THE FEASIBILITY STUDY REPORT ON THE ESTABLISHMENT OF A FUSED MAGNESIUM PHOSPHATE FERTILIZER PLANT IN THE REPUBLIC OF ZAMBIA (SUMMARY)

SEPTEMBER, 1987

JAPAN INTERNATIONAL COOPERATION AGENCY

TOKYO, JAPAN

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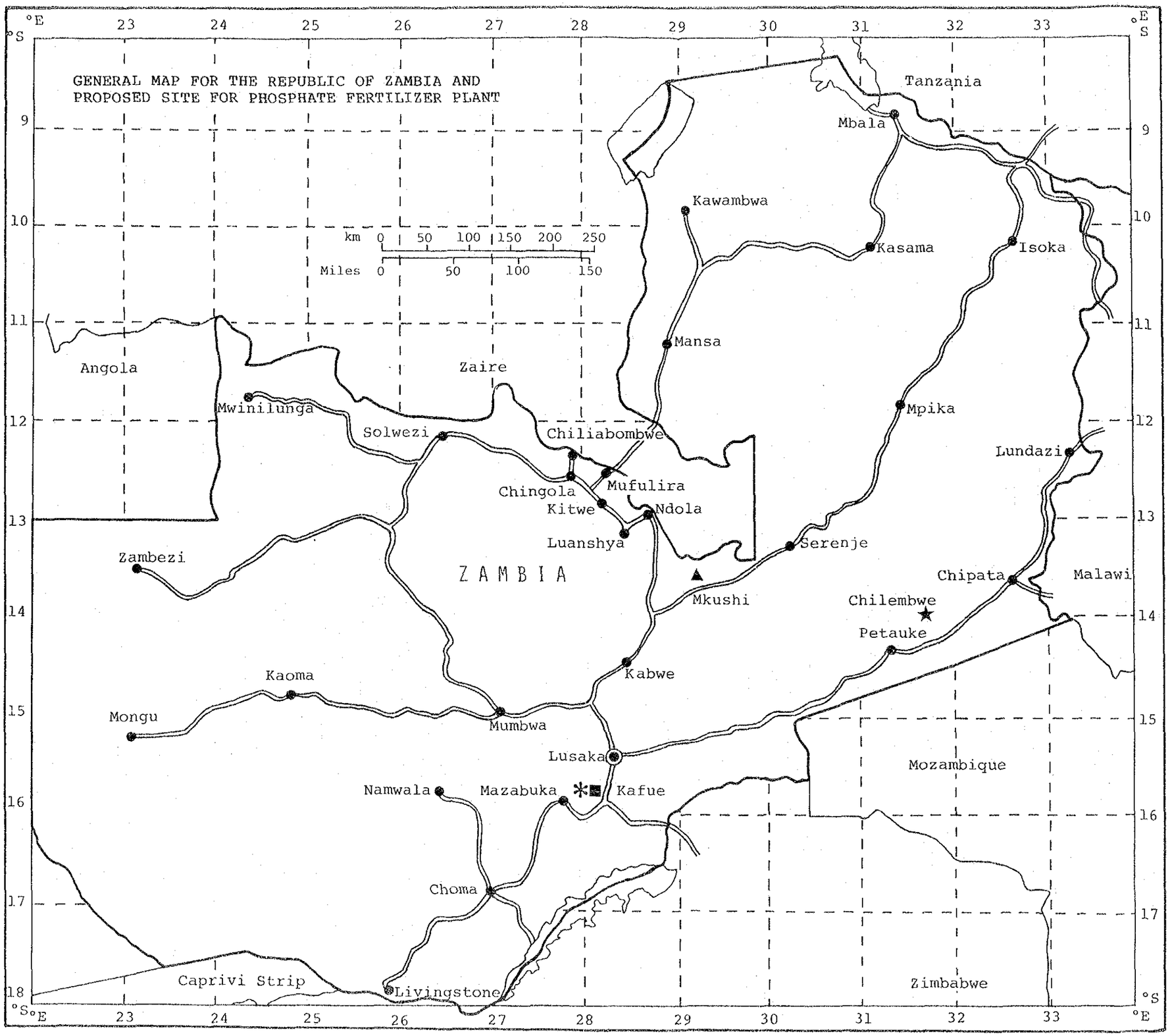
GENERAL MAP FOR THE REPUBLIC OF ZAMBIA AND PROPOSED SITE FOR PHOSPHATE FERTILIZER PLANT



Republic of Zambia

- Land Area : 753,000 km²
- Population : 6.88 Millions - 1986
  - Increase Rate : 3.1%/Year
- GDP/Capita : ZK1,759 - 1986
- Exchange Rate : ZK8.00/US$ - 1987

Reference Location for the Study Project

★ Chilembwe: Phosphate Reserve

- Ore Reserve : 1.55 Million Tons
- Ore Quality : 11.5% of P_2O_5
- Production Potential : Concentrate (30% P_2O_5, 35,181 TPY, 14 + years)
- Administration : MINEX, ZIMCO

▲ Mkushi: Serpentine Reserve

- Ore Reserve : 1.0 Million Tons
- Ore Quality : 32.8% of MgO (South Hill)
- Production Potential : Crushed Ore (32.8% MgO, 19,103 TPY, 32 + years)

■ Nitrogen Chemicals of Zambia Ltd. (NCZ), Kafue

- Ammonia : 96,000 TPY
- Nitric Acid : 120,000
- Sulfuric Acid : 60,000
- Ammonium Sulfate : 50,000
- Complex Fertilizer : 142,320
- Ammonium Nitrate : 140,000

✻ Proposed Site for Phosphate Fertilizer Plant: Southwest of NCZ Plant in Kafue

Plant Capacity:

- Fused Magnesium Phosphate : 50,400 TPY (20.11% C-P_2O_5)

or

- Single Super Phosphate : 57,205 TPY (17.20% Av-P_2O_5)

ABBREVIATIONS, ACRONYMS AND CONVERSION FACTORS

General

DCF	Discounted Cash Flow
Fiscal Year	January 01 to December 31 in Zambia
GDP	Gross Domestic Product
GNP	Gross National Product
IRR	Internal Rate of Return
ZK	Zambian Kwacha (ZK1.00 = Ngwe 100.0)
ROI	Return on Investment
ROE	Return on Equity
S/W	Scope of Work (INDECO-JICA, August 19, 1986)
The Study	The Feasibility Study on the Establishment of a Fused Magnesium Phosphate Fertilizer Plant in the Republic of Zambia
The Cost Estimate Date	January 1, 1987 for the Study
MM	Million
MVA	Manufacturing Value Added
NPV	Net Present Value
Ngwe	Ngwe 100.0 = ZK1.00
US$	U.S. Dollar

Exchange Rates

- October 11, 1986	ZK5.01/US$	Weekly foreign exchange auction system (Marginal Rate) at BOZ
- January 1, 1987	ZK12.71/US$	Weekly foreign exchange auction system (Dutch Rate) at BOZ
- May 1, 1987	ZK8.00/US$	Fixed foreign exchange rate system at BOZ
- The Study	ZK8.00/US$	Prevailing prices level in Zambia is estimated on January 1, 1987 but the exchange rate of ZK8.00/ US$ is applied because of adjustment delay of domestic prices to foreign exchange rate fluctuation observed during the study period.

