FEASIBILITY STUDY REPORT

ON

THE ESTABLISHMENT OF A FERROCHROME PLANT IN THE DEMOCRATIC REPUBLIC OF THE SUDAN

August [illegible]

JAPAN INTERNATIONAL COOPERATION AGENCY

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AUGUST 1981

JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)

PREFACE

In response to a request of the Government of the Democratic Republic of the Sudan the Government of Japan has decided to conduct a feasibility study on the establishment of a ferrochrome plant project and entrusted the work to the Japan International Cooperation Agency (JICA).

The JICA dispatched to the Sudan from March 1 to March 24, 1981 a survey team, headed by Mr. Hideo Haga.

The survey team had a series of discussions with the officials concerned of the Government of the Sudan, conducted a wide scope of field survey and data analyses and has prepared the present report.

I hope that this report will be useful as a basic reference for development of the project.

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

August 1981

Keisuke Arita
President

Japan International Cooperation Agency

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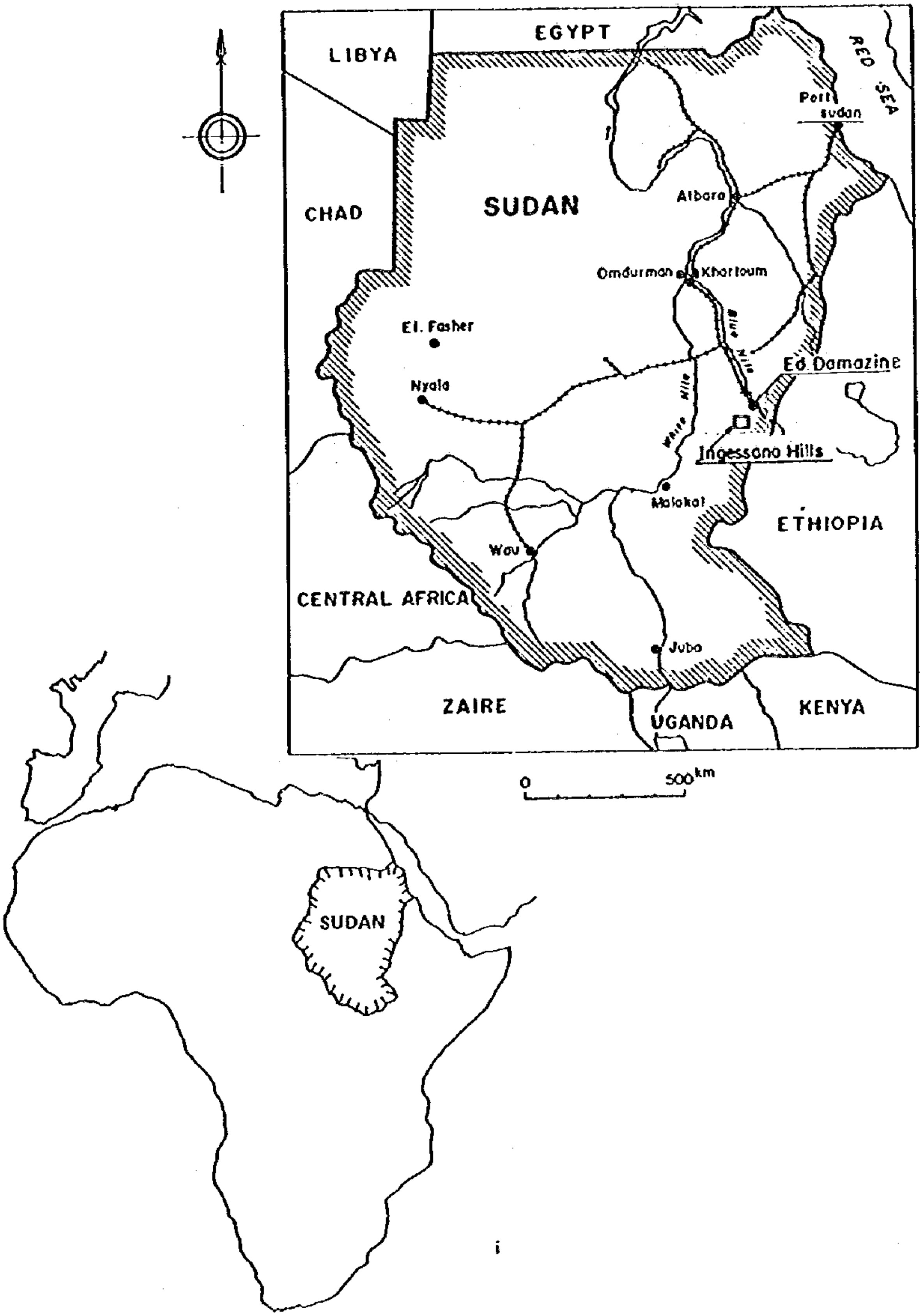
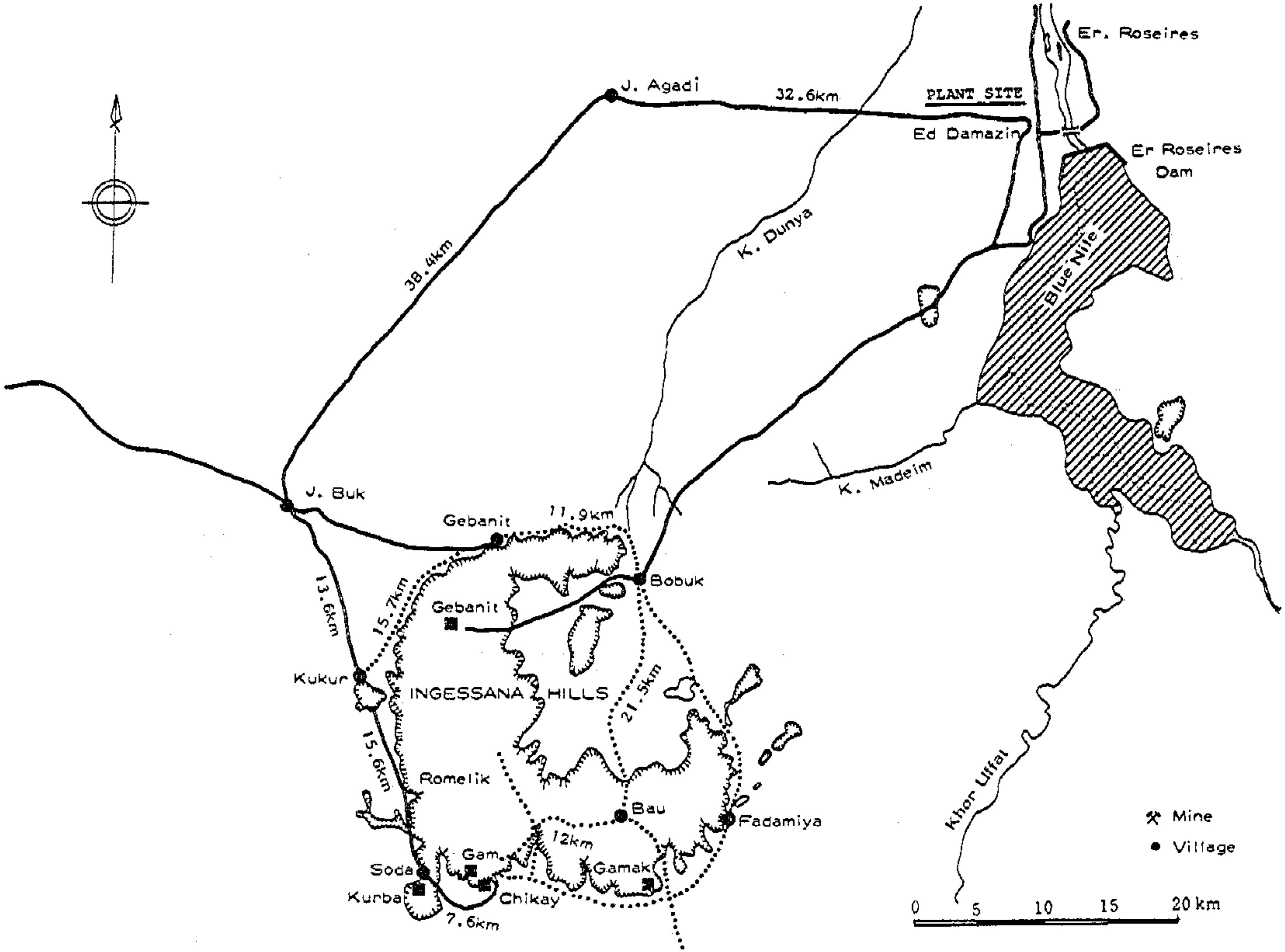


EGYPT
LIBYA
RED SEA
Port sudan
CHAD
SUDAN
Atbara
Omdurman
Khartoum
El. Fasher
Blue Nile
Ed. Damazine
Nyala
White Nile
Ingessana Hills
Malakal
ETHIOPIA
Wau
CENTRAL AFRICA
Juba
ZAIRE
UGANDA
KENYA
0
500km
SUDAN

Location Map of Plant Site



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MEMBERS OF THE JAPANESE STUDY TEAM

NAME	SPECIALITY	FUNCTION
Hideo Haga	Metallurgical Engineer	Leader
Akira Ayukawa	Geologist, Mining Engineer	Raw Material
Kazuta Kawamura	Geologist, Mining Engineer	Transportation
Shigeyuki No	Mechanical Engineer	Production Facility
Katuhiro Shoji	Mechanical Engineer	Equipments
Masaharu Shimomura	Electrical Engineer	Electricity
Hiroaki Ueno	Architectural Engineer	Civil Works, Architecture
Yoji Ono	Economist	Institutions, Market Analysis
Tsuyoshi Hashimoto	Economist	Economical and Financial Analyses
Hideo Yasuki	Planning & Survey Dept. Industrial Survey Div. Japan International Coop. Agency	Coordination
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SCHEDULE OF FEASIBILITY STUDY TEAM

March	1	Sun			Movement Tokyo Lv. 21:30 (LH 651)
	2	Mon			Movement Frankfult Ar. 07:50
					Frankfult Lv. 21:20 (LH536)
	3	Tue	Khartoom		Khartoum Ar. 03:55
					PM. Courtesy call on the Japanese Ambassador at Embassy
	4	Wed	Khartoum		Visit to Ministry of Energy and Mining
	5	Thu	Damazin		AM Movement (Kahrtoum - Damazin)
					PM Courtesy call on the Governor of the Blue Nile Prov.
	6	Fri	Damazin		Visit to Ingessana Hills Mines Corp.
	7	Sat	Damazin		Visit to Roseires Power Station
	8	Sun	Damazin		Visit to Plant site for geological survey of plant site
					Visit to Damazin Forest for investigation of charcoal and water supply
	9	Mon	Damazin		Visit to Roseires Power Station for study of water power generating equipment
					Visit to Plant Site for geological servey
	10	Tue	Damazin		Visit to the Blue Nile prov. for another plant site
					Visit to Plant site for survey
	11	Wed	Damazin	(A)	Visit to Cotton Ginning Factory for investigation of working condition
					Visit to Roseires Power Station for investigation of equipment and power supply situation
			Khartoum	(B)	Movement (Damazin – Khartoum)
	12	Tue	Damazin	(A)	Visist to Blue Nile for survey of water to be taken from the river
					Movement (Damazin – Khartoum)
			Khartoum	(B)	Visit to Ministry of Energy and Mining for exchange of Minutes
	13	Fri	Khartoum	(A)	Group meeting
				(B)	Movement (Khartoum – Paris – Tokyo)
	14	Sat	Khartoum		Visit to Public Electricity and Water Corp. for survey of power supply
					Visit to Road and Bridge Public Corp. for survey of road condition
					Visit to Sudanese Steel Products Co., Ltd. for investigation of working condition
	15	Sun	Khartoum		Visit to Ministry of Energy and Mining for exchange of confirmation
					Visit to Public Electricity and Water Corp. for survey of power supply
					Visit to Sudanese Mining Corp. for investigation of mining
			Port Sudan	(C)	Movement (Khartoum – Port Sudan)
	16	Mon	Khartoum		Visit to Geological and Mineral Resources Dept. for soil survey at plant site
					Visit to Sudanese Railways Corp. for survey of railway condition
					Visit to Sudanese Mining Corp. for survey of mining at Gam mine
					Visit to Statistics Dept., M. of National Planning for obtaining statistics
			Port Sudan	(C)	Visit to Sea Ports Crop. for survey of port condition

17	Tue			Visit to Union Contracting Co., Ltd. for survey of construction and machinery equipment Visit to Geological and Mineral Resources Dept. for soil survey at plant site Visit to Statistics Dept. for investigation of future development plan
			(C)	Visit to Khalafalla El-Bushra Trade and Commission for investigation of import tariff Movement (Port Sudan – Khartoum)
18	Wed	Khartoum		Visit to Public Electricity and Water Corp. for investigation of electricity situation Visit to Union Contracting Co., Ltd. for survey of construction and machinery equipment Visit to Geological and Mineral Resources Dept. for soil survey at plant site Visit to Public Social Insurance Institution for investigation of social insurance
19	Thu	Khartoum		Visist to Public Electricity and Water Corp. for survey of electricity situation Visit to Sudanese Mining Corp. for investigation of production cost of mining Visit to Geological and Mineral Resources Dept. for survey of raw materials supply
20	Fri	Khartoum		Group Meeting
21	Sat	Khartoum		Visit to Ministry of Energy and Mining for courtesy call Visit to Ministry of Industry for courtesy call Visit to Japanese Embassy for courtesy call
22	Sun			Movement Khartoum Lv. 10:10 (SR 297) Geneva Ar. 16:15 Geneva Lv. 18:00 (SR 728) Paris Ar. 19:00
23	Mon			Movement Paris Lv. 13:15 (JL 426)
24	Tue			Tokyo Ar. 14:25

VISITS BY THE STUDY TEAM

[Damazin]

- Cotton Ginning Factory
- Geological and Mineral Resources Dept.
- Governer's Office
- Governer of the Blue Nile Prov.
- Ministry of Irrigation
- Roseires Power Station

[Ingessana Hills]

- Gam Mine

[Khartoum]

- Companied Div., Taxation Dept., M. of Finance and National Economy
- Foreign Div., Labor Dept.
- Geological Dept.
- Ingessana Hills Mines Corp. (IHMC)
- Labor Dept., M. of Public Service and Administrative Reform
- Ministry of Energy and Mining
- Ministry of Industry
- National Income Accounts Div., Statistics Dept.
- Population Census Div., Statistics Dept.
- Public Electricity and Water Corp. (PEWC)
- Public Corporation for Irrigation
- Public Social Insurance Institution
- Statistics Dept., M. of National Planning
- Sudanese Mining Corp. (SMC)
- Sudanese Steel Products Co., Ltd. (SSP)
- Union Contracting Co., Ltd.

[Port Sudan]

- Afro-Asia Commission
- Khalafalla El-Bushra Trade and Commission
- Sea Ports Corporation
- Traffic Supt.

ABBREVIATION

ϕ	Diameter
1ϕ	1-phase
3ϕ	3-phase
%	Percent
A	Ampere
A.C.S.R.	Aluminum Cable Steel Reinforced
AV.	Average
B/T	Berth/terms
¢	Cent
°C	Centigrade
C I F	Cost Insurance and Freight
cm	Centimeter
Cur	Current
Dept.	Department
Div.	Division
DWT	Dead Weight Ton
EC	European Community
e.g.	For instance
ERR	Economic Rate of Return
FOB	Free on Board
Fig.	Figure
F.R.R	Financial Rate of Return
g	gram
G.D.P	Gross Domestic Product
GWH	Gigawatt hour
hr	hour
i.e.	that is
I.R.R	Internal Rate of Return
Ig-loss	Ignition loss
km	Kilo meter
KV	Kilo volt
KVA	Kilo volt - Ampere
KW	Kilo watt
KWH	Kilo watt - hour
ℓ	Liter
Lb	Pound
m	Meter
mm	Millimeter
M	Thousand
MM	Million
m^2	Square meter
m^3	Cubic meter
Max.	Maximum
Min.	Minimum
M/T	Metric ton
MVA	Megavolt -- Ampere
MW	Megawatt
Nm^3	Normal cubic meter
N.E	North East
N.W	North West
Pc.	Piece
Pcs.	Pieces
ppm	Parts per million
P.S.	Power station
SE	South East
SER	Shadow exchange rate
S£	Sudan pound
S/T	Short ton
SS	Suspened Solid
S.W.	South West
t	Metric ton
UK	United Kingdom
USA	United States of America
USSR	Union of Soviet Socialist Republics
US$	United States dollars
V	Volt
Yr. ,/year	Year
/t. ,/ton	Per ton
/y.	Per year
/m, /month	per/month
/h, /hour	Per hour

SUMMARY

1. Background

The manufacturing and mining sector is relatively minor in the economy of the Democratic Republic of the Sudan, accounting for some 8% of the gross domestic product of the country in the past few years (see Table 1-1). The Sudanese government, however, has been paying increasing attention to the development of the manufacturing and mining sector, and one of the priority projects in this sector is the development of chromium ore and ferrochrome industry. The Sudanese government expects that the establishment of a ferrochrome plant by utilizing the domestic low and high-grade chromium ore procured from Ingessana Hills would constitute a nucleus of the industrialization policy and contribute also to increasing foreign exchange earnings. With this view, the government of the Sudan requested the Japanese government to carry out a feasibility study on the project (hereinafter referred to as "The Project") to establish a ferrochrome plant in the Damazin area of the Sudan.

The government of Japan conducted a pre-feasibility study in 1977 through the Japan International Cooperation Agency (hereinafter referred to as "JICA"), the official agency responsible for the implementation of technical cooperation of the Japanese government. Follwoing this, a feasibility study (hereinafter referred to as "The Study") has been undertaken at this time for the purpose of investigating feasibility of The Project from technical and economic points of view. To accomplish this purpose, a study team (hereinafter referred to as "The Study Team") was sent by JICA to carry out field investigation.

