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Use of a multibeam echosounder and an acoustic Doppler velocity meter to measure bed-sediment movement

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Brenda K. Woodward, MS

U.S. Department of the Interior
U.S. Geological Survey

Outline

- Bed-Material Sediment Load
- Bedform Velocimetry
  - ISSDOTv2
  - Ponca data
- Virtual Velocity
  - Acoustic Doppler velocity meter

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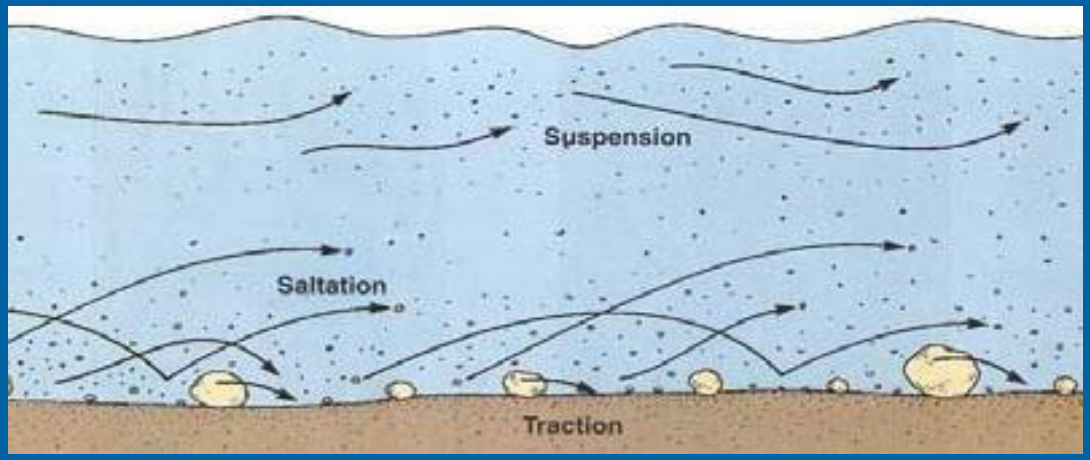
Sediment Load

- Suspended bed-material load
  - Within the water column
  - Supported by turbulence
- Bedload
  - Roll, slide, or saltate
  - Close proximity to the bed, particles stay in successive contact with the bed.
- Flow velocity, turbulence intensity, grain shear stress, entrainment of sediment from bed, concentration of sediment in the water column, sediment size, bedload transport, and the formation and maintenance of bed forms.



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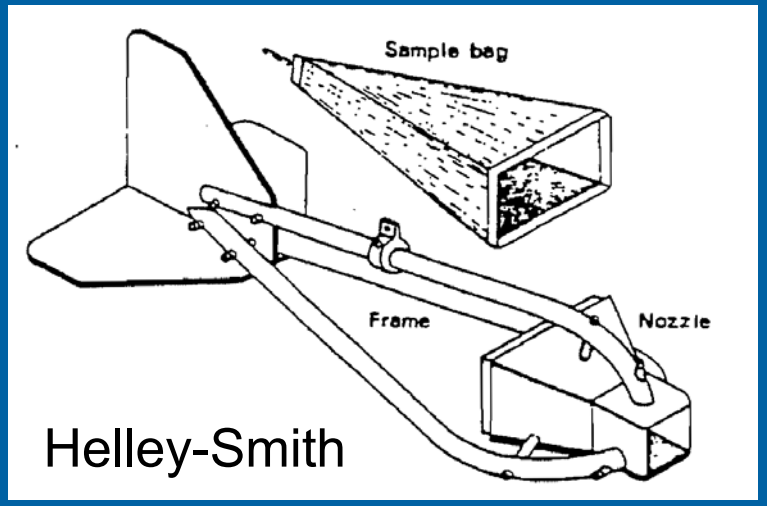
Estimating Bedload

- Direct measurement
  - physical sampling
- Indirect measurements
  - Bedform velocimetry
  - Virtual velocity



- Holmes, R.R. Jr., 2010, Measurement of Bedload Transport in Sand-Bed Rivers: A Look at Two Indirect Sampling Methods, *in* Gray, J.R., Laronne, J.B., Marr, J.D.G., Bedload-surrogate monitoring technologies: U.S. Geological Survey Scientific Investigations Report 2010-5091 available online at http://pubs.usgs.gov/sir/2010/5091/papers/.

