Flow Monitoring – Monitor Types, Comparisons and Accuracies

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Stantec Consulting, Inc.

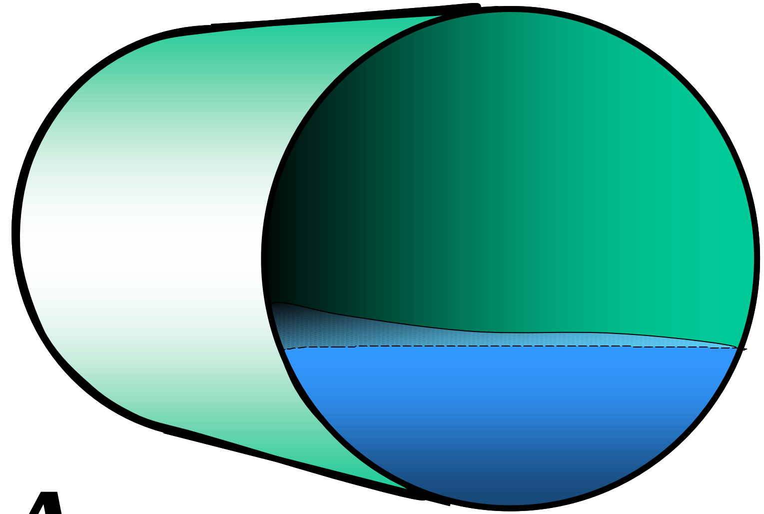
One Team. Infinite Solutions

Stantec

Area-Velocity Equipment

Pipe Flow

For steady open channel flow

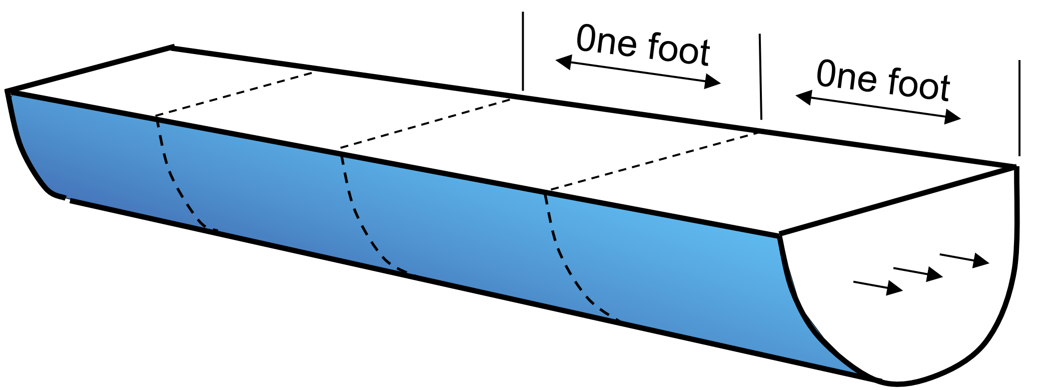


$$Q = V A$$

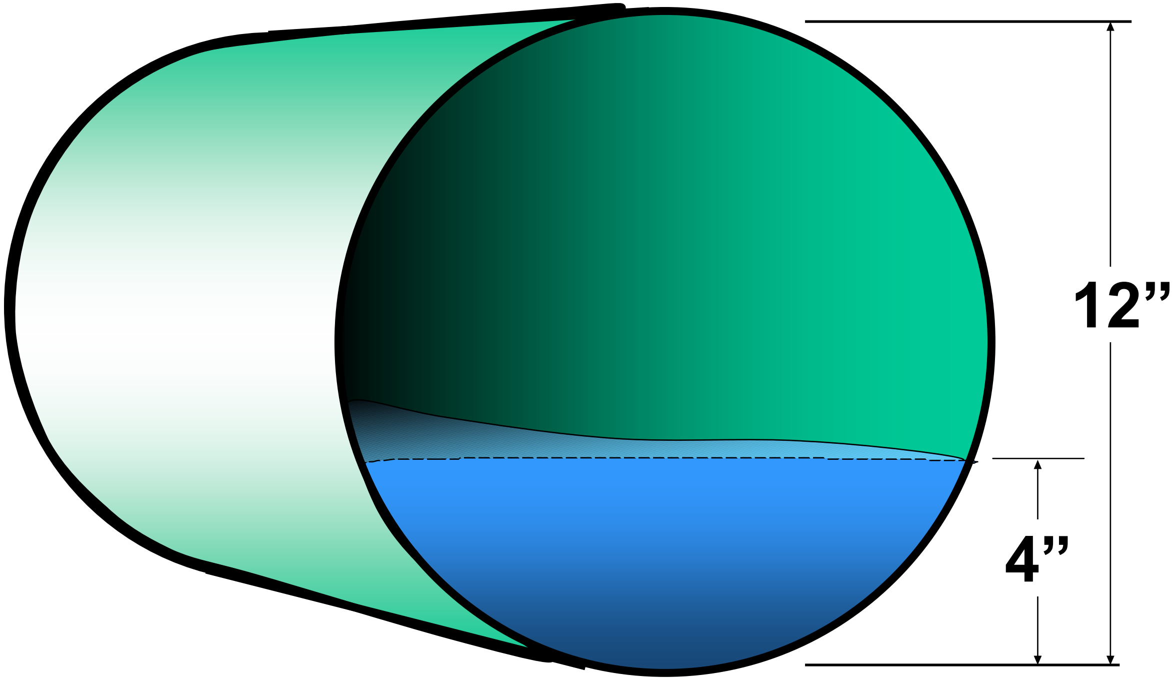
Volumetric Flow Rate equals the Average Advective Fluid Velocity times the Cross-Sectional Area of the flow perpendicular to the Velocity.

Pipe Flow

The velocity tells us the feet of water which passes a point every second.

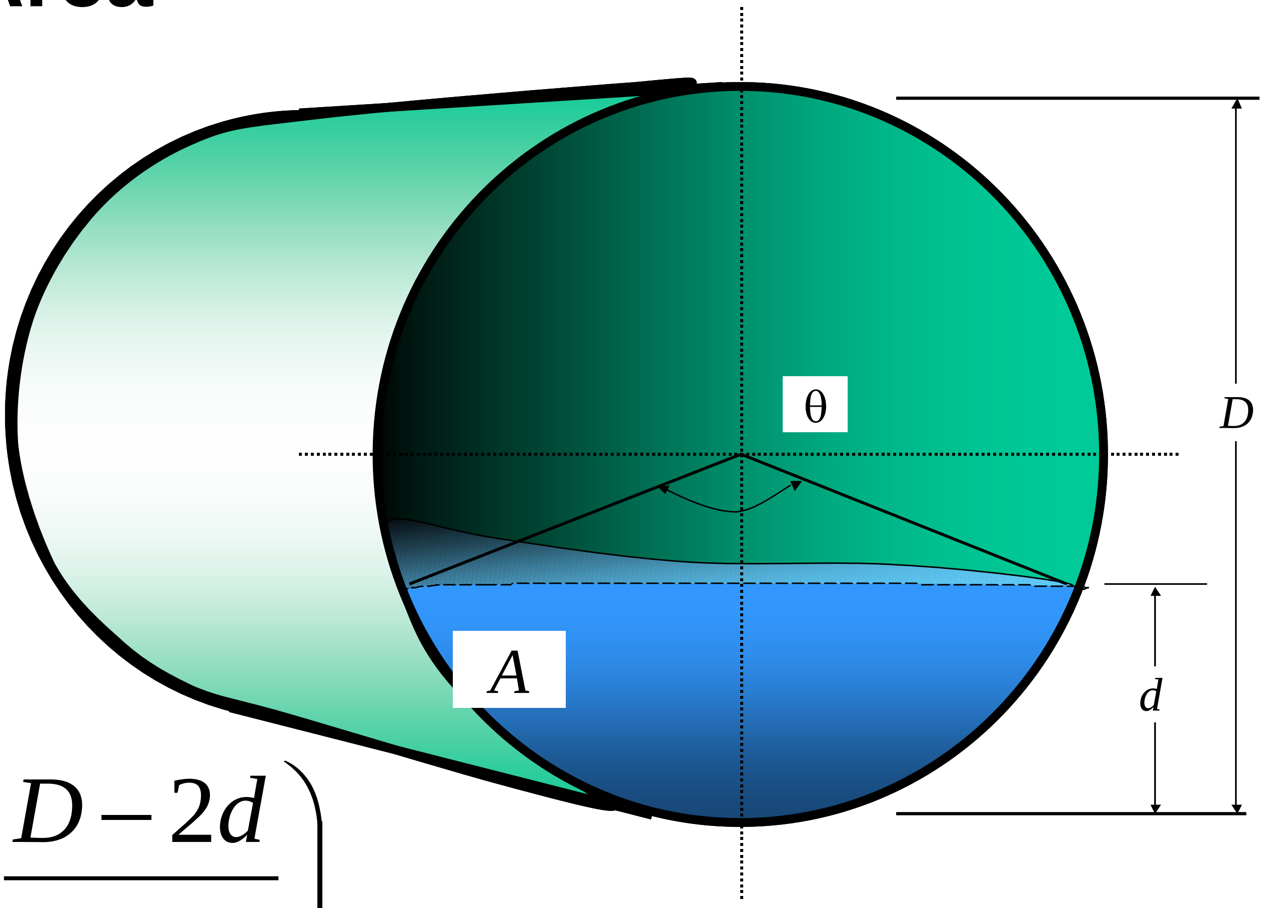


Circular Pipe Example



Consider a 12” pipe flowing 4 inches deep at 2 feet per second

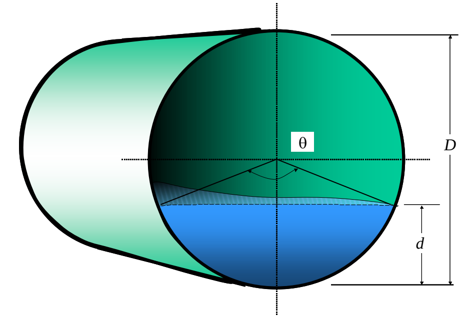
Calculating Area



$$\theta = 2\arccos\left(\frac{D-2d}{D}\right)$$

$$A = \frac{D^2}{8}\left(\theta - \sin\theta\right)$$

Calculating Area



For a 12” pipe flowing 4 inches deep,

D = 12 in, d = 4 in

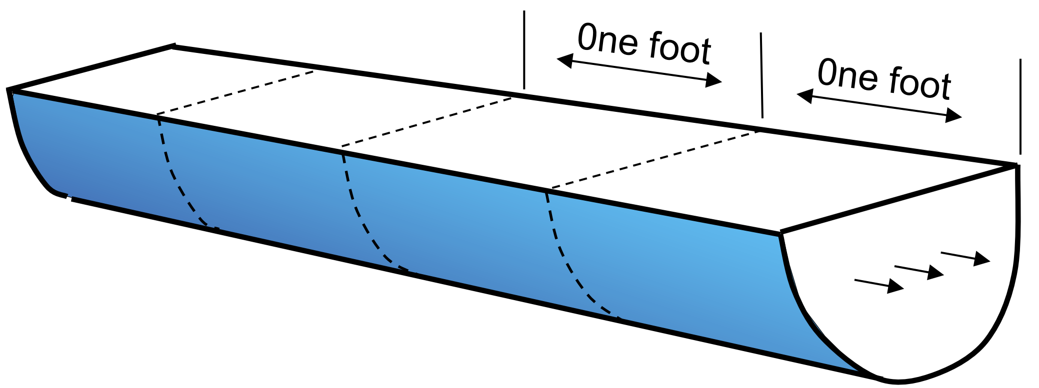
$$\theta = 2\arccos\left(\frac{12-2(4)}{12}\right) = 2\arccos(\frac{1}{3}) = 141° = 2.46 \text{ rads}$$

$$A = \frac{D^2}{8}\left(\theta - \sin\theta\right) = \frac{12^2}{8}\left(2.46 - \sin(2.46)\right) = 18\left(1.83\right) = 33.0 \text{ in}^2$$

A = 33.0 in^2 or 0.229 ft^2

Calculating Flow

At 2.0 $\frac{ft}{sec}$

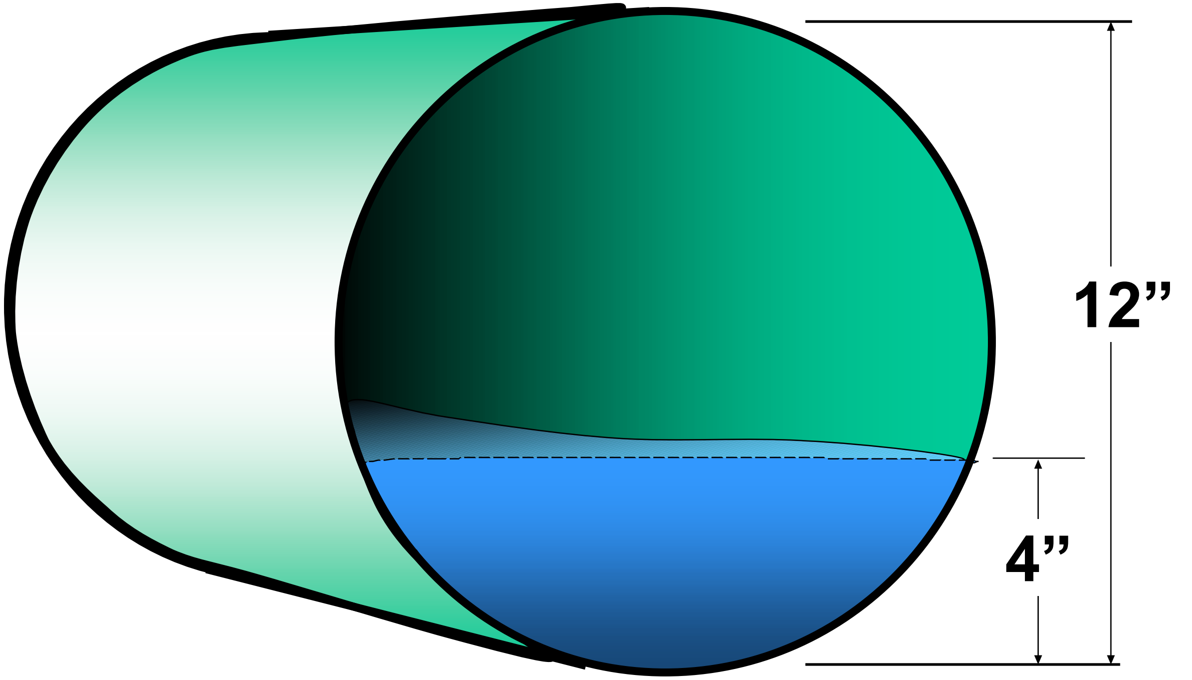


The volume every second is therefore,

$$Q = V A$$

$$Q = 2.0 \frac{ft}{sec} \;\; x \;\; 0.229\ ft^2 \;\; = \;\; 0.458 \frac{ft^3}{sec}$$

Example Answer

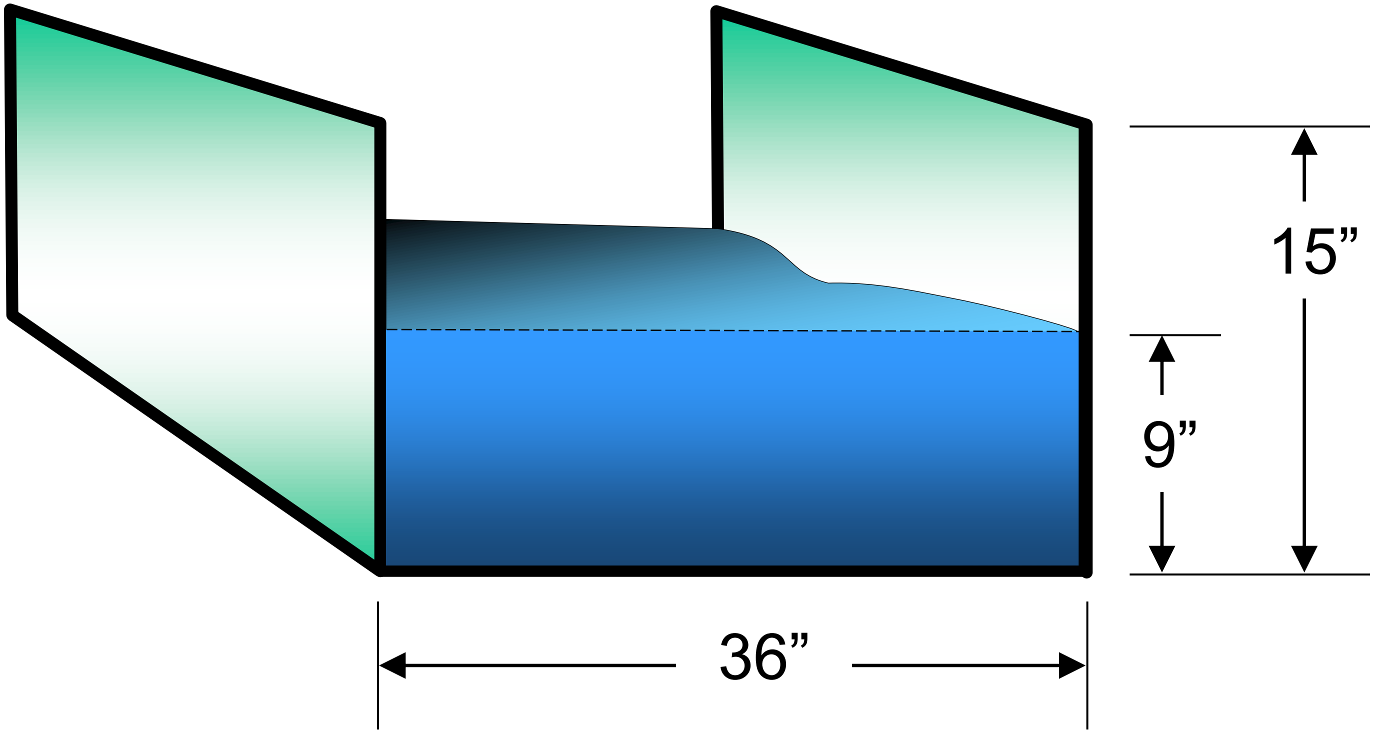


For the 12” pipe flowing 4 inches deep at 2 feet per second

Flow = 0.458 cfs

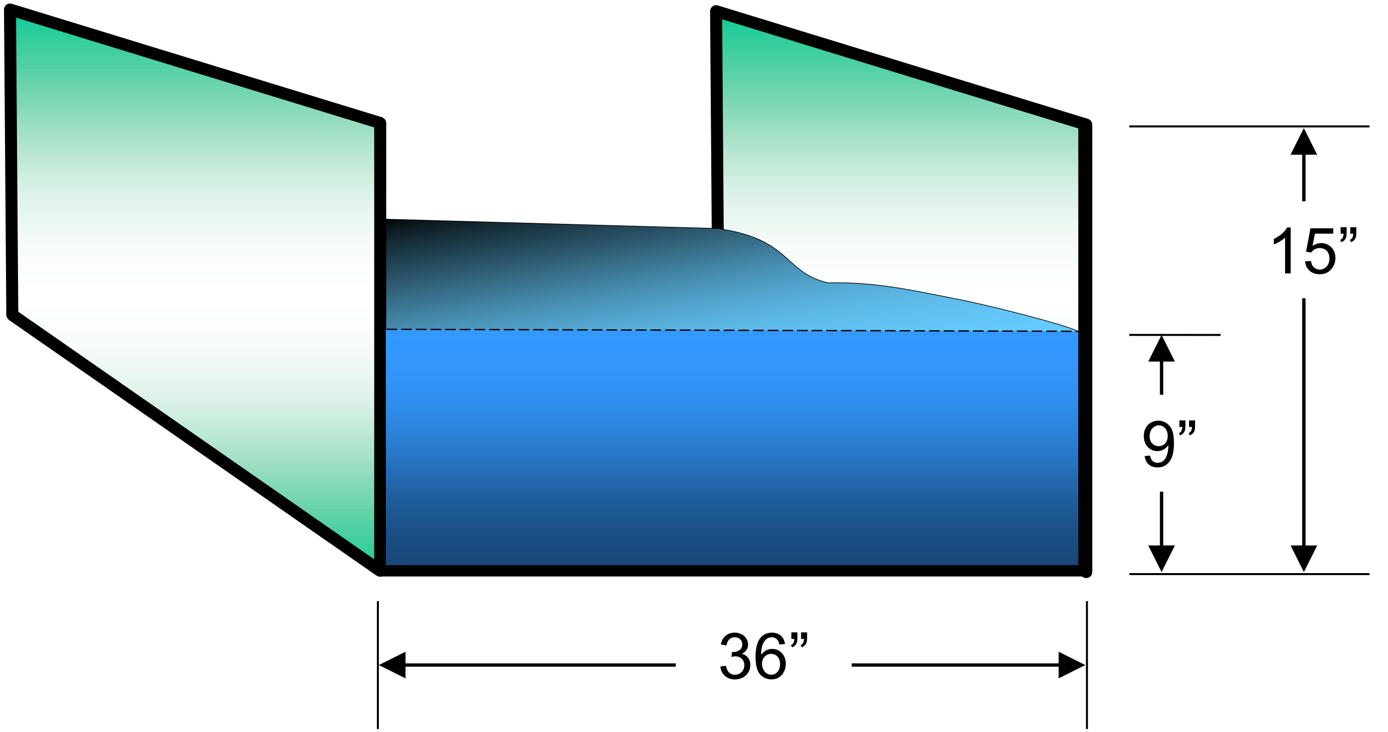
How About Other Shapes?

