



The Benefits of Using an Acoustic Doppler Current Profiler for Hydraulic Modeling

National Hydraulic Engineering Conference 2014

Iowa City, Iowa

Kevin Flora, P.E.
Caltrans

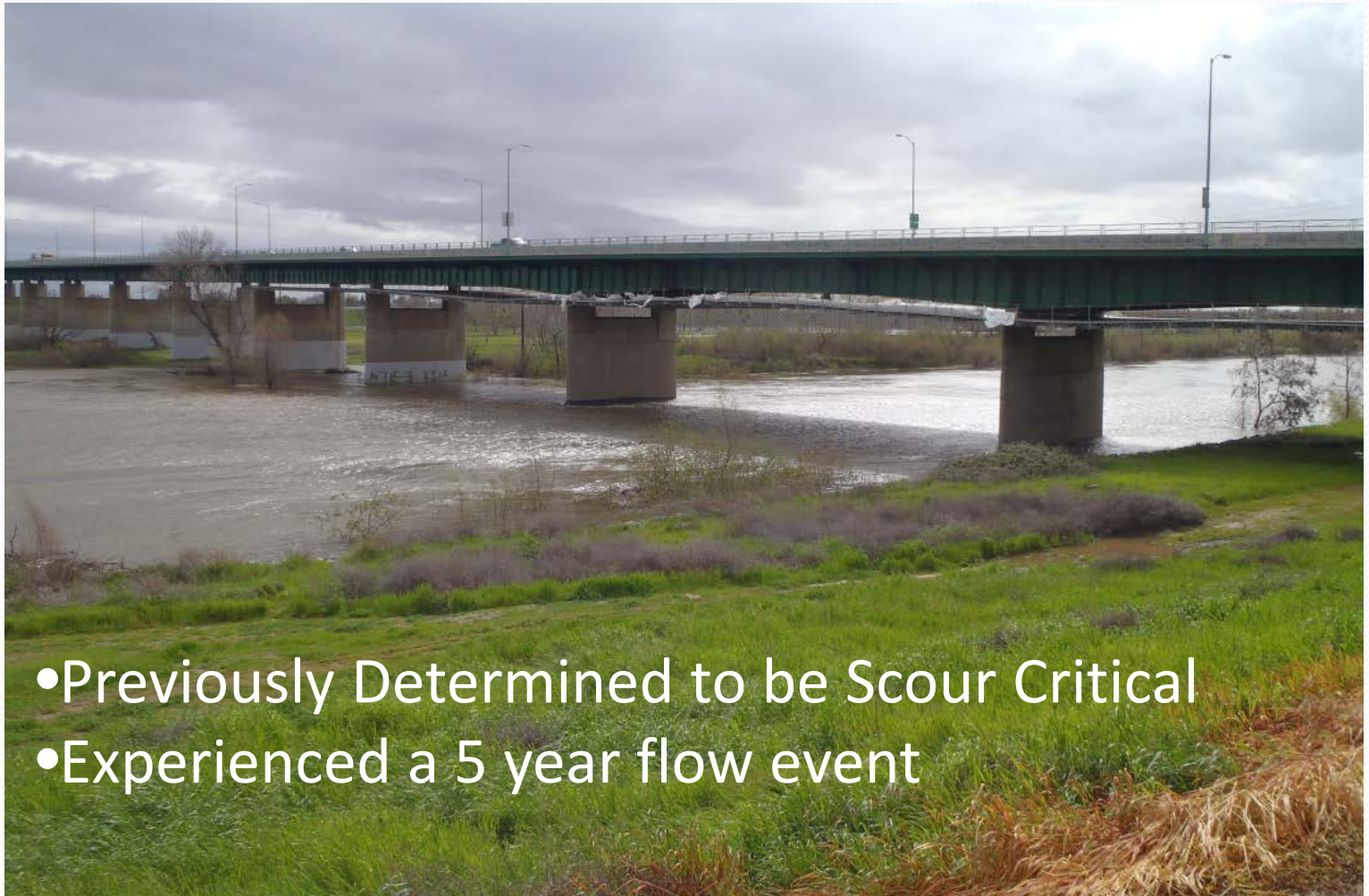


Key Questions ?