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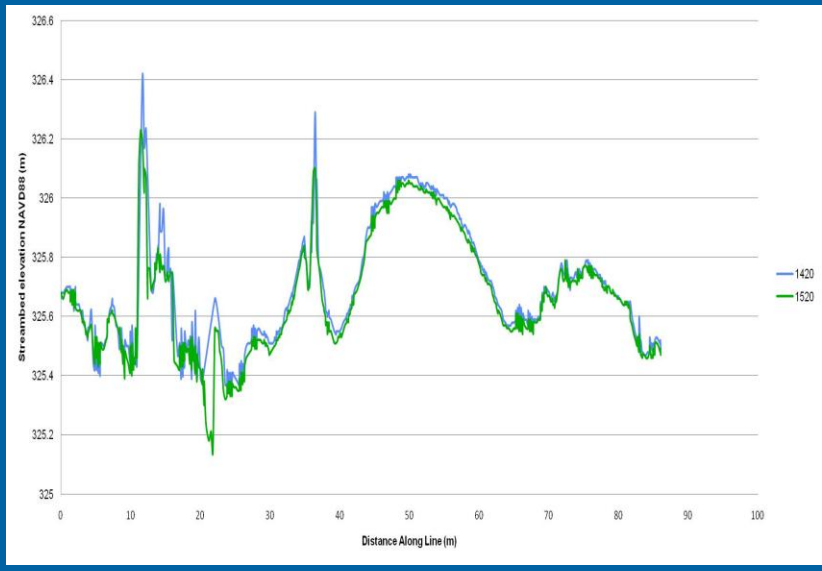
Bedform Velocimetry

- **Simons and others (1965)**

$$q_v = (1-p)U_b\Lambda/2$$

  - **Viewed dunes as triangles**



- **Engel and Lau (1980)**
  - **cross correlation of successive bathymetric profiles to determine lag**
  - **Absolute value of the departure of the bed elevation from the mean bed level**

$$q_v = \beta(1-p)U_b\Lambda$$

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Bedform Velocimetry

Integrated Section, Surface Difference Over Time
David Abraham, U.S. Army Corps of Engineers, Engineer Research and Development Center Coastal and Hydraulics Laboratory, Vicksburg, MS

- ISSDOT (1998)
  - Abraham and Pratt (2002), Abraham and Hendrickson (2003), and Abraham and Kuhnle (2006)
- ISSDOTv2
  - Version 2
  - Abraham D., Kuhnle, R.A., Odgaard, A.J., 2011, Validation of Bed Load Transport Measurements with Time Sequenced Bathymetric Data, Accepted by the Journal of Hydraulic Engineering

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ISSDOTv2

Integrated Section, Surface Difference Over Time

$$q_b = \beta \rho_s (1 - p) \Delta V / \Delta t$$

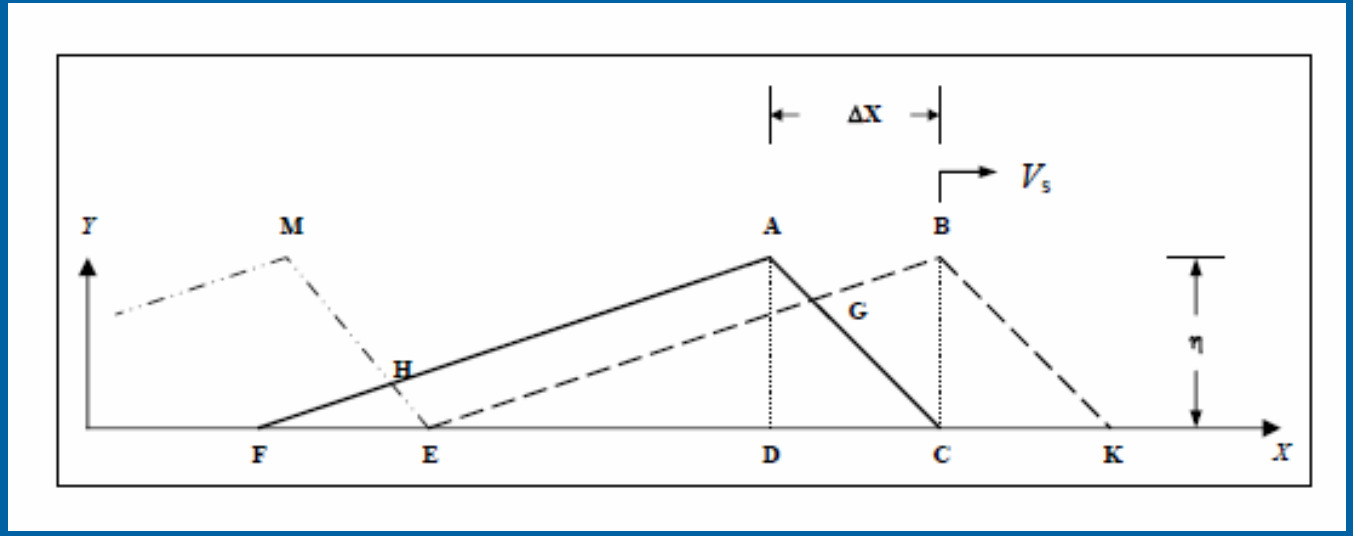

Diagram from Abraham and others, 2011

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Requirements and Field Application

