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BIO-OXIDATION OF SAND SIZED ORE

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ABSTRACT

A new treatment option for refractory sulfide gold ores has been developed. The new process, identified as Sand Farming, consists of the pond bio-oxidation of sand sized ore. Gold can subsequently be extracted by heap leaching, vat leaching and/or agitated tank leaching.

Gold extractions exceeding 85% have been achieved for all pyrite and arsenopyrite ores tested. Gold and copper extractions exceeding 75% have been achieved for one enargite ore tested.

Test work has included mesophile (40°C), moderate thermophile (55°C) and extreme thermophile (65°C) bacterial cultures. Detailed hydrodynamic test work has also been completed of the Sand Farming optimum particle size distributions.

Pre-feasibility level economic evaluations for multiple projects have indicated favorable project economics for Sand Farming treatment in each case with estimated capital and operating costs in the range of ½ to ⅔ to those of tank bio- oxidation and pressure oxidation treatment.

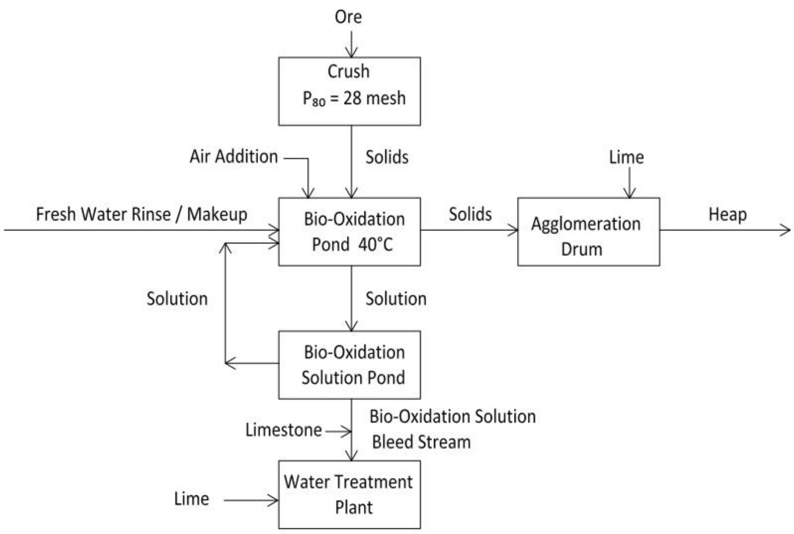
Description

- Enhanced natural bio-oxidation of sand sized sulfide ore
- Sulfide oxidation levels up to 85% achieved in lab scale testing
- Gold extractions of plus 85% for all ore types tested (total of 7 ore types)
- Sulfide sulfur concentrations ranging from 3% to 7% in ores tested

Description

- Mesophile (40°C) bacteria cultured from site sulfides
- Successful lab scale testing of moderate thermophile (50° C) and extreme thermophile (65° C) bio-oxidation
- Bio-reactor plastic lined pond
- Reactor retention times 30-90 days

Sand Farming Block Flow Diagram



Au EXTRACTIONS

(MAX Oxidation Level for Each Particle Size)

- P_{80} = 2 inch → **55% to 60% Au EXT**
- P_{80} = ¾ inch → **60%** to **65%** Au EXT
- P_{80} = ¼ inch → **65% to 70 % Au EXT**
- P_{80} = 10 mesh → Plus 85%

Mesophiles (40ºC) Mineral Gold Extractions

- Ultimate gold recovery primarily dependent on sulfide mineralogy
- Plus 90% of gold associated with arsenopyrite and sphalerite extracted

  < 10% of pyrite oxidized
- Plus 85% of gold associated with pyrite extracted at plus 80% pyrite oxidation

Mesophiles (40ºC) Mineral Gold Extractions

- Plus 85% ultimate gold recovery typical when gold is associated with these sulfide minerals
- Enargite oxidation requires extreme thermophiles (65ºC)