Organization and Others

BOZ	The Bank of Zambia
CAPC	Central Africa Power Company
CDA	Cattle Development Area
CFC	Cattle Financing Company
COZ	Credit Organization of Zambia
CPC	Copper Belt Power Company
CSO	Central Statistical Office
CSBZ	Cold Storage Board of Zambia
CSSL	Crushed Stone Sales Ltd./INDECO
DAO	District Agriculture Officer
DBZ	Development Bank of Zambia
DOM	Department of Meteorology
DPB	Dairy Produce Board
EOJ	Embassy of Japan
EF	Emergent Farmers
FAO	Food and Agriculture Organization
FD	Forestry Department
FINDECO	Financial Development Corporation
FPRD	Forest Products Research Department
GRZ	Government of the Republic of Zambia
IDZ	Intensive Development Zones
INDECO	Industrial Development Corporation Ltd.
IRDP	Integrated Rural Development Programme
JICA	Japan International Cooperation Agency
LINTCO	Lint Company of Zambia
MAWD	Ministry of Agriculture and Water Development
MCOOP	Ministry of Co-operatives
MCI	Ministry of Commerce and Industry
MCL	Maamba Collieries Ltd.
MD	Meteorological Department
MINEX	Mineral Exploration Department, Exploration House, ZIMCO
MLNR	Ministry of Lands and Natural Resources
MOF	Ministry of Finance
MOM	Ministry of Mine
Mount Makulu	Agricultural Research Station, Lusaka
MTC	Ministry of Transport and Communication

NAMBOARD	National Agricultural Marketing Board
NATCO	National Tabacco Company
NCDP	National Commission for Development Planning
NCSR	National Council for Scientific Research
NCZ	Nitrogen Chemicals of Zambia Ltd.
NEC	National Energy Council
NIEC	National Import and Export Corporation Ltd.
NMB	National Marketing Board
NSE	Nakambala Sugar Estate
OFP	Operation Food Production (Zambia: 1980 - 1990)
PCMU	Provincial Cooperative Marketing Unions
PFO	Provincial Forest Offices
PIC	Prices and Income Commission
PTA	Preferential Trade Area for Eastern and Southern Africa
SAA	Senior Agricultural Assistant
SADCC	Southern African Development Co-ordination Committee
SIDO	Small Industries Development Organization
TAZARA	Tanzan Railway
TBZ	Tabacco Board of Zambia
UNIP	United National Independency Party
UNZA	University of Zambia
Zambia	Republic of Zambia
ZADB	Zambia Agricultural Development Bank
ZABS	Zambia Bureau of Standards
ZCCM	Zambia Consolidated Copper Mines Ltd.
ZCF	Zambia Cooperative Federation
ZESCO	Zambia Electricity Supply Corporation Ltd.
ZHPL, ZAMHORT	Zambia Holiticultural Product Ltd. (Zam Hort)
ZIMCO	Zambia Industrial and Mining Corporation Ltd.
ZIT	Zambia Institute of Technology
ZNEL	Zambia National Energy Ltd.
ZR	Zambia Railways
ZSC	Zambia Sugar Company Ltd.

Units Conversion Factors

Acre, A	1.0 Acre = 4,047 m^2
ata	Atmospheric Pressure in Absolute
atg	Atmospheric Pressure in Gauge
BBL	Barrel, 1.0 BBL = 42.0 US Gallon = 34.97 Imperial Gallons
BSCF, BCF	Billion SCF
BSCFD	Billion SCF per Day
BTU	British Thermal Unit, 1.0 BTU = 0.252 kcal
Bushel	1.0 Bushel = 34.25 Liters
DWT	Deat Weight Ton
EL	Elevation Level
GW	Giga Watt, Billion Watt
Ha	Hectare, 1.0 ha = 10,000 m^2 = 2,471 Acres (A)
HHV	High Heating Value
Gallon	1.0 US Gallon = 0.003785 m^3 1.0 Imperial Gallon = 0.004546 m^3
kVA	Kilovolt-Ampere
kW	Kilowatt
kWh	Kilowatt-Hour = 3.413 BTU
LHV	Low Heating Value
Mills	US Cents 0.1/kWh
MW	Megawatt, Million Watt
MMBTU	Million BTU
MMSCF	Million SCF
MMSCFD	Million SCF per Day
MSCF	Thousand SCF
MSL	Mean Sea Level
Nm^3	Normal Cubic Meter measured at 0°C and 1.0 ata
psi	Pound per Square Inch 1.0 psi = 0.07031 kg/cm^2
SCF, CF	Standard Cubic Feet measured at 60°F and 14.7 lb/in^2 1.0 SCF = 0.0283 Nm^3
SCFD, CFD	Standard Cubic Feet per Day
STB	Standard Tankage Barrel 1.0 STB = 0.159 Litre (60°F)

TSCF, TCF	Trillion SCF	
TPH	Ton per Hour	
TPD	Ton per Day	
TPT	Ton per Ton	
TPY	Ton per Year	
Ton, ton	Metric Ton	
K, K_2O	1.0% K	= 1.2046% K_2O
	1.0% K_2O	= 0.8302% K
P, P_2O_5, BPL	1.0% P	= 2.2914% P_2O_5
		= 5.0073% BPL
	1.0% P_2O_5	= 0.4364% P
		= 2.1853% BPL
	1.0% BPL	= 0.1997% P
		= 0.4576% P_2O_5
Fe, FeO, Fe_3O_4 Fe_2O_3	1.0% Fe	= 1.2865% FeO
		= 1.3820% Fe_3O_4
		= 1.4297% Fe_2O_3
Ca, CaO, $CaCO_3$	1.0% Ca	= 1.3992% CaO
	1.0% CaO	= 1.7848% $CaCO_3$
Mg, MgO, $MgCO_3$	1.0% Mg	= 1.6582% MgO
	1.0% MgO	= 2.0916% $MgCO_3$
S, SO_2, SO_3	1.0% S	= 1.9980% SO_2
		= 2.4970% SO_3
		= 2.9960% SO_4

Fertilizer

Av-P_2O_5	Available Phosphate, Neutral Ammonium Citrate Soluble P_2O_5
AN	Ammonium Nitrate Fertilizer, (34.5-0-0)
A-N	Ammoniacal Nitrogen
APP	Ammonium Poly-Phosphates, (11-55-0)
AS	Ammonium Sulfate Fertilizer, (21.2-0-0)
BPL	Bone Phosphate of Lime in Terms of $Ca_3(PO_4)_2$, BPL/P_2O_5 = 2.1853
CAN	Calcium Ammonium Nitrate Fertilizer, (26-0-0)
CCN	Calcium Cyanamida Fertilizer, (21-0-0)
CF	Compound Fertilizer, (N-P_2O_5-K_2O)

