FEASIBILITY STUDY REPORT

ON

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

(SUMMARY)

[illegible]

JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)

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AUGUST 1981

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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.

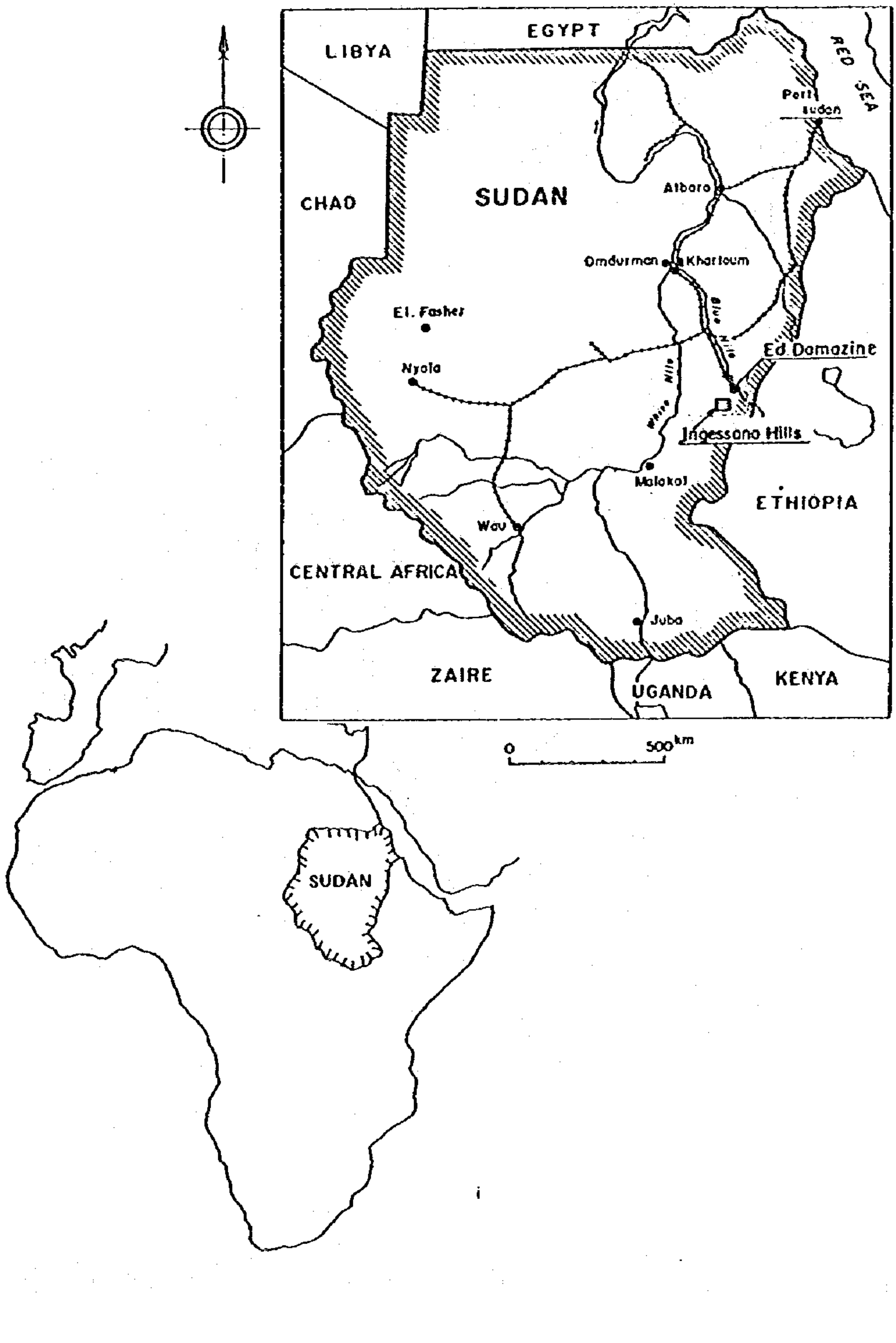
I hope that this report will be useful as a basic reference for development of the project.

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.