Cost Savings

- Comminution
- Flotation
- Power
- Labor
- Acid Neutralization

Project in Mexico

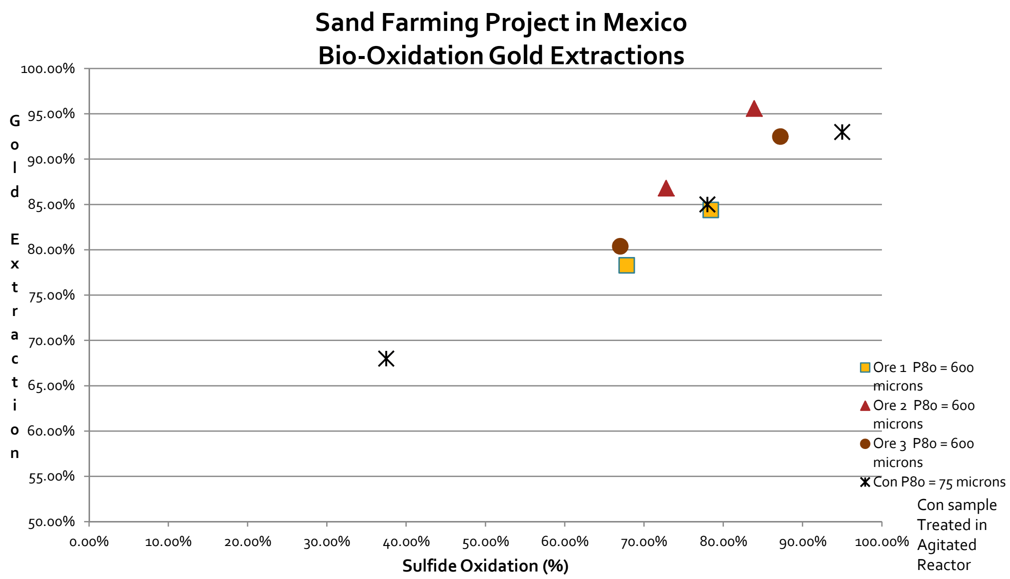
- Roasting test work unsuccessful
- Flotation gold recovery = 92%
- POX of float con gold recovery = 95% @ 97% sulfide oxidation

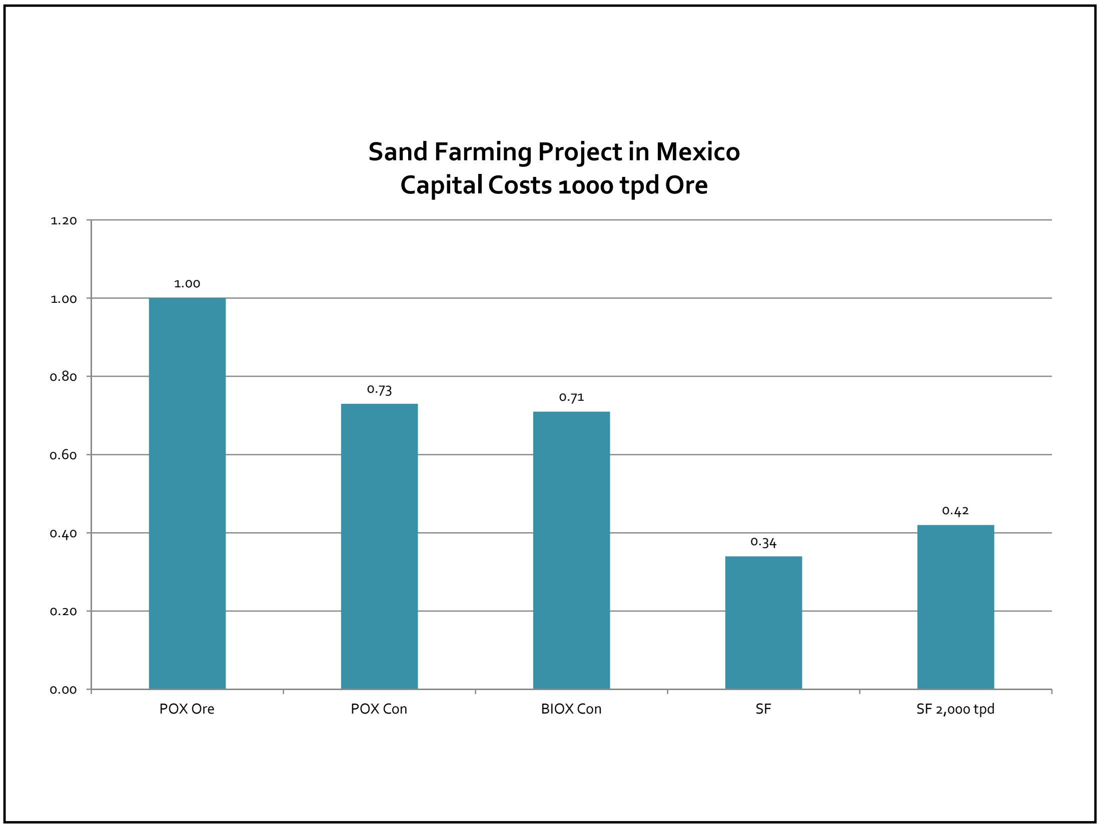
  Overall gold recovery = **87.4%**
- BIOX of float con gold recovery = 92% @ + 95% sulfide oxidation