CN	Calcium Nitrate Fertilizer, (16-0-0)
C-P_2O_5	Citric Acid Soluble P_2O_5
C-MgO	Citric Acid Soluble MgO
CX	Complex Fertilizer, (N-P_2O_5-K_2O)
DAP	Diammonium Phosphate Fertilizer, (18.2-46.4-0)
FMP	Fused Magnesium Phosphate, (0-20.11-0), P_2O_5 in Terms of C-P_2O_5
F-P_2O_5	Formic Acid Soluble P_2O_5
N	Nitrogen Nutrient Expressed in Terms of N
N-N	Nitrate Nitrogen
NP	Nitric Phosphate, (28-14-0) or (23-23-0)
NP/NPK	Compound Fertilizer or Complex Fertilizer, (N-P_2O_5-K_2O)
MAP	Monoammonium Phosphate Fertilizer, (16.2-48.4-0)
MOP	Muriate of Potash, Potassium Chloride Fertilizer, (0-0-60)
PAPR	Partially Acidulated Phosphate Rock
SOP	Sulfate of Potash, Potassium Sulfate Fertilizer, (0-0-50)
SSP	Single Super Phosphate Fertilizer, (0-17.20-0), P_2O_5 in terms of Av-P_2O_5
TCP	Tri-Calcium Phosphate; $CaO_3(PO_4)_2$, (0-45.76-0)
TPL	Tri-Phosphate of Lime; $CaO_3(PO_4)_2$, (0-45.76-0)
T-K_2O	Total Potash, Nitric Acid Soluble K_2O
T-N	Total Nitrogen
T-P_2O_5	Total Phosphate, Nitric Acid Soluble P_2O_5
TSP	Triple Superphosphate Fertilizer, (0-46.4-0)
U-N	Urea Nitrogen
Urea	Urea Fertilizer, (46.4-0-0)
W-N	Water Soluble N
W-K_2O	Hot Water Soluble K_2O
W-P_2O_5	Water Soluble P_2O_5

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SUMMARY, CONCLUSION AND RECOMMENDATIONS

1. OUTLINE OF THE PROJECT

1.1 Project Background

In accordance with the request of the Government of the Republic of Zambia (GRZ), Japan International Cooperation Agency (JICA) has undertaken a Feasibility Study on the Establishment of a Fused Magnesium Phosphate Fertilizer Plant in the Republic of Zambia.

The objectives of the study are to examine the marketing and technical aspects as well as financial and economic analysis on the proposed projects to produce two alternative products: fused magnesium phosphate (FMP) or single super phosphate (SSP) in Zambia by using domestic phosphate concentrate which will be mined and concentrated at Chilembwe, Zambia. At present all phosphate fertilizer is imported and the reserves of Chilembwe had been confirmed to serve 10,554 TPY of P_2O_5 supply over 14 years of project life as import substitute of phosphate fertilizer in Zambia.

The economy of Zambia has been heavily dependent on copper mines, but since the sharp decline of the copper export price in 1974, Zambia's development strategy has given high priority to agriculture and rural development, especially to achieve self-sufficiency in major foodstuffs. Fertilizer is the most important input for the agricultural development in Zambia. The availability of surplus hydroelectric power and sulfuric acid at low cost in Zambia are advantageous for the production of two product alternatives.

The JICA study team made a detailed study under the assistance and guidance of INDECO as coordinating body and counterpart agency for the study and took representative mineral samples of Chilembwe phosphate ore and Mkushi serpentine in Zambia during November and December 1986, and made evaluation tests for the concentration of phosphate and the production of two product alternatives.

The experimental works and studies have verified the technical feasibility of the proposed projects to produce standard quality products by conventional process technologies.

1.2 Project Facilities

Based on the experimental works and detailed analysis on the proposed projects, the conceptual design of the project facilities have been developed as outlined below:

Basic Features of Proposed Projects

Proposed Project	Location, Site Area, m2	Product and Specification	Rated Capacity TPY	Permanent Employment	Capital Investment US$, MM -1991
- Phosphate Mining and Concentrate, I	Chilembwe 779,000	Phosphate Concentrate (P_{2O5} 30.00%, CaO 41.11%)	35,181	117	14.6
- Fused Magnesium Phosphate, II	Kafue 27,000	Fused Magnesium Phosphate, Bags (0-20.11-0)	50,400	83	21.5
or					
- Single Super Phosphate, III	Kafue 20,800	Single Super Phosphate, Bulk (0-17.20-0)	57,205	74	19.8

The proposed project calls for the production of 50,400 TPY of fused magnesium phosphate or 57,205 TPY of single super phosphate using 35,181 TPY of Chilembwe phosphate concentrate, starting commercial production in 1991 for the 15 years of project life.

The processes applied are open pit mining, flotation and filtration for the phosphate mining and concentrate project, electric furnace reaction to process Chilembwe phosphate concentrate and Mkushi serpentine mixture to produce fused magnesium phosphate, and acidulation and curing of Chilembwe phosphate concentrate by sulfuric acid which will be supplied from NCZ, Kafue for the production of single super phosphate fertilizer.

It is assumed that new state-owned organizations would be established for the promotion of the projects as a national project under MINEX for the phosphate mining and concentrate project and under INDECO for the phosphate fertilizer project, and simultaneously seek the technical assistance of an international engineering consultant for the execution of the projects.

The phosphate mining and concentrate project will be located in Chilembwe in view of the access to the reserves and the phosphate fertilizer projects will be located in Kafue in view of the physical distribution of raw materials and product in Zambia. Kafue is selected as the optimum location among four pre-selected sites: Kafue, Kabwe, Ndola and Kitwe.

The construction schedule is projected that the contract will be awarded under a lump-sum and full-turn-key type contract in July, 1989 for the mechanical completion in March, 1991 and the commencement of commercial production in July, 1991.

The proposed phosphate fertilizer products would be sold in the domestic market through NCZ and NAMBOARD. The rated capacity of phosphate fertilizer will serve only a half to a third of the national requirements of Zambia due to the limited reserves of Chilembwe phosphate ores.

The annual sales and product selling price are projected as follows:

Product Sales Projection

Year	Fused Magnesium Phosphate			Single Super Phosphate		
	Product Sales TPY	Unit Price US$/Ton-Bags - 1991	Annual Sales US$,MM - 1991	Product Sales TPY	Unit Price US$/Ton-Bulk - 1991	Annual Sales US$,MM - 1991
1991						
(1/2 year)	15,120	180.0	2.72	17,162	150.0	2.57
2	37,800	180.0	6.80	42,904	150.0	6.44
3	45,360	180.0	8.16	51,485	150.0	7.72
4	50,400	180.0	9.07	57,205	150.0	8.58
5	50,400	180.0	9.07	57,205	150.0	8.58
...	...	...	...	...	...	...
2005						
(1/2 year)	30,240	180.0	5.44	34,323	150.0	5.15
Project Life Total/ Average	735,840	180.0	132.45	835,193	150.0	125.28

1.3 Financial Analysis and Economic Evaluation

Although the proposed projects are found to be technically feasible, the financial analysis shows that the projects are not financially viable in terms of return on investment as well as cash flow under assumed long term loan interest rates of either 4%/year or 12%/year. Financial internal return on investments are found to be all negative. The financial analysis is summarized as follows:

Project Financial Analysis Summary

	FIRROI, DCF, After Tax, %		Project Life Average Debt Service Ratio		Transfer Price of Phosphate Concentrate	
Long Term Interest Rate	4.0%	12.0%	4.0%	12.0%	4.0% $/Ton	12.0% $/Ton
Individual Projects						
- Phosphate Mining and Concentrate, I	(-)4.29	(-)4.27	0.35	(-)2.76	(130.0)	(130.0)
- Fused Magnesium Phosphate, II	(-)10.11	(-)10.06	(-)1.27	(-)3.50	(130.0)	(130.0)
- Single Super Phosphate, III	(-)3.53	(-)3.52	0.64	(-)2.18	(130.0)	(130.0)
Integrated Projects						
- Phosphate Mining and Concentrate, and Fused Magnesium Phosphate, I + II	(-)8.04	(-)8.00	(-)0.51	(-)3.12	120.3	120.3
- Phosphate Mining and Concentrate, and Single Super Phosphate, I + III	(-)3.85	(-)3.84	0.63	(-)2.27	131.3	131.3

The two alternative projects are financially not viable; it is noted, however, that the return is a little higher for the production of single super phosphate than fused magnesium phosphate. The sensitivity analysis reveals that the product price is the most sensitive and to realize financially viable returns, the product price should be more than 60% higher than the projected product price as import substitute pricing, which is considered unlikely in view of present and near future international phosphate fertilizer markets which are suffered from

excessive supply capacity as well as the expansion projects in developing countries.

