3.0
Analysis of Alternatives

3.1
Energy Sources

Two energy sources will supply the Project: co-generation from the sulphuric acid plant and the CELTINS Transmission Line (see Section 2.3.3).
The designed Sulphuric Acid plant will be capable of producing 7 Megawatts which facilitates reusing the electrical power consumption in the whole plant. The plant will have a turbo-generator composed of a turbine driven by hot steam and high pressure for generating electricity.

The plant will export superheated steam at 5200 kPa (g) pressure and 473ºC temperature to be used in the co-generation unit. The turbo generator unit will generate electrical energy in a condensing turbine.

3.2
Water Sources Alternatives and Reservoir Locations

The project requires 700 m^3/hr of water. The project options were to obtain groundwater or water from the nearby water bodies. It was evident that groundwater would not provide the high volumes necessary to the process. The flow variations of the water bodies in the municipality of Arraias region are highly seasonal, thus affecting run-of-the-river catchment during dry periods. Therefore the viable solution was to build a water dam.

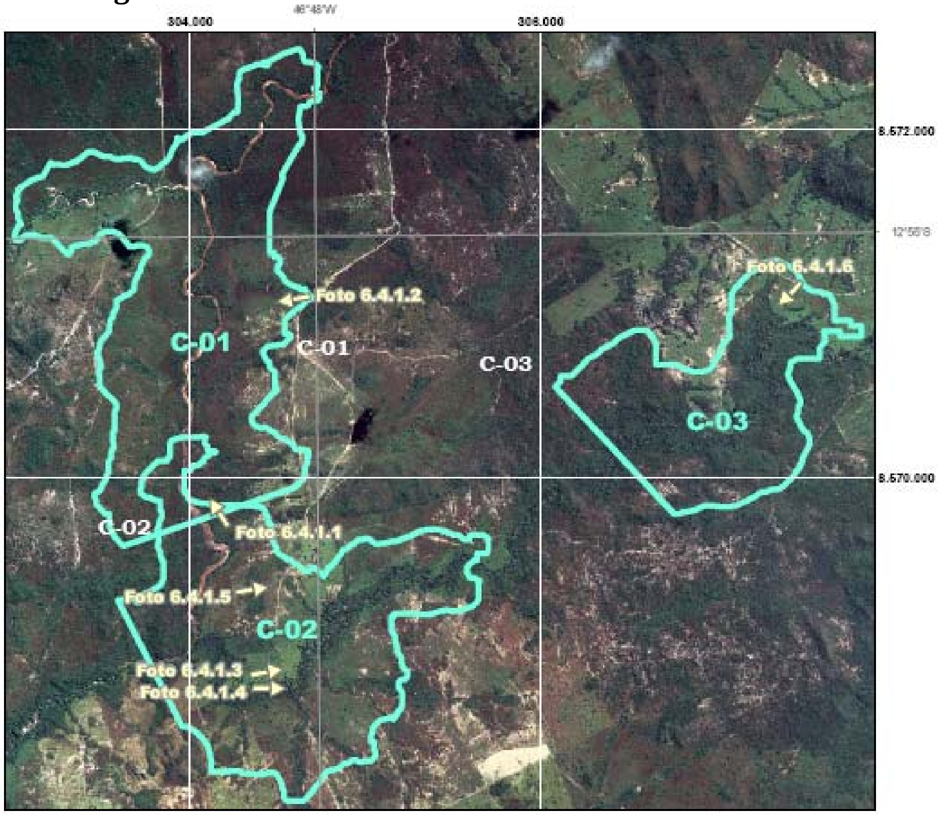
Itafos considered three alternatives for the location of the water dam, as illustrated in **Table 3.2.a** and **Figure 3.2.a.**

As can be seen, alternative C-03 is the closest to the industrial plant site. However, it is by far the one that would require the largest earth movement for dam construction (about 860,000 m3), which rendered this option economically unfeasible. The two other alternatives are at equivalent distances from the industrial plant. However, for a similar volume of stored water, alternative C-02 requires a much smaller dam (only 180,000 m3 of earth movement). Furthermore, it has the advantage of flooding a slightly smaller area and requiring less vegetation clearing than alternative C-01. For these reasons, alternative C-02 was chosen.