- What's up with the Feather River?
- What other tools are out there that can help me do my work better?

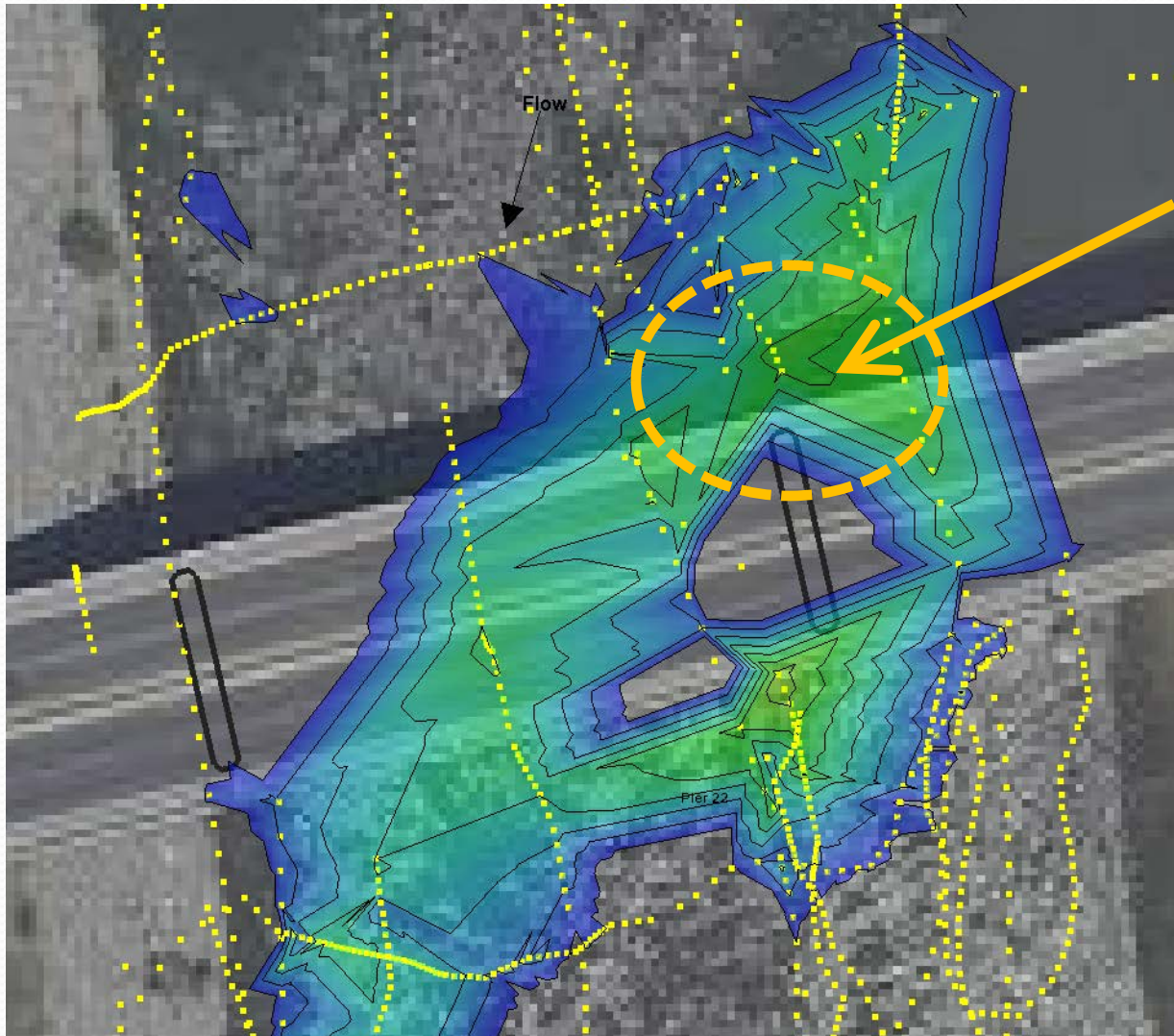
Feather River Br. No. 18-0009

