3.4. A MEANDER THROUGH SULPHIDE TAILINGS ASSESSMENT

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Abstract

It is evident that reactive waste rock and reactive tailings differ significantly in characteristics and oxidation behaviour. The purpose of this presentation as to highlight some of the issues that are relevant to tailings assessment but differ significantly from those commonly addressed in waste rock assessment. The main features that are unique to tailings include; 1) the relative homogeneity, 2) greater water retention that controls access to oxygen, 3) water table location in the waste that isolate the portion below the water table from oxygen, 4) dominance of small particles that increase reactivity for buffering and 5) longer subsurface travel times that allow more complete secondary reactions.

Measurements and modelling can be used to assess potential water quality impacts from sulphide mineral oxidation in tailings. Basic information on mineralogy and acid-base accounting can provide first order estimates of potential water quality concerns. Field testing for existing tailings impoundments can include standard hydrogeologic assessment and more innovative approaches such direct measurement of oxygen consumption to assess oxidation rates. Modelling approaches can range from back-of-the envelope calculations for neutralization potential to detailed geochemical and transport models. Models should be selected to address specific issues such as loadings and the effect of rehabilitation strategies.

The results of kinetic tests should not be applied directly to the assessment of tailings reactivity. Sample calculations show that by ignoring oxygen restrictions in tailings, predicted rates of oxidation can be hundreds of times greater than rates that have been measured in the field. Experience is needed to predict water quality in tailings resulting from oxygen diffusion, sulphide mineral oxidation and secondary chemical reaction.

CANADIAN PERSPECTIVE

Past Focus:	Tailings - An "Eastern Problem"
	Waste Rock - A "Western Concern"
Today:	Integrated Mine Waste Management

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PURPOSE:

- Focus on Tailings Issues
- Highlight Significant Contrasts with Waste Rock
- Address Similarities between Tailings and Waste Rock where appropriate

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COMPARISON OF TAILINGS AND WASTE ROCK CHARACTERISTICS

Tailings

- "Relatively" Homogeneous
- Fine Grained (<0.5 mm)
- Minerals Exposed (Sulphides/Carbonates/etc.)
- Relatively Simple Hydrology and Chemical Transport

Waste Rock

- Heterogeneous
- Variable Grain Size
- Mineral Exposure Highly Variable
- Complex Chemical Transport

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IMPLICATIONS FOR BEHAVIOUR OF TAILINGS

- "Homogeneous" chemical reactions (buffering/sorption etc.)
- Retain more water/greater resistance to oxygen migration
- Water Table in Waste isolates portion from oxidation
- Mineral exposure - availability for reactions
- Longer travel times for water results in more complete reactions

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TOOLS FOR ASSESSMENT (Prediction)

- Measurements
- Modelling

MEASUREMENTS ON TAILINGS

Lab

- Mineralogy
  - Sulphide Content (Pyrite/Pyrrhotite/others)
  - Carbonate Content (Calcite/Dolomite)
- ABA Testing with "Critical" Interpretation
- Grain Size Distribution (for water content and hydrogeologic behaviour)

MEASUREMENTS ON TAILINGS (Cont'd)

Field

- Conventional
  - Shallow wells in tailings
  - Porewater above water table (core squeezing)
  - Depth to Water Table
  - Moisture Content above Water Table (gravimetric, neutron probe, TDR)
  - Oxygen in gas above Water Table (O_2 profiles - oxygen gradients)
- New
  - Oxygen Consumption Rates at Surface (gives oxidation rates across tailings surface)

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MODELLING OF TAILINGS

"Back-of-the-Envelope"

- AP/NP calculations
- Inventories of Sulphide above water table (Oxidation Zone)
- Inventories of Neutralizing Solids along flow paths (Neutralization Zone)

Engineering Models (e.g., WATAIL)

- Assess Loadings of Major Oxidation Products
- Compare Management Options (e.g., Covers)
- Important Trends in Loadings with Time (How long is treatment required?)

