Raw data

1. User Inputs

- Gold head grade (grams/tonne)
- Particle size distributions
  - P50 value (microns)
  - P10 value (microns)
  - P80 value (microns)
- Ore mineralogy (% for each)
- Iron
- Arsenic
- Copper
- Zinc
- Lead
- Calcium
- Iron
- Silicon
- Potassium
- Aluminum
- Sodium
- Sulphur

- Throughput: tph or tpd

- Reagents:
 CN(kg/t),
 Lime(kg/t),
 Collector A(g/t),
 Collector B(g/t),
 Frother(mL/t)

2. Ore Classification

- Program analyzes minerals to determine ore type
 Ore Classification Percentages:
- Pyrite
  - Iron 40%+
  - Sulphur 40-50%
- Arsenopyrite
  - Arsenic 33%+

  - Iron 25-30%
  - Sulphur 35-40%
- Chalcopyrite
  - Copper 35%+
  - Iron 15-20%
  - Sulphur 35-45%
- Sphalerite
  - Zinc 50%+
- Galena
  - Lead 85-90%
- Calcite
  - Calcium carbonate 80%+
- Siderite
  - Iron carbonate 75%+
- Quartz
  - Silica 90%+
- Feldspars
  - Individual oxides (K, Na, Ca) 60%+
- Montmorillonite
  - Total Al and Ca oxides 12%+
- Kaolinite
  - Aluminum 38-45%
  - Silicon 46-52%

3. Flowsheet Selection
- Database retrieves relevant flowsheet based on:
  - Ore type
  - Grade & size ranges
  - Key mineral makeup

4. Process Models
A. Cyanidation
Rate of Gold Dissolution:
$d[Au]/dt = k[Au][CN^-]$
Where:
$k = A*\exp(-E_a/RT)$

Arrhenius Equation:

$k = A*exp(-Ea/RT)$

The rate constant k is calculated using the Arrhenius equation:

$k = A*exp(-Ea/RT)$

Where:
A = pre-exponential factor, typically 1011 m3/g-min
Ea = activation energy, usually 50 kJ/mol
R = universal gas constant, 8.314 J/mol-K
T = temperature in Kelvin

Carbon Adsorption:
Langmuir Equation:
$q = (q_{max}*b*C) / (1+b*C)$

B. Flotation
Collection Efficiency:
$\alpha = 1/(1 + exp((Eb/kT)))$

DLVO Theory:
$Eb = Evdw + Eedl$
$Evdw = -A*(H1*H2/(H1+H2))$
$Eedl = (2*\pi*\varepsilon o*\varepsilon r*\zeta 1*\zeta 2)*exp(-\kappa*H) / (1+\kappa*H)$

For the Evdw term:

$-A*(H1*H2/(H1+H2))$

The Hamaker constant (A) can range from 10-20 x 10-20 Joules.

Particle size (H1) is usually 1-100 µm.
Bubble size (H2) is typically 50-200 µm.

For the Eedl term:

$(2*\pi*\varepsilon o*\varepsilon r*\zeta 1*\zeta 2)*exp(-\kappa*H) / (1+\kappa*H)$

The permittivity of free space (ε_o) is a constant at 8.85×10^{-12} $C^2/N\text{-}m^2$.

The relative permittivity (ε_r) of process water ranges from 2-10.

Zeta potentials (ζ_1 and ζ_2) on particle and bubble surfaces usually fall between ±10-100 mV.

The inverse Debye length (κ) is commonly 10^8-10^{10} m^{-1}.

The separation distance (H) in colloid systems is on the nanoscale, around 1-1000 nm.

C implicitly using the integrated rate law formula:

$$C = C^* - (C^* - C_0)e^{-kt}$$

Where:
C_0 = initial concentration in pulp/feed
C^* = equilibrium/maximum concentration (65-90% of the head grade.)
k = rate constant from Arrhenius equation
t = time.