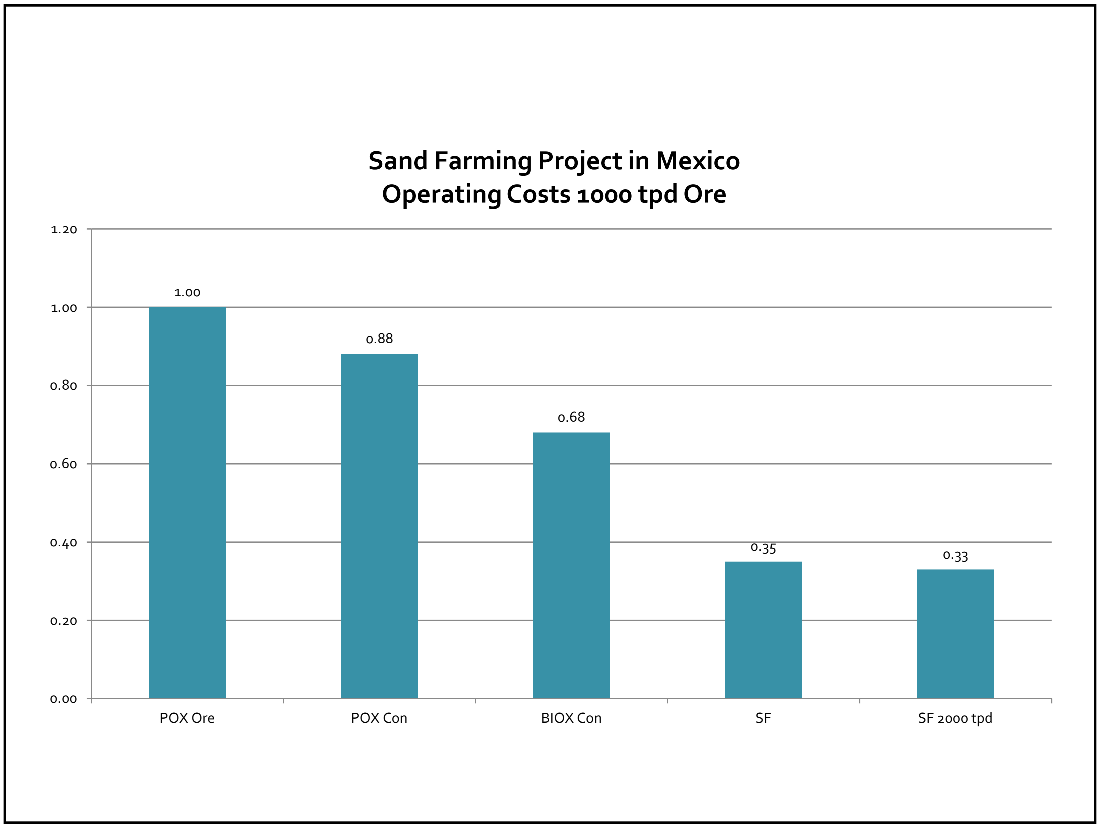
  Overall gold recovery = **84.6%**

Project in Mexico

- POX of whole ore gold recovery = **95%** @ +97% sulfide oxidation
- Sand Farming of whole ore gold recovery = **90%** @ 85% sulfide oxidation




Sand Farming Project in Mexico
Capital Costs 1000 tpd Ore
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1.00
0.73
0.71
0.34
0.42
POX Ore
POX Con
BIOX Con
SF
SF 2,000 tpd


Sand Farming Project in Mexico
Operating Costs 1000 tpd Ore
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1.00
0.88
0.68
0.35
0.33
POX Ore
POX Con
BIOX Con
SF
SF 2000 tpd

Evaluation Process

- Bio-amenability testing
- Diagnostic leach analysis
- Lab scale bio-oxidation
- Bottle roll cyanidation
- Hydrodynamic testing
- Pilot scale testing

CURRENT STATUS

- Test Results
- Pilot Scale Planning and Design
- Commercial Scale Plant Design
- Assembled Development Team
- Sand Farming Services and Business Arrangements Available

SAND FARMING DETAILS

A general description of the Sand Farming treatment process and an example case of projected Sand Farming economics verses pressure oxidation and tank bio-oxidation is presented in the power point presentation titled "Bio-Oxidation of Sand Sized Ore". This document is meant to be an addendum to that presentation.

The purpose of this document is to provide detailed information regarding the facilities and operating procedures of the refractory ore treatment process identified as Sand Farming. Sand Farming consists of the bio-oxidation of "sand" sized ore in a simple plastic lined pond bio-reactor. The "sand" reference relates to the ore particle size utilized in this process which is similar to that of manufactured sand, approximately P_{80}= 650 microns.

A flow sheet of the Sand Farming treatment process is presented in Figure 2 – Sand Farming. This flow sheet depicts an operation that would be utilizing a mill to produce the P_{80}= 650 microns ore feed. The ore feed could also be produced with a crushing circuit, with an HPGR system as the final step being the preferred crushing option.

The crushed ore is fed to an agglomeration drum and agglomerated with active bio-oxidation solution and loaded into the bio-reactor pond to produce a high performance free-drained ore bed with an equal balance of micropores and macropores. Ore beds with an equal balance of micropores and macropores have been shown to be most ideal for free drained bio-oxidation. Detailed information regarding the role of micropores and macropores in bio-oxidation can be found in the paper "Hydrodynamic Properties of Ore for Leach" authored by Amado Guzman July 7, 2012

Once the pond bio-reactor is loaded with agglomerated ore to a typical bed depth of 5 meters, recirculated bio-oxidation solution is added to the top of the ore bed with drip emitters and air is blown into the bottom of the ore bed through a manifold system with a high-volume low-pressure blower. Air addition system consists of the permanent manifold that runs along each side of the pond bio- reactor and disposable drip emitters with the appropriate opening size run perpendicular to the manifold out into the bottom of the ore bed on one meter centers. A constant level of solution is maintained in the bio-reactor drainage system to ensure that air does not short circuit out the solution drainage system. The bottom of each bio-reactor pond is sloped and covered with an adequate quantity of drainage material to maintain free drained conditions through the ore bed.

Bio-oxidation solution is recirculated through the ore bed and air is added to the bottom of the ore bed for the entire bio-oxidation cycle which is typically 30 to 60 days.