March 22, 2011



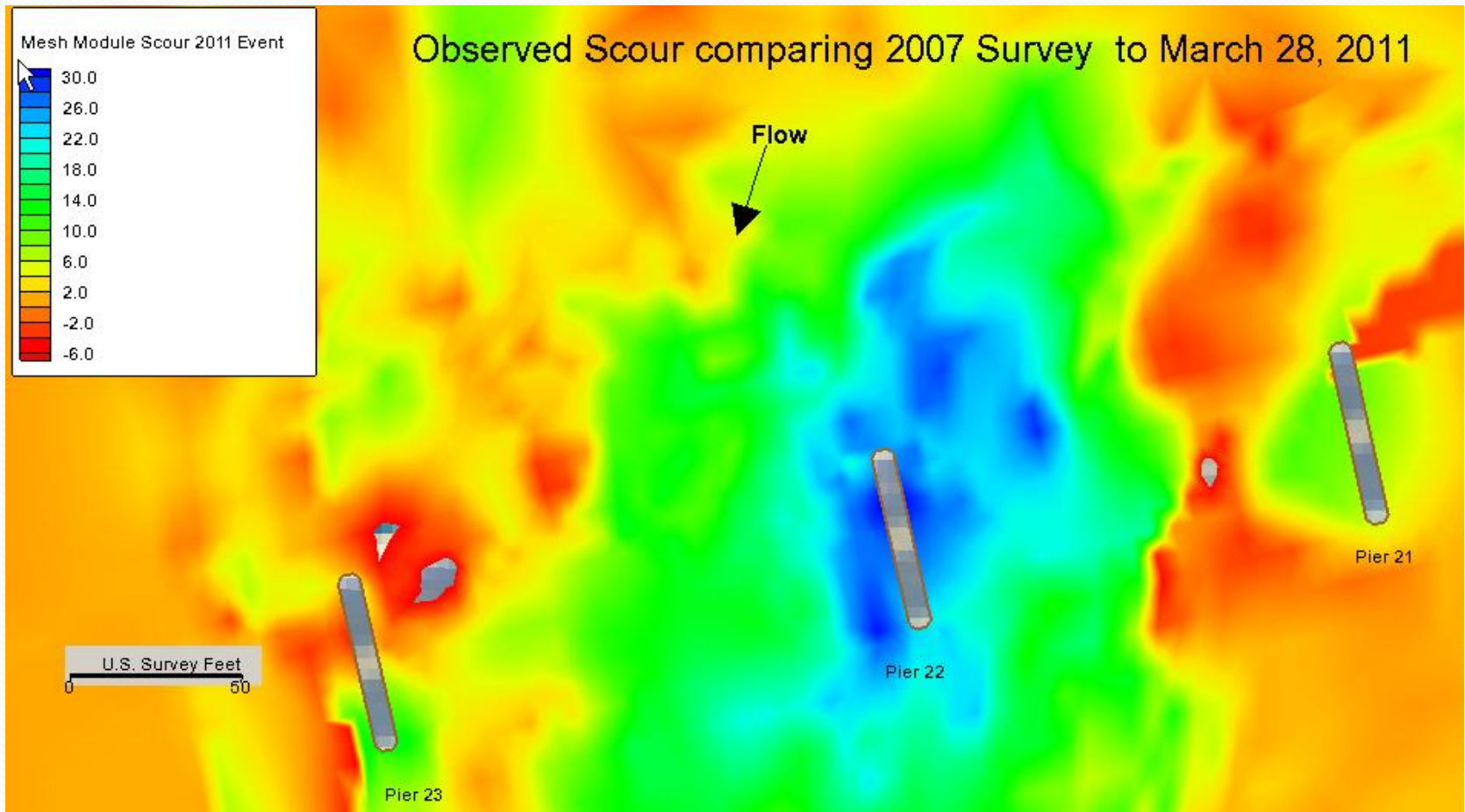
- Previously Determined to be Scour Critical
- Experienced a 5 year flow event

Emergency or Not?