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MODELLING OF TAILINGS (Cont'd)

- Research Models
  - more detailed
    - chemistry
    - hydrology
- Focus on "Potential" Controls on Concentrations of Metals (Equilibrium Processes)
- Fundamental process studies
- Testing hypotheses

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CONCEPTUAL FRAMEWORK FOR TAILINGS ASSESSMENT

Above Water Table

- Inventory of Sulphide Mineral(s) (Acid Generation/ Metals Release)
- Rates of Oxidation (converts to loadings)
- Other Chemical Reactions (some neutralization/leaching of metals)

Below Water Table

- Buffering reactions (Ca, Mg - Carbonates)
- Precipitation/Sorption of Metals and Others

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CONTROLS ON OXIDATION

- With Free Access to Oxygen (i.e., "The Lab")
  - Surface Reaction Controlled - Key Variable
  - Bacterially Enhanced
- In a Tailings Impoundment
  - Oxygen Availability controlled (diffusion through tailings)
  - Resistance of Tailings and Water to Oxygen Movement
  - Oxidation from Surface Downward (oxygen transport controls rates).

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LABORATORY RATES ON PURE SULPHIDES (No Oxygen Restriction)

	Oxidation Rates*		Typical Tailings**
	(Mol $m^{-2}s^{-1}$)	(mg-SO_4 $m^{-2}wk^{-1}$)	(mg-SO_4 $kg^{-1}wk^{-1}$)
Pyrite	5×10^{-10}	60	1,500
Pyrrhotite	5×10^{-8}	3,000	75,000

* Rates given per area exposed sulphide and per kg of typical tailings

** Typical tailings may have 5% S with a surface area of 0.5 m^2g^{-1} of sulphide or 25 m^2kg^{-1} of tailings

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EXAMPLES OF CALCULATED FIELD RATES (Ignoring Oxygen Restriction):

Percent Sulphur (Pyrrhotite)	1	15	30
Pyrrhotite Content (kg m^{-3})	50	750	1,500
Calculated Oxidation Rate (kg-$SO_4 m^{-3}a^{-1}$)	450	6,800	13,608
Measured Oxidation Rate (kg-SO_4 $m^{-2}a^{-1}$) (Oxygen Consumption measurement on fresh tails in impoundment)	1	10	240
Calc/Meas*	450	680	60

*Lower Measured rates are due to restriction by Oxygen Diffusion

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SUGGESTED APPROACH TO ASSESSMENT OF PLANNED SULPHIDE TAILINGS

1) Quantify - Sulphides
   - Carbonates
2) Mineralogic Identification
3) "Back of the Envelope" for Magnitude of Problem
   - Above the Water Table
     - Acid Potential
     - Neutralization Potential
   - Identify Flow Paths
   - Below Water Table
     - Neutralization Potential

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SUGGESTED APPROACH TO ASSESSMENT OF PLANNED SULPHIDE TAILINGS (Cont'd)

4) Identify other Water Quality Issues (some non-acid waters can have elevated metals)
   - Ferrous Iron
   - Zinc
   - Nickel
   - Arsenic
   - TDS

   (Others NOT Attenuated at Neutral pH?)
5) Laboratory Testing to Verify Potential Water Quality Problems ***Not to Assess Rates**

SUGGESTED APPROACH TO ASSESSMENT OF PLANNED SULPHIDE TAILINGS (Cont'd)