The economic analysis shows that the return on investment for the proposed projects are also negative. The net foreign exchange savings gained from import substitution of phosphate fertilizer are fairly large for the single super phosphate project but are marginal for the fused magnesium phosphate project. However it is anticipated that the savings for the fused magnesium phosphate project might be improved if the higher effectiveness of fused magnesium phosphate fertilizer is confirmed by the agronomical tests in Zambia. The economic benefit is not so attractive for the economy of the Republic of Zambia under the present and assumed near future conditions of phosphate fertilizer industries in the world.

2. SUMMARY OF THE STUDY RESULTS

2.1 Market Aspects

2.1.1 Agriculture and Fertilizer Consumption, Supply and Distribution in Zambia

(1) Consumption of Fertilizer in Zambia

The consumption of fertilizer in Zambia had increased year by year until 1977 as shown in Table 2-1-1. However, after that, the consumption level fluctuated year to year, and the highest consumption level recorded after 1980 was 218,800 tons (in nutrient equivalents, 57,800 tons for N, 21,700 tons for P_2O_5 and 8,000 tons for K_2O respectively).

One of the characteristics of fertilizer consumption pattern in Zambia is that most fertilizer is consumed as compound fertilizer. Most fertilizer has been used on maize. Large and medium-scale commercial farmers apply fertilizer on maize almost without exception. In the case of small-scale commercial farmers, they apply fertilizer on maize in general, but sometimes do not apply it because of lack of money or credit to buy fertilizer. However, subsistence farmers do not apply fertilizer at all because of lack of purchasing power, although they desire to apply fertilizer since they know the effectiveness of fertilizer for improving yields, having seen what large-scale farmers achieve.

(2) Fertilizer Supply and Distribution in Zambia

The total balance of fertilizer in Zambia in 1983 through 1986 is shown in Table 2-1-2. Most supply has been imported. NCZ is the sole producer of fertilizer in Zambia, and has production facilities for ammonia, ammonium nitrate, ammonium sulphate and compound fertilizer.

Fertilizer distribution has been monopolized by NAMBOARD; except for the raw material fertilizers imported by the NCZ, all the fertilizers have been imported by the NAMBOARD, and all the fertilizers produced by the NCZ have been distributed by the NAMBOARD. (Figure 2-1-1).

In 1986, the government decided to liberalize fertilizer distribution by abolishing the monopoly of NAMBOARD.

However, because of insufficient provision with respect to funds and facilities (especially transportation facilities) together with existence of subsidies (or official prices), liberalization was not materialized this year and the NAMBOARD handled the distribution as in the past.

(3) Fertilizer Price and Subsidy on Fertilizer

The price of fertilizer has been fixed at two levels by the government, namely, the sales price of NCZ to NAMBOARD and the price at outlets. The sales price of NCZ to NAMBOARD has been set lower than the production cost of NCZ in recent years, and the difference is to be compensated by the government. This difference is called the producer subsidy.

The sales prices at all outlets are the same regardless of the location of the outlets. The difference between the set price and the cost delivered to the outlet, which varies depending on the distance from the origin, is called transportation subsidy.

Table 2-1-3 compares the landed cost of imported fertilizer by NAMBOARD, official purchase price from NCZ, and official sales price by NAMBOARD.

(4) Physical distribution of fertilizer

The domestically produced fertilizer is purchased by NAMBOARD at the factory from NCZ, transported to the major depots either by road or rail, and further to outlets.

Imported fertilizers are unloaded mainly at Dar-es-Salaam in Tanzania, bagged there and transported directly to main depots by rail.

2.1.2 Marketability of FMP and SSP in Zambia

(1) Marketability of FMP

1) Marketability of FMP as a phosphate fertilizer

All the phosphate fertilizer used in Zambia contains water-soluble phosphate, while the FMP contains citric-soluble phosphate only. So far, no well organized field experiments have been conducted in Zambia regarding the effectiveness of citric-soluble phosphate on crop yield. According to a limited number of FMP applications in Zambia, the effectiveness of FMP is understood to be equal to that of water-soluble phosphate fertilizers.

One percent of citric-soluble phosphate is equivalent to that of water-soluble phosphate in its effectiveness in general, in the acidic soil area widely distributed in Zambia. The area of Zambia where the effectiveness of FMP is expected covers most except for limited areas as shown in Figure 2-1-2.

According to the prevailing fertilizer application practice, the phosphate fertilizer is applied as basal dressing, and in compound fertilizer. Therefore, the introduction of FMP will not be easy in Zambian market without modifying the present fertilizer application practice. At present, there is an opinion among the leaders in agricultural sector to promote the use of domestically produced fertilizer, modifying the fertilizer application practice in view of financial difficulty of the country. With such support for the introduction of FMP as a domestically produced fertilizer, the marketability of FMP may be expected despite the above described difficulties in its introduction.

2) Marketability of FMP based on the additional effects by the accessory contents

In the case of FMP, the effect of the accessory contents in addition to the phosphate fertilizer may be expected due to MgO, CaO and silicic acid in it. One is the effect to supply the soil with these nutrients, and another is the effect on the soil acidity. The former effect is not taken into account in examining the marketability of FMP in this study, since no experiment has been undertaken on this point in Zambia.

The CaO and MgO contained in the FMP are effective to amend soil acidity, as stated in the foregoing section. However, in order to expect such effect, a large volume of FMP must be applied. The present recommended dosage of phosphate fertilizer is 20 - 40 kg P_2O_5/ha at most in Zambia, and it is hard to expect the significant acidity ammendment effect from that level of FMP application even with several years of continued application.

Thus, it may be concluded that the effect of contained CaO and MgO as acidity amendment material is hard to evaluate in addition to that of contained phosphate, without confirming the effectiveness through field tests on Zambian soil.

(2) Marketability of SSP

The phosphate contained in SSP is mostly water-soluble, and the effectiveness of the contained phosphate is equivalent to that of other phosphate fertilizers now used in Zambia. Therefore, marketability of SSP in view of effectiveness is not in question at all.

Further, sulphur application is effective in the case of Zambian soil, and therefore, contained sulphur is valuable in addition to the above.

2.1.3 Projection of Sales Prices of FMP/SSP

(1) Condition and Assumptions of Sales Price Projection

The distribution and market price of fertilizer is controlled by the government. The import and distribution are monopolized by the state company, NAMBOARD, and the market price is set by the government. The basic policy of the government is to gradually reduce governmental control. An effort to abolish the distribution monopoly was made in 1986 as the first step of this liberalization. In this price projection, the market price is assumed to be formulated on the basis of competition among the products from various sources as well as suppliers, with decontrol in setting the price.

(2) Projection of Sales Price of FMP/SSP

In the case of introduction of FMP/SSP to a market where the use of compound fertilizer is established, there are some non-price disadvantages. Namely, the introduction of FMP/SSP will increase the number of total bags of fertilizer to be used and moreover, pre-mix of FMP with other fertilizers is necessary in the case of FMP, thereby increasing inconvenience. Thus, the total cost of FMP and other fertilizer, or compound fertilizer using SSP, should be less than that of the present application pattern if use of FMP/SSP is to be accepted.