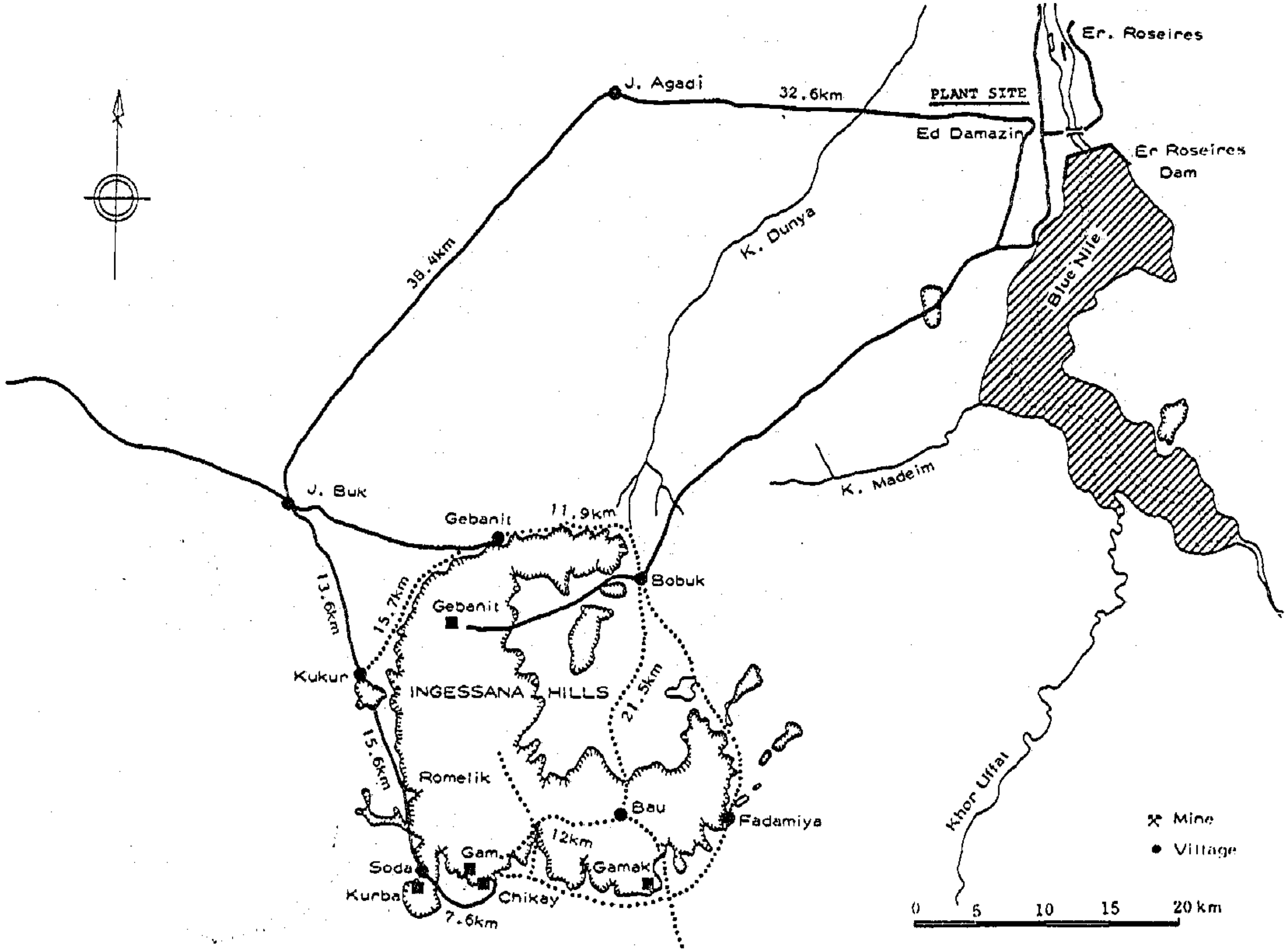
August 1981

Keisuke Arita
President

Japan International Cooperation Agency


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
Gen-ichi Koguchi	Iron & Steel Produciton Div. Basic Industries Bureau Ministry of International Trade & Industry	Technical Cooperation Policy

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

Table S-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
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	114.4	160.5	210.9	262.1	284.8	360.6	396.5
GDP at Marker Price	896.8	2246.2	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

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. Following 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 Domestic Republic of the Sudan concerned with The Proejct 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").

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 (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 "). 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 S-2). 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 S-3). 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.

Table S-2 Chromium Ore Reserves in the World (as of 1978)

(Unit: 1,000 tons)

	High chromium		High iron		High Aluminium		Total	
	Proven	Others	Proven	Others	Proven	Others	Proven	Others
South Africa	56,000	56,000	1,100,000	2,200,000	–	–	1,156,000	2,256,000
Zimbabwe	560,000	560,000	56,000	56,000	–	–	616,000	616,000
Others	33,180	31,510	20,400	34,900	15,930	14,600	69,510	81,010
Total	649,180	645,510	1,176,400	2,290,900	15,930	14,600	1,841,510	2,953,010

Source: U.S. Mining Bureau

2-2 Ferrochrome Industry

The total production capacity of ferrochrome in the free world was approximately 2.6 milliontons/year in 1980 (see Table S-4), but the actual production was estimated to be about 1.7 million tons/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/year.

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 S-5. 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

Table S-3 Actual Chromium Ore Outputs

(Unit: 10^3 metric tons)

	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	531	538	531
Finland			148	155	165	175	594	719
Canada								
India	60	274	288	394	499	402	357	266
Malagasy			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).

Table S-4 Ferrochrome Production Capacity of Free World (as of 1980)

(Unit: 1,000 tons)

Country	Production capacity
South Africa	725
Japan	519
Sweden	285
U. S. A.	250
Zimbabwe	185
West Germany	160
Others	476
Total	2,600

Table S-5 Forecast of Demand/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	1,751	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

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 payment of the Sudan.

(3) To utilize the plant as a training ground for Sudanese workers to acquire experiences and knowledge in high-temprature 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. S-1 and S-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. S-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 ton/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 ton/year ferrochrome production as an alternative.

Both of these two alternative plant scales, 7,000 ton/year (hereinafter called Case A) and 15,000 ton/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 S-6.

