Treatment of Mine Runoff TSS Using Ponds & Optimizing Flocculant Addition to Ensure Discharge Compliance

Erosion Process

Erodibility of Soils ....Soil Sampling, Grain-size Analyses, Settling Tests

Hydrology

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Erosion Control Plan. Calculate SOIL LOSS → RUSLE

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Estimate Site Runoff : Inflow Rate into Pond and TSS Concentration

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Sediment Pond Size + Decision on Need for Flocculants

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Estimate Pond Discharge Quality TSS, Turbidity, Toxicity

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Estimate Downstream Compliance: TSS, Turbidity + Sub-lethal effects
→→ **Receiving Water** →→ **Downstream Dilution**

Reason for the Presentation

1. ***Reviewed available BMP guidelines*** → absence of ***predictive* methodology** to address regulatory **discharge compliance for TSS, turbidity, flocculant-induced toxicity**.
2. **Proposal → develop procedures to supplement existing BMP to *estimate: pond discharge quality for TSS, Turbidity, Toxicity.....and downstream impact for TSS, Turbidity, Toxicity***, based on site specific ***soil particle size distributions*** of upslope soils eroded into the pond.
3. **Cost savings** may be realized by constructing only the necessary works to achieve discharge compliance and avoid future costly retrofitting and regulatory legal costs, and subsequent fines in some jurisdictions. 2

A Pond Design Guideline Methodology Should Include Discharge Quality Predictive Testing

Testing methods should ideally include:

1. Testing methods which determine the need for settling aids.
2. Testing methods which avoid over/under -designing the pond size.
3. Guidance on installing the optimal flocculant system. (based on the potential toxicity of the chosen flocculants).
4. Minimizing risk of exceeding regulatory pond discharge standards, downstream water quality standards and avoiding flocculant-induced toxicity. 3

Balancing Erosion Control and Ponds

1. Maximize erosion control?: Why dam up the runoff?
2. Sediment ponds unavoidable – too much Soil Loss.
3. Sediment Control Strategies - a slow remedy.
4. Estimate Soil Loss – use RUSLE or other methods to estimate TSS into pond.

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What Testing should be Included in a Methodology?

1. Major cause of excessive sediment to receiving waters is: abundant **un-settleable fine particles in the soils** ("fines").
2. Problematic soils cause discharge problems based on:

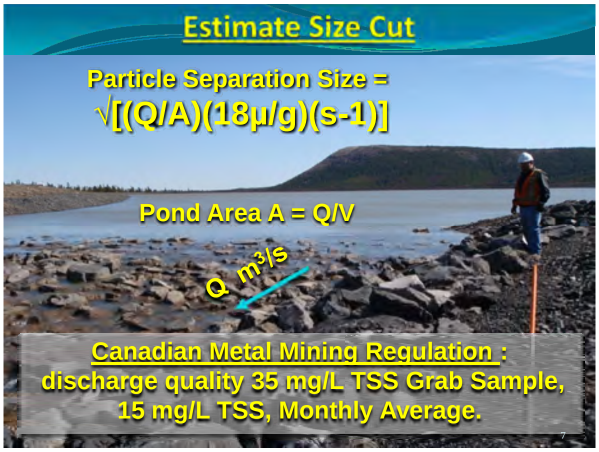
   Elevated TSS of fine particle fraction into the pond.

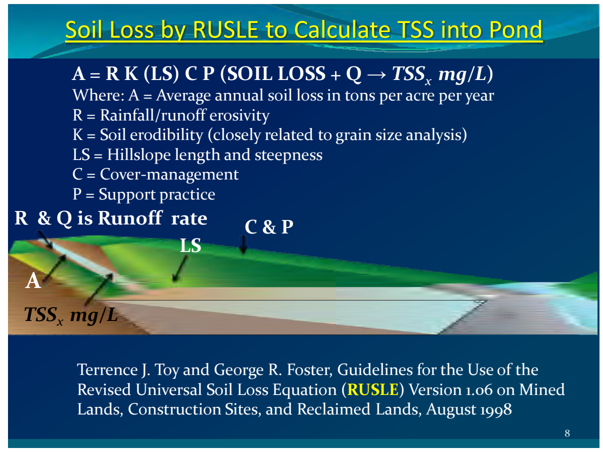
   The size "split" the pond is capable of achieving at various inflow rates is too coarse.