C. Gravity
Particle Settling:
$$v = g*(\rho_p - \rho_f)/18*\mu * d^2$$

The variables are:
v = terminal settling velocity
g = acceleration due to gravity, 9.81 m/s^2
ρ_p = particle density, 2500 - 4000 kg/m^3
ρ_f = fluid density, approximately 1000 kg/m^3
μ = fluid viscosity, ranging from 0.0005-0.005 Pa·s
d = particle diameter

D. Heap/CIL/CIP
Leaching:
Same as cyanidation above

Dynamic Tank Model:
$$dV/dt = F_{in} - F_{out}$$

$dC/dt = (FinCin - FoutCout)/V + R - kC$

Dynamic Tank Model:

$dV/dt = Fin - Fout$

Fin = Inlet flow rate (m3/hr)
Range: Depends on tank size, usually 0.5-50 m3/min or 50-5000 m3/hr

Fout = Outlet flow rate
Calculated from volume and residence time (5-60 min typical)

$dC/dt = (FinCin - FoutCout)/V + R - kC$

Cin = metal concentration entering tank (g/L)
Ranges: 0.1-10 g/L

Cout = metal concentration leaving tank (g/L)
Calculated based on recovery performance

V = volume in tank (m3)
Ranges: 10-1000 m3

R = metal recovery/extraction rate (g/L-hr)
Estimated using leach kinetics rate equations

k = metal dissolution/desorption rate constant (1/hr)
Ranges: 0.001-0.1 1/hr

Carbon Contact:
Forward: k1CQ
k1 range: 0.005 - 0.015 L/g-min

Reverse: k-1Q
k-1 range: 0.0025 - 0.0075 1/min

For carbon saturation Q:

$Q = Q0 * e^{(-k3*t)}$

Q0 range: 50 - 150 mg metal/g carbon
k3 range: 0.0005 - 0.0015 1/min
t is time elapsed.
The C concentration in the dynamic tank model is calculated from:

$C = C^* - (C^* - C0)e-kt$

C0 range: Head grade +/- 20%
C* range: 70-95% of C0
k from Arrhenius equation: A=1011, Ea=30-80 kJ/mol

E. Comminution:
- Bond Work Index (kWh/t) = 13.048*(P80)-0.4915

5.
Comminution:
  R_comminution = 100 * (1 - e^(-k_comminution * t))
  where k_comminution = A * e^(-E_a/(R*T))

Cyanidation:
  R_cyanidation = 100 * (1 - e^(-k_cyanidation * t))
  where k_cyanidation = A * e^(-E_a/(R*T))

Flotation:
  R_flotation = 100 * (1 - e^(-k_flotation * t))
  where k_flotation = 1 / (1 + e^((-A * (H1*H2)/(H1+H2)) + (2 * π * ε_0 * ε_r * ζ_1 * ζ_2) * e^(-κ*H) / (1 + κ*H)) / (k*T))

Carbon Adsorption:
  R_adsorption = 100 * (1 - e^(-k_adsorption * t))
  where k_adsorption = (q_max * b * C) / (1 + b * C)

Heap/CIL/CIP Leaching:
  R_leaching = 100 * (1 - e^(-k_leaching * t))

where $k\_leaching = A * e^{(-E\_a/(R*T))}$

Gravity Separation:

$R\_gravity = 100 * (1 - e^{(-k\_gravity * t)})$

where $k\_gravity = \alpha * (g * (\rho\_p - \rho\_f) * d^2) / (18 * \mu)$

Total Recovery Rate:

Rt = Rc + Rcyan + Rf + Ra + Rl + Rg - Rc* Rcyan - Rc * Rf- Rc* Rl - Rc * Rg- Rcyan * Rf - Rcyan * Rl - Rcyan* Rg - Rf * Rl - Rf * Rg - Rl * Rg+ Rc* Rcyan * Rf + Rc * Rcyan* Rf + Rc * Rcyan * Rg + Rc * Rf * Rl + Rc * Rf * Rg+ Rc* Rl * Rg + R_c * Rf * Rl + Rcyan * Rf * Rg + Rcyan * Rf * Rg + Rf * Rl* Rg - Rc * Rcyan * Rf * Rl - Rc * Rcyan * Rf * Rg - Rc * Rcyan * Rl * Rg - Rc * R_flotation * Rl * Rg - Rcyan * Rf * Rl * Rg + Rc * Rcyan * Rf * Rl * Rg

Constants:
- Gravity recovery limits = 95-98%
- Leach residence times = 6-72 hrs
- Equipment throughputs in tph
- Bond Work Index ranges by ore type = 10-18 kWh/t
- Carbon loading capacities = 25-50 g Au/t
- Reagent consumptions per tonne of ore

Parameters:
- Rate constants (k) from batch tests = 0.01-1 hr-1
- Process water requirements in m3/hr
- Energy inputs by unit operation

6. Total Recovery Projection
- Monte Carlo simulations varying inputs 1000 times
- Returns mean, standard deviation, confidence intervals

7. Optimization Simulation
- Adjusts parameters over ranges to maximize recovery