Fig. S-1 Location Map of Project Area

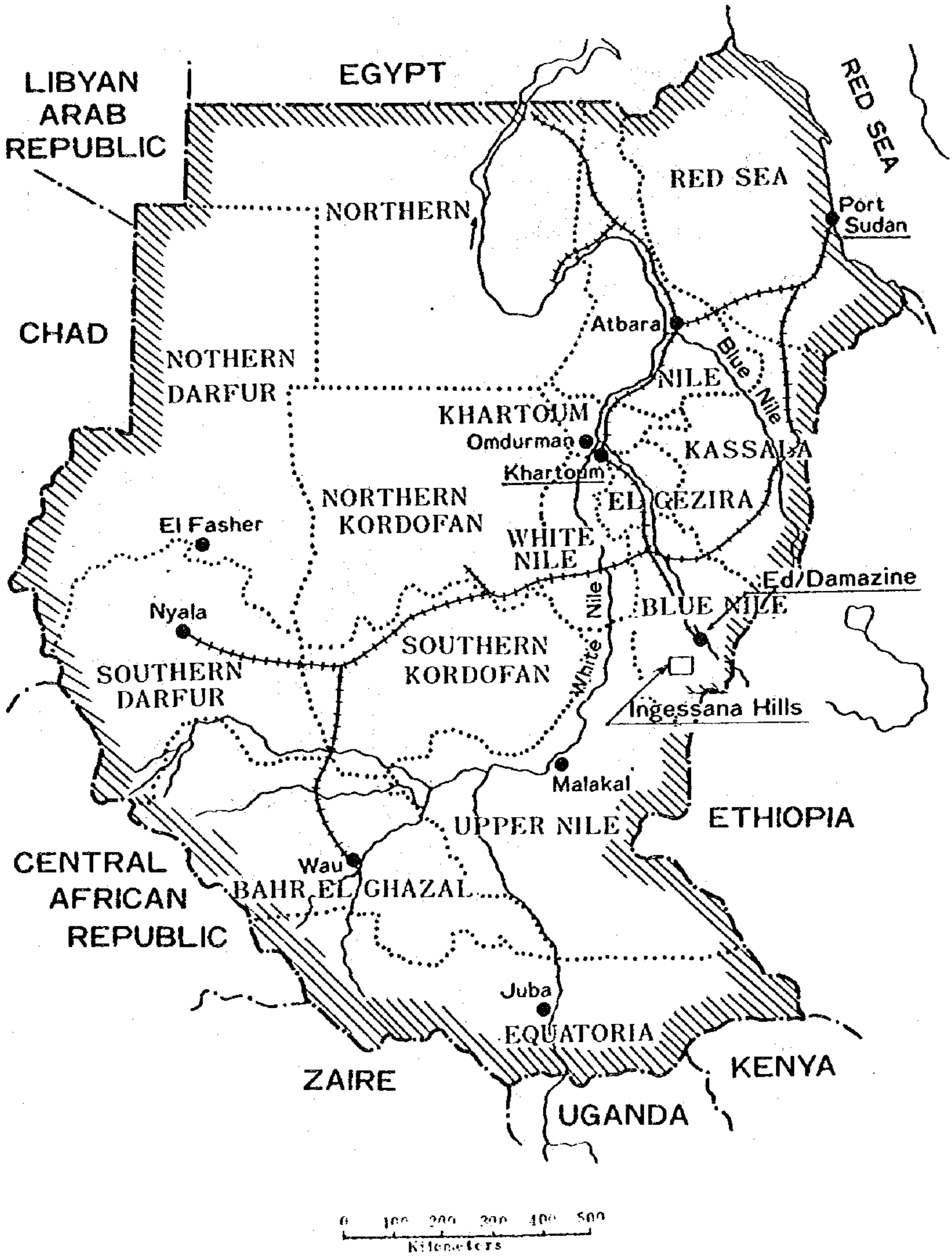


Fig. S-2 Location Map of Plant Site

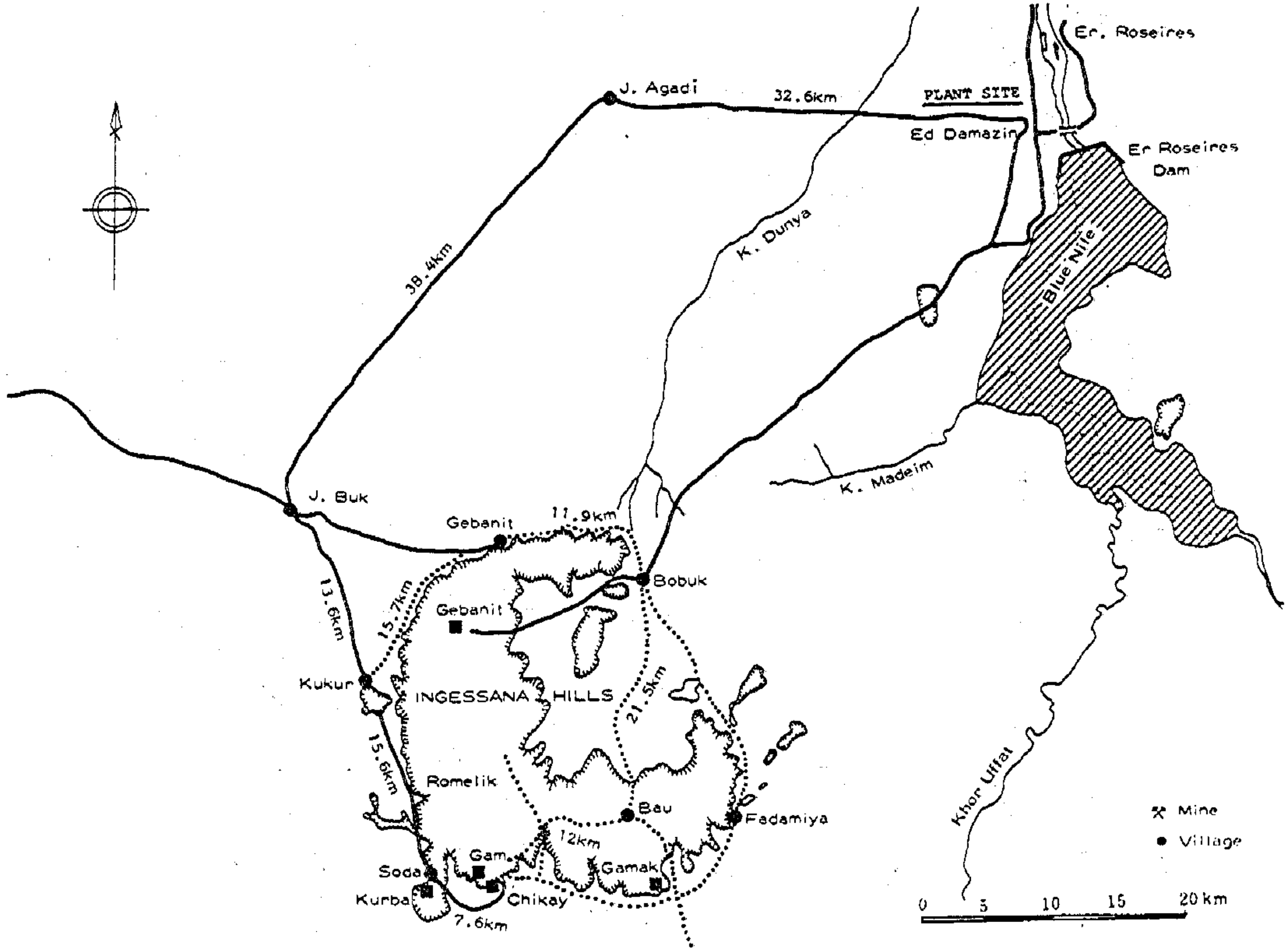


Fig. S-3 Site for Ferrochrome Plant

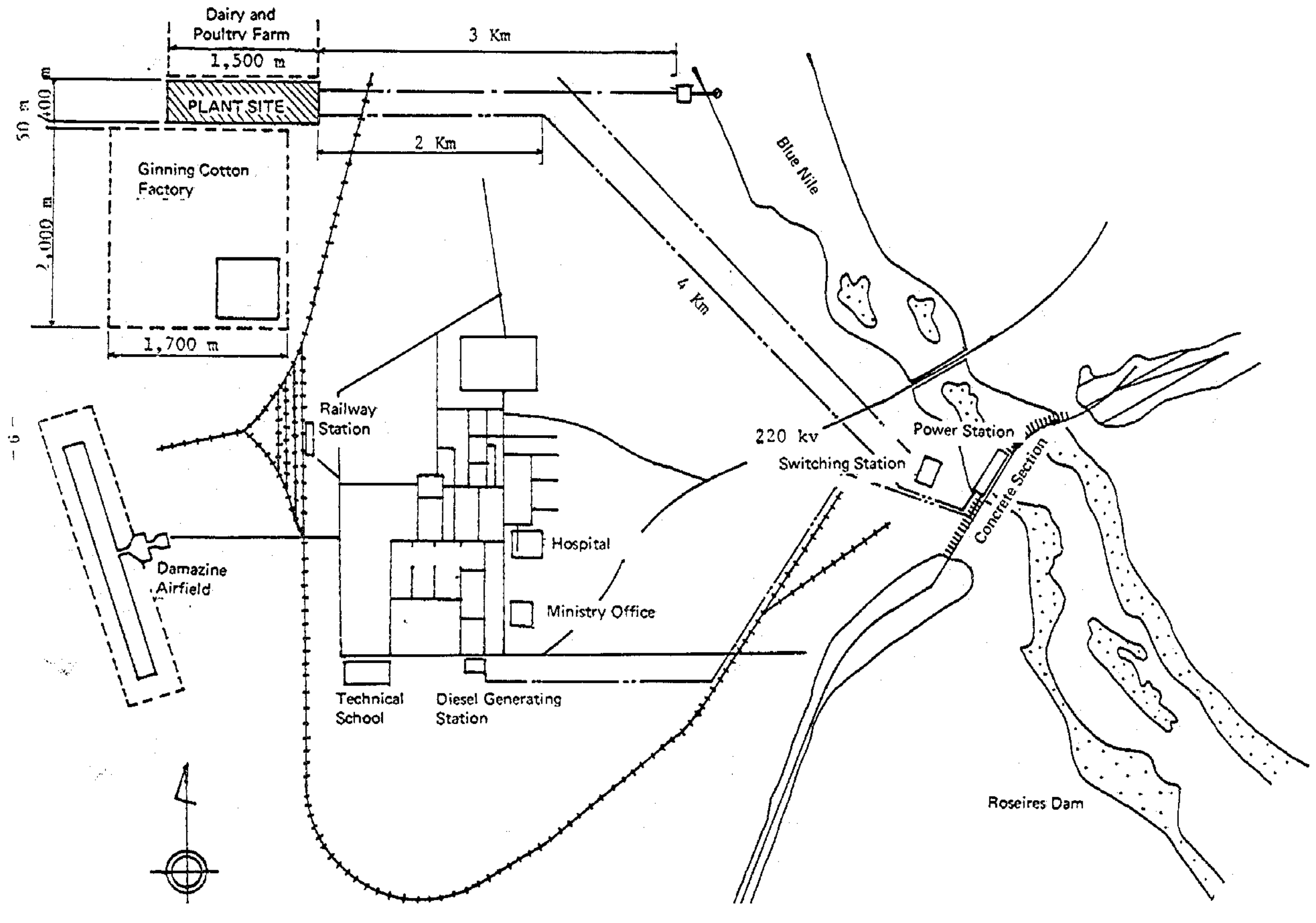


Table S-6 Basic Dimensions of The Project

		Case A	Case B
Ferrochorme production	ton/year	7,000	15,000
Quality of products	Cr %	66.6	64.4
	Si %	3.0	3.0
	C %	7.5	7.5
Electric furnace capacity	KVA	6,000	14,000
Electric furnace load	KW	4,500	9,500
Power requirements	GWh/year	32.3	72.3
Chromium ore requirements	ton/year	15,400	33,800

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 ore at Gam mine is currently 15,000 to 25,000 tons (see Table S-7). 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 ferro-chrome plant is given in Table S-8 for both Case A and Case B.

The chromium ore price is 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.

Table S-7 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 S-8 Quality of Chromium Ore Used in Case A and Case B

(Unit: %)

	Cr_2O_3	SiO_2	FeO	P	Al_2O_3	MgO	Cr/Fe
Case A	48.3	9.6	12.9	0.004	5.3	17.9	3.3
Case B	45.2	9.4	13.6	0.007	7.2	18.5	2.9

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 around 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 11KV or 33KV 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 US $0.043/KWH for both Case A and Case B (see Table S-9).