   The **critical settling particle size** prevents the pond capturing minus 2 micron particles, without using settling aids.
3. Must be based on the particle size distribution of the soils so that the pond discharge TSS quality/turbidity can be estimated. 5

Current Regulatory Requirements for Pond Design

1. British Columbia Canada: e.g. 0.0001 cubic metre/s/1.0 square metre of pond area (at 25°C), which removes 10 micron and larger particles , for the 10-year, 24-hour rainfall event. Coal mines to achieve 50 mg/L TSS; Metal mines 35 mg/L.
2. Some US jurisdictions require pond sizing in terms of pond volume and geographical location.
3. Maryland, 0.5 inches/acre, or a pond size of 1,300 yd3/acre drained.
4. Removal efficiency of the TSS input (e.g. remove 95% of pond input TSS).
5. ***These methods do not address pond discharge quality*** - yet these jurisdictions may specify permit requirements for pond discharge TSS concentration, toxicity and downstream quality. 6


Estimate Size Cut
Particle Separation Size =
√[(Q/A)(18μ/g)(s-1)]
Pond Area A = Q/V
Q m³/s
Canadian Metal Mining Regulation :
discharge quality 35 mg/L TSS Grab Sample,
15 mg/L TSS, Monthly Average.


Soil Loss by RUSLE to Calculate TSS into Pond
A = R K (LS) C P (SOIL LOSS + Q → TSSx mg/L)
Where: A = Average annual soil loss in tons per acre per year
R = Rainfall/runoff erosivity
K = Soil erodibility (closely related to grain size analysis)
LS = Hillslope length and steepness
C = Cover-management
P = Support practice
R & Q is Runoff rate
C & P
LS
A
TSSx mg/L
Terrence J. Toy and George R. Foster, Guidelines for the Use of the Revised Universal Soil Loss Equation (RUSLE) Version 1.06 on Mined Lands, Construction Sites, and Reclaimed Lands, August 1998
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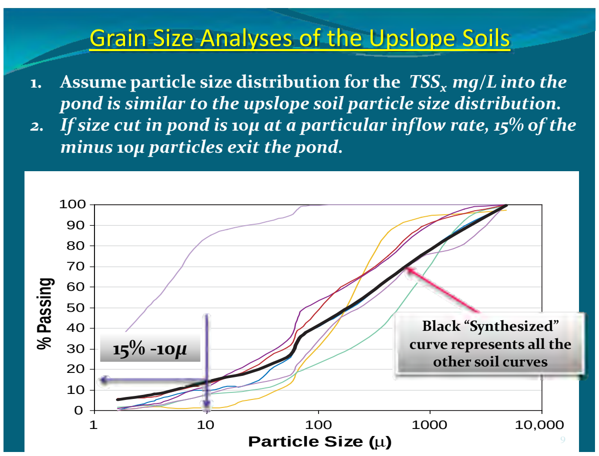
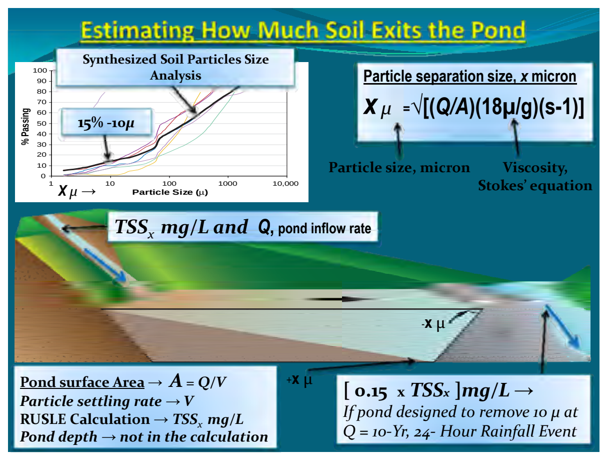
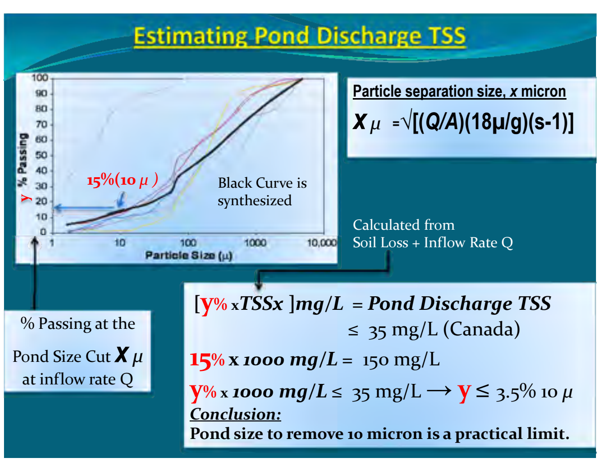
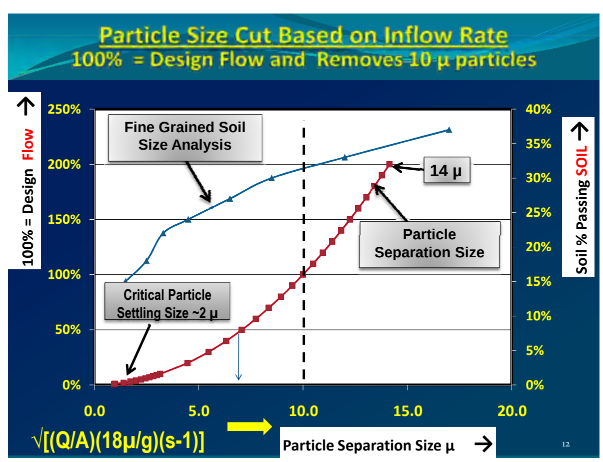