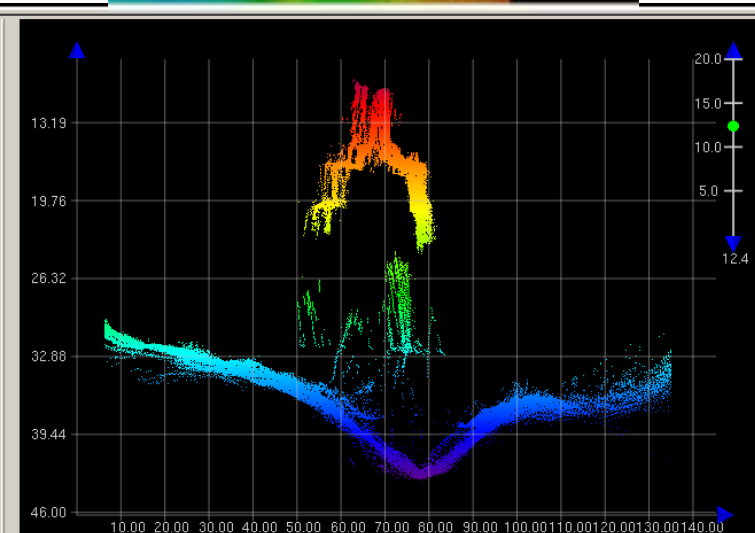
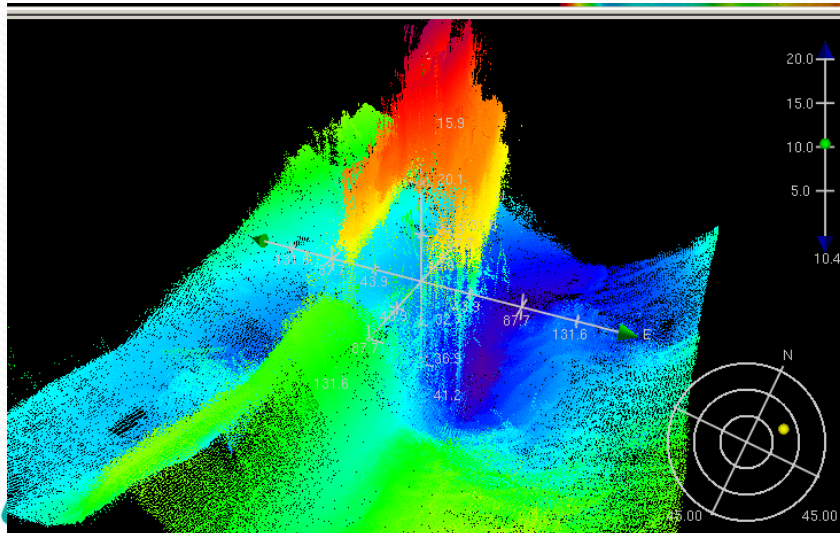
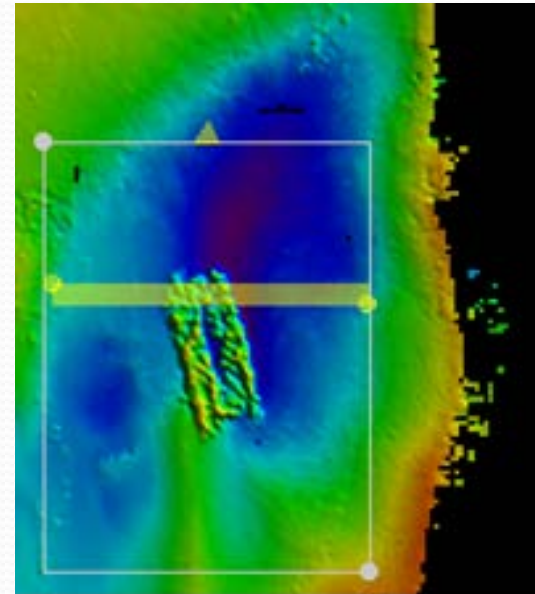