Rectangular Channel



Consider a 36 inch wide by 15 inch deep channel flowing 9 inches deep at 3.6 feet per second

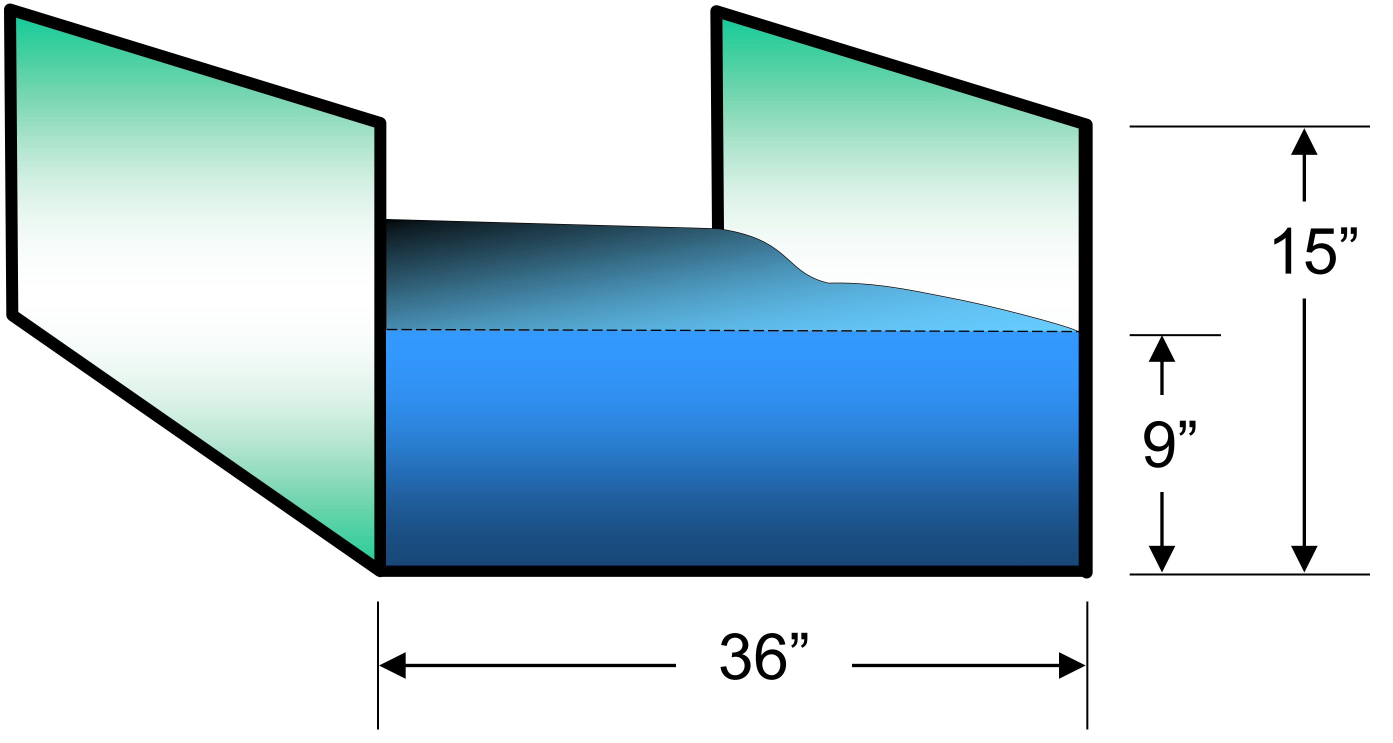
Calculate Area



$$A = (36 \text{ in}) \; (9 \text{ in}) = 324 \text{ sq in}$$

$$A = (324 \text{ sq in}) \frac{(1 \text{ sq ft})}{(144 \text{ sq in})} = 2.25 \text{ sq ft}$$

Calculate Flow

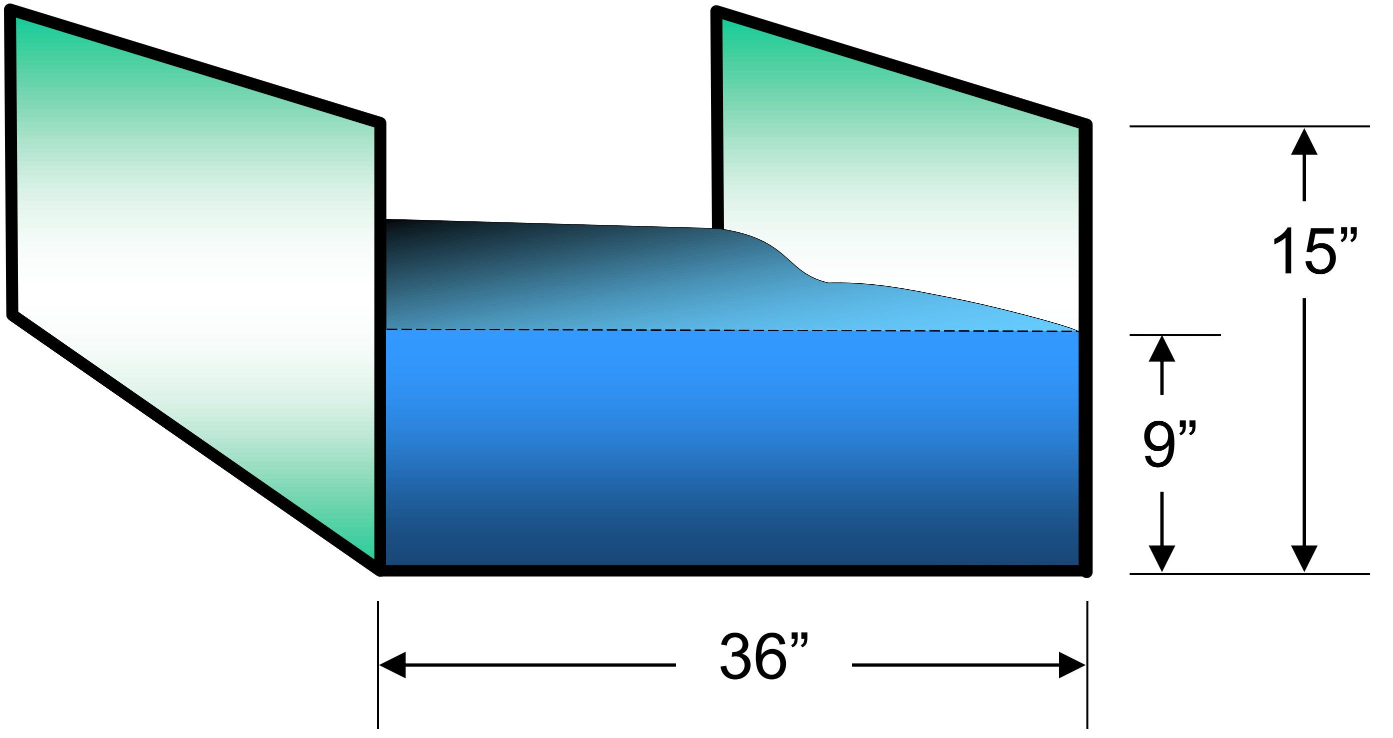


The volume every second is therefore,

$$Q = VA$$

$$Q = 3.6\,\frac{\text{ft}}{\text{sec}} \quad \text{x} \quad 2.25\ \text{ft}^2 \quad = \quad 8.1\,\frac{\text{ft}^3}{\text{sec}}$$

Depth of Channel?



In the Circular Pipe we used the Diameter of Pipe (D) in the flow calculation. Why did we not use Depth of Channel (15”) in the rectangular channel calculation?

What Do We Actually Measure?

Depth

Pressure Transducer

Airspace Ultrasonic

Water Depth Ultrasonic

Velocity

Continuous Wave Doppler

Range Gated Doppler

Faraday

Surface Radar

Some Common Monitors

ISCO 2150, 2151

Sigma 910, 920, 930

ADS FlowShark, Triton

Marsh McBirney Flo-Tote

Marsh McBirney Flo-Dar

ADS Pulse

ISCO 2150: Technology

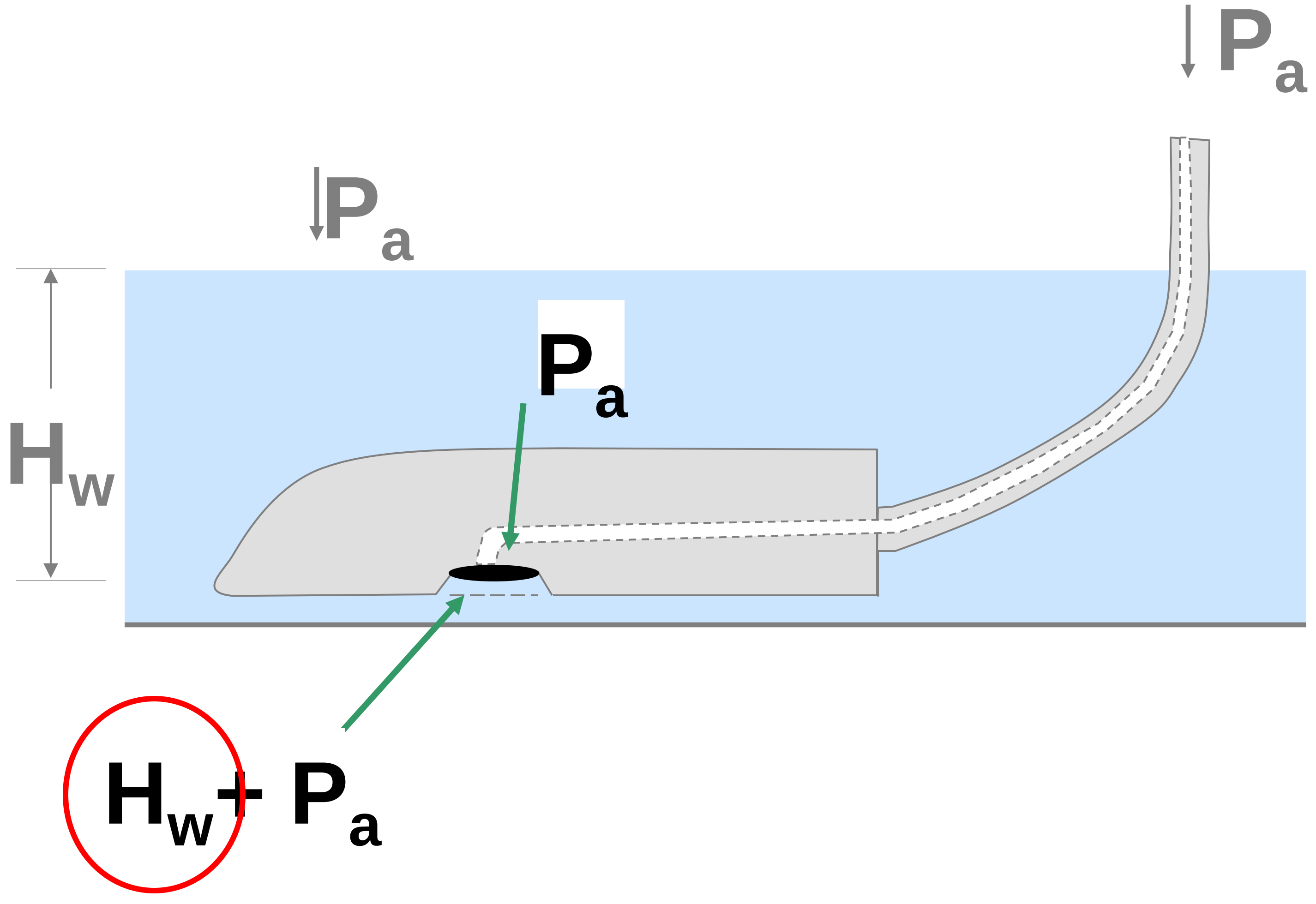
Level

- Pressure transducer, or
- 2150 with Ultrasonic

Velocity

- Continuous Wave Doppler velocity
- Centroid of return spectrum

Pressure Sensor



All this to keep Atmospheric Pressure on the back side.

Pressure Sensor

He is so fragile that if you touch him, he dies.

Pressure Sensor – Dessicant up at the top

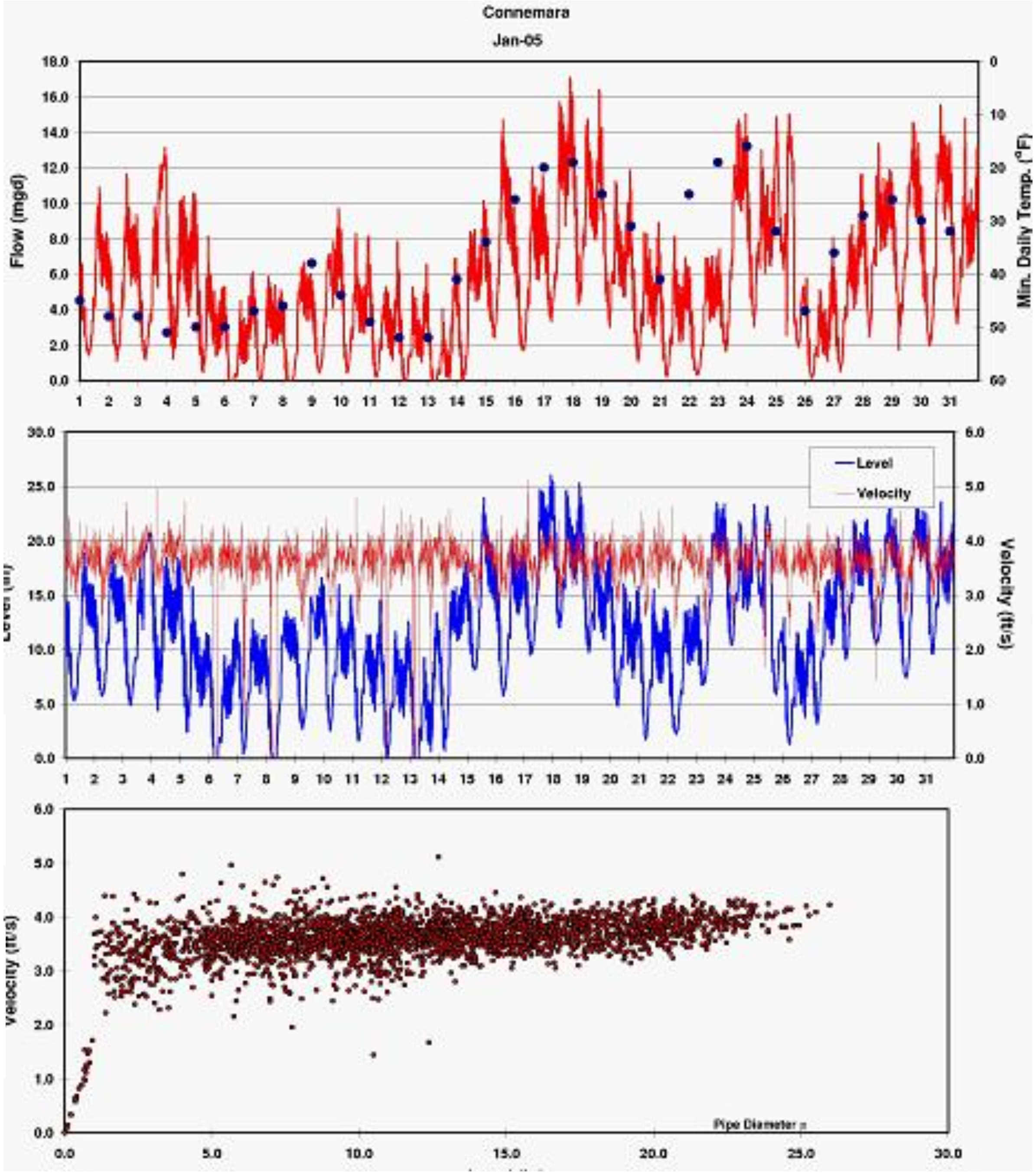
Cable runs up to the top of the manhole where the tube vents to the atmosphere.

Pressure Sensor - Dessicant

Desiccant keeps the electronics dry.

Pressure Sensor - Dessicant

Level Problem



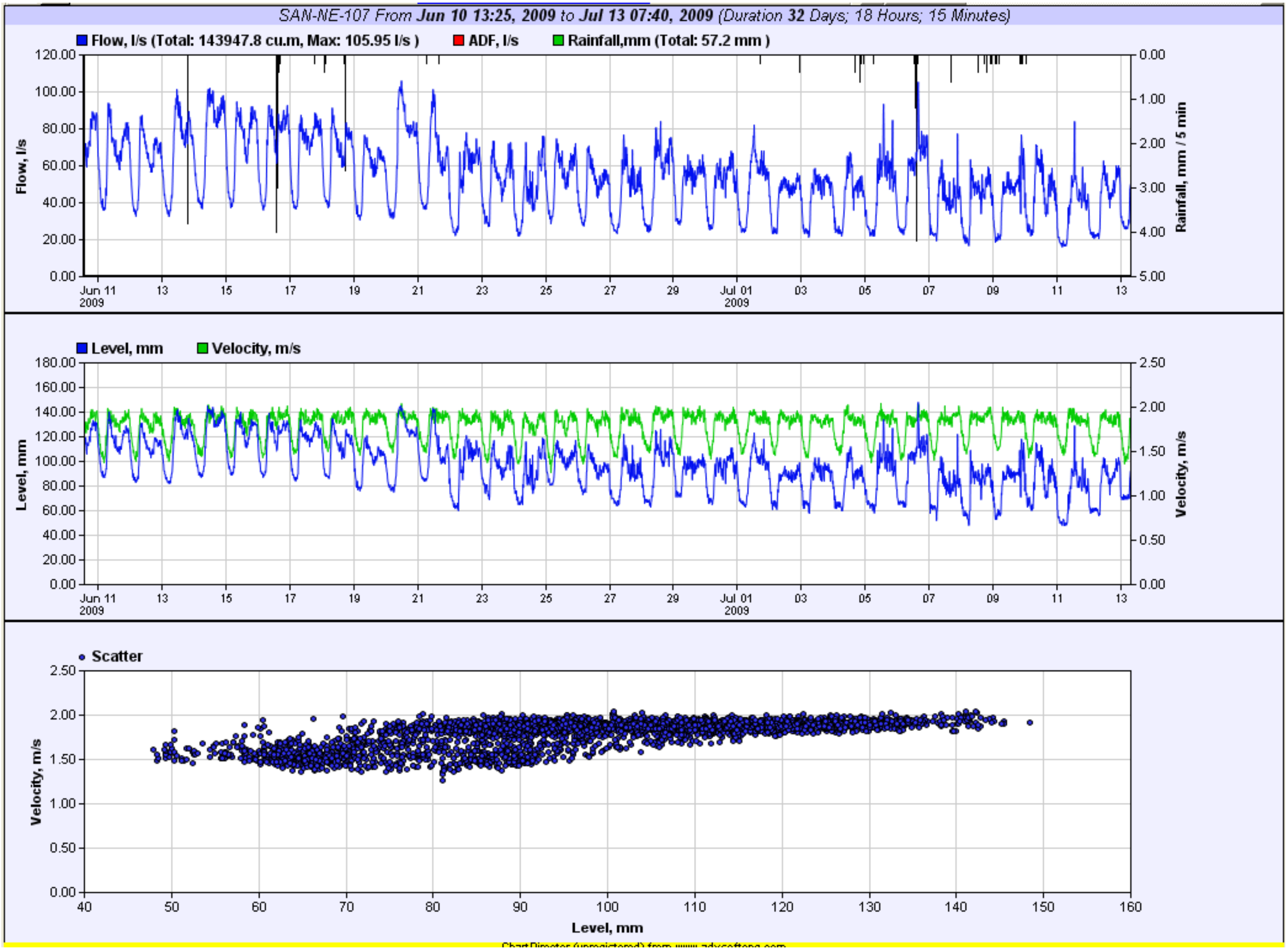
Hydrophobic Filter gets plugged

Has been replaced with a Gortex filter

Pressure Sensor

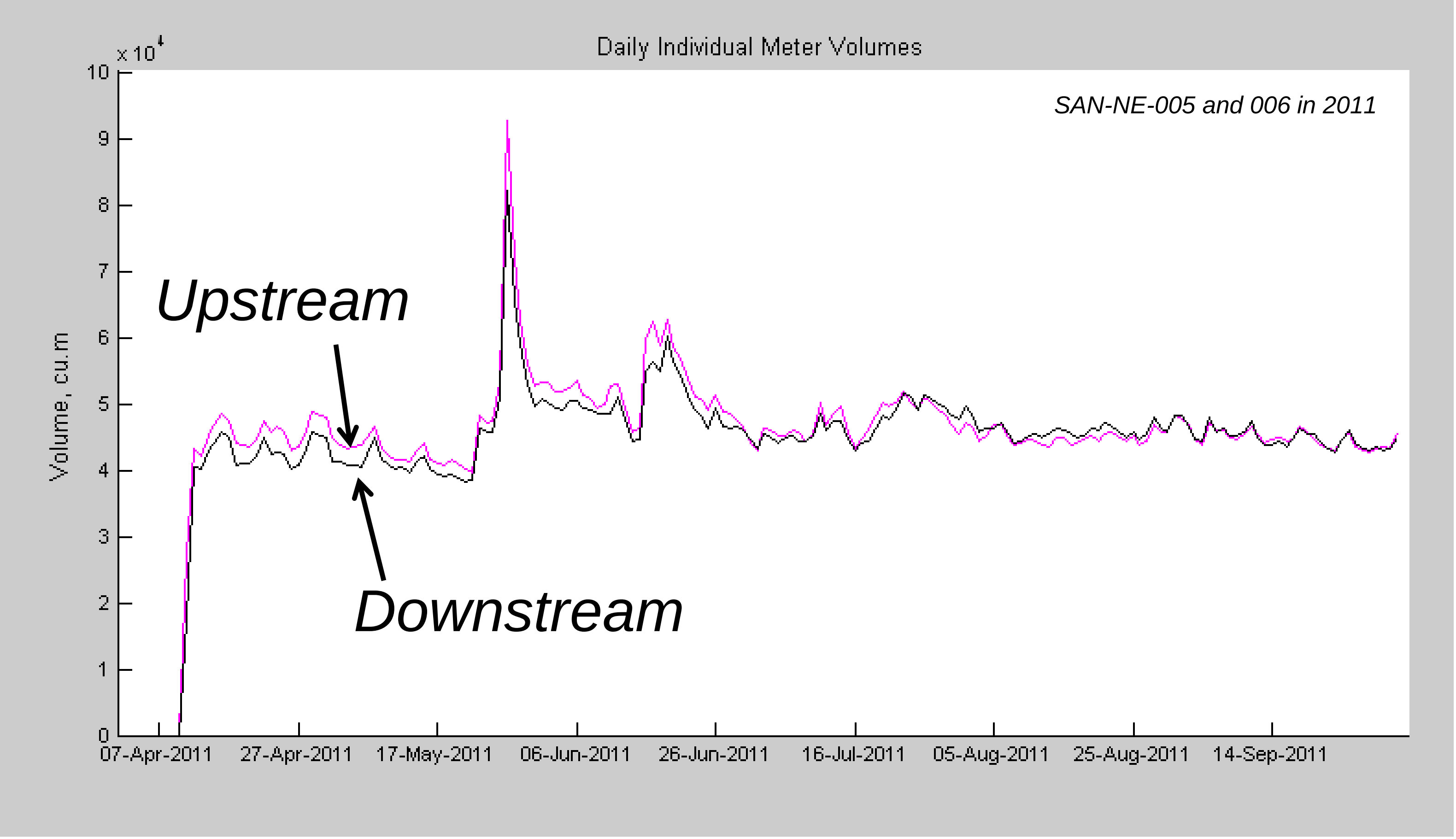
Can cause quite a disturbance to the flow.

Level: drift over long time



Stainless Steel Membranes are subject to creep over time..

Level Drift?

