Estimating Solute Release from Mining Operations

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BACKGROUND

- NEW MINE CHANGES LANDSCAPE
  - Physical
  - Geochemical

- NEW MINING CONCERN

  Water quality impacts

Some Pits Serve as Municipal Water Supply

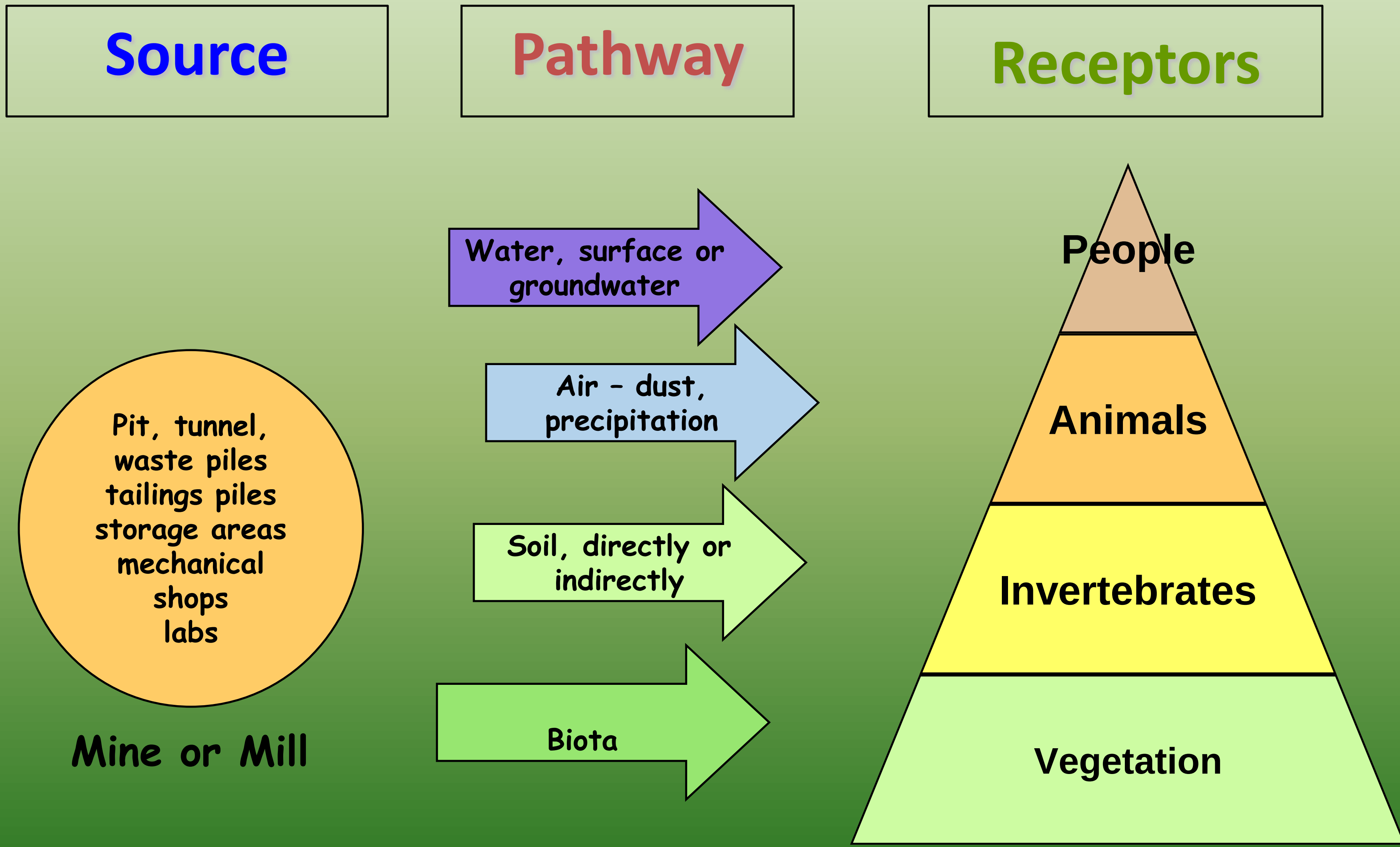
Other Pits Don’t

BACKGROUND

TO ADDRESS CONCERN

- NEED PRIOR TO OPERATION
  Estimates of solute release from source terms

- ESTIMATES USED
  - Impact assessment
  - Mitigation design
  - Financial assurance



From Carol Russell

BACKGROUND

- MINE WASTES OF CONCERN
  - Mine
  - Waste Rock
  - Tailings
  - Metallurgical wastes
  - Other

BACKGROUND

- WATER QUALITY CONCERNS
  - Acidic drainage
  - Neutral drainage with heavy metals
  - Neutral drainage with sulfate
  - Process related solutes

OBJECTIVE: ESTIMATE SOLUTE RELEASE FROM MINE WASTES

GENERAL APPROACH

1. Determine baseline conditions
2. Impose mine plan
3. Mine waste geochemical characterization
   3.1. Existing information
   3.2. Conduct tests (some peripheral information)
4. Develop model to estimate release

1. BASELINE CONDITIONS

- Water quality
- Hydrology
  - Surface
  - Ground water
- Soils
- Glacial overburden
- Bedrock
- Climate (Precipitation, Temperature)
- Topography
- Other

2. IMPOSE MINE PLAN

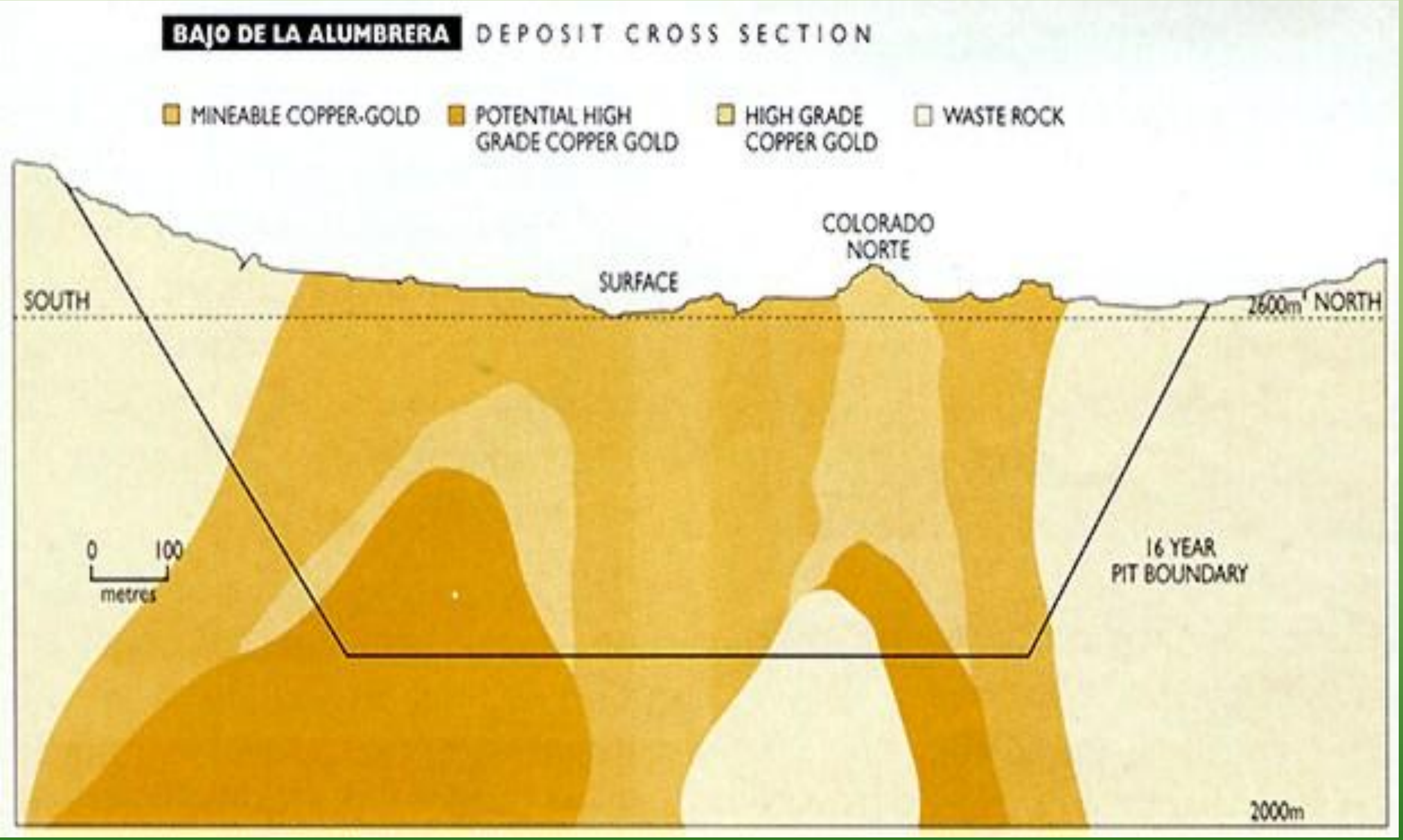
2.1. Conventional economic components

- Mine → → Ore
- Mineral Processing → → Concentrate
- Metallurgy → → Refined product

