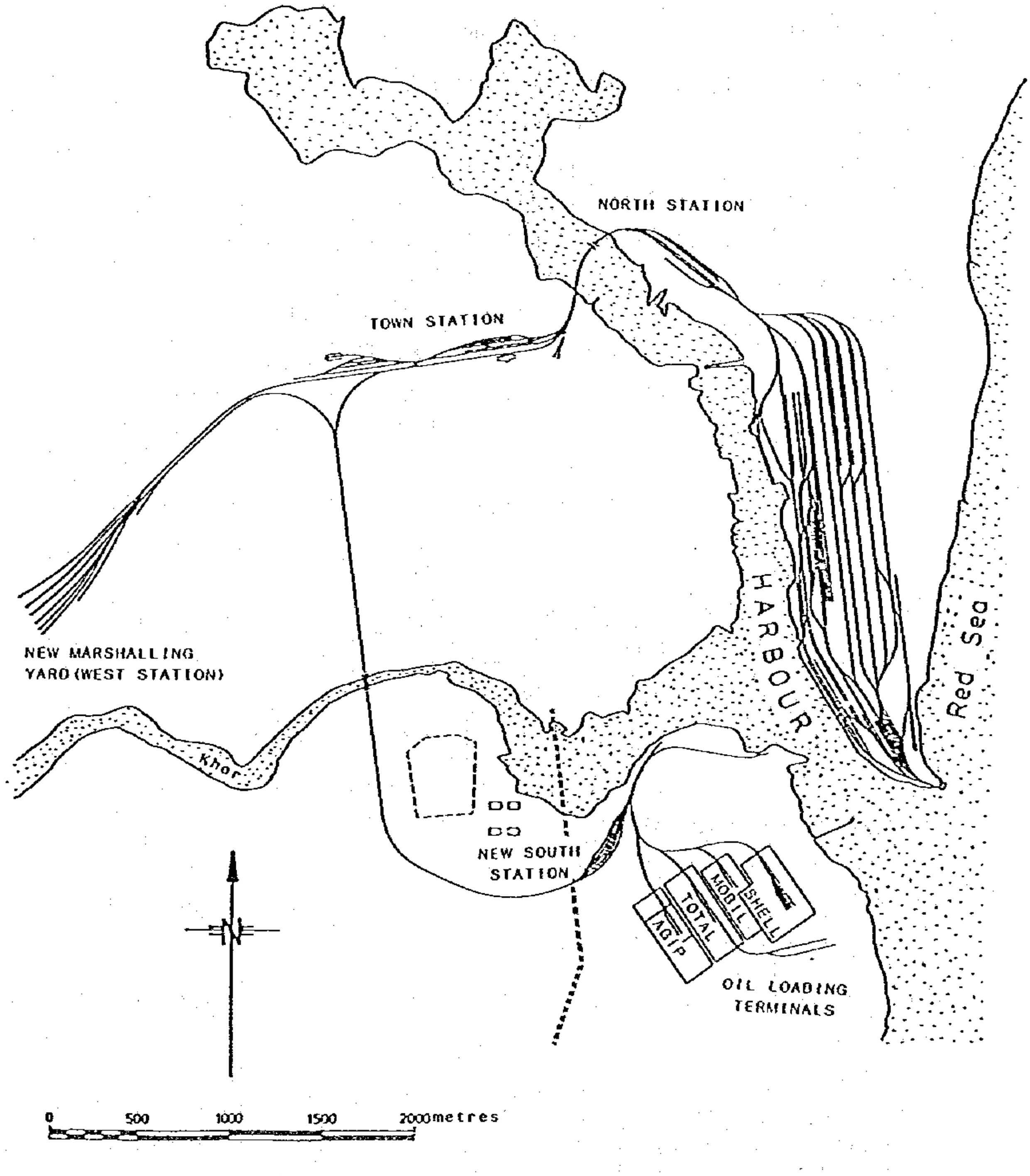


Fig. 2-3 Terminal Facilities in Port Sudan

2) Fuel discharge facilities

Tank wagons hauled to the Khartoum North power plant are to be detached at Khartoum North Station and those to Burri Power Station are to be channeled through Khartoum Station. Track layout in Khartoum is shown in Fig. 2-4.

Khartoum North Power Station was recently constructed and has new discharge facilities. On the other hand, Burri Power Station is old and under renewal works. The discharge facilities are old and polluted with oil spillage in Burri Station but discharge sidings and storage tanks were added recently.

Track layouts at the power stations are shown in Fig. 2-5 and their discharge facilities are summarized in Table 2-21.

Table 2-21 Discharge Facilities at Power Stations in Khartoum

	Burri	Khartoum North
Discharge point	5 wagons × 2 tracks 9 wagons × 2 tracks	10 wagons × 2 tracks
Discharge pump	54 m^3/h × 4	120 m^3/h × 2
Storage tank	1,500 t × 4 2,700 t × 3	20,000 t × 2

(200 t × 4 ... for gas oil)

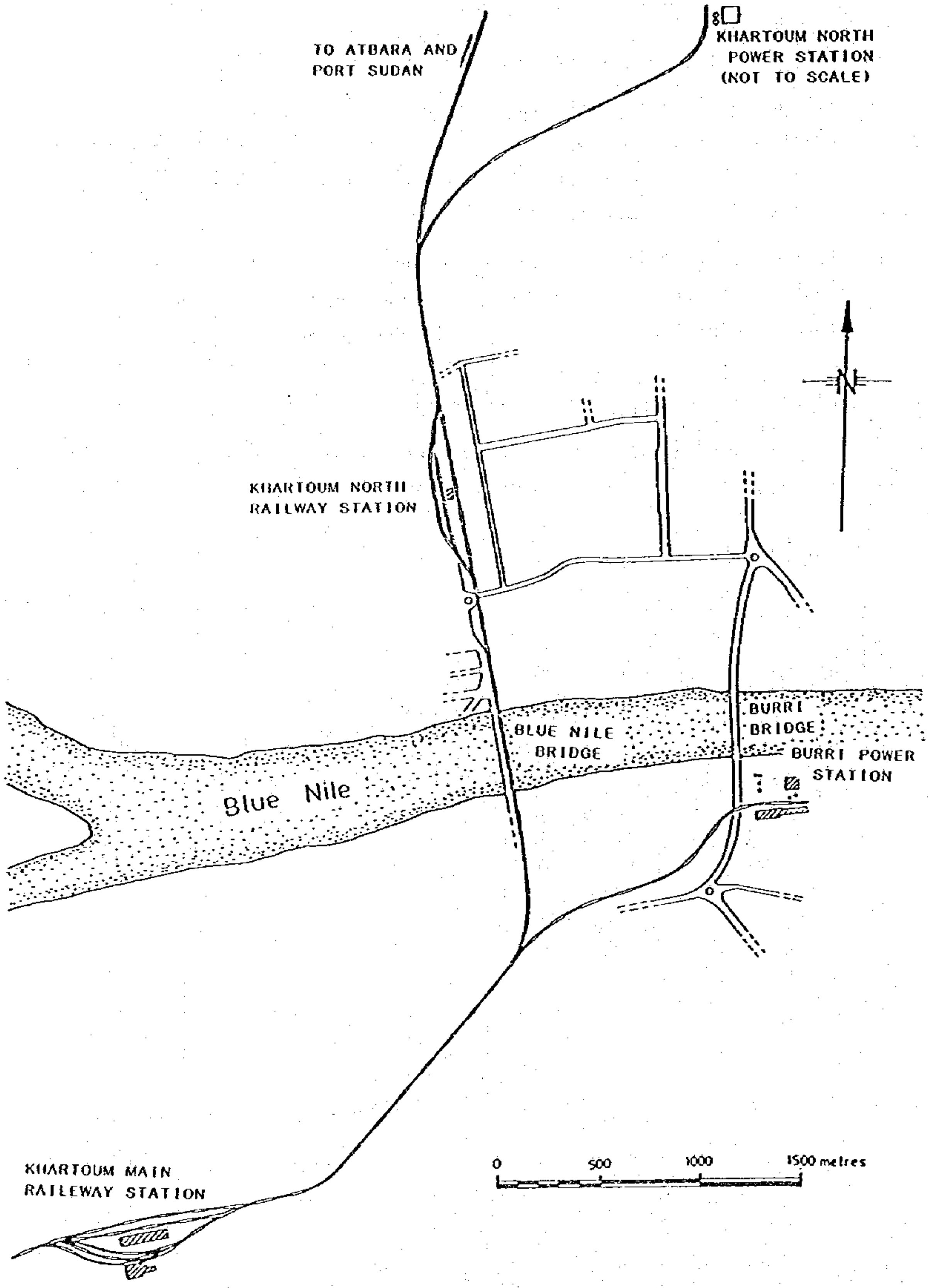


Fig. 2-4 Track Layouts in Khartoum

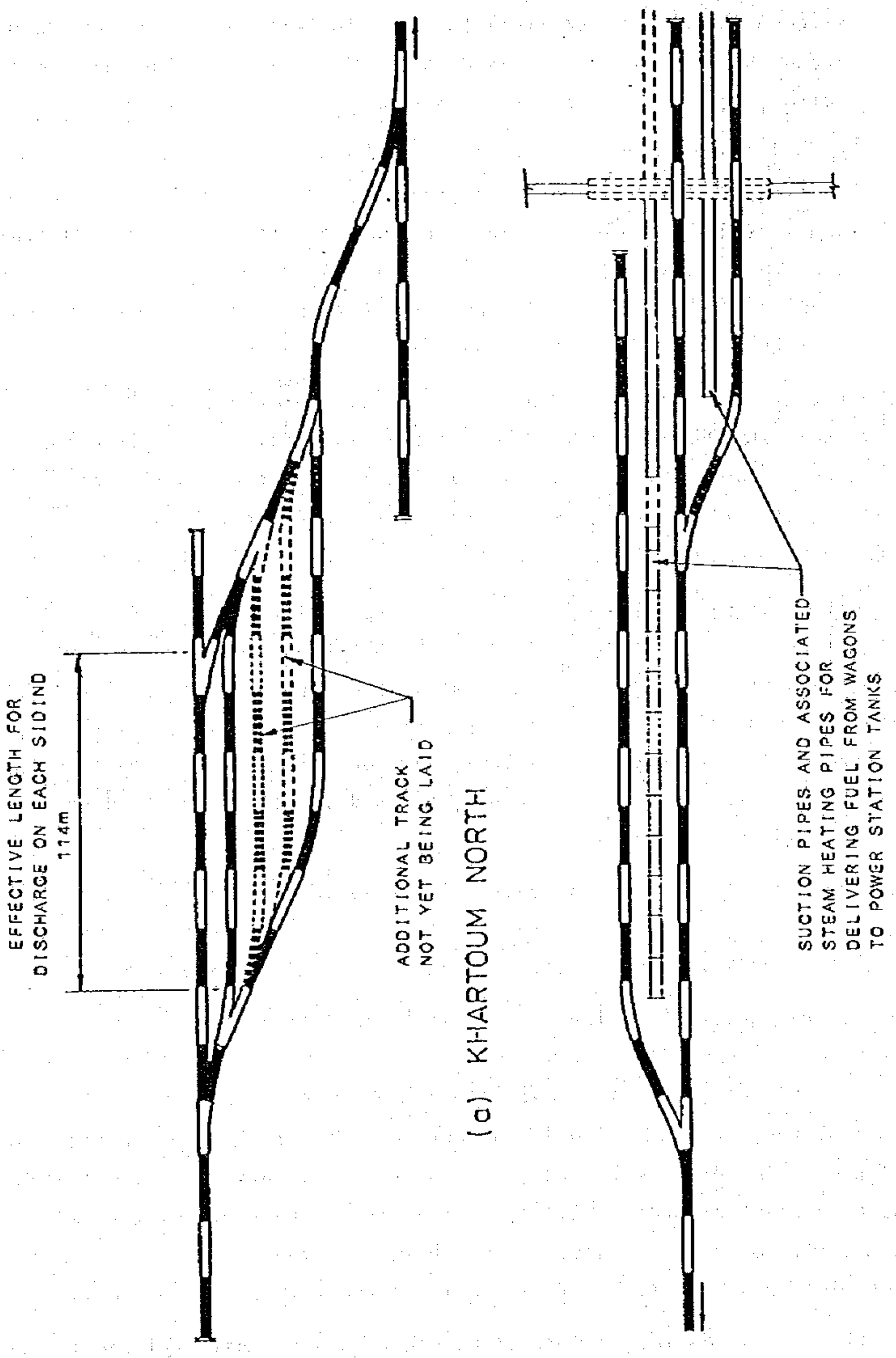


Fig. 2-5 Conceptual Track Layouts at Power Stations

Khartoum North power station plans to add two storage tanks (20,000 tons each) and already reserved the land for them. Also, the power stations plan to install steam raising facilities to heat tank wagons.

Shunting works at the power stations are not carried out efficiently since shunting locomotives owned by SRC are not always prepared when needed.

2-6 Present State of Fuel Transportation

Actual fuel consumption in Khartoum area was approximately 70 × 103 tons in 1983/84 and 90 × 103 tons in 1984/85. These correspond to daily transport of 240 tons in 1983/84 and 305 tons in 1984/85, assuming that the transportation was carried out for 295 days each year.

Capacities of existing loading and discharge facilities are considered sufficient to handle these tonnages. On the other hand, not all of the required fuel was carried by rail due to shortage of rolling stock: Althogh SRC's maximum transport capacity was 800 tons per day, the average daily transport capacity was 150 tons since trains could not be operated continuously. As a result, NEC had a half of the tonnages transported by tank lorries.

Shortage of rolling stock is particularly serious in diesel locomotives; trains carrying food and other relief items cannot be operated as scheduled, and tank wagons are often hauled in a mixed train.

Trains are constantly delayed from established timetables.

2-7 Background and Contents of the Request

Since hydropower generation is subject to seasonal fluctuation and that the production drops well below the power demand during the dry season, the Government of Sudan shifted its priority to thermal power generation after Power III Project and established a fuel transport improvement plan to secure stable fuel supply to thermal power stations.

The plan envisages the need for 140 tank wagons to meet fuel requirements at the power stations (28 wagons × 4 trains + 1 stand-by make-up) and 10 locomotives to haul the trains (2 locomotives double hauling) × 4 trains + 2 stand-by locomotives).