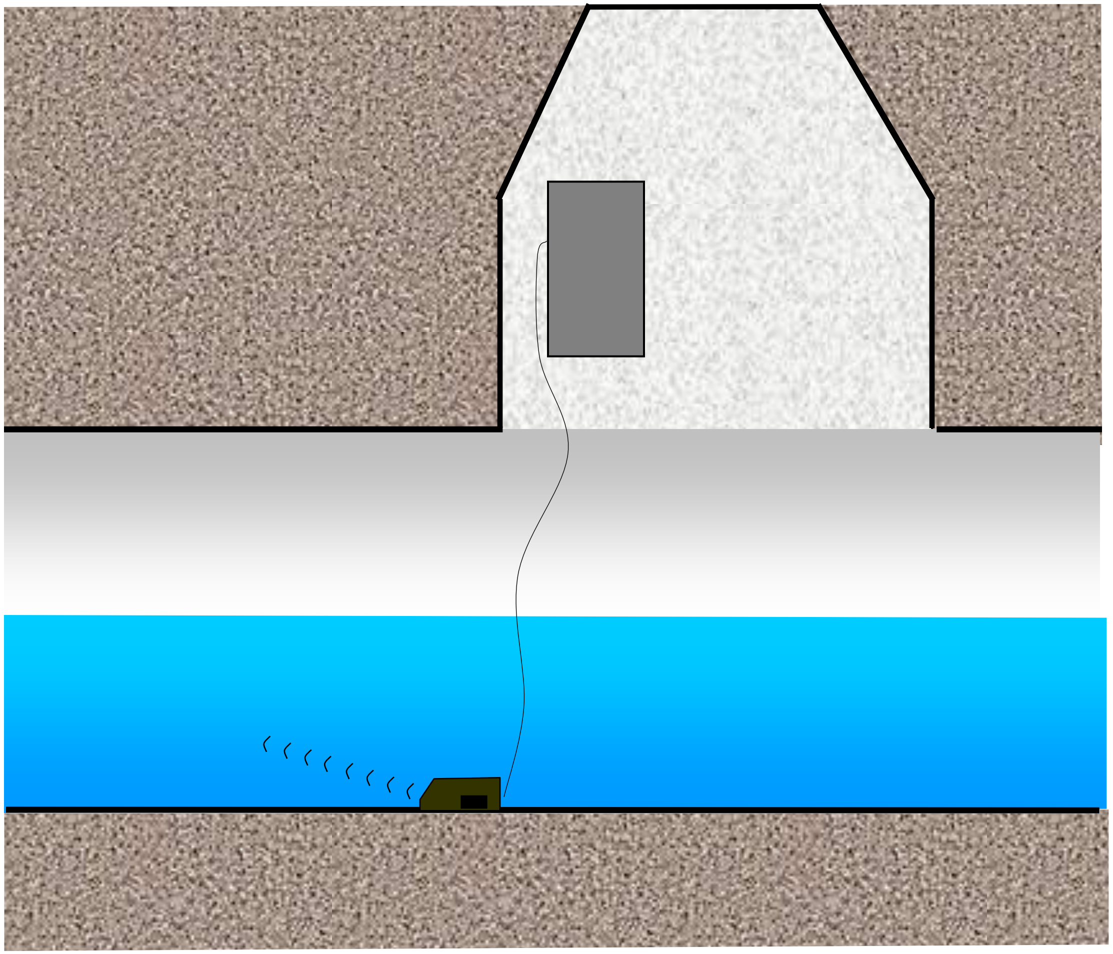


Daily total flow get closer and closer. Most likely drift.

Level: Redundant Probe Solution

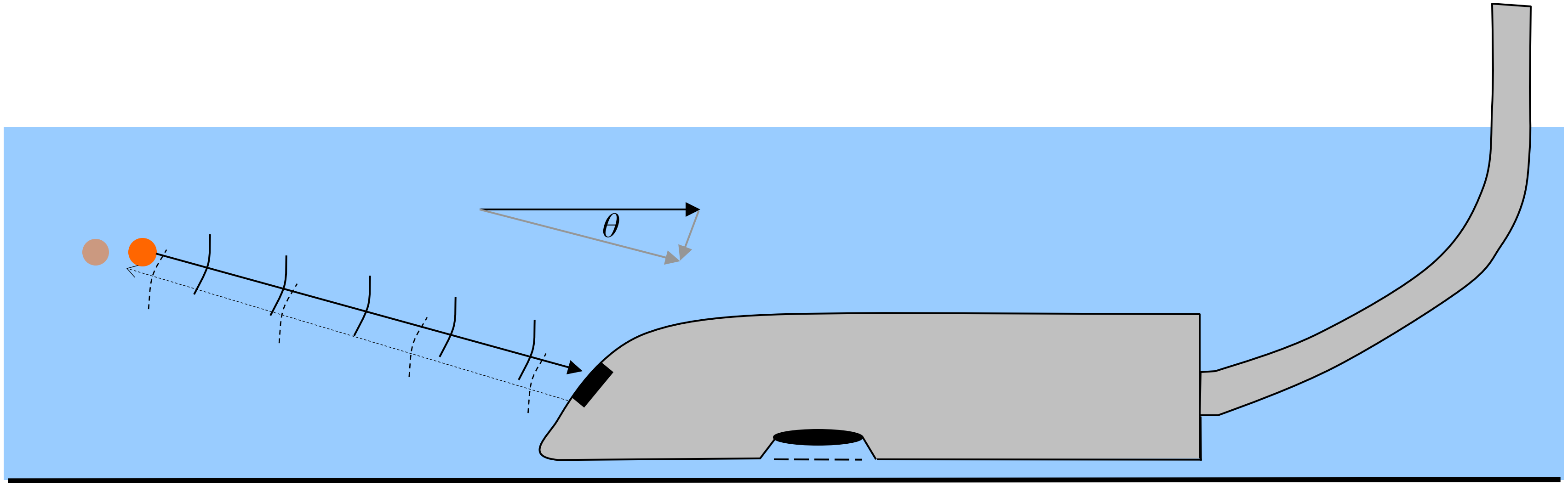
Multiple Probes: Dual AV or AV and Ultrasonic

Doppler Velocity



Continuous Wave Doppler Velocity

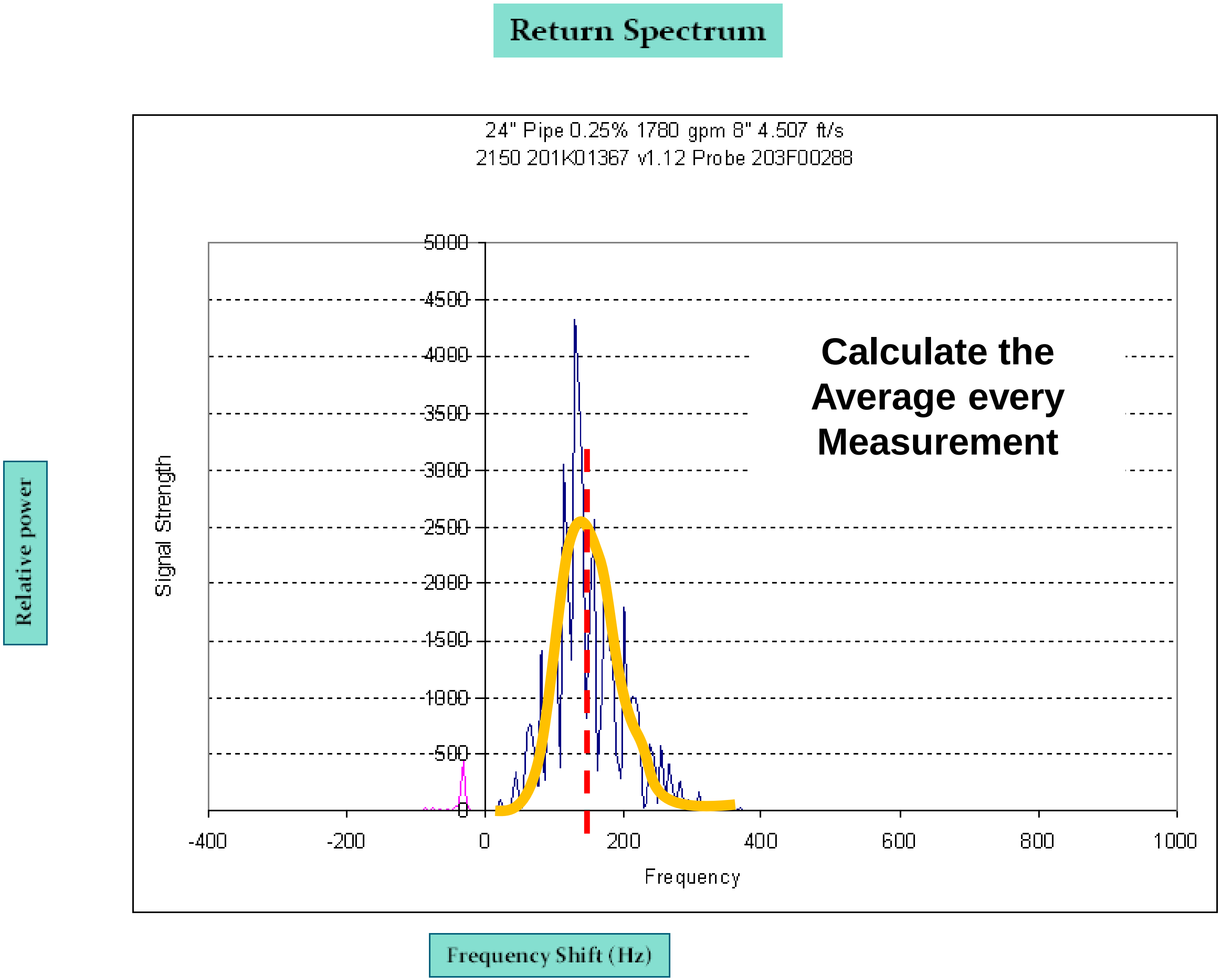
The 1.0 MHz Ultrasonic Pulse is emitted by one sensor and recorded by the other



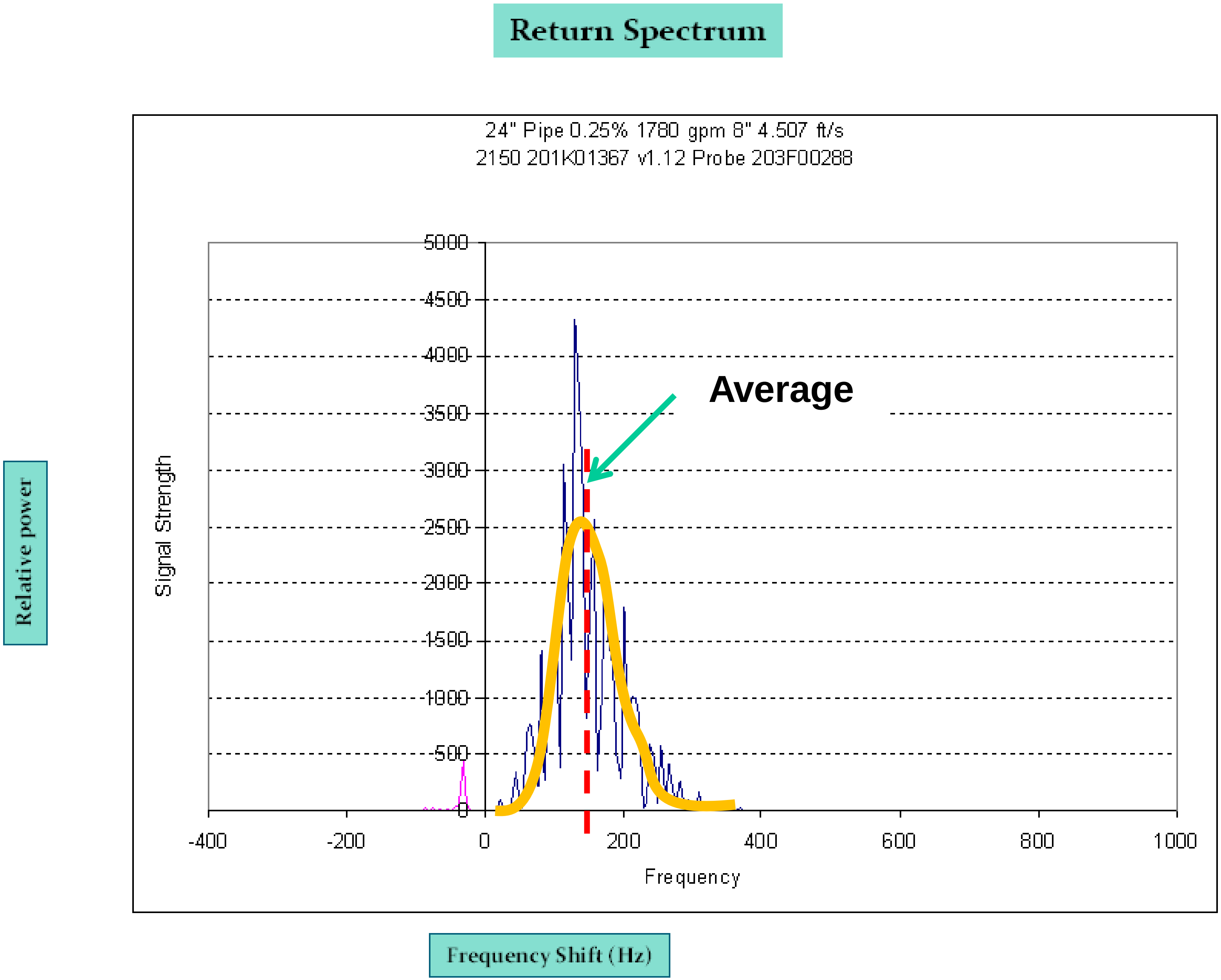
The faster the particle moves towards the probe, the higher the return frequency

The bigger the particle, the greater the strength of the return signal

Frequency – Average



Frequency – Peak to Average



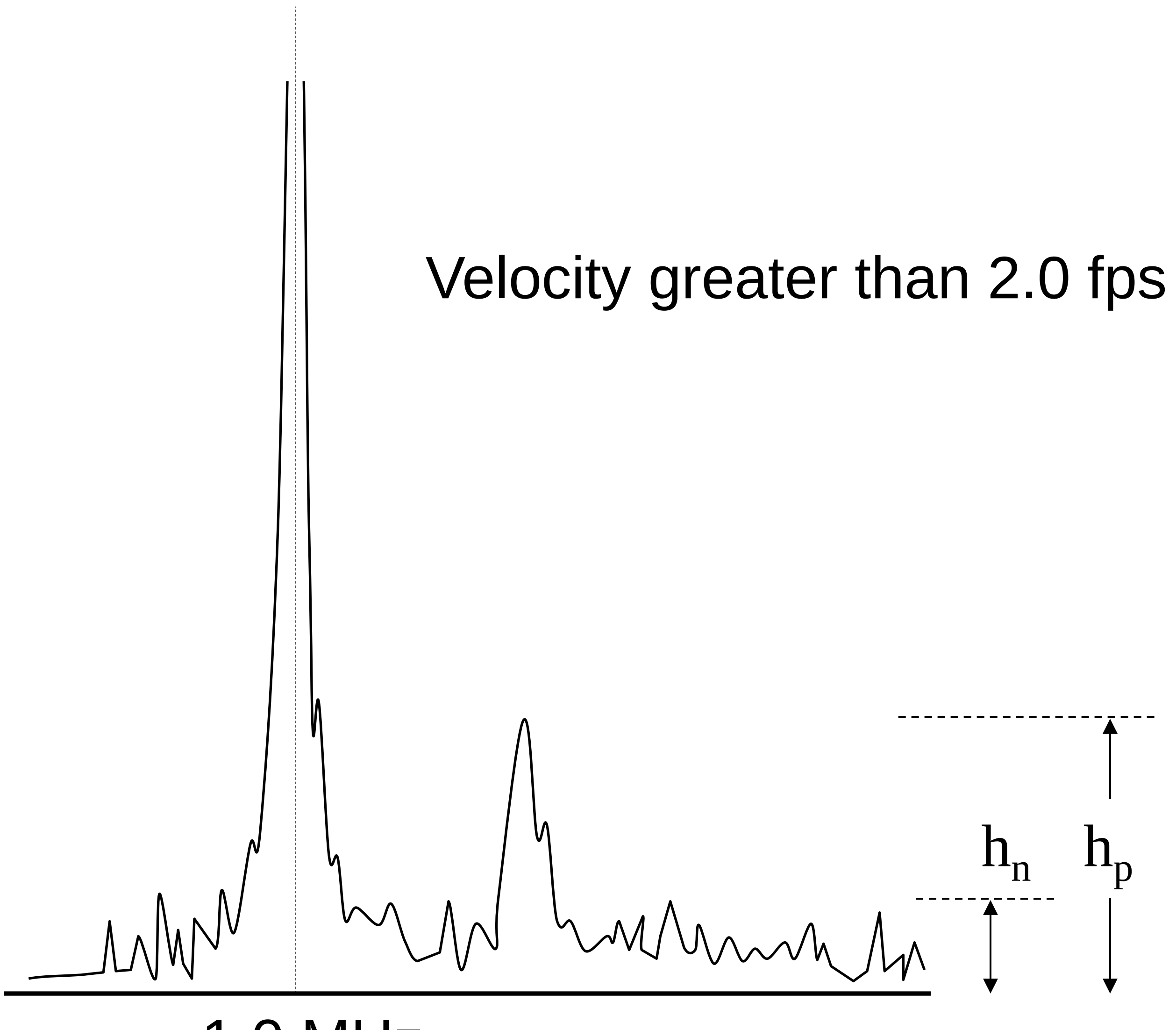
Limitations of Continuous Wave: :Low Velocity

The continuous wave Doppler is sending at the same time is it receiving.

ADS Probe Shown

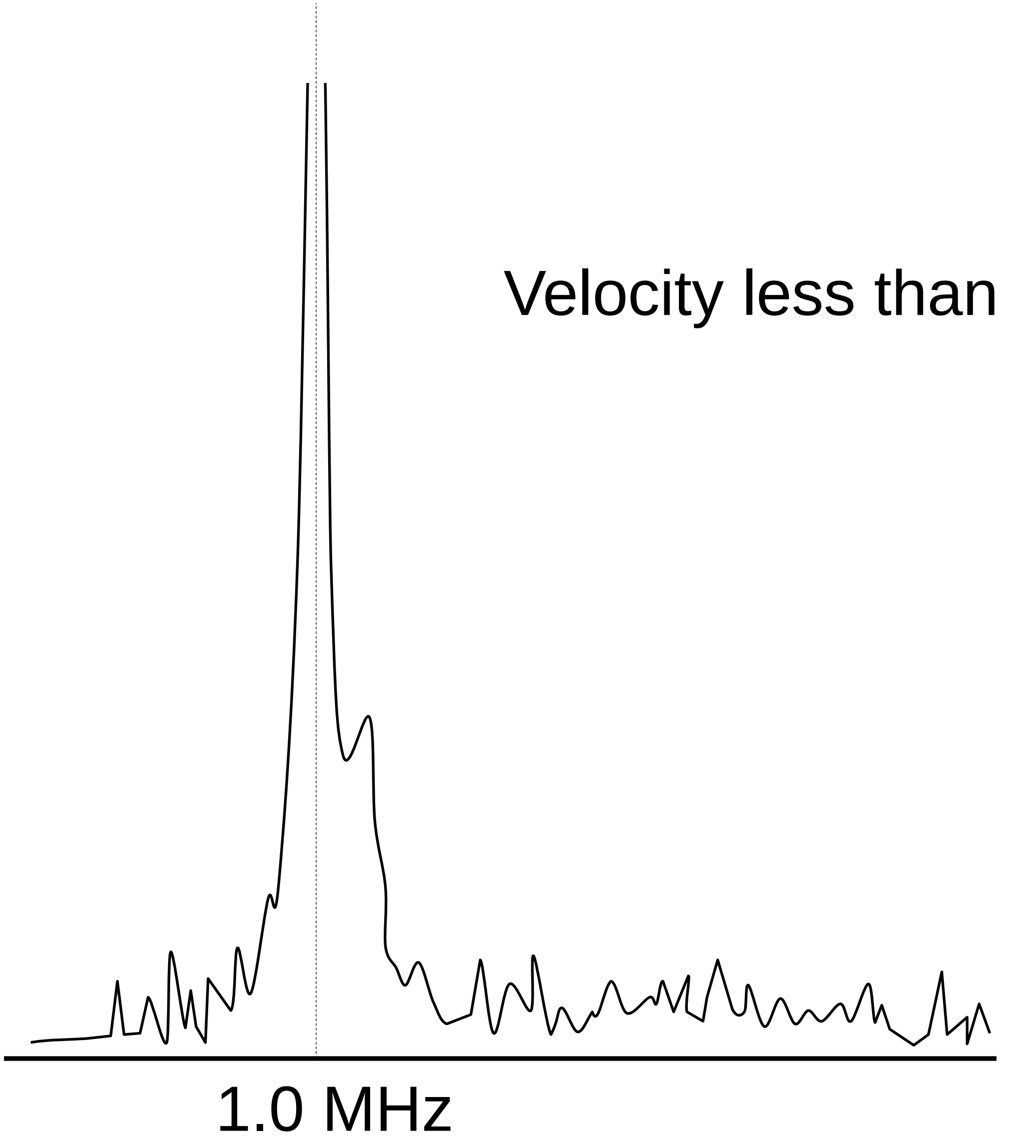
Frequency

Velocity



Frequency Slow Flow

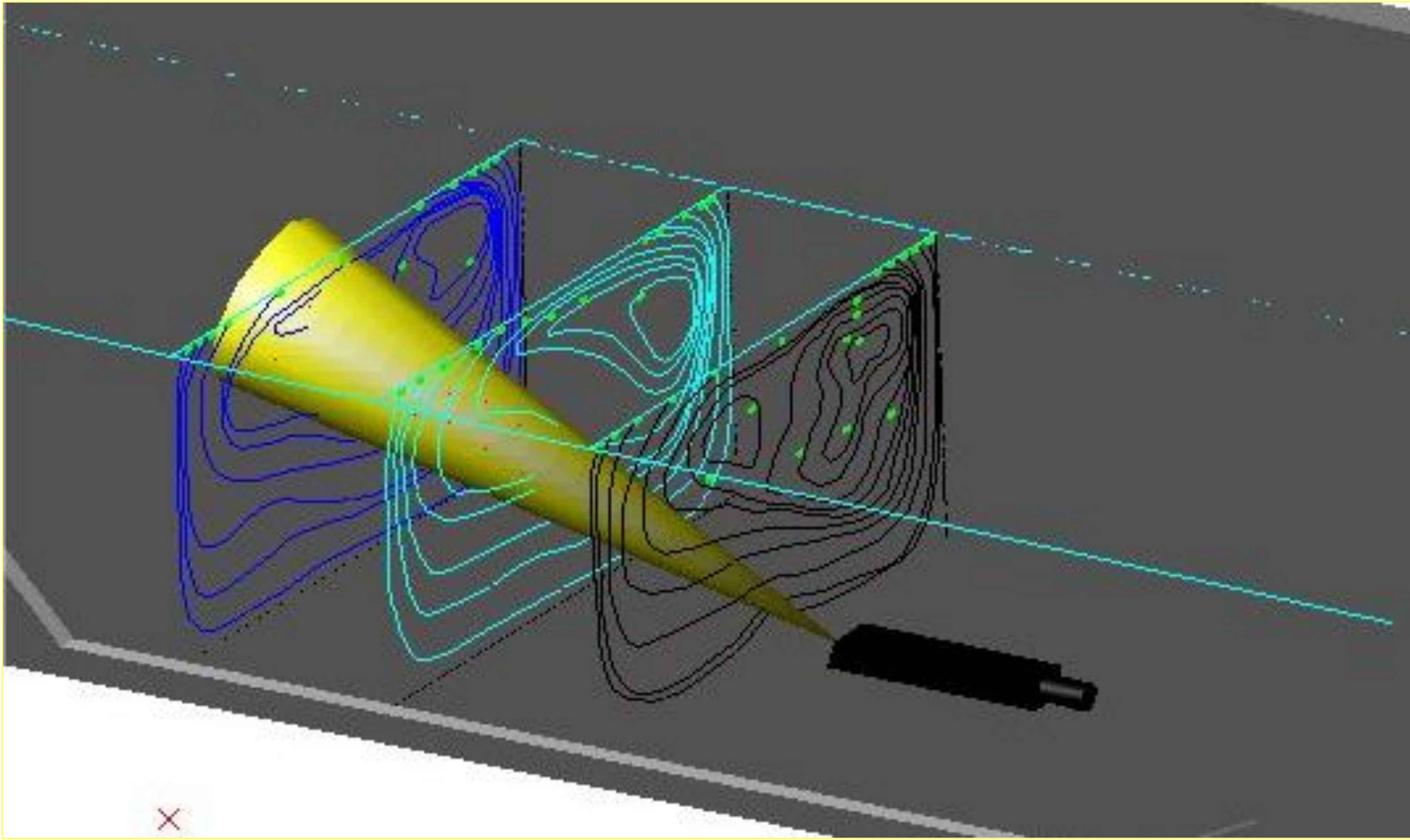
Velocity



Velocity less than 0.5 fps

Velocity: Deep Flow Underestimation

Velocity



Slide Provided by ISCO corp.