However, if the farmers change their practice of using a combination of straight fertilizer by the time of introduction of FMP/SSP, as a result of liberalization of fertilizer distribution, then the farmers' attitude toward the selection of new fertilizer is a little different from the case examined in the foregoing section. In such case, whether the farmers will use the FMP/CX-SSP or not depends on the cost to them of using FMP/CX-SSP in comparison with that of phosphate fertilizer. The price of FMP should be equivalent to or less than that of the fertilizer now in use, in terms of 1% phosphate content.

On the basis of the foregoing examination, the sales price of FMP/SSP is projected as follows:

Projected Potential Sales Prices of FMP/SSP

	Ex-factory Price (US$/ton)
FMP	US$110/ton±20%
SSP	US$97/ton*/

Note: */ Expected maximum price

(3) Policy Option on Fertilizer Distribution, and its Influences on Sales Prices

In the foregoing section, the price of FMP/SSP was projected on the assumption that the distribution of fertilizer will be liberalized. However, it will take time before a number of distributors will become established in the business, in view of present situation of distribution. At the same time, the liberalization of price formulation is also doubtful since the liberalization of prices must be done together with that of other goods. The possibility to realize the free import is closely related to the policy option of how to deal with domestic production, namely the operation of NCZ. In the following sections, the influence on the projected prices of FMP/SSP of such policy options relating to the fertilizer distribution is examined.

1) The case in which the price increase rate will be controlled at the same rate of general price increase (Scenario 1)

This scenario assumes that the prices of all the fertilizers are increased by 3.0% p.a. (the same increase rate as that of general price) from the official price in 1986. In this case, the prices in mid-1991 will be lower than the imported cost of fertilizers and it implies that the fertilizers are subsidized at that time.

Assuming the introduction of FMP to such a market, the projected salable price of FMP will be as low as US$80/ton (ZK640/ton). This is because the cost of fertilizers to be replaced by the FMP is kept at a lower level than import costs by the official prices.

The producer of the FMP will be entitled to receive a subsidy, in this case. The rate may vary depending on the policy decision with respect to the extent of protection of domestic producers. The projected sales price of FMP will be about US$110/ton (ZK880/ton), assuming the rate 25%.

The SSP cannot be priced with this scenario again.

2) The case in which the operation of NCZ is assumed as the basis of policy option (Scenario 2)

The shortage of foreign exchange in Zambia might remain unchanged in the future if the international copper market stays soft. Since the operation of NCZ results in foreign exchange saving through utilization of domestic resources of nitrogen, there is possibility for the distribution of fertilizer, which competes with that of NCZ, to be restricted to protect the operation of NCZ.

If such is the case, the liberalization will be limited to some extent. However, at what cost level the price is to be set varies depending on such factors as general price change, extent of foreign exchange shortage, direction of agricultural policy, availability of financial funds for fertilizer subsidies, etc.

The lowest case among them will be the one in which the fertilizer price is increased at the rate of general price increase, as shown in Scenario 1, and the highest case is the one in which the price is set to cover the cost of domestic production of NCZ for domestic compound fertilizers and the cost of import for imported straight fertilizers. There are various alternatives of price level between the two extreme cases depending on the policy option.

The sales price of FMP was projected with the assumption that the formulation cost of compound fertilizer accounts for 15-25% of total production cost. Since the FMP replaces a part of compound fertilizer now used, the higher the price of compound fertilizer, the higher the possible sales price of FMP, with the highest case being US$178/ton (ZK1,424/ton).

Assuming that NCZ continues to operate, the possible sales price of SSP as a raw material of compound fertilizer for the producer of compound fertilizer (NCZ) will be equivalent to, or less than, that of other phosphate fertilizer in terms of 1% phosphate content. The highest price under such circumstance is US$142/ton (ZK1,139/ton).

2.1.4 Projected Market Quantity Volume of FMP/SSP in Zambia

Most fertilizer in Zambia is consumed for maize. In this context, the major factor affecting the demand for fertilizer is change in the cultivation area of maize in commercial farm sector. In the long term, the maize cultivation area increases in accordance with increase in urban population, which results in the increase in maize demand and gives an incentive for maize production. However, the maize cultivation area does not necessarily increase directly in response to increase in the urban population and therefore demand for maize.

Therefore, in the projection of phosphate fertilizer demand, the maize cultivation area is firstly projected, and then, multiplying the 112 N kg/ha, 40 P_2O_5 kg/ha, and 20 K_2O kg/ha of present recommended dosages by the above-forecast cultivated areas, the potential demand was projected. Further, using the realization rate of the potential demand in the past, by province, the demand for fertilizer was projected by province.

The result of projections for the phosphate fertilizer is given in Table 2-1-4.

What extent of demand for phosphate fertilizer will be materialized as the demand for FMP, depends on the sales promotion measures to be taken when FMP is introduced, the level of sales price as well as the support given by the leaders in the agricultural sector. In this projection, these factors are assumed to be fulfilled sufficiently.

SSP is applicable for all areas where phosphate demand exists, since it contains water-soluble phosphate and is sold as compound fertilizer.

Thus, the market quantity may be decided by the potential amount that can be supplied instead of market size. The market volume of FMP, assuming that the sales is confined to the acidic soil area, and that of SSP with assumption that 30% of requirement of phosphate is fulfilled by the SSP, are given in Tables 2-1-5 and 2-1-6.

2.2 Raw Material Suppliability

2.2.1 Fertilizer Production Plant

In Zambia, there is one fertilizer manufacturing plant of Nitrogen Chemicals of Zambia Ltd. (NCZ) which is located in the Industrial Estate of Kafue, approximately 44 km south from Lusaka and has two trains of ammonia production facility using Maamba coal as raw material with annual combined capacity of 96,000 TPY of ammonia. Product ammonia is captively consumed for the production of nitric acid, ammonium nitrate, ammonium sulfate and compound fertilizer granulation. The capacity utilization has been less than a half and the plant is now under rehabilitation programs.

After the completion of the rehabilitation works in 1988, the overall inputs and outputs of the NCZ is projected as follows:

Production Balance Projection at NCZ — Unit: 1,000 TPY

Inputs		Intermediates		Salable Products	
Coal, Maamba	191.7	Ammonia	96	Nitric Acid	7.7
Pyrite, Nampundwe	40	Nitric Acid	120	Sulfuric Acid	10
Lime, CSSL	8.5	Sulfuric Acid	60	Ammonium Nitrate	
DAP, Import	27.5	Ammonium Nitrate	140	- Fertilizer	85
TSP, Import	23.7	Ammonium Sulfate	50	- Explosives	24
SOP, Import	9.6	Compound		Compound	
MOP, Import	3.8	Fertilizer	142.32	Fertilizer	142.32
Conditioner, Import	1.5	Methanol	1.65	Methanol	1.65
Raw Water, Kafue River	21,600 TPD	Carbon Dioxide	1	Carbon Dioxid	1
Electricity, ZESCO	46 MW				

All the fertilizer product from NCZ is sold to NAMBOARD, parastatal agency under the Ministry of Cooperatives for domestic marketing and physical distribution in Zambia. The domestic transport of the products are in bags and through railways and/or road vehicles to the NAMBOARD's depots at 15 locations in Zambia. NAMBOARD receives subsidies for fertilizer price differential and fertilizer handling cost and has monopoly role over the procurement of fertilizer both from the domestic plant and imports (commercial and bilateral aid). Final marketing and distribution of fertilizer is undertaken by Provincial Cooperative Marketing Units (CMU) under the Ministry of Cooperatives, which have 18 fertilizer depots throughout Zambia.