2. IMPOSE MINE PLAN

2.2. Environmental components

- Mine → →
  - Mine walls and floor
  - Waste rock
- Mineral processing → → Tailings (coarse, fine)
- Metallurgy → →
  - Slag
  - Hydrometallurgical wastes



BAJO DE LA ALUMBRERA
DEPOSIT CROSS SECTION
MINEABLE COPPER-GOLD
POTENTIAL HIGH GRADE COPPER GOLD
HIGH GRADE COPPER GOLD
WASTE ROCK
COLORADO NORTE
SURFACE
SOUTH
2600m
NORTH
0
100
metres
16 YEAR PIT BOUNDARY
2000m

2. IMPOSE MINE PLAN

2.2. Environmental components

Waste Rock Information for Modeling

- Rock units present
- Mass of rock units
- Compositional variation of rock units

2. Impose Mine Plan

2.2. Environmental Components

- Drill core data for waste rock
  - Logging (e.g. rock types, visual examination)
  - Chemical analysis
  - Mineralogy/Petrology
- Mineral processing pilot tests
- Metallurgical processing pilot tests

2. IMPOSE MINE PLAN

2.3. Mine Waste Management

- Water treatment
- Covers
  - Soil + Vegetation
  - Clay
  - Geotextiles
- Subaqueous

3. Geochemical Characterization

3.1. Existing information: Rock → Water

- Baseline water quality
- Soil signatures
- Vegetative signatures
- Geological description
- Geoenvironmental model
  - Solute release related to rock composition
  - Solute release related to mining and processing

3. Geochemical Characterization

3.1. Existing information

- Drill core data for waste rock
- Mineral processing pilot tests
  - Tailings composition
  - Water quality
  - Release rates
- Metallurgical processing pilot tests

3. Geochemical Characterization

3.2. Conduct tests

- Why?
  - Better understand rock → water quality

- On what?
  - Drill core
  - Tailings from mineral processing tests
  - Wastes from metallurgical tests

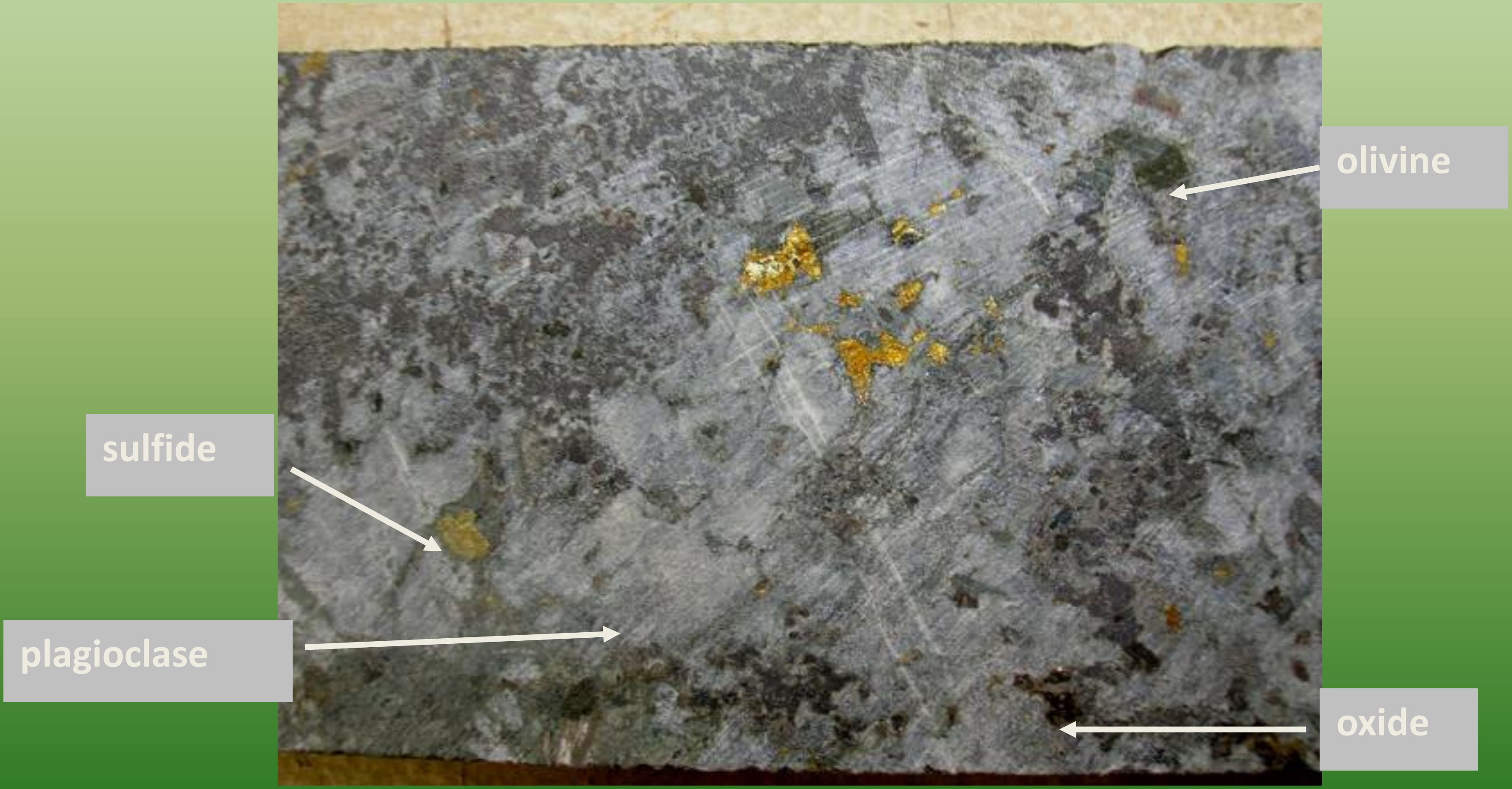
3. Geochemical Characterization

3.2. Conduct tests

Drainage quality = f(solid-phase characteristics)