Following the bio-oxidation cycle, the ore is rinsed with a chemical rinse that removes reaction products that would consume excess cyanide during the subsequent cyanidation leach cycle. Finally the ore is rinsed with fresh water and removed hydraulically or alternatively air dried with the air addition system and mechanically unloaded from the bio-reactor pond.

The bio-oxidized and rinsed ore then reports to the cyanidation circuit or circuits for leaching. Typically the ore would be classified into slime and sand fractions with slimes reporting to a CIL circuit and the sands reporting to a simple sand vat leach circuit. Alternatively for operations with existing heap leach circuits a portion or the entire quantity of bio-oxidized rinsed ore could report to the heap leach circuit for alkaline agglomeration with the heap leach feed.

Continuous bio-reactor pond loading and unloading is accomplished by the utilization of multiple bio-reactor ponds with one of the ponds always in a loading stage and one of the ponds always in an unloading stage with the remainder of the bio-reactor ponds at various stages of the bio-oxidation cycle. A typical bio- reactor pond general arrangement is presented in Figure Conceptual General Arrangement.

The total number of bio-reactor ponds would typically be in the range of six to ten. As one of the ponds is always in the loading phase and one of the ponds is always in the unloading phase, the incorporation of six or more ponds results in a higher percentage of the overall bio-reactor pond volume operating in the bio- oxidation phase at any given time.

A typical Sand Farming treatment facility includes the following components.

- Ore Crushing and Agglomeration Circuit
- Target ore particle size is 80% passing approximately 650 microns
- Bio-Reactor Pond Loading System
  - Typically this would consist of a conveyor system
- Bio-Oxidation Circuit
  - 6 to 10 plastic lined bio-reactor ponds
  - One or two bio-oxidation solution ponds
  - Bio-oxidation solution recirculation piping and pumps
  - High-volume low-pressure blower
- Bio-Reactor Pond Unloading System
  - Either slurry pump system for hydraulic unloading or a mechanical system to unload ore after partial drying with air addition

The overall footprint for all components of a typical 2,000 tonne per day Sand Farming treatment facility with 8 bio-reactor ponds and a 60 day bio-oxidation cycle would be approximately 80,000 square meters.