Prior to the field investigation, representatives of the Democratic Republic of the Sudan concerned with The Project and The Study Team had a meeting on March 4, 1981 at Geological Department, the Ministry of Energy and Mining. Basic agreements were reached between the both sides concerning the Scope of Work for The Study (refer to "Minutes of the Meeting concerning the Feasibility Study on the Establishment of a Ferrochrome Plant in the Democratic Republic of the Sudan, March 4, 1981" in Annex 1)

The field investigation was carried out by The Study Team for the period between March 4 and March 21, 1981 in accordance with the Scope of Work, covering the Khartoum, Damazin, Ingessana Hills and Port Sudan areas. An interim report containing major findings of the field investigation as well as basic conditions of The Study was prepared by The Study Team and submitted to the Sudanese side (see Annex 2 for "Interim Report of the Feasibility Study on the Establishment of a Ferrochrome Plant in the Democratic Republic of the Sudan, March 21, 1981"). Based on this, feasibility of The Project has been fully investigated by The Study Team through their works in Japan.

2 Present Status and Future Prospects of Ferrochrome Industry

2–1 Chromium ore production and market situations

According to the investigation by the Mining Bureau of the United States, the confirmed reserve of chromium ore in the world amounts to 1,800 million tons as of 1978, and the total reserve is estimated to be about 4,700 million tons. The reserve is extremely unevenly distributed with 63% of the confirmed reserve being in South Africa and 33% in Zimbabwe (see Table 2-4). The total production of chromium ore in the world was approximately 10 million tons in 1980, of which more than half was produced by two countries, South Africa accounting for 3.2 million tons and the Soviet Union for 2.3 million tons (see Table 2-5). Of the total production, about 60% is turned into ferrochrome and the rest is used for chemicals and refractories.

The international market for chromium ore has been in the state of oversupply since 1977, due to stagnant demand of major user countries and increase in production capacity of producer countries. This has resulted in the fall in chromium ore prices, and the situation seems to persist in the near future. The chromium ore produced in the Sudan, however, is of high quality lumpy type, and its performance in the international market has been and will continue to be stable due to specialized demand for it.

2–2 Ferrochrome Industry

The total production capacity of ferrochrome in the free world was approximately 2.6 million ton/year in 1980 (see Table 2-2), but the actual production was estimated to be about 1.7 million ton/year. Two major producing countries account in total for more than a half of the world production; i.e. South Africa produced 630,000 tons in 1980 and Japan 330,000 tons, followed by the United States, Sweden and Zimbabwe. Expansion of production capacity planned in South Africa, Turkey, Finland and other countries will add to the total production capacity by as much as 600,000 tons.

Demand for ferrochrome, on the other hand, is significantly affected by fluctuations in production of stainless steel. The annual growth rate of stainless steel production is expected to be about 3%, and the ferrochrome market has been and will continue to be in the state of oversupply as can be seen from Table 2-3. Accordingly the prices of ferrochrome in the international market have been hanging low.

3. The Project

3–1 Scope and Objectives

The Project consists of establishing a ferrochrome smelting plant in the Damazin area by utilizing the chromium ore to be procured from mines in Ingessana Hills and hydropower generated at Roseires power station on the Blue Nile. Objectives of The Project are as listed below.

(1) To construct a ferrochrome plant in the Damazin area.

(2) To earn foreign exchanges through exporting ferrochrome in order to improve balance of payments of the Sudan.

(3) To utilize the plant as a training ground for Sudanese workers to acquire experiences and knowledge in high-temperature furnace industry.

(4) To place the plant as a core or a symbol of the industrialization policy of the Sudanese government for the purposes of educating the Sudanese people and bringing about a better understanding of the policy.

(5) To promote the development of industry in the Sudan related to the ferrochrome production.

3–2 Project Area

The project area is located in Blue Nile Province, which holds an eastern part of the Sudan bordering on Ethiopia (see Figs.3-1 and 3-2). The ferrochrome plant is to be situated in the Damazin area, the south-eastern part of Blue Nile province. The plant site was selected as shown in Fig. 3-3, after a few alternative sites were carefully studied.

The climate of the project area is tropical continental with annual precipitation of about 800 mm and annual average temperature of approximately 28°C. A year is devided into two distinct seasons, a dry season (November through March) and a wet season (April through October).

3–3 Plant Scale

The Study Team proposed the plant scale of 7,000 tons/year ferrochrome production based on their past experiences, consideration of the objectives of The Project, international market situations of ferrochrome as well as the estimated exploitable reserve and the present production capacity in the Ingessana Hills area. The Sudanese side, however, expressed a strong concern for establishing a larger-scale plant and suggested 15,000 tons/year ferrochrome production as an alternative.

Both of these two alternative plant scale, 7,000tons/year (hereinafter called Case A) and 15,000tons/year (hereinafter, called Case B) ferrochrome production – have been investigated by the Study Team. The basic dimensions of The Project corresponding to each plant scale are summarized in Table 3-2.

4. Raw Materials

4–1. Chromium ore

The chromium reserve in Ingessana Hills is estimated to be about 950,000 tons. Quality and quantity of the reserve in different areas are found by exploration heretofore as given below.

CLASSIFICATION	LOCATION	RESERVE (ton)	QUALITY (Cr_2O_3%)
High-grade ore	Gam mine	579,000	50.1
	Unexploited areas	152,000	48.0
	Sub Total	731,000	49.7
Low-grade ore	Unexploited areas	221,000	38.3
Total		952,000	47.0

The annual production of chromium are at Gam mine is currently 15,000 to 25,000 tons (see Table 4-2). Since the amount of chromium ore required for Case B or 33,800 tons/year exceeds the production quantity of existing mines, development of new deposits in the surrounding areas would be necessary. Quality and quantity of some of these deposite are found to be lower as indicated by the above table. Quality of chromium ore at the ferrochrome plant is given in, Table 4-7 for both Case A and Case B.

The chromium ore price is set estimated based on the production costs at the existing mine. The price used in The Study is US $69/ton or US$63/ton at the ferrochrome plant for Case A or Case B, respectively.

4-2. Subsidiary raw materials

No data obtained at this time support improvement in availability of cokes in the Sudan since the time of pre-feasibility study, and thus The Project is planned based on the assumption that all the requirements for cokes are met by imports. The CIF price of cokes at Port Sudan is estimated to be US $166/ton, to which are added transportation and other costs to obtain the price at the ferrochrome plant as US $210.6/ton. Use of domestic charcoal is not considered very feasible due to insufficient production quantity.

It was confirmed during the field investigation that the reserve of silica stone exists in Ingessana Hills in sufficient quantity and quality so that The Project will make use of it. The price at the ferrochrome plant is estimated to be US $40/ton..

Bauxite is not produced domestically in the Sudan and thus to be imported from Greece. The estimated CIF price at Port Sudan is US $60/ton, which will make the price at the ferrochrome plant to be US $102.3/ton.

There is no domestic production of electrode paste, and importation from Norway is assumed for The Study. Its price is estimated to be US $600/ton, CIF at Port Sudan or US $640.2/ton at the ferrochrome plant.

5. Infrastructure

5–1. Electric power

The demand/supply situations of electricity in the Sudan are severe, since development of supply capacity has not kept pace with a rapid increase in demand. As the ferrochrome production is a high-electricity consuming industry, it is essential to prepare a better power supply system.

Power requirements at the ferrochrome plant are given below for each plant scale.

	Capacity required (KW)	Total power consumed (GWH/year)
Case A	4,500	36.2
Case B	10,000	72.3

A power supply plan for the ferrochrome plant has been drafted based on the supply from the Roseires power station with 11 KV or 33 KV line for Case A or Case B, respectively.

To calculate power costs, the electricity tariff that is currently effective was used. Applying the rate for heavy industry, the power-costs were calculated to be 0.043 US$/KWH for both Case A and Case B (see Table 5-9).

5–2 Water

Water requirements of the ferrochrome plant primarily for cooling are 70tons/hour for Case A and 150tons/hour for Case B. A substantial part of water, however, will be recycled and thus the amount of water to be taken from the Blue Nile will be only 10tons/hour or 30 tons/hour for Case A or Case B, respectively. In rainy seasons, the water quality will deteriorate with high suspended solid (SS) content so that sedimentation basins, filters and other equipment will be necessary.

5–3 Transportation

(1) Roads

The roads between Gam mines in Ingessana Hills and Damazin are not paved, and its transportation becomes extremely difficult or sometimes impossible during rainy season. (May to October).

There is a plan for developing roads in relation to the development in surrounding area. Further investigation is needed for such a plan.

The current transportation cost of chromium ore between Gam mines and Damazin is US$13.3/ton.

(2) Railways

Presently the chromium ore is transported from Damazin to Port Sudan by railway. A comparison is made below between transportation requirements at present and in the future after The Project is implemented (under Case A):

There seems to be little problem in utilizing the railway system between Damazin and Port Sudan, as long as the total transportation requirements are concerned. Transportation costs between these two points are estimated to be US$31.3/ton.

(3) Port

Port Sudan is the only port in the Sudan, where the chromium ore is presently exported from. Maximum handling capacity is 15,000 DWT, and the cranes are capable of unloading the maximum cargo weight of 75 tons. A railway siding is provided on the quay, which enables direct unloading from a vessel to freight cars.

6. Facility Planning

6–1 Outline of Plant Facilities

Since the ferrochrome plant will constitute the first electric-furnace industry in the Sudan, ease of operation and maintenance was taken into consideration in selecting plant facilities. Measures for environmental protection were also taken into account. Main facilities are listed below.

(1) Raw material treatment facilities: for crushing, blending and conveying of raw materials

(2) Electric furnaces:

		Case A	Case B
Electrode diameter	mm	800	1,050
Furnace shell diameter	mm	6,500	9,000

(3) Product handling equipment: for sizing and screening of finished products

(4) Dust collecting facilities: for collecting dust contained in exhaust gas from electric furnaces

(5) Utility facilities: related to water, fuel and air

(6) Power receiving equipment: power receiving transformer and distribution facilities

The plant layout, production processes and a cross-section of electric furnace are illustrated in Figs. 6-5 through 6-12.

6–2 Construction Plan

For construction works, Sudanese contractors and subcontractors are used as much as possible, but most construction materials will have to be imported. Construction period is estimated to be 36 months for Case A or 48 months for Case B. Requirements for technical experts during this period for supervision and technical assistance are estimated to be 320 person-months for Case A and 540 person-months for Case B.

6–3 Construction Costs

Construction costs were estimated under the following conditions.

(1) All the figures were estimated as of March, 1981.
(2) Price inflation was not included in estimates.
(3) Taxes and custom duties on import machinery and equipment were all exempted.

The estimated construction costs with domestic and foreign currency portions are summarized in Table 6-7. As seen from the table, the domestic currency portion accounts for about 30% of the total costs, a reasonable figure for this kind of projects.

7. Organization and Manpower Planning

For efficient implementation of The Project , two separate contracts would be necessary, covering works in Khartoum and in Damazin. First, the Head Office would be set up in Khartoum to handle administrative affairs, overall planning, procurement and marketing. Secondly, the ferrochrome plant in Damazin would deal with matters directly related to plant operation and management of production facilities.

Organization charts are given in Fig. 7-1. Total manpower required for the Head Office is 19 persons, and the manpower requirements for the ferrochrome plant are 151 persons and 211 persons for respective plant scale under Case A and Case B. (see Table 7-1 and 7-2).

Annual labor costs are estimated to be US$253,200 for Case A or US$322,200 for Case B. Since ferrochrome production techniques belong to one of the more sophisticated among ferroalloy technology, it is indispensable to send some Sudanese workers to a developed country in order to train them at existing ferrochrome plants. Total requirements for such a vocational training would be 90 person-months at the minimum.

8. Operation Planning

It is desirable that operation of a ferrochrome plant continues throughout the year. Power supply conditions of the Sudan, however, would allow only 300 days annual operation of the plant.

Operation of the ferrochrome plant will reach its full production capacity after 6 months from initiation of the operation. During this initial operation period, 54 person-months will be required for assistance and guidance of operation. Operating performance of the plant after the operation reaches a normal state was estimated based on material/heat balance, and the results are summarized in Table 8-6. Calculation of unit costs is given in Table 8-8.

9. Comprehensive Evaluation

9-1 Method of analysis

The Project was evaluated in a comprehensive manner by using the discount cash flow analysis and the internal rates of return. In financial analysis, viability of The Project was investigated from a viewpoint of an enterprise. The financial rate of return was calculated for various cases of two alternative plant scales 7,000tons/year(Case A) and 15,000tons/year (Case B) ferrochrome production. In economic analysis, The Project was evaluated from a viewpoint of nation's economy. The economic rate of return was calculated for the standard case of both alternative plant scales, and sensitivity analysis was also performed on a few key parameters.

9-2 Financial Analysis

All the cost and benefit data used in the standard cases of financial analysis represent the most likely conditions that would prevail. For instance, the prices of materials are the prices at which those materials would most likely be purchased, if The Project is to be implemented, and the electricity rate was determined based on the electricity tariff that is currently effective. However in view of the fact that the costs of cokes account for a significant fraction of the production costs as shown in Table 8-8, and also taking account of the concern of the Sudanese side for utilizing domestic charcoal, the assumption is made herein that one-third of requirements for reducing agents necessary for ferrochrome production are satisfied by the charcoal. Also the price of chromium ore was estimated based on its production costs at existing mines rather than the current export price at FOB price at Port Sudan in order to improve financial performance of The Project. Actual values applicable to the enterprise, however, may vary for a variety of reasons; e.g. a lower rate may be applied to electricity by some political decision. Therefore, sensitivity analysis was perfomred to investigate effects of those variations.

The calculated value of financial rate of return is −11.0% or −10.1% for the respective plant capacity of 7,000 tons/year of 15,000 tons/year ferrochrome production. The Project is thus financially infeasible as long as those conditions that constitute the standard cases prevail. The sensitivity analysis for Case B shows that the 30% reduction in electricity rate, the 20% increase in ferrochrome price, the 30% cut in initial investment costs and exemption of all the taxes and custom duties improve the financial rate of return to a varying degree, but the value is still all negative. Only in the most optimistic case investigated, where all of the favorable conditions above are combined, the value of financial rate of return turns positive to 5.4%. Possibility of such a combination, however, may not be very high.

9–3 Economic Analysis

The cost and benefit figures used in economic analysis were carefully derived so that they represent to the extent possible real costs and benefits to the nation's economy rather than nominal ones such as prevailing prices in imperfect markets. Using the concept of "opportunity costs", economic or accounting costs and benefits were derived, including costs of electricity, labor costs, prices of chromium ore and foreign exchange. Internal transfer portions were eliminated from the cost data used in financial analysis. An attempt was made to evaluate the benefits associated with vocational training, one of the objectives of The Project, to see their effects on economic viability of The Project.

The value of economic rate of return for the standard cases was calculated to be −13.2% or −12.3% for the plant capacity of 7,000 tons/year or 15,000 tons/year ferrochrome production, respectively. These figures are worse than the results of corresponding financial analysis. Although all the internal transfer portions of costs included in financial analysis are eliminated, and the economic value of ferrochrome is calculated to be higher by application of the shadow exchange rate, effects of these favorable factors are cancelled out by the significantly higher economic costs of electricity: US$0.068/KWH as compared with US$0.043/KWH used in financial analysis. If the benefits of vocational training are included in economic analysis, the economic rate of return is improved but only slightly.

The sensitivity analysis on a few key parameters representing exogenous factors has revealed the following. The 20% increase in ferrochrome price improves the calculated value of economic rate of return to −1.1%. The 30% reduction in initial investment costs also increases the economic rate of return, but if this reduction is combined with the 20% reduction in operating rate of the plant, the result is no better than the standard case. If the 20% increase in ferrochrome price is combined with the 30% out in initial investment costs, the economic rate of return turns positive, but the value is as low as 2.9%.

10. Conclusions

Table 9-12 summarizes the results of calculation of internal rates of return, including the calculated values of financial rate of return and economic rate of return for the standard runs of both Case A and Case B. Also included in the table are the results of sensitivity analysis for Case B, which appeared to be slightly more promising than Case A.

The values of internal rates of return calculated for the standard cases are all negative for both Case A and Case B. That is, The Project is infeasible both financially and economically at either plant capacity of 7,000 tons/year or 15,000 tons/year ferrochrome production, as long as those conditions that constitute the standard cases prevail. Financial infeasibility means that The Project would not be successfully undertaken by any private enterprise. Economic infeasibility implies that implementation of The Project may not be justified from a viewpoint of nation's economy. If the estimated benefits of vocational training are included in economic analysis, the economic rate of return is improved but only slightly, indicating that these positive effects would not totally save The Project.

A note of precaution here, however, is that there may be other benefits associated with The Project including the intangible, which can not be easily measured in monetary terms. Among these possibilities are (i) promotion of industrialization in the Sudan and provision of a better-balanced economic base, (ii) direction of attention to a less developed region, (iii) provision of employment opportunities and improvement of income distribution, and (iv) other symbolic value of implementing The Project.

The results for Case B are somewhat better than those for Case A, primarily because of scale economy pertaining to establishment and operation of the ferrochrome plant. It should be noted that, however, that the total amount of subsidy required to make The Project financially viable, should it be implemented, would be larger for Case B than for Case A, since the former is larger in development scale.

Sensitivity analysis for Case B has revealed that the 30% reduction in electricity rate, the 20% increase in ferrochrome price, the 30% cut in initial investment costs or exemption of all the taxes and custom duties would not by itself make The Project sufficiently viable financially. Only in the most optimistic case of financial analysis investigated, where all of the favorable conditions above are combined, the value of financial rate of return becomes positive, but the value is regrettably low 5.4%. Even more annoying is the fact that the economic rate of return corresponding to this case is as low as 2.9%.

Taking all of the conditions described above into consideration, The Study Team recommends that a very careful attitude be taken in proceeding toward implementation of The Project at this time.

CHAPTER 1

INTRODUCTION

1. Background

In proceeding with the economic development plans, the Government of the Democratic Republic of the Sudan places high priority not only on the development of agriculture but also on the industrialization of mineral resources of the country. One of the priority projects in the mining industry is the development of chromium mines and ferrochrome industry. In the hope that establishment of a ferrochrome plant would constitute a nucleus of the industrialization policy of the Sudan and contribute also to earning foreign exchanges, the Government of the Sudan requested cooperation of the Japanese Government in carrying out a feasibility study on the project (hereinafter referred to as "The Project") to establish a ferrochrome plant in the Sudan.