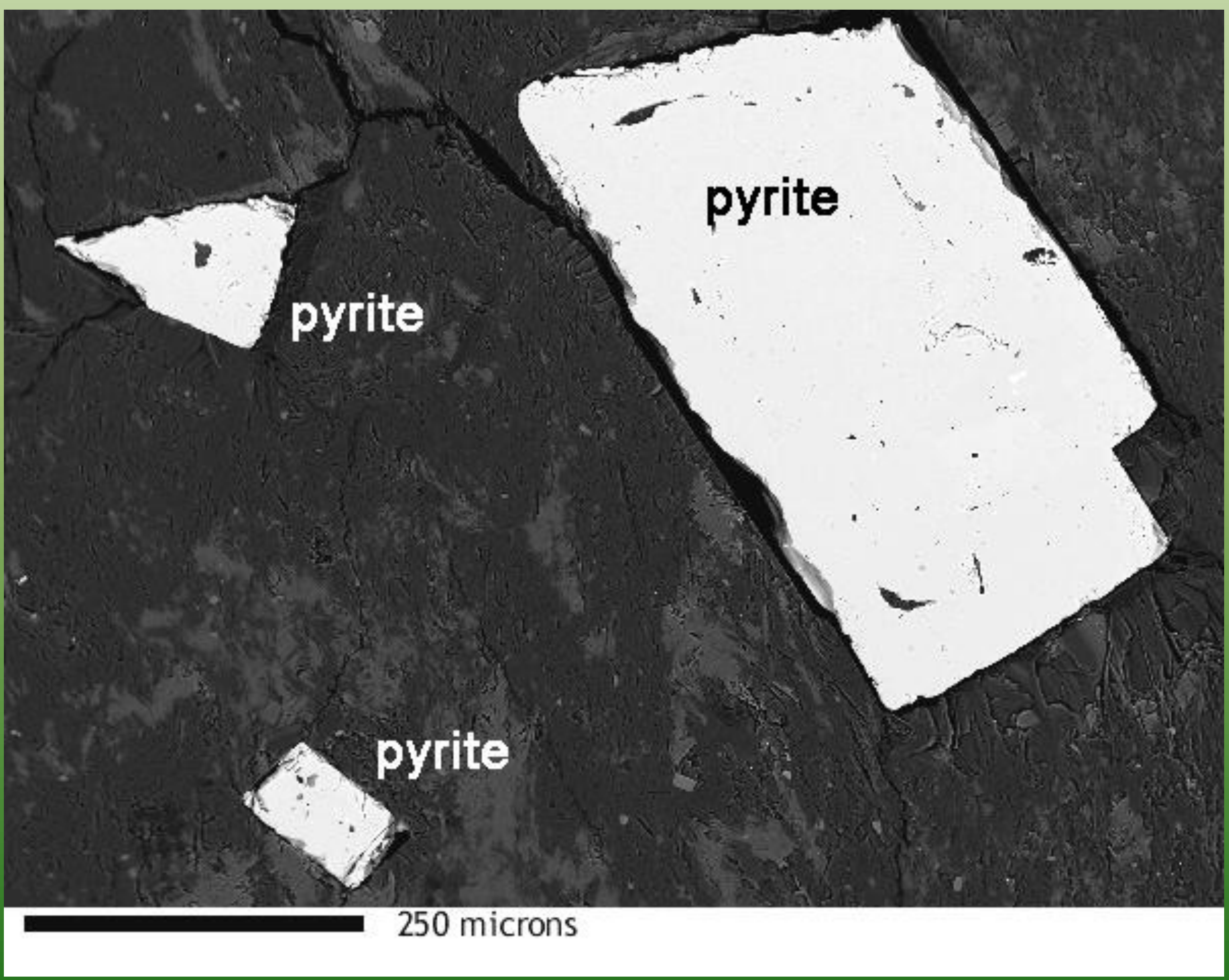
- Solid-phase characterization
  - Chemical analysis (What’s here? How much?)
  - Mineralogical/petrological analysis (How occurs?)
  - Metal partitioning (How readily released?)
  - Static tests (acid and neutralization potentials)
    - (See White et al. 1999)

Duluth Complex drill core

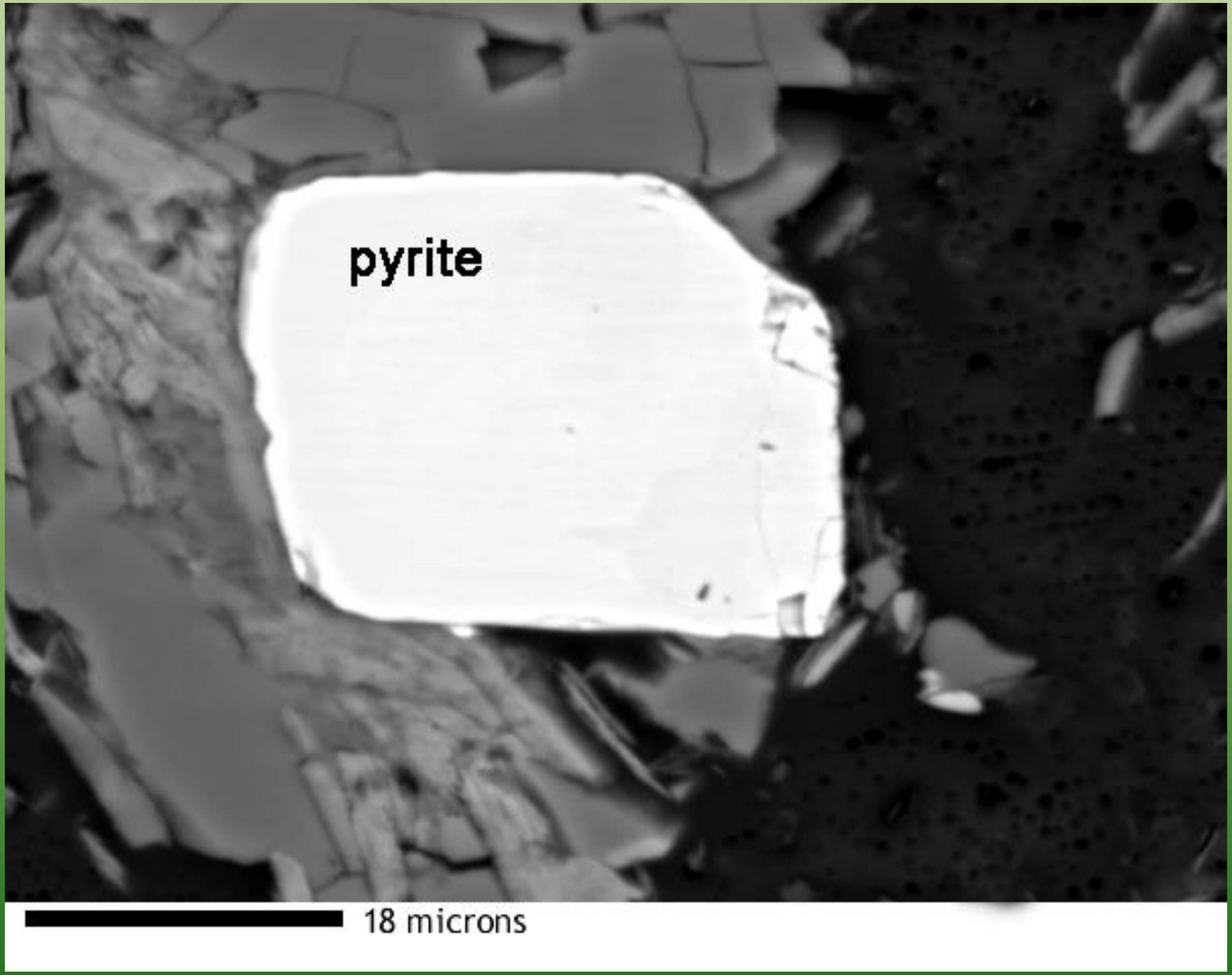


Core is 2" in diameter (vertical dimension in photo).

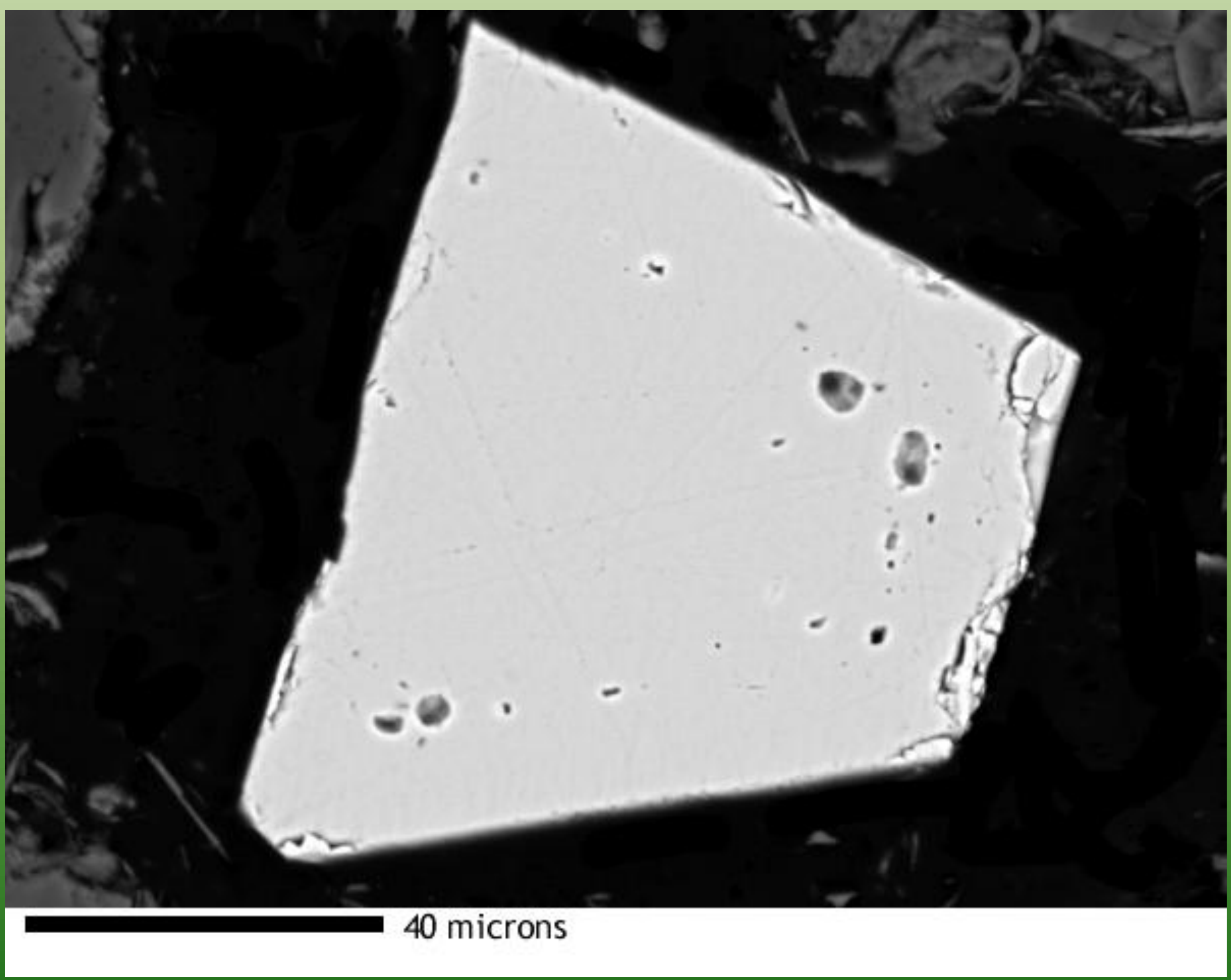
Pyrite included in +2000 µm rock particle