Integrated Section, Surface Difference Over Time

- Highly precise bathymetric surveys
  - Resurvey of the exact same area
  - Equipment properly calibrated and error estimated
  - Timing correct
- Yet to understand
  - Changing dune speed and shape
  - The volume that goes into suspended sediment
  - Lateral movement of dunes
  - Small areas of volume change not calculated (can be quantified)

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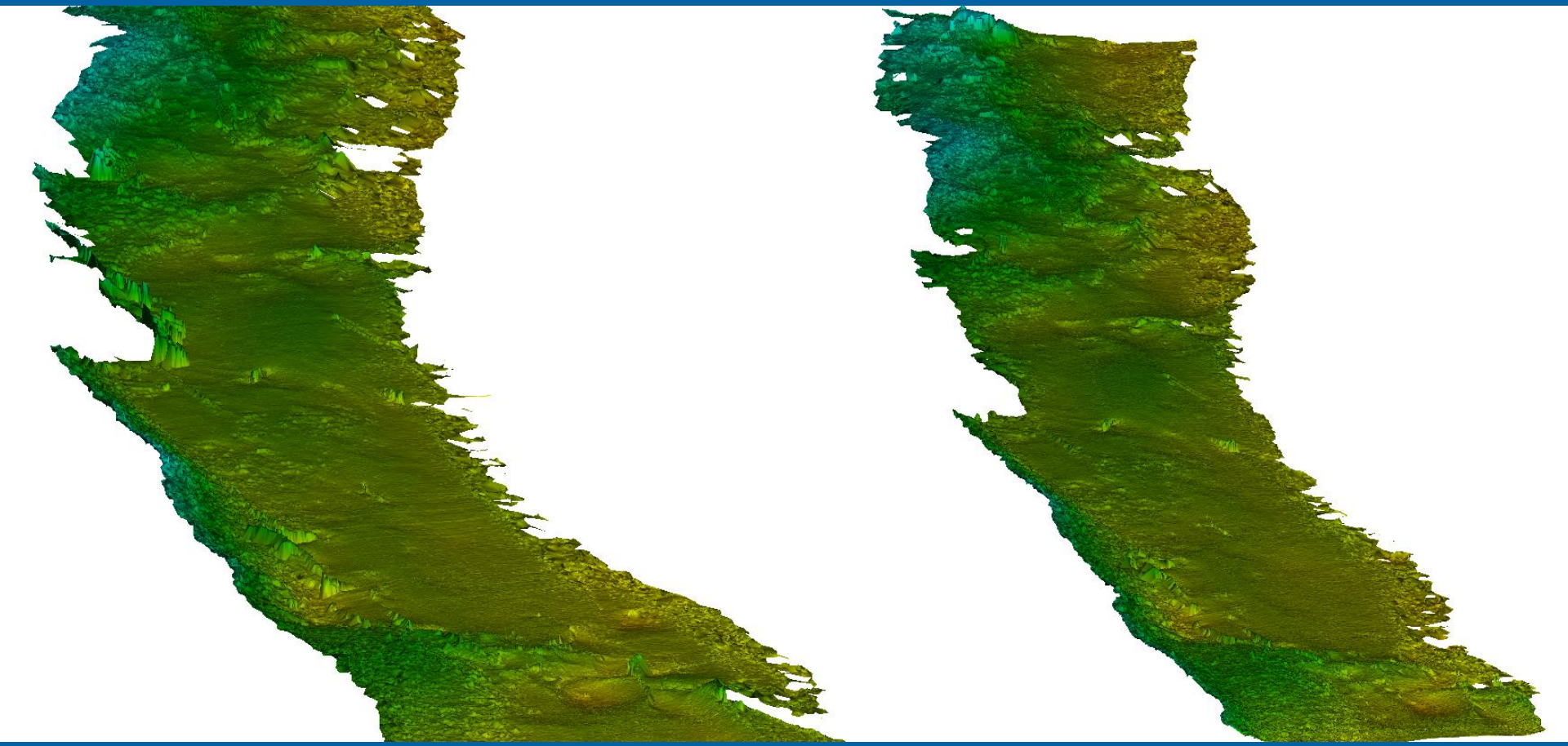
Ponca, Nebr. Data: December 2010

1420

1510



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Volume Calculation

Volume Calculation Mode

- Tin to Level
- Tin to Channel
- Tin to Tin
- Philadelphia

MultiCHN Philadelphia (Beta)

