Acoustic Measurements of Clays and Silts

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Research Objective

• Develop a technique for using a single acoustic frequency to measure fine particle concentration in water
  – Compile a database of attenuation and backscatter data with the goal of using acoustic techniques to measure the concentration of fine sediment particles (0.1 – 64 micron diameter) in water.
  – Attenuation and backscatter data will be analyzed and presented for known concentrations of bentonite (0.2 – 1 µm), illite (0.2 – 2 µm), kaolinite (2 – 5 µm), and silt (45 – 60 µm) as well as clay/silt mixtures.
Calibration Tank

- Run known concentrations, particle sizes, and distances
- Obtain physical samples to measure concentration
- Measure acoustic backscatter/attenuation to develop empirical models

Receive Transducer

Transmit Transducer
Cal. Tank (cont.)

Using 20 MHz immersion transducers, data were acquired by a computer equipped with a 1GS/s oscilloscope and a preamp.

- Input Signal: 20 Mhz, 300 V_{p-p}, 100 cycle, 10 ms wait between bursts, 1000 pings/data set (3 data sets total)
Summary of Attenuation Data

Signal Level Difference (dBV re clear water) vs. Concentration (g/L)

- Bentonite
- Illite w/ Defloculant
- Kaolinite
- Silt

Larger particles vs. Smaller particles

Concentration (g/L)
Close-up Detail of Low Concentration Data

Concentration (g/L)

Signal Level Difference (dBV re clear water)

-5 -4 -3 -2 -1 0 0.2 0.4 0.6 0.8 1

Smaller particles

Larger particles

Bentonite  Illite w/ Defloculant  Kaolinite  Illite  Silt

Close-up Detail of Low Concentration Data

Concentration (g/L)

Signal Level Difference (dBV re clear water)

-5 -4 -3 -2 -1 0 0.2 0.4 0.6 0.8 1

Smaller particles

Larger particles

Bentonite  Illite w/ Defloculant  Kaolinite  Illite  Silt
Comparison between Clay/Silt Mixtures vs. Kaolinite Clay and Silt

Signal Level Difference (dBV re to clear water) vs. Concentration (g/L)

- Kaolinite
- Kaolinite & Silt
- Silt
Attenuation for Varied Clay/Silt Mixtures

Signal Level Difference (dBV re clear water) vs. Concentration Added (g/L)

- 1.41 g/L Silt with Kaolinite additions
- 1.41 g/L Kaolinite with Silt additions
- 5.6 g/L Silt with Kaolinite additions
- 5.6 g/L Kaolinite with Silt additions
Close-up Detail of Low Concentration Data (Revisited)

Signal Level Difference (dBV re clear water) vs Concentration (g/L)

Range of possibilities

Smaller particles vs Larger particles

- Bentonite
- Illite w/ Defloculant
- Kaolinite
- Illite
- Silt
Backscatter and Attenuation for Bentonite (0.2 – 1 µm)

Signal Level Difference (dBV re clear water) vs Concentration (g/L)

- Bentonite Backscatter
- Bentonite Attenuation
Backscatter and Attenuation for Kaolinite (0.2 – 2 µm)

Signal Level Difference (dBV re clear water)

Concentration (g/L)

Kaolinite Backscatter
Kaolinite Attenuation
Backscatter and Attenuation for Silt (45 – 60 µm)
Data Summary

**Backscatter**

- **X-axis:** Concentration (g/L)
- **Y-axis:** Signal Level Difference (dBV re to clear water)

**Legend:**
- Bentonite
- Kaolinite
- Illite
- Silt

**Attenuation**

- **X-axis:** Concentration (g/L)
- **Y-axis:** Signal Level Difference (dBV re to clear water)

**Legend:**
- Bentonite
- Kaolinite
- Illite
- Silt
Summary and Conclusions

- New attenuation and backscatter data were collected for a wide range of concentrations for clays, silts, and clay/silt mixtures.
- Attenuation levels for mixtures fell between levels for individual constituents.
- Backscatter levels were less responsive to particle size than expected.
  - Likely due to flocculation, in spite of careful procedure.
  - Must measure in-situ particle size.
- Based on the data here, it is likely that the combination of backscatter and attenuation will allow for rough (clay vs. silt) particle size discrimination with 20 MHz signal.
Future Work

• In-situ effective particle-size measurements will be obtained for clays, silt, and clay/silt mixtures using LISST-100X from Sequoia Scientific.

• More rigorous measurements of the detection threshold and resolution of the measurements.

• Based on the results presented and those obtained in future experiments, a technique for using a single acoustic frequency to measure fine particle concentration in water will be developed.

• Construct a prototype instrument and install on a floating instrument platform in the ARS Goodwin Creek Experimental Watershed and use it to monitor fine sediment concentrations during storm events.
Questions?

Thank you for your attention.