Table 3.2.a
Technical data of the water catchment dams

Axis	Purpose	Average distance from Plant (km)	Crest elevation (m)	Reservoir Volume (x 10^6 m³ of Water)	Dam Volume (x10^6 m³ of Earth)	Reservoir/ Dam Volume Proportion	Flood Area (ha)	Reservoir Volume/ Flooded Area	Area of Vegetation Clearing (ha)
C- 01	Bulk Water Caption	7.3	617	7.1	0.41	17.32	250.5	0.02834	255.4
C- 02	Bulk Water Caption	7.8	607	7.3	0.18	40.56	213.7	0.03416	215.1
C- 03	Bulk Water Caption	4.8	660	7.3	0.86	8.49	97.2	0.07510	127.8

Figure 3.2.a
Aerial image with water catchment alternatives



3.3 Tailings Dam Alternative Locations

The tailings dam is the single largest component in the Project's direct footprint, and therefore, the decision on its location was based on thorough alternatives' analysis. The first step of the process focused on two basic location strategies: whether to locate the tailings area outside of natural drainage channels, or whether to install it in one of the valleys near the mining areas. The first option was investigated first, as this was, a priori, considered to be preferable if it was to be proven feasible.

The criteria adopted for analyzing alternatives initially considered the following aspects:

- Average distance from the industrial plant
- Crest elevation
- Reservoir volume
- Volume of the dam mass

Supplementary analysis of dam axis alternatives further considered the following criteria:

- Flooded area
- Ratio of volume/flooded area
- Vegetation impacted by the flooded area
- Population affected by the flooded area
- Distance to material borrow areas
- Geological/geotechnical aspects

The integrated analysis of these conditions resulted in the selected tailings dam location.

In searching for alternative tailings dam locations, a 20-year life-cycle, the planned Project duration at the time, was considered for calculations. Given the Project's final capacity (330,000 tons per annum of 28% P_2O_5 concentrate; 94,000 tons per annum of 15% P_2O_5 concentrate; and 500,000 tons per annum of SSP), volume of tailings to be generated was estimated at $2.5.10^6$ cubic meters per year , totaling $50.8.10^6$ cubic meters over the 20-year period. An average depth of eight meters was adopted for the tailings deposit areas, in order to estimate the approximate size of the area necessary. This resulted in an area of 725 hectares. Analysis of the local topography revealed that relatively flat areas outside of the natural drainage channels are not that large.

The flattest region develops immediately to the north of the site selected for the water reservoir, between the Espraiado Creek and the Bezerra River. A tailings deposit in this region will have to adopt a thoroughly irregular geometry, and it is unlikely that it would be able not to interfere directly with at least parts of the natural drainage system. Additionally, containment of tailings in such an area would require extensive construction of dikes and other structures, requiring large amounts of borrow material and volumes of earth movements that would be significantly larger than those required in the event that a valley were to be used for the tailings. Finally, interference with current land use would be greater, given that these flat regions concentrate significant agricultural activity.

Due to the factors mentioned above, alternative tailings dam locations within the regions' river valleys were searched for. These alternatives would generally allow for a higher average depth of tailings deposits and, hence, for a proportionately smaller footprint. At the same time, the amount of containment works would be much more limited, concentrating on the downstream end of the valleys to be interfered with.

The dam location studies consisted in 10 alternatives.. **Table 3.3.a** presents the technical data of tailings dams' axis.