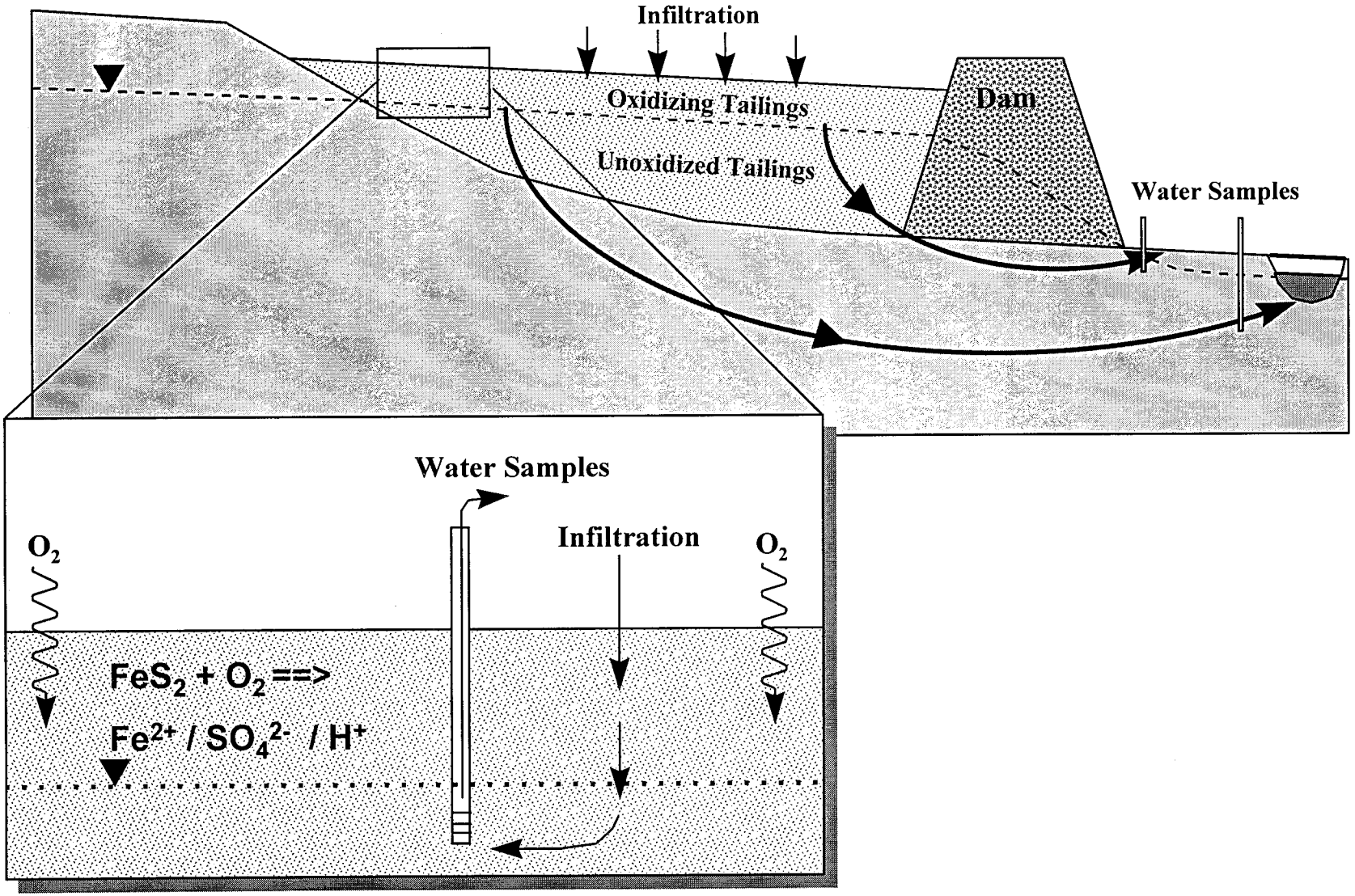
6)Modelling/Assessment (Experience Required)
   - Chemical Kinetics
   - Aqueous - Solids Reactions
   - Physics of Diffusion
   - Subsurface Hydrology, etc.