Limited Data showed a 30-foot Scour hole at the Pier

Confirmation from Follow-up Surveys



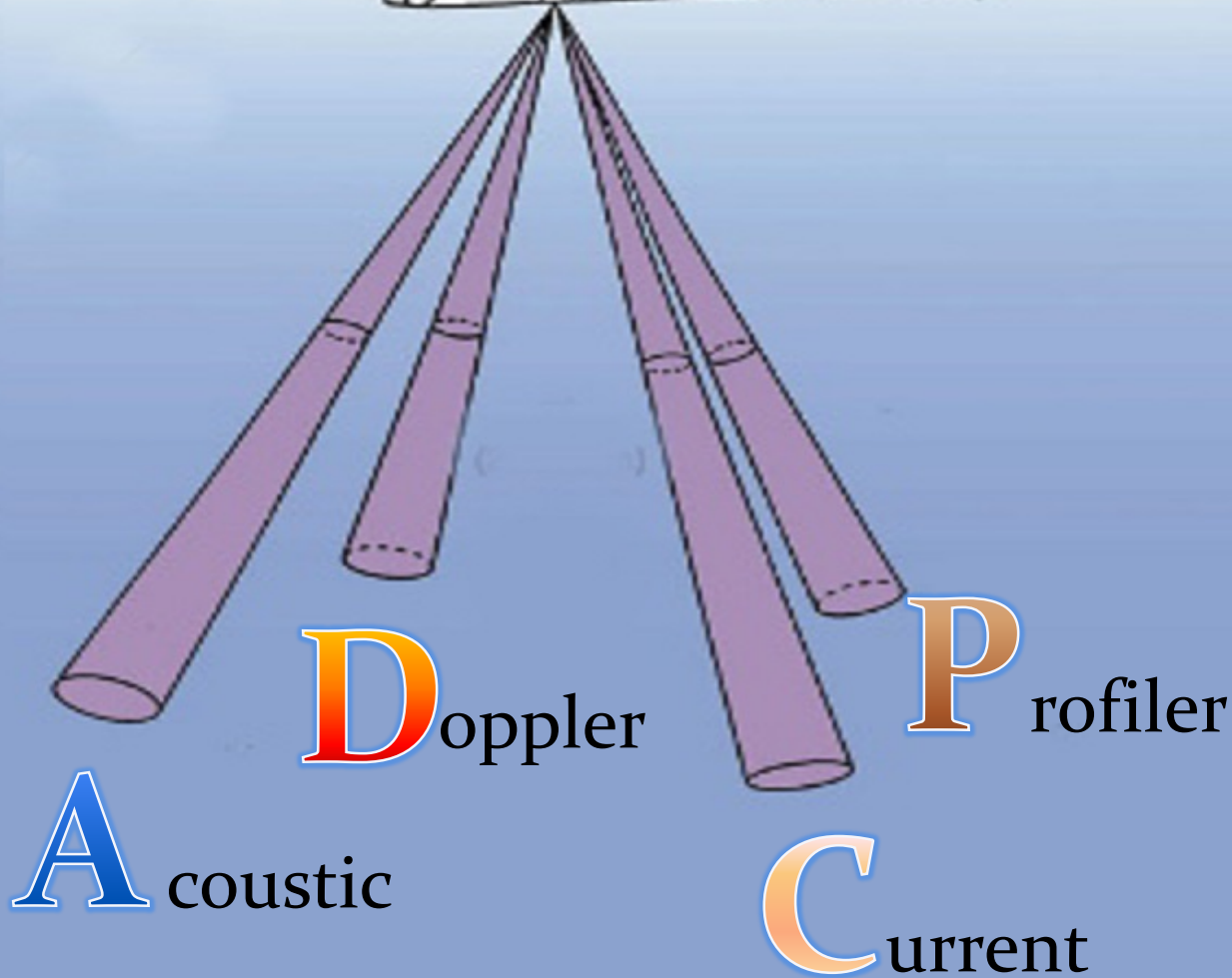
Multi-beam Bathymetry by Contract



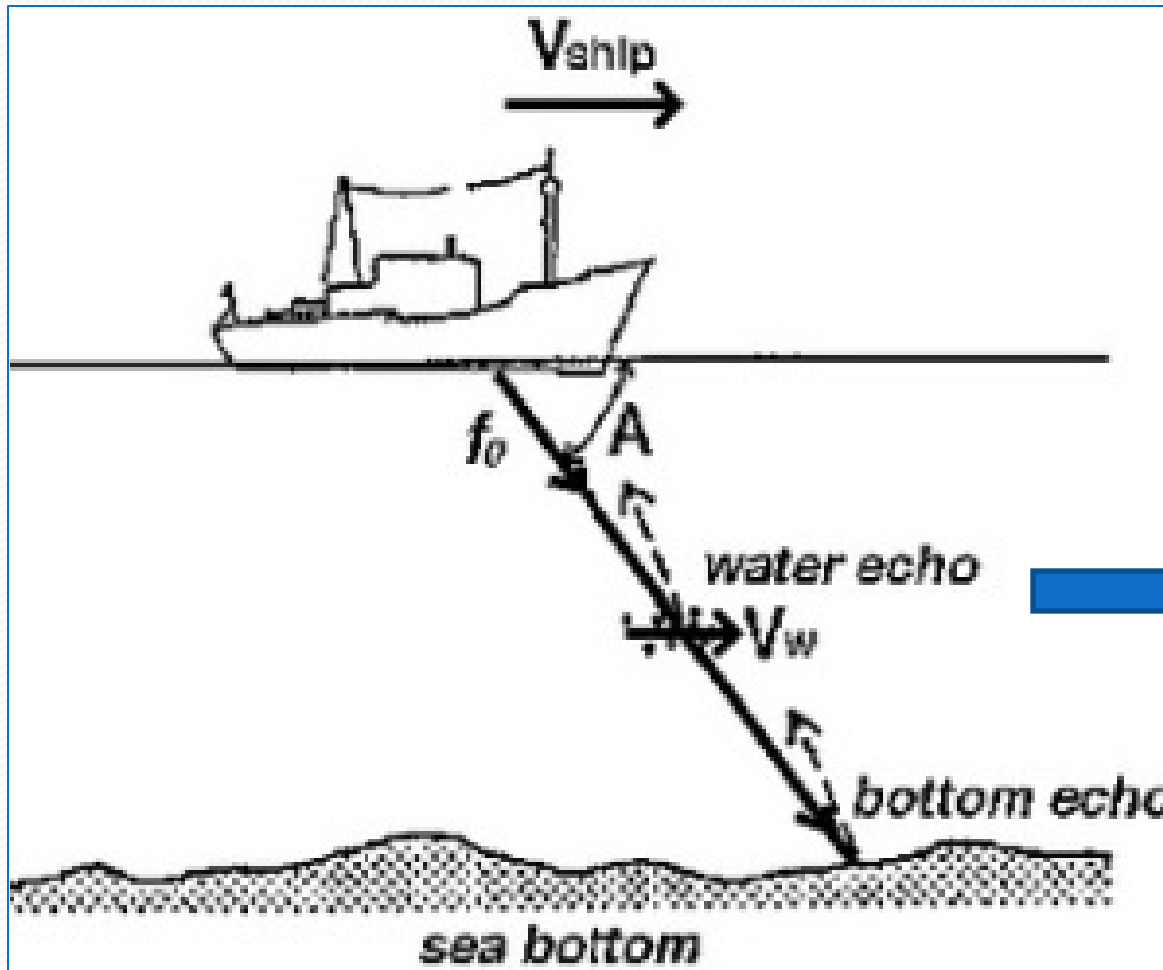
Lessons Learned

- Capturing Scour Data during or immediately after an event is critical
- Acquisition of Baseline Bathymetric Data is invaluable
- **Clear need for improved methods for collecting data under a bridge**
- **Need for better estimates of Key Hydraulic Parameters**
 - **Hydraulic Skew**
 - **Upstream Flow Distribution**
 - **Roughness**