2.2.2 Fertilizer Control and Regulation

In Zambia, regulation and control of fertilizer are as stipulated in the Agriculture (Fertilizers and Feed) Act - Chapter 351 of the Law of Zambia which defines the fertilizer, method of analysis and maximum variation allowance for nutrients as well as the quantity and quality control of fertilizer in Zambia.

The main features of fertilizer regulation in Zambia are: fertilizer is quantified in terms of elements not only in N but also P and K instead of oxides, water soluble phosphate is recognized as legally effective phosphate fertilizer, and nitrate nitrogen and sulfate type potash are given high importance in the legislation. However, among industry and commerce the international practices are widely accepted in Zambia.

2.2.3 Supply of Raw Materials

For the production of proposed phosphate fertilizer products, several raw materials are required and their suppliability in Zambia are studied. The combination of raw material and product studied is summarized as follows:

Product Alternatives and Raw Materials

Product Alternatives	Raw Materials
Fused Magnesium Phosphate	Phosphate Concentrate and Serpentine
Single Super Phosphate	Phosphate Concentrate and Sulfuric Acid
Triple Super Phosphate	Phosphate Concentrate and Sulfuric Acid
Diammonium Phosphate	Phosphate Concentrate, Sulfuric Acid and Ammonia
Nitric Phosphate	Phosphate Concentrate, Nitric Acid, Ammonia and Carbon Dioxide

(1) Phosphate

MINEX concluded that the development of Chilembwe phosphate ore is the most promising in Zambia, and a detailed study was undertaken in 1984/85. The study results are presented in "A Pre-Feasibility Study for the Phosphate Development Project, the Republic of Zambia, 1985, Japan International Cooperation Agency".

The study demonstrates that the minable phosphate reserve in Chilembwe is 1.55 million tons of 11.5% P_2O_5 quality and 40,000 TPY-wet of phosphate concentrate with 30.00% P_2O_5 quality (dry) will be recovered annually by the flotation process. The reserve is small and limited, and will be mined out in 15 years of project life.

(2) Serpentine

MINEX, ZIMCO made a study on the serpentine reserve at Muloba, Mkushi in 1986. The study results are documented in "Occasional Report on the Muloba Serpentine, Mkushi District, Central Province, Zambia, MINEX, ZIMCO, September, 1986". The reserve is located at 55 km north-east of Kapiri Mposhi along Great North Road and TAZARA railways system.

According to the report, the major minerals of the reserves are antigorite ($3\ MgO \cdot 2SiO_2 \cdot 2H_2O$) and calcite. Tourmaline, chrysotile and serpophite are associated. The crystalline size is averaged 0.2 mm in diameter and specific gravity of the minerals measured as 2.5. The reserve is high quality in MgO and SiO_2, and large enough for supporting the project for more than 32 years of operation.

It is assumed that MINEX, ZIMCO will implement the serpentine mining project and supply crushed serpentine to the fused magnesium phosphate project upon the approval of the project.

(3) Sulfuric Acid and Others

For the production of single super phosphate, approximately 20,000 Tons of sulfuric acid is required for the proposed project, annually. Sulfuric acid is produced at NCZ, Kafue and ZCCM, Chambishi and Nkana, both near Kitwe, Zambia.

NCZ has a sulfuric acid plant using pyrite from Nampundwe Mines of ZCCM, approximately 50 km west of Lusaka. Annual design capacity of the plant is 60,000 TPY and was completed in 1983. The supply of pyrite is considered adequate but the capacity utilization in 1986 is less than a half because of the low operating rate of the down-stream ammonium sulfate plant.

Sulfuric acid balance at NCZ upon the completion of rehabilitation works in 1988 is estimated as follows:

Sulfuric Acid Balance at NCZ, 1989

Design Capacity	60,000 TPY
Annual Production	60,000
Consumption	
- NCZ's Captive Uses	50,075
- Ammonium Sulfate (50,000 TPY)	(39,075)
- Direct Use for Compound Fertilizer (142,300 TPY)	(11,000)
Outside Sales	
- Alum Production in Kafue	7,000
Surplus	2,925

Therefore, in principle, under the assumed conditions above, sulfuric acid supply is not adequate for the proposed single super phosphate project in Zambia. However, in practice, considering the objectives of ammonium sulfate production at NCZ is to supply sulfur nutrients in compound fertilizer for applying sulfur to sulfur deficit soil in Zambia, then the diverting sulfuric acid from present ammonium sulfate production to single super phosphate production will create a same result in sulfur balance in Zambian agriculture, because the new product of single super phosphate is containing sulfur nutrient and destined to the farm soil in Zambia.

From the discussion above, it may be reasonable to assume that NCZ will agree to divert a portion of sulfuric acid from the present production of ammonium sulfate to the proposed single super phosphate production according to the pricing of sulfuric acid and other national economic benefits, if manifested.

2.3 Technical Aspects

2.3.1 Production Tests

(1) Phosphate Concentrate

The representative phosphate ore was taken at Chilembwe on November 28, 1986 in consultation with MINEX and a 220 kg weight sample was taken back to Japan for the detailed analysis and for preparation of phosphate concentrate, which was further used for the production tests of fused magnesium phosphate and single super phosphate.

The minerals in the phosphate concentrate from Chilembwe ore are identified by X-ray diffraction and chemical analysis that the major minerals are fluorapatite [$3Ca_3(PO_4)_2 \cdot CaF_2$] and hydroxyapatite [$3Ca_3(PO_4)_2 \cdot Ca(OH)_2$], and quartz ($SiO_2$) and hornblende ($2CaO \cdot 5MgO \cdot 8SiO_2 \cdot H_2O$) are associated as minor contaminants.

The analysis of recovered phosphate concentrate is 33.69% P_2O_5 and 46.18% CaO on a dry basis and production tests were carried out using the phosphate concentrate, but the conceptual design of phosphate fertilizer plants were formulated assuming that phosphate with 30.00% P_2O_5 and 41.11% CaO analysis will be supplied from Chilembwe as an average during the project life because of allowance of design basis of phosphate mining and concentrate project.

(2) Fused Magnesium Phosphate

Fused magnesium phosphate is produced in an electric furnace by melting and reacting of phosphate concentrate and serpentine. The production tests were carried out by using batch-wise experimental electric furnace with 7 kg batch sample which is melted at 1,300°C for 50 minutes and the molten reaction product is quenched in water bath to obtain glassy fused magnesium phosphate product. The product quality is high in citric acid solubility of phosphate. No difference in quality is observed between Zambian and Japanese products in chemical analysis and X-ray diffraction analysis.

(3) Single Super Phosphate

Single super phosphate is a reaction product between phosphate concentrate and sulfuric acid, and its production reaction is expressed in the case of fluorapatite as follows:

$$\underset{\text{(Fluorapatite)}}{3Ca_3(PO_4)_2 \cdot CaF_2} + 7H_2SO_4 + 3H_2O$$

$$= \underset{\text{(Single Super Phosphate)}}{3Ca(H_2PO_4)_2 \cdot H_2O} + 7CaSO_4 + 2HF$$

Production tests of single super phosphate were undertaken by using phosphate concentrate recovered from Chilembwe phosphate ore in comparison with Florida phosphate concentrate, the USA because Florida phosphate is widely used for the commercial production of phosphate fertilizer throughout the world.