Borders

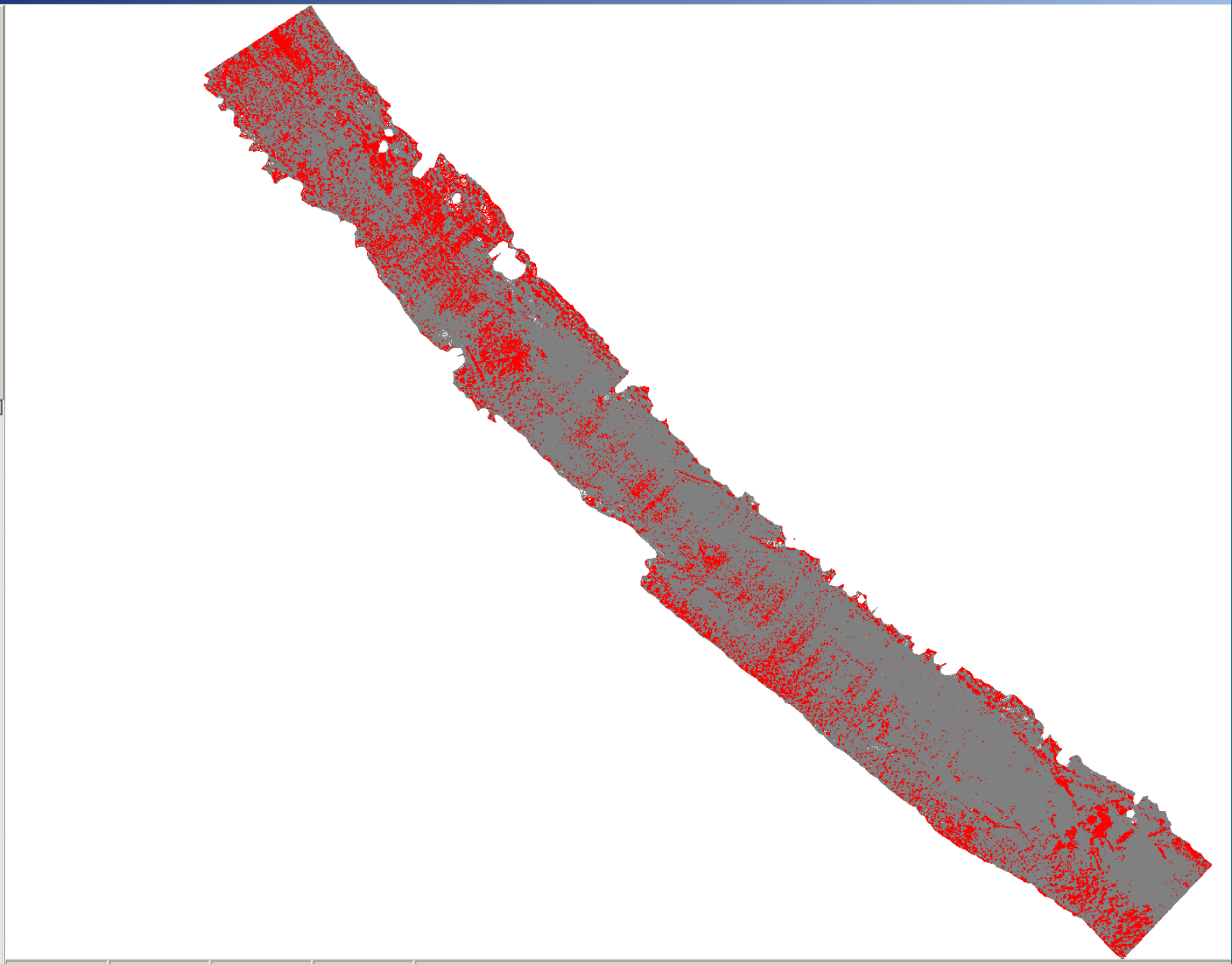
Area Name	File Name

Add Border | Remove Border

Show Picture | Step In

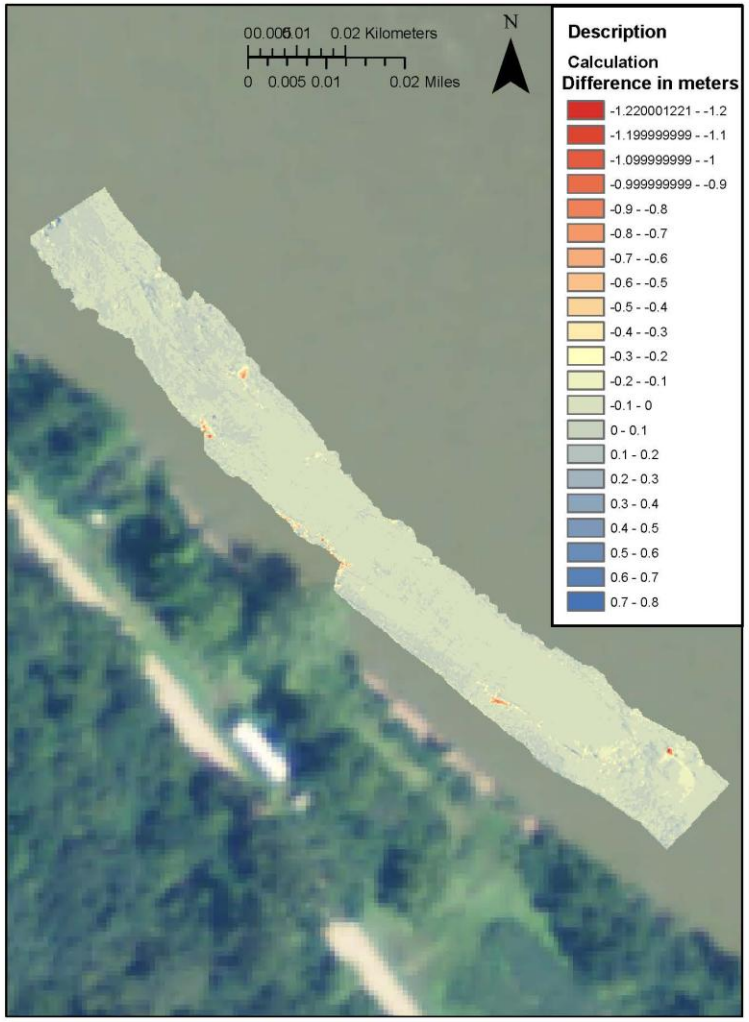
Calculate | Exit

Volume Tin1 Above Tin2 = 113.63
Area Tin1 Above Tin2 = 2611.09
Volume Tin1 Below Tin2 = 19.17
Area Tin1 Below Tin2 = 636.82



Equipment Precision

- Know what is volume change and what is measurement error
- Use only volume on the upstream face of the dunes



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Virtual Velocity

- Haschenburger and Church (1998)

$$q_v = (1 - p) V_b d_s$$

- Virtual velocity
  - Follow one particle
  - Velocity of all particles moving across a cross section
- Acoustic Doppler Current Profiler (ADCP)
  - Water velocity in three dimensions throughout the water column