ISCO 2150: Pros and Cons

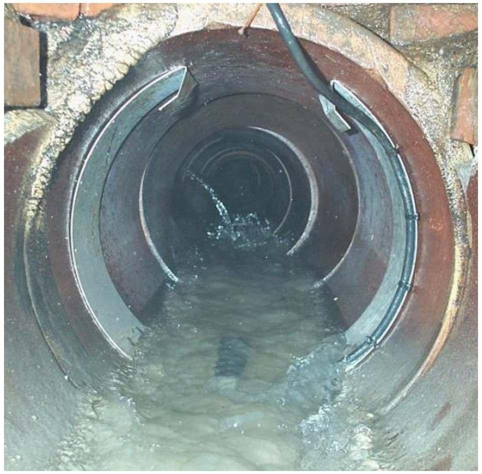
Advantages

- Cost Effective
- Easy to Use
- Wireless capabilities
- Hard to lose data (But you can)

Disadvantages

- Low flows not accurate
- Pressure Transducer can ramp at high V
- Pressure Transducer can drift
- Relatively big probe
- Not for greater than 24” of flow

SIGMA 910 : Technology



Level

- Pressure Transducer

Velocity

- Doppler
- Peak to Average Conversion
- Self Measures Peak and Average

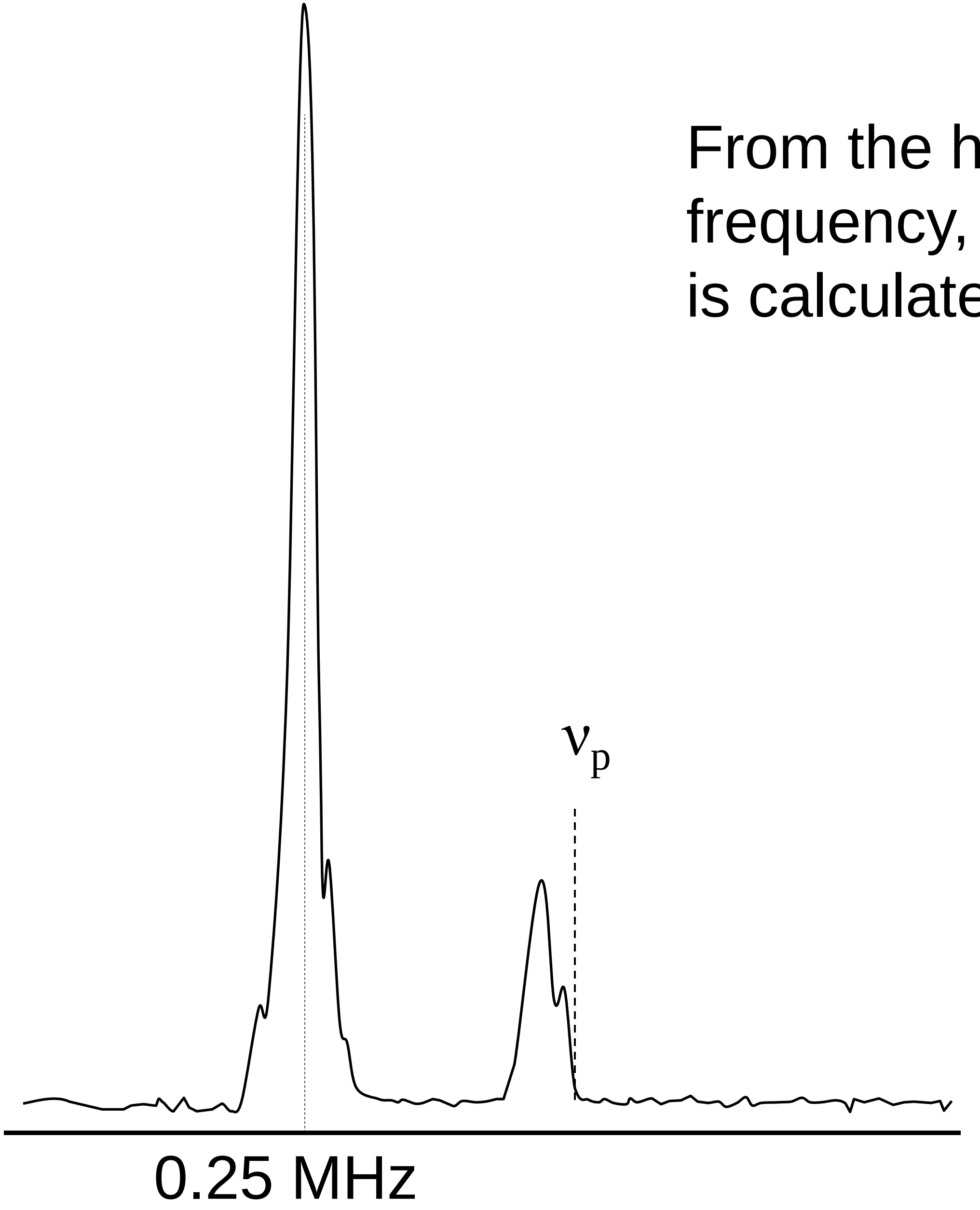
Frequency – Peak to Average

Convert Peak Velocity to Average Velocity

By monitor measurement of Average

Peak

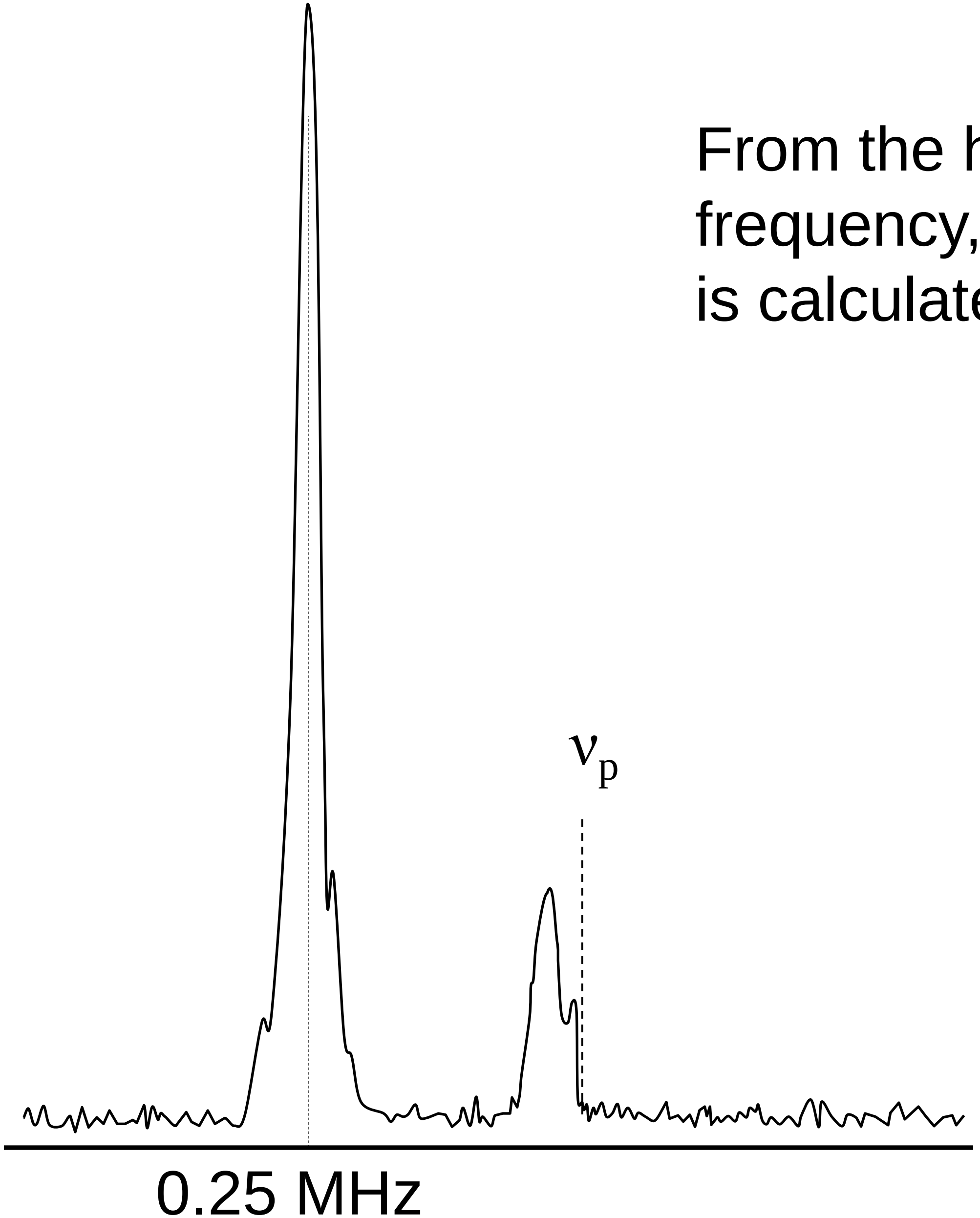
Velocity



From the highest returned frequency, the Peak Velocity is calculated.

Peak

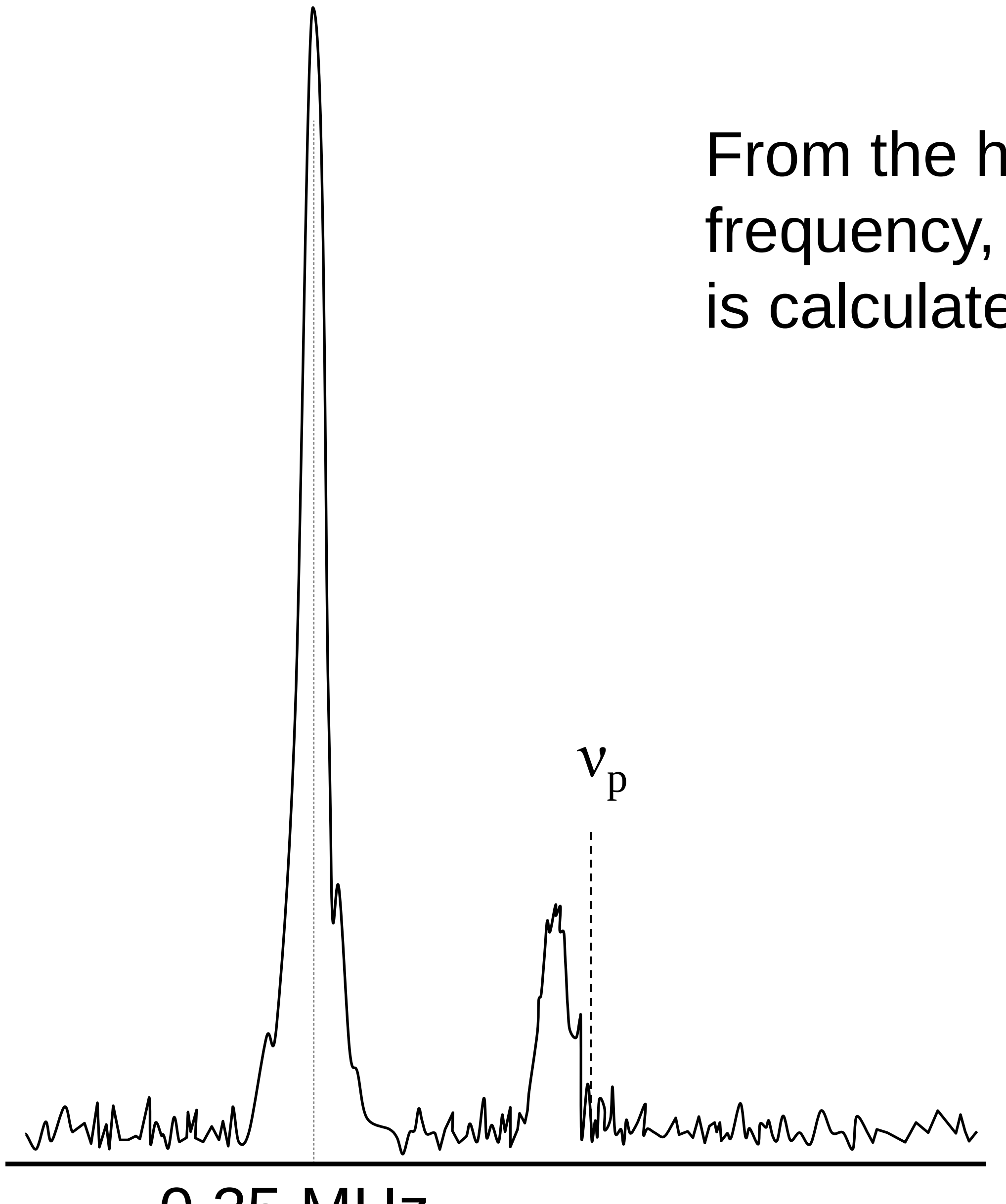
Velocity



From the highest returned frequency, the Peak Velocity is calculated.

Peak

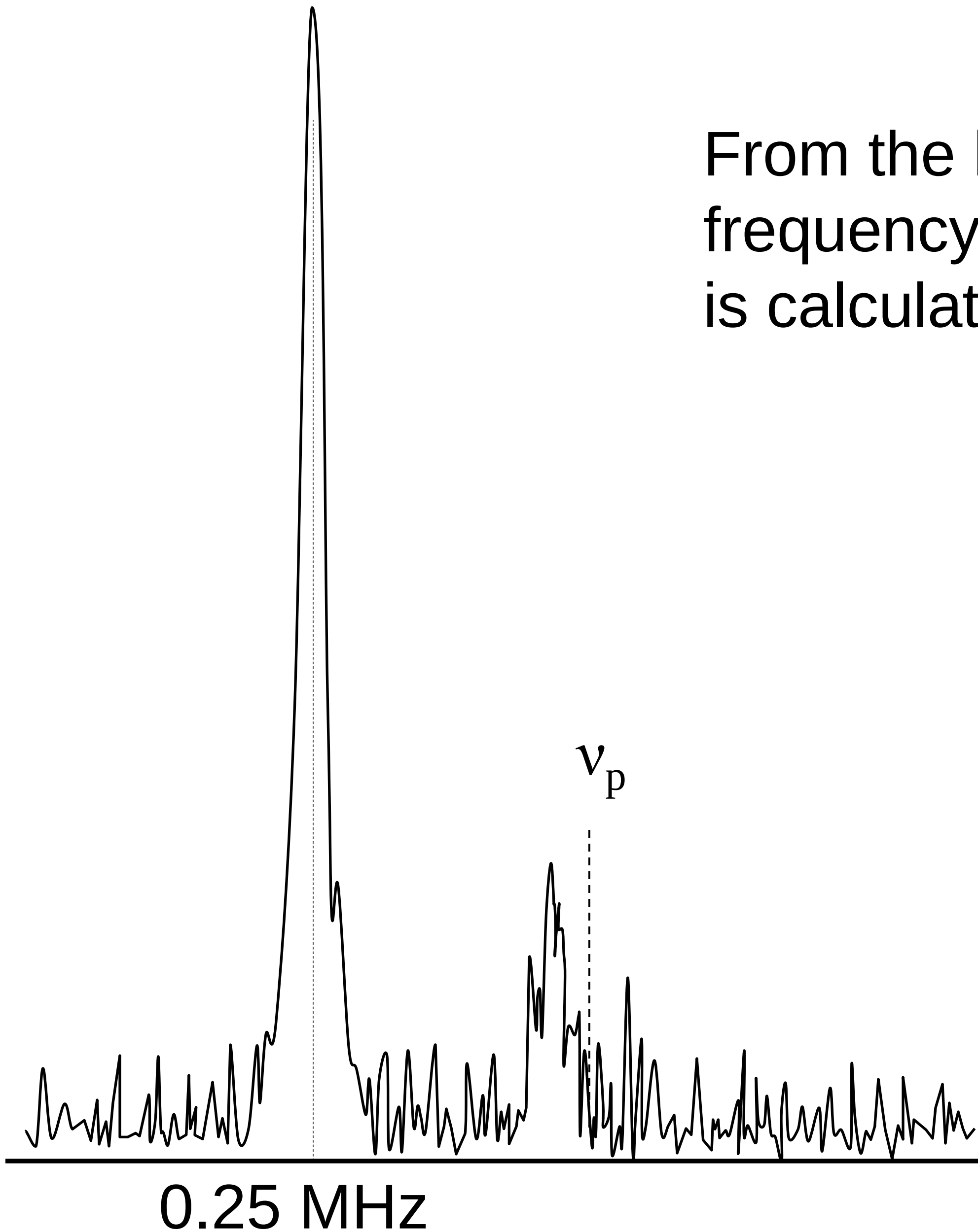
Velocity



From the highest returned frequency, the Peak Velocity is calculated.

Peak

From the highest returned frequency, the Peak Velocity is calculated.



SIGMA 910: Pros and Cons

Advantages

- Cost Effective
- Very easy to Use
- Hard to lose data
- Has a digital probe

Disadvantages

- Limited data storage (21 days) (Now Hach 900)
- CW not accurate < 1.0 fps
- Does not work well in ramping
- Does not work well in deeper flows
- Pressure transducer can drift