SRC will procure 40 tank wagons by aid of the Government of France and is modifying exisitng wagons for the Project. Also, negotiation is underway (as of October 1985) to procure 60 more tank wagons by aid of the Government of France. However, there is no definite plan for procuring these ten locomotives.
Also, procurement of communication equipment to ensure smooth fuel transport is not finalized although the plan aims to establish means of communication between SRC, NEC, GPC and oil companies to control fuel loading and discharge facilities as well as fuel trains in coordinated manners, between SRC, NEC, GPC and oil companies in Port Sudan and Khartoum, and between trains and nearby stations.

To overcome this situation, the Government of Sudan made a formal request to the Government of Japan to provide the locomotives and communication equipment under the grant-aid program.

Details of the request are as follows:

1) Locomotives

   10 diesel electric locomotives with 1,600 - 1,700 HP and axle load of 16 tons.

2) Communication equipment

   (1) Radio equipment for inter- and intra-city communications between related organizations in Khartoum, Atbara and Port Sudan, independent of the existing communication network.

   (2) On-board radio equipment to be installed on the above locomotives for communications between trains and nearby stations.

CHAPTER 3 PROJECT DESCRIPTION

CHAPTER 3 PROJECT DESCRIPTION

3-1 Description of the Sudanese Project

The project planned by Sudan is based on the FTS Report and is described in the following. The target year of the project is 1987/88.

1) Power generation project and fuel consumption

The power demand in the Blue Nile Grid was examined when the Power IV Project executive plan was prepared. The reference year of the forecast is 1983/84. By the low forecast the annual increase rate is 9%, and by the main forecast the annual increase is approximately 215 GWH, including unserved demand taken into consideration.

These power demand forecasts are shown in Table 3-1.

Table 3-1 Power Demand Forecast (Initial Version of the Project Prepared by the Sudanese Government)

Year	Main forecast (GWH)	Low forecast (GWH)
1983/84	1,134	1,089
1984/85	1,329	1,187
1985/86	1,544	1,294
1986/87	1,760	1,410
1987/88	1,974	1,540
1988/89	2,184	1,680
1989/90	2,413	1,830

(When the Japanese study team visited Sudan, it was clarified that the Sudanese authorities had changed the demand forecast to 1,406 GWH for 1984/85, calculated by adding the unserved demand to the power generation record, and to values calculated by assuming an annual growth rate of 7.5% for the subsequent years. The fuel transportation plan remains unchanged, however, because it is assumed that there is no large change in fuel consumption.)

Efforts are being made to implement the Power IV Project, which consists of reinforcing mainly the Khartoum North and Burri thermoelectric power plants, and the Roseires hydroelectric power plant to cope with the aforementioned power demand growth.

Based on the main forecast values of Table 3-1, the power demand, the hydroelectric energy to be generated, the thermoelectric energy required, and the consumption of fuel required in this connection are calculated for each month in 1987/88, with assumption of both average and adverse hydrological conditions. Results of these calculations show that the proportion of thermoelectric power generation will increase from 15% in 1981/82 to 35% in 1987/88, and that the fuel consumption will be 228,000 t/year in 1987/88 in average hydrological condition and 288,000 t/year in adverse hydrological condition.

As can be seen, the fuel consumption is significantly influenced by the hydropower situation. An annual average of 260,000 t, which is the average value between mean and adverse hydrological conditions, is therefore adopted in this study.

2) Transportation plan

The annual fuel consumption as of 1987/88 is assumed to be 260,000 t/year, but it must be remembered that the monthly fuel consumption varies greatly depending on the hydropower situation. Designing the transportation capacity to conform with the maximum fuel consumption incurs the risk of overdimensioning the facilities. Therefore, the power plants will be equipped with fuel storage tanks to absorb fluctuations in the consumption and level the transportation rate as much as possible. Monthly average of annual consumption becomes the monthly minimum transportation capacity requirement, and the larger grows monthly transportation capacity, the smaller capacity of the storage tank is required. The aforestated relationship is shown in Fig. 3-1.

It is thus concluded that the optimum monthly transportation capacity is 21,500 t, which corresponds to an annual transportation capacity of 260,000 t, by assuming a storage tank capacity of 94,000 t, of which 54,000 t is stored in the existing facilities and 40,000 t in facilities planned to be built in the Power IV Project.

The fuel transportation scheme is planned by assuming a daily transportation capacity of 1,000 t/day (calculated by assuming 260 effective transportation days per year, which is obtained by considering a safety margin for recovery in the case of troubles within the 295 working days per year (excluding holidays)).

This daily transportation capacity is equivalent to 28 tank wagons each with 35 t capacity. Therefore, one train consisting of 28 tank wagons will be operated every day to satisfy the expected fuel transportation demand. The fuel transportation trains will be operated under a fixed train system and will have a four-day operation cycle (turn round time) including loading at Port Sudan — transporting to Khartoum — unloading at Khartoum — return to Port Sudan, as shown in Table 3-2. Four trains will be used in this transportation scheme so as to fill the annual fuel consumption of 260,000 tons.

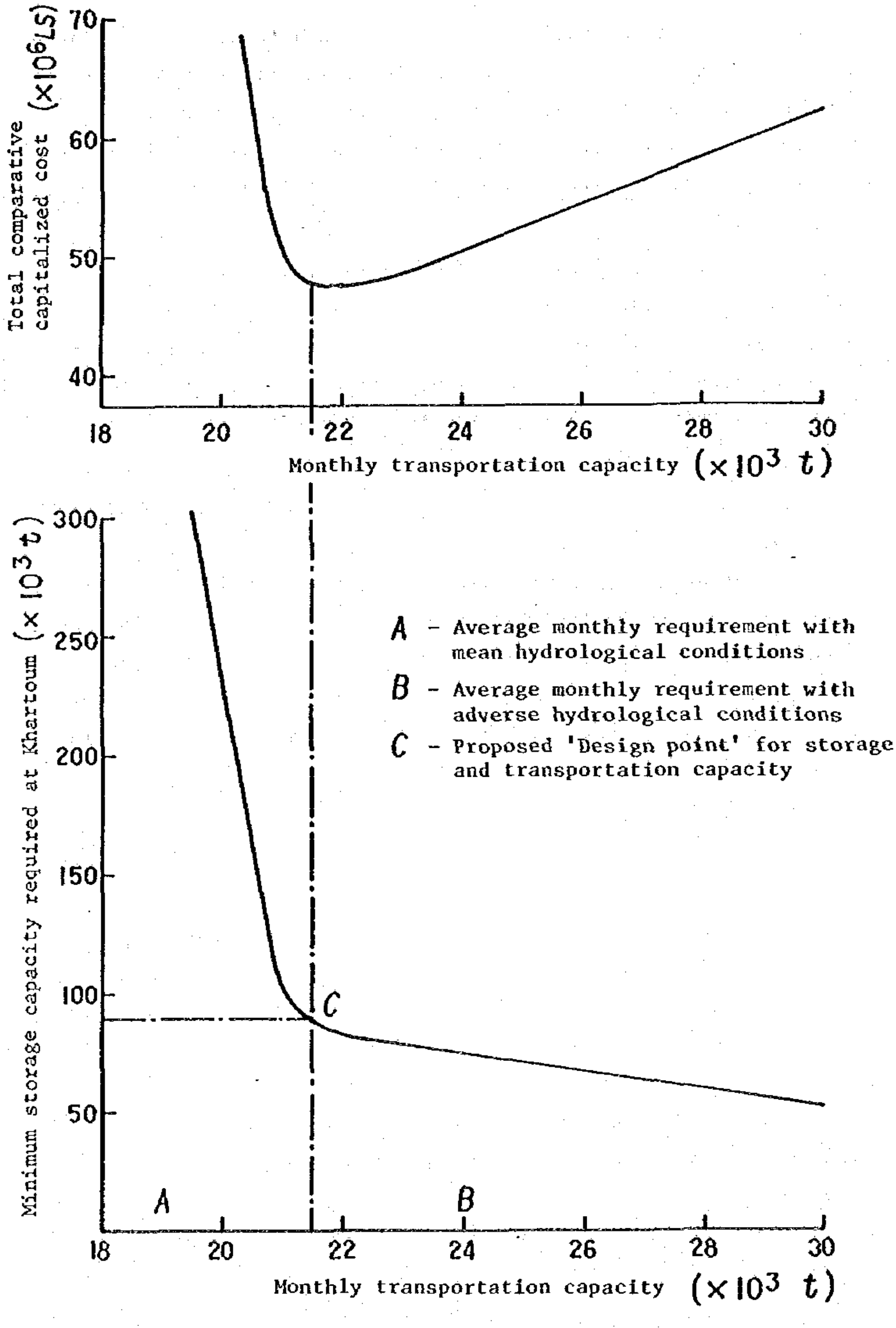


Fig. 3-1 Transportation Capacity and Storage Tank Requirement

Turn round time will be shortened to three days in the future by improving the loading facilities at Port Sudan and by upgrading the scheduled train speed to meet the transportation demand, as shown in Table 3-2.

Table 3-2 Required Cycle Time

(Unit: hour)

Location	Activity	1987/88 Plan	Case I	Case II
Port Sudan (PS)	Shunting Loading Contingency	6 14 6	6 8 6	1 6 1
PS to KTM	Running (including inspection halfway) Recovery	27.5 3.5	24 3	24 3
Khartoum (KTM)	Shunting Discharge Contingency	2 7 1	2 7 1	2 7 1
KTM to PS	Running Recovery	26 3	24 3	24 3
Total (Including recovery + contingency) (i.e., Turn round time in days)		96 hrs (13.5) 4	84 hrs (13) 3.5	72 hrs (8) 3

3) Equipment and facilities

As mentioned before, one train consisting of 28 tank wagons will be operated every day in a four-day cycle to transport 1,000 tons of fuel each day. The equipment and facilities below will be required.

(1) Diesel locomotives

The hauling load of the train consisting of 28 tank wagons, Manama and brake van is 1,486 tons when loaded and 506 tons when unloaded. Double heading operation with 1,650 HP locomotives with 13 tons axle load will be required for hauling the load for the following reasons:

a) For running at high speeds (particularly in uphill sections).

b) The lower the axle load, the less the track deterioration; furthermore bypass transportation via Kassala will be possible in case of any accident.

c) Even if one of the locomotives malfunctions, the train can be operated with little delay.

d) It is possible to accommodate future growth in the transportation demand by using additional tank wagons in the trains.

(We learned from this survey that the permissible axle load is 16.5 tons even when transported via Kassala.)

The required number of locomotives is calculated by the following:

2 (double heading) × 4 (No. of trains) + 2 (stand-by units) = 10 (locomotives)

Until the new locomotives are introduced, the existing 10 cars of Class 1,900 diesel locomotives that are presently out of service will be rehabilitated and used. (During this survey they were not restored yet, and there was no plan for restoration in the immediate future).

(2) Tank wagons

Tank wagons with 35 ton capacity, equipped with air brakes and heating coil will be used in this project. The required number of tank wagons is calculated by the following:

28 units × 1.1 (10% stand-by units) × 5 (trains) = 154 tank cars

(When this study was conducted, SRC was planning 28 units × 5 trains = 140 tank cars).

It is possible to fulfill part of the requirement by installing heaters in the relatively new tank wagons procured from France, but it is then necessary to consider fuel transportation for sectors other than NEC. In any case, it will be necessary to introduce new tank wagons to satisfy the fuel transportation demand.

(3) Terminal facilities

The new unloading facilities to be installed at Khartoum in this project are the extension of the unloading tracks at the Burri and Khartoum North thermoelectric power stations, installation of additional unloading inlets and installation of steam heating coil. Furthermore, the fuel storage tank capacity will be increased by 54,000 t at the end of the Power III Project and 40,000 t in the Power IV Project.

The petroleum company will be responsible for improving the loading facilities, but to reduce the operation cycle of the fuel transportation train it is necessary to increase the number of loading ports, install heating coil, etc. The FTS Report recommends that the Government and NEC carefully consider improving the loading capacity of the various companies and the allotment of purchases.

All yard rails of Port Sudan and Khartoum will be replaced with 37 kg/m rails.

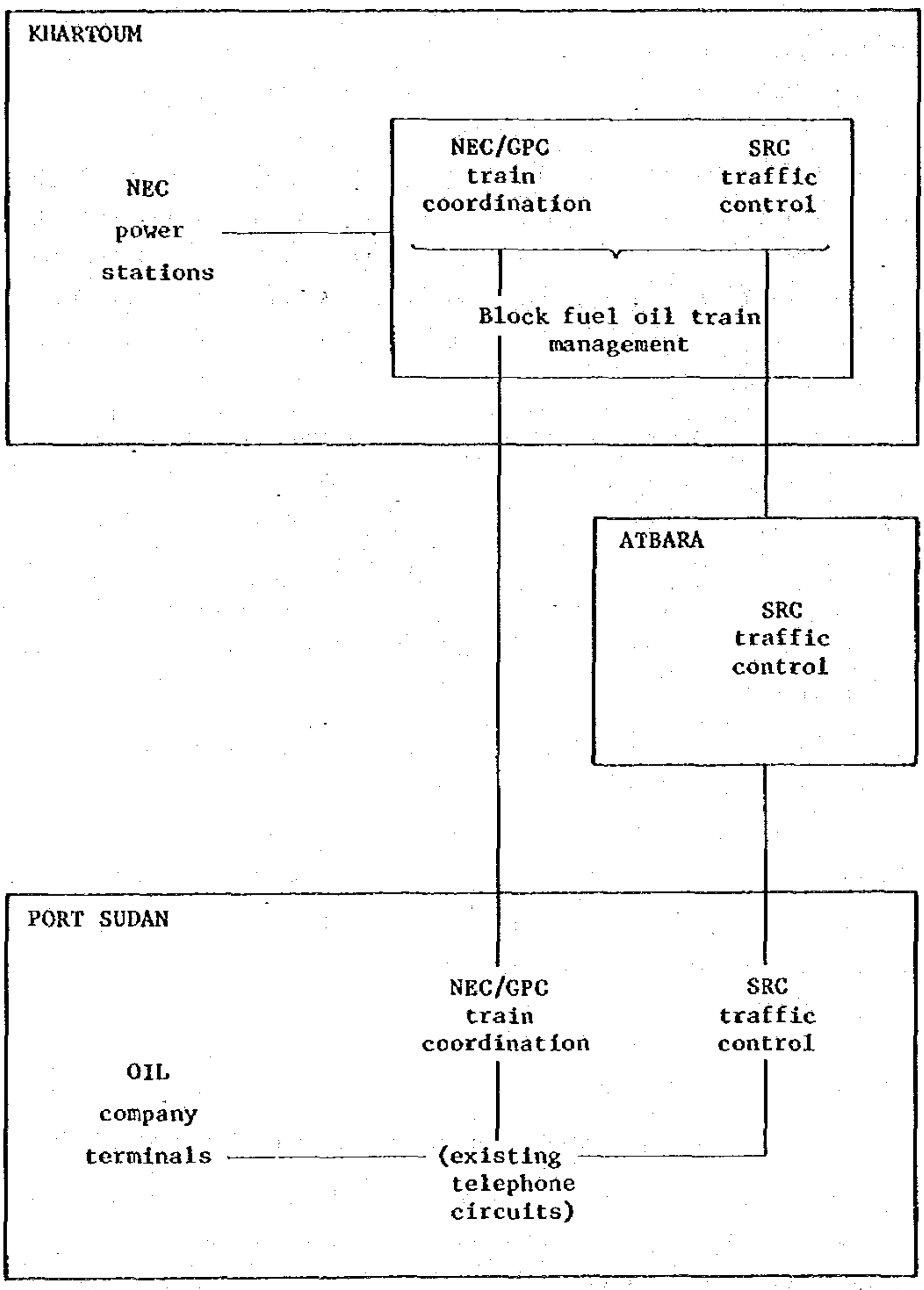
4) Communications equipment

Radio equipment between trains and stations and communications equipment interconnecting related sections of Khartoum, Atbara and Port Sudan are being considered to enable exchange of the transportation scheme, train operation state, and other relevant information.