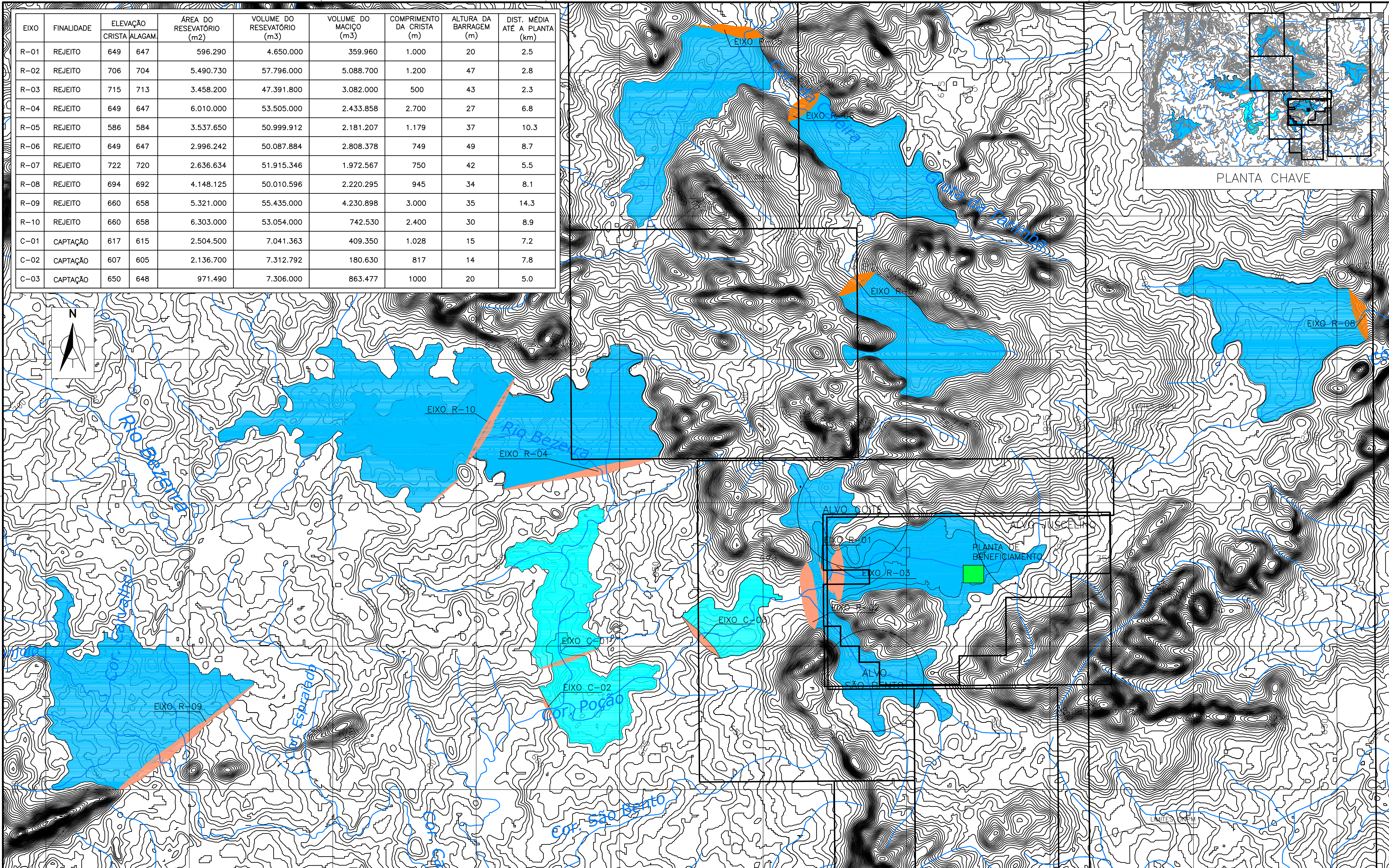
Table 3.3.a
Technical data of tailings dams' axis

Axis	Purpose	Average distance from Plant (km)	Elevation of Crest (m)	Reservoir Volume (x 10^6 m³)	Massif Volume (x10^6 m³)	Volume Proportion Tailing/Massif	Flood Area [1] (ha)	Vegetal Suppression Area[2] (ha)
R-01	Tailing Contention	2.6	690	4.65	0.36	12.9	59,7	82,4
R-02	Tailing Contention	2.3	706	57.8	5.01	11.5	549,1	628,2
R-03	Tailing Contention	2.9	715	47.3	3.1	15.25	345,8	379,7
R-04	Tailing Contention	6.7	649	53.5	2.4	22.3	601,0	765,6
R-05	Tailing Contention	10.3	586	51.0	2.2	23.2	353,8	412,4
R-06	Tailing Contention	8.7	649	50.1	2.8	17.9	299,6	317,9
R-07	Tailing Contention	5.5	722	51.9	2.0	26.0	263,7	283,6
R-08	Tailing Contention	8.2	694	50.0	2.2	22.7	414,8	468,9
R-09	Tailing Contention	14.2	660	55.4	4.2	13.2	532,1	645,9
R-10	**Tailing Contention**	**8.5**	**660**	**53.1**	**1.8**	**29.5**	**433,2**	**737,1**

Figure 3.3.a illustrates the location of those 13 locations (3 for the water catchment dam and 10 for the tailings dam).