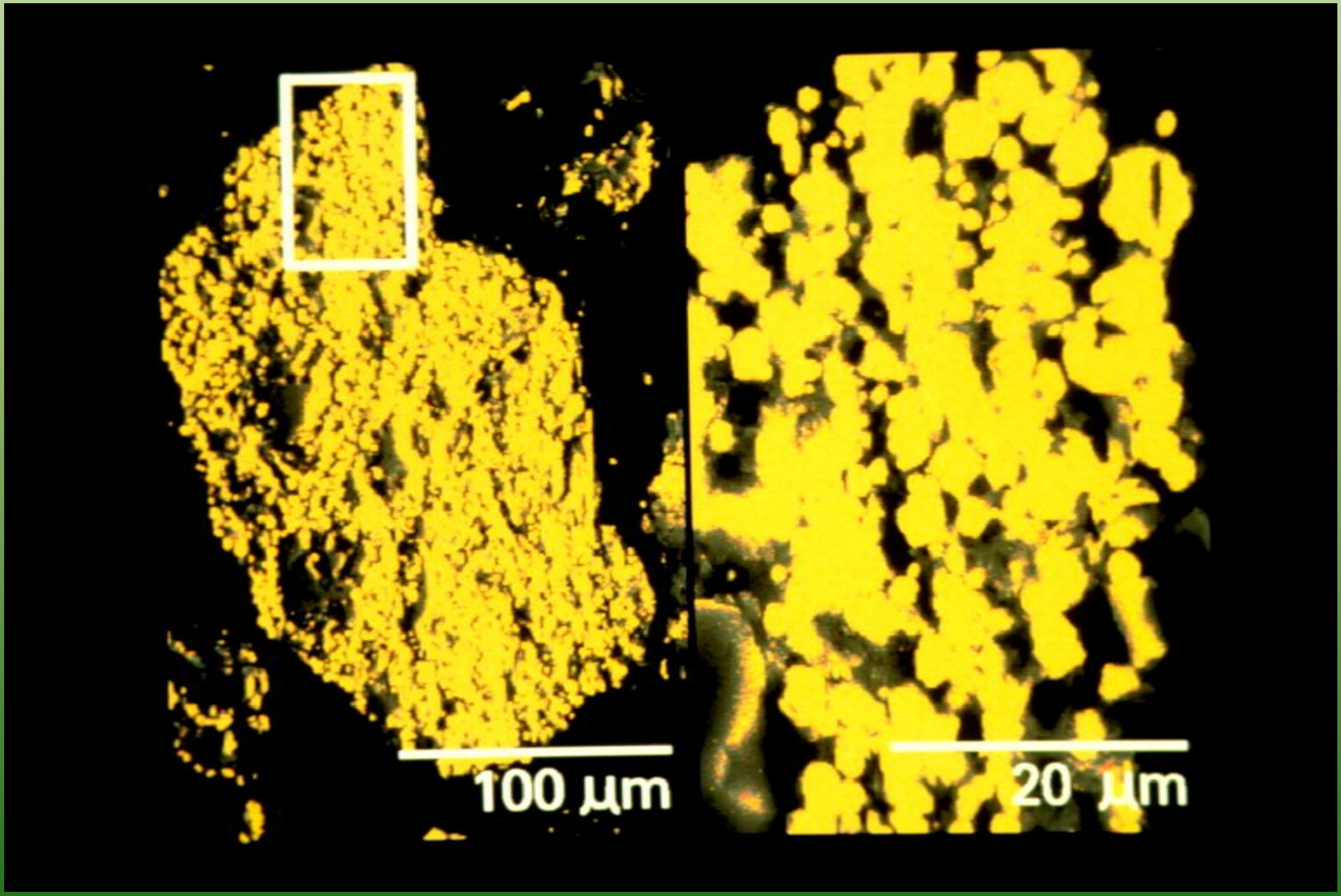
Partially exposed pyrite in 75-150 μm particle



Liberated pyrite in 75-150 size fraction



Framboidal Pyrite is Bumpy and has High Area/Unit Mass



3. Geochemical Characterization

3.2. Conduct tests

- Short-term dissolution tests (soluble salts)
- ***Kinetic tests (long-term dissolution tests)***
  - Soluble salts, other mineral dissolution

3.2. Conduct tests
ASTM 5744 kinetic testing of waste rock

Provide rates for modeling solute release in field

Test representative samples.

ASTM 5744

Mine Waste Dissolution Test Method

- Provides detailed description of protocol
  - Provide guidance for new practitioners
  - Promote method consistency
  - Increase reproducibility of results
- See Bucknam et al. 2009 for changes

ASTM 5744 Protocol

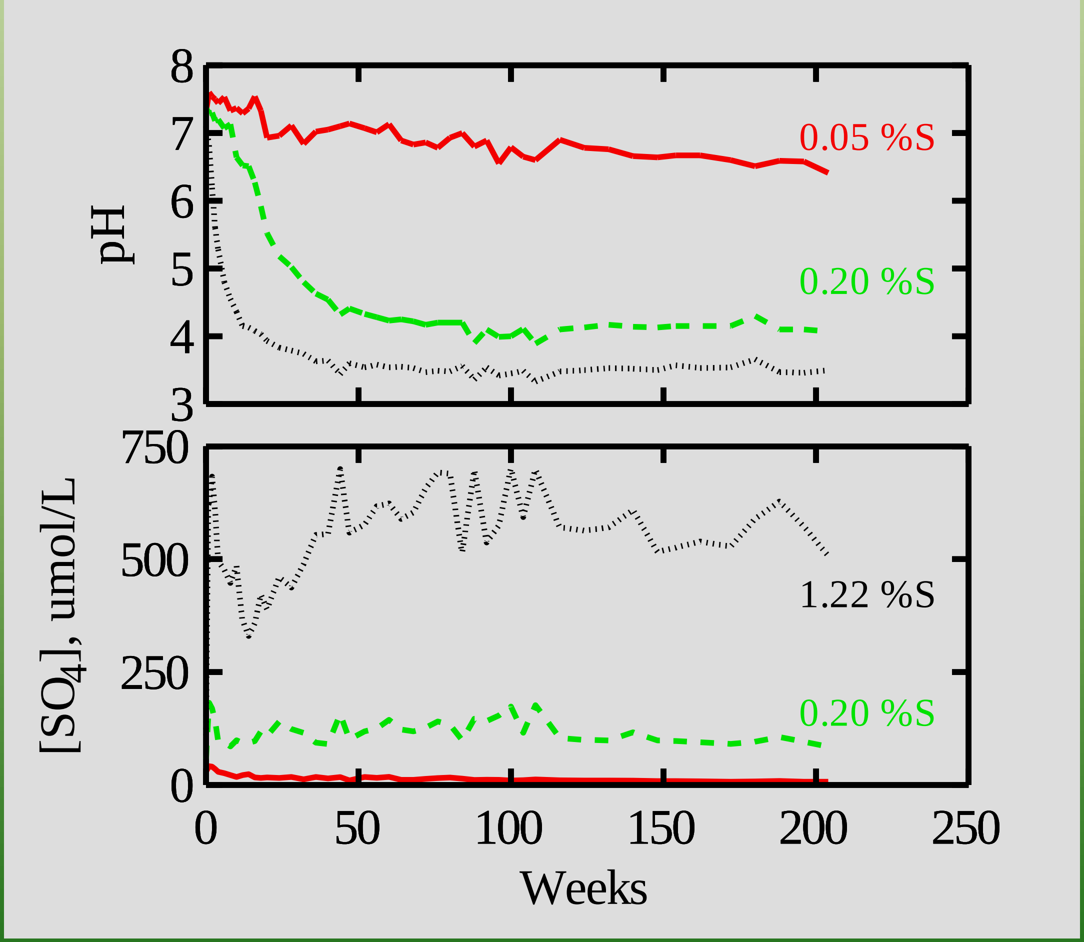
- 1 kg sample used for testing
- Waste rock particle diameter < 6.25 mm
- Characterize sample
  - Particle size distribution
  - Chemistry
  - Mineralogy