5-2. Water

Water requirements of the ferrochrome plant primarily for cooling are 70tons/hour for Case A and 150 ton/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.

Tabls S-9 Trial Balance of Electricity Charge for Ferrochromium Smelting Plant

(a) Case A (7,000 t/yr. production)

Service Capacity Charge	S£ 0.4 x 6,500 KVA x 12 months	= S£ 31,200.00
Demand Charge		
– Operation (10 months)	S£1.2 x 5,500 KVA x 10 months	= S£ 66,000.00
– Repair (2 months)	S£1.2 x 500 KVA x 2 months	= S£ 1,200.00
KWH Charge		
– Critical Season (Mar. 1 ~ Jun. 27) (operate)		
Peak hour	S£0.057 x 4,500 KW x 119 days x 11 hrs.	= S£ 335,758.50
Off-peak hour	S£0.025 x 4,500 KW x 119 days x 13 hrs.	= S£ 174,037.50
– Critical Season (Jun. 28 ~ Aug. 31) (repair)		
Peak hour	S£ 0.057 x 100 KW x 65 days x 11 hrs.	= S£ 4,075.50
Off-peak hour	S£0.025 x 100 KW x 65 days x 13 hrs.	= S£ 2,112.50
– Other Seasons (Sept. 1 ~ Feb. 28) (operate)		
Peak hour	S£0.0375 x 4,500 KW x 181 days x 11 hrs.	= S£ 335,981.25
Off-peak hour	S£0.0155 x 4,500 KW x 181 days x 13 hrs.	= S£ 164,121.75
TOTAL Payment per year		= S£1,114,487.00
Total Consumption in KWH		= S£ 32,556,000
Unit Price per KWH		= S£ 0.0342329 (US $0.0433)

(b) Case B (15,000 t/yr. production)