Grain Size Analyses of the Upslope Soils
1. Assume particle size distribution for the TSSx mg/L into the pond is similar to the upslope soil particle size distribution.
2. If size cut in pond is 10μ at a particular inflow rate, 15% of the minus 10μ particles exit the pond.
% Passing
100
90
80
70
60
50
40
30
20
10
0
15% -10μ
Black "Synthesized" curve represents all the other soil curves
1
10
100
1000
10,000
Particle Size (μ)


Estimating How Much Soil Exits the Pond
Synthesized Soil Particles Size Analysis
15% -10μ
Xμ →
Particle Size (μ)
Particle separation size, x micron
Xμ =√[(Q/A)(18μ/g)(s-1)]
Particle size, micron
Viscosity, Stokes' equation
TSSx mg/L and Q, pond inflow rate
x μ
Pond surface Area → A = Q/V
Particle settling rate → V
RUSLE Calculation → TSSx mg/L
Pond depth → not in the calculation
+X μ
[0.15 x TSSx]mg/L →
If pond designed to remove 10 μ at Q = 10-Yr, 24- Hour Rainfall Event


Estimating Pond Discharge TSS
y % Passing
15%(10 μ)
Black Curve is synthesized
Particle Size (μ)
Particle separation size, x micron
Xμ =√[(Q/A)(18μ/g)(s-1)]
Calculated from Soil Loss + Inflow Rate Q
% Passing at the Pond Size Cut X μ at inflow rate Q
[y% xTSSx]mg/L = Pond Discharge TSS
≤ 35 mg/L (Canada)
15% x 1000 mg/L = 150 mg/L
y% x 1000 mg/L ≤ 35 mg/L → y ≤ 3.5% 10 μ
Conclusion:
Pond size to remove 10 micron is a practical limit.