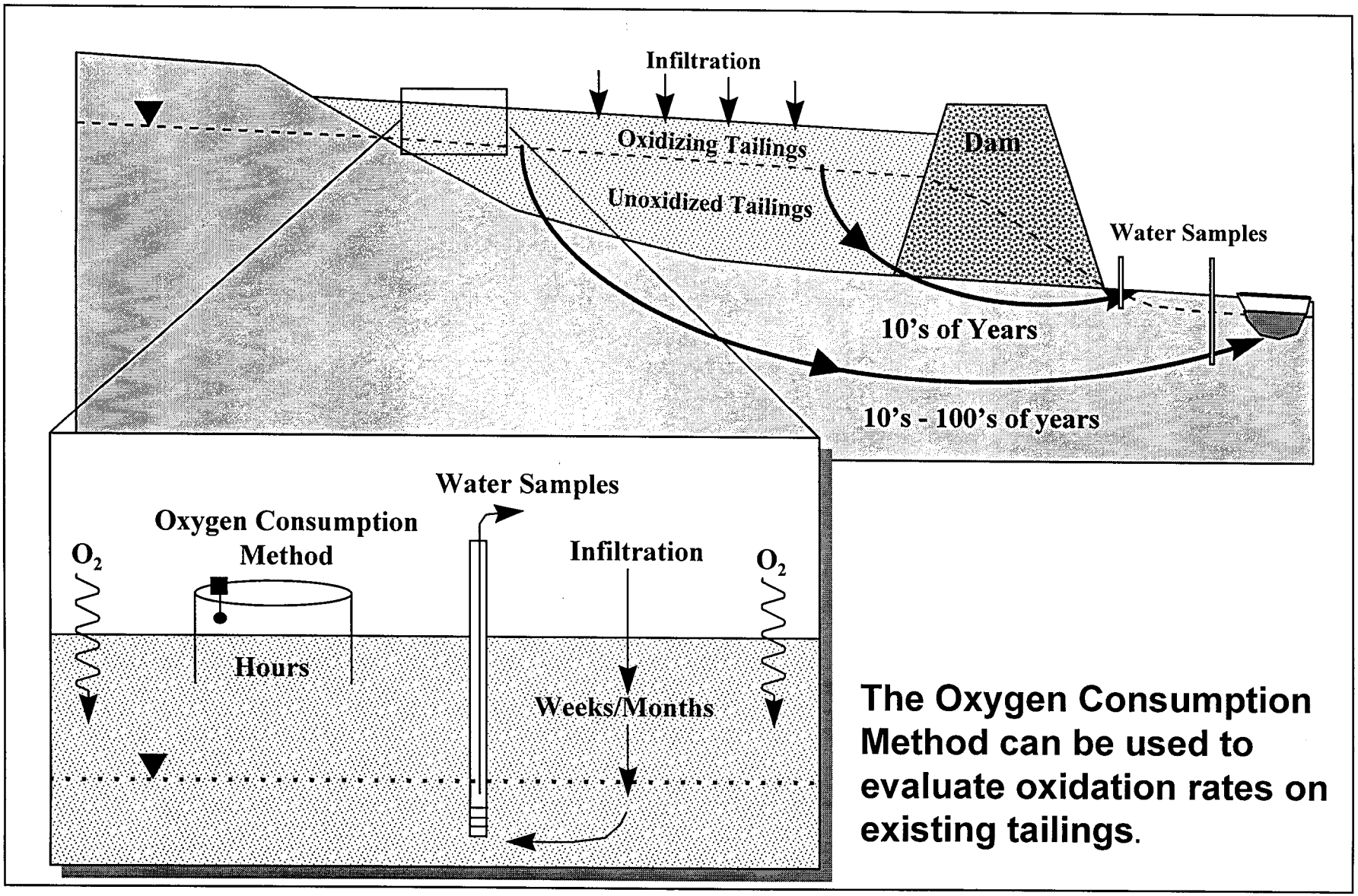
CONCLUSIONS

- Waste Rock Assessment Paradigm should NOT be applied to Tailings evaluations.
- Ignoring Oxygen Diffusion in Calculation of Oxidation Rates "Grossly" Overestimates Rates and Loadings