ADS FlowShark: Technology

Level

Pressure Transducer

Air Space Ultrasonic

Velocity

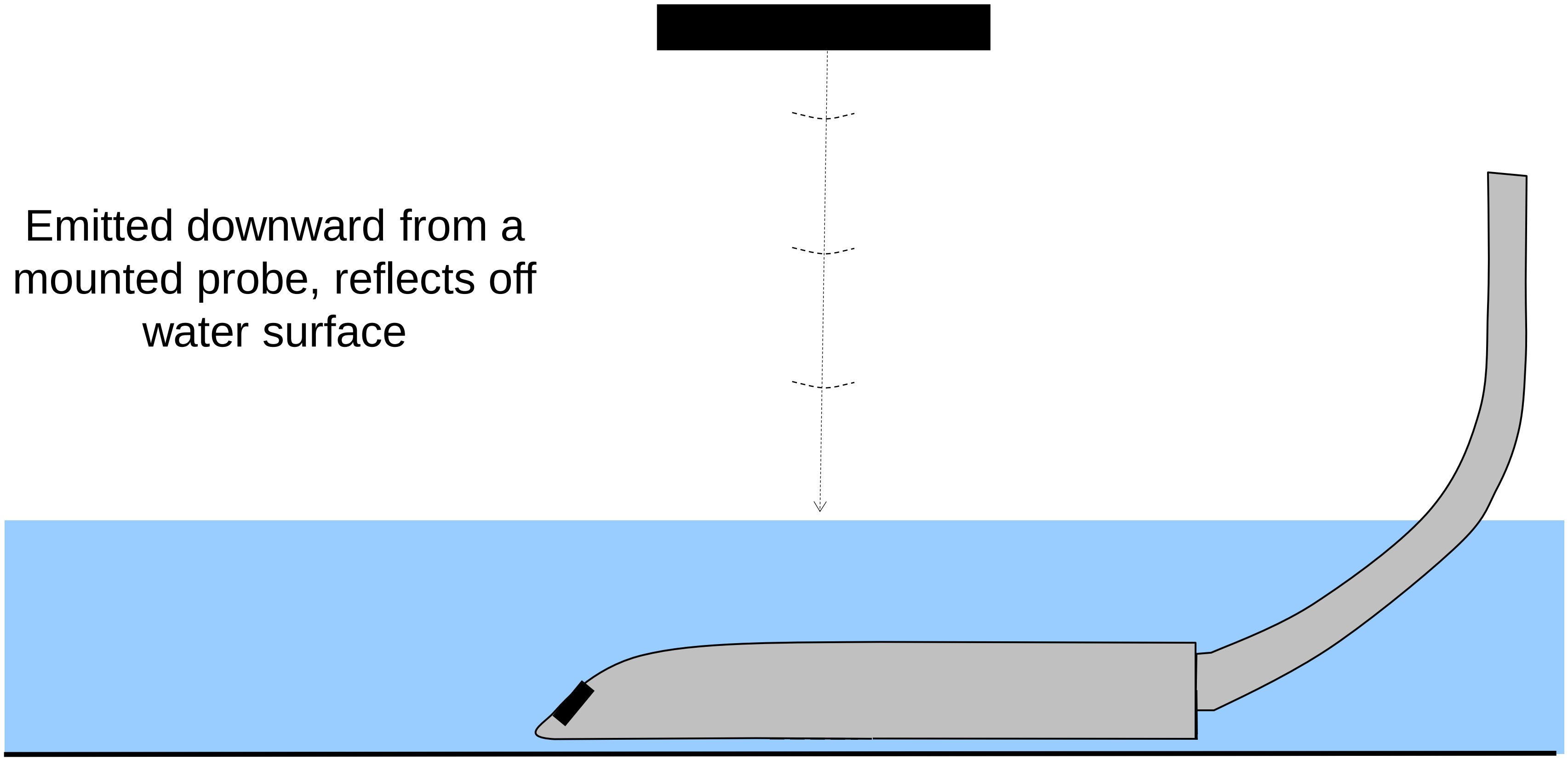
Doppler

Peak to Average conversion

Average (and Peak) to be measured in Field

Ultrasonic Sensor – Airspace

ULevel

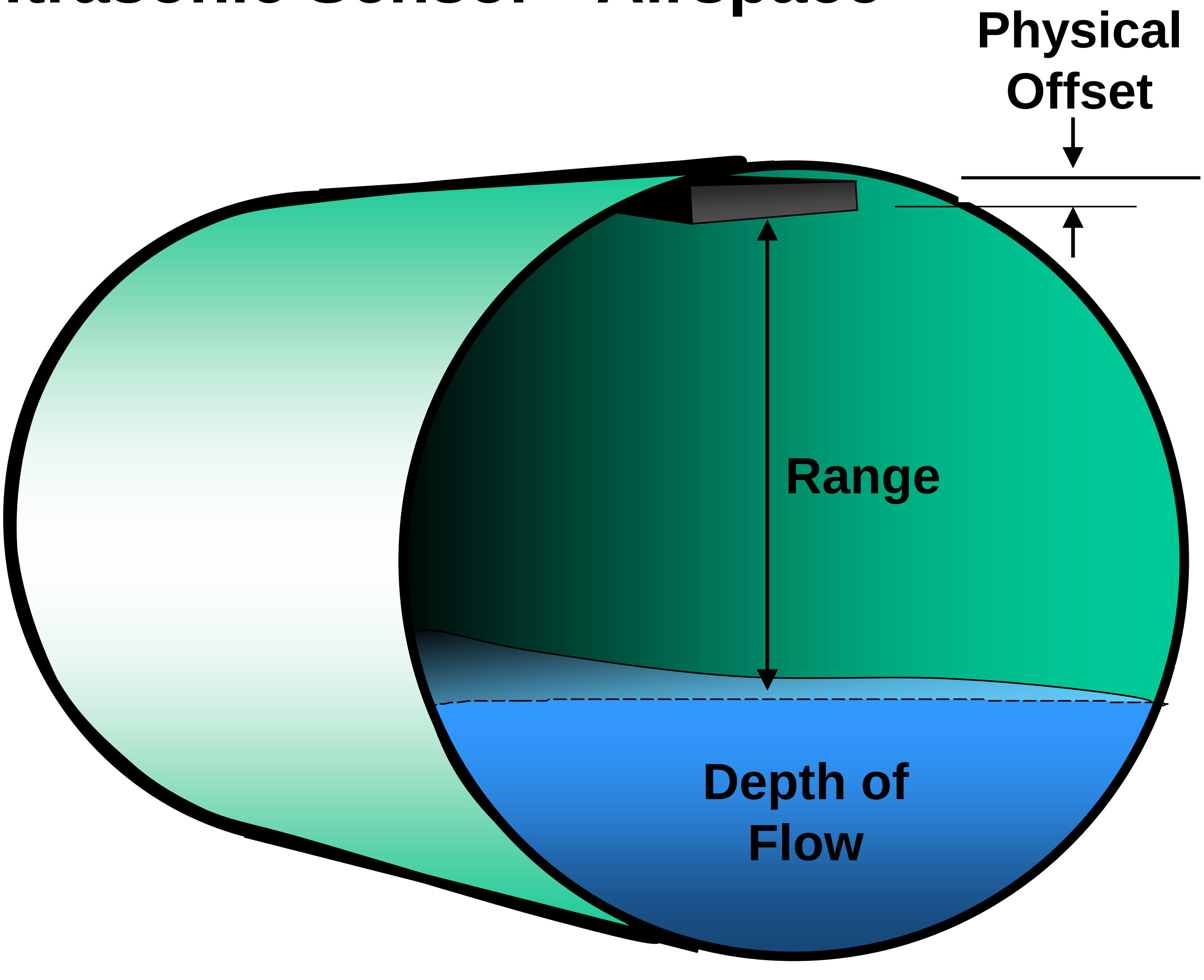


Emitted downward from a mounted probe, reflects off water surface

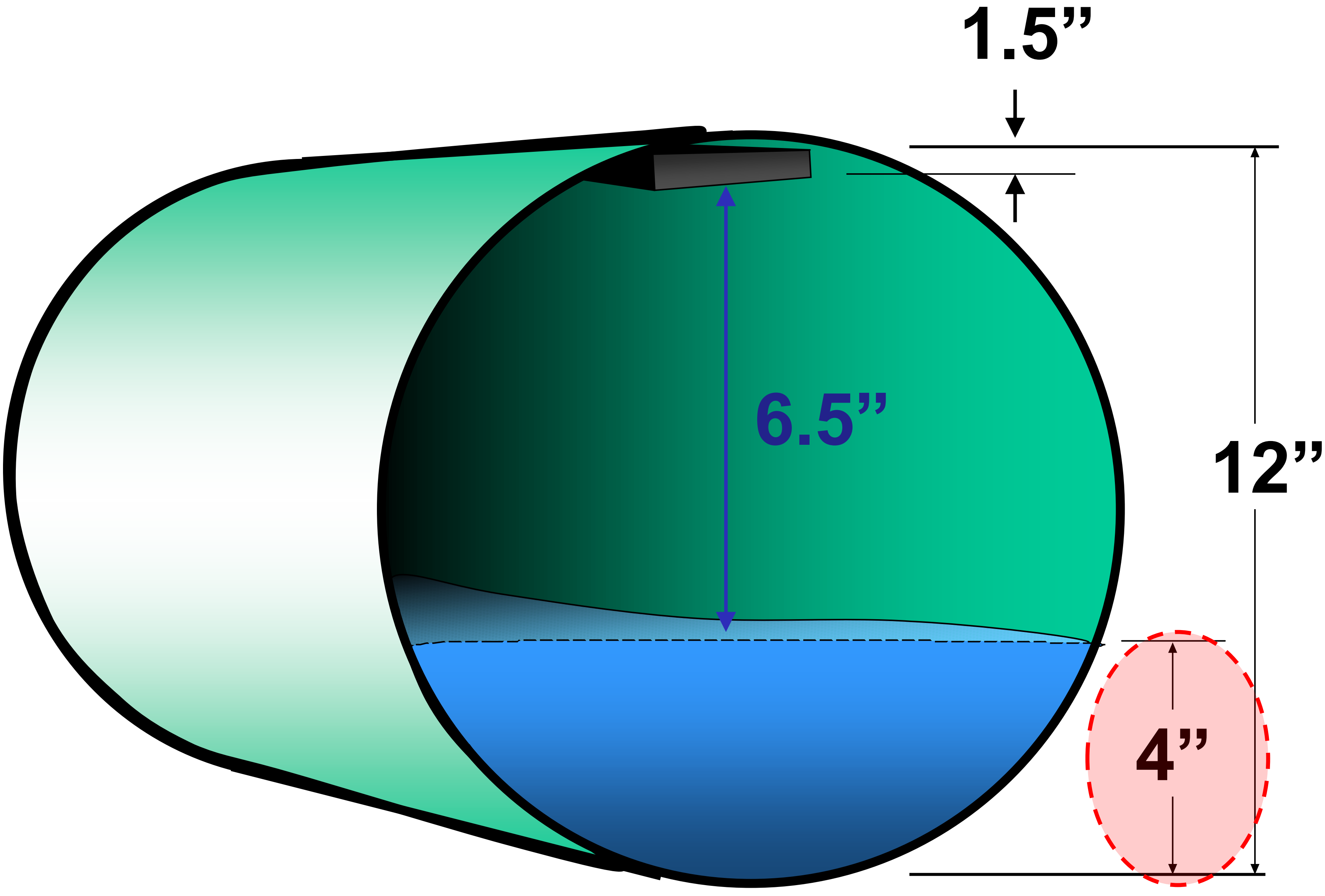
Very stable with time

Can’t be covered by silt

Ultrasonic Sensor - Airspace



Ultrasonic Sensor - Airspace



Ultrasonic Sensor - Airspace

ADS Flowshark

Ultrasonic Sensor - Airspace

What kind of conditions might cause trouble for an Airspace ultrasonic?

Very rough water

Foam

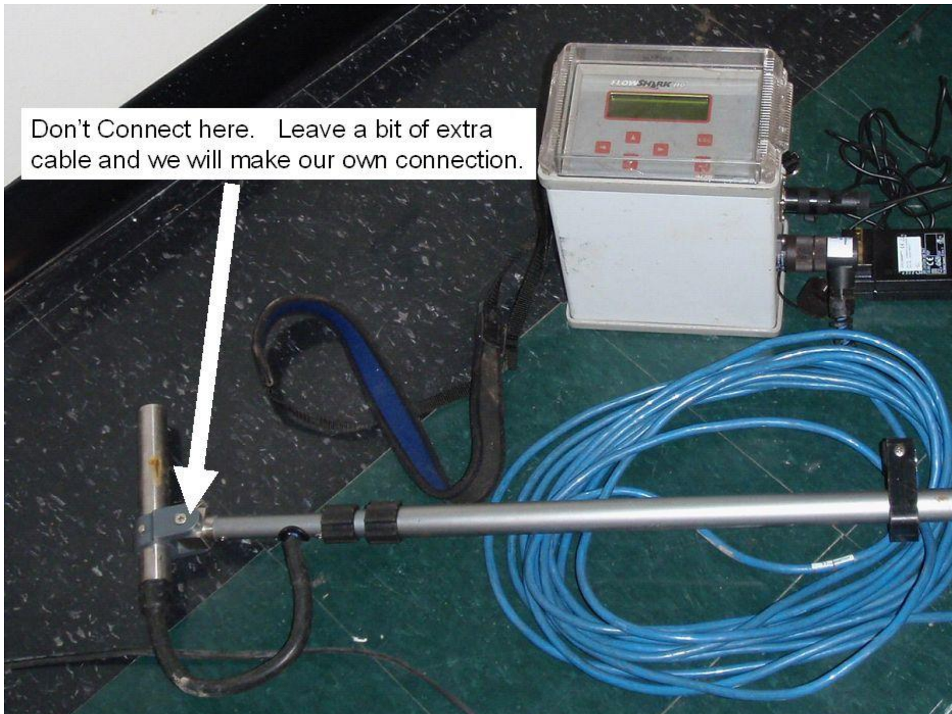
Velocity – Peak to Average

Convert Peak Velocity to Average Velocity

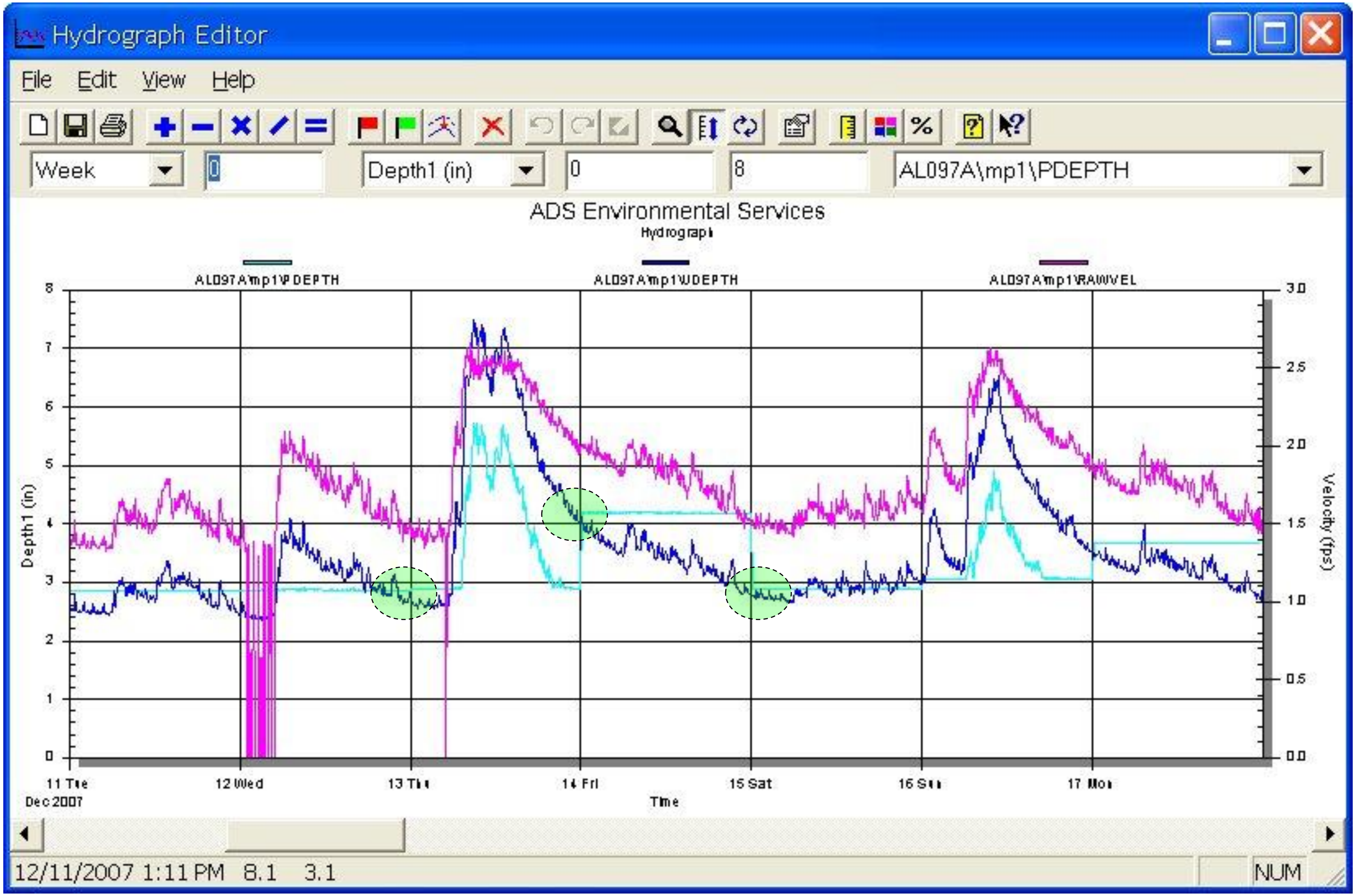
By field measurement of Average

Peak to Average Conversion

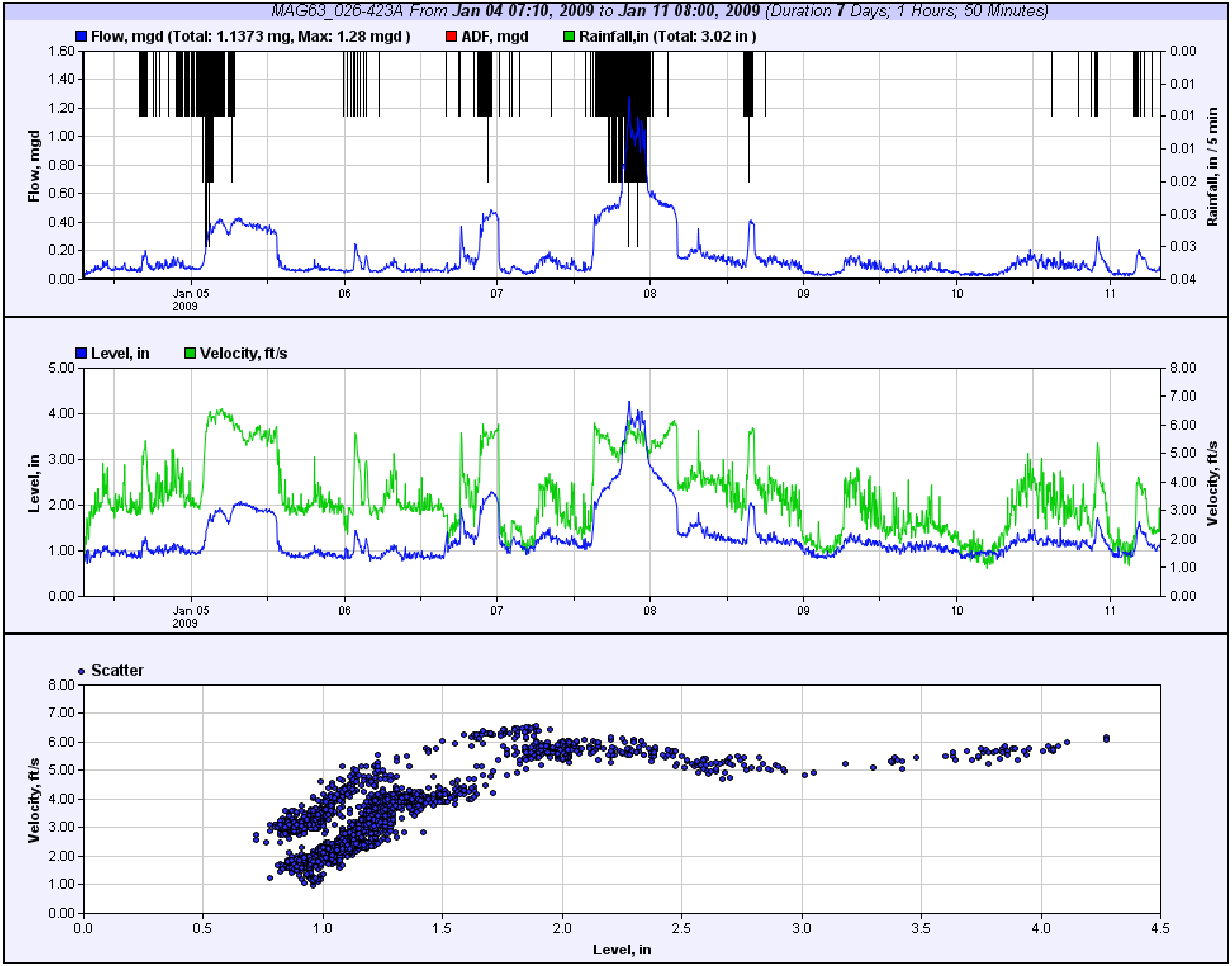
Must measure the Average Velocity by hand, with a PVM.



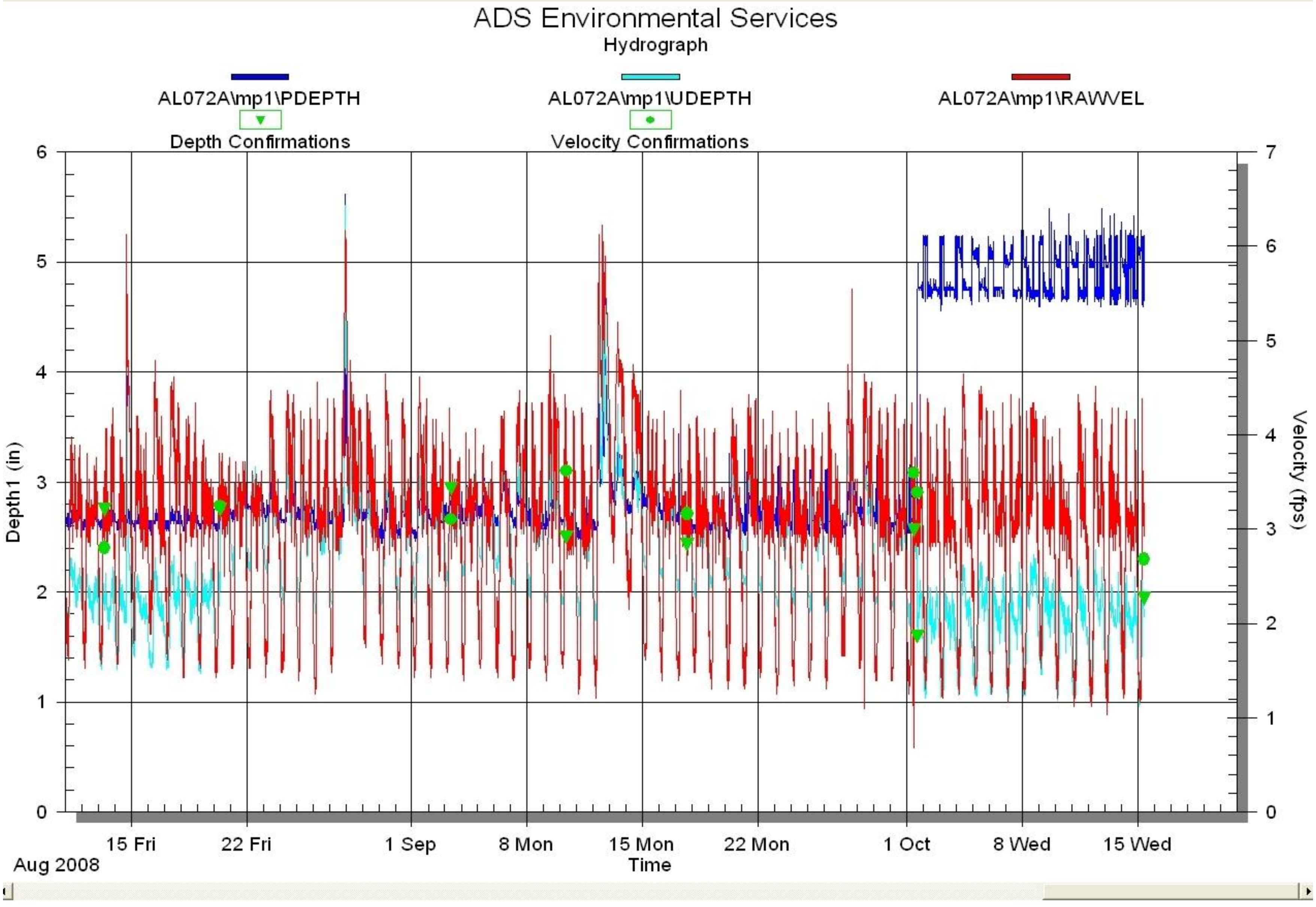
Unique to ADS: MLI level resets



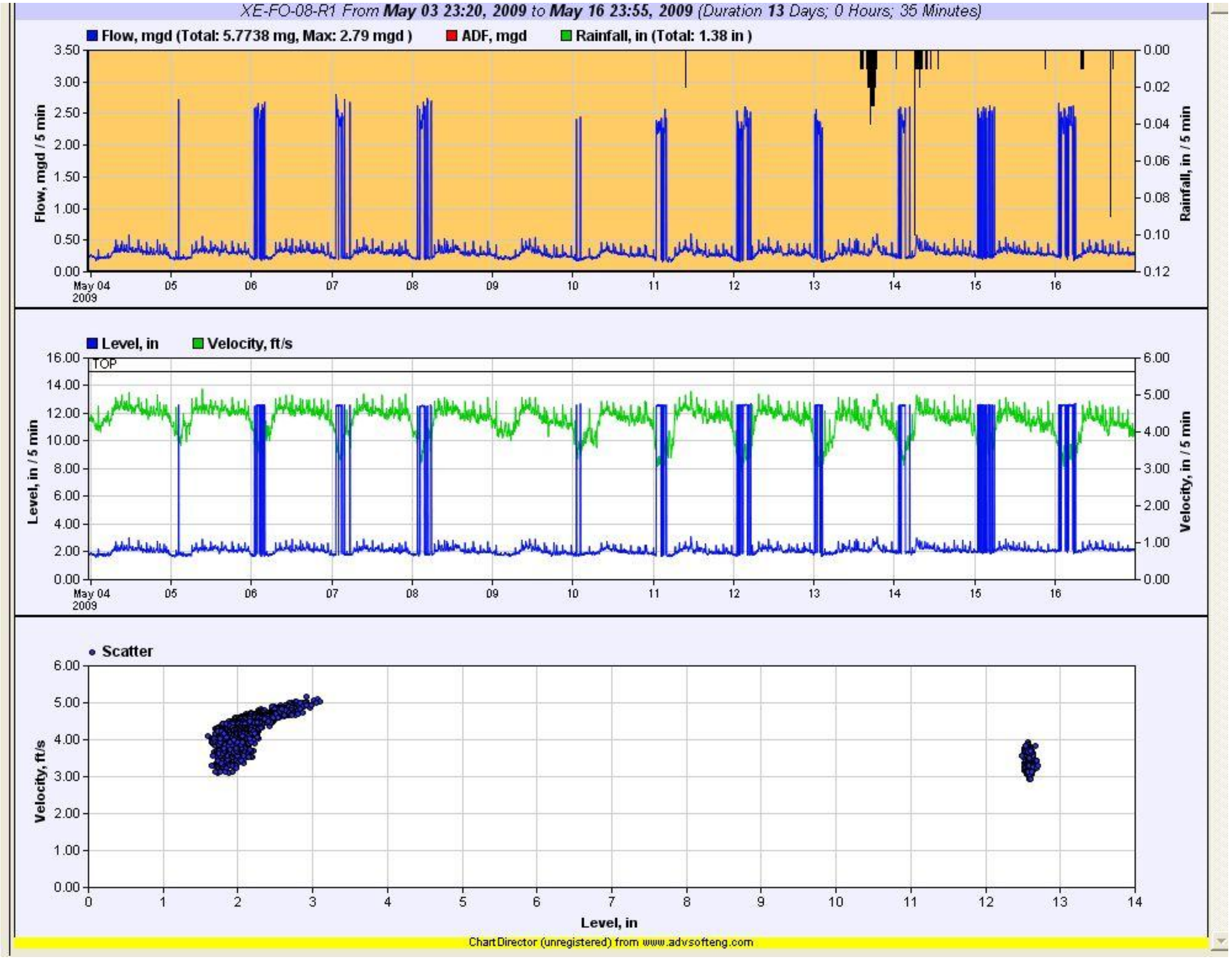
MLI Velocity shifts



Lif file Overwriting



Level Spikes in Ultrasonic



ADS FlowShark: Pros and Cons

Advantages

Long term Stability

Disadvantages

Can have the wrong velocity

Very susceptible to slight changes in upstream hydraulics

Data Management errors (lif, bin etc)