On the basis of this request and in accordance with the technical cooperation policy of Japan, the Japan International Cooperation Agency, the official agency responsible for the implementation of technical cooperation of the Government of Japan, made a decision to send a study team (hereinafter referred to as "The Study Team") to carry out a feasibility study (hereinafter referred to as "The Study") on the ferrochrome smelting plant to be located in the Damazin area.

Representatives of the Democratic Republic of the Sudan concerned with The Project and The Study Team had a meeting on March 4, 1981 at Geological Department, the Ministry of Energy and Mining. Basic agreements were reached between both sides (See Annex I for "Minutes of the Meeting concerning the Feasibility Study on the Establishment of a Ferrochrome Plant in the Democratic Republic of the Sudan, March 4, 1981") The field investigation was carried out by The Study Team for the period between March 4 and March 21, 1981 in accordance with the Scope of Work, covering the Khartoum, Damazin, Ingessana Hills and Port Sudan areas.(Refer to "Interim Report of the Feasibility Study on the Establishment of a Ferrochrome Plant in the Democratic Republic of the Sudan, March 21, 1981" of Annex II).

2. Organization of the Report

In the remaining part of this chapter, general economic situations, in particular, mining and manufacturing sector of the Sudan, are described. Chapter 2 provides brief description of past development and present status of the ferrochrome industry, and future prospects.

The following six chapters describe The Proejct in detail. First, Chapter 3 presents the outline of The Project including its scope, objectives, project area and the scale of ferrochrome plant. Availability and procurement of raw materials necessary for the plant and the infrastructure related to The Proejct are described in Chapter 4 and Chapter 5, respectively. In Chapter 6, a plan for constructing the ferrochrome plant is presented with preliminary engineering design of facilities and estimation of construction costs. Chapter 7 provides a possible form of organization and manpower planning; labor costs are also estimated. Operation planning is presented in Chapter 8, where the operating performance of the plant is established and production costs are estimated.

The last two chapters evaluate The Projects in a comprehensive manner. Viability of The Project is investigated from both financial and economical points of view in Chapter 9, using the discount cash flow analysis and internal rates of return. Conclusions are drawn in Chapter 10, together with recommendations regarding the implementation of The Proejct.

3. Economic Situations of the Sudan

3–1 General

Gross domestic product (GDP) figures of the Sudan at current prices are given by sector in Table 1-1 for the years 1971/72 through 1978/79. The table indicates that the GDP has grown at an average annual rate of over 20% during the past several years, but the real growth rate appears to be less than 10% due to substantial increases in consumer prices during this period.

Clearly agriculture is a dominant sector of the Sudan's economy, accounting for some 40% of the GDP. Although agriculture provides the mainstay of almost 80% of the population and employs about 65% of the labor force (see Table 7-3), its share in the GDP shows a slightly declining trend.

Table 1-1 Gross Domestic Product at Market Price by Economic Activity, 1972/73 – 1978/79

(Unit: Million S£)

	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78	1978/79*
Agriculture	344.6 (38.4%)	516.4 (41.4%)	585.3 38.7%)	628.2 (34.0%)	843.5 (36.1%)	1083.3 (37.6%)	894.4 (32.0%)
Commerce	142.9	175.7	245.2	315.3	445.3	555.8	442.9
Manufacturing & Mining	82.9 (9.2%)	111.3 (8.9%)	142.9 (9.5%)	161.1 (8.7%)	199.7 (8.5%)	225.4 (7.8%)	238.9 (8.6%)
Transport & Communication	61.5	74.8	89.4	192.4	229.0	280.4	345.0
Construction & Public works	81.2	61.0	65.0	88.8	108.3	124.1	163.3
Electricity & Water	17.5	18.6	20.9	28.6	84.3	38.6	34.3
Government Services	104.8	127.9	151.2	171.5	184.8	214.5	269.1
Other Services	111.4	160.5	210.9	262.1	284.8	360.6	396.5
GDP at Marker Price	896.8	1246.2	1510.8	1848.0	2339.7	2882.7	2784.4

Source: Bank of Sudan, Twentieth Annual Report, 1979 (1972/73 – 1975/76, 1978/79), Ministry of National Planning, National Income, Accounts and Supporting Tables (1976/77, 1977/78).

Note: * Provisional

Agricultural products are major foreign exchange earners as can be seen from Table 1-2. In particular, cotton exports constitute more than half of the Sudan's total exports in value terms. Main items of imports as shown in Table 1-3 include machinery and equipment, crude materials, transport equipment and chemicals, accounting in total for more than 60% of imports in 1979 in value terms.

The trade balance has shown persistent deficits in the past several years, imposing a burden on the country's balance of payments as can be seen from Table 1-4. The government's decision in 1976 to cut back imports particularly by public sectors, together with better export performance, once improved the balance of payments considerably. The situation, however, is getting deteriorated again as a result of a sharp increase in payments for both government and private imports mainly due to substantial rise in prices of imports including oil and petroleum products and other raw materials. In the long run, the balance of payments are expected to improve, as a number of export-oriented or import-substituting projects are implemented. Those projects presently on the line involve many industries such as textiles, cement, sugar, and others.

3–2 Manufacturing and Mining Sector

As already seen from Table 1-1, the manufacturing and mining sector is relatively minor in the Sudan's economy. Although the total production of this sector increased from 82.9 million S£ in 1972/73 to 284.0 million S£ in 1977/78 current prices, the percentage share to the GDP fell slightly during this period.

Table 1-2 Main Items of Imports as Percentage of Total Value of Exports, 1972 – 1979

(Unit: %)

Items	1972	1973	1974	1975	1976	1977	1978	1979
Cotton	58.6	55.6	35.5	46.0	50.7	57.2	51.8	65.0
Groundnuts	7.8	8.5	14.9	22.6	20.2	12.5	10.2	4.3
Sesame	7.4	7.0	13.5	7.8	9.0	7.9	9.5	2.7
Gum Arabic	7.3	4.9	11.7	5.0	5.8	5.9	7.3	8.0
Cake and Meal	3.5	5.2	1.8	2.7	2.6	3.4	3.3	3.2
Others	15.4	19.0	22.6	15.9	11.7	13.1	17.9	16.8
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Bank of Sudan, Twentieth Annual Report, 1979

Table 1-3 Main Items of Imports as Percentage of Total Value of Imports, 1972 – 1979

(Unit: %)

Items	1972	1973	1974	1975	1976	1977	1978	1979
Machinery and Spare Parts	13.3	13.2	12.2	16.4	32.4	33.4	24.9	21.1
Crude Materials	1.3	1.0	13.7	7.8	9.3	12.1	11.3	15.3
Transport Equipments	11.4	16.7	13.6	17.9	12.6	10.5	12.8	14.8
Chemicals and Pharmaceutical Products	12.1	12.5	11.0	11.2	9.8	8.7	9.3	10.2
Textiles	14.4	10.7	9.7	12.0	6.4	7.5	8.3	5.6
Other Foodstuffs	8.5	8.0	5.7	4.0	5.1	3.7	4.1	6.6
Sugar	8.7	9.7	13.5	11.0	6.4	3.6	4.2	4.3
Tea	5.2	3.3	2.5	1.2	1.1	1.7	3.8	1.3
Coffee	1.6	1.3	1.1	0.6	0.6	0.5	0.1	0.5
Others	23.5	23.6	17.0	17.9	16.3	18.3	21.2	20.3
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Bank of Sudan, Twentieth Annual Report, 1979.

Table 1-4 Balance of Payments, 1974 – 1979 (in million S£)

(Unit: Million S£)

Year	1975	1976	1977	1978	1979
Trade Balance	–138.1	–30.2	–15.6	–72.9	–158.9
Imports (CIF)	284.4	239.4	245.9	290.3	386.0
Exports (FOB)	146.3	209.2	230.3	217.4	227.1
Services (net)	–28.2	–34.6	–19.7	+30.6	+35.2
Payments	62.9	76.6	76.2	92.1	132.1
Receipts	34.7	42.0	56.5	122.7	167.3
Current Account	–166.3	–64.8	–35.3	–42.3	–123.7
Capital Account	+ 32.2	+25.7	+35.7	+30.9	+109.8
Errors and Omissions	+0.7	+0.9	–0.4	–0.5	–0.3
Balance of Payments	–133.4	–38.2	–0	–11.9	–13.6

Source: Bank of Sudan, Twentieth Annual Report, 1979.

It has been pointed out that there are two major bottlenecks against industrial development of the Sudan; namely, scarcity of managerial and technical skills, and inadequate transportation, communications and power supplies. Procurement of spare parts and raw materials and improvement of capacity utilization in existing industries have been hampered by these conditions.

The Sudanese government, however, has given increasing attention to the development of the manufacturing and mining sector as reflected in the latest Six Year Plan. Among the objectives of the Six Year Plan related to this secotr are:

- Development of agro-industries based on local agricultural production.
- Production of agricultural inputs such as cement, insecticides, agricultural equipment and spare parts.
- Development of small scale industries based on local materials.
- Exploration and exploitation of mineral wealth for broadening the economic base of the nation.

The Six Year Plan aims at increasing contirubution to the GDP of the industrial sector to 16% by 1982/83, of which 10% is expected for manufacturing and mining. Future development of manufacturing and mining sector certainly hinges on better utilization of natural endowments of the country, i.e., agricultural products and mineral resources.

CHAPTER 2

THE FERROCHROME INDUSTRY

1. Chromium Ore

1–1 Chromite

It is only chromite that is worthy as a natural resource among minerals containing chromium.

From a viewpoint of mineralogy, chromite belongs to the spinel group and is indicated as $FeCr_2O_4$ or $FeOCr_2O_3$.

In the most cases, chromite contains a large amount of magnesium and aluminium in lieu of iron and chromium.

Chromite is a sole industrial raw material for the manufacture of ferrochrome, chromium metal and chromium compound.

1–2 Usage of Chromium Ore

Chromium ore is consumed in industries such as iron/steel, metals, chemicals, refractory and foundry.

For iron/steel, the ore is used for the manufacture of ferrochrome. it is used as a chromium additive to making special steel.

The ore consumed for ferrochrome represents approximately 60% of the world's total output.

In addition, as to metal application, the ore is used for chromium metal, as for chemcial application, for chrome salts such as sodium bichromate, chromic anhydride, etc., as to refractory, for chromium brick and as for foundry, for molding sand.

To cite the generally accepted figures, of the global chromium ore output, consumption for metallurgy and metal making accounts for 60%, for chemical industry and molding sand 20% and for refractory production 20%. (Standard Research Institute "World Minerals Availability; Volume 4")

The generally recognized types of chromium ore are (1) high chromium, (2) high iron and (3) high aluminium content.

High chromium ore is used almost entirely for metallurgy, specially for the manufacture of ferrochrome. The hard lumpy form of the high chromium ore is essential for controlling the carbon content of ferrochrome. An insignificant amount is used for refractory. The high iron content ore is used for the manufacture of chromium-based chemicals and low quality ferrochrome. At the same time, it is consumed for refractory and used as molding sand. Most of the high aluminium ore is consumed for refractory.

1–3 Deposits

Of elements existing in the crust, chromium is the 21st most abundant element (Clarket number). According to the survey of the Bureau of Mines of the United States, the proven chromium deposits reach 1.8 billion tons. If the estimated deposits are added, the estimated total tonnage will be 4.7 billion tons.

The following is a list of countries having the proven deposits given in the quantitative order.

South Africa	63%
Zimbabwe	33%
USSR	1.3%
Finland	0.6%

Only South Africa and Zimbabwe combined possess the chromium deposits equivalent to more than 95% of the world total, controlling almost all the global chromium deposits. Of this quantity, apprroximately 36% is represented by high chromium ore containing more than 46% of Cr_2O_3 with Cr:Fe set at ratio of more than 3:1. The 63% is represented by high iron content ore containing 40% to 46% of Cr_2O_3 with Cr:Fe set at less than 3:1. The remaining 1% is represented by high aluminium ore containing more than 20% of $A\ell_2O_3$ with more than 60% of $Cr_2O_3 + A\ell_2O_3$.

The world chromium deposits are shown in Table 2-1.

1–4 World Chromium Ore Output

The world's gross chromium ore output through 1978 is as shown in Table 2-2. South Africa and USSR produce more than 56% of the global gross output. The seven countries including these two countries are producing 87% of the world's total output. The total output is increasing on a yearly basis. Especially the increase in outputs of South Africa and Albania are conspicuous.

Table 2-1 Chromium Ore Deposits in the World

(Unit: 1,000 S/t)

	High Chromium		High Iron		High Aluminium		TOTAL	
	Proven	Others	Proven	Others	Proven	Others	Proven	Others
U.S.A.	50	400	–	5,600	–	100	50	6,100
Brazil	2,800	3,400	3,900	2,200	100	150	6,800	5,750
Canada	–	100	–	2,800	–	–	–	2,900
Greenland	–	–	–	11,000	–	–	–	11,000
Finland	–	–	11,000	5,600	–	–	11,000	5,600
India	5,600	4,500	2,200	2,200	–	–	7,800	6,700
Iran	1,700	1,100	–	–	–	–	1,700	1,100
Madagascar	4,500	3,400	1,100	2,200	–	–	5,600	5,600
Philippines	780	560	–	–	4,500	2,200	5,280	2,760
Zimbabwe	560,000	560,000	56,000	56,000	–	–	616 000	616,000
South Africa	56,000	56,000	1,100,000	2,200,000	–	–	1,156,000	2,256 000
Turkey	5,600	5,600	–	–	–	–	5,600	5,600
U.S.S.R.	11,000	11,000	1,100	2,200	11,000	11,000	23,000	24,200
Greece	50	50	–	–	50	50	100	100
Others	1,000	1,400	1,100	1,100	280	1,100	2,480	3,600
TOTAL	649,180	647,510	1,176,400	2,290,900	15,930	14,600	1,841,510	2,953,010

Source: US Bureau of Mines

Table 2-2 Actual Chromium Ore Outputs

(Unit: 1,000 M/t)

	1965	1970	1973	1974	1975	1976	1977	1978
South Africa	942	1,427	1,650	1,877	2,075	2,409	3,319	3,145
Zimbabwe	635	363	550	590	590	610	608	600
Turkey	567	519	436	666	670	869	630	635
U.S.S.R	1,422	1,750	1,900	1,950	2,085	2,120	2,180	2,300
U.S.A.								
Philippines	554	566	580	530	520	431	538	531
Finland			148	155	165	175	594	719
Canada								
India	60	274	288	394	499	402	357	266
Madagascar			158	156	194	218	165	138
Cuba			20	20	20	20		30
Yugoslavia	80	41						
Albania	315	454	611	715	750	780	880	930
Iran	152	220	140	175	275	160	165	165
Greece			18	10	23	27	30	40
New Caledonia								10
Japan	42	33	23	26	23	22	18	9
Brazil			73	88	90	120	150	190
Sierra Leone								
Cyprus			30	34	28	7	14	15
Pakistan							12	9
Others	209	453	32	20	25	15	46	53
TOTAL	4,978	6,100	1,696	7,427	7,941	8,407	9,700	9,785

Source: Metal Bulletin (1965 – 1977, Roskill Report (1978).

1–5 Demand for Chromium Ore in the World and Production Forecast

(1) Reliable data based on an estimated future world demand for chromium ore was not available. Supposing that consumption for 1980 is 10 million tons (the output for 1978 was 9.8 million tons and the annual increase of consumption is 3%, consumption for 1990 will be 13.43 million tons. Accordingly, consumption will increase by 3.5 million tons 10 years later.

(2) The forecast of the world's chromium ore output against this consumption is as follows:

From the present uncertain condition, it is difficult to map out a reliable chromium ore output schedule to whatever extent may be practicable. In addition, it is also difficult to obtain reliable data regarding the future production of the major producing countries in the world.

However, since the combined proven deposits of both South Africa and Zimbabwe account for 96% of the world's total output, these countries will, of course, maintain their position as the principal suppliers on a long-run basis. Especially South Africa is favored with ideal ore mining conditions, so it is possible for this country to increase production to meet demand with ease. In addition to these two countries, it is considered that India, Madagascar, the Philippines, etc. with their proven deposits, will be able to easily keep the present output level and further raise it on a long range basis.

(3) To take a look at the shape and quality of the ore of these countries which can afford to increase production in future, South Africa is a high iron content ore producing country. Of high chromium ore, the lumpy ore is produced by Zimbabwe, USSR, Iran, Turkey, Sudan, etc. It is considered that except for Zimbabwe, the other countries would find not it easy to increase production of this ore.

From the above, it is estimated that high iron content-chromium ore will be the main type which output will be increased in the future.

1–6 Price

(1) Past price transition up to now

With the oil crisis in 1973, the price of chromium ore in the world skyrocketed. As the background for it, the increased consciousness of "natural resources" nationalism, stringent demand and supply for chromium ore following a rapid expansion of the world trade and maldistribution of chromium ore output in the specific areas (South Africa, USSR, Zimbabwe, Turkey, etc.) are cited.

In and after 1977, consumption in the major consuming countries (USA, Western Europe, Japan) decreased and the production capacity of the ore producing countries increased, resulting in a glut and a reduced price of chromium ore.

"Transition of Chromium Ore Price" is shown in Table 2-3.

As things stand, the export price applied by South Africa producing high iron ore in the main has come to stay, reflecting a glut. The price of high chromium ore is higher than that of high iron ore because of the ban on exports of high-quality ore by USSR and the difficulty to export high-quality ore by high-quality ore exporting countries such as Zimbabwe.

(2) Future forecast

Imports by traditional importing countries of the world's chromium ore, namely, Japan, Sweden, West Germany, USA and France reached the peak in 1975. However, after that, the volume tended to decrease annually. However, during this period, South Africa the world's largest deposits holder, Albania, USSR, Finland, etc. increased their respective production capacities beyond the actual requirement level. Consequently, the global demand and supply balance for chromium ore has eased.

It is considered that the ore price will gradually soar due to production cost hike and overland transportation fee under the world-scale inflation.