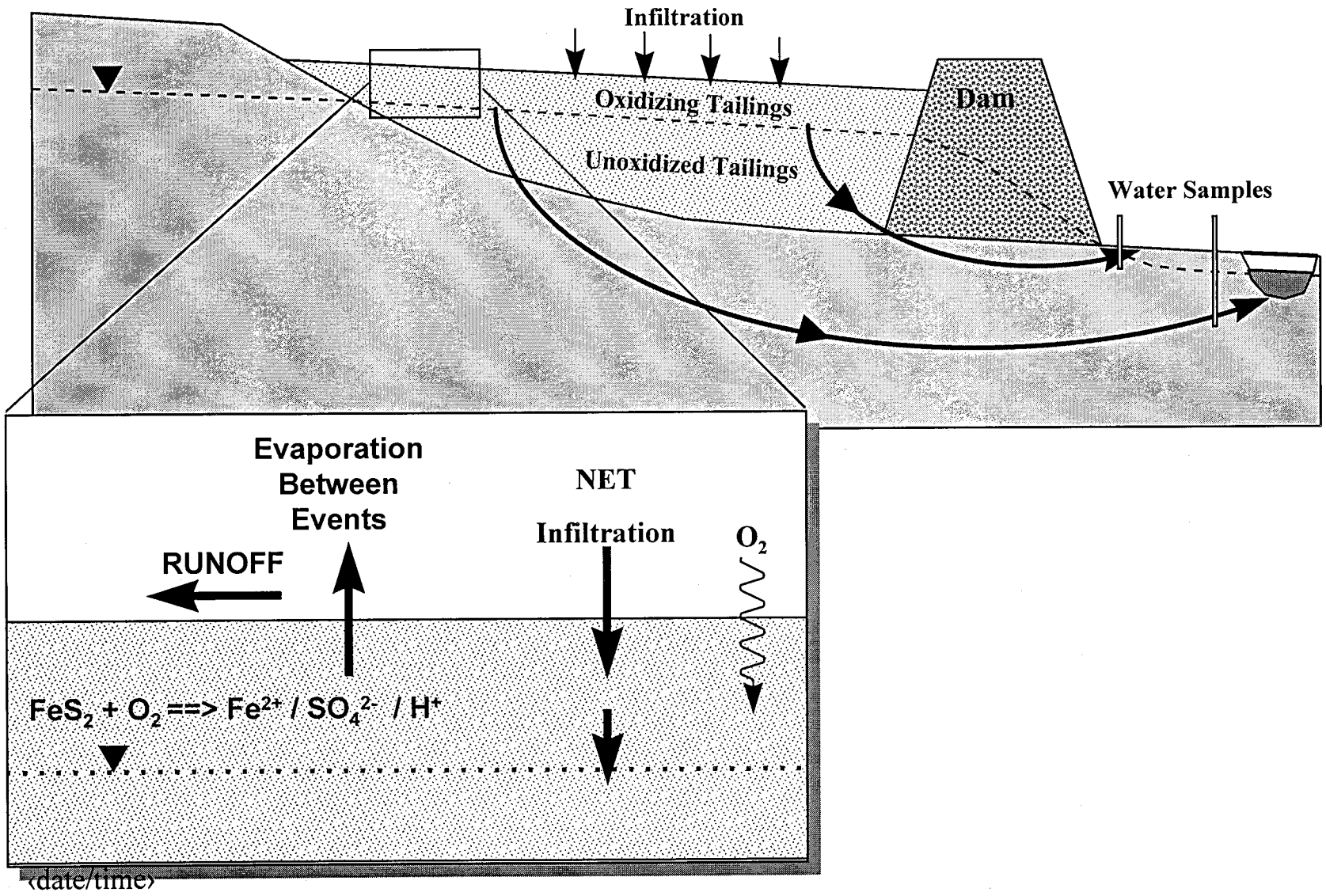
CONCLUSIONS (Cont'd)