Ultrasonic and Velocity Pops


Environmental Technology Verification Report

Wet Weather Flow Monitoring Equipment

ADS Environmental Model 3600 Open Channel Flow Monitor

Part I – Laboratory Test Results

Prepared by

NSF

NSF International

Under a Cooperative Agreement with

EPA U.S. Environmental Protection Agency

MMI Flo-Tote 3 - Technology

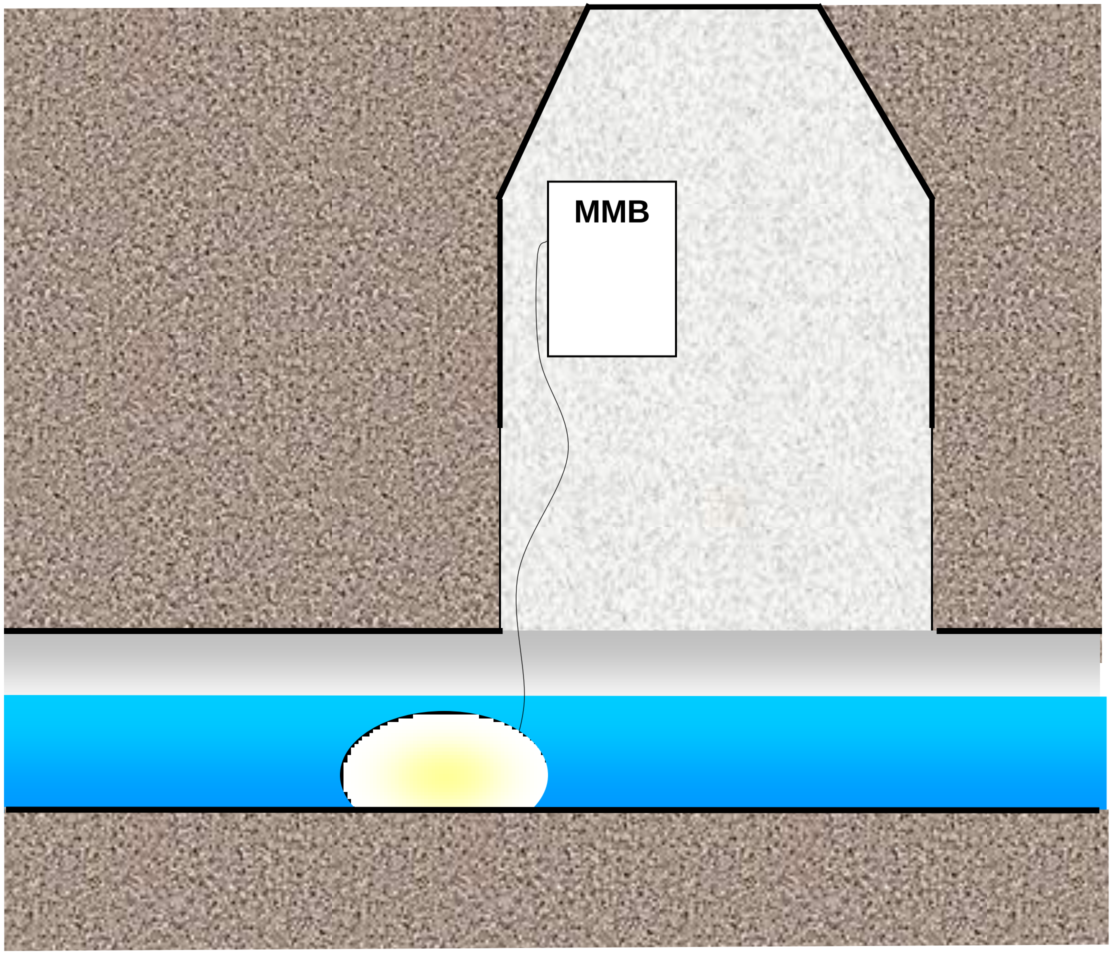
Level

Pressure Transducer

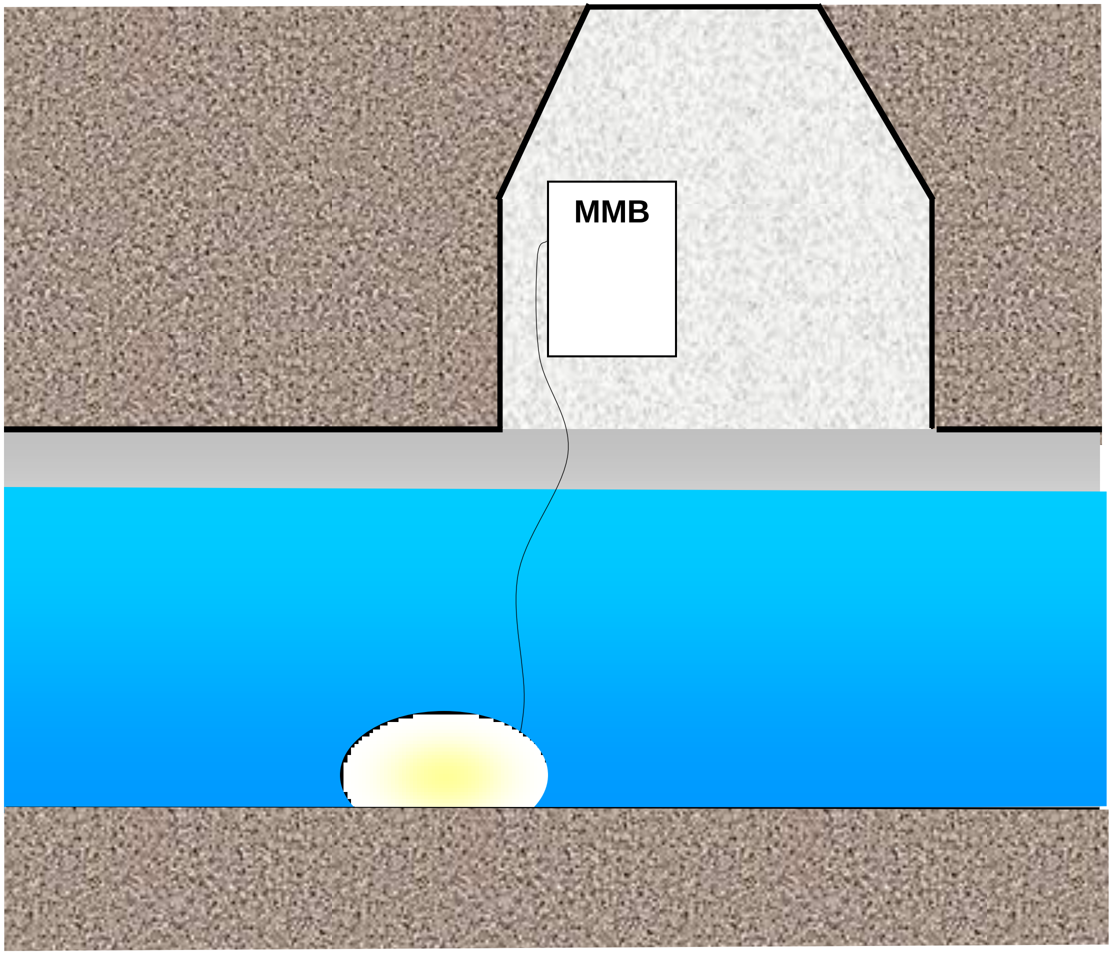
Velocity

Faraday sensor

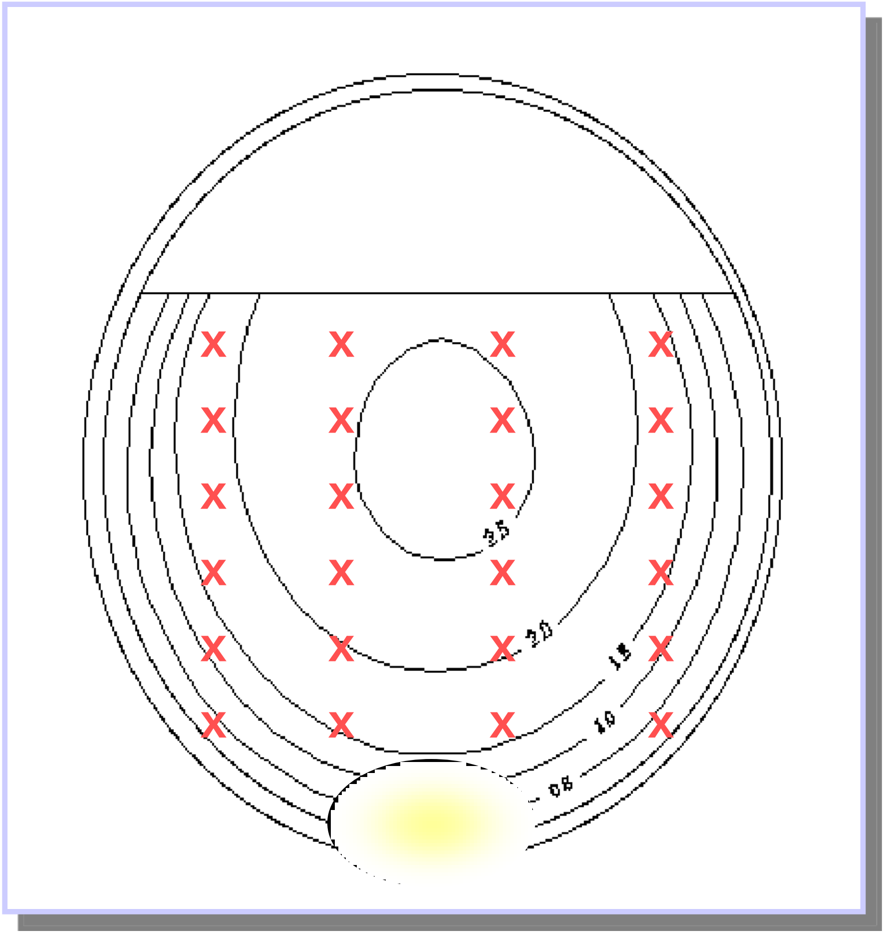
Faraday Velocity



Faraday Velocity



Faraday Velocity



The Calibration Coefficient relates the Sensed Velocity to the Average Velocity.

MMI Flo-Tote 3 – Pros and Cons

Advantages

- Works in churning water
- Works in Clear Water
- Works in Zero Velocity

Disadvantages

- Must be profiled to be accurate
- Can be wrong and you don’t know it
- Does not work well if flows do not continually cover the probe (Dry Pipe)

MMI Flo-Dar - Technology

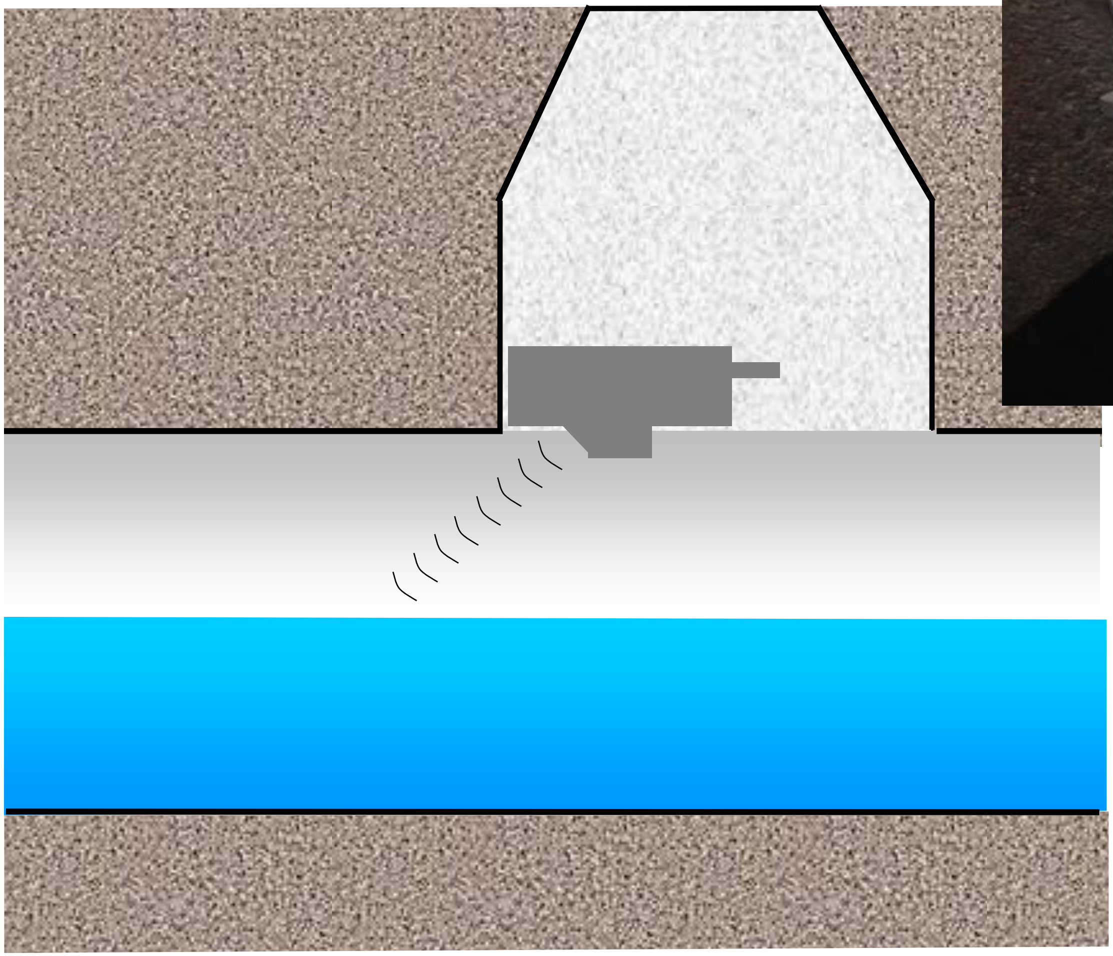
Level

- Airspace Ultrasonic
- Supplemental pressure transducer

Velocity

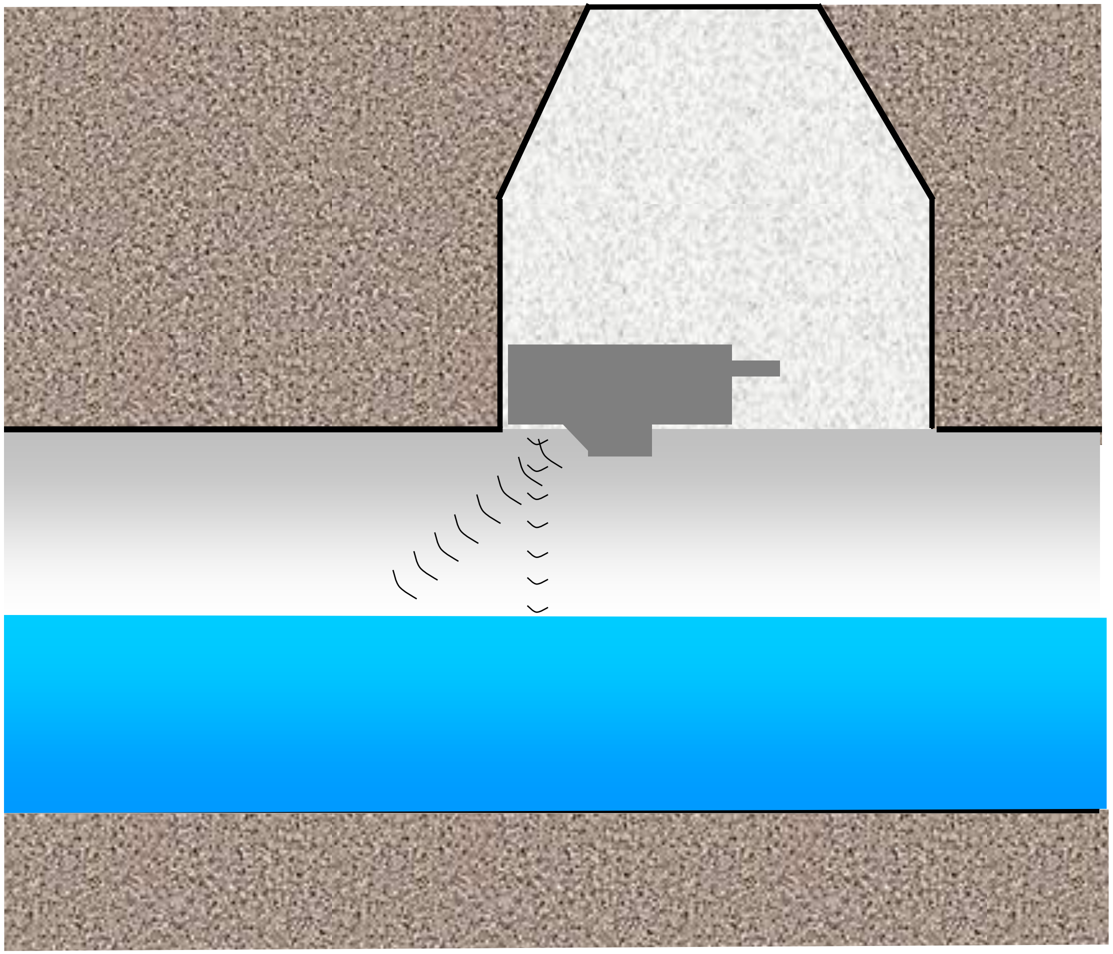
- Surface Radar
- Supplemental submergence probe

Radar Surface Velocity



Converts Surface Velocity to Average Velocity.

MMI Flo-Dar – Manhole Transition

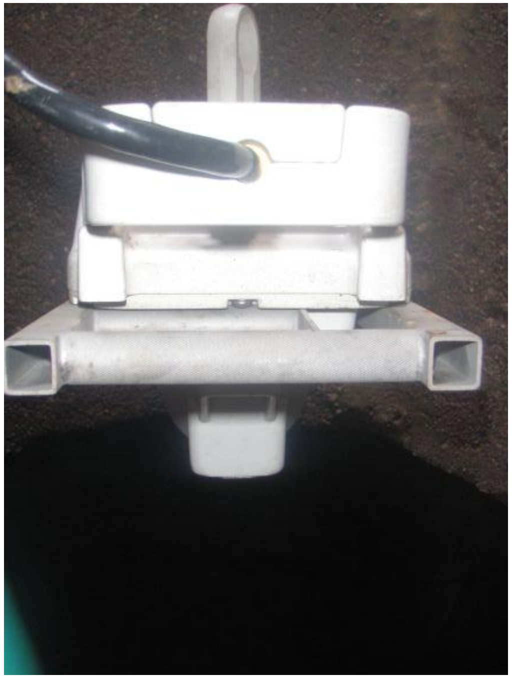


We try to get velocity in the pipe, but level is measured in the Manhole.

How many pipe to manhole transitions are smooth?