ASTM Humidity Cell

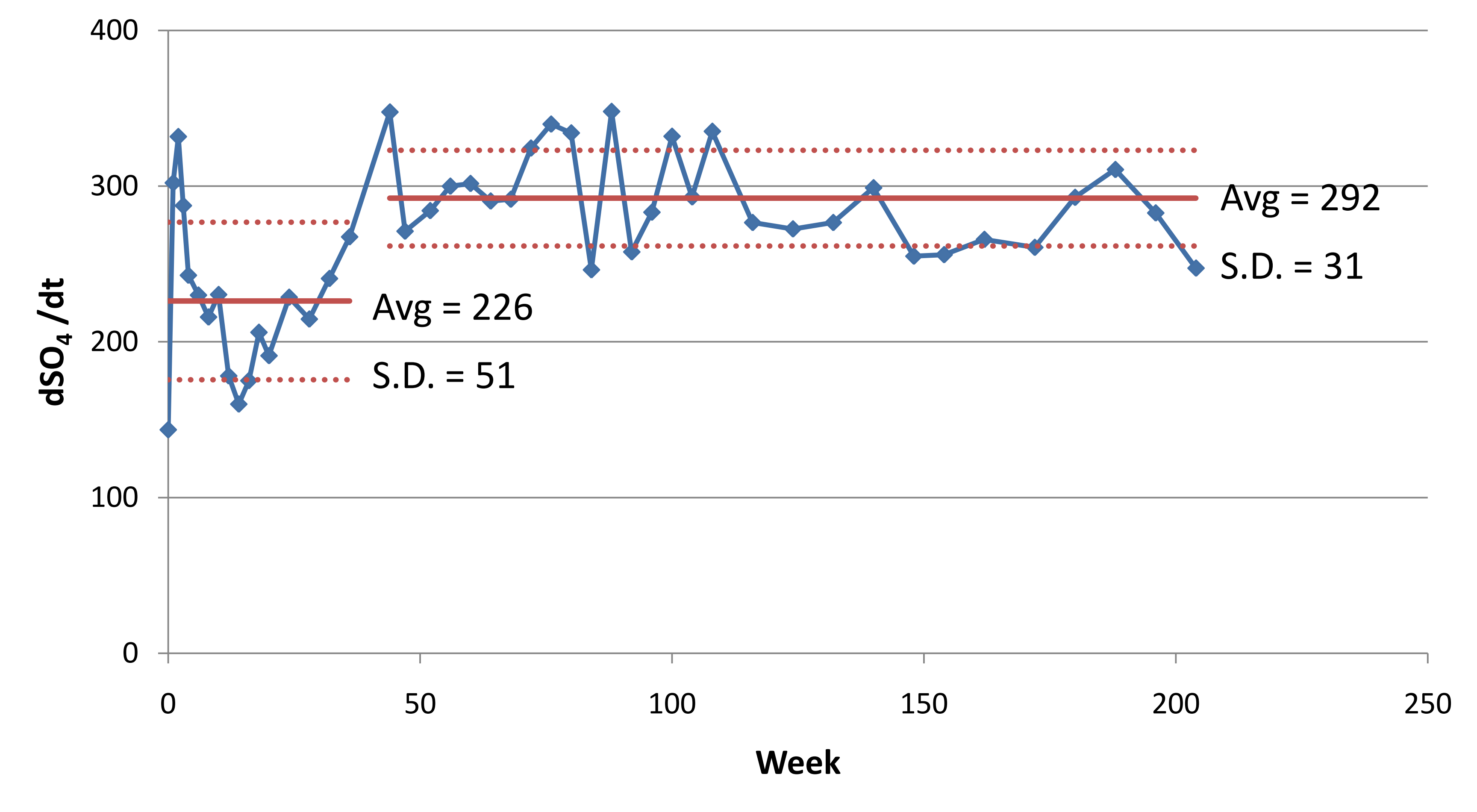
ASTM 5744 Protocol

- React with air, humidity in cell for 1 week
- Rinse on seventh day (500 or 1000 mL)
- Analyze drainage for
  - pH
  - Acidity, alkalinity
  - Sulfate
  - Other solutes

Determine SO_4 release rates for Archean Greenstone, 1.22% S



Average sulfate rates: µmol(kg•wk)$^{-1}$



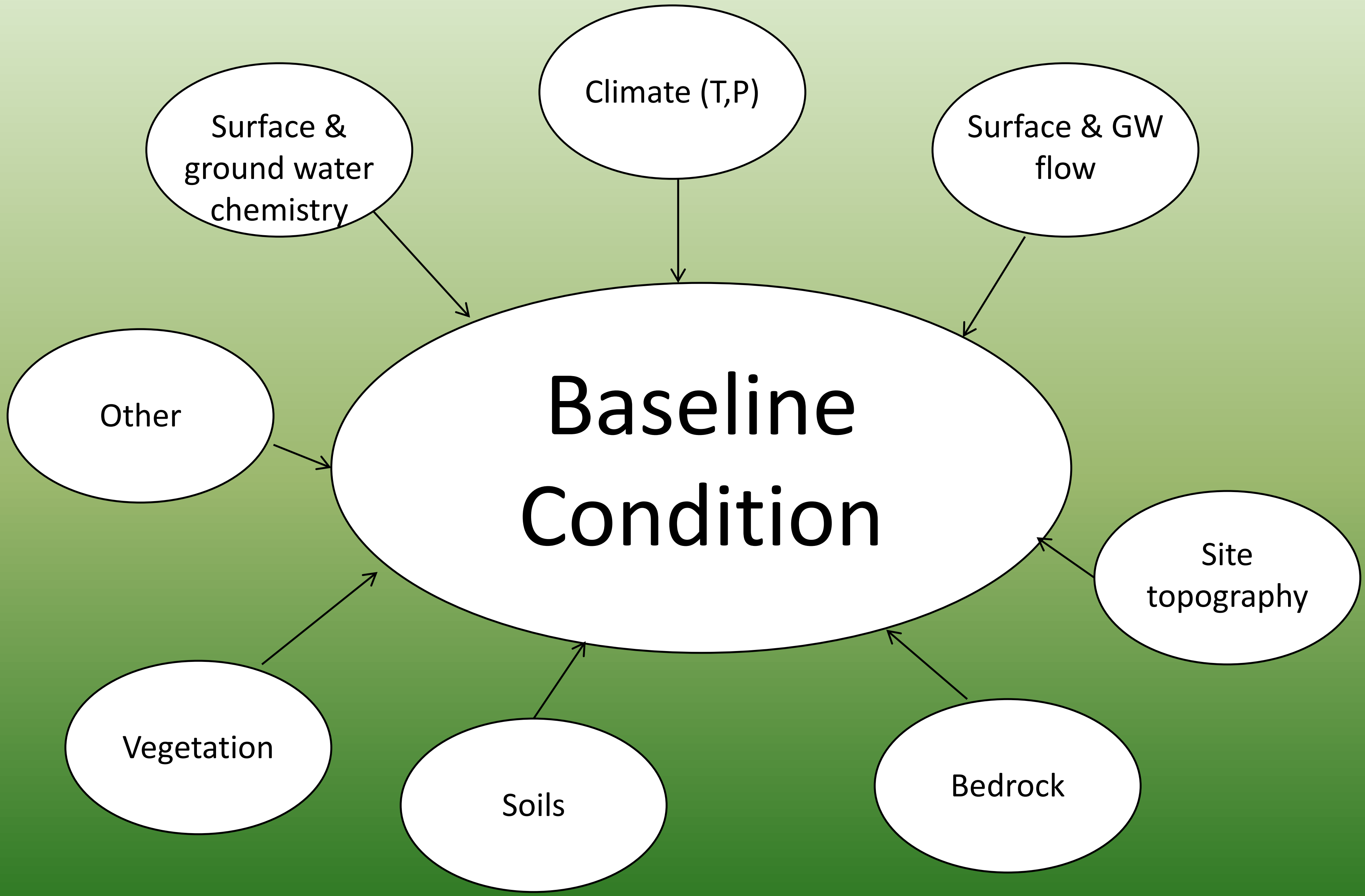
4. Modeling
Lab to Field?