Service Capacity Charge	S£0.4 x 15,000 KVA x 12 months	= S£ 72,000.00
Demand Charge		
– Operation (10 months)	S£1.2 x 12,000 KVA x 10 months	= S£ 144,000.00
– Repair (2 months)	S£1.2 x 500 KVA x 2 months	= S£ 2,400.00
KWH Charge		
– Critical Season (Mar. 1 ~ Jun. 27) (operate)		
Peak hour	S£0.057 x 10,000 KW x 119 days x 11 hrs.	= S£ 746,130.00
Off-peak hour	S£0.025 x 10,000 KW x 119 days x 13 hrs.	= S£ 386,750.00
– Critical Season (Jun. 28 ~ Aug. 31) (repair)		
Peak hour	S£0.057 x 200 KW x 65 days x 11 hrs.	= S£ 8,151.00
Off-peak hour	S£0.025 x 200 KW x 65 days x 13 hrs.	= S£ 4,235.00
– Other Seasons (Sept. 1 ~ Feb. 28) (operate)		
Peak hour	S£0.0375 x 10,000 KW x 181 days x 11 hrs.	= S£ 746,625.00
Off-peak hour	S£0.0155 x 10,000 KW x 181 days x 13 hrs.	= S£ 364,715.00
TOTAL payment per Year		= S£2,474,996.00
Total Consumption in KWH		= 72,312,000
Unit Price per KWH		= S£ 0.0342266 (US $0.0433)

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):

Comparison of Annual Transportation Requirements

	Item to be transported	Present	Case A
Damazin —— Port Sudan	Chromium ore	25,000 tons	10,000 tons
Damazin —— Port Sudan	Ferrochrome	–	7,000
Port Sudan —— Damazin	Cokes	–	3,500
Port Sudan —— Damazin	Bauxite	–	2,100
Total		25,000	22,600

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 chormium 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. S-4, S-5 and S-6, respectively.

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 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.

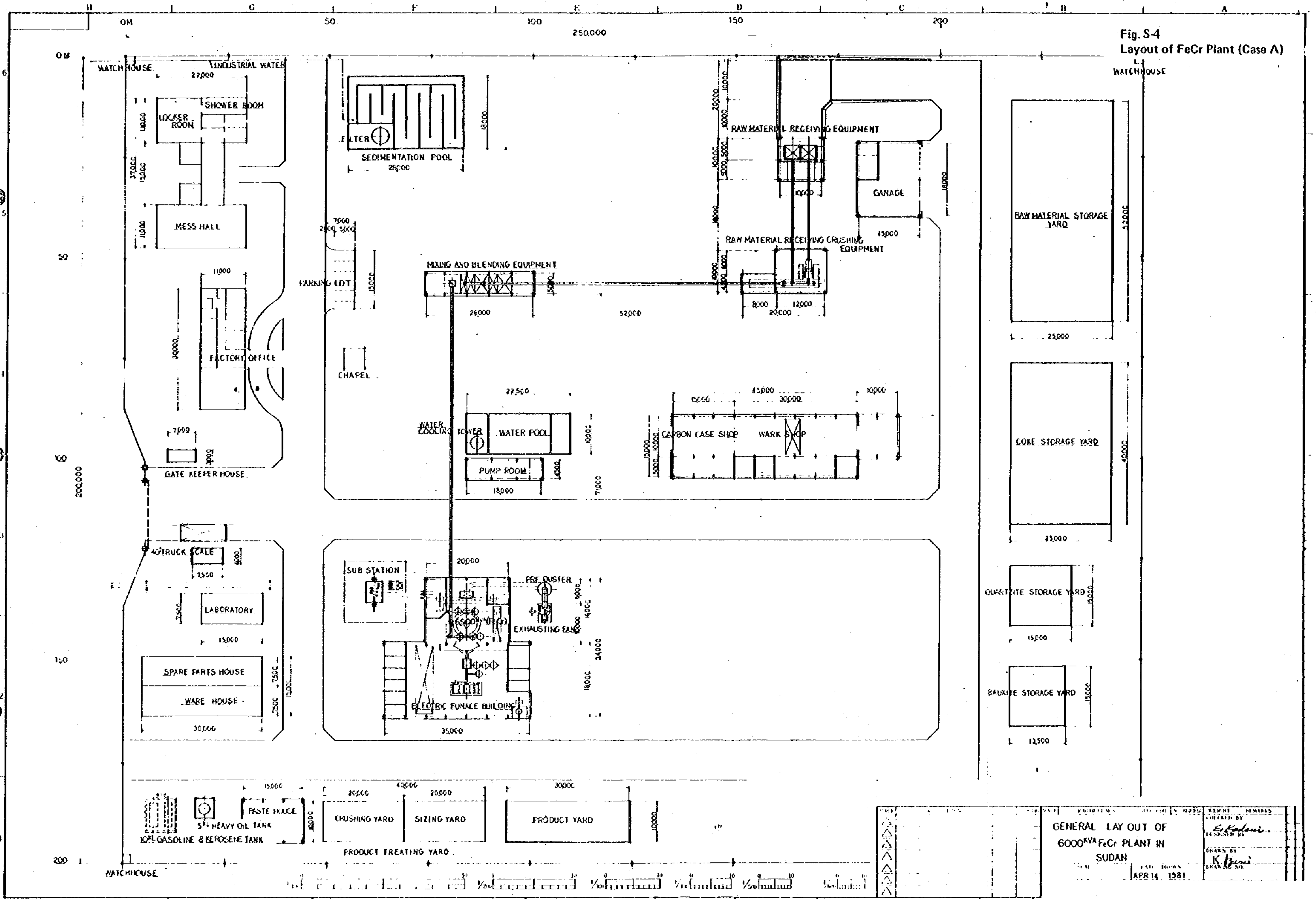
(1) All the figures were estimated as of March, 1981.
(2) Price inflation was not included in estimates.
(3) Taxes and custom duties on import machinery and equipment were all exempted.

The estimated construction costs with domestic and foreign currency portions are summarized in Table S-10. 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 Projects, 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.