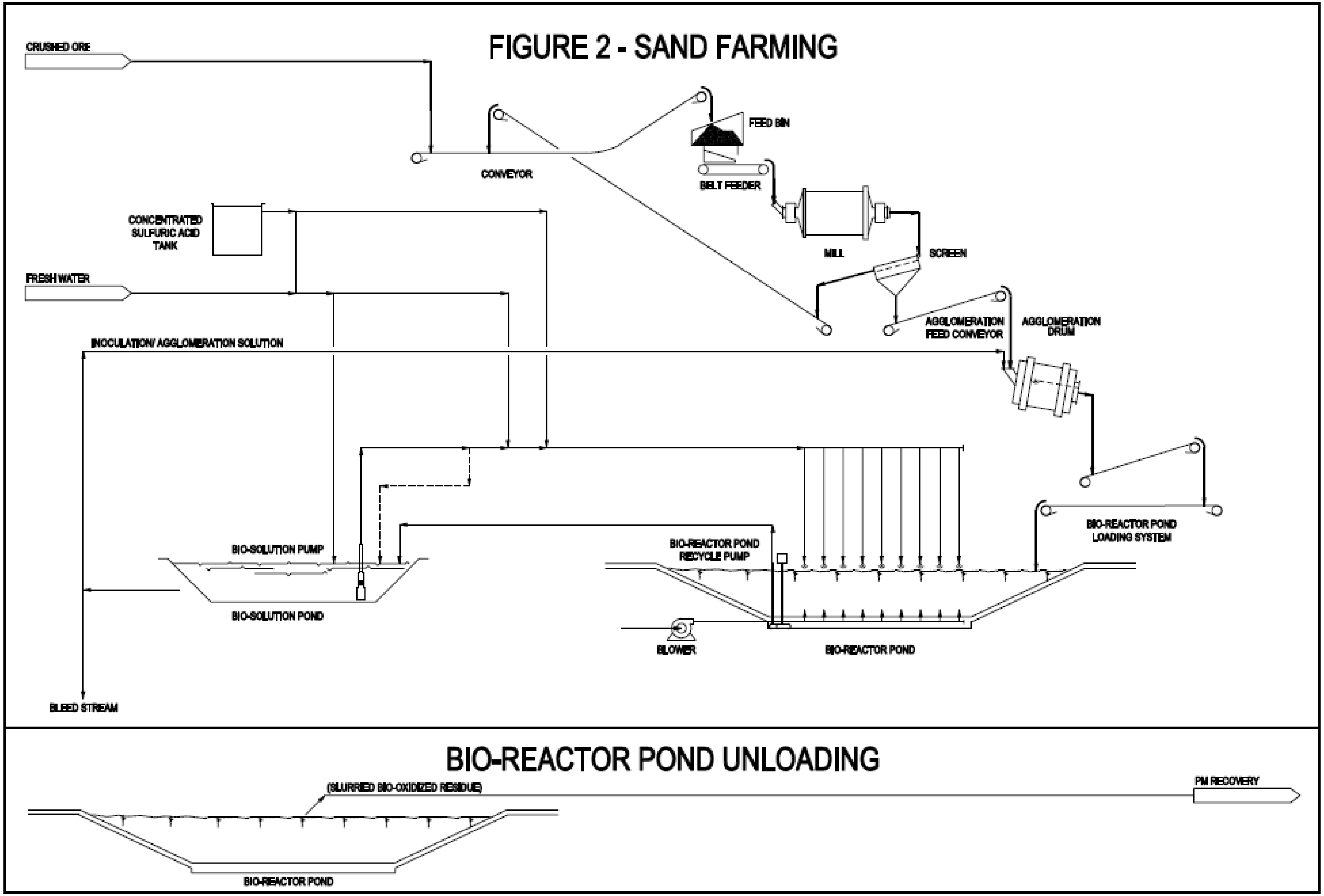