The radio equipment is required to allow prompt communications between the train crew and the ground personnel in case of any trouble in the train between stations because the railroad is located in a desert zone with much sand, dust, and high temperature where locomotives are apt to malfunction, that the distance between adjacent stations is large and that the whole railroad has a single track.

SRC is presently equipped with radio equipment between the train and the nearest station to cope with the above situation. The same kind of equipment will be installed in the fuel transportation locomotives under this project.

For communications between the related cities and concerned organizations, a special-purpose communications network exclusively for fuel transportation, similar to that used for livestock transportation, will be provided. The outline of the system is shown in Fig. 3-2.



(1) Dedicated Locomotives equipped with cab radio similar to LMMC locomotives to communicate with stations.

(2) Additional outstations, of strategic importance in train control, equipped with radio links to traffic controls and trains.

Fig. 3-2 New Radio Links for Block Fuel Oil Trains

3-2 Review on the Request

1) Diesel locomotives

According to the plan by the Sudanese side, 140 tank wagons (28 units × 4 compositions + 1 stand-by unit) and 10 diesel locomotives hauling the wagons in double header will be required to transport 260,000 tons of fuel oil for thermal power stations annually. These estimates appear to be reasonable in terms of fuel requirements and turn round time.

The Government of Sudan plans to procure 100 tank wagons by aid of the Government of France and provide 40 wagons by modifying existing vehicles (installation of heating coil and modification of air brakes). The study team found that 40 tank wagons were being manufactured and provision of 60 wagons was not yet finalized between the two Governments although the Government of France had made a commitment.

Therefore, the number of locomotives to be provided under the grant-aid program should be determined on the basis of the number of tank wagons which will be provided for certain, or 40 tank wagons being manufactured plus 40 existing tank wagons being converted.

On the other hand, air brakes of the existing wagons are being converted to attach air brakes and heating coil will be installed in near future.

2) Communication equipment

(1) Communication equipment between trains and nearby stations

Since the railway runs mostly in the desert, locomotives are susceptible to engine trouble caused by sand and high temperature. Once a train is stalled in the mid-way, train - station radio is the only means of communication because of great distance between stations. Thus, the locomotives to be provided should be equipped with radio equipment compatible with existing radio system to secure emergency communications.

(2) Inter-city communication equipment

SRC maintains a short-wave radio system and overhead bare lines (leased from STC) for long distance communications. However, the former is restricted on use and has no stand-by units while the latter is not reliable due to poor transmission quality. Although it is desirable to install independent radio equipment in Khartoum, Atbara and Port Sudan to provide communications for efficient fuel transportation, these are not urgently required because of less frequent communications (once each day) and relatively small amount of information to be transmitted.

Other organizations such as NEC, GPC have their own radio system, and STC maintains telephone lines. Although it is preferable to install different types of radio equipment to improve the reliability of communication line and equipment, the priority is not particularly high as these are not used frequently or directly for train operations.

(3) Intra-city communication equipment

To carry out shunting work before and after fuel loading and discharging efficiently, it is preferable to install communication equipment in SRC, NEC and oil companies located in each city for this purpose exclusively. However, existing STC lines appear to be suitable for this purpose and should be used as much as possible.

3-3 Project Outline

1) Power demand

The power generation record in recent years in the Blue Nile Grid is shown in Table 3-3.

Table 3-3 Recent Power Generation Record

Year (July to June)	1983/84	1984/85 (% compared with previous year)
Peak power (MW)	188	210 (117)
Electric energy generated (GWH)		
Hydroelectric power	764	928 (121)
Thermoelectric power	250	281 (112)
Total	1,014	1,209 (119)
Power shortage (due to troubles and capacity shortage)(GWH)	143	42 (29)
Power demand record (GWH)	1,157	1,251 (108)

NEC was forecasting an annual growth rate of 9% for power demand as of 1984, but when Japanese study team visited NEC (Sudan), the annual growth rate was modified to 7.5% as shown in Table 3-4, in consideration of the decreasing rate of social facilities investments.

Table 3-4 Power Demand Forecast (Modified by Sudan)

Year	Power demand forecast (GWH)	Peak power generation demand (GWH)
1984/85	1,406	268
1985/86	1,511	288
1986/87	1,625	309
1987/88	1,747	332
1988/89	1,878	357
1989/90	2,018	384
1990/91	2,170	413

The forecasted values are examined based on the past record, for the cases with and without unserved demand, in the same way as for the FTS Report, and the relevant results are shown in Table 3-5. These forecasts are compared in Fig. 3-3.

Table 3-5 Power Demand Forecast

(Unit: GWH)

Year	Low forecast	Main forecast	Average
1984/85	1,251	1,251	1,251
1985/86	1,353	1,453	1,403
1986/87	1,462	1,657	1,560
1987/88	1,581	1,858	1,720
1988/89	1,710	2,056	1,883
1989/90	1,848	2,271	2,060

*1 1984/85 shows the actual results.

*2 The growth rate of the low forecast is assumed to be approximately 8%, in view of previous growth rates.

*3 The growth rate of the unserved demand forecast mentioned in the FTS Report is used for the main forecast.

As can be seen, the modified values proposed by NEC and the median value of the values forecasted in this study are practically the same as of 1988/89.

The average values of the forecast carried out in this study will be used.

The power demand as of 1988/89 divided into monthly demand is shown in Table 3-6. The same values are shown in the graph of Fig. 3-4.

Table 3-6 Monthly Power Demand in 1988/89

(Unit: GWH)

Month	Power generation requirements	With mean hydrological conditions		With adverse hydrological conditions	
		Hydroelectric power	Required thermoelectric power	Hydroelectric power	Required thermoelectric power
July	167	125	42	116	51
August	142	107	35	100	42
September	157	134	23	113	44
October	170	153	17	153	17
November	160	139	21	139	21
December	156	136	20	123	33
January	141	114	27	96	45
February	126	79	47	64	62
March	142	56	86	37	105
April	162	55	107	34	128
May	178	73	105	42	136
June	182	122	60	97	85
Total	1,883	1,293	590	1,114	769

These values take into account the expansion of the Roseires hydroelectric power plant, which is expected to be completed in June 1988 (means for raising financial resources for this construction are undefined). If the plant should not be expanded, the required thermoelectric power would be increased by approximately 30% with mean hydrological conditions and by approximately 20% with adverse hydrological conditions.

As can be seen from Table 2-6, the power generation capacities can satisfy these power demands, but it will be necessary to further increase the operation rates of the thermoelectric power plants if the Roseires hydroelectric power plant should not be expanded as planned.

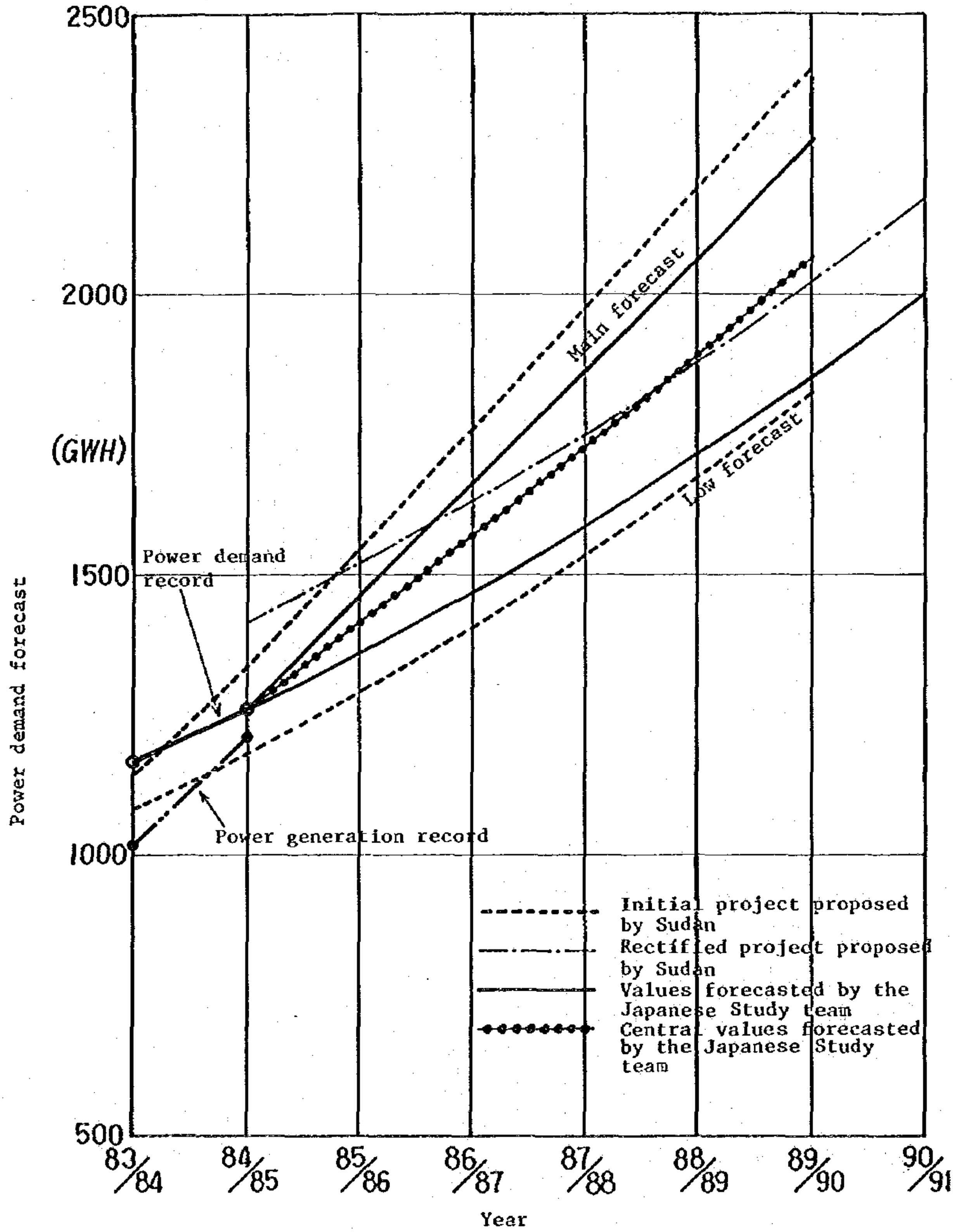


Fig. 3-3 Power Demand Forecast

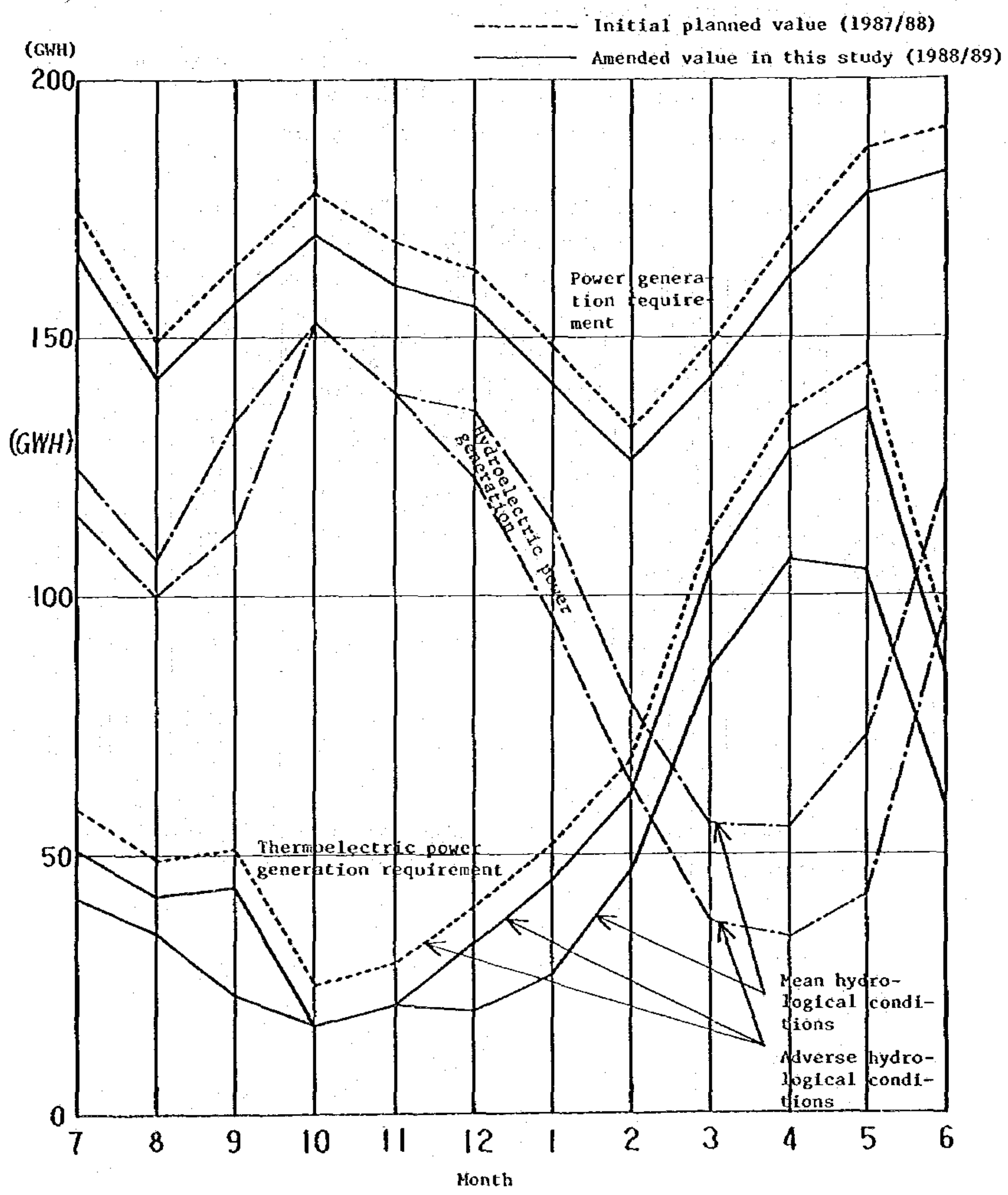


Fig. 3-4 Monthly Power Demand in 1988/89

2) Fuel consumption and transportation

The thermoelectric power requirement and the fuel consumption of each year, calculated from the power demand mentioned in the previous Chapter, are shown in Table 3-7 and Fig. 3-5.