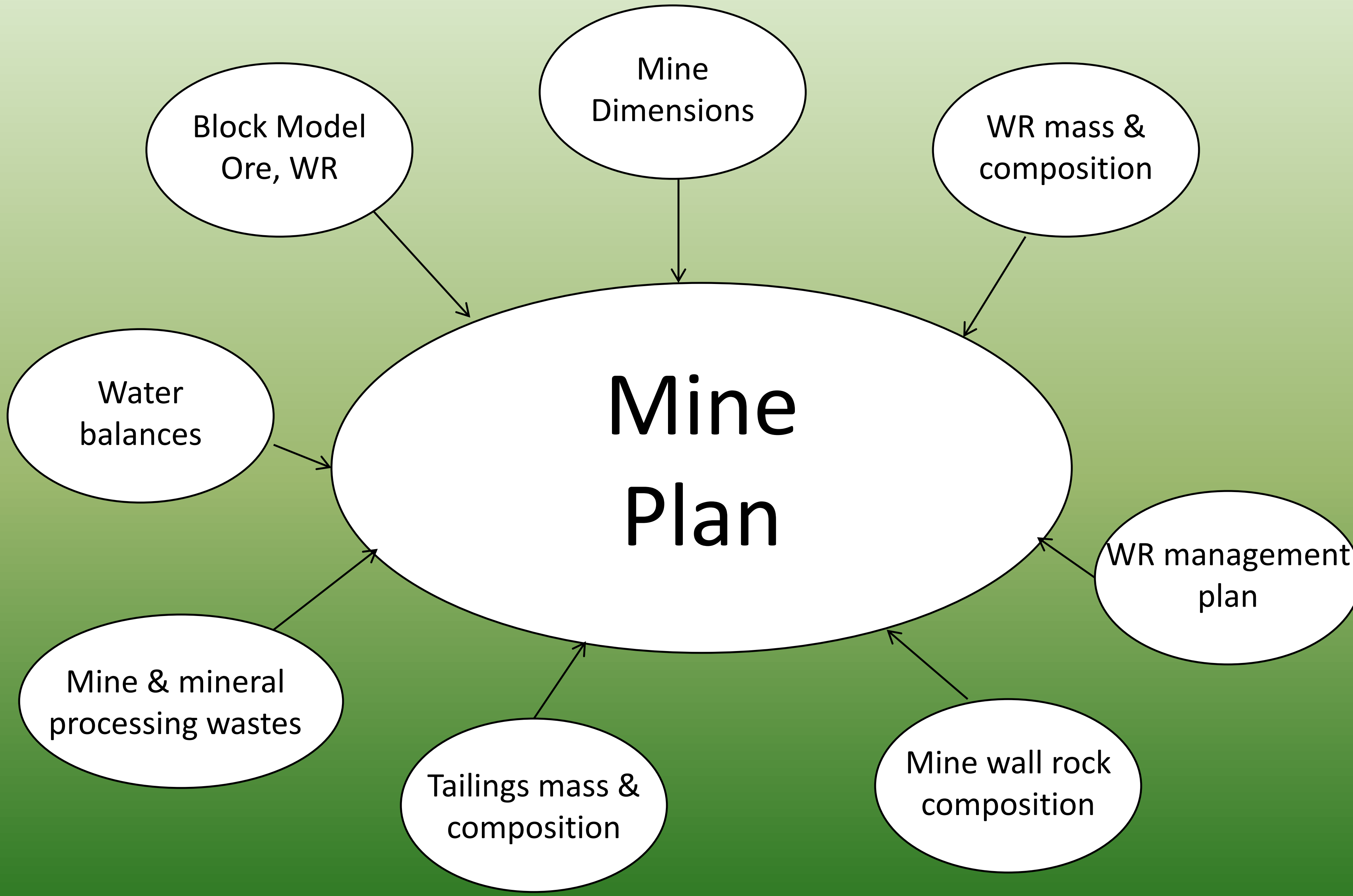
4. Modeling lab to field
~1000 t Duluth Complex Test Piles

4. Modeling lab to field
~60-ton test piles & barrel tests

4. Lab to Field Modeling: A general description.

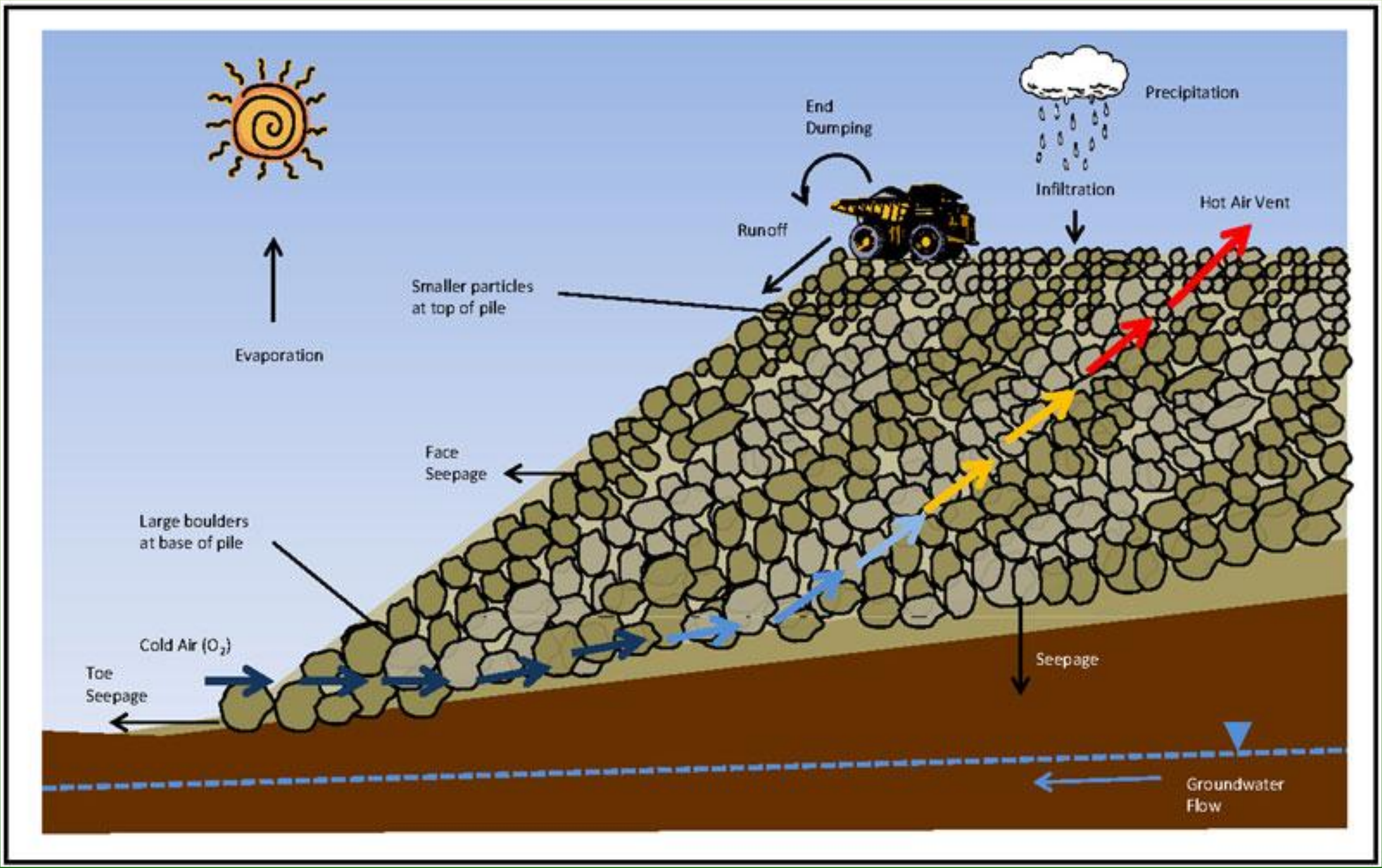
- Practical modeling to inform mine waste management decisions
- Focus on waste rock
- Interface of geochemistry and regulation
- Don’t have all answers