MMI Flo-Dar – Manhole Transition

MMI Flo-Dar – Pros and Cons



Advantages

- Non Contact
- Clear Water

Disadvantages

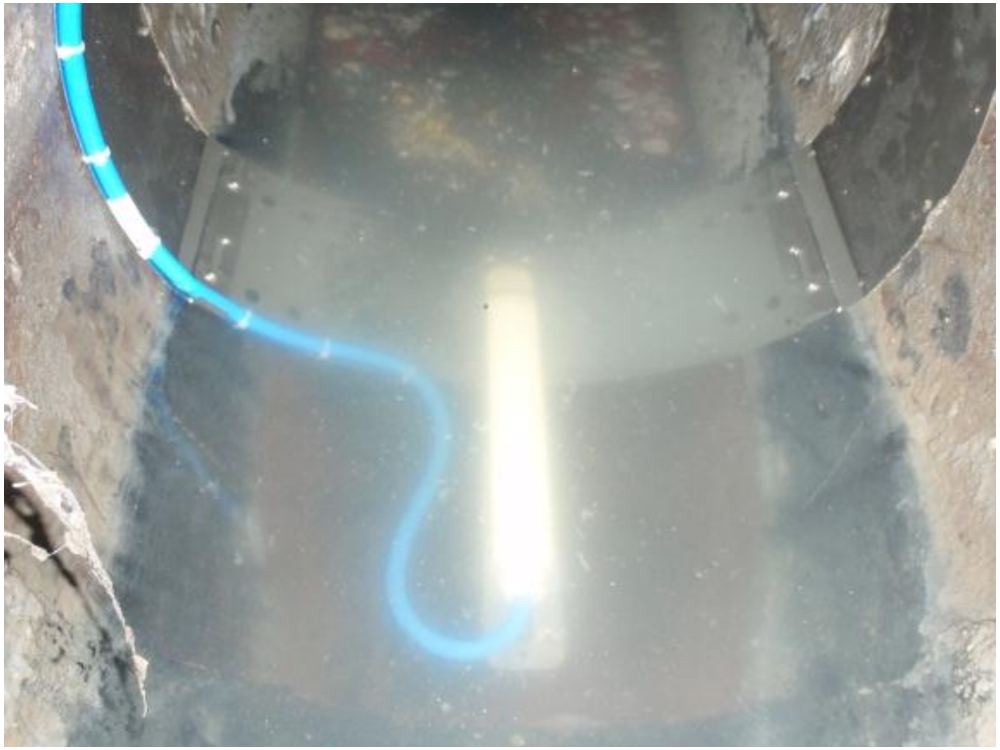
- Expensive with ‘extras’
- Pipe to Manhole transition
- Manhole Fillet
- Sensitive signal
- Surface Velocity to average conversion

FlowShark Pulse - Technology

Level

Ultrasonic under water

Can take airspace ultrasonic also



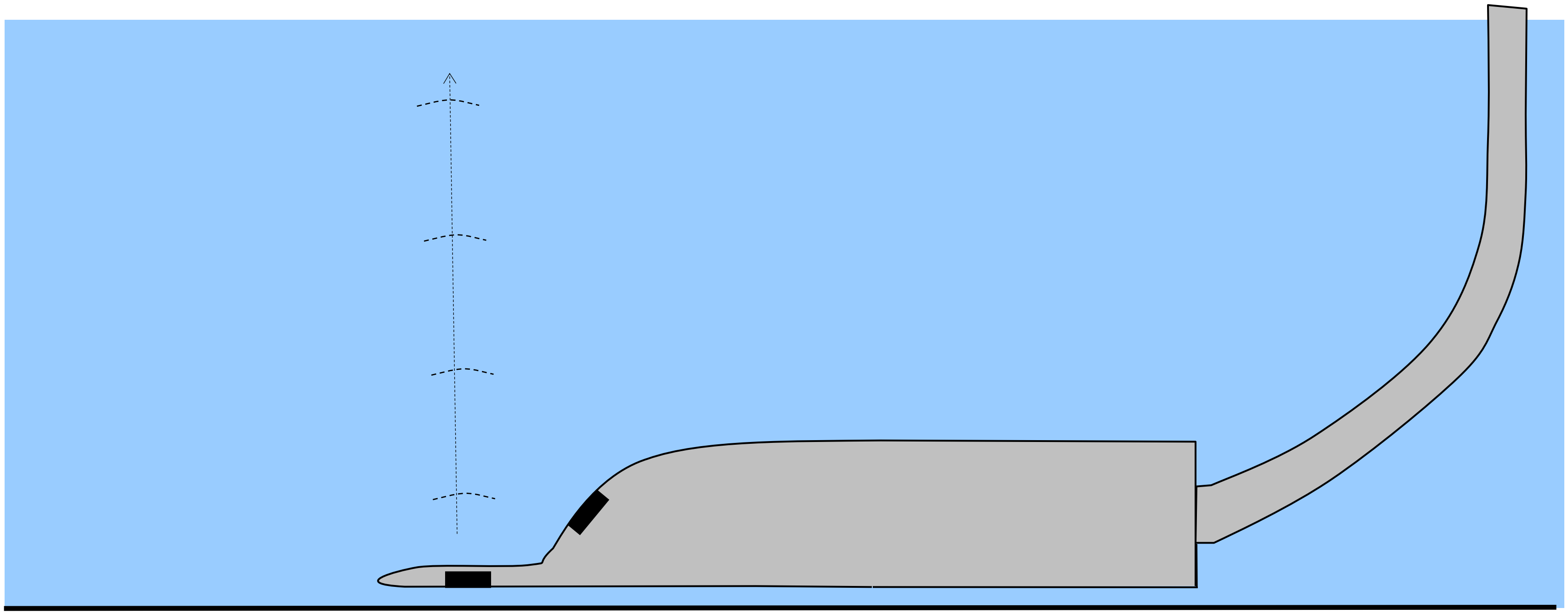
Velocity

Range Gated Doppler

Ultrasonic Sensor – Water Depth

ULevel

Emitted upward by tip of probe.

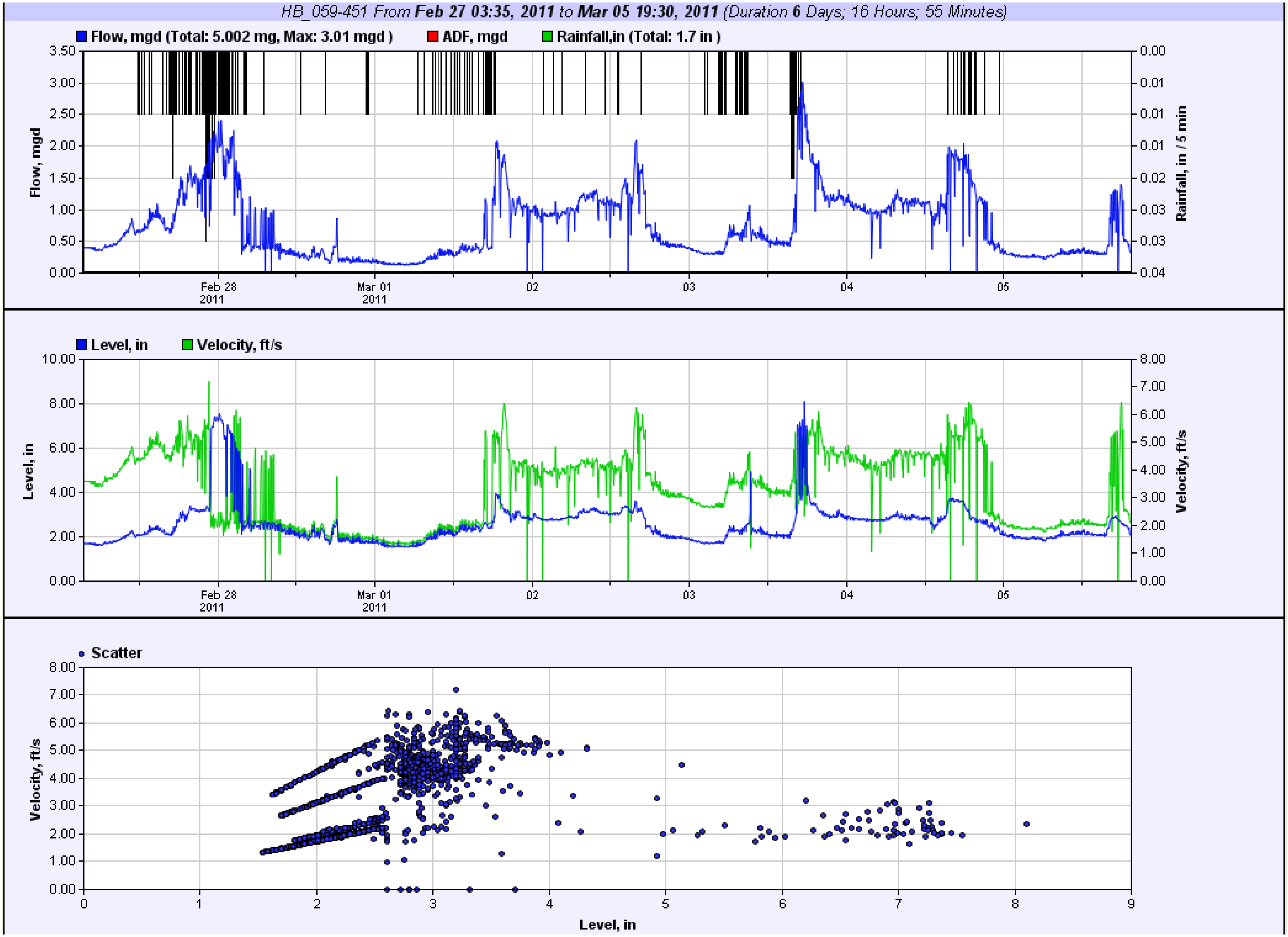


Needed for accurate range gating.

Can be covered by silt.

Can’t be used in shallow flow.

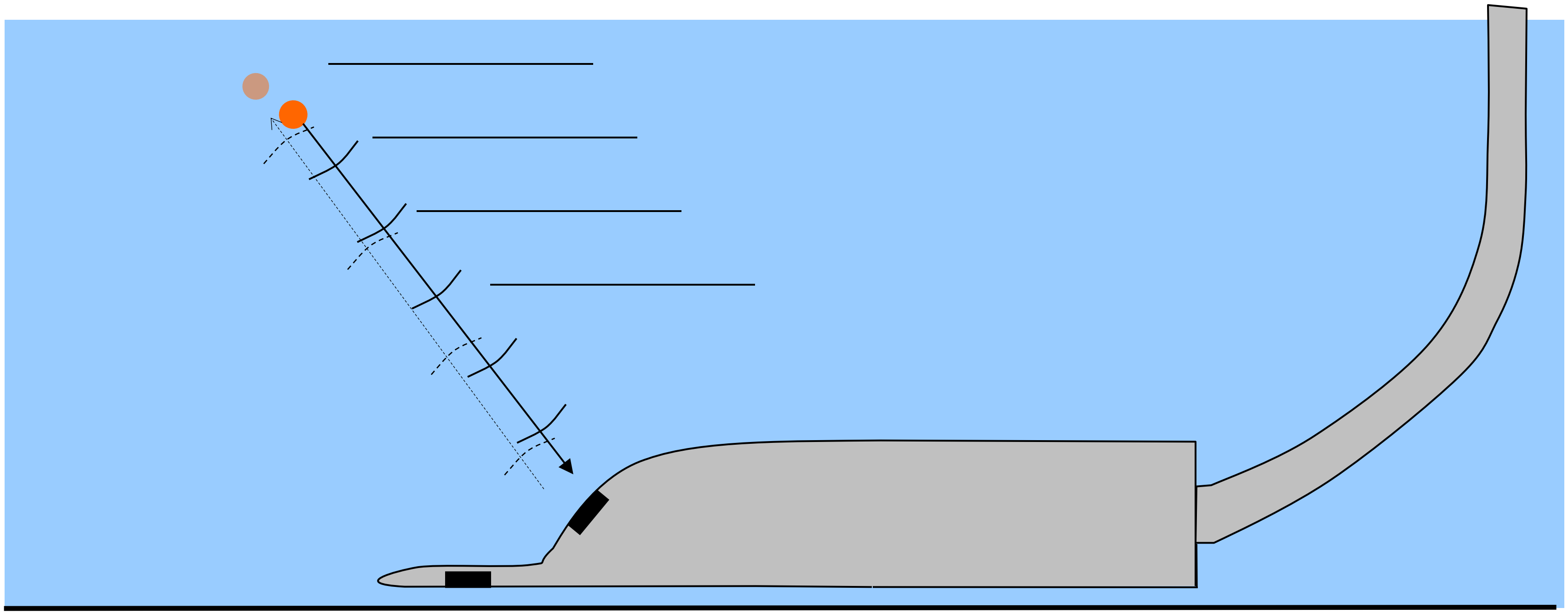
FlowShark Pulse: Low Depth (2.5”)



Range Gated Doppler

Velocity

The Ultrasonic Pulse is emitted by one sensor and recorded by the same

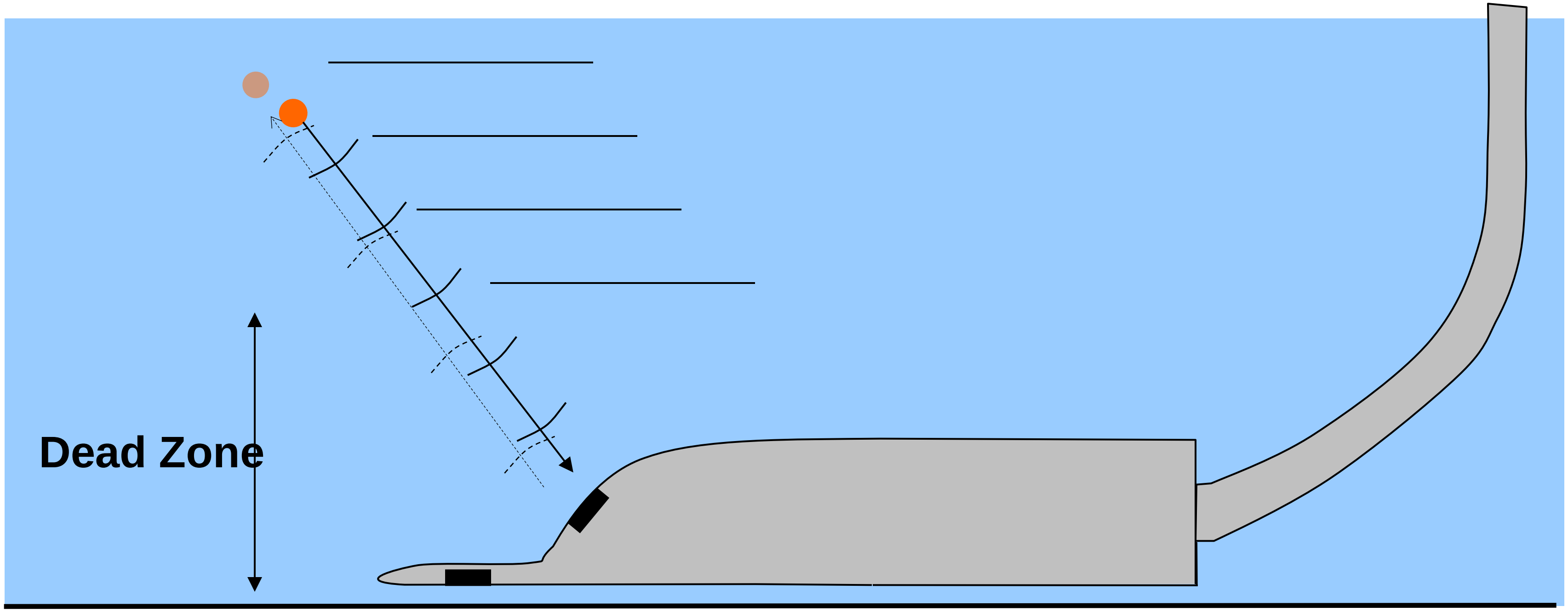


Each piece of the signal is separated into a different bin

Has some limitations

Range Gated Doppler

The Ultrasonic Pulse is emitted by one sensor and recorded by the same



Must have level information to prevent reflection processing

Must be placed on bottom of pipe

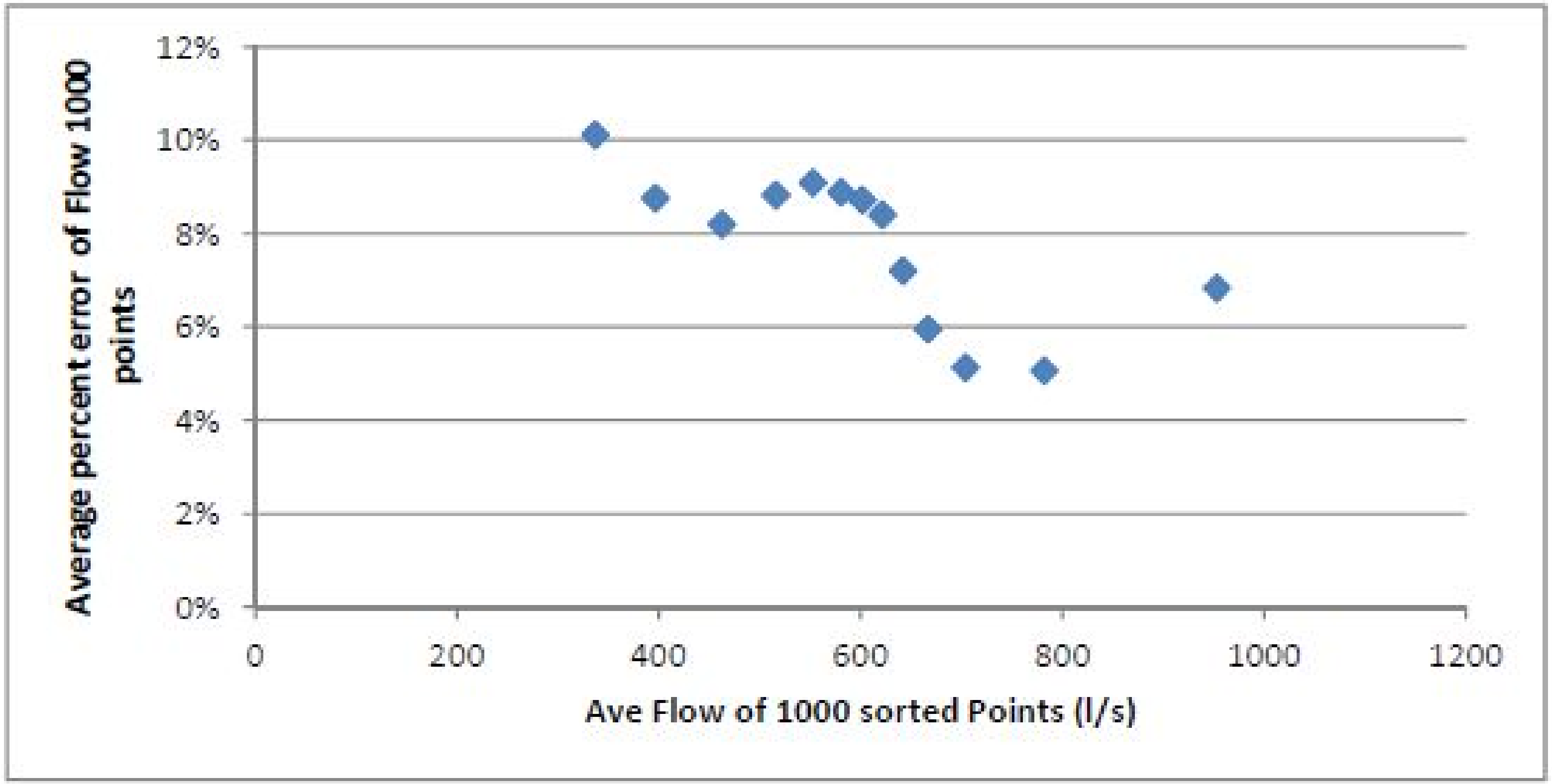
How do RG and CW Doppler Compare for Large Pipes

Calibration

Pulse (RG) and ISCO 2150 (CW) installed in the same 72” pipe

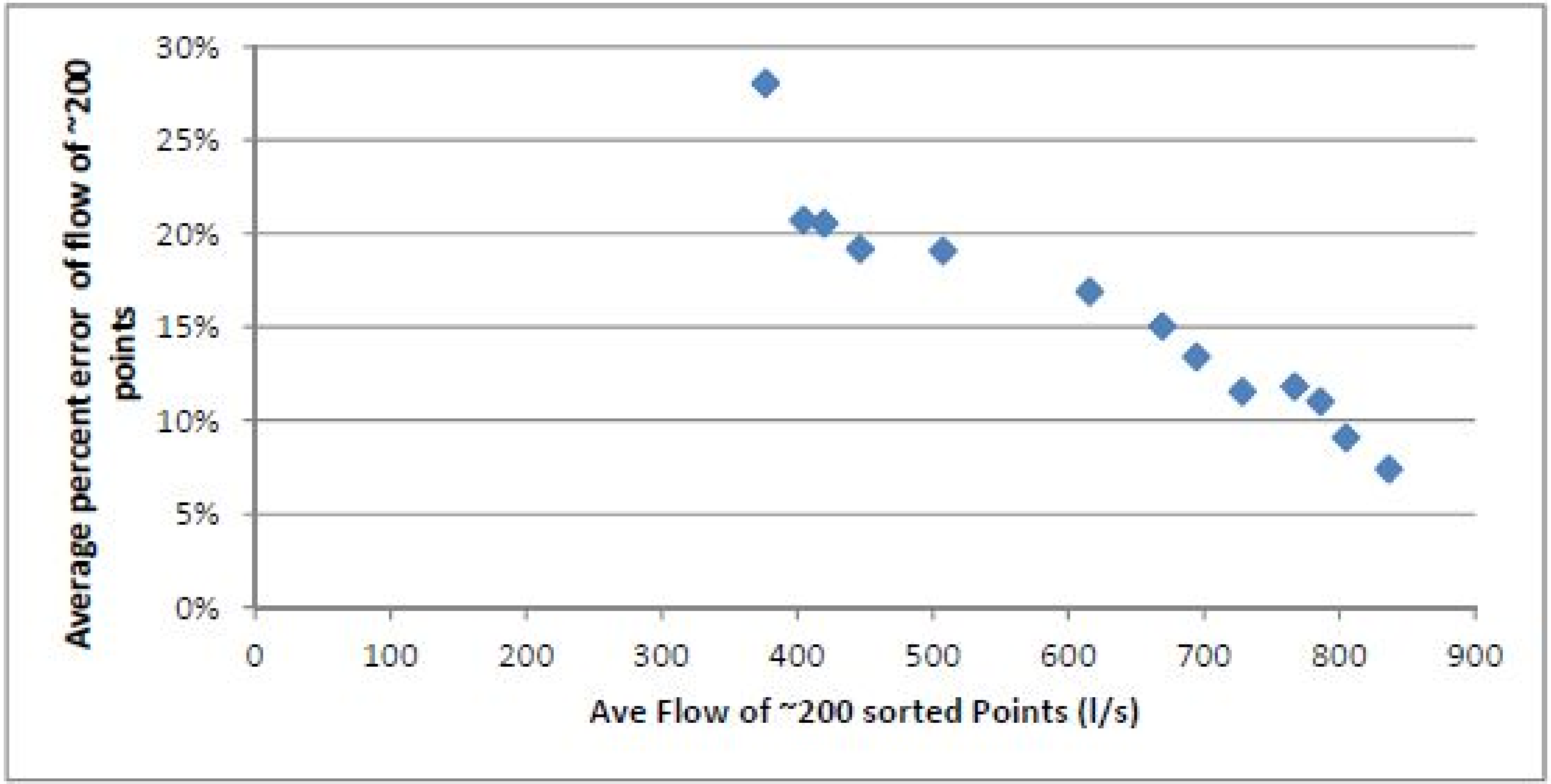
Pulse vs ISCO 2150

Calibration



Flow Error

MMI Flo-Dar vs Pulse



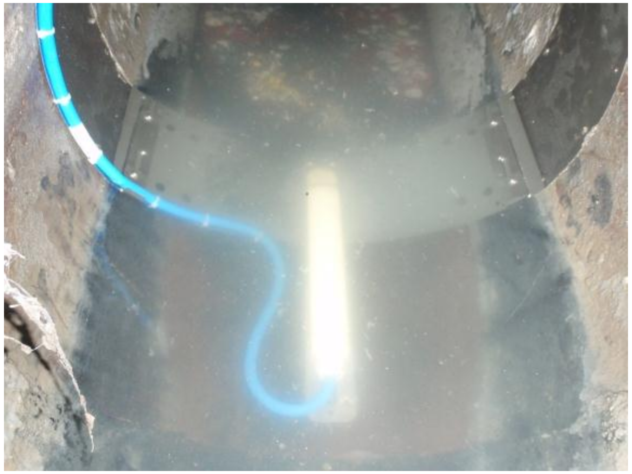
Flow Error

FlowShark Pulse: Pros and Cons

Advantages

- Accurate Range gated Doppler
- Works in churning water
- Works in Deep and Slow water

Disadvantages



- Expensive
- Does not work well with silt
- Not integrated with Profile
- Does not work in flows less than about 3-4 inches

Concluding Observations

Long Term Monitoring Must have ultrasonic for the level, or both pressure and ultrasonic.