Table 3-7 Annual Thermoelectric Power Requirement and Fuel Consumption

Year	Power demand (GWH)	Hydroelectric power generation (GWH)		Thermoelectric power generation (GWH)		Fuel consumption (10^3 t)	
		Mean hydrological conditions	Adverse hydrological conditions	Mean hydrological conditions	Adverse hydrological conditions	Mean hydrological conditions	Adverse hydrological conditions
1984/85	1,251	1,102	950	149	301	50	101
85/86	1,403	1,102	950	301	453	101	152
86/87	1,560	1,102	950	458	610	153	204
87/88	1,720	1,102	950	618	770	207	258
88/89	1,883	(1,102) 1,293	(950) 1,114	(781) 590	(933) 769	(262) 198	(313) 258
89/90	2,060	(1,102) 1,293	(950) 1,114	(958) 767	(1,110) 946	(321) 257	(372) 317

Figures in parentheses assume no investment in new Roseires No. 7 hydropower plant.

As can be seen, fuel consumption demand increases by 20 or 30%, if Roseires No. 7 plant is not completed.

The minimum transportation requirement in 1988/89, assuming 295 working days per year, excluding holidays, is shown in the following:

- With mean hydrological conditions

  16.5×10^3 t/month or 672 t/day

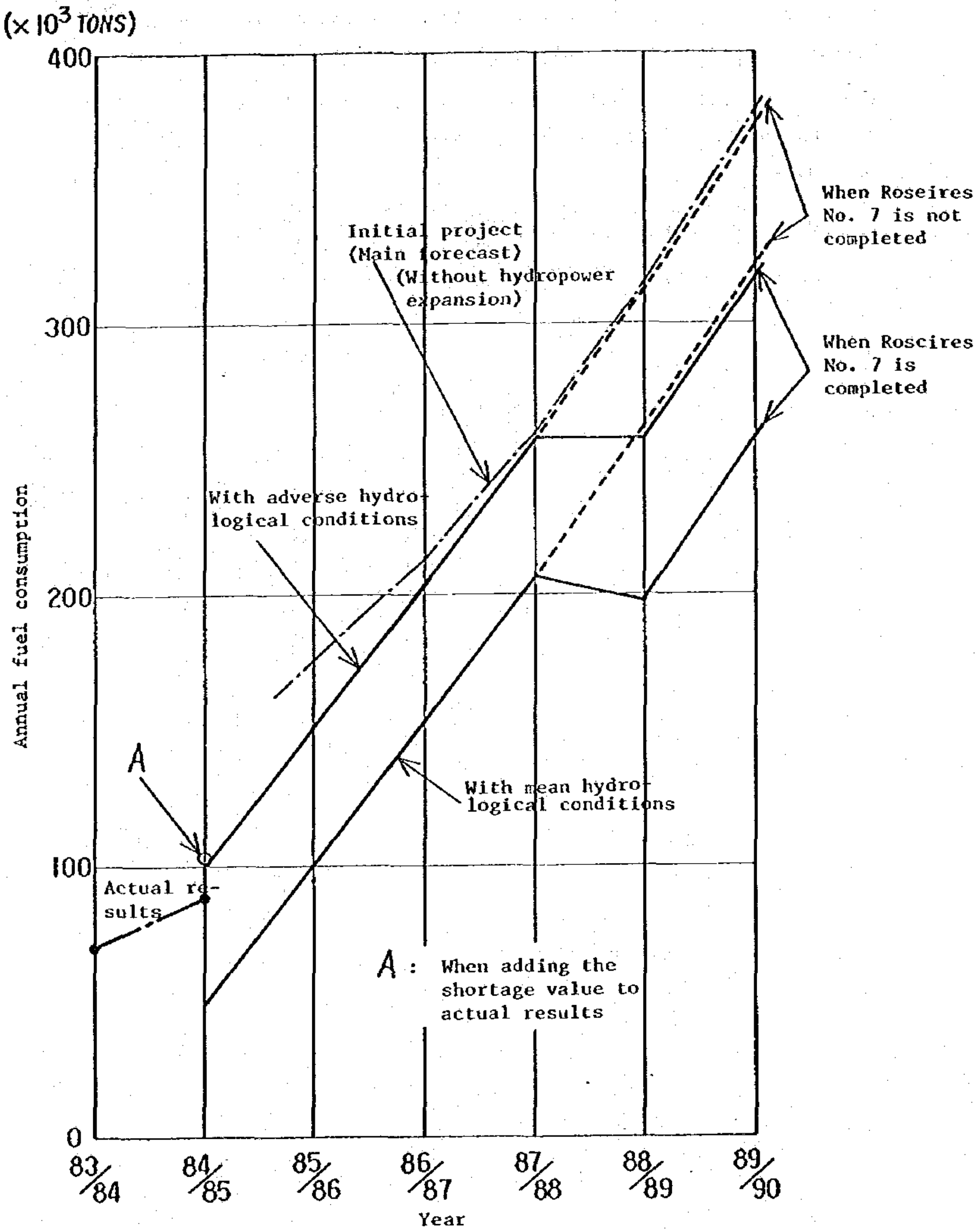


Fig. 3-5 Annual Fuel Consumption

∘ With adverse hydrological conditions

21.5×10^3 t/month or 875 t/day

The fuel transportation capacity must be determined by considering these values, and the storage tank capacity provided for seasonal fluctuations, troubles, and the recovery after a trouble. Figure 3-6 shows the monthly fuel consumption and the fuel remaining in the storage tank for the minimum transportation rate, Fig. 3-7 shows the transportation capacity and the minimum capacity requirement of the storage tanks.

When the hydrological conditions are adverse, the storage tank capacity is short by 13,000 t, which is expressed as the difference between the minimum fuel requirement and the existing storage capacity of the tanks. In reality, it is necessary to expand the storage capacity by approximately 20,000 t in consideration of a safety margin covering approximately five days. The transportation capacity should be about 900 t/day (calculated by considering some safety margin above the minimum transportation capacity requirement with adverse hydrological conditions) on the premise that in an emergency fuel will be transported even on holidays.

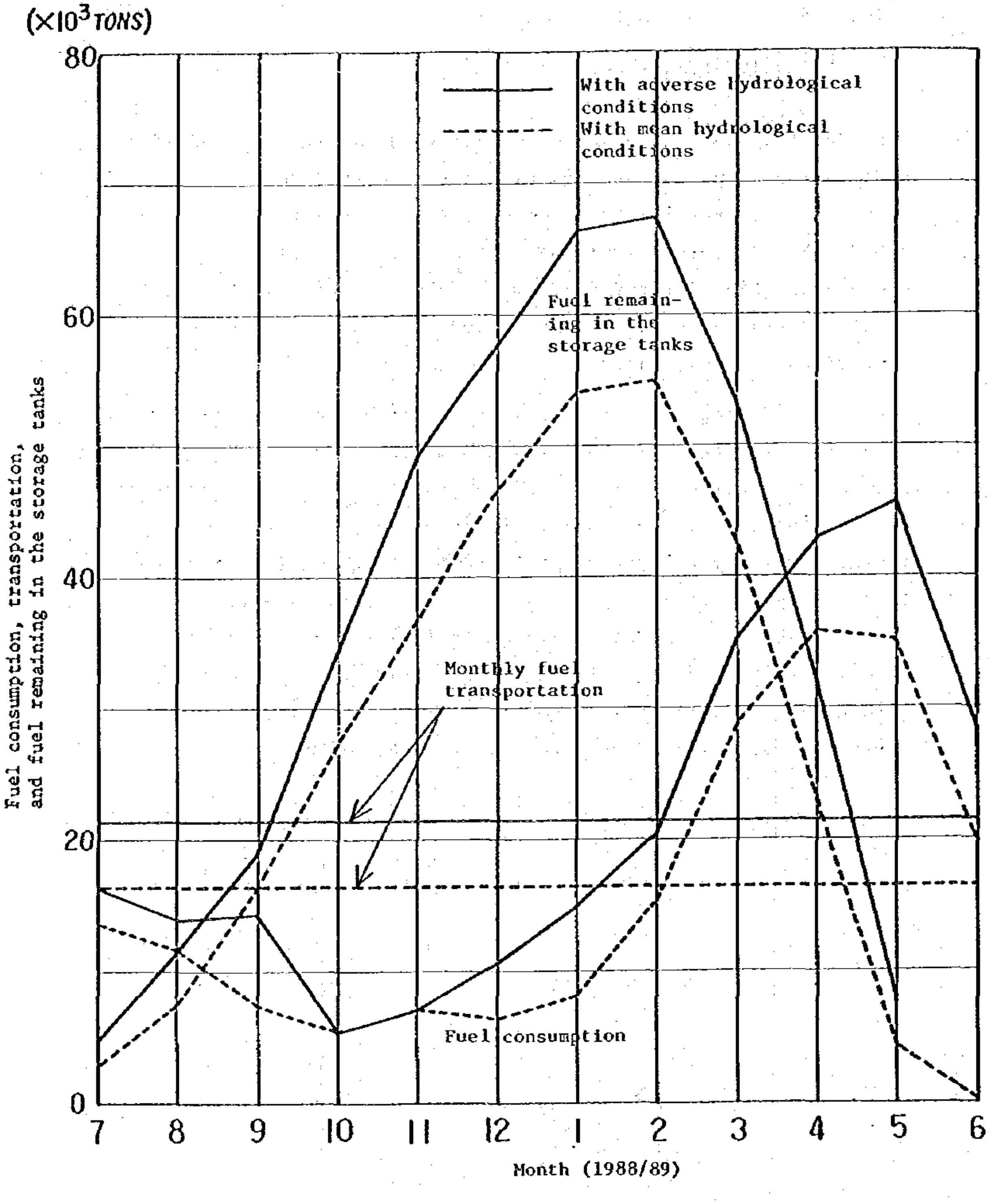


Fig. 3-6 Monthly Fuel Consumption and Fuel Remaining in the Storage Tank

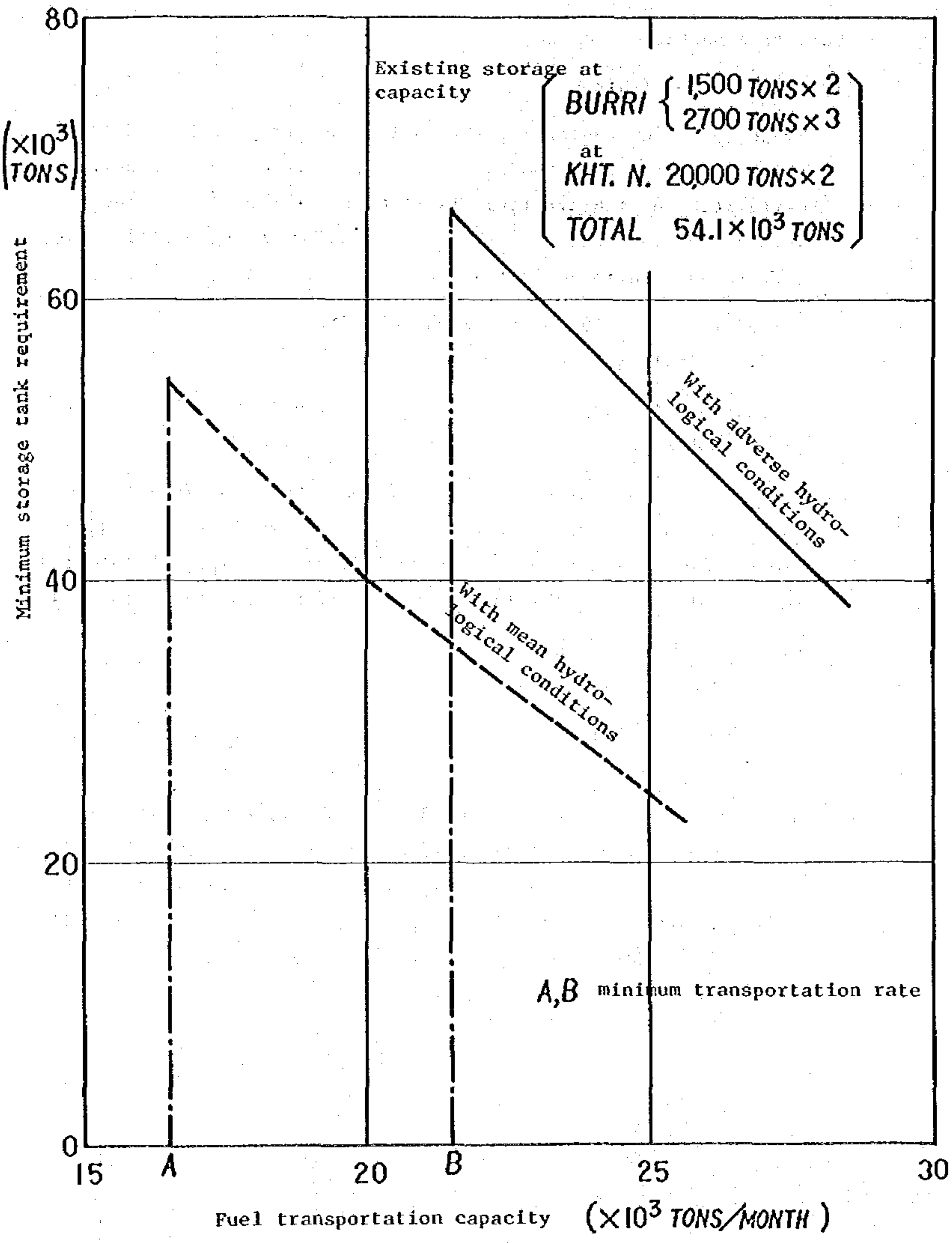


Fig. 3-7 Fuel Transportation Capacity and Storage Tank Requirement

3) Fuel transportation scheme

(1) Formation of trains

Train formation concerning the fuel transportation method and the daily transportation rate should be leveled for effective utilization of the available facilities. The number of tank wagons for fuel train is calculated from the transportation rate requirement mentioned in the above.