High iron ore produced in South Africa has comparatively more favorable mining conditions, so it is estimated that it would be easy to increase production. For these reasons, the production cost will show a moderate upward curve and the price will continue to be stable.

1–7 Position of Sudanese Ore

(1) Foreign trade trends

Chromium resources are not produced in the traditional chromium-consuming countries such as USA, France, West Germany, Sweden and Japan. Therefore, these consuming countries are importing the ore for their consumption from the ore-producing countries.

However, in and after 1977, the ore-producing countries, specially South Africa and Zimbabwe began increasing ferrochrome production and exporting it to the consuming countries. As a result, the ore trade volume has reduced.

Table 2-3 Transitions of Chromium Prices (Actual Purchases by Japan)

(Unit: FOB US $)

	Quality		1973	1974	1975	1976	1977	1978	1979	1980
	Cr_2O_3 (%)	Cr/Fe (%)								
South Africa (Powder)	44	1.5	18.00	28.00	35.00	45.00	54.00	50.00	48.50	51.00
Madagascar	48	2.4	29.50	34.40	75.00	90.00	108.75	87.00	80.00	80.00
India (H-Grade)	54	3.2	54.63	62.10–128.00	121.50–165.30	162.84	133.00–115.00	115.00–89.00	100–120	108–115
Philippines (Acoje)	48	2.2	33.00	42.00–76.00	88.00–125.00	115.00–122.00	122.00–90.00	92.00	C&F 90.00–98.00	C&F 105–103

Index Indication

South Africa (Powder)	44	1.5	100	160	190	250	300	280	270	290
Madagascar	48	2.4	100	120	250	300	370	290	270	270
India (H-Grade)	54	3.2	100	110–230	220–300	300	240–210	210–160	180–220	200–220
Philippines	48	2.2	100	130–230	270–380	350–370	370–270	280	–	–

Table 2-4 Chromium Ore Exports/Imports in the World

(Unit: 1,000 tons)

	1974	1975	1976	1977	1978
Exports					
South Africa	1,129	1,003	1,259	1,169	1,122
U.S.S.R.	1,139	1,172	975	673	738
Turkey	646	648	670	596	213
Albania	590	670	690	197	71
Zimbabwe	155	307	264		
Philippines	642	501	312	433	215
India	301	359	330	283	91
Sub-Total	4,602	4,650	4,500	3,351	2,460
Others	341	680	629	312	65
TOTAL	4,943	5,230	5,129	3,662	2,525
Imports					
Japan	1,155	1,269	1,217	900	670
Sweden	270	396	378	385	559
West Germany	387	561	547	416	372
U.S.A.	1,000	1,136	1,157	432	346
France	365	364	346	281	243
Sub-Total	3,177	3,726	3,645	2,414	2,190
Others	763	735	622	824	445
TOTAL	3,940	4,561	4,267	3,238	2,635

Source: Roskill Report, Second Edition, 1978.

(2) Breakdown of chromium ore production

It is estimated that the world's chromium ore output for 1980 was approximately 10 million tons.

From Japanese ferrochrome manufacturers' experiences in trade with the world's major ore-producing countries, their producion by type and shape is as follows:

South Africa: High iron ore, pulverized and lumpy.

USSR : Mostly middle quality, pulverized and lumpy ores. The remainder is high chromium ore, pulverized and massive.

Zimbabwe : High chromium ore, pulverized and lumpy.

Turkey : High chromium middle quality ore, pulverized and lumpy.

Albania : Mostly middle quality, lumpy ore. The remainder is high chromium ore, pulverized.

Iran : High chromium ore, pulverized and lumpy.

No statistics on the output of high chromium ore and lumpy ore are available. However, it is estimated that in 1980, the output would reach 1 million tons. Nevertheless, the USSR has banned exports of high chromium ore and Iran has suspended exports at this moment.

Zimbabwe gives priority to its own domestic consumption, so there is almost no export.

Turkey seems to have difficulty in increasing high chromium ore because of a small mining scale of Turkish ore producers except for the government-run Etibank.

For the above reasons, the export volume of highchromium lumpy ore throughout the world is limited.

(3) Position of Sudanese ore

Chromium ore has physical and chemical properties which the consumers require depending on its application.

Chromium ore produced in Sudan is high chromium lumpy ore. It has particularly excellent properties of lumpy hardness. These properties are indispensable for keeping the carbon content of ferrochrome at low level.

In addition, it is daid that this ore is highly required for the manufacture of some of the refractory products.

Accordingly, the output of the ore similar to the one of Sudanese ore is limited and its export volume is also limited. Considering the fact that constant demand for this ore as an essential one by particular consumers exists, it is certain that the current export volume of the Sudanese ore will be kept on the export makret even henceforth. As to price, it is presumed that it will continue at a stable level supported by its demand.

2. Ferrochome Industry

2–1 Present Situation

(1) Status of demand distribution

Approximately 80% of the ferrochrome output is consumed for the manufacture of stainless steel and the rest for special steel in the main.

The total production of stainless steel in the Free World registered an all-time high record of 7,413,000 tons in 1979 as shown in Table 2-5. Since 1960, the stainless steel output indicated a significant growth of 3.3-fold as against the 2.2-fold growth of the total crude steel production. In the demand sections such as chemical plants, construction machinery, automobile, home culinary appliances, etc. a new application has been developed one after another.

In 1980 and 1981, due to the world-scale recession, it is estimated that production will drop slightly from that of 1979.

(2) Ferrochrome demand and supply condition

Ferrochrome is classified into three grades, i.e. high-carbon ferrochrome (HCFeCr), low-carbon ferrochrome (LCFeCr) and silicochrome (SiCr). With the introduction of new stainless steel manufacturing methods such as AOD, etc. HCFeCr consumption in Japan accounts for 92% of the total ferrochrome consumption. Even on the global scale, it is considered that HCFeCr consumption should reach as high as 90%.

As to the world's ferrochrome production facilities, a significant expansion centering around South Africa was seen during the period from 1970 through 1975. This has resulted in a continued glut up to now. Of the ferrochrome facilities in the Free World, HCFeCr production equipment capacity is as per Table 2-6.

In 1979, for the first time after the first oil crisis, the global ferrochrome output showed a sharp increase to approximately 1,900 tons (estimated consumption – 1,700 tons).

In 1980, due to the recession in Europe, USA and Japan, production is now at the low level for inventory adjustment and slow demand.

Table 2-5 Actual Stainless Steel Production in the Free World (in Terms of Ingot)

(Unit: 1,000 tons)

Year \ Country	Japan	U.S.A.	West Germany	France	Sweden	U.K.	Italy	Other Countries of Free World	Total
1960	329	980	259	186	176	224	58	101	2,241
1965	660	1,353	285	240	275	240	127	159	3,339
1970	1,640	1,163	504	467	373	290	237	295	4,969
1971	1,404	1,143	401	406	339	191	216	261	4,361
1972	1,421	1,413	518	430	382	196	260	330	4,950
1973	2,128	1,716	620	521	467	240	288	400	6,380
1974	2,037	1,955	688	570	519	226	311	482	6 788
1975	1,645	1,013	437	419	419	148	267	352	4,700
1976	2,203	1,528	673	497	418	224	366	420	6,329
1977	2,168	1,696	636	572	325	194	418	468	6,477
1978	2,074	1,763	761	538	361	238	440	407	6,582
1979	2,421	1,912	821	613	418	260	500	468	7,413

Note: 1) Includes heat-resistant steel and cast steel products, depending on a country.

2) For Japan, it is estimated based on the yielding rate of 75% between hot roll products and steel ingots.

Sources: Roskill Report, Japan Stainless Steel Association, etc.

Table 2-6 Estimated HCFeCr Production Capacity of Free World (as of April, 1981)

Country	Production Capacity (M ton)
Finland	50
Norway	23
Sweden	285
W. Germany	160
France	70
Italy	40
Spain	38
Yugoslavia	38
Turkey	50
S. Africa	725
Zimbabwe	185
U.S.A.	250
Canada	50
Brazil	80
India	18
Philippine	10
R. of Korea	3
Taiwan	6
Japan	519
TOTAL	2,600

2–2 Future Forecast

(1) Production Forecast for Stainless Steel

It is difficult to make a definite forecast of the world's iron/steel output. However, according to various investigation agencies' announcements, an annual growth of 2 to 3% is expected. In the meantime, stainless steel production is expected to increase at higher rate than ordinary-type steel under the circumstances when the world is obliged to save natural resources and energies. Suppose the annual growth is 3%. Then conceivable stainless steel production 10 years later will be as follows:

Stainless Steel Output (Based on Ingot)

1979	7,413	tons
1985	8,851	tons
1990	10,261	tons

(2) Demand and Supply Balance of HCFeCr

As explained earlier, HCFeCr demand and supply balance in the Free World continued to be in a glut since the first oil crisis. However, a look at the above-mentioned stainless steel forecast suggests the restoration of an equilibrium of supply and demand in 1985.

In the meantime, there is a 600,000-ton expansion project in Turkey, India, Philippines, Greece, etc. centering around South Africa at present. If this project were realized, that would be a contributing factor toward impeding a normalization of the demand and supply balance.

The demand and supply balance under the existing equipment capacity is shown in **Table 2-7**

Table 2-7 Forecast of Demand and Supply Balance for HCFeCr in the Free World

(Unit: 1,000 tons)

Year	Stainless Steel Output	HCFeCr Consumption	Production Capacity (Equipment Capacity x 80%)	Equipment's Spare Capacity
1979	7,413	1,700	2,080	380
1980	7,635	1,751	2,080	329
1981	7,864	1,803	2,080	277
1982	8,100	1,858	2,080	222
1983	8,343	1,913	2,080	167
1984	8 594	1,971	2,080	109
1985	8,851	2,030	2,080	50

2-3 Ferrochrome Market Price

The past price trends from 1973 up to the recent days on the international market are as per separate chart.

In 1974, the temporarily overheated market during the so-called oil crisis continued to run down the drain.

In June, 1978, the European Community put into effect restrictions to apply the minimum import price on HCFeCr imports from South Africa and Sweden so that ferrochrome manufacturers in the EC might be protectd against such imports. In addition, in

November, 1978, in the USA, the International Trade Commission recommended and executed import curbing procedures (the improted ferrochromium floor price was set at US ¢ 38 per lb of chromium FOB and a punitive duty of US ¢ 4 per lb of chromium would be imposed, if imported at a price lower than the floor price applicable to imported HCFeCr) over a 3-year period.

As a result, in the latter part of 1978, the market price began turning upward, but the increase margin was so insignificant that the set floor price level managed to be cleared. In 1979 and 1980, no significant change in the global demand/ supply relationship was seen and the market price has shown almost no fluctuation from the latter part of 1978 up to now (**Fig. 2.1** shows a conspicuous wave of price change in the UK. This is due to the fluctuation of an exchange rate between Sterling pound and US dollar).

As to future forecast, contrary to the basic maldistribution of chromium ore resources, ferrochrome is expected to be in a long over-supply position. Therefore, it may be difficult to anticipate a significant improvement of the current market price level for some time to come.

Rather it is expected that South Africa, Sweden, Brazil, Turkey, etc. which augmented the production facilities recently and Turkey, Greece, India, Philippines, etc. which plan to increase production in near future will stage an aggressive export offensive.

The imported product market prices in Europe, USA and Japan as of April, 1981 are as follows:

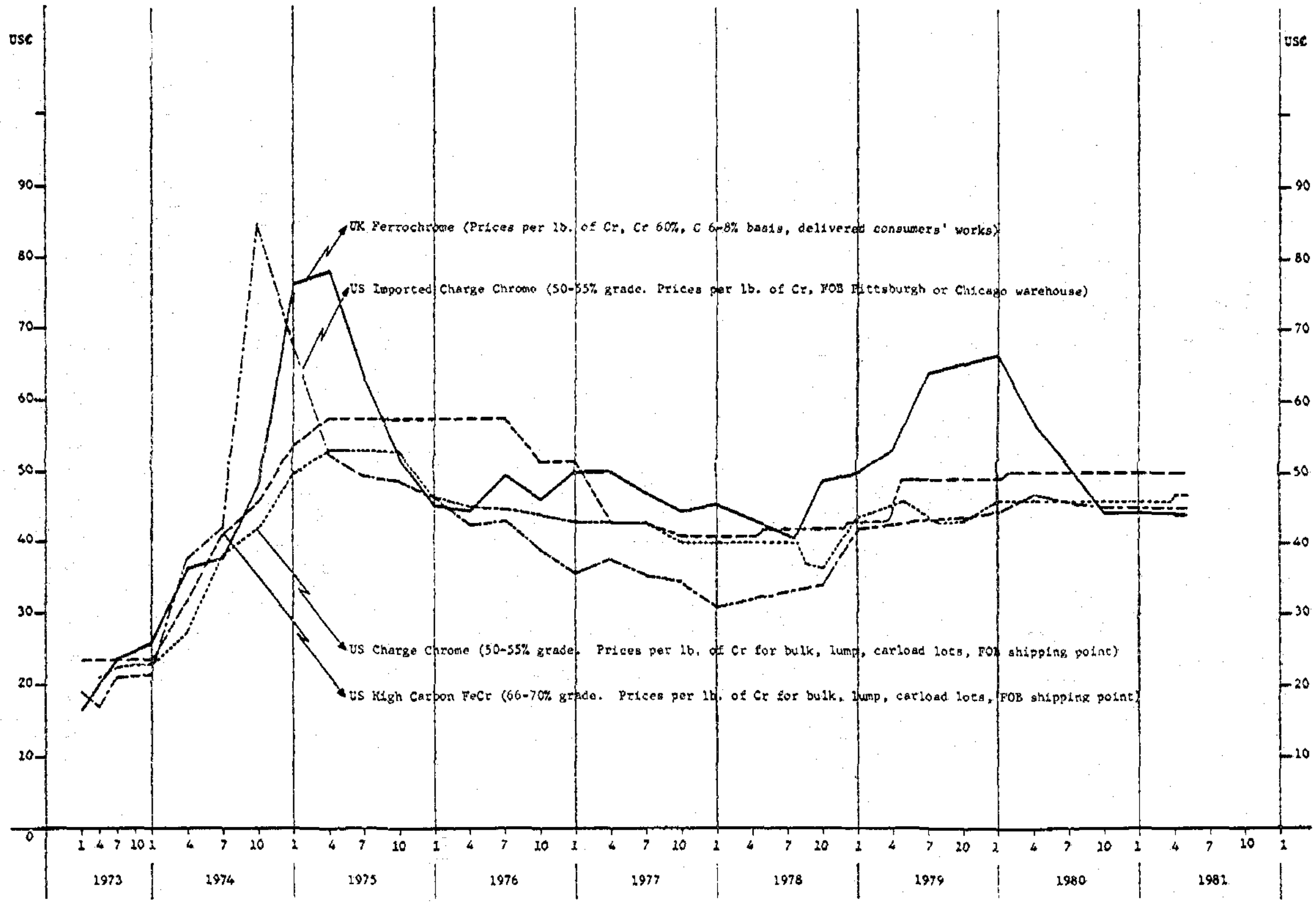
(1) Europe

The price level as of April, 1981 is as per the following:

1) In Europe, there are three different price levels by grade, if roughly classified.

Specification	Price
– Charge chrome	
Cr 50–55%	US ¢46.0 per lb. of Cr
C 7.5% max.	ex-warehouse in Europe.
Si 2.5–5% max.	

Fig. 2-1 Transition of Ferrochrome Price



Sources: Metal Bulletin
Metals Week

– High-carbon ferrochrome

Cr 62–68% C 4–6.5% Si 1.5–3%	US ¢48.0 – ¢49.0 per lb. of Cr ex-warehouse in Europe.

– High-carbon ferrochrome

Cr 60–65% C 7–10% Si 1.5–3%	US ¢47.0 per lb. of Cr ex-warehouse in Europe.

Remarks: The above prices are based on payment terms of "Net cash 30 days after the end of the month of delivery".

2) The breakdown of the above three grades in Europe is:
Charge chromium accounts for 70% of the total high-carbon ferrochrome requirements. The remaining 30% is shared by the aforementioned two high-carbon grades at the rate of 15% each.

3) When ferrochrome imports from Sudan have been realized, it is possible to import it without quantitative import restrictions and duty imposition in the light of the regulations in force in Europe. The improt duty currently imposed on the products of foreign origin by EC countries is as follows:

– Zimbabwe, Sweden & Turkey: No duty
– South Africa, Yugoslavia, Brazil & Albania : 8%

(2) USA

The price level of imported products as of April, 1981 is:

Specification	Price
Cr 50–55%	US ¢45.5 – ¢46.0 per lb. of Cr ex-warehouse.
Cr 60–65%	US ¢48.5–¢52.5 per lb. of Cr ex-warehouse.

Remarks: Payment net 30 days after delivery.

(3) Japan

The recent price level of imported ferrochrome is as follows:

Specification		Price
– Charge chrome		
	Cr 50–54%	US ¢45.0 per lb. of Cr
	C 8% max.	CIF Japan.
	Si 6% max.	
– High-carbon ferrochrome		
	Cr 65% min.	US ¢45.0 – ¢47.0 per lb.
	C 6–9%	of Cr CIF Japan.
	Si 2.5% max.	
– High-carbon ferrochrome		
	Cr 60–65%	US ¢45.0 per lb. of Cr
	C 8% max.	CIF Japan.
	Si 2.5% max.	

Remarks: Payment "Cash against documents" or "Case 30 days after shipping date".

2–4 Trial Calculation Cost

As the above market prices are self-explanatory, the international ferrochrome price on the global scale does not show a noticeable difference among the markets.

Of course, ferrochrome produced in Sudan could be sold to the USA and Japan. However, on precondition that it be sold to the European market which is geographically closer to Sudan and requires lower ocean freight rate than the other areas, a trial calculation was made to find what the current European market price will be in terms of FOB Port Sudan. This conversion shows the following:

– Current European Market Price	:	US ¢49.00 per lb. of Cr ex-warehouse in Euórpe.
– Total Charge		US ¢7.62 per lb. of Cr
Breakdown cost		
Ocean freight 1)	:	US ¢4.30 per lb. of Cr
Insurance	:	US ¢0.22 per lb. of Cr
Unloading charge2)	:	US ¢0.45 per lb. of Cr
Warehouse rent for two months	:	US ¢0.20 per lb. of Cr
Loading charge onto truck/ barge3)	:	US ¢0.45 per lb. of Cr
Interest for total four months4)	:	US ¢2.00 per lb. of Cr
– FOB Port Sudan Price	:	US ¢41.38 per lb. of Cr

Remarks: 1) Ocean freight

In case shipments are made at a rate of 2,000–3,000 tons in one shipment lot, ocean freight from Port Sudan to the main European ports in US $60.00 – $65.00. Taking the average US $62.50 per ton, the ocean freight will be US $4.30 per lb. of net chromium contained (Cr 66% base).