Particle Size Cut Based on Inflow Rate
100% = Design Flow and Removes 10 μ particles
100% = Design Flow
250%
200%
150%
100%
50%
0%
Fine Grained Soil Size Analysis
14 μ
Particle Separation Size
Critical Particle Settling Size ~2 μ
Soil % Passing SOIL
40%
35%
30%
25%
20%
15%
10%
5%
0%
0.0
5.0
10.0
15.0
20.0
√[(Q/A)(18μ/g)(s-1)]
Particle Separation Size μ
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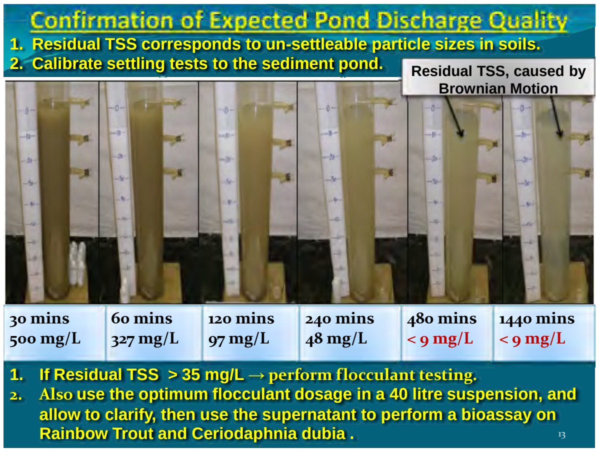
Confirmation of Expected Pond Discharge Quality
1. Residual TSS corresponds to un-settleable particle sizes in soils.
2. Calibrate settling tests to the sediment pond.
Residual TSS, caused by Brownian Motion
30 mins 500 mg/L
60 mins 327 mg/L
120 mins 97 mg/L
240 mins 48 mg/L
480 mins < 9 mg/L
1440 mins < 9 mg/L
1. If Residual TSS > 35 mg/L → perform flocculant testing.
2. Also use the optimum flocculant dosage in a 40 litre suspension, and allow to clarify, then use the supernatant to perform a bioassay on Rainbow Trout and Ceriodaphnia dubia .
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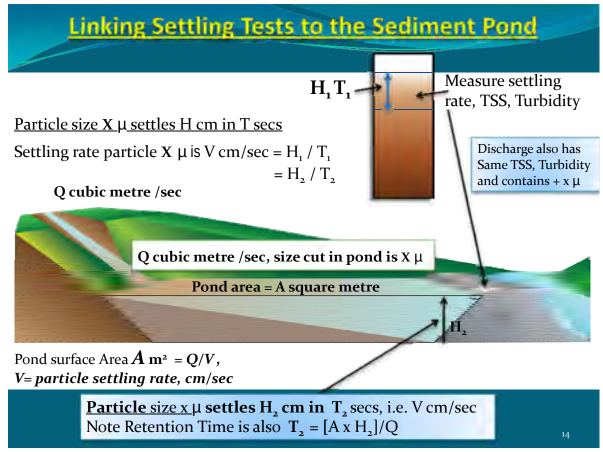
Linking Settling Tests to the Sediment Pond
H1 T1
Measure settling rate, TSS, Turbidity
Particle size X µ settles H cm in T secs
Settling rate particle X µ is V cm/sec = H1 / T1 = H2 / T2
Q cubic metre /sec
Discharge also has Same TSS, Turbidity and contains + x µ
Q cubic metre /sec, size cut in pond is x µ
Pond area = A square metre
H2
Pond surface Area A m² = Q/V,
V= particle settling rate, cm/sec
Particle size x µ settles H2 cm in T2 secs, i.e. V cm/sec
Note Retention Time is also T2 = [A x H2]/Q
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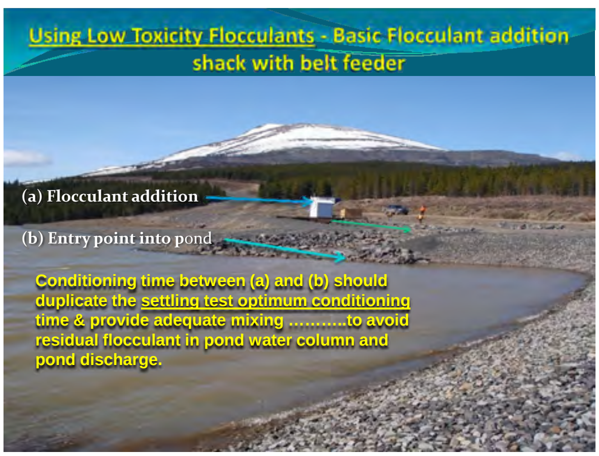
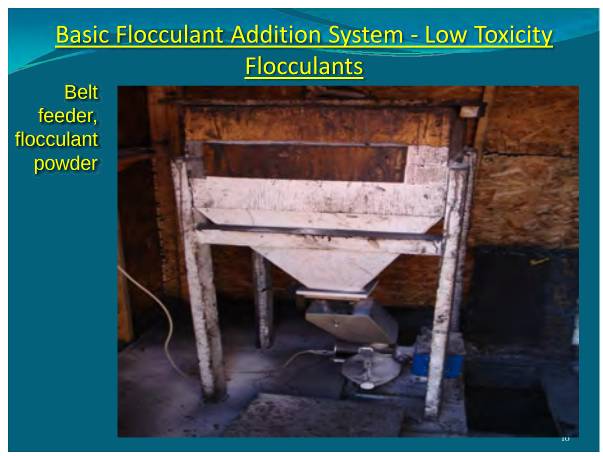
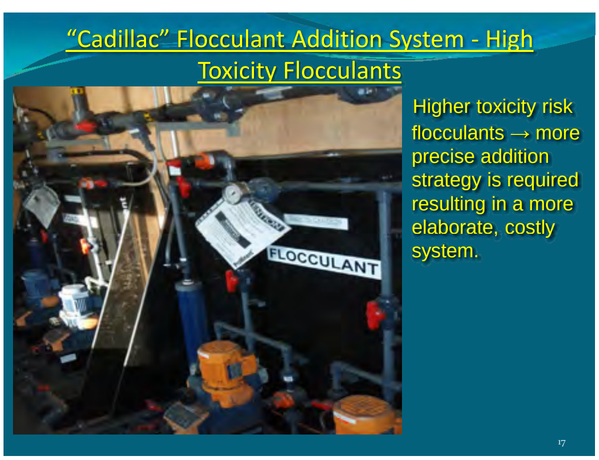