900 ton/day ÷ 35 tons/tank wagon = 25.7
..... 26 tank wagons/day

Therefore, the standard fuel transportation train should consist of 26 tank wagons.

The weight of each tank wagon is 17 tons when empty and 52 tons when loaded. One Manama and one brake van (20 tons tare each) are coupled at the head and the tail of each train. Therefore, the hauling load of the fuel transportation train is as follows:

From Port Sudan to Khartoum

52 tons × 26 + 20 tons × 2 = 1,392 tons

From Khartoum to Port Sudan

17 tons × 26 + 20 tons × 2 = 482 tons

The running resistance with 0, 5, and 10‰ gradient with the train loaded, and the locomotive power requirement are shown in Figs. 3-8 and 3-9. The starting resistance is assumed to be 6 kg/t for locomotives and 5 kg/t for freight cars, on the premise that all bearings are roller-type ones, and the Davis' Formula is used when the train is running.

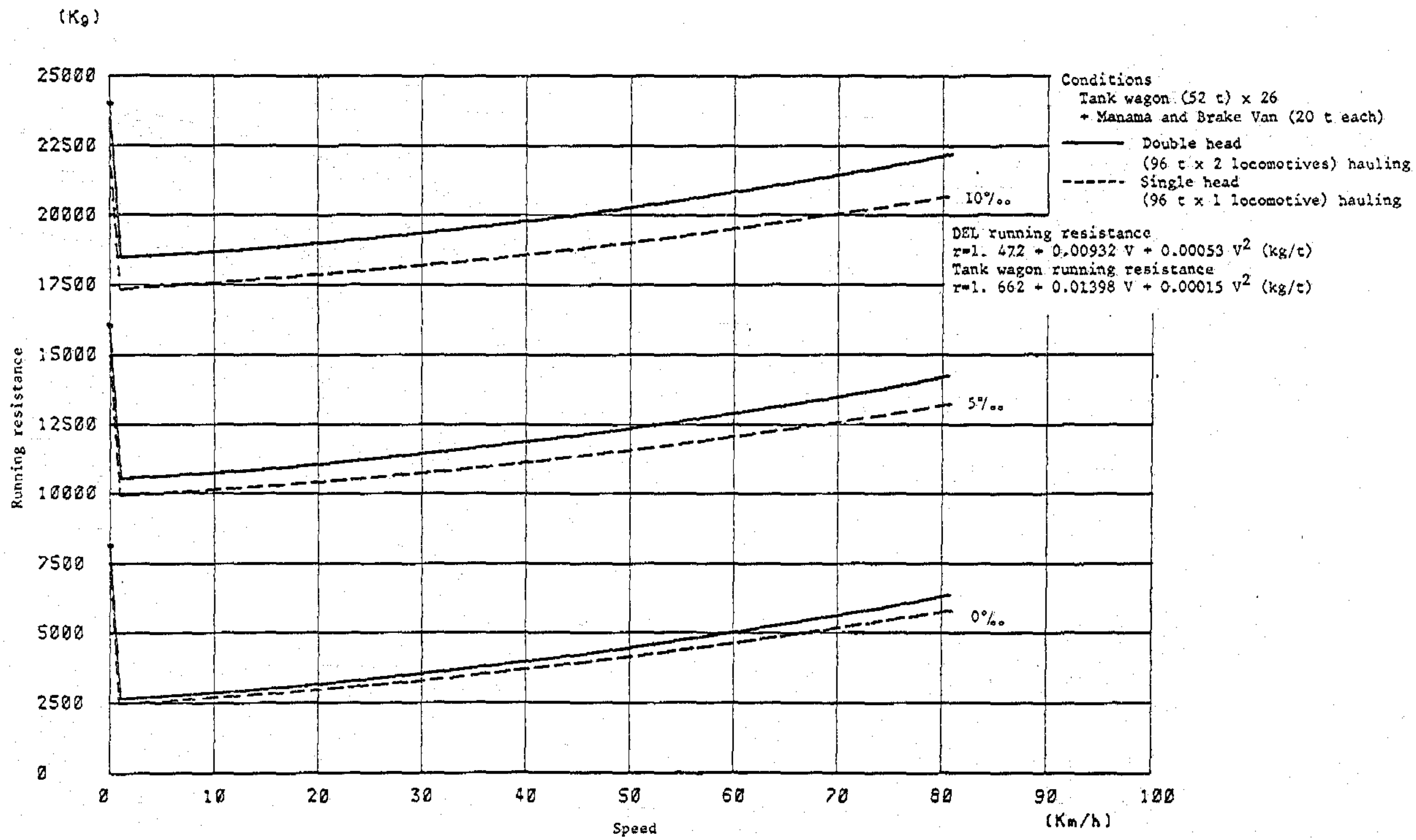


Fig. 3.8 Running Resistance

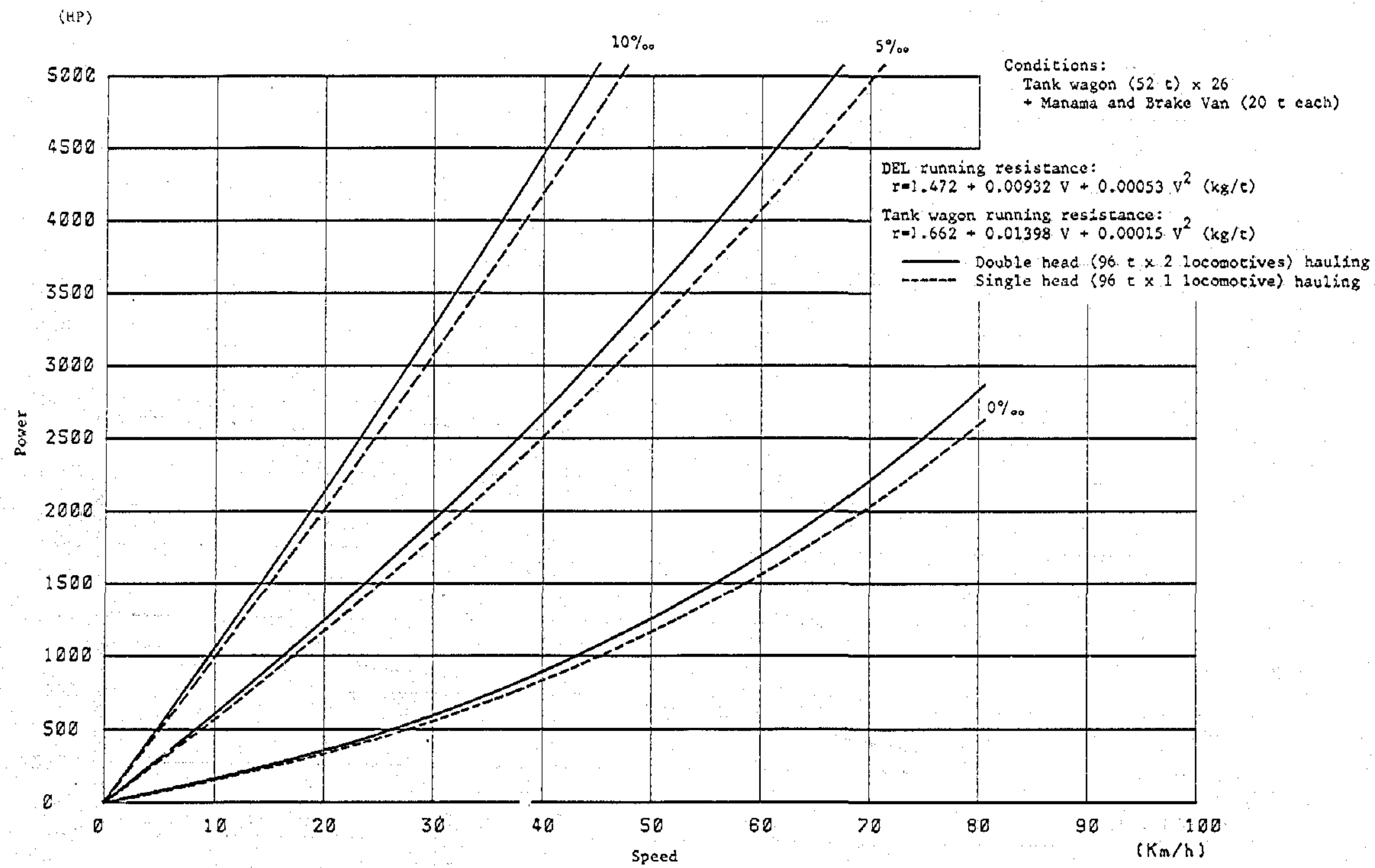


Fig. 3.9 Locomotive Power Requirement

(2) Required cycle time (Turn round time)

The required cycle consists of loading at Port Sudan, loaded running from Port Sudan to Khartoum, unloading at Khartoum, unloaded return from Khartoum to Port Sudan, shunting for car arrangement and train composition, and contingency at each stage. In the project proposed by Sudan, the turn round time at each stage is planned as shown in Table 3-8, and these figures are regarded reasonable in view of the situation regarding handling and the railroad facilities.

Table 3-8 Required Turn Round Time

Task		Required time
Port Sudan (PS)	Shunting	6 hr
	Loading	14 hr
	Contingency	6 hr
PS to KTM	Running (including inspections)	27.5 hr
	Recovery	3.5 hr
Khartoum (KTM)	Shunting	2 hr
	Unloading	7 hr
	Contingency	1 hr
KTM to PS	Running	26 hr
	Recovery	3 hr
Total		96 hr (4 days)

These turn round time requirements are plotted in Fig. 3-10.

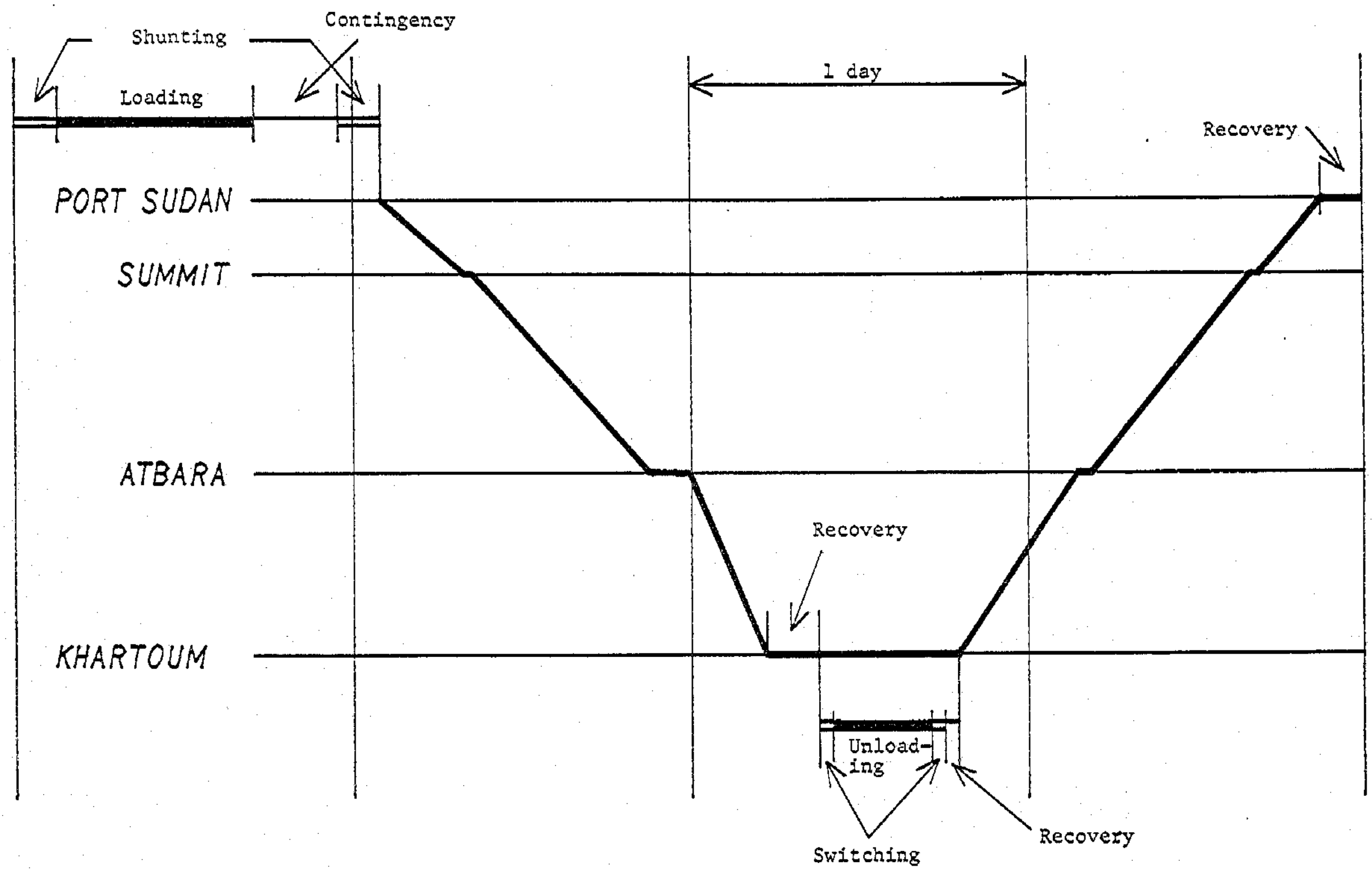


Fig. 3.10 Fuel Transportation Turn round Time

According to the project proposed by Sudan, if the fuel transportation demand should increase further, the turn round time would be shortened to three days by improving the various facilities and by shortening the loading and running time. The loading time and the running time account for a considerable proportion of the turn round time, but the former can be reduced considerably by simultaneous loading at various oil companies and by improving the shunting work efficiency through proper use of shunting locomotives. On the other hand, it is difficult to improve the running speed significantly, in view of the SRC facilities and their state of maintenance. In reality however, it is possible to achieve a fair reduction in the time by upgrading the limit speed of the tank wagons and by reviewing the inspection system at the way stations. The inspection system for rolling stock, including passenger coaches, is a matter to be decided by considering the special situation in Sudan and the experience of SRC; inspection at way stations seems too frequent at present. For example, if the inspections were conducted every 24 hours (in Japanese National Railways daily inspection is conducted every 48 hours), and if the train were scheduled to minimize stopping time at the way stations, most of the stopping time at the stations (approximately 9 hours now) would be saved.