– Trial calcualtion formula : US $62.50 ÷ 2,204.62 lbs ÷ 66%
= US ¢4.30 per lb. of Cr

2) Unloading charge/loading charge

Take an instance of Rotterdam, although the charge vary slightly depending on each port in Europe. Unloading and loading charges are Dutch florin 15.50 per ton respectively (corresponding to approximately US $6.65). That is, each charge will be US $0.45 per lb. of net chromium contained based on 66% chromium content.

– Trial calculation formula : US $6.65 ÷ 2,204.62 lbs. ÷ 66%
= US ¢0.45 per lb. of Cr

3) Warehouse rent fee

The current cost in Rotterdam is Dutch florin 0.105 per ton per day (corresponding to approximately US $1.25 per/ton per month). *That is, it is equivalent to US $0.10 per month per lb. of net chromium contained based on 66% chromium content.*

The above was calcualted on the basis of average storage period of 2 months.

– Trial calculation formula : US \$1.35 X 2 months ÷ 2,204.62 lbs. ÷ 66%
= US ¢0.20 per lb. of Cr.

4) Interest

Interest rate was set at 15% per annum for 4 months on an estimated cost based on FOB price of US \$0.40 per lb. of Cr. As to period, the number of days involved from the shipping date to the date when sales proceeds are collected are presumed as follows:

– No. of voyage days from Port Sudan to main European port .... 20 days
-- Import customs clearance procedures at European prot .... 10 days
– No. of average storage days .... 60 days
– No. of days from th date of delivery from warehouse to the date of sales proceeds collection .... 30 days
TOTAL .... 120 days

- Trial calculation formula : US 0.40 per lb. of Cr X 15% p.a. X 120/360 = US ¢2.00 per lb. of Cr

The aforementioned market price (US ¢49.00 per lb. of Cr) was equal to the highest price level of the current European high-carbon grade (US ¢47.0–¢49.0 per lb. of Cr).

The above charge does not include dealer's margin (normally 3% – 4%, i.e., US ¢1.0 – ¢2.0 per lb. of Cr). However, if any dealer intervenes in a transaction, FOB Port Sudan price will be reduced by his margin.

CHAPTER 3

THE PROJECT

1. Scope and Objectives

1–1 Scope

The Project consists of establishing a ferrochrome smelting plant in the Damazin area of the Democratic Republic of the Sudan by utilizing chromium ore to be procured from the mines in Ingessane Hills. Separate Studies are going on related to exploration of chromium ore reserves and rationalization of mine operations in the Ingessana Hills area and also establishing a concentration plant. Evaluation of The Project will be made taking due account of implementation of these other projects, but The Project itself concerns only with the ferrochrome plant.

1–2 Objectives

The objectives of The Project are listed below:

(1) To construct a ferrochrome plant in the Damazin area.

(2) To earn foreign exchanges through exporting ferrochrome in order to improve balance of payments of the Sudan.

(3) To utilize the plant as a training ground for Sudanese workers to acquire experiences and knowledge in high-temperature furnace industry.

(4) To place the plant as a core or a symbol of the industrialization policy of the Sudanese Government for the purposes of educating the Sudanese people and bringing about a better understanding of the policy.

(5) To promote the development of industry in the Sudan related to the ferrochrome production.

2. Project Area

2–1 Location

The project area is located in Blue Nile Province of the Democratic Republic of the Sudan, which holds an eastern part of the country bordering on Ethiopia (see Figs. 3-1 & 3-2). The ferrochrome plant is to be located in the Damazin area, the south-eastern part of Blue Nile Province. The plant site has a dimension of 1,500m x 400m, and is situated just north of the plot for the existing ginning factory close to the railway line (see Fig. 3-3).

Fig. 3-1 Location Map of Project Area

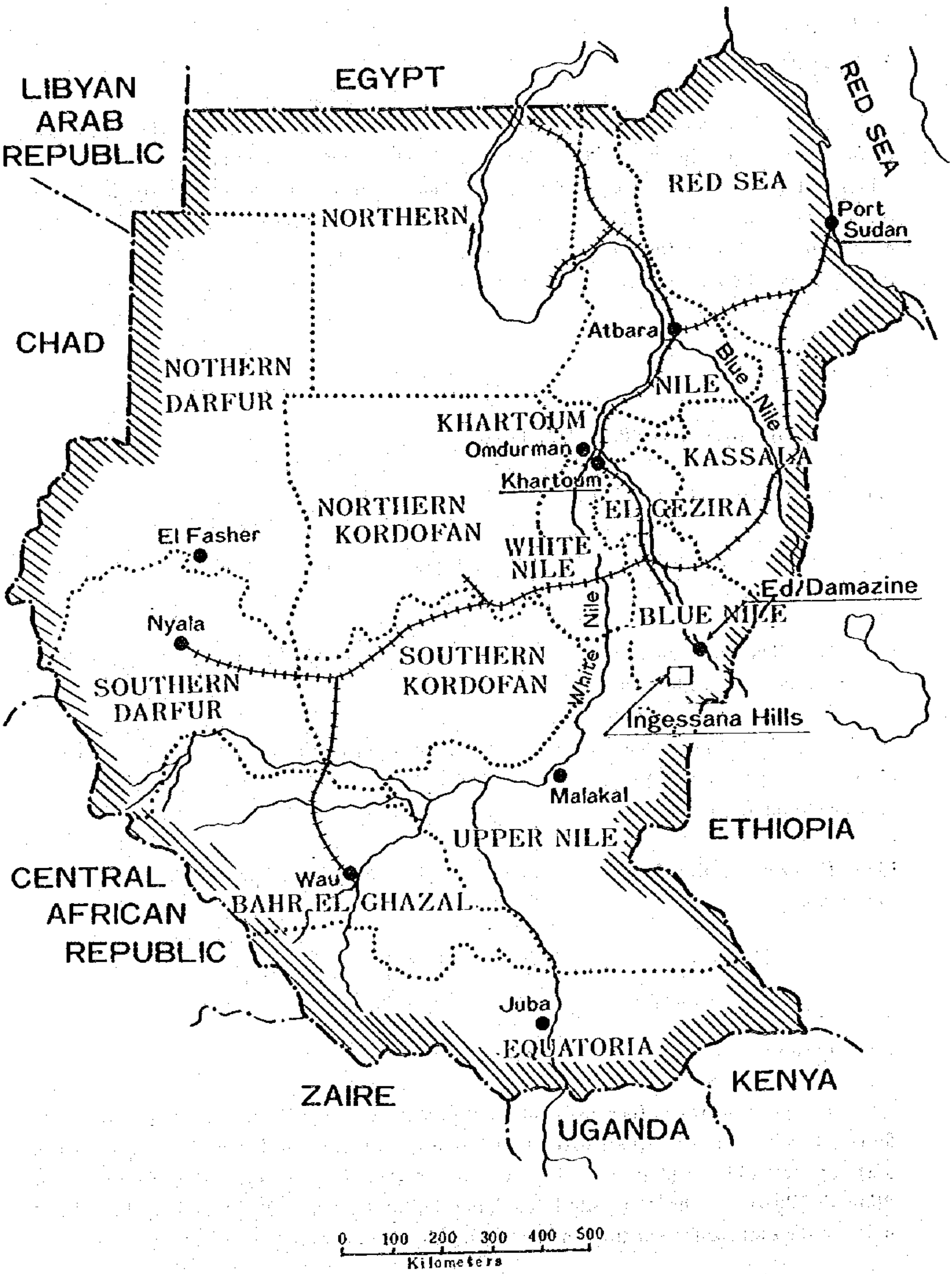


Fig. 3-2 Location Map of Plant Site

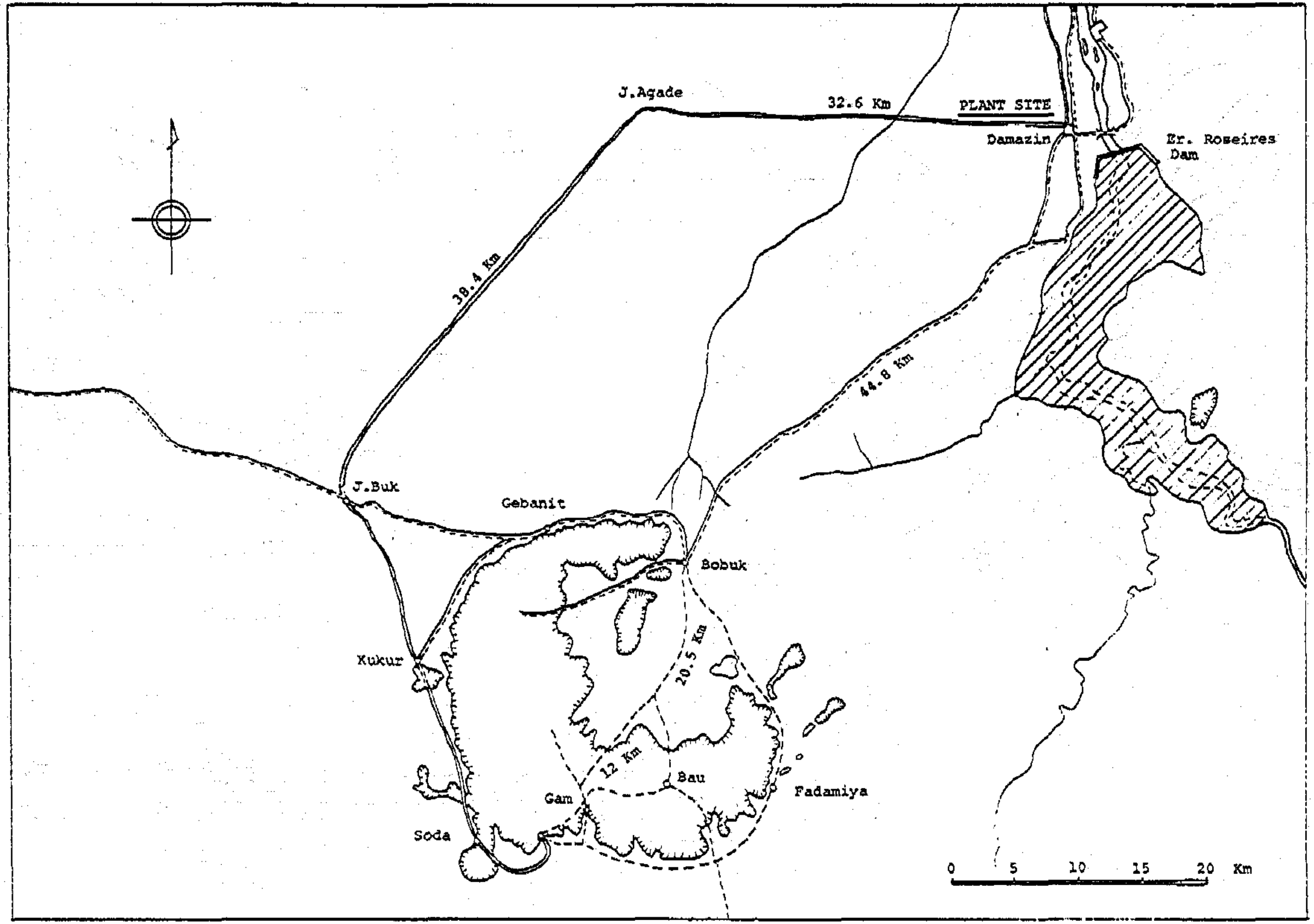
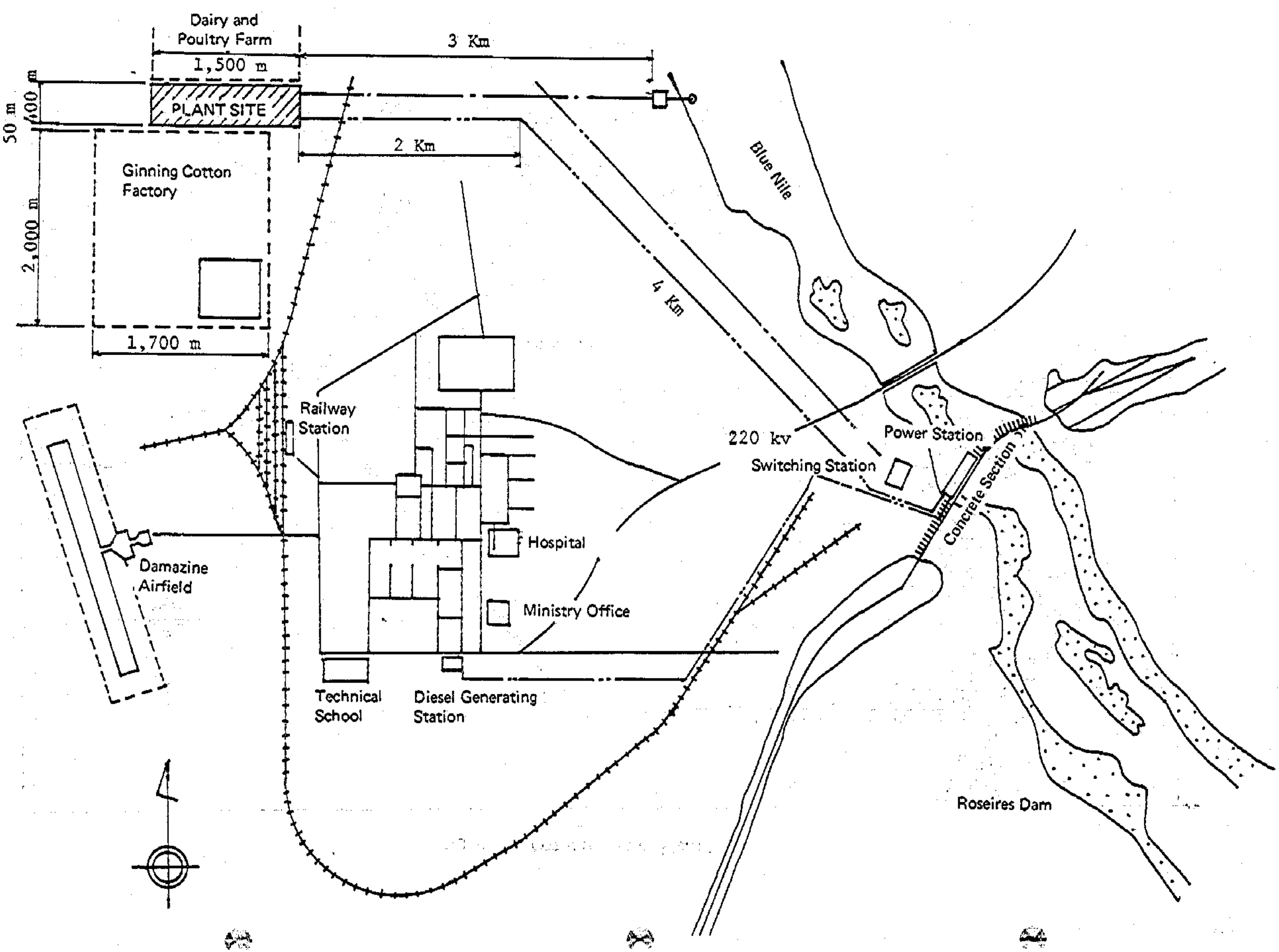


Fig. 3-3 Site for Ferrochrome Plant



2–2 Natural Conditions

Blue Nile Province is divided by the Blue Nile into the eastern and the western parts. The western part, where both Damazin and Ingessana Hills are located, constitutes a part of the fertile Gezira region, a triangle bounded on the west by the White Nile. Flow in the Blue Nile accounts for about 80% of the total flow of the Nile River at the confluence of the White and the Blue Nile, and is more variable than flow in the White Nile.

The Damazin area is in general a flat plain covered in some parts by thorny bushes and short trees. The Ingessana Hills area is an area of low mountains with relatively thin vegetation cover during dry seasons.

The climate of the Sudan is generally tropical continental. Blue Nile Province has a variable rainy season of medium precipitation. Some meteorological data for the Damazin area are given in Table 3-1. As seen from the table, annual as well as seasonal variations in rainfalls are quite significant.

3. Scale and Basic Dimensions of the Plant

3–1 Plant Scale

Capacity of the ferrochrome plant has been determined, taking into account not only the estimated exploitable reserve of about 950,000 tons and the present production capacity of 15,000 to 25,000 tons/year at Ingessana Hills but also of various other important factors. The plant scale should be small enough to be manageable by those who have not acquired high skills to operate the plant, but large enough to provide most appropriate opportunities for the Sudanese workers to develop their skills in view of the objectives of The Project. Also, the international market for ferrochrome at present is characterized by high variability in prices and over-supply. These situations imply that high risk may be involved in launching a large-scale ferrochrome plant at this time.

The Study Team proposed the plant scale of 7,000 tons annual ferrochrome production based on those factors described above as well as their past experiences. The Sudanese side, however, expressed a strong concern for establishing a larger scale plant and suggested 15,000 tons annual ferrochrome production as an alternative. In this report, both of these two alternatives are studied.