  - Bottom track

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Acoustic Doppler Velocity Meters (ADVMs)

- Used to measure cross-channel velocity
- Uses both “Ranged Average” and “Multi-Cell” components
- Used to define a velocity index used in the computation of discharge
- Instrument programmed to user specifications
- Data recorded internally and to Data Collection Platform (DCP) for telemetry

Missouri River Near Ponca, Nebr.

- SonTek Argonaut SL 500 kHz ADVM
- Sample Interval 900 (s)
- Averaging Interval 300 (s)
- Ranged Average Cell: 5.00’ – 30.00’
- Multi-Cell option used: 10 cells, 5.00’ each
- Solinst Pressure Transducer

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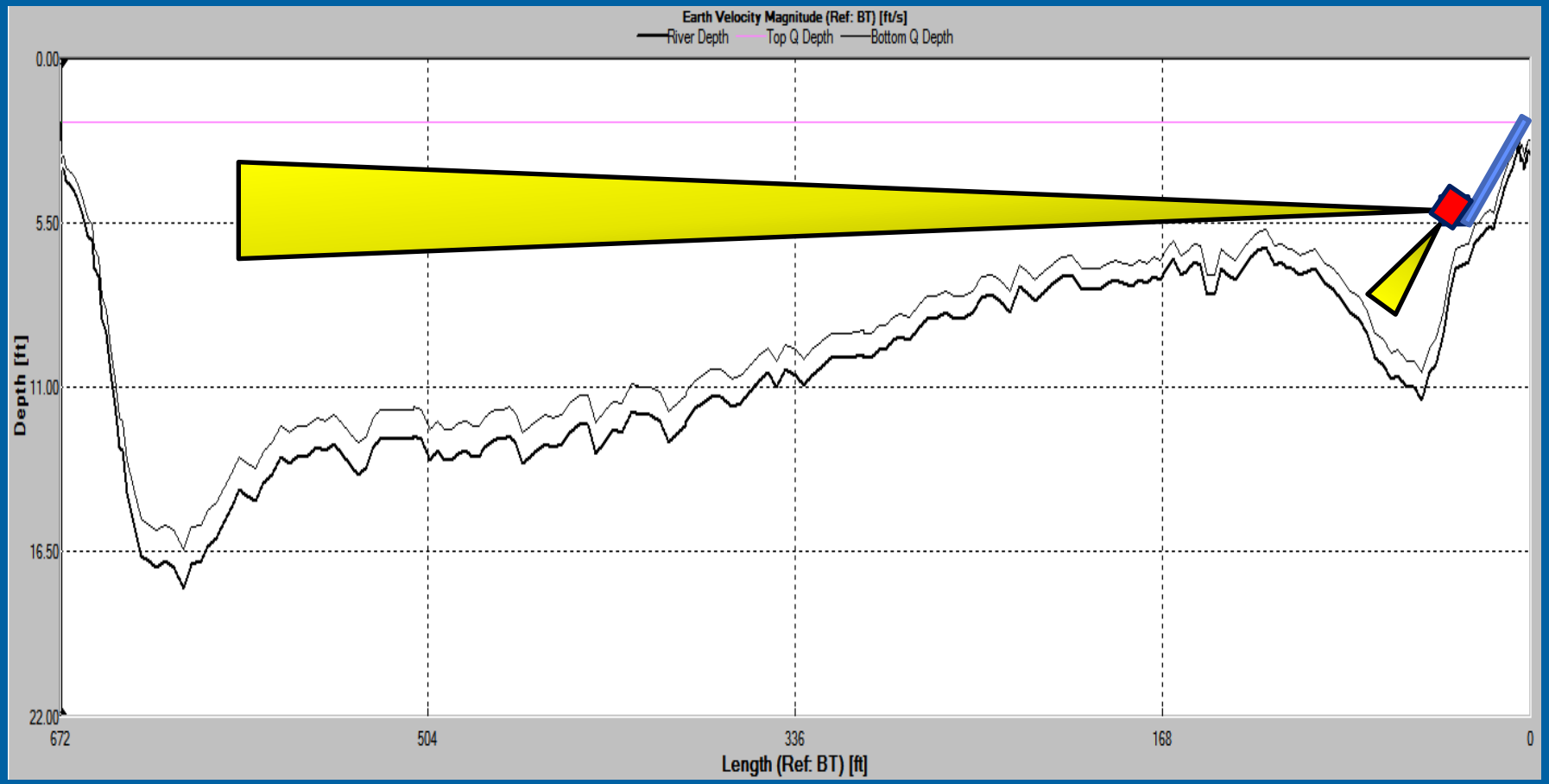
ADVM: Conventional vs. Modified Use