(3) Usage of the locomotives

If the train consisting of 26 loaded tank wagons, Manama and brake van should climb the section with 10‰ gradient and 388 m locomotive (96 t dead weight) would be required to have an adhesion coefficient of 0.26 or more at the slopes, for a single heading haul. This value would be permissible in abnormal cases, but it seems rather severe in Sudanese railroads which do not have good track conditions. Therefore, in this section it is necessary either to adopt double heading or to reduce the number of tank wagons of the train.

There are three locomotive usage alternatives.

(A) Double heading throughout the whole route.

(B) Double heading only in the uphill section (Port Sudan to Summit) and single heading in the other sections.

(C) Reducing the number of tank wagons of each train and increasing the number of trains only in the uphill sections. In this case, the trains would be rearranged at the top of the grade section, increasing the number of tank wagons per train (26 tank wagons).

Of the alternatives, the operation diagram of the case (B) is shown in Fig. 3-11. In case (C) the locomotives would haul 20 tank wagons train in the uphill section, with additional 18 tank wagons train operated once in every three days up to the top of the uphill section. The wagons of the 18 tank wagon train would be divided into three parts each of which would be attached to one of the 20 tank wagons trains to form one normal fuel transportation train composition (26 wagons).

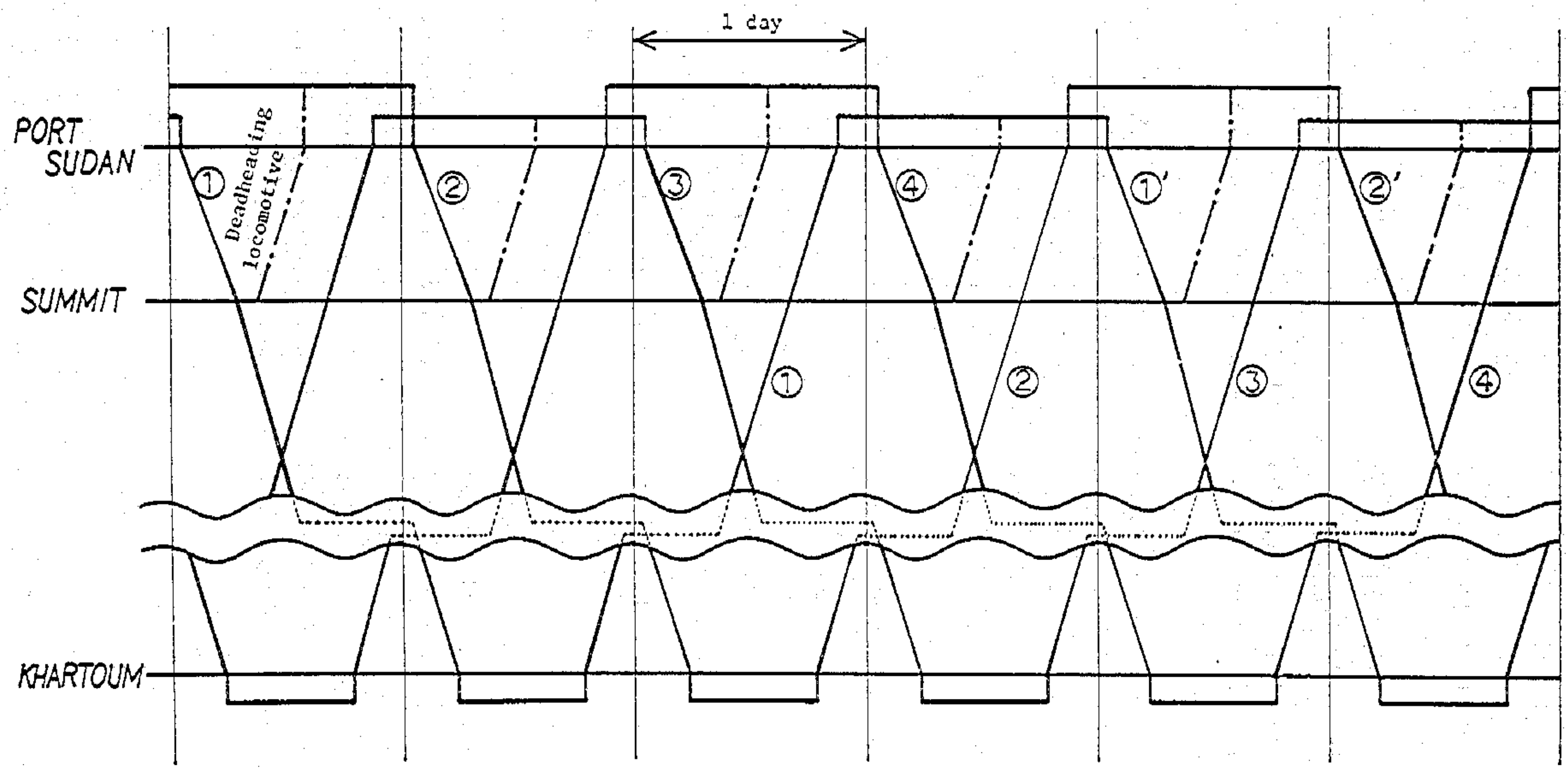


Fig. 3.11 Double Heading Operation only in the Uphill Section (Port Sudan to Summit)

These three traction alternatives are compared in Table 3-9. The following factors must be considered when evaluating the table.

① Speed in the uphill section

Approximately 30 km/h in alternatives (A) and (B); (Locomotive power 1,600/1,700 HP)
Approximately 28 km/h in alternative (C); (Locomotive power 2,250 HP)

In any case, there is no problem regarding the uphill section speed because it is approximately 30 km/h. If the uphill section speed should slow down to approximately 20 km/h, an additional two hours would be required to negotiate the uphill section, considerably influencing the total time requirement.

② Shunting work on the way through the route

The way stations are located in the desert, and there are problems regarding the allocation of personnel there. Therefore, the shunting workers must be carried by the train, and this means additional manpower requirement.

③ Measures to cope with problems in the locomotives

In view of the Sudanese topography, most of the railroads are located in the desert, and the locomotives are prone to have problems. Furthermore, once trouble occurs, a lot of time is required to send the rescue locomotive, in view of the location of the locomotive depots and other relevant factors. At present, delays of more than five hours account for 40% of the total, far outnumbering the 10% of delays between 30 minutes and five hours; this fact is a symptomatic manifestation of the problem mentioned above.

A long delay in the fuel transportation scheme influences the loading work and other phases of the process, and in some cases the next train will have to be canceled. It thus becomes necessary to consider a substantial safety margin in the transportation capacity, and this results in expensive investments in equipment and facilities.

Table 3-9 Comparison in Locomotive Usage

Alternative	Merit	Demerit
(A)	1. Higher running speed on the gradient 4.3 hours to run from Port Sudan to Summit (130 km) at 30 km/h speed. 2. No shunting work required (halfway) through the route. 3. The train can be operated even when one of the locomotives fails. 4. Efficient transportation is possible in Khartoum by dividing the train into two parts (Khartoum North and Burri). 5. This alternative has the greatest flexibility for accommodating future growth in demand.	1. This alternative requires many locomotives (10).
(B)	1. The speed improvement in uphill sections is the same as in alternative A. 2. This alternative requires a relatively small number of locomotives (seven). 3. Shunting of tank wagons is not required halfway through the course. (It does not take long to disconnect locomotives.)	1. Any problem in the locomotive significantly influences the transportation scheme. The dispatch of a rescue locomotive takes considerable time. 2. There is no safety margin in the hauling speed capacity in level sections. Furthermore, this alternative requires more powerful locomotives. 3. Deadheading of locomotives for gradient sections is required (i.e., it requires more manpower).

Alternative	Merit	Demerit
(C)	1. This alternative requires a relatively small number of locomotives (seven).	1. This alternative requires a large number of tank wagons (additional number of tank wagons equivalent to one complete composition). 2. Any problem in the locomotive significantly influences the transportation scheme. 3. Shunting work of tank wagons is required at the way stations (i.e., it requires additional manpower and additional time). 4. This alternative requires more powerful locomotives.

The allotment of rescue locomotives at intermediate bases helps shorten the rescue time but requires additional locomotives (for example, four stand-by locomotives would be required if they should be alloted every 200 km so as to reach the broken down train in two hours). This alternative is not practical because many sheds and inspection/repair facilities are required for the additional locomotives.

Measures to handle problems in locomotives are particularly important in Sudan, in view of the topographic and climatic conditions of the country.

Alternative A is concluded to be the most appropriate for this project, as a result of an overall judgement considering the above facts.

4) Fuel transportation equipment

To implement the transport project, rolling stock such as diesel locomotives and tank wagons, communication equipment, other railroad facilities and terminal facilities for fuel loading/discharge will be required.

Of these equipment and facilities, diesel locomotives and communication equipment requested by the Sudanese Government are described as follows.

(1) Diesel locomotives

To transport 900 tons of fuel oil per day, four trains (26 tank wagons of 35 ton load in each train) will be needed in consideration of turn round time (4 days). To haul these trains, 10 locomotives will be needed; 8 locomotives for 4 trains (double header), stand-by locomotives for inspection and operation (generally, 5 - 10% of locomotives in operation, minimum one locomotive for each purpose).

However, the study team found that 80 tank wagons would be procured for certain (40 wagons being manufactured and 40 wagons being converted).

Assuming that 26 tank wagons are made into one train for carrying 900 tons per day, 80 tank wagons available to SRC can be divided into 3 trains. To haul the three trains in double header, 6 locomotives (2 locomotives x 3 trains) will be required (not including stand-by locomotives).

With this arrangement, the annual transport capacity is estimated to be 195,000 tons, which corresponds to 100% of fuel requirements in mean hydrological condition (198,000 tons/year) and 75% in adverse hydrological condition (258,000 tons).

It should be noted, however, that stand-by locomotives need to be procured by other means or obtained from existing ones.

(2) Communication equipment

In consideration of geographical and other conditions, radio equipment equivalent to present ones are necessary to be installed on the newly provided locomotives; one radio per locomotive would suffice because of double header operation.

On the other hand, inter-city communication equipment appears not to be of urgent necessity since it is not used frequently nor directly for train operations, although it is preferable to provide a separate system in the future in consideration of poor reliability of the existing equipment.

5) Implementation and management organizations

All the rolling stock to be used for the project will be managed by SRC. Fuel loading, transport and discharging will be carried out by the following organizations.

(a) Loading	Oil companies
(b) Transportation (including shunting)	SRC
(c) Unloading	NEC

In addition, management and maintenance of railway facilities including the rolling stock and tracks will be carried out by SRC.

6) Facility management/manpower arrangement

Facilities for the project will be maintained and managed by organizations assigned of responsibility as mentioned above. Diesel locomotives will be maintained and managed by SRC at the following facilities:

Locomotive depot assigned: Atbara locomotive depot
Workshop assigned : Atbara workshop

Weekly, monthly and yearly check will be carried out at the depot, and overhauling and major repairs at the workshop. On the other hand, daily check will be carried out at Port Sudan, Atbara or Khartoum to ensure efficient operation schedules.

Operation of fuel trains will be controlled by Eastern Region Office in Port Sudan, Northern Region Office in Atbara, or Central Region Office in Khartoum, under supervision of the head office in Atbara.

As to manpower requirements, it is difficult to estimate the exact number to be required since it depends on facility design and working conditions of each organization. Nevertheless, rough estimate on train crew requirement has been done as follows.

- Crews per train
{Driver (1), assistant driver (1), conductor (1)} × 3 teams (shift)
Inspection personnel (1) × 3 shifts
Altogether, 12 crews will be required to operate each train.

In addition, security personnel may be added if SRC considers it necessary (currently assigned to other trains). Each round of train operation amounts to 70 hours including rest periods in Khartoum. Since ordinary working hours of SRC are 42 hours per week, each crew will be assigned to train operation once per 1.7 weeks (70 ÷ 42 = 1.7).

Assuming that average attendance rate is 0.9 by taking into account paid leave and absence, the total train crew is:
12 persons × 1.7 weeks × 7 days × 295/365 ÷ 0.9 = 129 persons.

In addition, personnel engaged in maintenance of rolling stock and ground facilities and in station management need to be considered. However, the exact number is difficult to estimate since they are assigned to various works other than fuel transport works.

CHAPTER 4 BASIC DESIGN

CHAPTER 4 BASIC DESIGN

4-1 Design Policy

It is easy to construct diesel locomotives in Japan, and the Japanese rolling stock industry has an extensive record of production and exports.

Therefore, the locomotives required for this fuel transportation project will be constructed in Japan.

The parts and components mentioned below, however, will be imported from other countries for the reasons described in the following.

o Engine
  Large diesel engines for locomotives (over 1,600 HP) have not been manufactured lately in Japan in view of the small demand in the domestic market. As a matter of fact, most of diesel locomotives recently exported from Japan use imported engines of this class. That being so, it seems appropriate to use imported engines also in this case.

o On-board radio equipment
  SRC is presently using on-board radio equipment in its locomotives, and the radio equipment to be used in the diesel locomotives of this project must be compatible with the existing ones. Under the circumstances, the best alternative seems to be to purchase compatible radio equipment from the manufacturer that made the existing equipment, in view of the cost and efficiency advantages.

4-2 Design Conditions

The following design conditions are considered.

(a) Measures to cope with clouds of sand must be considered with special care (particularly for seals, air intakes, etc.) because most of the railroad sections are located in desert regions with frequent sand storms.

(b) The environmental temperature for normal use is assumed to be 15°C to 43°C, from the monthly average values of the minimum and maximum temperatures recorded in the past. The maximum allowable temperature is 48°C, which is the maximum atmospheric temperature.

(c) The track gauge is 1,067 mm, and the SRC rolling stock gauge is to be used.

(d) In principle, the UIC (International Union of Railways) Standards are to be used in these locomotives.

(e) The required performance of the locomotives should be sufficient to negotiate the 10‰ continuous uphill section between Port Sudan and Summit with a balanced speed of 30 km/h, and the other flat sections at 60 km/h or more.

(f) The diesel-electric driving system is to be adopted in this project, considering of its big power and SRC's experience.

(g) The tank wagons of this project do not use vacuum brakes. Therefore, an air brake system is to be equipped, and regenerative brakes will be used in the downhill section between Summit and Port Sudan.

(h) The axle load is 16 t (permissible load being 16.5 t) with six-axle driving, and the gross weight of the locomotive is 96 t.

(i) The bonnet-type and one side cab locomotive configuration is to be adopted in this project, by considering the ease of maintenance. Two master controllers, one in each traveling direction, will be provided, however, to reduce the fatigue of the driver on long trips.