Table 3-1 Metrological Data for Damazin Area

Month	Rainfall mm				Humidity %					
	1973		1980		1973			1980		
	Total Monthly Rainfall	Max. Rainfall	Total Monthly Rainfall	Max. Rainfall	Av.	Max.	Min.	Av.	Max.	Min.
Jan.	Nil		Nil		-	-	-	34	46	22
Feb.	Nil		Nil		27			27.5	41	14
Mar.	Trace		Trace		20			40.5	63	18
Apr.	1.8	1.8	5.5		31			49	68	30
May	-	-	15.2	6.6	-			53.5	69	38
Jun.	50.6	14.9	75.2	8.1	65			73.5	93	54
Jul.	116	57.3	457.4	14.5	77			87.5	98	77
Aug.	101.7	16.9	218.4	7.3	79			87	98	76
Sept.	212.1	50.1	94.1	3.1	82			83	97	69
Oct.	35.4	17.8	188	17.6	68			71.5	93	50
Nov.	Nil		Nil		35			42	65	19
Dec.	Nil		Nil		35			38.5	50	27

Month	Wind Direction		Temperature °C					
	1973	1980	1973			1980		
			Av.	Max.	Min.	Av.	Max.	Min.
Jan.	--	North and N.W.	-	-	-	33.5 14.5	39.6	18.5
Feb.	N.W and variable	N.E and N.W	40.1 21.1	44.3	18.6	32.6 14.2	42.2	22.3
Mar.	N.W and N.E	N.W and S.E	40.5 24.0	44.2	20.3	32.0 13.4	44.2	29.0
Apr.	S.W and N.W	S.E	41.2 26.8	43.8	21.2	38.8 20.0	43.5	30.8
May	S.W	S.E	-	-	-	34.5 22.6	42.6	29.5
Jun.	S.W and variable	South and S.W	35.3 23.1	38.9	19.3	27.8 19.4	39.0	25.2
Jul.	South and S.W	S.W	32.6 22.2	37.5	19.4	27.5 18.0	36.5	22.5
Aug.	S.W	South and S.E	30.8 20.0	36.2	24.6	24.6 18.5	33.2	22.4
Sept.	South and S.W	South and S.E	31.8 20.7	35.7	18.1	26.0 17.5	39.5	23.3
Oct.	S.W and N.W	South and S.E	34.3 21.5	37.4	19.2	26.5 18.0	38.0	23.3
Nov.	North and N.E	N.W and N.E	36.3 17.7	38.0	14.5	34.0 15.7	39.5	22.3
Dec.	North and N.E	North and N.E	36.2 16.4	39.0	14.5	36.0 13.0	40.0	20.6

3–2 Basic Dimensions

Basic dimensions of the ferrochrome plant are summarized in Table 3-2 for the alternative plant scales. Bases for determining these dimensions are detailed in subsequent chapters.

Table 3-2 Basic Dimension of Ferrochrome Plant

Item	Unit	Case A	Case B	Remarks
Production Amount	t/yr.	7,000	15,000	
Production Facility	KVA	6,000 x 1	14,000 x 1	
Receiving Voltage	KV	11	33	
Land Area for Plant	m^2	50,000 (200 x 250)	88,000 (220 x 400)	
Raw Material Requirement	t/yr.			
Chrome Ore		15,300	33,700	Cr_2O_3 48%
Coke		3,500	7,400	Fc 80%, up 5 – 30 mm
Bauxite		2,100	3,400	Al_2O_3 50% up 3 – 50 mm
Silica stone		900	2,200	SiO_2 90%, up 3 – 50 mm
Electrode Paste		130	300	Soederberg type
Power Requirement				
Contract demand	KVA	5,500	12,000	
Usage (hourly rate)	KW	4,500	10,000	
Usage (total year)	KWH	$32,600 \times 10^3$	$72,300 \times 10^3$	
Water Requirement	t/hr.	70	175	

CHAPTER 4

RAW MATERIAL

1. Chromium Ore

There is a hilly mountainous terrain called "Ingessana Hills" in the neighborhood approximately 70 km southwest of Damazin. It is a circular mountainous terrain 200 to 500 m in relative height and 25 km in diameter located in the plain. There many chromium ore deposits are distributed. (Refer to Fig. 4-1) These deposits were discovered by the members of the Geological & Mineral Resources Department of The Sudan in 1960 and production was initiated by a certain private enterprise in 1963. Since then, it has continued for more than a decade. During this period, the mines were nationalized in 1970 and later were placed under the management of the Ingessana Hills Mines Corporation (IHMC). The IHMC's mines are one of the metal mines in Sudan. For this country which depends mainly on agriculture, these chromium ore represent the important mineral resources. The authorities concerned continued to put their concentrated efforts in their management. Fortunately, the chromium ore of Ingessana origin is of high quality containing 48 to 52% of Cr_2O_3 and 3.0 to 3.6 of Cr/Fe. In addition, it shows a satisfactory quality in terms of smelting. Approximately 20,000 tons/year of the ore are exported to the European countries and Japan. Thus its exports have contributed toward the reserves of foreign currencies for Sudan.

In the meantime, the survey and exploration of the mines has been underway with the cooperation of China, Japan, other countries and some international agencies. As things stand, approximately 950,000 tons ore reserves are confirmed.

The Sudanese Government considered increasing the added value of this chromium ore and has projected the establishment of a ferrochromium industry. Accordingly, the Sudanese authorities has intention to use this locally produced chromium ore as raw material for the projected industry.

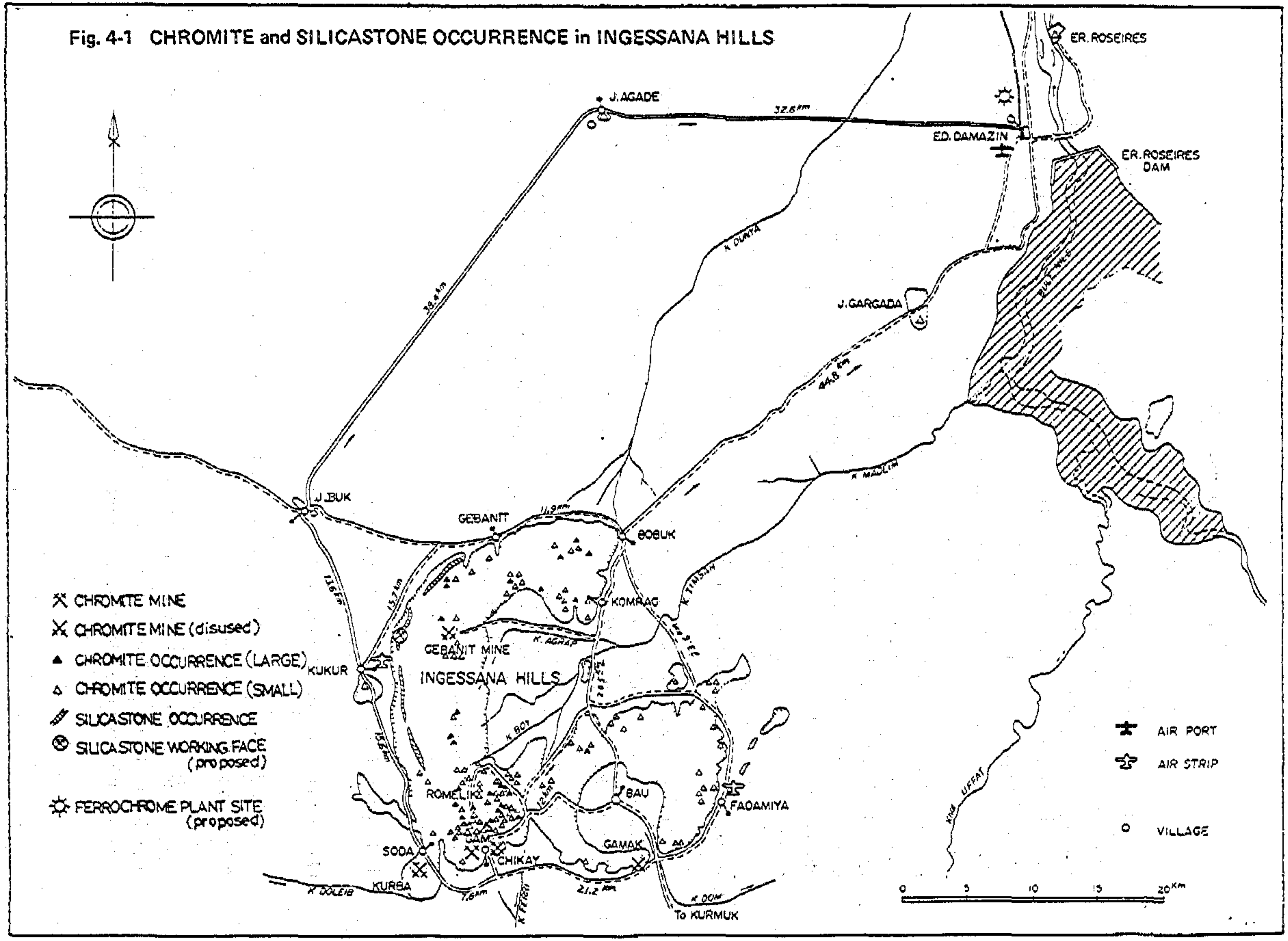
1-1. Chromium ore mines in the Ingessana Hills area

(1) Outline of chromium ore deposits

The Ingessana Hills is made up of ultrabasic igneous rocks presenting a spectacular view for its largest scale in Sudan.

There approximately 160 chromium ore deposits are scattered. At present, six ore deposits on a comparatively larger scale are operated as "Gam Mine". The other 150 odd ore deposits remain unexploited (some of them are disused).

Fig. 4-1 CHROMITE and SILICASTONE OCCURRENCE in INGESSANA HILLS



The ore deposits are formed chromite occurring in the ultrabasic igneous rocks. The ore comes out in forms such as massive, disseminated and banded. The ore body is of the shapes such as layer, lens, vien, etc. It extends 10 to 200 lengthwise and 0.3 to 10 m widthwise. Therefore, the ore reserves range from a few hundreds of tons to hundreds of thousands tons. Most of the ore bodies known thus far are of the scale of a few thousands of tons. thousands of tons.

(2) Chromium ore reserves

In the Ingessana Hills area, the following 10 mine sections are provided as chromium ore concessions.

IHMC	5 mine sections (Gam Mine & others)
Nile Chromium Corp.	1 mine section (disused)
Bayoumi Mines Co.	2 mine sections (disused)
Gulf International Corp.	2 mine sections (unexploited)

In the mine sections other than IHMC, one or two deposits are found per mine section. For the other many deposits, no concessions have ever been established.

All the ore produced from the subject area could be used as raw material for ferrochrome depending on the intention of the Sudanese Government.

The Gam Mine ore reserves consist of six ore deposits, providing an estimate of approximately 90,000 tones per one ore deposit on the average. However, despite this large size, the said mine tends to present gradually worsening mining conditions henceforth due to the stope shifting to the underground depth recently.

The unexploited area ore reserves was calculated based on thirty-four deposits where the survey and exploration were then in progress. One deposit averages approximately 10,000 tons and on a small scale. In the unexploited area, 100-odd deposits are known in addition to the above-mentioned deposits. Since these deposits are scattered within the range of 25 km in diameter, the operating conditions are not necessarily satisfactory.

Table 4-1 Chromium Ore Reserves
(At end of January, 1981)

— Classified by location

Location	Classification	Reserves (Ton)	Quality (Cr_2O_3%)
Gam Mine	Proved. Probable	579,000	50.1
Unexploited areas	Possible	373,000	42.3
Total		952,000	47.0

- Classified by grade

Classification	Location	Reserve (ton)	Quality (Cr_2O_3%)
High-grade ore	Gam mine	579,000	50.1
	Unexploited areas	152,000	48.0
	Sub Total	731,000	49.7
Low-grade ore	Unexploited areas	221,000	38.3
Total		952,000	47.0

Base for calculation: Referential data (c) (e) (g) (h) (k) (m)

Based on the afore-mentioned ore reserves, the quantity of concentrate varies according to production conditions, operating techniques, etc. Nevertheless, the following could be accomplished by carrying out explorations in the future.

1) It is possible to evaluate 100-odd deposits which are not yet evaluated.

2) There is the possibility that the ore reserves of the already evaluated deposits may further increase.

3) There is the possibility that the concealed deposits may be discovered.

In order to see a development of the mines, it is necessary to explore the deposits according to plans henceforth. However, the exploration technics is difficult, so that sufficient studies are required.

(3) Outline of Gam Mine

The Gam Mine belong to the IHMC. In addition, IHMC is under the administration of the Sudanese Mining Corporation (SMC).

1) Personnel

Head Office in Khartoum	23 persons
Gam Mine	150 to 200 persons

Mining personnel change seasonally.

2) Production equipment (currently in operation)

8 units of rock drill, 6 units of air compressor, 5 units of air hoist, 12 units of mine tub, 6 units of truck, 14 units of other vehicles, 3 units of electric generator, 3 units of pump, 1 unit of truck scale, 1 set of communications equipment, workshop, office, powder magazine, cap lamp room, oil tankage, material warehouse, clinic, guest house, personnel quarters, dormitories, assembly hall, general store, water supply facilities, others.

3) Operation mode

300 operating days	Stope, electric:	two-shift operation
	Repair, administration:	single-shift operation

4) Stope

At present, mining takes place at the working faces of each levels such as 5A, 8D, 8E and 10A. The pit mouthes on the Gam Mine total 24 and the total extension of headings is approximately 3,500 m.

5) Mining capacity

Estimated max. 25,000 tons/year (as of March, 1981).

6) Past actual outputs

The Gam Mine is now the sole active mine in the Ingessana Hills area. The bulk of the chromium ore output comes from this Mine. The production status are as per the Actual Output Table 4-2, and Table 4-3.

Table 4-2 Annual Actual Output Table for Gam Mine Chromium Ore

Fiscal Year (July to June)	Quantity of Concentrate (ton)	Remarks (ton)
1963 ~ 1972 10 years	190,002	1963 ~ 1972 Average output per year 19,000
1973 1974 1975 1976 1977	15,155 15,500 10,873 17,273 20,557	1973 ~ 1977 Average output per year 15,872
1978 1979 1980 (July to Jan.)	19,148 23,215 14,297	1978 ~ 1980 Average outut per year 20,387
Total	326,020	Average output per year 18,542

Source: Technical data by Gam Mine

Table 4-3 Monthly Actual Output Table for Gam Mine Chromium Ore (1978 through 1980)

(Unit: Ton)

Month	1978/79	1979/80	1980/81
7	411	2,257	2,028
8	2,109	792	1,926
9	1,118	2,282	2,357
10	287	2,259	1,436
11	1 107	1,701	2,240
12	1,767	2,195	2,130
1	1,313	2,069	2,180
2	1,742	2,088	
3	1,907	2,022	
4	2,302	2,137	
5	2,630	2,013	
6	2,455	1,400	
Total	19 148	23,215	14,297

Chromium ore quality: Cr_2O_3 48% min.
Cr/Fe 3.0 to 3.4

Source: Technical data by Gam Mine

Beside this Mine, a few other mines were operating. However, their past actual outputs are unknown: it is estimated that they may have produced tens of thousands of tons.

(4) Production capacity of Gam Mine and ore quality

As clearly indicated by the Actual Output Tables, the outputs averaged 19,000 tons per year for 10 years since the startup of mining operations. During this period, an open-cut mining or a shallow depth mining was employed. It is estimated that the mining conditions were satisfactory. Later the output decreased presumably due to the advance of stope to the depth. After 1977 inclusive, the output was recovered through the efforts of mining engineers. It is forecasted that for fiscal 1980, the output will top 24,000 tons.

Through 1980, the output continued at a favorable level. Recently, however, the exploitation and ore output capacity of the Gam Mine has shown signs of reduction. This is because of the delay in grasping the picture of the body through boring and tunneling, and the opening of mining faces, i.e. the retarded mining preparations. It is an urgent matter to expedite these preparations. It is also important to develop the deposits of the area urgently and push production along with the Gam Mine. This is meant for operating the chromium ore deposits throughout the entire Ingressana Hills rationally and harmoniously.

In Case A

The present output of 24,000 tons/year and quality containing 48 ~ 50% of Cr_2O_3 will be sufficient so that the existing operation will continue as such condition. Brake down output are as listed in Table 4-4.

In Case B

The chromium ore deposits in the Ingessana Hills are mostly of high quality containing 50% of Cr_2O_3. While the deposits in the unexploited area contain slightly low quality of Cr_2O_3. Accordingly, the chromium ore as a whole contains an average 47.0% of Cr_2O_3, so that production may be carried out at 45% of Cr_2O_3, taking into account the said quality and the loss in mining and dressing. In this case, however, it is required to control the quality, i.e. adjust to obtain a sufficient blending of low-quality ore and high-quality ore. Break down output are as shown in Table 4-5.

As a result of the afore-mentioned operation, the ore of under-mentioned quality is produced.