All variables and conditionants for the selection of the tailing dam's axis were taken into consideration for the analysis, including necessary vegetation clearing and total reservoir area. The final choice was axis R10, due mostly to the fact that it requires the smallest volume of earth movemen for its construction and the best proportion between earth movement and tailings storage capacity.

EIXO	FINALIDADE	ELEVAÇÃO		ÁREA DO RESEVATÓRIO (m2)	VOLUME DO RESEVATÓRIO (m3)	VOLUME DO MACIÇO (m3)	COMPRIMENTO DA CRISTA (m)	ALTURA DA BARRAGEM (m)	DIST. MÉDIA ATÉ A PLANTA (km)
		CRISTA	ALAGAM.						
R-01	REJEITO	649	647	596.290	4.650.000	359.960	1.000	20	2.5
R-02	REJEITO	706	704	5.490.730	57.796.000	5.088.700	1.200	47	2.8
R-03	REJEITO	715	713	3.458.200	47.391.800	3.082.000	500	43	2.3
R-04	REJEITO	649	647	6.010.000	53.505.000	2.433.858	2.700	27	6.8
R-05	REJEITO	586	584	3.537.650	50.999.912	2.181.207	1.179	37	10.3
R-06	REJEITO	649	647	2.996.242	50.087.884	2.808.378	749	49	8.7
R-07	REJEITO	722	720	2.636.634	51.915.346	1.972.567	750	42	5.5
R-08	REJEITO	694	692	4.148.125	50.010.596	2.220.295	945	34	8.1
R-09	REJEITO	660	658	5.321.000	55.435.000	4.230.898	3.000	35	14.3
R-10	REJEITO	660	658	6.303.000	53.054.000	742.530	2.400	30	8.9
C-01	CAPTAÇÃO	617	615	2.504.500	7.041.363	409.350	1.028	15	7.2
C-02	CAPTAÇÃO	607	605	2.136.700	7.312.792	180.630	817	14	7.8
C-03	CAPTAÇÃO	650	648	971.490	7.306.000	863.477	1000	20	5.0



NOTAS

1 – TODAS AS ELEVAÇÕES ESTÃO EM METRO.
2 – RESTITUIÇÃO TOPOGRÁFICA FORNECIDA PELA ITAFÓS

DOCUMENTOS DE REFERÊNCIA

1 – PARA DETALHES DAS BARRAGENS R-04 E R-10, VIDE DESENHO IO-100-DS-20600;
2 – PARA DETALHES DAS BARRAGENS C-01, C-02 E C-03, VIDE DESENHO IO-100-DS-20601;

REVISÕES

REV.	T.E.	DESCRIÇÃO	PROJ.	DES.	VER.	APR.	DATA
00	C	EMISSÃO FINAL PARA O CLIENTE	TMV	IPM	PL	RJB	08/07/10
0A	B	PARA APROVAÇÃO	TMV	IPM	PL	RJB	22/02/10

T.E. TIPO DE EMISSÃO
(A) PRELIMINAR (B) PARA APROVAÇÃO (C) PARA CONHECIMENTO (D) PARA COTAÇÃO (E) PARA CONSTRUÇÃO (F) CONFORME COMPRADO (G) CONFORME CONSTRUÍDO (H) CANCELADO

PIMENTA DE AVILA
CONSULTORIA LTDA

PROJETO FOSFATO ITAFÓS

ESTUDO CONCEITUAL
PROJETO FOSFATO SEDIMENTAR – CAMPOS BELOS/GO
ESTUDO LOCACIONAL DO EIXO DAS BARRAGENS DE REJEITO E CAPTAÇÃO
ARRANJO GERAL
PLANTA E QUADRO

FIGURA 3.3.a

ESCALA	SE	Nº CONTRATADA	Nº CLIENTE	REVISÃO
30000	–	IO-100-DS-20599-00		00

PE-G-601 – Rev 2 (A1)