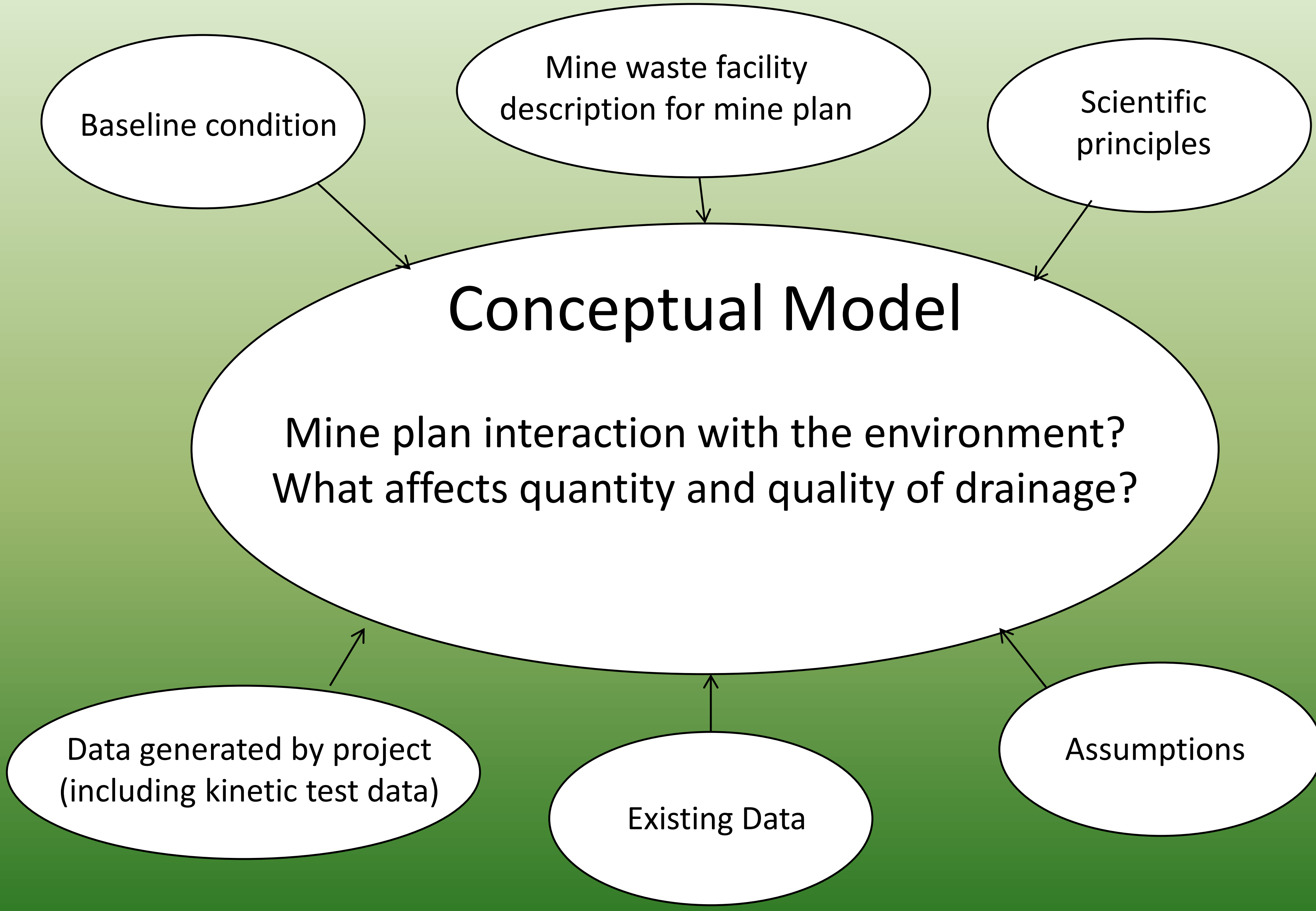

Surface & ground water chemistry
Climate (T,P)
Surface & GW flow
Other
Baseline Condition
Site topography
Vegetation
Soils
Bedrock

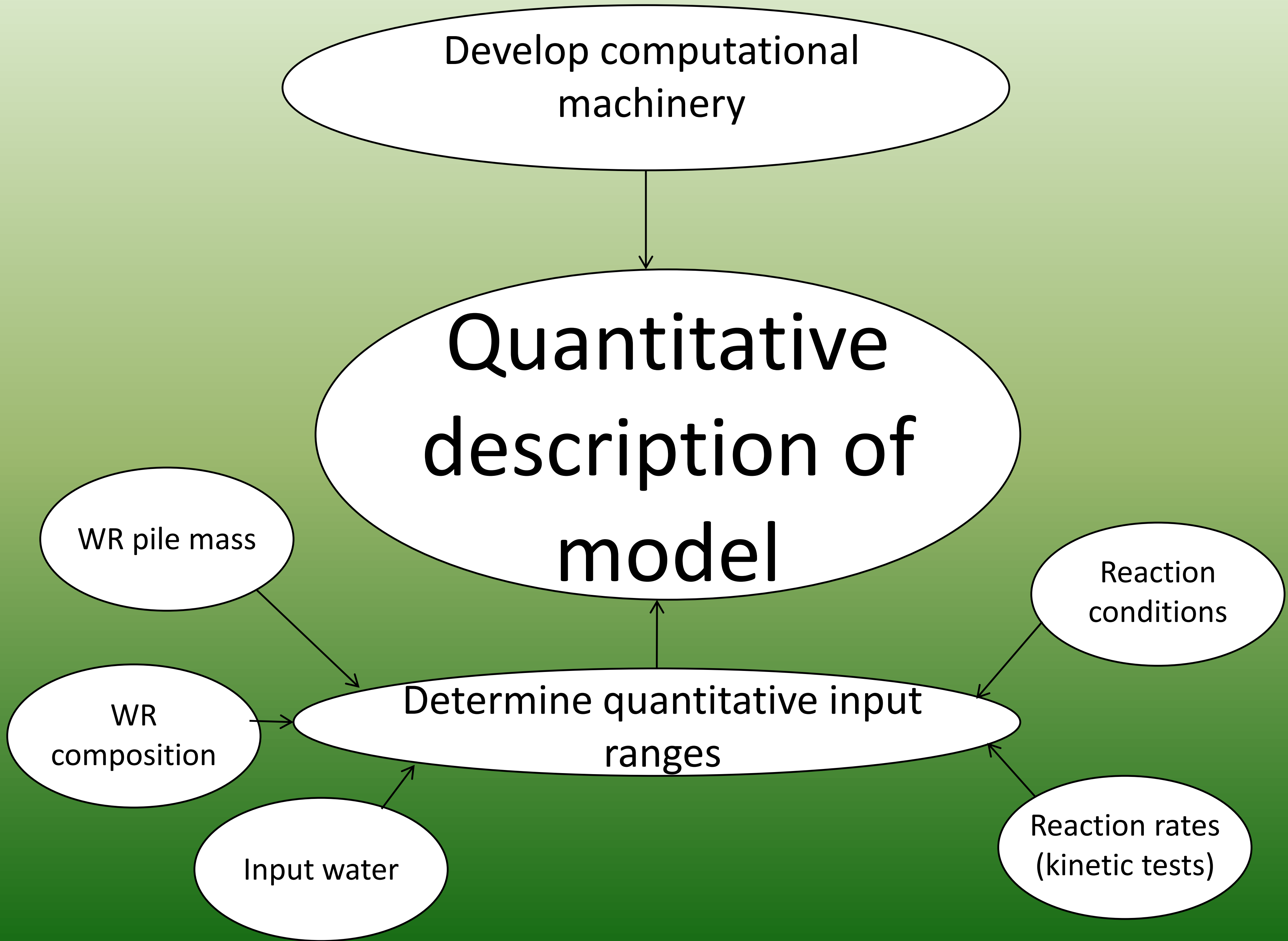

Mine Dimensions
Block Model Ore, WR
WR mass & composition
Water balances
Mine Plan
WR management plan
Mine & mineral processing wastes
Tailings mass & composition
Mine wall rock composition