Table 4-4 Cr_2O_3 48% concentrate production break down

Gam Mine (high grade ore)

	(A) Ore reserves	(B) Mined ore	(C) Country rock (in)	(D) Crude ore	(E) Waste (out)	(F) Concentrate
Quantity (ton)	579,000	(A)x80% 463,200	(B)x10% 46,320	(B) + (C) 509,520	69,895	(D) – (E) 439,625
Cr_2O_3 (%)	50.1	50.1	10	46.45	33.9	48.5
Cr_2O_3 Content (ton)	290,079	232,063	4,632	236,695	23,669	213,026

Unexploited areas (low-grade ore)

	(A) Ore reserves	(B) Mined ore	(C) Country rock (in)	(D) Crude ore	(E) Waste (out)	(F) Concentrate
Quantity (ton)	152,000	(A)x70% 106,400	(B)x10% 10,640	(B) + (C) 117,040	18,866	98.174
Cr_2O_3 (%)	48.0	48.0	8	44.36	27.52	47.6
Cr_2O_3 Content (ton)	72,960	51,072	851	51,923	5,192	46,731

Total (Cr_2O_3 48% concentrate)

	(A) Ore reserves	(B) Mined ore	(C) Country rock (in)	(D) Crude ore	(E) Waste (out)	(F) Concentrate
Quantity (ton)	731,000	569,600	56,960	(B) + (C) 626,560	88,761	537,799
Cr_2O_3 (%)	49.7	49.7	9.6	46.06	32.5	48.3
Cr_2O_3 Content (ton)	363,039	283,135	5,483	288,618	28,861	259,757

Yearly production plan

Location	Cr_2O_3 (%)	Production (ton)	Rate (%)
Gam Mine	48.5	19,600	81.7
Unexploited areas	47.6	4,400	18.3
Total	48.3	24,000	100.0

Table 4-5 Cr_2O_3 45% concentrate production break down

Gain Mine (high grade ore)

	(A) Ore reserves	(B) Mined ore	(C) Country rock (in)	(D) Crude ore	(E) Waste (out)	(F) Concentrate
Quantity (ton)	579,000	(A)x85% 492,150	(B)x15% 73,823	(B)+(C) 565,973	65,414	(D)−(E) 500,559
Cr_2O_3 (%)	50.1	50.1	10	44.87	23.0	47.7
Cr_2O_3 Content (ton)	290,079	246,567	7,382	253,949	15,034	238,915

Unexploited areas (high grade ore)

	(A)	(B)	(C)	(D)	(E)	(F)
Quantity (ton)	152,000	(A)x80% 121,600	(B)x13% 15,808	(B) + (C) 137,408	23,776	113,632
Cr_2O_3 (%)	48.0	48.0	8	43.40	23.8	47.0
Cr_2O_3 Content (ton)	72,960	58,368	1,265	59,633	6,226	53,407

Unexploited areas (low grade ore)

	(A)	(B)	(C)	(D)	(E)	(F)
Quantity (ton)	221,000	(A)x80% 176,800	(B)x13% 22,984	(B) + (C) 199,784	29,332	170,452
Cr_2O_3 (%)	38.3	38.3	8	34.81	25.0	36.5
Cr_2O_3 Content (ton)	84,643	67,714	1,839	69,553	7,338	62,215

Total (Cr_2O_3 45% concentrate)

	(A)	(B)	(C)	(D)	(E)	(F)
Quantity (ton)	952,000	790,550	112,615	903,165	118,522	784,643
Cr_2O_3 (%)	47.0	47.1	9.3	42.42	24.1	45.2
Cr_2O_3 Content (ton)	447,682	372,649	10,486	383,135	28,598	354,537

Yearly production plan

Location	Cr_2O_3 (%)	Production (ton)	Rate (%)
Gam Mine	47.7	21,700	63.8
Unexploited areas	47.0	4,900	14.5
Unexploited areas	36.5	7,400	21.7
Total	45.2	34,000	100.0

Size

The Ingessana Hills chromium ore is composed mainly of hard massive ores. The lump concentrate prepared by mining and hand picking is carried out in the size of less than 300 mm. The size distribution is as shown Table 4-6.

Table 4-6 Size distribution

Grain Size (mm)	300 ~ 150	150 ~ 100	100 ~ 50	50~25	25~10	10~5	5~3	3~1	1 ~
Distribution Ratio (%)	12.5	26.7	30.0	16.5	7.3	2.8	0.4	2.0	1.8

Chemical composition

Based on the summary of the past actual outputs and survey data, the production grade in the future is estimated as per Table 4-7.

Table 4-7 Chemical Composition

Grade	Cr_2O_3 (%)	SiO_2 (%)	Feo (%)	P (%)	Al_2O_3 (%)	CaO (%)	MgO (%)	Igloss (%)	Cr/Fe
48% Ore	48.3	9.6	12.9	0.004	5.3	0.5	17.9	3.2	3.3
45% Ore	45.2	9.4	13.6	0.007	7.2	0.6	18.5	3.3	2.9

Source: Referential data (b) (c) (e) (f) (g) (h) (i) (k) (m)
Technical data by Gam Mine
Delivered-ore test data of December 1976 and December 1980.

(5) Location conditions of mine

The Ingessana Hills is located at the savanna belt between the Blue Nile River and the White Nile River southwest of Damazin. The ore is currently hauled from the Gam Mine southwest of the Ingessana Hills through the following route:

Gam Mine —— Road 70 to 110 Km / Truck 2.5 to 3.5 hours ——→ Damazin Railway Station or Plant

—— Railway 1,286 Km / Goods Wagon 7 to 10 days ——→ Port Sudan

The three different routes between the Gam Mine and Damazin are available, i.e. east of, through and west of the Ingessana Hills. The route through the Ingessana Hills is rough making its usage difficult. Therefore, usually the ore is transported east or west of the said place (recently, the route east of the Ingessana Hills is used).

In the future when the unexploited deposits of the Ingessana Hills are developed and the ore is produced out, it is required to remodel and use the route through the Ingessana Hills.

In the future, when the unexploited deposits of the Ingessana Hills are exploited and the ore is produced out, it is required to improve and use the road through the Ingessana Hills.

Most of these unpaved roads run through the cotton soil and laterite zone so that it is difficult for the truck to pass during the rainy season. A large amount of money will be required to pave the road. For this reason, the ore will be transported only for dry 6 months from the middle of November through of middle of May. Accordingly, it is necessary to put into full consideration the problem of ore storage at the mine and the plant.

1–2 Estimate of Chromium Ore Price

(1) Case A (ore consumption: 15,000 tons/year, Cr_2O_3 : 48%)

The present output of 24,000 tons/year will be sufficient so that the existing operation will continue as such. The surplus ore of 9,000 tons will be exported in the form of ore.

In order to make a stable supply of the ore at low cost to the smelting plant, expansion and rationalization costs were entered on an assumption that an expansion and rationalization work (boring, tunneling for accelerating mining preparations using the heading, exploitation of new deposits in the unexploited area, etc.) would be embarked on at the Gam Mine immediately in or after 1981.

– Estimated cost per ton delivered Damazin stockyard in 1981.

Production cost	S£ 39.000
Expansion/rationalization cost	S£ 4.500
Freight	S£ 11.000
TOTAL	S£ 54.500 = US$68.99

(2) Case B (ore consumption: 34,000 tons/year; Cr_2O_3 : 45%)

In this case, low quality ore will be blended with high quality ore to adjust the availability of the ore containing 45% of Cr_2O_3. Thus, it is anticipated that 34,000 tons/year of the blended ore will be produced.

–Estimated cost per ton delivered Damazin stockyard in 1981

Production cost	S£ 32.300
Expansion/nationalization cost	S£ 6.700
Freight	S£ 11.000
TOTAL	S£ 50.000 = US$63.29

(3) Sumamry of ore price

Ore Output (Ton/Year)	Quality	Production Condition & Price (S£/Ton, US$/Ton)	A Actual Total e Concentrate Quality (Ton)
Case A Lumpy concentrate 24,000	Cr_2O_3: 48% Size: 300 mm max.	The current production will be continued. S£ 54.500 (US$69.0)	Approx. 530,000
Case B Lumpy Concentrate 34,000	Cr_2O_3: 45% Size: 300mm max.	High-quality ore and low-quality ore will be blended for adjustment S£ 50.000 (US$63.3)	Approx. 780,000

Base for calculation: Referential data (c) (g) (h) (i) (j)
Technical data by Gam Mine
Accounting data by Gam Mine

1–3 Referential Data

The principal agencies and enterprises which compiled data are mentioned below as abbreviated.

GMRD: Geological and Mineral Resources Department, Ministry of Energy and Mining, Democratic Republic of The Sudan

Chinese Geological, Technical Team:	The Chromite Geological Technical Team of the People's Republic of China
MC:	Mitsubishi Corporation
JMC:	Japan Metals & Chemicals Co., Ltd.
NMC:	Nittetsu Mining Consultants Co., Ltd.

Data which were used as references for the preparation of this Report are as follows:

(a) GMRD (1974)
Mining and Oil Exploration Laws in The Sudan. Bull. No. 25.

(b) JMC (1976)
Preliminary concentration test for Sudanese chrome ore.

(c) MC, JMC & NMC (1977)
The first survey report on the chromite deposits of the Ingessana Hills. The Democratic Republic of The Sudan.

(d) Sikka & Associates, Ltd. (1977)
A preliminary feasibility report on the chromite occurrences in the Ingessana Hills area, Sudan.

(e) Chinese Geological, Technical Team (1977)
Report on chromite geological prospecting and exploration of the Ingessana Hills of Blue Nile Province of The Democratic Republic of The Sudan.

(f) JMC (1978)
Test of Ferrochrome Manufacture using choronium ore of Sudanese origin.

(g) MC, JMC & NMC (1978)
Feasibility study report on expansion and rationalization of Gam Mine, The Democratic Republic of The Sudan.

(h) MC, JMC & NMC (1978)
Survey report on the chromite deposits of the Ingessana Hills, The Democratic Republic of The Sudan.

(i) MC & JMC (1978)
Feasibility study report on the establishment of ferrochrome industry, The Democratic Republic of The Sudan.

(j) MC & JMC (1979)
Proposal for development of chromium resources in The Democratic Republic of The Sudan.

(k) MC, JMC & NMC (1980)
Tunneling survey report on the chromite deposits of the Ingessana Hills, The Democratic Republic of The Sudan.

(l) GMRD (Abdalla Hassan Ishag) (1980)
A guide to mineral investment in the Sudan, bull No. 31.

(m) MC, JMC & NMC (1981)
Drilling survey report on the chromite deposits of the Ingessana Hills, The Democratic Republic of The Sudan.

(n) Metal Mining Agency of Japan (1978)
Infrastructure Development Planning for Ingessana Hills Area, The Democratic Republic of The Sudan.

2. Subsidiary Raw Materials

2–1 Silica Stone

There are large-scale silica deposits in the Ingessana Hills 70 km southwest of Damazin where construction of the ferrochrome smelting plant is projected. Accordingly, silica stone which will be used for the project will be supplied to the said plant through the development of the said deposits. The deposits in this area are still unexploited now.

(1) Outline of deposits

The silica deposits extend into the south and north areas of the mountain side west of the Ingessana Hills. The quartzite formation (N20°W, 70°E) is 60 to 80 m thick, more than 40 m high and approximately 16 km long (4 km x 4 pcs.). This indicates that the mineral quantity occurred there may be enormous or an estimated millions of tons, hence there is no problem quantitywise. As to quality, it contains 95% of SiO_2 and 0.001% of phosophrus which is sufficient for ferrochrome smelting.

(2) Procurement of silica stone

1) The said silica stone deposits will be exploited and produced by the Gam Mine of IHMC.

2) Only the quantity of silica stone required for the smelting of required ferrochrome will be produced.

Output	Case A	1,100 tons/year	
	Case B	2,300 tons/year	
Production quality		SiO_2	95% min.
		P	0.002% max.

3) The silica stone will be mined and transported to Damazin for 6 months from the middle of November through the middle of May.

4) The mining site will be on the mountain side (2 km from the road) 6 km northeast of the Kukur tribal community. Therefore, the open-cut mining is scheduled. Because of the small output, large-size equipment and machinery will not be required.

5) The estimated silica stone price is as follows (based on the terms ex-stockyard at Damazin plant).

Case A (in the case of production at rate of 1,100 tons/ year)	S£ 35.500/ton (US$44.94/ton)
Case B (in the case of production at rate of 2,300 tons/year)	S£ 30.500/ton (US$38.61/ton)

Due to the small output, it is anticipated that the price will be higher.

2–2 Charcoal

An approximately 90,000 tons of charcoal per year is produced in the Blue Nile province where the projected ferrochrome smelting plant is located in Damazin. Approximately 85% is supplied to the other provinces, and approximately 15% is consumed in the said province.

Almost all of this supply is for use as home fuel (cooking) and the quantity used for industries (brick and bread baking, etc.) is insignificant. Consequently there are no specifications on its quality, and size available. Such tests have never been conducted.

(1) Outline of charcoal

Material wood for the charcoal is Taleh (which takes 50 years to fully grow), Higleig (which takes 10 to 12 years to fully grow), etc. It is said that the average 2.25 tons of charcoal could be obtained from one Feddan (equals 60 x 70 m) of forest where these trees grow.

(2) Procurement of charcoal

If all the quantity of coke used for smelting is entirely substituted by charcoal, 3,500 tons/year of charcoal will be required for Case A and 7,400 tons/year for Case B. However, the present supply capability in the Damazin area may be only 90 to 140 tons/year.

Therefore, if a large quantity of charcoal is required, it will be necessary to conclude a new long-term contract with charcoal suppliers for entrusting them with making charcoal for sale.

Considering the above-mentioned points, under this project, coke will be used exclusively as carbonaceous material for immediate requirements. Then the application of charcoal will be studied after surveying in detail the situation on availability of woods.

For reference, the quality and price of charcoal are shown here.

(3) Price of charcoal

Damazin area: S£44.400 ~ S£55.600 (US$56.20 ~ US$70.38)

(4) Quality of charcoal

	F.C. (%)	V.M. (%)	Ash (%)	P (%)	S (%)	Size
Taleh Charcoal	83.5	11.5	5.0	0.048	0.08	Max. 20 cm x 8 cm
Combritum Charcoal	82.4	9.6	8.0	0.064	0.10	Max. 20 cm x 8 cm

2–3 Bauxite

Bauxite is used as flux during the manufacture of ferrochrome. The required grade of bauxite is such that it contains more than 50% of $A\ell_2O_3$. If the annual consumption of 1,300 to 2,800 tons is required, there is no anxiety about its availability.

Table 4-8 Bauxite World Survey of 1974 (Actual Production)

Country	Production (million tons)	Country	Production (million tons)
India	1.3	Guyana	3.6
Indonesia	1.3	Haiti	0.8
Malaysia	1.1	Jamaica	15.3
Turkey	0.5	Suriname	6.9
China	0.7	France	3.3
Australia	21.8 *	Greece	2.8
U.S.A.	2.0	Yugoslavia	2.4
Brazil	0.9	U.S.S.R.	6.0
Dominica	1.4	Guinea	7.6

Note: *Actual production of 1975.

Of the Table 4-8, from a geographical viewpoint, the most ideal supply source for Sudan would be Greece. The availability conditions as of April, 1981 are as mentioned below:

–Location:	Parnassos–Giona–Oiti Mt. Area
–Specification	
$A\ell_2O_3$:	52% min.
SiO_2:	6% max.
TiO_2:	About 3.5%
$A\ell_2O_3/Fe_2O_3$:	2.2 min.; 2.6 max.
Size:	40 – 150 mm, 5 – 30 mm, etc.
–Price:	US$27 per metric ton FOB ITEA, Greece (moisture 5% base)
–Loading Port:	ITEA, Greece
–Loading Condition:	1,200 metric tons per day WWDSHEX, U.U.

Based on the above FOB price, the CIF Port Sudan price will be US$60.00 per dry ton.

FOB	US$27.00 per wet ton
FOB	US$28.40 per dry ton
Freight/Insurance	US$31.60 per dry ton
CIF	US$60.00 per dry ton

2–4 Coke

Coke is used as reductant. Coke for metallurgical use in connection with ferrochrome production is so called the under-size grade which is generated during the manufacture of coke for iron making.

Accordingly, the availability and pricing of coke for metallurgical use are significantly influenced by the iron and steel market. It is considered that there is no problem in obtaining 3,400 to 7,200 tons annually. However, the price of the product in available quantity considerably flucturate depending on the iron and steel market conditions. The price of obtainable product as of April, 1981 would be as below.

(1) From Japan

–Specification	
Ash:	About 12%
Volatile matter:	About 1.5%
Sulpher:	About 0.7%
Fixed carbon:	About 86.5%
Moisture:	About 10%
Size:	5 – 25 mm
–Price:	US$110 per wet ton FOB Sakaide, Japan
–Ocean Freight:	US$90 – $100 per ton (from Sakaide to Port Sudan)

(2) From Europe

–Specification		
Fixed carbon:	80% min.	
Price (ex-works):	DM 272.50 per ton (US$129.00 per ton)	Size 8 – 16 mm

CHAPTER 5

INFRASTRUCTURE

1. Electric Power

1–1 Present Demand and Supply Conditions

Electric power is supplied by the Public Electricity and Water Corporation (PEWC) in Sudan. For fiscal 1979, the said corporation is distributing 680×10^6 KWH of electric power to 182×10^3 users. The maximum demand for electric power in Sudan is approximately 165×10^3 KW and the per capita power consumption is approximately 30 KWH per year, which means Sudan is one of the lowest power consuming countries in the world (approximately 5,000 KWH/year in Japan). If the above power consumption is broken down area wise, it comes that the Blue Nile Grid remains the largest coverage as shown in Table 5-1.

Table 5-1 Demand and Present Generator Capacity for 1978/79

	Sales Volume (GWH)	Power Production (GWH)	Max. Demand (MW)	Generator Capacity (MW)
Blue Nile Grid	583	747	137	192
Eastern & Others	97	112	28	43
TOTAL	680	859	165	235

Source: PEWC, 1980 Development Plan for Electricity

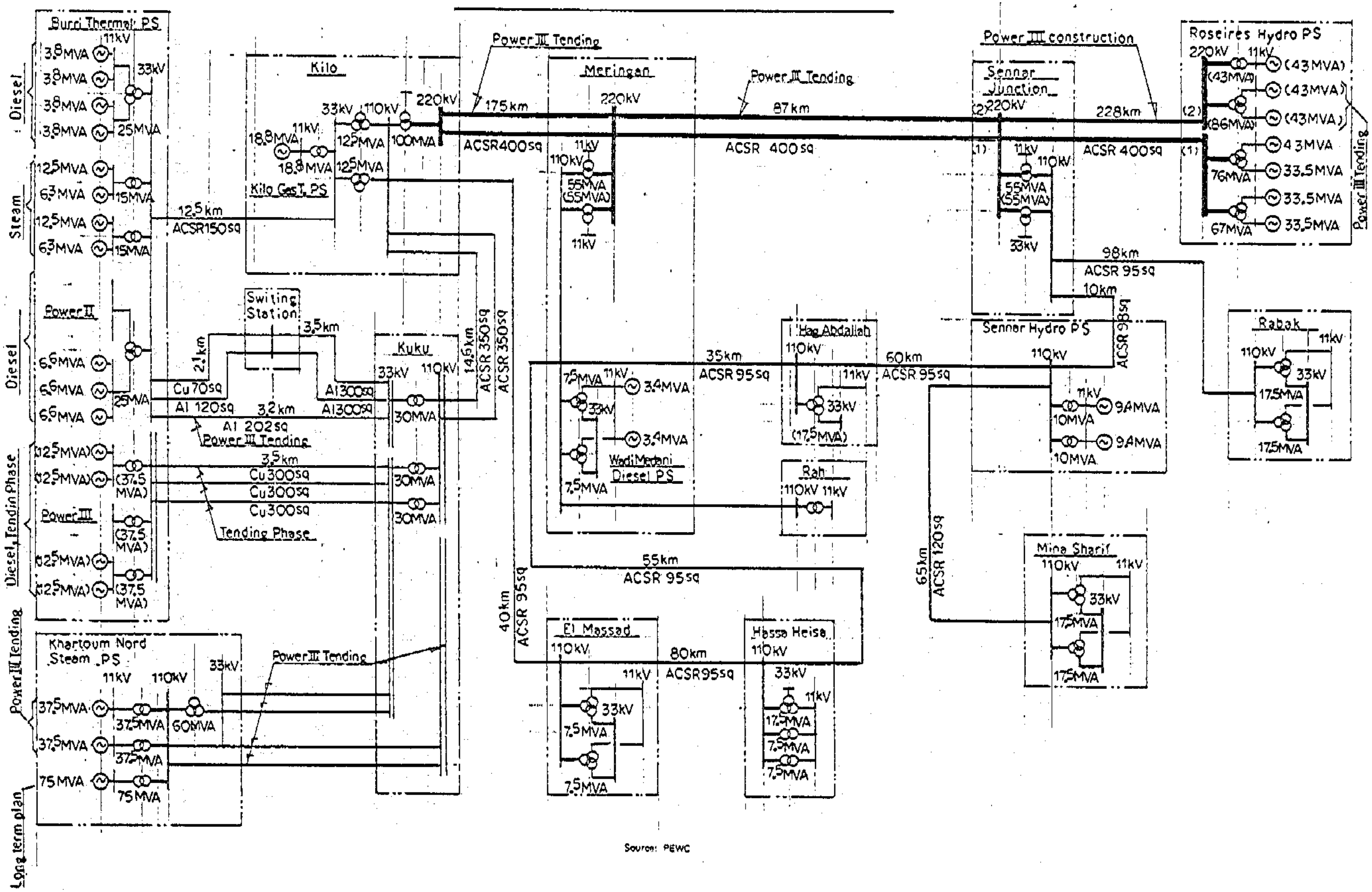
The Blue Nile Grid equipped with hydroelectric plants at the Er Roseires Dam and the Sennar Dam built at the Blue Nile River and 220 KV power transmission line is transmitting electric power to Khartoum. In places other than Khartoum, power requirements are met by small-capacity diesel engine-driven power generators.