(j) The Co-Co type truck is to be adopted, by considering the SRC's experience. The welded structure bogie is accepted, in view of the small quantity to be constructed.

(k) Double heading multiple unit control operation should be possible. Multiple unit control operation with the existing locomotives is not considered however.

(l) The AC main generator is to be adopted, in view of the ease of maintenance and lower rates of troubles.

4-3 Design Specifications

The basic specifications of the diesel locomotives designed under the aforementioned design conditions are shown in Table 4-1, and the figure is shown in Fig. 4-1.

Table 4-1 Basic Specifications of Diesel-electric Locomotives

Classification		96 t diesel-electric locomotive
Type		
Use		Main line locomotive for fuel transportation
Rolling stock gauge		SRC Rolling stock gauge
Axle layout		Co - Co
Weight	Gross weight (t)	96 t
	Tare weight (t)	90 t
Performance	Maximum operation speed	80 km/h
	Maximum tractive force (kg)	28,800 (μ = 0.3)
Overall gear ratio		
Main dimensions	Gauge (mm)	1,067
	Overall length (between coupling centers mm)	16,800
	Overall width (mm)	3,022
	Overall height (mm)	4,000
	Overall wheel base (mm)	12,900
	Distance between truck centers (mm)	9,000
	Driving wheel diameter (mm)	914
	Coupler height (mm)	851
Body type		Bonnet type One side driver's cab
Truck	Type	
	Fixed wheel base (mm)	3,900
	Type	Cast steel or welded, coil-spring supported type
Minimum radius of curvature (m)		137

User			Sudan
Outline	Designed for fuel transportation in tropical desert zone. Dust-proof construction, equipped with train radio.		
Engine	Classification		Diesel engine
	Type		
	Quantity		1
	Continuous rating		1,650 - HP/ rpm
	Fuel		Diesel oil
	Fuel consumption rate		g/HP/h
	Accessories	Supercharger type × quantity	
		Intercooler × quantity	
		Starting motor × quantity	
		Charging generator × quantity	
	Weight (dry) (kg)		
Main generator	Classification & type		
	Continuous rating	Capacity × quantity	950 - 1,000 KW × 1
		Voltage × current	
		Rotation speed	
	Weight (kg)		
Main rectifier	Classification & type		
	Continuous rating		
Traction motor	Classification & type		
	Continuous rating	Capacity × quantity	145 - 155 KW × 6
		Voltage × current	
		Rotation speed	
	Weight (including gear & case) (kg)		

Ventilator for traction motor	Driving system		
	Capacity × quantity		
Cooling equipment	Method		Forced ventilation Radiator type cooler installed at the chamber side
	Radiator		
	Ventilator	Driving system	
		Capacity × quantity	
Brake equipment			Automatic air brake
			Dynamic brake
			Hand brake
Air compressor	Type		
	Driving system		Belt-driven
	Capacity × quantity		
Control system			Double-heading multi-unit control operation
Control circuit voltage			
Operation safety equipment			Dead-man equipment
Broadcasting & communications equipment			On-board radio equipment
Battery	Type		NIFE
	Method		Nickel-Cadmium
	Capacity × quantity		
	Voltage		

Air-conditioning & ventilation	Air-cooling & ventilation	Ventilator × 2 Ventilation equipment
	Heating	Not provided
Train heating equipment		Not provided
Coupling equipment	Coupler	Alliance No. 2
	Damper	Rubber damper
Lighting	Interior	Driver's cab 40 W × 2 Engine room 20 W × 6
	Exterior	Headlight 200 W × 4 Taillight 40 W × 4
Auxiliary equipment		
Expendables	Fuel	5,000 ℓ
	Sand	360 ℓ
	Water	800 ℓ
Remarks		

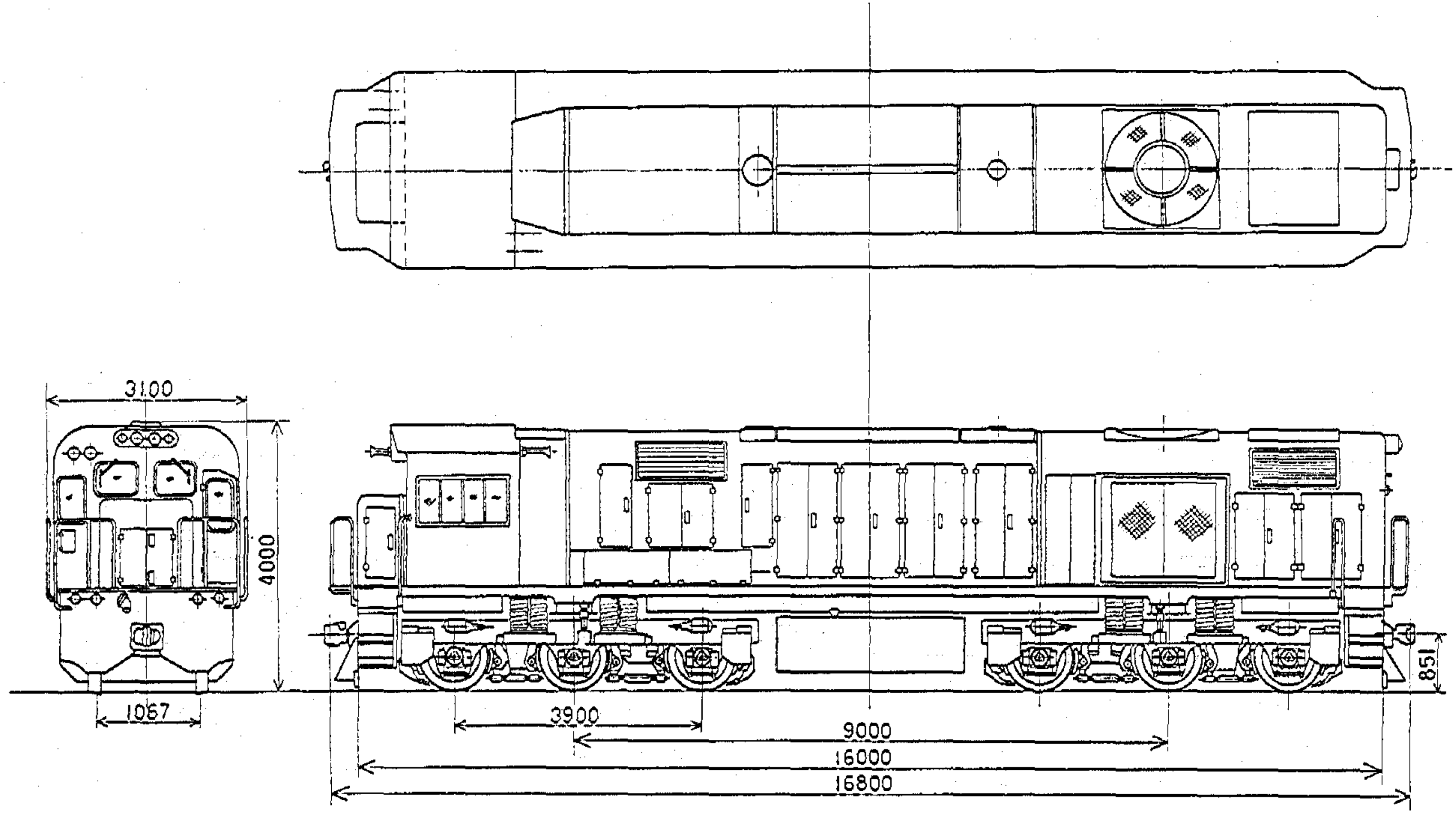


Fig. 4-1 Diesel-electric Locomotive Figure

4-4 Implementation Plan

1) Scope of work

For the locomotives to be procured, Japan will be responsible for work including the detailed design, construction (including the installation of train radio equipment), transportation to Port Sudan, and landing of the diesel locomotives. Furthermore, Japan will dispatch technical personnel responsible for the operation and handling guidance.

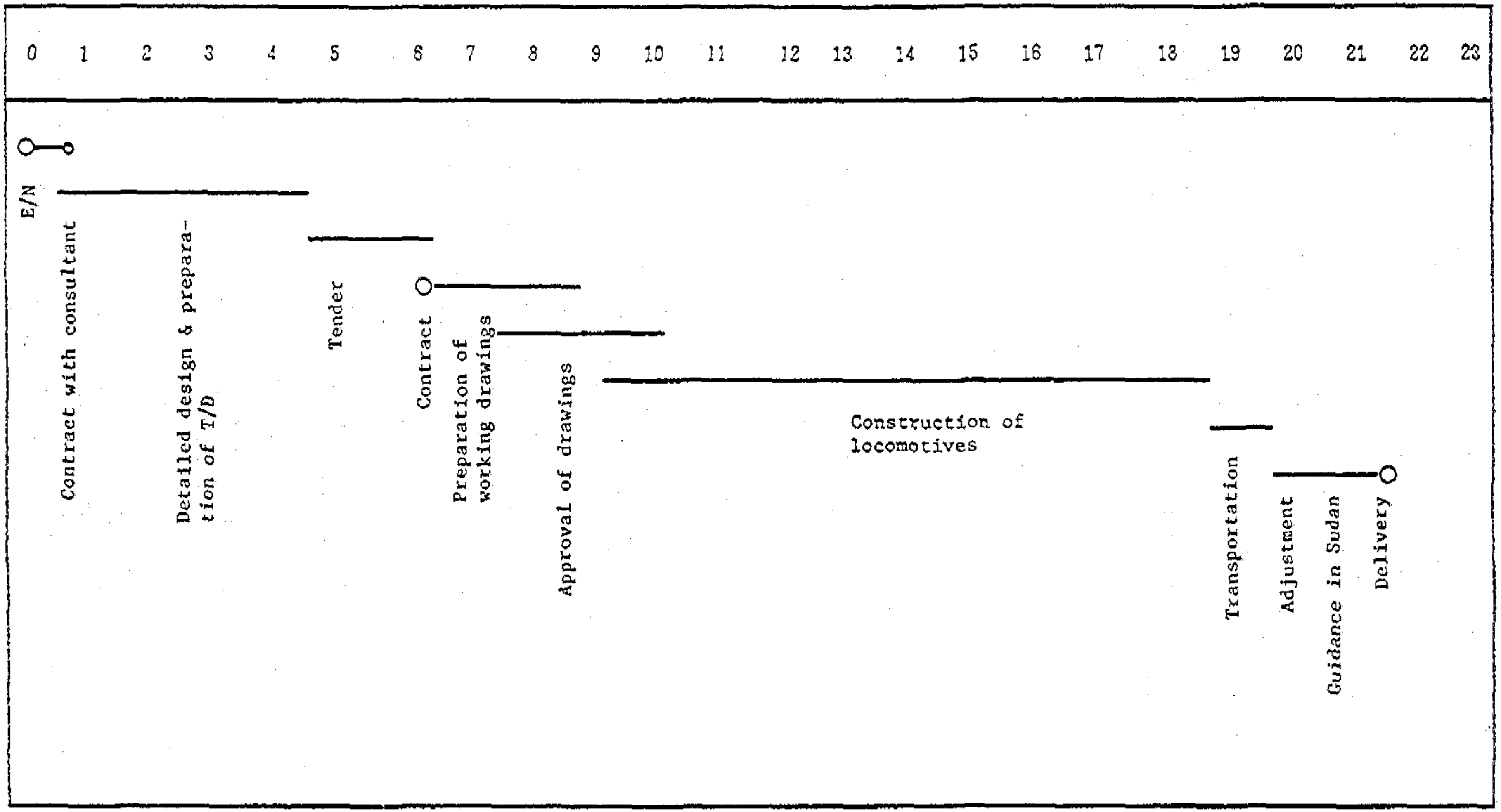
Sudan will be responsible for allocating fuel required for dead-heading of the locomotives after their landing, hiring workers including drivers, supplying other required equipment.

2) Implementation schedule

The implementation schedule comprising the preparation of the D/D and T/D after the E/N, construction of locomotives, guidance on operation and handling, delivery, etc., is shown in Table 4-2.

Table 4-2 Implementation Schedule

Unit ······ Month



4-5 Maintenance and Administration Problems

Before starting this project, it is necessary to define the scopes of responsibilities of the various organizations concerned in Sudan to prevent mistakes and delays.

The rolling stock will be alloted to the SRC, but particular care will be required to prevent confusion caused by the mixed operation of fuel transportation trains with other trains, and to prevent low operation rate occurring at present by securing appropriate maintenance, particularly funds for spare parts.

To efficiently use the rolling stock, particularly the locomotives, it is very important to define an effective operation scheme.

The procurement of spare parts and the improvement of maintenance techniques are vitally important for the diesel locomotive maintenance and particularly critical in Sudan where the locomotives are operated under unfavorable conditions of large quantities of dust and high temperatures.

Approximately 3% of the cost of a new locomotive is alloted as cost of spare parts to maintain similar diesel locomotives in Japan. It is obvious that a larger percentage will be required for maintenance materials in Sudan, in view of the unfavorable environmental conditions.

The main replacement spare parts are the wear parts of the engine, compressor, brake rigging equipment and packings, etc., and other parts found defective during inspections; a systematic change of lubricating oil is also very important.

Furthermore, clean environment at the time of overhaul and inspection, and precaution against dust when assembling the locomotive must be carefully worked out. It is therefore necessary to keep the workshop clean and secure a dustfree space for assembling the bearings and the engine.

Systematic and uninterrupted training is required to achieve technical progress. It is especially important to define the responsibilities regarding accidents and troubles, and to promote the spirit for accomplishing duties.

The maintenance and administrative costs required by this project must be examined within the context of conditions in Sudan. In reality, an accurate calculation of these costs is difficult, but the approximate costs related to diesel locomotives are calculated in the following.

(a) Fuel cost

Fuel cost is calculated by assuming a fuel consumption rate at 180 g/HP.hr.

- The fuel consumption in a Port Sudan - Khartoum trip is calculated in the following equation:

  $180 \text{ g/HP.hr} \times (3{,}300 \text{ HP} \times 4.3 \text{ hr} + 1{,}000 \text{ HP} \times 14.7 \text{ hr})$

  $= 5.2 \text{ t}$

- The fuel consumption in a Khartoum - Port Sudan trip is calculated in the following equation.