Fig. S-4
Layout of FeCr Plant (Case A)



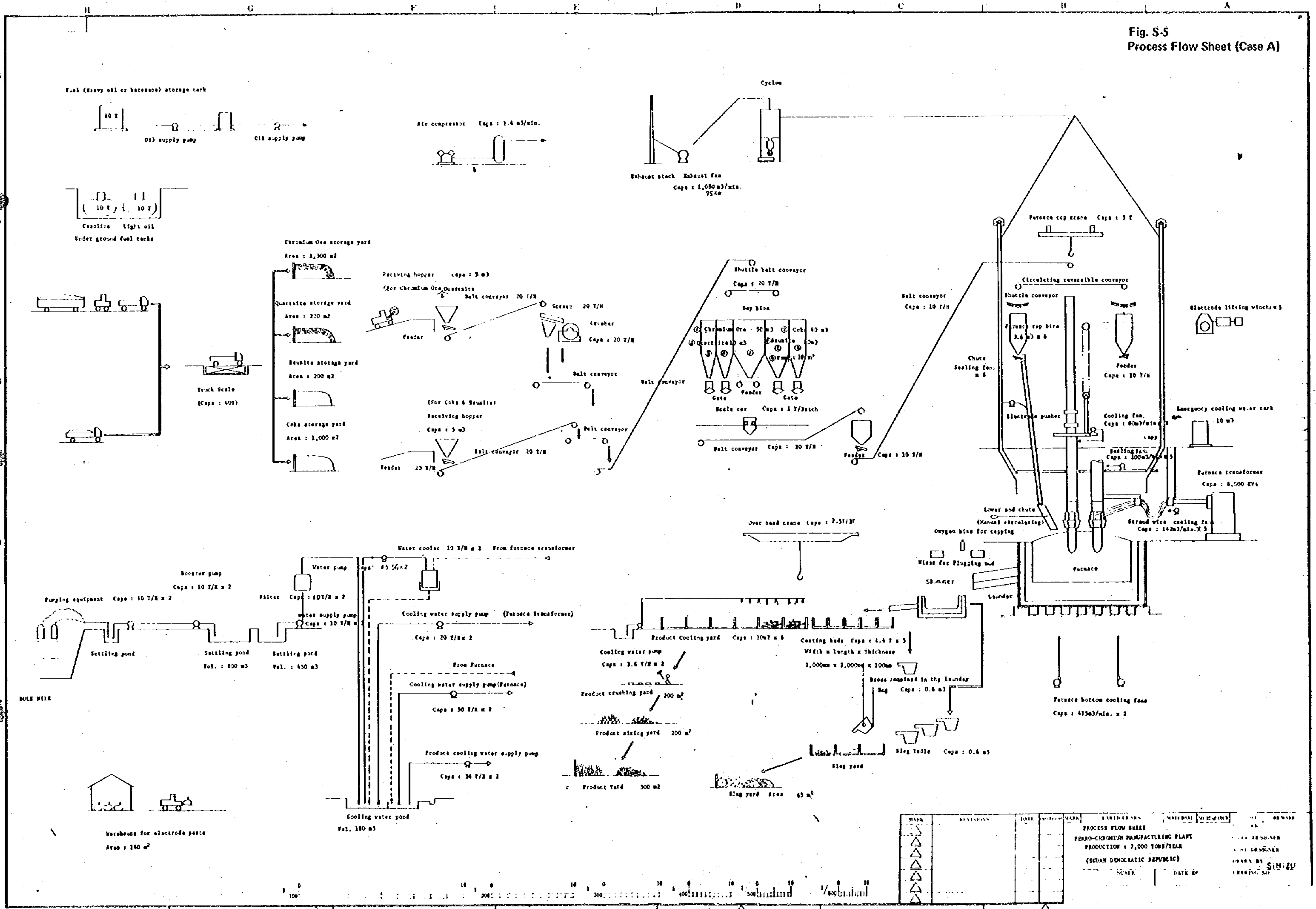


Fig. S-5
Process Flow Sheet (Case A)

Fig. S-6.
Cross Section View of FeCr Plant (Case A)