The single line diagram of the Blue Nile Grid is shown in Fig. 5-1.

(1) Power supply facility capacity

As explained earlier, Sudan's total power generator capacity is 235 MW and it is broken down into 150 MW (68%) for the hydroelectric power station and 77 MW (32%) for the thermal power station. The thermal power generation is powered by the diesel engines capable of 28 MW, the steam engines of 16 MW and the gas turbines of 13 MW, each on the small scale.

Fig. 5-1 Blue Grid Single Line Diagram



Source: PEWC

The most important hydroelectric power station is located in Er Roseires and is equipped with three 30 MW units and one 40 MW unit. Its actual power generation varies significantly according to season as shown in Fig. 5-2. This is due to the unavoidable control of the dam's water level for flood prevention purpose. In addition, the accumulation of earth and sand in the dam poses another problem. It is noteworthy that specially the output in August has shown a significant decrease for three years in succession. It is considered that the water intake should be difficult due to temporary inflow of sand, earth and lumber. At present, measures are being to dredge an accumulation of earth and sand.

(2) Power demand and Supply

The power consumption ratio by user for fiscal 1978/79 in Sudan is shown in Table 5-2.

Table 5-2 Power Consumption of Each Category (1978/79)

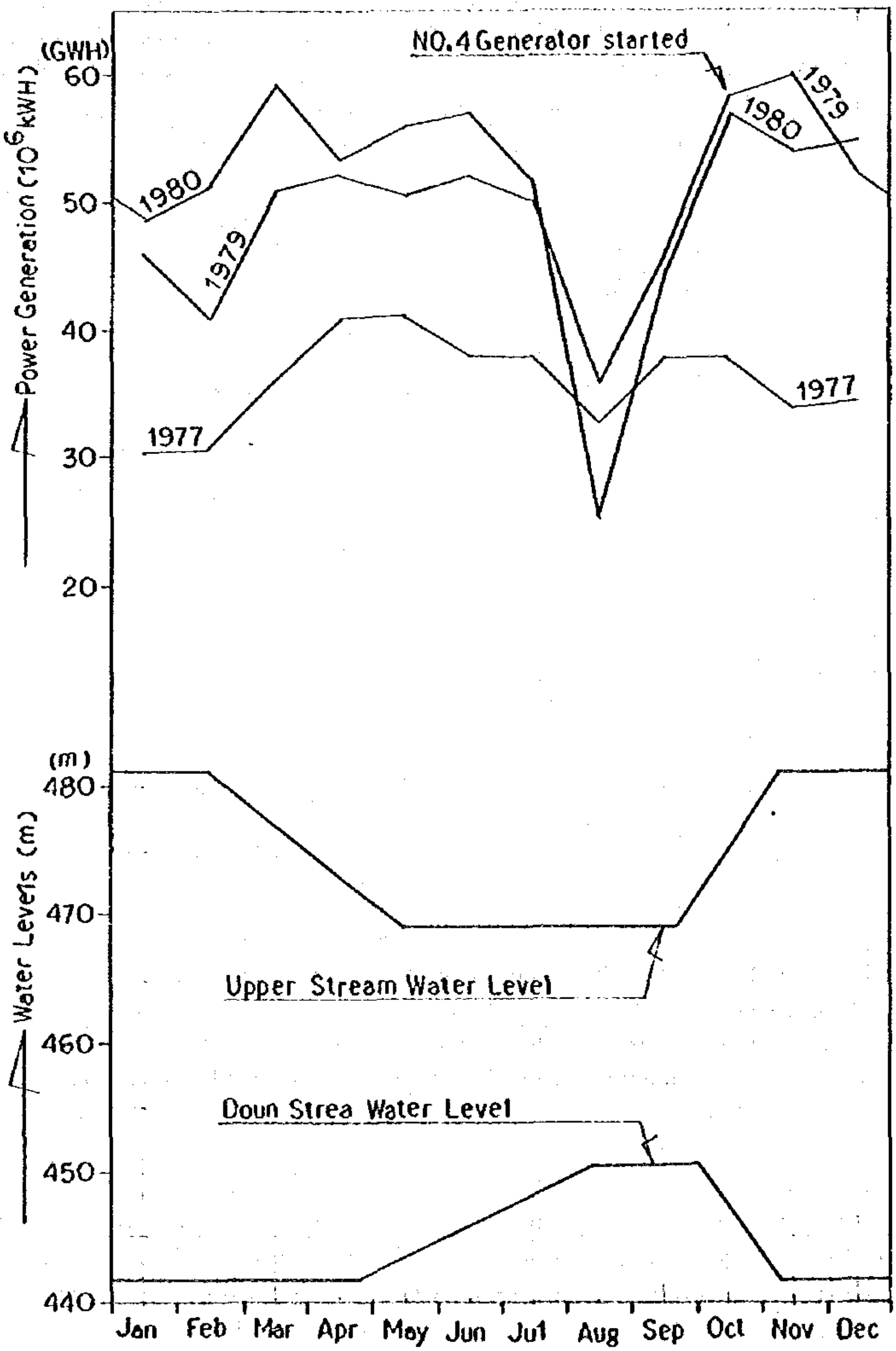
	Total All System		Blue Nile Grid	
	GWH	%	GWH	%
Residential	238	35	198	34
Industrial	279	41	265	44
Agricultural	82	12	76	13
Others	81	12	49	9
TOTAL	680	100	583	100

Source: PEWC, 1980 Development Plan for Electricity

The seasonal demand tendency shows that the power consumption peaks in May and June, followed by that of September and October with the lowest in December and January. The demand increase in May and June is attributed to the use of electric fans and air-conditioning equipment as well as a seasonal demand by certain agricultural processing industries. The Second largest consumption period falls in the autumnal months when irrigation pumps are operated at full load.

On a daily basis, residential loads are at their peak in the evening while industrial loads in total have a morning peak. Irrigation loads, particularly for large schemes, may run up to 21 hours per day and tend to have a morning peak; their contribution to the evening peak is zero as the tariff of small irrigation schemes does not permit pumping in the period 18:00 to 21:00 hrs.; large irrigation schemes are requested not to pump during this period.

Fig. 5-2 Monthly Power Generation at the Roseires Power Station and Upstream/Downstream Water Levels



Source: Roseires Power Station

The combined effect is for a typical system to have a pronounced evening peak with a secondary peak in the morning. However, the recent rapid development of agricultural and industrial loads have increased the morning peak so that in some system (e.g., Blue Nile Grid), it has exceeded the evening peak during some months.

Blackouts are usual during the summer season peak hours. Average hours in the year for the black out is 24 hours and usually the black out continues for 2 hours.

As explained above, in short, the electric power demand/supply situation in Sudan is extremely severe.

(3) Electricity charge

The electricity tariff system in Sudan is such that the charge is determined by user category under the two different power supply systems. Like Japan, the two-part rate schedule is in force. That is, either of the KW rate determined based on the maximum power requirements and the KWH rate proportional to power consumption is chosen according to the user category.

The electricity charge for the heavy industry by the Blue Nile Grid is set forth as below:

- Demand rate [1]: S£ 1.2/KVA
- Service capacity rate [2]: S£ 0.4/KVA

Rate based on power consumption

- For the critical months (March through August)
  - Off-peak rate: 7 ~ 14°, 18 ~ 22°; S£ 0.025/KWH
  - Peak rate: S£ 0.057/KWH
- For the other months (September through February)
  - Off-peak rate: 7 ~ 14°, 18 ~ 22°; S£ 0.0155/KWH
  - Peak rate: S£ 0.0375/KWH

Notes: 1) The maximum KVA for 30 minutes during the peak time.
2) KVA required for the maximum load equipment under a contract between PEWC and the user.

1–2 Estimated Demand and Supply for Electric Power

(1) Demand forecast

According to the 1980 Development Plan for Electricity prepared by PEWC, a spectacular growth of demand for the electric power in Sudan is forecasted as indicated in Table 5-3 and 5-4.

Table 5-3 Forecast of Energy Generation (GWH)

	78/79	79/80	80/81	81/82	82/83	83/84	84/85	85/86
Blue Nile	747	860	1,039	1,204	1,372	1,475	1,590	1,729
Others	108	190	243	300	338	373	408	470
TOTAL	857	1,050	1,282	1,504	1,710	1,848	2,014	2,199

Source: PEWC 1980 Development Plan for Electricity

Table 5-4 Forecast of Maximum Demand (MW)

	78/79	79/80	80/81	81/82	82/83	83/84	84/85	85/86
Blue Nile	137	162	204	236	269	287	312	340
Others	28	42	54	68	77	85	95	107
TOTAL	165	204	258	304	346	372	407	447

Source: PEWC 1980 Development Plan for Electricity

In addition, it is estimated that the growth of energy consumption per user category will be as high as 10% per year as indicated in Table 5-5.

Table 5-5 Energy Consumption per User Category (GWH)

	77/78	78/79	79/80	80/81	81/82	82/83	83/84
Residential	206	224	245	264	280	297	315
Industrial	225	293	384	454	525	567	612
Agricultural	105	212	238	270	285	305	325
Others	48	53	58	64	70	77	85
TOTAL	584	782	925	1,052	1,160	1,245	1,337

Source: PEWC 1980 Development Plan for Electricity

Especially the significant growth of power consumption in the industrial and agricultural sectors is noteworthy.

Comparison of historic figures of monthly energy sold and generated reveals inconsistencies which are difficult to explain and which suggest that the monthly sales figures for each category may not be wholly accurate. Nevertheless, the forecasts are considered to be best obtainable at present.

(2) Supply capacity expansion plan

Following the aforementioned increased demand, an expansion of the generator capacity and the power transmission system is planned. The forecast of the output capacity is the following according to the 1980 Development Plan for Electricity. (Table 5-6)

Table 5-6 Forecast Output of existing and Committed Generators

System	Output Capacity (MW)						
	79/80	80/81	81/82	82/83	83/84	84/85	85/86
Blue Nile	189	207	209	288	347	385	385
Others	37	64	82	93	98	98	96
TOTAL	226	271	291	381	445	483	481

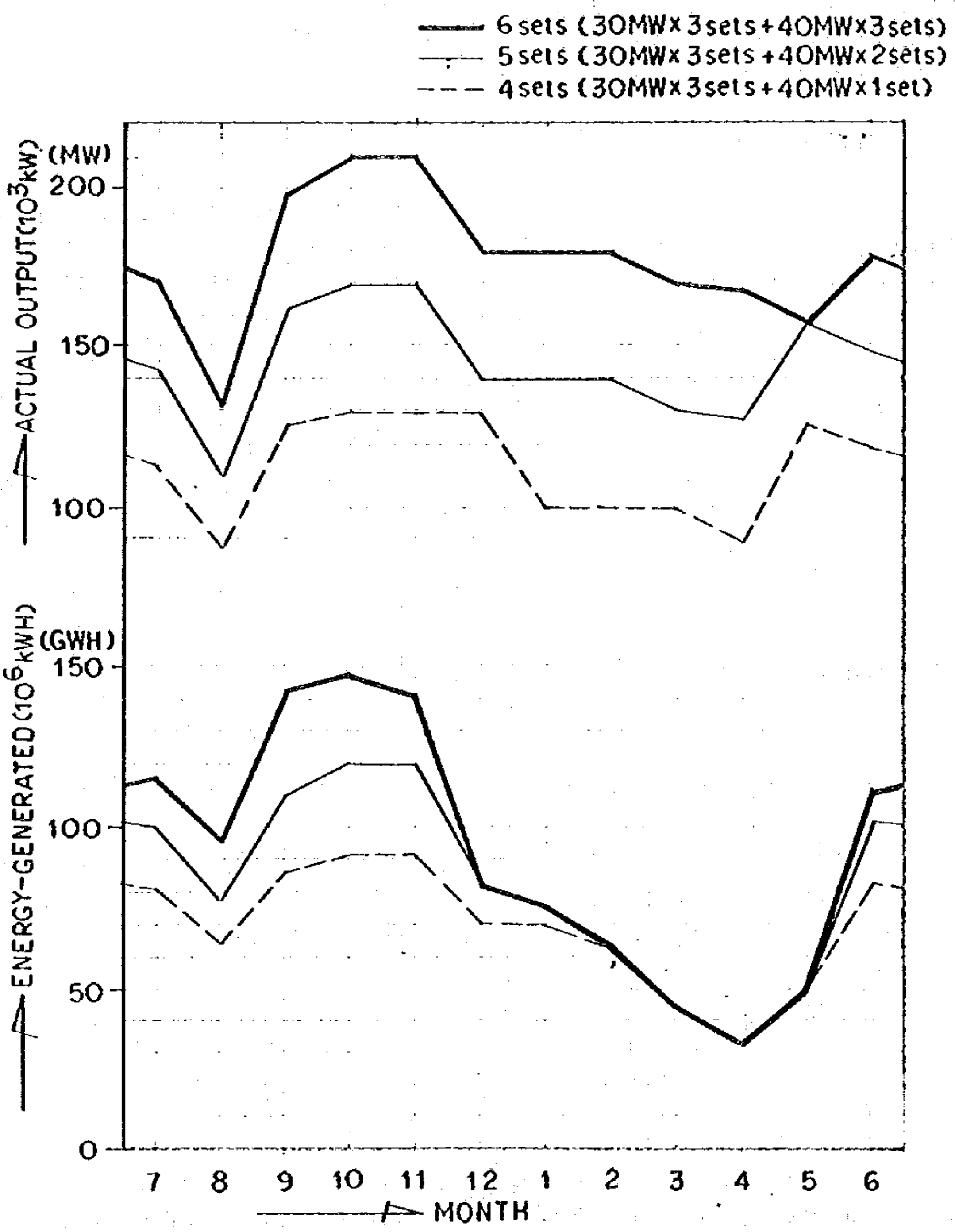
Source: PEWC 1980 Development for Electricity

The expansion plan for the Blue Nile Grid envisaged power plants is as follows:

Year	Plant	MW
Jan. '80	Burri Diesel	3 x 5
Mar. '82	Burri Diesel	4 x 10
Mar. '82	Kh. N. Steam set 1	30
Apr. '83	Kh. N. Steam set 2	30
Apr. '83	Er Roseires set 5	40
May '84	Er Roseires set 6	40

Of the above, the monthly output and the power output of the Er Roseires power station after the expansion of its Nos. 5 and 6 units are as shown in Fig. 5-3. It is noted that even after the expansion, the power output for the period from December through May showed almost no increase.

Fig. 5-3 Monthly Output and Power Output of the Roseires



Source: 1980 Development Plan for Electricity "PEWC"

The annual gross power output by the Er Roseires power station is as shown in Table 5-7. It is noted that the increase of power output after the expansion of generator capacity is insignificant.

Especially the power output during the period from January through December, 1980 after the expansion with the No.4 unit is equivalent to 75% of the planned power production. It is questionable whether the power output after the expansion with the No.5 and No.6 units can be maintained at the scheduled level.

Table 5-7 Actual/Estimated Hydroelectricity Production of Er Roseires (481m)

Item	3 x 30 MW	3 x 30 + 1 x 40		3 x 30 + 2 X 40	3 x 30 + 3 x 40
	Act.	Act.	Est. *	Est.	Est.
Year	1977	1980	—	—	—
GWH	435	611	815	967	1,096

*Estimated based on water data and assumptions in power III project report.

1–3 Demand for Electric Power at Ferrochrome Plant

The operation at the ferrochrome plant is continuous. Therefore, it is required that its power supply be stable and dependable. The power requirements to be studied this time by feasibility study based on both proposed cases are shown Table 5-8.

Table 5-8 Demand for Electric Power following the Construction of Ferrochrome Plant

Description	Unit	Case A	Case B
Ferrochrome Production	t/yr.	7,000	15,000
Electric Power Requirements for Facilities (max.)	KVA	6,700	15,500
Hourly Power Consumption	KWH	4,500	10,000
Breakdown	KWH		
For furnace		4,000	9,000
For subsidiary equipments		500	1,000
Annual Power Consumption	GWH	32.6	72.3