  $180 \text{ g/HP.hr} \times 500 \text{ HP} \times 14.7 \text{ hr} = 1.32 \text{ t}$

When the hydrological condition is normal, the annual fuel consumption is calculated in the following equation, assuming that 220 round trips are annually made:

$(5.20 \text{ t} + 1.32 \text{ t}) \times 220 \text{ times/year} = 1{,}434 \text{ t/year}$

Assuming unit cost of 640 LS per ton and 15% of lubricating oil, the annual fuel cost will be:

$640 \text{ LS/t} \times 1{,}434 \text{ t/year} \times 1.15 = 1{,}060 \times 10^3 \text{ LS/year}$

(b) Maintenance cost

Generally, the maintenance cost is assumed to be about 6% of the cost of the new locomotive.

Assuming that the new locomotive costs US$1,200 × 10^3 (according to the FTS report), the maintenance cost will be:

US$1,200 $\times 10^3 \times 2.43 \times 0.06 \times 10$ units = LS $1{,}750 \times 10^3$

(Assuming an exchange rate of US$1 = 2.43 LS as of 14 October, 1985)

Approximately 1/3 of this must be secured as spare parts purchasing cost. It is necessary to secure the maintenance cost plus a sufficient margin of security, by considering the conditions in Sudan, where failures are prone to occur due to a large quantity of blowing dust.

(c) Wage of the train crew

Each train requires a regular crew consisting of one locomotive driver, one assistant driver and one conductor. Two additional regular crew teams for shifts are required in view of the long-distance trip this fuel transportation project involves. As a result, each train will be served by a 12-man crew, including the inspection personnel.

Assuming a personnel expenditure of 2,000 LS/year-man for the SRC, and 50% for traveling expenses and overtime work, the total wages to be paid to the train crew will be:

LS 2,000 × 129 persons × 1.5 = 387 × 10^3 LS/year

CHAPTER 5 EVALUATION OF THE PROJECT

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Fuel transportation is indispensable for thermoelectric power generation, and electricity is one of the most important energy sources for the industry and the life of the people. For this reason, this project needs to be implemented urgently with high priority. Particularly in Sudan the hard currency is badly lacking, and the reinforcement of the power supply system contributes toward currency-earning industries stably supplying electric energy for irrigation pumps, tanneries, textile industries, etc.

This Chapter examines the effects of the fuel transportation on NEC and SRC, transportation cost, and evaluation when compared with truck transportation.

5-1 Effects Exerted on NEC

By the same token, fuel transportation is indispensable for NEC, since the stable and low-cost transportation of the required volume of fuel significantly influences the stability and cost of the electric power supply.

After the completion of this fuel transportation project, NEC will be able to secure a stable fuel supply at low transportation cost, with the possibility of expanding the transportation capacity by improving the transportation facilities. As a consequence, it will facilitate the further expansion of the power supply capacity.

5-2 Influence on SRC

Freight transport presently outnumbers by far the passenger transport in SRC, and revenues attributable to freight transport account for approximately 80% of the total as of 1982/83. It must be remembered, however, that the volume of freight transport is declining year after year, and in 1983/84 it was as little as 42% (ton·km) of the volume recorded 5 years before (1979/80).

The transport demand under this project as of 1988/89 is forecasted in this study to be 198×10^3 tons $\times$ 787 km = 156×10^6 t·km/y with mean hydrological conditions, and this is some 20% of the total transport record (836×10^6 t·km) of SRC as of 1983/84.

As can be seen, the implementation of a huge fuel transportation such as the one being considered in this project will be a valuable opportunity to improve the financial situation of SRC itself.

Assuming the charge tariff of 159 LS/t for transporting fuel from Port Sudan to Khartoum, the annual revenue SRC is expected to realize is given by the following equation (assuming average hydropower condition):

$$159 \text{ LS/t} \times 198 \times 10^3 \text{t} = \text{LS } 31.5 \times 10^6$$

This sum is equivalent to approximately half of the freight revenue and 38% of the total revenue of SRC as of 1982/83.

In reality it is necessary to consider how to reduce the railroad tariff concurrently with the transportation expenses to derive the maximum benefit from the massive transportation scheme considered in this project. Nevertheless, this project is expected to account for a substantial portion of SRC's business.

5-3 Transportation Cost

Transportation expenses consist of the initial facilities investment (depreciation cost), facilities, maintenance cost, power cost of the locomotives (fuel), personnel expenditures, administrative costs, etc. In reality, it is difficult to calculate these costs accurately, but they are examined in this section by referring to the FTS Report. The calculations are made by assuming an exchange rate US$1 = ¥215.9 = LS 2.43 (as of 14 October, 1985).

1) Initial investment

The initial investment includes rolling stock, track, signaling, stations, etc. This study assumes that only new rolling stock will be procured. As for the other items, the project will be implemented by using the existing facilities.

The breakdown of the rolling stock cost assumed in this study is shown in Table 5-1.

Table 5-1 Rolling Stock Cost

Item	Unit cost*	Quantity	Total cost
Diesel locomotive	US$1,615 $\times 10^3$ = LS 3.92 $\times 10^6$	10 units	LS 39.2 $\times 10^6$
Tank wagon	US$80 $\times 10^3$ = LS 194 $\times 10^3$	130 units	LS 25.2 $\times 10^6$
Manama + Brake Van	US$95 $\times 10^3$ = LS 231 $\times 10^3$	5 sets	LS 1.2 $\times 10^6$
Shunting locomotive	US$750 $\times 10^3$ = LS 1.82 $\times 10^6$	2 units	LS 3.6 $\times 10^6$
		Total	LS 69.2 $\times 10^6$

* Unit cost of rolling stock mentioned in the FTS Report (including spare parts and transport costs).

Assuming a depreciation period of n = 20 years and an annual interest rate of r = 0.08, the annual depreciation (reimbursement) cost N is given by the following equation:

$$N = \frac{rA\ (1 + r)^n}{(1 + r)^n - 1} = \frac{0.08 \times 69.2 \times 10^6\ (1 + 0.08)^{20}}{(1 + 0.08)^{20} - 1}$$

$$= 7.05 \times 10^6 \text{ LS/year}$$

This calculation assumes 0 salvage value by considering the scrapping cost.

2) Fuel cost

Fuel consumption by main line locomotives is assumed to be 1,434 tons per year, from Chapter 4-5.

According to a report prepared by the UK, fuel consumption of the shunting locomotive is 22.5 t/year. The price of diesel oil is 640 LS/t, and the annual fuel cost is given by the following, assuming 15% for lubricating oil and other requirements:

$$640\ (1{,}434 + 22.5) \times 1.15 = 1.07 \times 10^6\ \text{LS/year}$$

3) Personnel expenditure of the train crew and other workers

From Chapter 3-3, (6), it is assumed that 129 persons (members) will be required to operate the fuel trains, 18 persons will be required for shunting works, assuming that 2 persons are assigned to the works in Port Sudan as well as in Khartoum on a three-shift basis (four teams) and attendance rate 0.9:

$$4\ \text{persons} \times 4 \div 0.9 = 18\ \text{persons}$$

Altogether, 147 (129 + 18) persons will be required as direct labor in fuel transport.

Direct labor cost is thus calculated by multiplying the average annual salary of SRC (LS 2,000) by 147 persons plus 50% extra as on-board allowance and overtime wages:

$$2{,}000\ \text{LS/person/year} \times 147\ \text{persons} \times 1.5 = 0.441 \times 10^6\ \text{LS/year}$$

4) Rolling stock maintenance

The FTS Report assumed a maintenance cost equivalent to 6% of the purchasing cost for main line locomotives and 3% for tank wagons and other kinds of rolling stock. The annual maintenance cost is calculated in the following, considering these percentages.

Locomotives for main line:

$US\$1,200 \times 10^3 \times 10 \text{ units} \times 0.06 \times 2.43 = LS\ 1,750 \times 10^3$

Shunting locomotives

$US\$750 \times 10^3 \times 2 \text{ units} \times 0.03 \times 2.43 = 109 \times 10^3$

Tank wagons

$US\$65 \times 10^3 \times 130 \text{ units} \times 0.03 \times 2.43 = 616 \times 10^3$

Manama, etc.

$US\$95 \times 10^3 \times 5 \text{ sets} \times 0.03 \times 2.43 = 34.6 \times 10^3$

Total 2.51×10^6 LS/year

The maintenance cost of the Japanese National Railways diesel locomotives similar to those considered in this project is 20 million/unit-year, equivalent to 230×10^3 LS/year per unit. Considering the difference of labour costs these restated figures can be regarded as realistic.

5) Other costs

Other costs required for this project concern ground facilities such as track, signaling systems, and stations as well as their maintenance; personnel of the stations and other facilities; administrative and technical personnel; loan reimbursement; etc.

It must be remembered that it is difficult to calculate these costs accurately because they are applicable not only to fuel transportation but to other kinds of transportation as well. Such being the case, the relevant figures mentioned in the FTS Report are adopted in this study.

The costs for these items are as follows:

Track and other facilities, and their maintenance:
2.03×10^6 LS/year

Transportation:
1.813×10^6 LS/year

Administrative and technical personnel:
1.26×10^6 LS/year

Loan reimbursement:
0.715×10^6 LS/year

Total:
5.82 LS/year

6) Overall cost

The overall cost to be borne by SRC for transporting fuel, calculated by summing up above cost items, is shown in the following.

Initial investment (rolling stock):
7.05×10^6 LS/year

Fuel cost:
1.07×10^6 LS/year

Personnel expenditure (train crew):
0.441×10^6 LS/year

Rolling stock maintenance cost:
2.51×10^6 LS/year

Others:
5.82×10^6 LS/year

Total:
16.9×10^6 LS/year

Dividing this total by the annual fuel transportation volume (with normal hydropower situation), 198×10^3 t, the transportation cost per ton is to be approximately LS 85 from Port Sudan to Khartoum.

These costs must be decided by examining in further detail the conditions and policies of Sudan and SRC, but the transportation cost is presumed to be considerably lower than the present tariff of 159 LS/t.

5-4 Comparison with Truck Transportation

It is difficult to accurately compare rail transport with lorry transportation because in most cases highway construction costs are borne by the national Government or the local administrative units.

That being so, in this study the comparison is made by considering only the trucks and rolling stock used exclusively for fuel transportation, as well as their maintenance, power cost (fuel) and drivers expenditure. The other cost items mentioned in Chapter 5-3 are assumed to offset the road construction and maintenance costs.

1) Initial investment cost

Assuming that a large tank truck has 12 t loading capacity, the number of lorries required to satisfy the daily fuel transportation demand is 875 t ÷ 12 = 157 units.

The transportation turn round time is assumed to be five days, as shown in Fig. 5-1, because trucks are presently running only during the night and it takes two nights from Port Sudan to Khartoum.

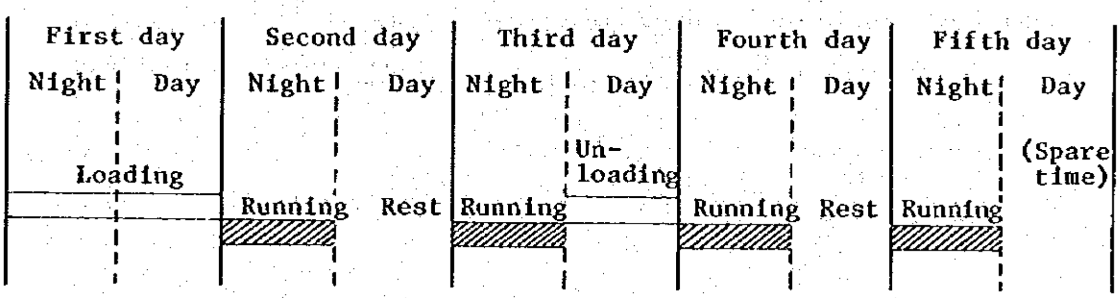

Fig. 5-1 Turn Round Time for Truck Transportation

The total tank truck requirement is given by the following equation, considering 2% of spare units for statutory vehicle inspection and accidents.

$$157 \text{ units} \times 5 \times 1.02 = 801 \text{ units}$$

Assuming a unit cost of ¥9 million (LS 101×10^3), 10 years of life (both are in cases of Japan) and interest rate of 8%, the depreciation cost is given by the following equation.

$$101 \times 10^3 \times 801 \text{ units} \quad \frac{0.08\ (1+0.08)^{10}}{(1+0.08)^{10}-1}$$

$$= 12.1 \times 10^6 \text{ LS/year}$$

2) Fuel cost

Transportation by truck is done via Kassala, and the distance between Port Sudan and Khartoum is approximately 1,200 km.

Assuming an annual transportation demand of 198×10^3 t of fuel with normal hydropower conditions, $198 \times 10^3 \div 12 = 16{,}500$ truck trips are required.

Assuming a fuel consumption rate of 3 km/ℓ, the total consumption of fuel is given by

$$(1{,}200 \text{ km} \times 2/3) \times 16{,}500 = 13.2 \times 10^6 \text{ ℓ/year}$$

$$= 12.1 \times 10^3 \text{ t/year.}$$

Assuming unit cost of 640 LS/ton of diesel oil and approximately 15% for lubricating oil and the like, the annual fuel cost is given by

$$640 \times 12.1 \times 10^3 \times 1.15 = 8.91 \times 10^6 \text{ LS/year}$$

3) Personnel expenditure

Assuming two drivers per truck and one round trip per week (including stand-by personnel), the total number of drivers is given by

$$2 \text{ drivers} \times 7/5 \times 801 \text{ lorries} = 2{,}243 \text{ drivers}$$

Assuming a salary of 2,000 LS/year, the personnel expenditure is given by

$$2{,}000 \times 2{,}243 = 4.49 \times 10^6 \text{ LS/year}$$

4) Vehicle maintenance

The cost of the statutory automotive vehicle inspection depends on conditions in each country, but in Japan it is about 200 to 300 thousand yen/unit.

The inspection cost is assumed to be ¥250,000/year·unit as inferred from the standard case in Japan. The annual maintenance cost is given by the following equation.

$$250 \times 10^3 \text{ Yen} \times 801 \text{ units} \times 0.0113 = 2.26 \times 10^6 \text{ LS/year}$$

5) Overall comparison

An overall comparison of truck transportation and railway transportation summarized from the above considerations is shown in Table 5-2.

As can be seen, the railway transportation alternative is more economical for all items, and in total amounts to 40% of the truck transportation alternative.

Table 5-2 Comparing Railway and Truck Transportation

(Unit: 10^6 LS)

Item	Railway transportation	Lorry transportation
Initial investment (vehicle)	7.05	12.1
Fuel cost	1.07	8.91
Personnel expenditure (driver)	0.441	4.49
Vehicle maintenance cost	2.51	2.26
Total	11.1	27.8

Furthermore, it must be remembered that for truck transportation, the operation of the large tank truck fleet mentioned above entails the risk of social problems such as danger for the people in general, traffic jams, etc.