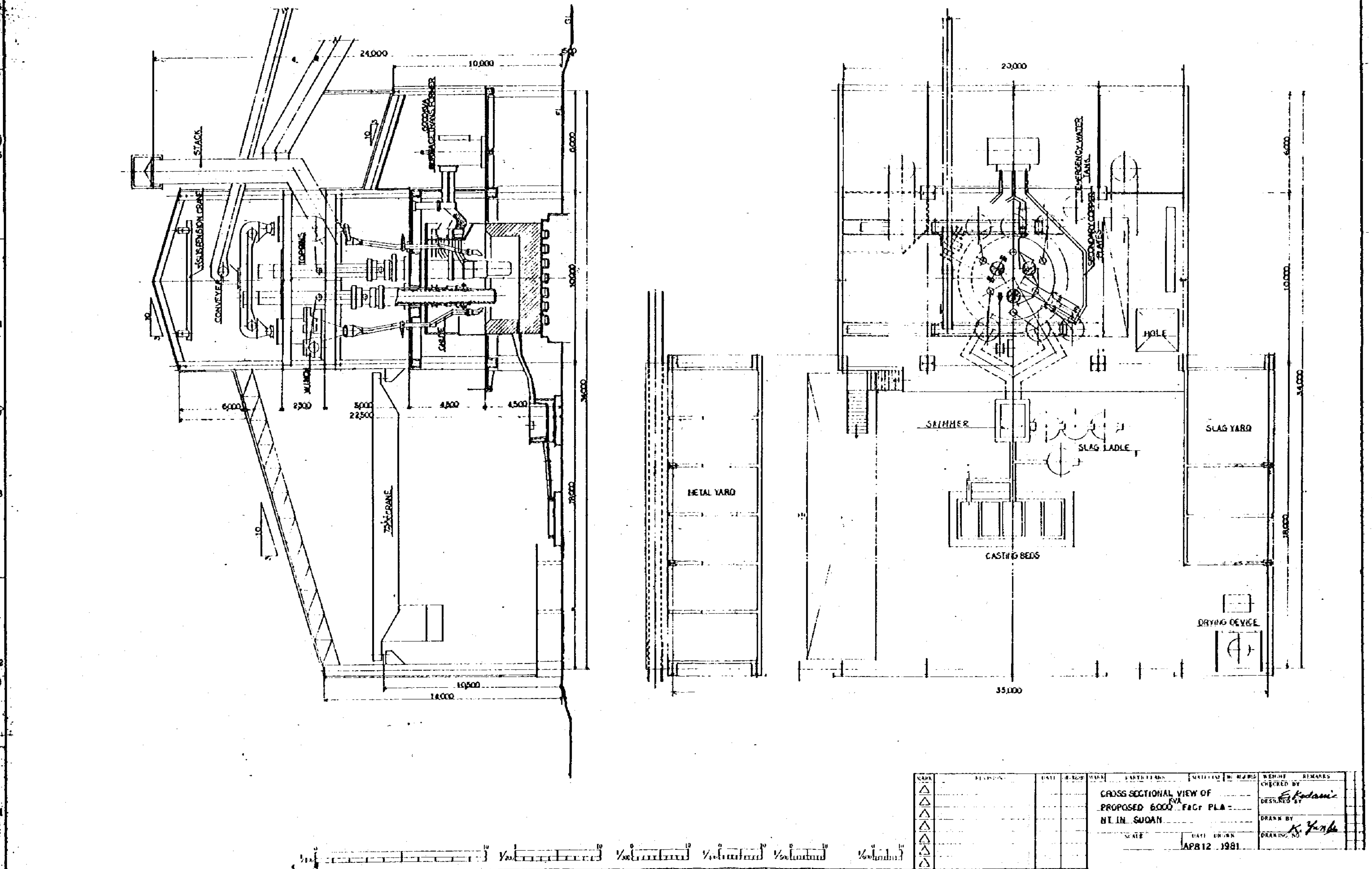


Table S-10 Estimated Construction Costs

(Unit: 10^3 US$)

Item	Case A			Case B			Detailed Cost Element
	Imports	Domestic	Total	Imports	Domestic	Total	
Raw Material conveying and Blending facilities	685	290	975	910	610	1,520	Raw material receiving and storage facilities, blending equipment.
Electric Furnace Facilities	2,245	380	2,625	5,500	490	5,990	Electric furnace, transformer for furnace, dust collector and other equipment.
Product Handling Facilities	5	50	55	555	65	620	Product crushing equipment, storage yards for products and slag.
Power Receiving and Transforming Facilities	310	575	885	930	1,065	1,995	Power receiver and distributor, power receiving equipment for pumps, power transmission equipment.
Utilities Facilities	960	350	1,310	1,200	905	2,105	Water pumping and transporting equipment, water supply equipment, air compressor, equipment for fuels, vehicles and others.
Subsidiary equipment	415	10	425	375	80	455	Office equipment, workshop machinery and Laboratory equipment.
Buildings	865	1,640	2,505	1,405	2,315	3,720	Building for electric furnace, product handling room, buildings for welfare facilities and other auxiliary buildings.
External Structure	120	595	715	175	830	1,005	Paved service roads in the plant site, ditches, fences, lighting and others.
Construction Materials and Machinery	665	795	1,460	670	800	1,470	Road from the railway station to the plant site, trucks, cranes, buldozers, stagings and temporary facilities.
Materials for Operation	160	30	190	310	60	370	Consumables necessary for plant operation such as oxygen.
Spare Parts	355	–	355	640	–	640	Spare parts for machinery.
Sub-Total	6,785	4,715	11,500	12,670	7,220	19,890	
Various Charges	680	–	680	1,270	–	1,270	
Packing and Inland Transportation	970	–	970	1,615	–	1,615	
Ocean Freight	1,630	–	1,630	2,540	–	2,540	
Unloading and Overland Transportation	150	680	830	270	1,175	1,445	
Supervision	2,140	–	2,140	3,355	–	3,355	
Sub-Total	5,570	680	6,250	9,060	1,175	10,225	
TOTAL	12,355	5,395	17,750	21,720	8,395	30,115	

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. S-7. 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

Annual labor costs are estimated to be US $253,200 for Case A or US $322,200 for Case B. Since ferrochrome production techeniques 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.

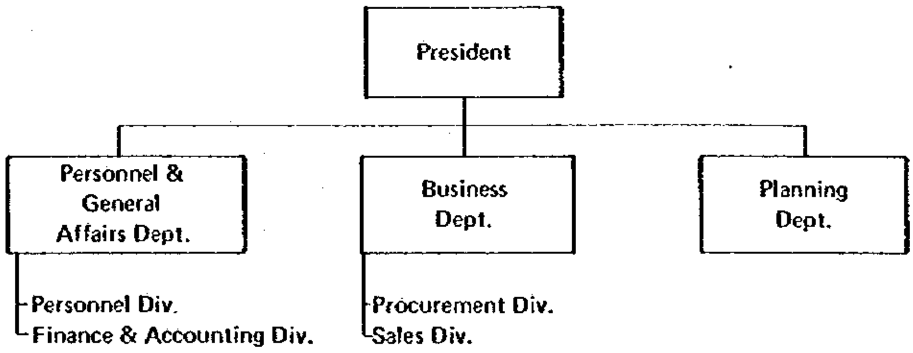
Operation of the ferrochrome plant will reach its full production capacity after 6 months from initiation of the operation. During this initial operation period, 54 person-months will be required for assistance and guidance of operation. Operating performance of the plant after the operation reaches a normal state was estimated based on material/heat balance, and the results are summarized in Table S-11. Calculation of unit costs is given in Table S-12.

Table S-11 Operating Performance of Ferrochrome Plant

	Unit	Case A	Case B	Remarks
Ave. Furnace Load	KW	4,300 (4,500)	9,000 (9,500)	( ) shows max. load.
Electric Unit Consumption	KWH/t	4,250	4,193	
Daily Output	t/d	24.3	51.5	
Annual Operation Days	days	290	290	Excluding 10 days after startup.
Annual Output	t	7,047	14,940	