3.4
Alternative Fertilizer Plant Site

Basic criteria taken into account for location were:

- Absence of ore: Except for a small mineral portion in one of the site ends, no relevant amounts of ore. Such situation was confirmed by exploration that excluded the area for reserve purposes;

- Using the relief: The Project will rely on the gravitational flow of materials to save energy for transportation of materials. Project components were set in different altitudes so as to facilitate the transport of pulp and dry materials;

- Geographical distribution of reserves: a site close to the geographical center of ore reserves was chosen (see **Figure 2.6.1.a**)

3.5
Alternative Process Technologies

Since natural phosphate ore has low levels of P_2O_5 concentration, it must be processed to increase the P_2O_5 concentration as required to produce Super Simple Phosphate (SSP). This involves separating the apatite from ore with a phosphate concentration below the standards to allow economic viability of its use for SSP production.

Itafos selected flotation concentration as the concentration technology since this is the only concentration technique available at an industrial scale for processing the phosphate mineral. In this technique, air bubbles selectively adhere to particles rich in a certain mineral and take them to the surface of a watery bed while the particles of other minerals sink,

Flotation technique allows two primary types of flotation cells:

- Mechanical cells: Churned tanks, with similar in vertical and horizontal dimensions, where pulp aeration occurs with rotor movement that sucks air to the interior of the cell;
- Column cells: Tanks with no churning, longer vertically than they are horizontally and aerated through injections of compressed air.

The flotation plants prefer column cells because thei offer the following advantages:

- Energy savings: The columns do not need motors and churning mechanisms;
- Space savings: Because of their elongated shape, a single column facilitates the same flotation probability as a set of several mechanical cells of similar size.

Due to these advantages, PROJECT ARRAIAS has choosen to use the flotation columns for the phosphate ore concentration.

Alternative Technologies for Production of Sulphuric Acid

There are two distinct technologies for producing sulphuric acid:

- Wet sulphuric acid production or WSA ("Wet Sulphuric Acid"); and
- Dry sulphuric acid production.

Wet Sulphuric Acid (WSA) Plant Technology is a wet catalytic process which recovers SO2 as concentrated sulphuric acid. Drying of the flue gas is not required in this technique. The energy of the gas phase hydration from SO3 to H2SO4 gas and the condensation energy of the H2SO4 are recovered in the form of hot air that is used for the combustion of sulphur and to preheat the boiler feed water. This leads to an increased rate of steam production compared to the dry gas process.

In the dry process, this heat is traditionally lost in the cooling water. The feedstock for the WSA process is wet SO2 gas.

The most pronounced advantages of the WSA process are described below:

- Energy efficiency

  The WSA process has much higher energy efficiency. Energy is recovered partly in the form of high pressure steam and partly in the form of hot air that can be used e.g. as combustion air. Only the cooling duty of the produced sulphuric acid is lost with cooling water.

  The plant will export superheated steam at 5200 kPa (g) pressure and 473ºC temperature to be used in the co-generation unit. The turbo generator unit will generate electrical energy in a condensing turbine. A small portion of low pressure steam will be extracted from the turbine casing. This low pressure steam at 600 kPa will be used for the sulphur melting and de-aerator needs. The balance of the steam flow will be condensed at the exit of the turbo-generator and returned as make-up to the de-aerator.

- No by-products

  Since the process gas does not have to be dried in the WSA process, there is no loss of sulphuric acid and no generation of sour waste water.

The WSA technology has the following limitations:

- limited SO_2 content in feed gas, and
- limited conversion efficiency

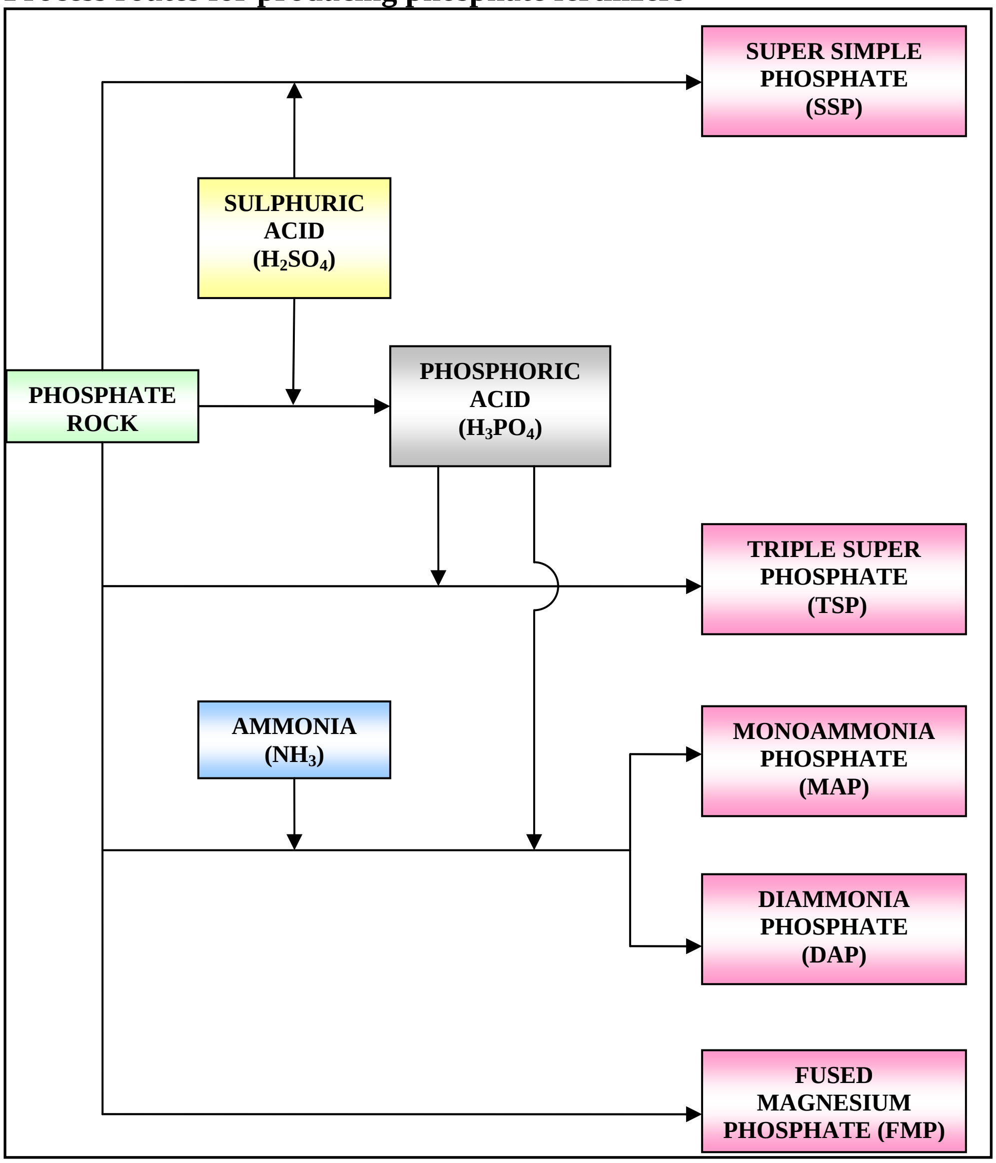
However, since the benefits are more significant ITAFOS has choosen the WSA technology for the production of sulphuric acid.

<u>Alternative Technologies for Producing SSP</u>

Production of SSP from phosphate rock and sulphuric acid has alternative technologies that produce other phosphate fertilizers, as shown in **Figure 3.5.a**, in which two principal routes can be observed:

- Wet routes: The phosphate rock is digested by sulphuric acid;
- Thermal routes: Production of soluble compounds from phosphate rock through calcination or fusion, thus generating fused magnesium phosphates (FMP).

Figure 3.5.a
Process routes for producing phosphate fertilizers



Most of the fertilizers produced in Brazil are obtained through wet routes. The simplest process is attaining simple super phosphate through the reaction of phosphate rock with sulphuric acid.

The choice of SSP production in PROJECT ARRAIAS is due to the simplicity of the production process compared to that of other phosphate fertilizers. Its consolidated presence in the Brazilian agricultural market makes it the most highly-produced fertilizer in the country.