Using Low Toxicity Flocculants - Basic Flocculant addition shack with belt feeder
(a) Flocculant addition
(b) Entry point into pond
Conditioning time between (a) and (b) should duplicate the settling test optimum conditioning time & provide adequate mixing ....to avoid residual flocculant in pond water column and pond discharge.


Basic Flocculant Addition System - Low Toxicity Flocculants
Belt feeder, flocculant powder


“Cadillac” Flocculant Addition System - High Toxicity Flocculants
FLOCCULANT
Higher toxicity risk flocculants → more precise addition strategy is required resulting in a more elaborate, costly system.
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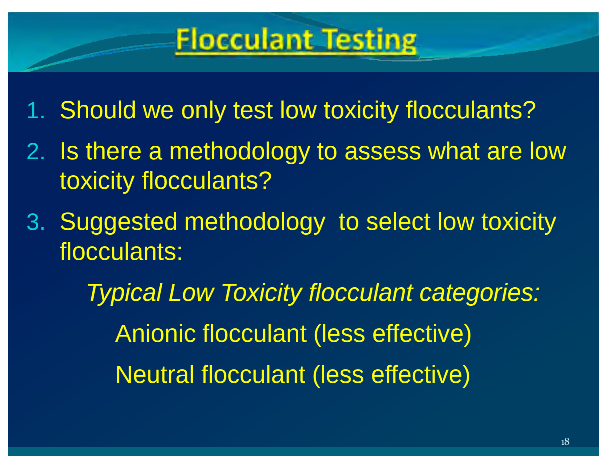
Flocculant Testing
1. Should we only test low toxicity flocculants?
2. Is there a methodology to assess what are low toxicity flocculants?
3. Suggested methodology to select low toxicity flocculants:
Typical Low Toxicity flocculant categories:
Anionic flocculant (less effective)
Neutral flocculant (less effective)
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Flocculants Testing - Toxicity

1. Higher Toxicity flocculants: Cationoc flocculant (More effective) Cationic/anionic flocculant Pair (More effective)
2. Fish gill assumed to be negatively charged (a result of evolution?)
3. Particulate in natural waters is typically negatively charged.
4. Predominance of particle negativity due generally to the preferential adsorption of OH^- .