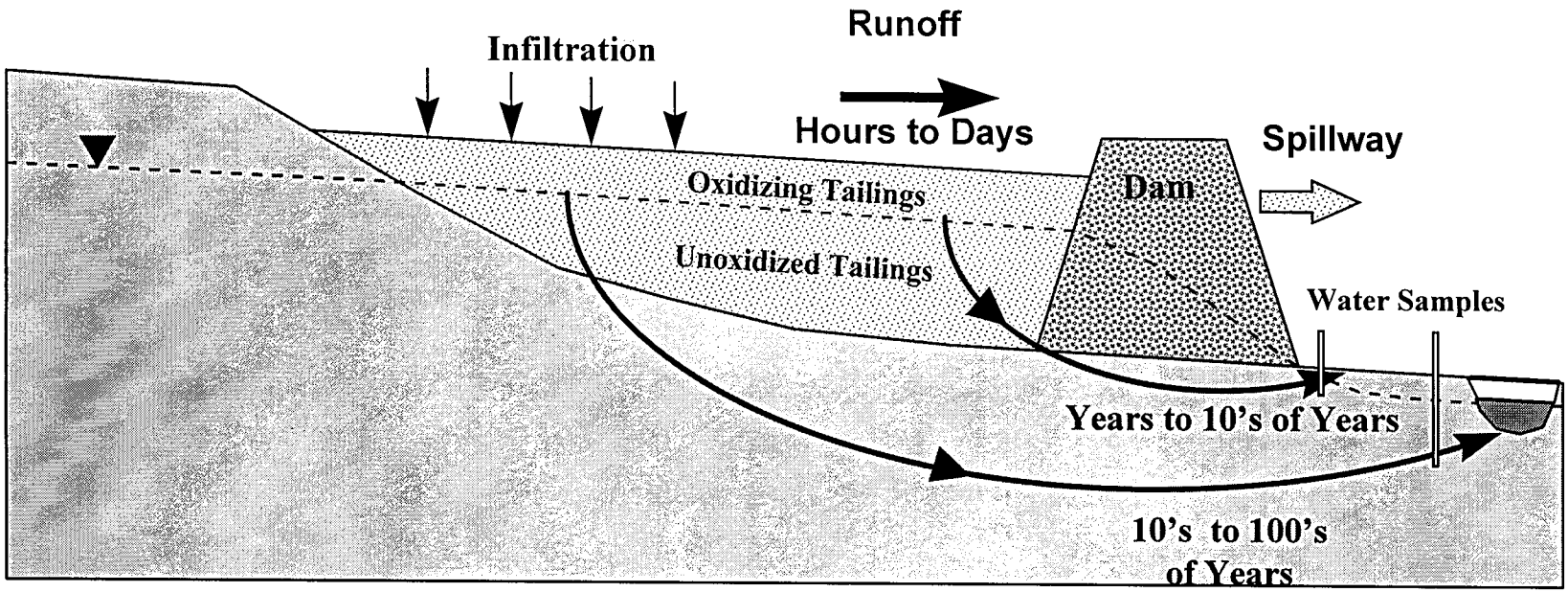
- Direct Measurements of Tailings Oxidation Rates is now possible
- Acid-Base Accounting is NOT the sole issue
  - Fe^{2+}, Ni^{2+}, Zn^{2+}, $HAsO^{2-}_4$
    can be released during oxidation and are mobile at neutral pH
- Water quality from lab testing should be used only to identify potential elements of concern - not rates or concentrations.


Infiltration
Oxidizing Tailings
Unoxidized Tailings
Dam
Water Samples
Water Samples
Infiltration
O2
O2
FeS2 + O2 ==>
Fe2+ / SO4 2- / H+



The Oxygen Consumption Method can be used to evaluate oxidation rates on existing tailings.


Infiltration
Oxidizing Tailings
Dam
Unoxidized Tailings
Water Samples
Evaporation
Between
Events
NET
Infiltration
O_2
RUNOFF
$FeS_2 + O_2 ==> Fe^{2+} / SO_4^{2-} / H^+$
‹date/time›



Evaporation can cause upward migration of oxidation products (salts) with water that can be flushed during rainfall events. This effectively by-passes the long travel pathways in the subsurface and can lead to unexpected surface water quality concerns.