Flows deeper than 18or 20 inches should have range gated doppler.

New Technologies for small flows

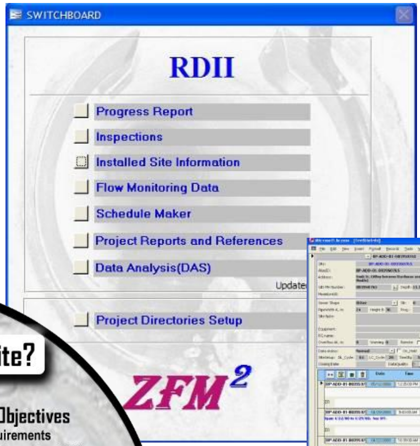
Micromonitor

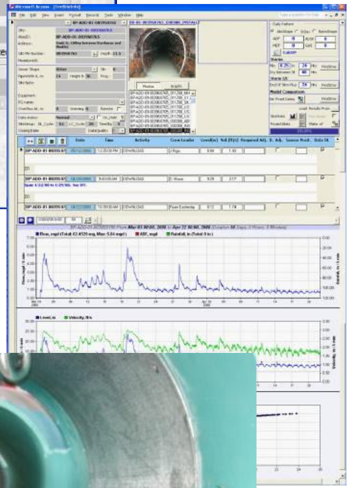
ADS Triton Non-contact probe (Like a mini FloDar which fits in the pipe)

Micro-Monitoring:

An innovation in monitoring low flo in sanitary sew

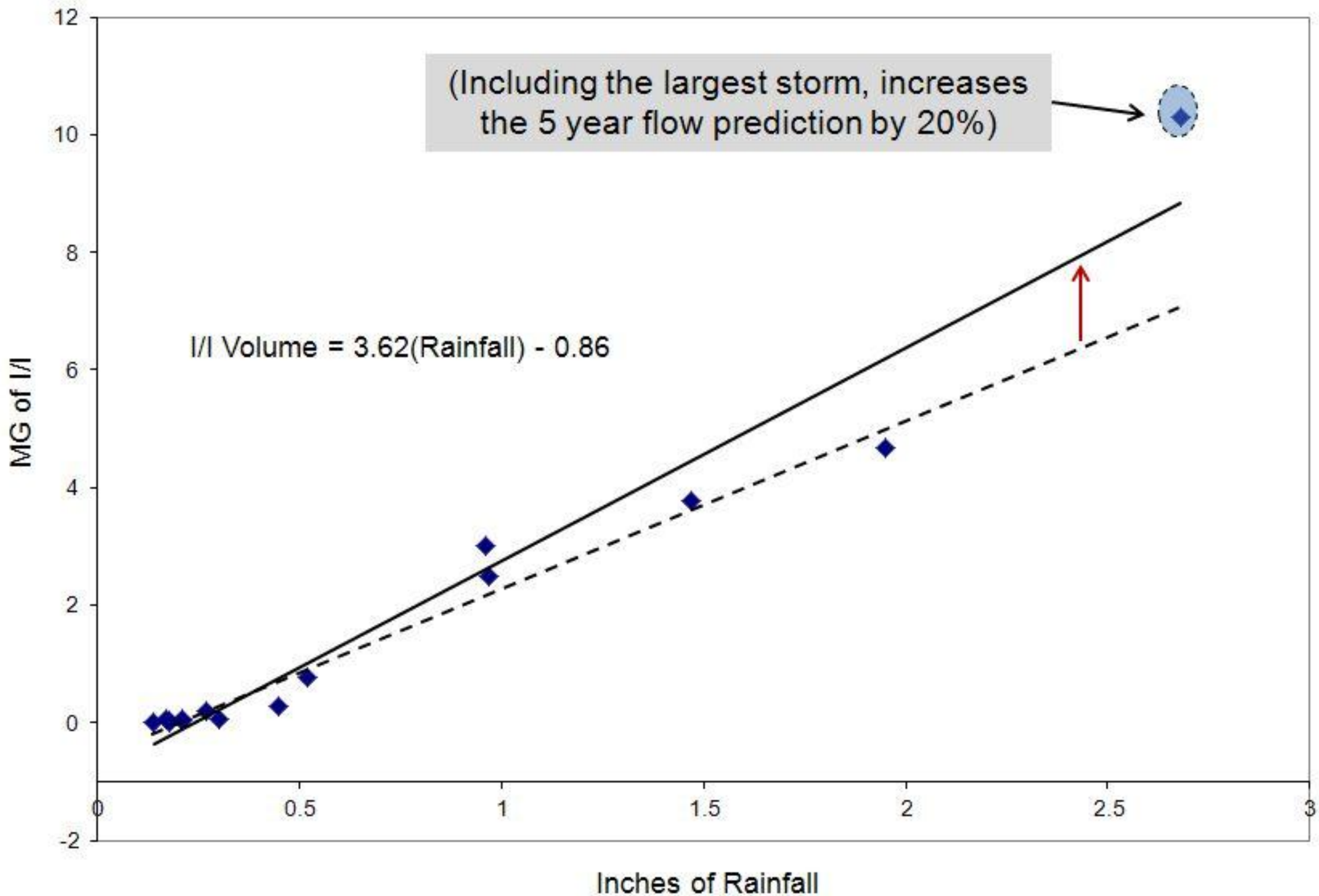
John M.H. Barton PhD, PE;
Stantec Consulting, Inc.



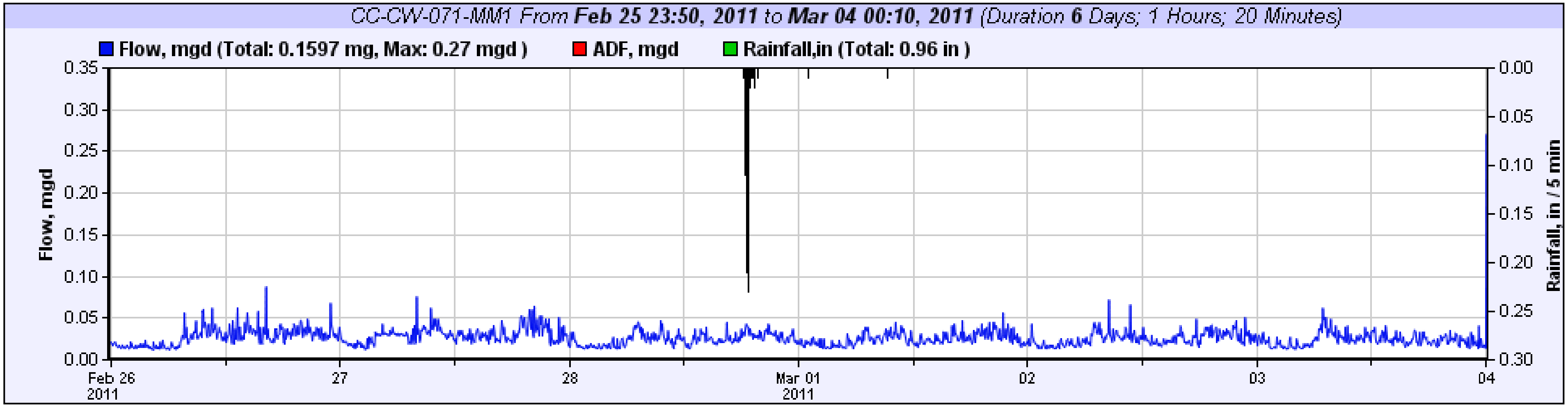


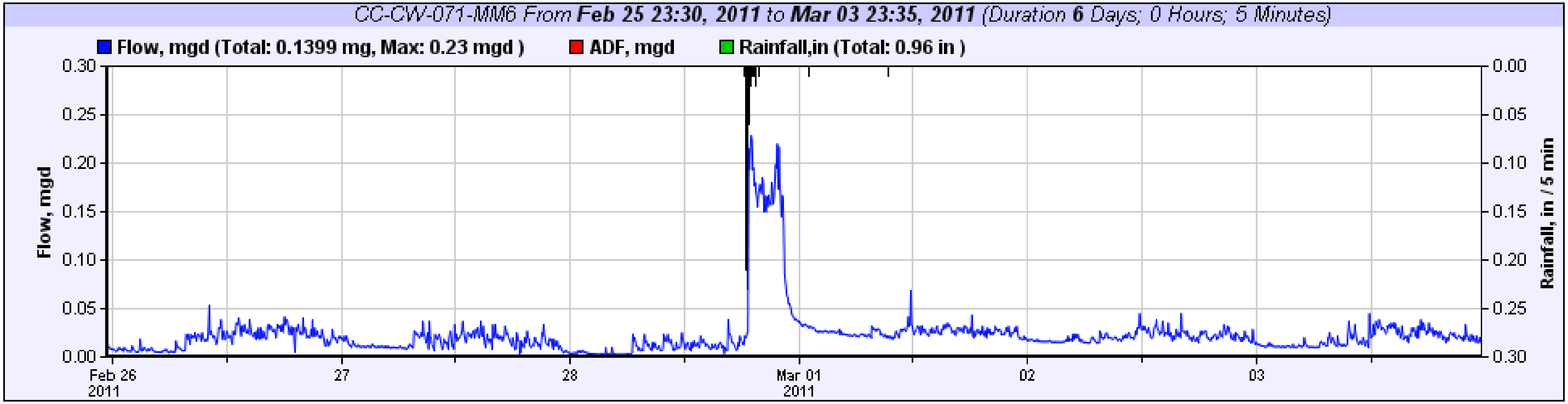
How Many Storms Do You Need to Quantify I/I?

For the Modeler?

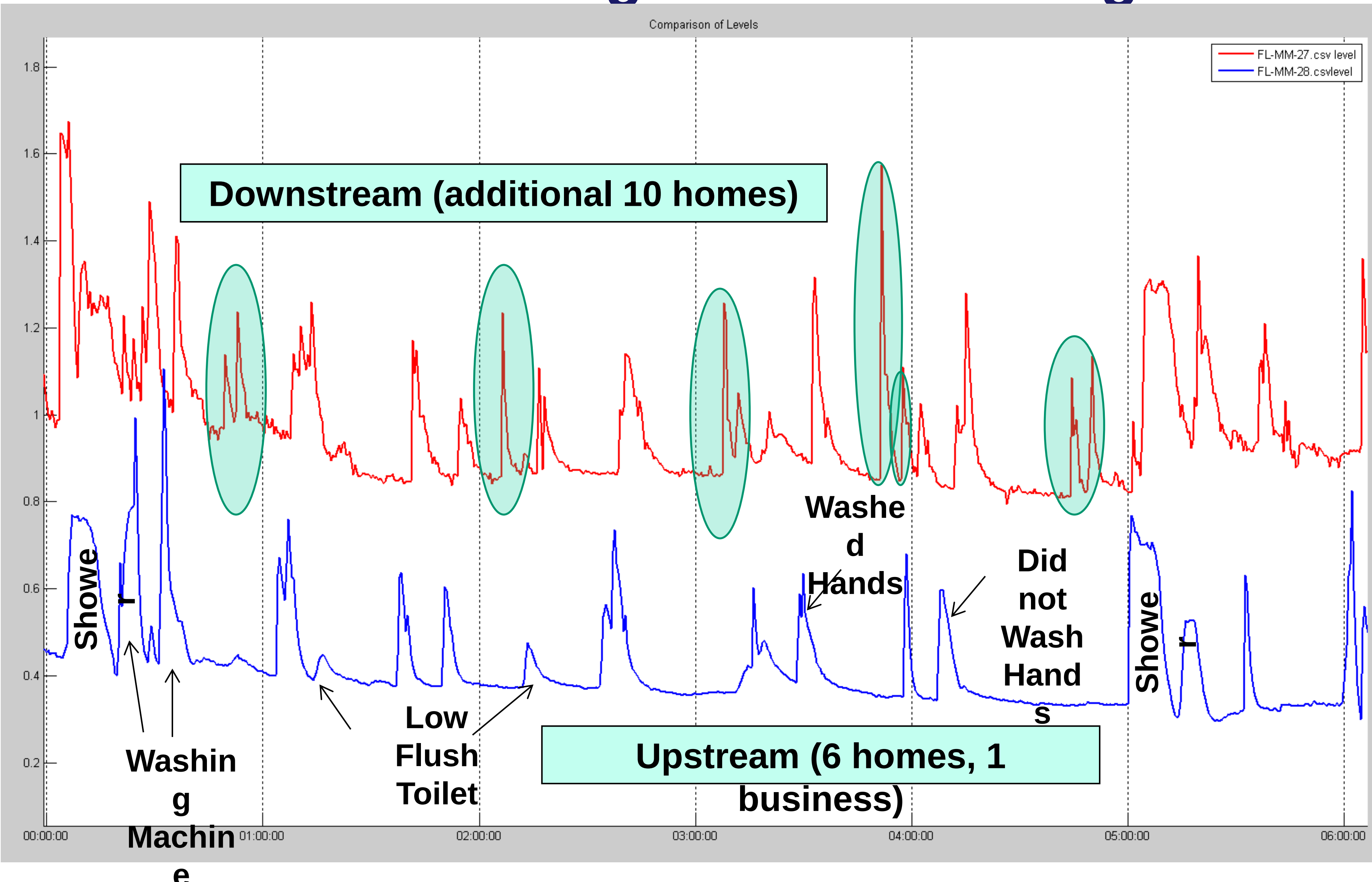


For the I/I guy?



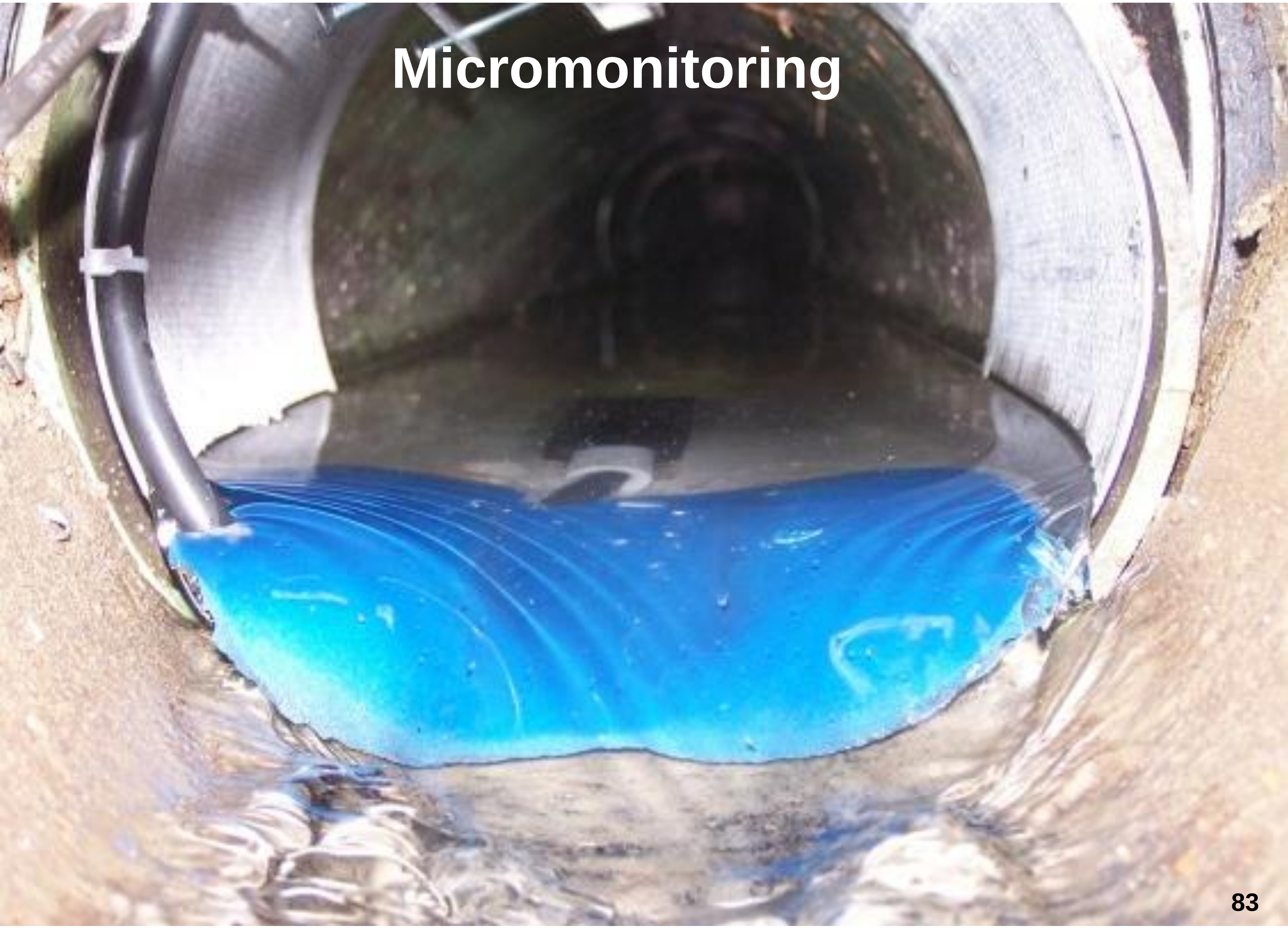


Micromonitoring: Domestic Usage



30 second level data,

Micromonitoring



Some Questions

Which technology will work best with slow deep flow?

What flow conditions are the most likely to result in silt and sediment?

Which technology is most limited by silt and sediment?

Some Questions

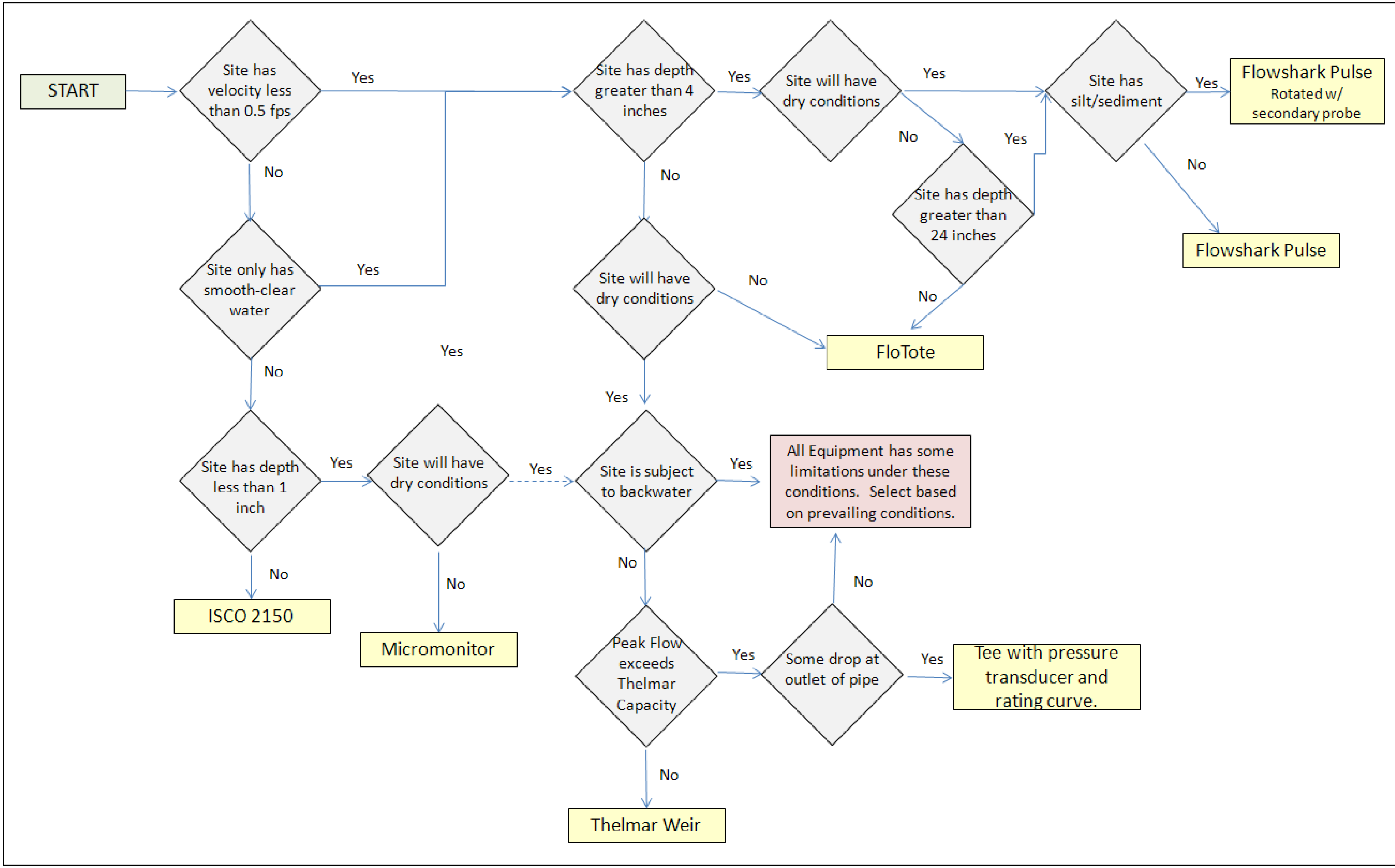
How does the Hach convert obtain the Peak to Average conversion?

How does the Flowshark obtain the Peak to Average conversion?

How does the FloTote obtain the Peak to Average Conversion?

Why doesn’t the ISCO 2150 need a conversion to the average flow?

Some Guidelines



Add ADS, Sigma, FloDar