Fig. S-7 Organization Charts

(a) Head Office in Khartoum



(b) Ferrochrome plant in Damazin

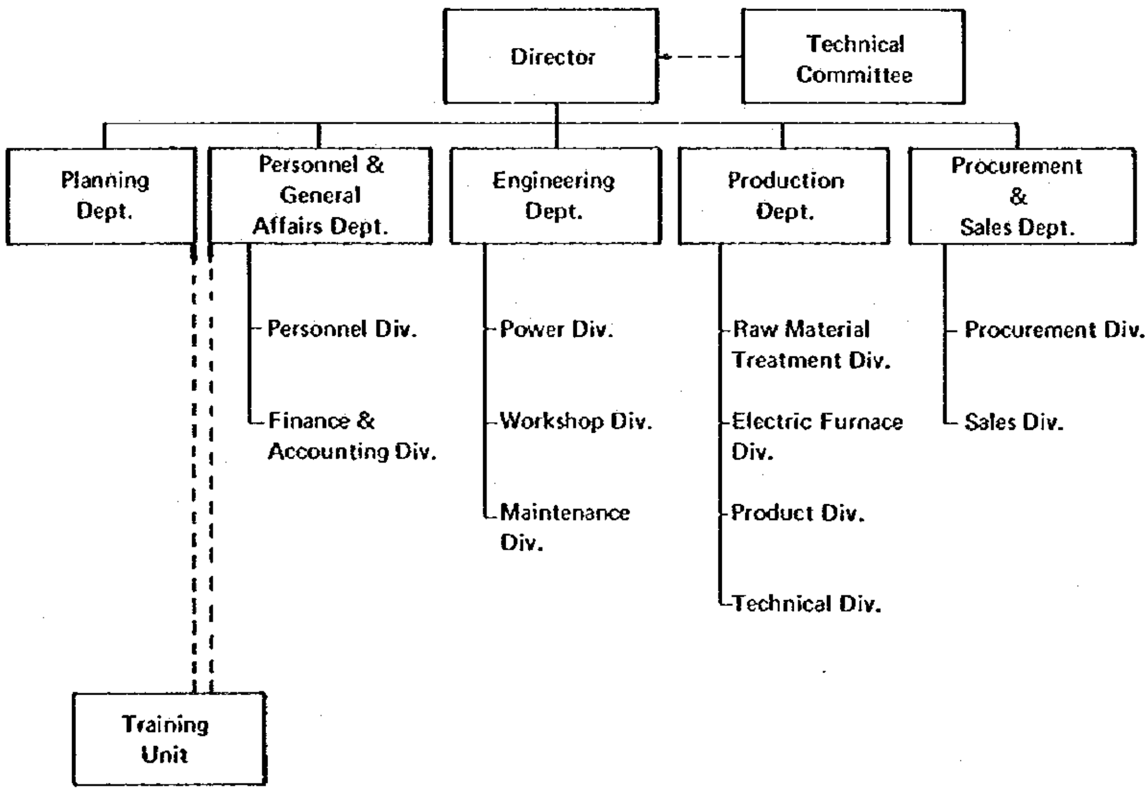


Table S-12 Calculation of Unit Costs

(Unit: US$/ton)

Item	Unit Price	Case A Unit Consumption	Case A Amount	Case A %	Case B Unit Consumption	Case B Amount	Case B %
Chromium Ore (A)	69.0	2,182 Kg/t	150.6	15.9			
Chromium Ore (B)	63.3				2,248 Kg/t	142.3	16.6
Coke	210.6	495 Kg/t	104.2	11.0	491 Kg/t	103.4	12.1
Bauxite	102.3	296 Kg/t	30.3	3.2	227 Kg/t	23.2	2.7
Silica (A)	44.9	127 Kg/t	5.7	0.6			
Silica (B)	38.6				144 Kg/t	5.6	0.7
Electric Power	0.0433	4,650 KWH/t	201.4	21.3	4,593 KWH/t	198.9	23.2
Electrode	640.2	19 Kg/t	12.2	1.3	19 Kg/t	12.2	1.4
Consumables			20.0	2.1		20.0	2.3
Auxiliary Costs			15.0	1.6		15.0	1.7
Variable Production Costs			(539.4)	(57.0)		(520.6)	(60.7)
Labor Cost		$253,200/yr	36.2	3.8	$322,228/yr.	21.5	2.5
Depreciation		$17.750Mx6%	152.1	16.1	$30.115Mx6%	120.5	14.1
Expenses (for maintenance & repair)			30.0	3.1		30.0	3.5
Fixed Costs at the Plant			(218.3)	(23.0)		(172.0)	(20.1)
Total Accounting Costs at the Plant			(757.7)	(80.0)		(692.6)	(80.8)
Sales Cost			40.2	4.2		40.2	4.7
General Administration Cost		757.7 x 3%	22.7	2.4	692.6x3%	20.8	2.4
Interest Paymeto (Facility)		$17.750Mx4%	101.4	10.7	$30.115Mx4%	80.3	9.4
Interest Payment (Operation)		$757.7 \times 8\% \times \frac{5}{12}$	25.3	2.7	$692.6 \times 8\% \times \frac{5}{12}$	23.1	2.7
Fixed Costs at the Head Office			(189.6)	(20.0)		(164.4)	(19.2)
Total Unit Cost			947.3	100.0		857.0	100.0
Selling Price			602.1			587.5	
Profit/Loss			-345.2			-269.5	

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 7,000 tons/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 S-12, 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 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 performed to investigate effects of those variations.

The calculated value of financial rate of return (as shown in Table S-13) is –11.0% or –10.1% for the respective plant capacity of 7,000 ton/year or 15,000 ton/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 calcualted 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 calcualted 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%.

Table S-13 Summary of IRR Calculation

Case A (7,000 ton/year ferrochrome production)	
Financial analysis	FRR
Standard	–11.0%
Economic analysis	ERR
Standard	–13.2%
+ Benefits of vocational training	–10.8%
Case B (15,000 ton/year ferrochrome production)	
Financial analysis	FRR
Standard	–10.1%
Sensitivity	
Electricity rate: 30% down (0.0239 S£/kwh)	–5.2%
Ferrochrome price: 20% up (557 S£/ton)	–1.4%
Initial investment costs: 30% down	–9.1%
Taxes and Custom duties: all exempted	–9.6%
Most optimistic: all of the above	+5.4%
Economic analysis	ERR
Standard	–12.3%
+ Benefits of vacational training	–10.6%
Sensitivity	
Ferrochrome price: 20% up (557 S£/ton)	–1.1%
Initial investment costs: 30% down	–11.0%
+ Operating rate: 20% down	–13.7%
+ Ferrochrome price: 20% up	+2.9%

10. Conclusions

Table S-13 summarizes the results of calcualtion 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.
than Case A.

The values of internal rates of return calculated for the standard case 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 7,000tons/yearor 15,000tons/yearferrochrome 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 note 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.

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