The results indicate that standard grade single super phosphate is produced from phosphate concentrate recovered from Chilembwe phosphate ore in Zambia.

It is noted that the reactivity of phosphate from Chilembwe with sulfuric acid is lower than that of Florida and takes longer den residence time and higher temperature for complete reaction and solidification of the reaction mass.

2.3.2 Project Site Selection and Utility Supply

During the course of the field work from November to December, 1986 in Zambia, four alternative sites for the proposed phosphate fertilizer plant project were pre-selected in consultation with INDECO. Major factors taken into consideration were the raw materials and product transport, utilities supply of industrial water and electricity as well as the infrastructure development situation and technical level of personnel available in the region at present and in near future.

The pre-selected candidate sites in Zambia are as follows:

Township of Alternative Sites		Locality
(1)	Kafue	Southwest of NCZ
(2)	Kabwe	Chimanimani Village
(3)	Ndola	Industrial Area
(4)	Kitwe	Industrial Area

The pre-selected four project sites have different features, but Kafue, Ndola and Kitwe are almost identical in utility, infrastructure and technical level while Kabwe is disadvantageous in water supply at present.

The most important factor for the selection of the site is the transport cost for raw material and product. For the production of fused magnesium phosphate, approximately 40,000 TPY of phosphate concentrate from Chilembwe, 20,000 TPY of serpentine from Mkushi to the project site and 50,000 TPY of product should be transported. For the production of single super phosphate, approximately 40,000 TPY of phosphate concentrate from Chilembwe, 20,000 TPY of sulfuric acid from NCZ, Kafue to the project site and 57,000 TPY of product to NCZ, Kafue should be transported.

Therefore, the proposed phosphate fertilizer project should be located in Kafue as the optimal site in view of raw material and product transport. Phosphate concentrate should be transported by road from Chilembwe. Kafue is located nearest to Chilembwe and also nearest to the center of the phosphate fertilizer market in Zambia. The utility supply, infrastructure and technical aspects are considered almost identical among Kafue, Ndola and Kitwe except in Kabwe where raw water supply is tight at present. Kafue is also advantageous in view of the well established operations of NCZ which will be able to assist and collaborate with the phosphate fertilizer project in utility supply, maintenance and operation as well as project management during implementation and operation stages.

2.3.3 Conceptual Design of the Projects

In this feasibility study, there are three projects to be studied. One up-stream project: the phosphate mining and concentrate project located in Chilembwe, and two alternative down-stream projects: the fused magnesium phosphate project or the single super phosphate project, both located in Kafue. There is another small scale project of up-stream: the mining of serpentine project located in Mkushi, but in view of smaller investment cost required the project is assumed as an independent operation of MINEX to deliver the crushed serpentine to the fused magnesium phosphate project in Kafue at cost.

(1) Phosphate Mining and Concentrate Project

The conceptual design and feasibility study of the up-stream project were completed in 1985. The project will be located in Chilembwe to mine and process 332,400 TPY of phosphate ore to produce 35,181 TPY--dry phosphate concentrate: 30.00% P_2O_5 and 41.11% CaO. The phosphate concentrate is coming out as wet with 12% free moisture which will be transported for 541 km by road under a long term haulage contract to Kafue.

(2) Fused Magnesium Phosphate Project

The project will be located in Kafue and consume 35,181 TPY-dry of phosphate concentrate from Chilembwe as well as 19,103 TPY-dry serpentine from Mkushi to produce 50,400 TPY of fused magnesium phosphate as final product.

Specification of the product is C-P_2O_5 20.11%, C-MaO 14.05% and S-SiO_2 26.16%, and citric acid solubility of phosphate is over 99% in the product.

(3) Single Super Phosphate Project

The project will be located in Kafue and consume 35,181 TPY-dry of phosphate concentrate from Chilembwe as well as 19,850 TPY of sulfuric acid from NCZ to produce 57,205 TPY of single super phosphate as final product.

Specification of the product is Av-P_2O_5 17.20%, W-P_2O_5 15.15% and available phosphate solubility is over 96% in the product.

(4) Integrated Projects

For the financial and economic analysis of the overall projects, an integrated project scheme should be formulated. There are two integrated projects: the phosphate mining and concentrate project (I) with the fused magnesium phosphate project (II) or the phosphate mining and concentrate project (I) with the single super phosphate project (III).

Complete conceptual design of five projects are prepared and financially analyzed: (I), (II), (III), (I + II) and (I + III).

2.4 Financial Analysis and Economic Evaluation

2.4.1 Financial Analysis

The financial viability of the project is analyzed in terms of financial internal rate of return on investment in constant price by the discounted cash flow method. In addition to the internal rate of return on investment, the cash flow during the project life is also carefully examined in terms of debt service ratio and annual requirements of short term loan.

Total financing required for the proposed projects are estimated using the prevailing prices in Zambia as well as the international market. The costs at the estimate date are escalated to the total financing required on the commencement date of the commercial production for the projects.

The capital cost estimates for the proposed projects are summarized as follows:

Financing Required and Financing Plan for the Projects, $,MM

Proposed Project	Financing Required			Financing Plan			Annual Sales
	Foreign Currency	Local Currency	Total	Equity	Long Term Loan	Total	
Individual Projects							
- Phosphate Mining and Concentrate, I	10.11	4.45	14.56	3.64	10.92	14.56	4.57
- Fused Magnesium Phosphate, II	16.66	4.86	21.52	5.38	16.14	21.52	9.07
- Single Super Phosphate, III	14.58	5.21	19.79	4.95	14.84	19.79	8.58
Integrated Projects							
- Phosphate Mining and Concentrate, and Fused Magnesium Phosphate, I + II	26.77	9.31	36.08	9.02	27.06	36.08	9.07
- Phosphate Mining and Concentrate, and Single Super Phosphate, I + III	24.69	9.67	34.36	8.59	25.77	34.36	8.58

Base Case: Interest Rate of Long Term Loan; 12.0%/year

Calculation results on the financial analysis, assuming two cases for long term interest rates: 4.0% and 12.0% for the proposed projects are summarized as follows:

Project Financial Analysis Summary

Long Term Interest Rate	FIRROI, DCF, After Tax, %		Project Life Avarage Debt Service Ratio		Transfer Price of Phosphate Concentrate	
	4.0%	12.0%	4.0%	12.0%	4.0% $/Ton	12.0% $/Ton
Individual Projects						
- Phosphate Mining and Concentrate, I	(-)4.29	(-)4.27	0.35	(-)2.76	(130.0)	(130.0)
- Fused Magnesium Phosphate, II	(-)10.11	(-)10.06	(-)1.27	(-)3.50	(130.0)	(130.0)
- Single Super Phosphate, III	(-)3.53	(-)3.52	0.64	(-)2.18	(130.0)	(130.0)
Integrated Projects						
- Phosphate Mining and Concentrate, and Fused Magnesium Phosphate, I + II	(-)8.04	(-)8.00	(-)0.51	(-)3.12	120.3	120.3
- Phosphate Mining and Concentrate, and Single Super Phosphate, I + III	(-)3.85	(-)3.84	0.63	(-)2.27	131.3	131.3