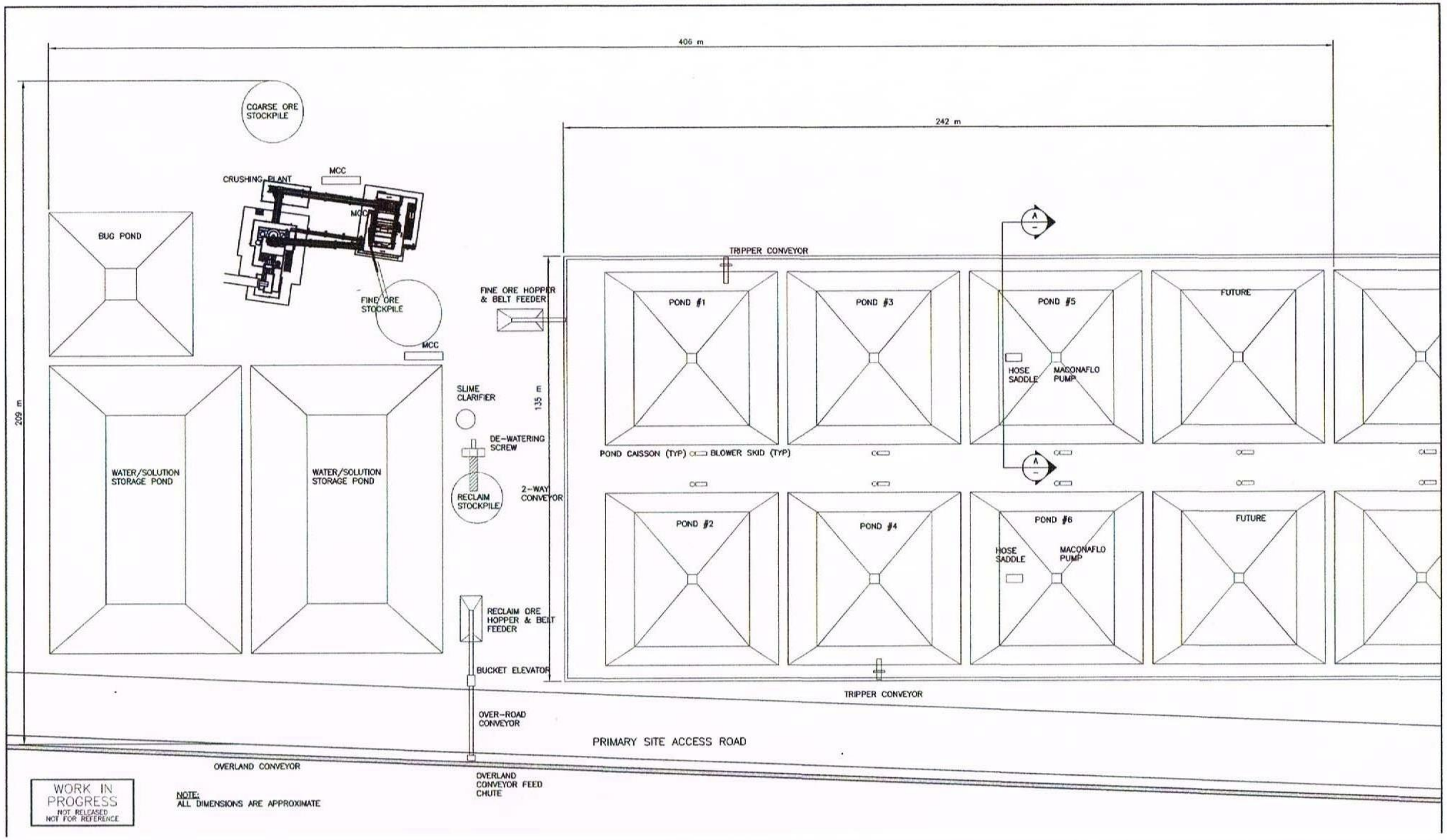