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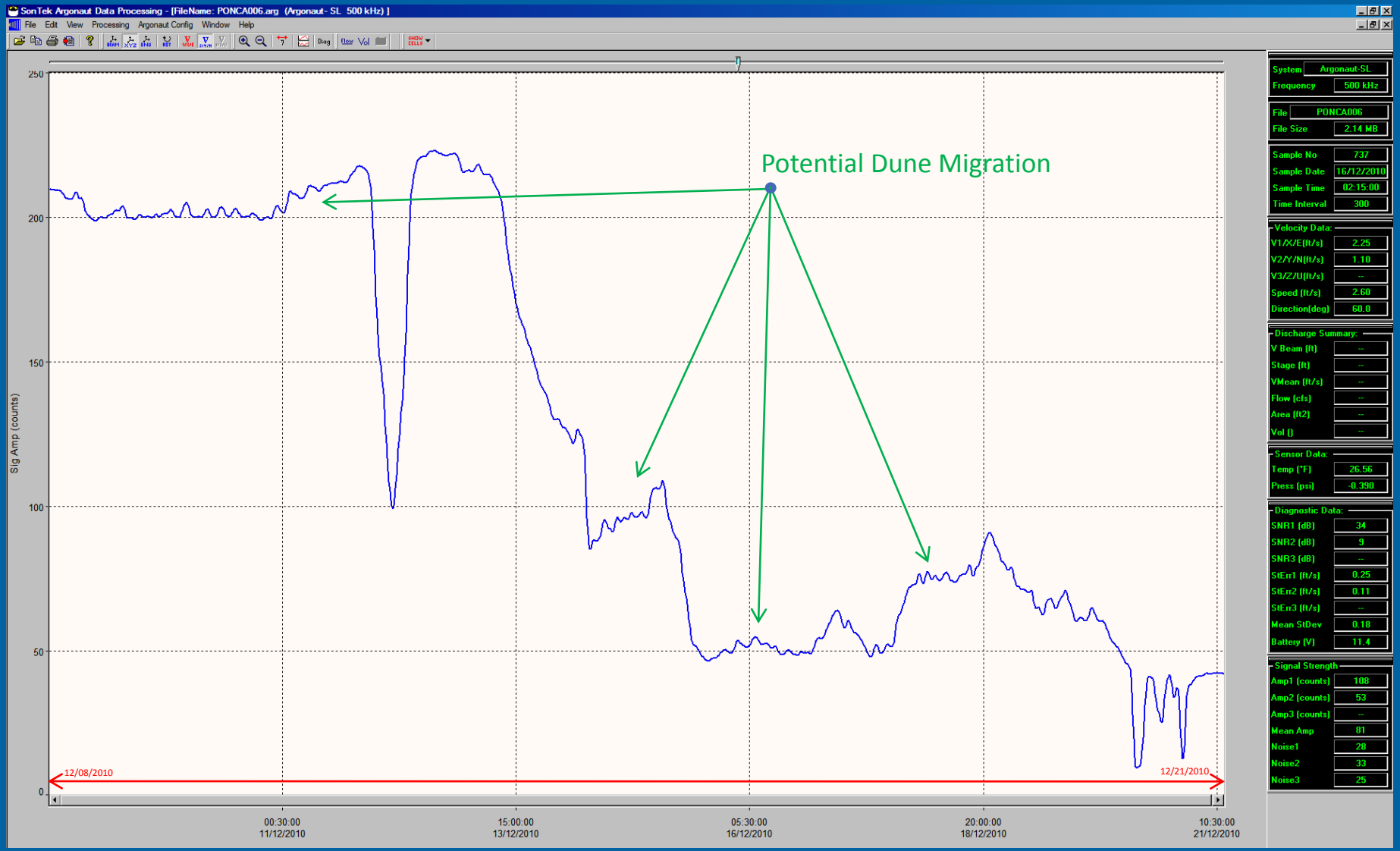
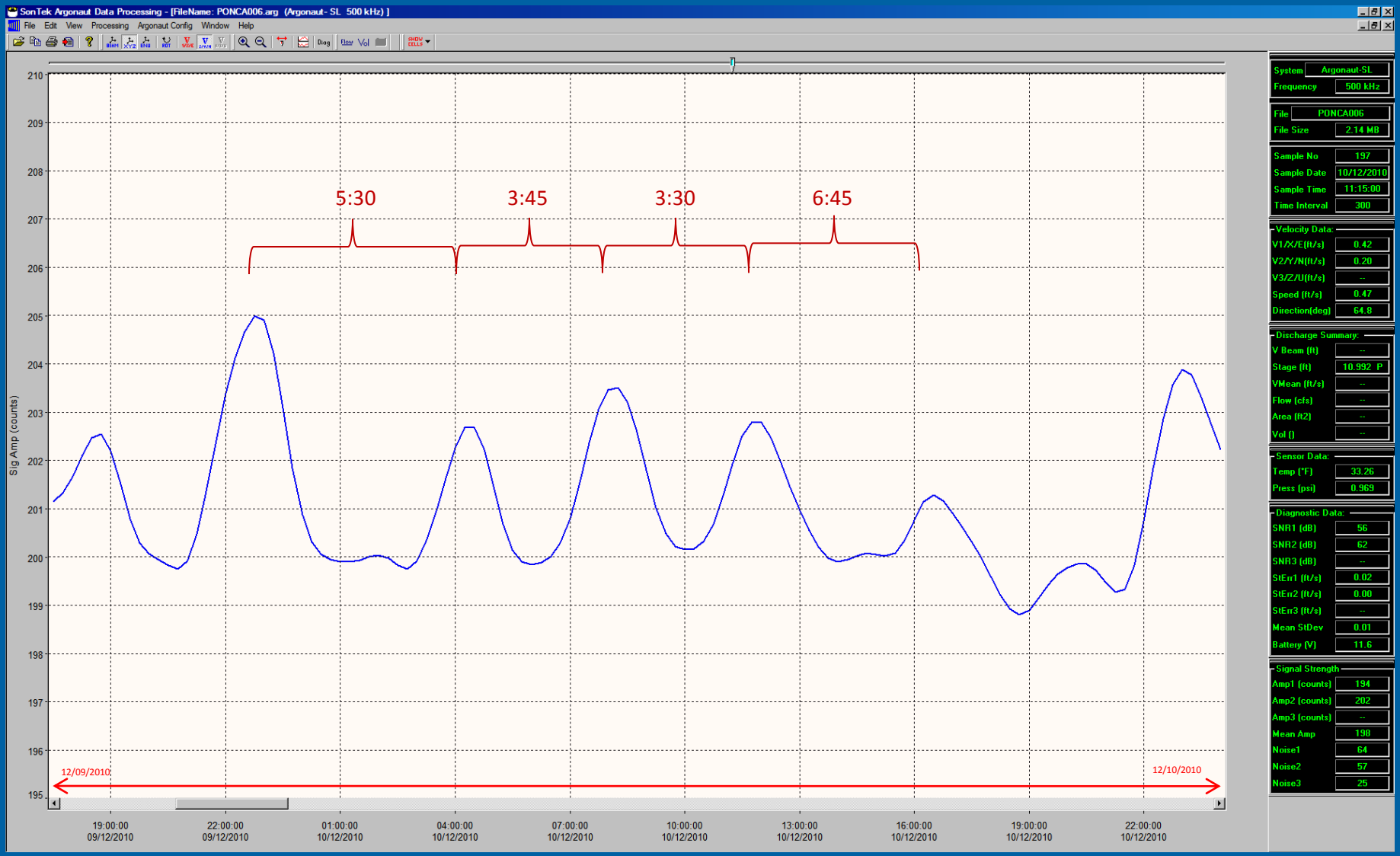
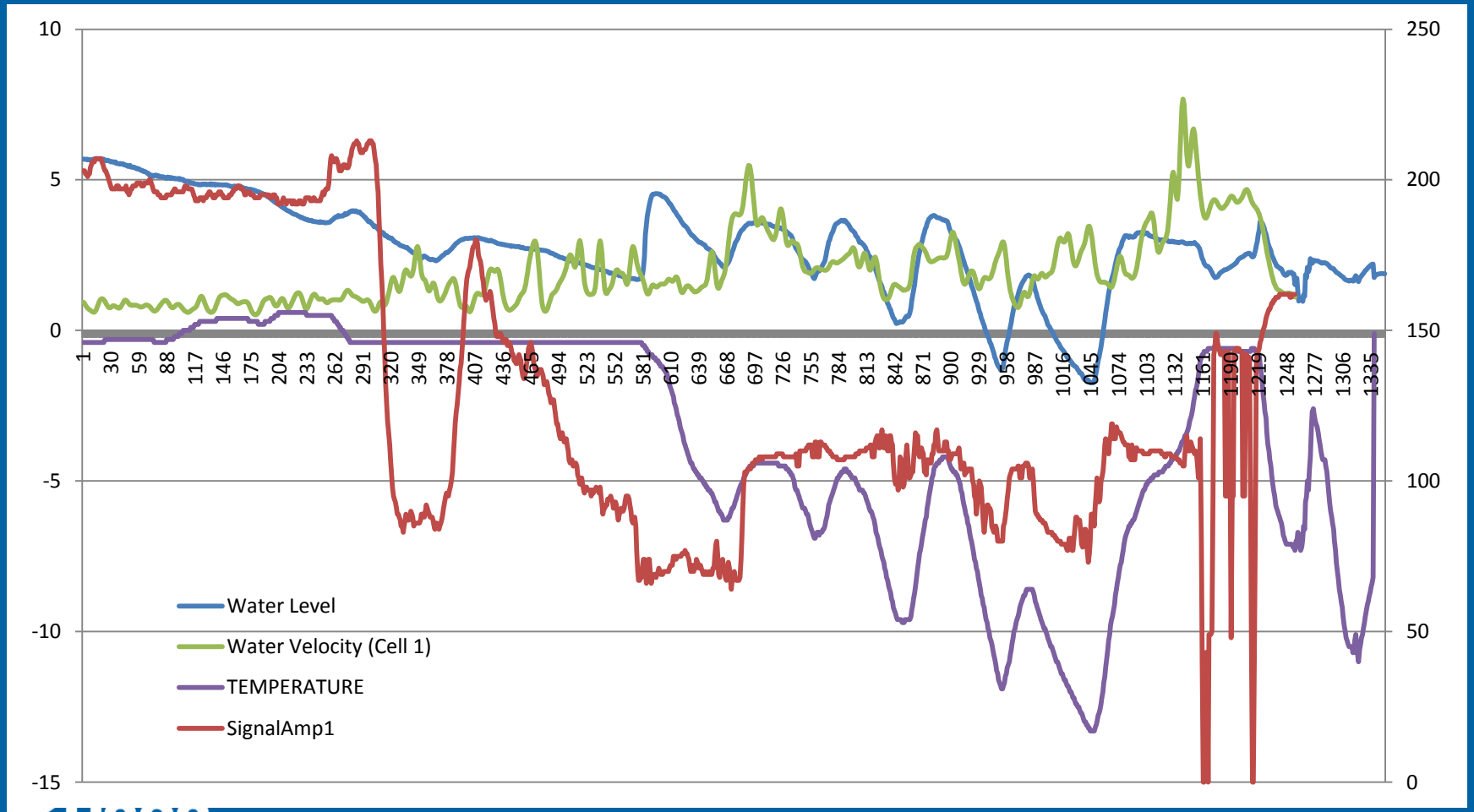
Missouri River Near Ponca, Nebr.
ADVM – Signal Amplitude



Missouri River Near Ponca, Nebr.
Dune Migration Cycle Time



Missouri River Near Ponca, Nebr.



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CONTACT INFORMATION

USGS Nebraska Water Science Center **(402) 328-4100**
5231 South 19th St. **http://ne.water.usgs.gov**
Lincoln, NE 68512-1271

Brenda K. Woodward **(402) 328-4145**

e-mail: bkwoodwa@usgs.gov

Robert B. Swanson
Director
(402) 328-4110
rswanson@usgs.gov

Richard C. Wilson, P.E.
Associate Director of
Hydrologic Studies
(402) 328-4120
wilson@usgs.gov

Jason M. Lambrecht
Associate Director for
Hydrologic Data
(402) 328-4124
jmlambre@usgs.gov

Ronald B. Zelt
Associate Director for NAWQA
(402) 328-4140
rbzelt@usgs.gov

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