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Guideline for Selectioning Flocculants

1. A "just pass" 96HrLC50 = 1.0 Toxic Unit, by definition.
2. Flocculant addition dosage = $C_{flocadd}$ mg/L
3. Flocculant 96 Hour LC50 concentration = C_{floc} mg/L
4. If $[C_{flocadd}] / [C_{floc}] \geq 1.0$ consider this potentially a high risk to generate toxicity.
5. If $[C_{flocadd}] / [C_{floc}] \leq 0.25$ consider this a *low risk*.

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What if the only Effective Flocculants Have "High Risk" Toxicity?

1. Attempt to avoid high toxicity flocculants, if possible.
2. If this is unavoidable, operating the pond becomes more challenging for the operator.
3. Special provisions are required to avoid generating "residual" flocculant in the pond discharge.
4. May require installing the "Cadillac" flocculant addition system + more.

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Causes of Toxicity in the Discharge?

1. What happens when excess flocculant is added to the runoff/TSS ?
2. Excess flocculant implies too much flocculant and not enough particles to "consume" the excess.
3. This will result in residual flocculant in the pond discharge.
4. Insufficient particle surface area to adsorb the excess flocculant.
5. Flocculant stays in the pond supernatant.

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Causes of Toxicity in the Pond Discharge – Inadequate Conditioning Time?

1. The excess flocculant is not removed from the pond supernatant to settling particles.
2. Polymer transfer mechanism from fluid phase to TSS particles also requires efficient mixing (not present in the pond).
3. Inadequate mixing conditions and insufficient conditioning time prior to runoff entering the pond may also lead to residual flocculant.

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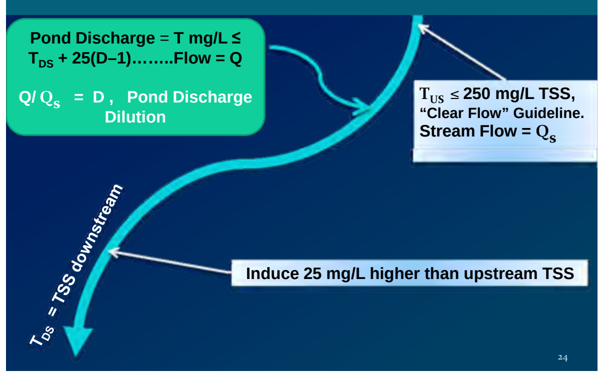
Pond Discharge Quality – TSS and Impact on Receiving Water, British Columbia Example



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Tools to Achieve Compliance of Pond Discharge

1. Draw down pond after rainfall event.
2. This will generally create more than 12 to 24 hours holding capacity - may allow settling the +2 micron particles prior to next rainfall event.
3. May avoid some of the costs of adding flocculants.
4. Use turbidity measurement of discharge to ensure pond bottom sediment not being remobilized.

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Tools to Achieve Compliance of Pond Discharge

1. Rapid settling tests at pond location performed on samples into pond after flocculant has been added.
2. On-site Zeta Meter to guide flocculant addition – to avoid over-dosing and creating toxicity and reduce flocculant consumption.
3. On-site particle size analysis (mobile particle size analyser) to guide flocculant addition.

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Need for additional work

1. Study relationship between particle size analyses : (a) soils above the pond (b) soil eroded and entering the pond (c) TSS in pond discharge.
2. Rapid toxicity measurement methods that are suitable for use at the mine site (IQ-Tox, Microtox, etc.)
3. Prediction of pond discharge toxicity when using flocculants.
4. Particle size analyser methods that are suitable for use at the mine site.

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END

Treatment of Mine Runoff TSS Using Ponds & Optimizing Flocculant Addition to Ensure Discharge Compliance