FIGURE 2 - SAND FARMING
CRUSHED ORE
CONVEYOR
FEED BIN
BELT FEEDER
MILL
SCREEN
CONCENTRATED SULFURIC ACID TANK
FRESH WATER
INOCULATION/ AGGLOMERATION SOLUTION
AGGLOMERATION FEED CONVEYOR
AGGLOMERATION DRUM
BIO-REACTOR POND LOADING SYSTEM
BIO-SOLUTION PUMP
BIO-SOLUTION POND
BIO-REACTOR POND RECYCLE PUMP
BLOWER
BIO-REACTOR POND
BLEED STREAM
BIO-REACTOR POND UNLOADING
(SLURRIED BIO-OXIDIZED RESIDUE)
PM RECOVERY
BIO-REACTOR POND


406 m
242 m
COARSE ORE STOCKPILE
CRUSHING PLANT
MCC
BUG POND
FINE ORE STOCKPILE
MCC
FINE ORE HOPPER & BELT FEEDER
TRIPPER CONVEYOR
POND #1
POND #3
POND #5
FUTURE
HOSE SADDLE
MACONAFLO PUMP
SLIME CLARIFIER
135 m
209 m
DE-WATERING SCREW
WATER/SOLUTION STORAGE POND
WATER/SOLUTION STORAGE POND
POND CAISSON (TYP)
BLOWER SKID (TYP)
RECLAIM STOCKPILE
2-WAY CONVEYOR
POND #2
POND #4
POND #6
FUTURE
HOSE SADDLE
MACONAFLO PUMP
RECLAIM ORE HOPPER & BELT FEEDER
BUCKET ELEVATOR
TRIPPER CONVEYOR
OVER-ROAD CONVEYOR
PRIMARY SITE ACCESS ROAD
OVERLAND CONVEYOR
OVERLAND CONVEYOR FEED CHUTE
WORK IN PROGRESS
NOT RELEASED
NOT FOR REFERENCE
NOTE:
ALL DIMENSIONS ARE APPROXIMATE