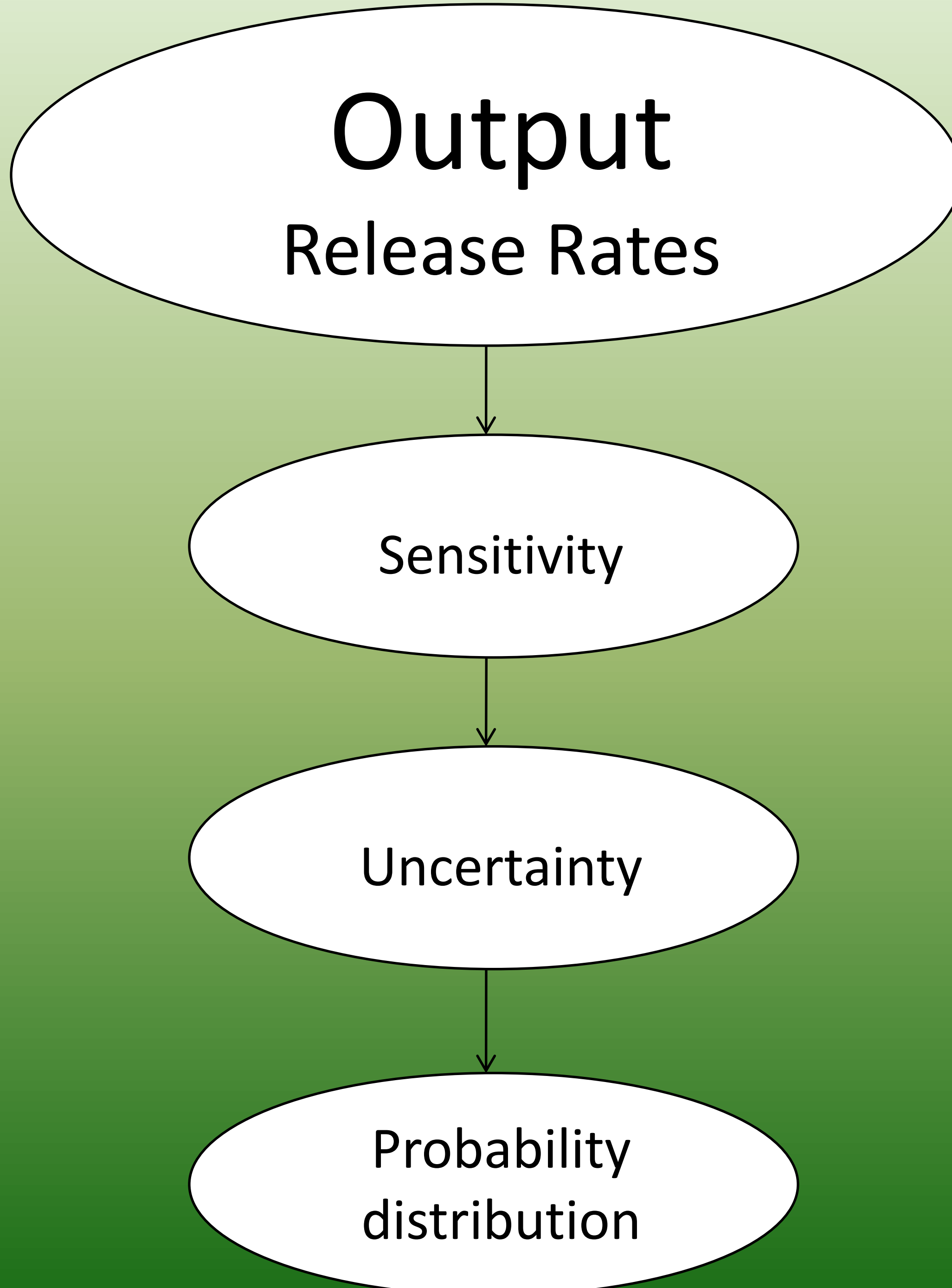
Conceptual view of waste rock pile

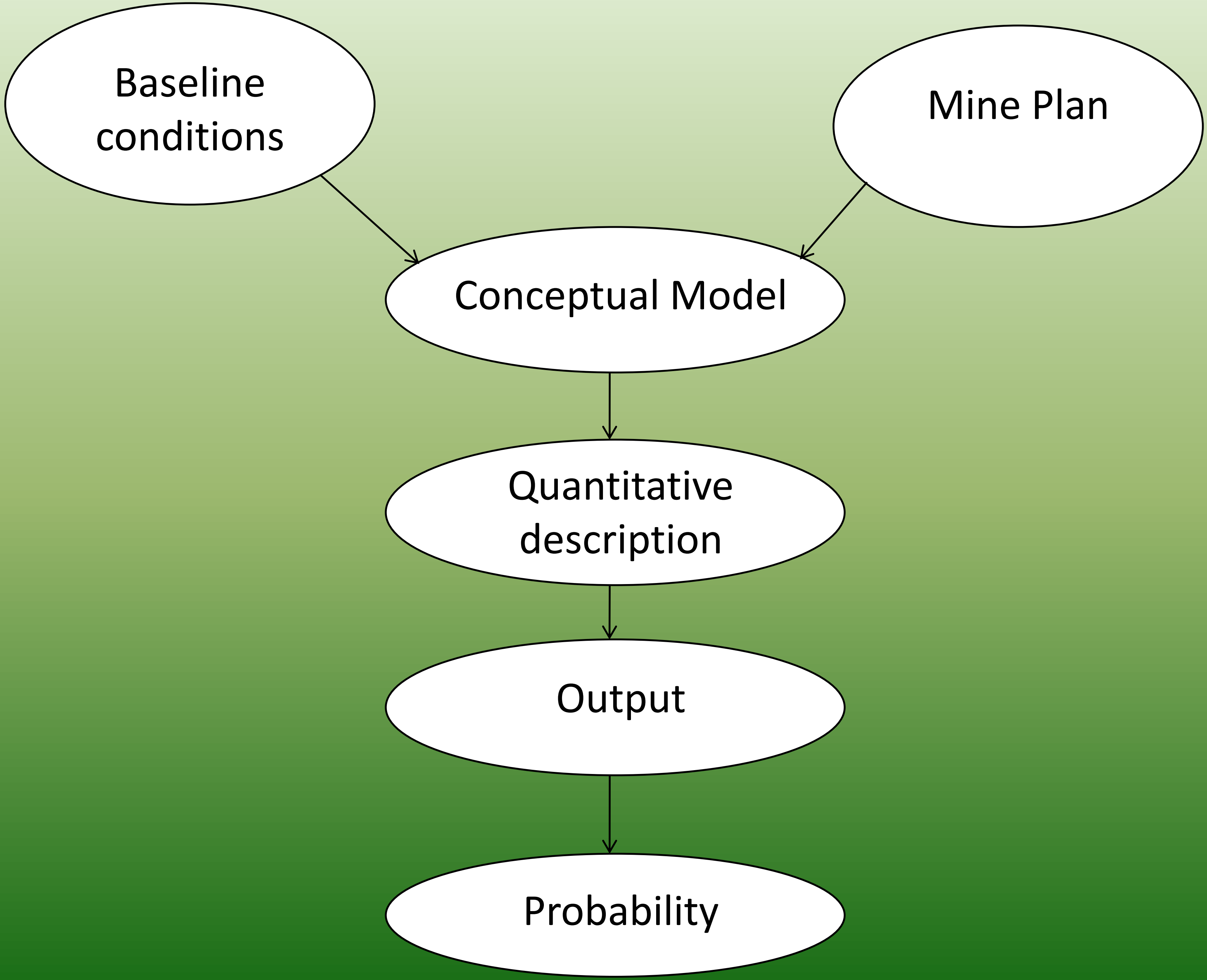
(Gard Guide).




Baseline condition
Mine waste facility description for mine plan
Scientific principles
Conceptual Model
Mine plan interaction with the environment?
What affects quantity and quality of drainage?
Data generated by project (including kinetic test data)
Existing Data
Assumptions


Develop computational machinery
Quantitative description of model
WR pile mass
Reaction conditions
WR composition
Determine quantitative input ranges
Input water
Reaction rates (kinetic tests)


Output
Release Rates
Sensitivity
Uncertainty
Probability
distribution


Baseline conditions
Mine Plan
Conceptual Model
Quantitative description
Output
Probability

Guidance (see NRC 2007)

- Transparency (balance simplicity < > rigor)
- Computational checks on calculations (e.g. *vs.* simplifications, other models, empirical data)
- Conceptual model scientifically sound
- Algorithms accurately reflect conceptual model
- Inputs and assumptions sound
- Sensitivity (important inputs)
- Uncertainty (probabilistic reflection of output)

Summary

- Prior to mining, predict mine drainage quality, solute release rates
- Need site conditions, mine plan
- Characterization/prediction program based on above

Summary

- Kinetic tests yield solute release rates
- Modeling required to apply laboratory results to field
  - Mine plan superimposed on existing conditions
  - Conceptual model based on science
  - Transparent
  - Sensitivity analysis
  - Output expressed as probability

References and Helpful Publications

Bucknam. C.H., White III, W., Lapakko, K.A. 2009. Standardization of Mine Waste Characterization Methods by ADTI-MMS. *In* Proc. Securing the Future and 8th ICARD, June 22-26, 2009, Skellefteå, Sweden (CD ROM). 12 p.

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