The project life average production costs are higher than the projected price as are cited below:

Project Life Average Production Cost, US$/Ton-1998

Project	Production Cost					Projected Price
	Variable/ Transport	Direct Fixed	Depreciation	Sales/ Interest	Total	
Individual Projects						
- Phosphate Mining and Concentrate, I	98.5	14.5	25.8	111.4	250.2	130.0 - Bulk
- Fused Magnesium Phosphate, II	162.3	9.9	25.8	128.1	326.1	180.0 - Bags
- Single Super Phosphate, III	127.4	7.7	19.9	79.2	234.2	150.0 - Bulk
Integrated Projects						
- Phosphate Mining and Concentrate, and Fused Magnesium Phosphate, I + II	141.4	19.7	43.8	200.9	405.8	180.0 - Bags
- Phosphate Mining and Concentrate, and Single Super Phosphate, I + III	108.0	16.3	35.8	141.2	301.3	150.0 - Bulk

Base Case: Interest Rate of Long Term Loan; 12.0%/year

The financial analysis for the proposed projects concludes that under the assumed conditions, the projects are not financially viable and give negative returns as well as negative net present values regardless of the interest rate of the long term loan within the range of 4.0% to 12.0% annually.

2.4.2 Economic Evaluation

The economic return is calculated in four steps: estimate of economic project cost, economic annual cost, economic benefits and computation of the return using converted economic data over the financial basic data of the proposed projects.

The economic evaluation are undertaken for the two integrated projects of up-stream and down-stream alternative projects in view of project features in Zambia.

Economic Internal Rate of Return on Investment, %

	EIRROI, DCF, %	
	Low Interest Rate Case, 4.0%/Year	Base Interest Rate Case, 12.0%/Year
Integrated Projects		
- Phosphate Mining and Concentrate, and Fused Magnesium Phosphate, I + II	(-) 10.07	(-) 10.07
- Phosphate Mining and Concentrate, and Single Super Phosphate, I + III	(-) 5.02	(-) 5.02

The net present value, if using cut-off rate of 12%, is negative, too.

The calculated net foreign exchange savings are $1.22 MM for fused magnesium phosphate and $23.63 MM for single super phosphate project as is summarized belows:

Project Life Foreign Exchange Savings, US$, MM/Year - Net Present Value - 1991

	Foreign Exchange for Import of Phosphate Fertilizer	Foreign Exchange Outlays from the Project		Net Foreign Exchange Saving
		Debt Service of Foreign Loan	Foreign Procurement	
Integrated Projects				
- Phosphate Mining and Concentrate Project, and Fused Magnesium Phosphate Project, I + II	87.46	28.49	57.75	1.22
- Phosphate Mining and Concentrate Project, and Single Super Phosphate Project, I + III	84.91	26.91	34.37	23.63

Notes:
- Interest rate for long term loan : 4.0%/Year
- Assumed import price of triple super phosphate : US$286/Ton at Kafue in 1991
- Escalation rate : 3.0%/Year
- Deflator : 3.0%/Year

Although the proposed project will create approximately 200 employment opportunities and will be contributable to technology transfer as well as the regional development in Zambia, the proposed and studied projects will not be contributable to the national economy in Zambia as a whole.

3. CONCLUSION AND RECOMMENDATIONS

3.1 Conclusion

The Feasibility Study on the Establishment of a Fused Magnesium Phosphate Fertilizer Plant in the Republic of Zambia concludes that the proposed projects are technically feasible to recover phosphate concentrate (35,181 TPY, P_2O_5: 30.00%, CaO: 41.11%) in Chilembwe and to produce fused magnesium phosphate [50,400 TPY, (0-20.11-0), P_2O_5 in citric acid soluble] or single super phosphate [57,205 TPY, (0-17.20-0), P_2O_5 in ammonium citrate soluble] by using Chilembwe phosphate concentrate as major inputs in Kafue, Zambia.

However, the financial analysis illustrates that the proposed projects are not financially viable in terms of return on investment as well as cash flow during project life assuming the long term loan interest rates of 4.0 and 12.0%/year, respectively. The return on investments are negative in figure for the proposed projects, and far lower than the pre-determined cut-off rate of project evaluation criteria observed in Zambia at present.

Economic returns on investment are also negative. The net foreign exchange savings as import substitution of phosphate fertilizer are fairly large positive value for the single super phosphate project while marginal for the fused magnesium phosphate project. However it is anticipated that the savings for the fused magnesium phosphate project might be improved if the higher effectiveness of fused magnesium phosphate fertilizer is confirmed at the agronomical testings in Zambia.

The major reasons behind the conclusion are summarized as follows:

- The phosphate reserves in Chilembwe are of small scale and one can not expect the economy of scale for mining and concentration cost saving

- The origin of phosphate reserves in Chilembwe is igneous and low in P_2O_5 analysis, and intensive beneficiation and concentration processes are required to produce phosphate concentrate

- The location of phosphate reserves in Chilembwe is sited in a remote area where transport infrastructure, especially the railways system is not developed and the transport cost by road to the phosphate fertilizer plant in Kafue is excessive

- In addition to the above reasons, due to the depressed international market of phosphate concentrate at present, the domestic cost of phosphate concentrate from Chilembwe is higher than the landed cost of imported phosphate concentrate from overseas where a large scale and high quality reserves are mined at large scale operation

- The production costs of fused magnesium phosphate and single super phosphate are higher than the import substitute price of phosphate fertilizers, because of the small scale production, high costs of phosphate concentrate from Chilembwe as well as high costs of supplementary inputs such as serpentine and sulfuric acid in Zambia, and because of the depressed international market of high concentrated phosphate fertilizers such as triple super phosphate and diammonium phosphate throughout the world at present and in near future

- It should be noted that the project feasibility will not be positive in return on investment even using imported phosphate concentrate as raw material instead of domestic material from Chilembwe

- The sulfur content in single super phosphate is evaluated in product pricing as a fertilizer nutrient for sulfur deficit soil in Zambia, however effectiveness of soluble magnesia, silica and alkali in fused magnesium phosphate is not counted in product pricing because no verifiable experimental data has been developed in Zambia, so far. Therefore, the return on investment for the fused magnesium phosphate project is a little lower

- Among various product alternatives, the feasibility will be higher for the production of nitric phosphate intermediate if the modification of compound fertilizer plant at NCZ in Kafue is technically and financially possible

The proposed and studied projects are technically feasible but financially not viable and economically not justifiable as an immediate industrial and commercial project for import substitution of phosphate fertilizers in Zambia.

3.2 Recommendations

Because of the low financial and economic return on investment for the proposed projects mostly due to the depressed international market of phosphate concentrate as well as phosphate fertilizers at present and near future, the following recommendations are made:

- To wait, for the time being, the project promotion and preparation activities as an immediate industrial and commercial project in Zambia

- To continue survey and study work for the improvement of the project's potential: the discovery of larger and higher quality reserves of phosphate minerals in Zambia and the study on the production of nitric phosphate at NCZ in Kafue

- To promote the agronomical research programs in Zambia for the verification of effectiveness of not only water soluble phosphate as is stipulated in the Agriculture Act of Zambia but also citrate and citric acid soluble phosphate, soluble magnesia, silica and alkali in fertilizer to utilize various kinds of phosphate fertilizer for the diversifying and intensifying agriculture in Zambia

- To promote the efficient procurement and distribution system of fertilizer in Zambia for the agricultural development of Zambia