ADCP



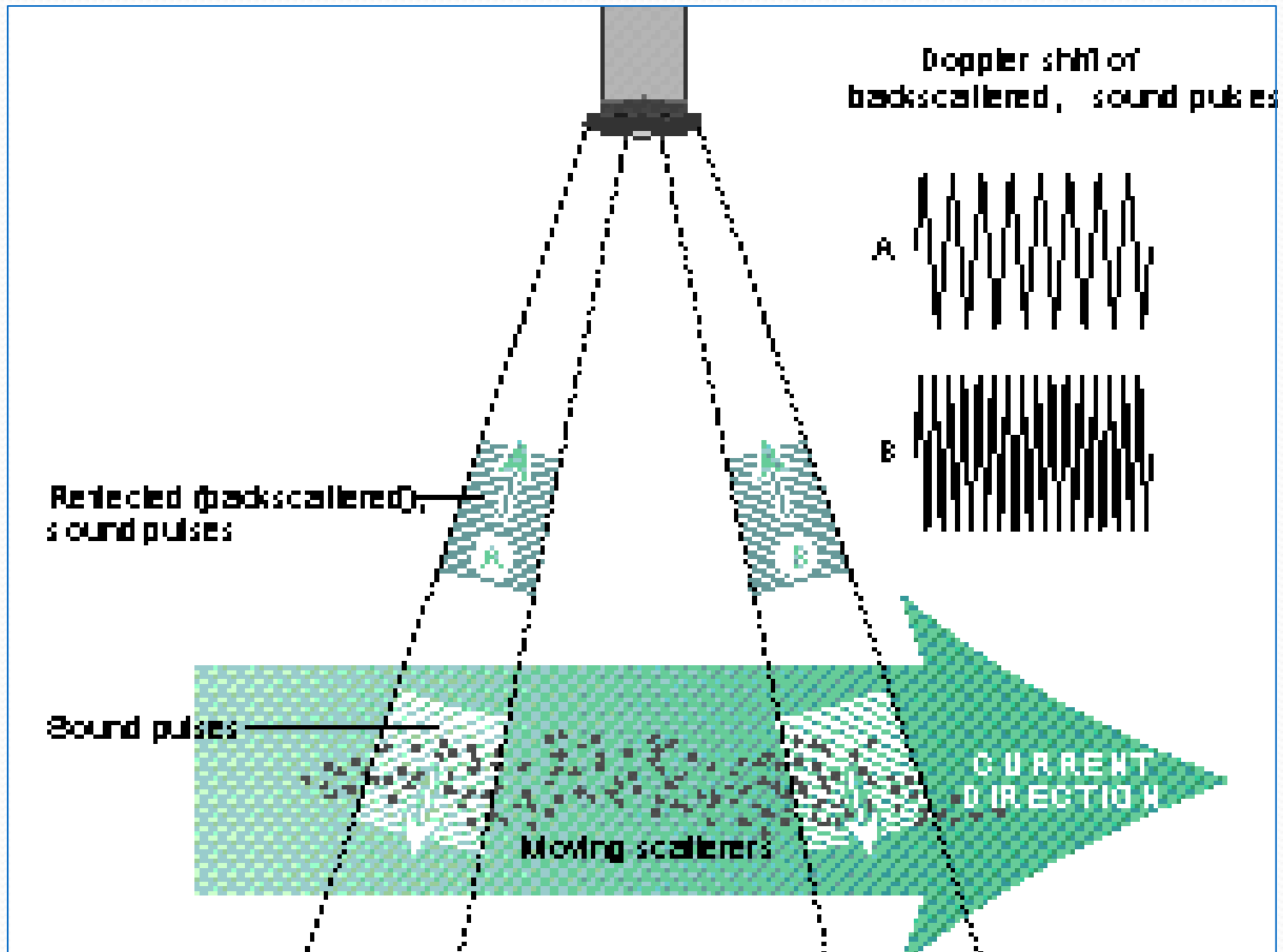
ADCP Operation



Velocity of Flow

Location

ADCP Operation



ADCP Acquired in Spring 2012

- RDI Rio Grande Workhorse ADCP
 - 1200 kHz
 - High Speed Sampling (Mode 12)
 - Shallow water bottom tracking
- USGS Kentucky Mounted on 12-foot Achilles Inflatable Boat
- RDI's WinRiver II Software



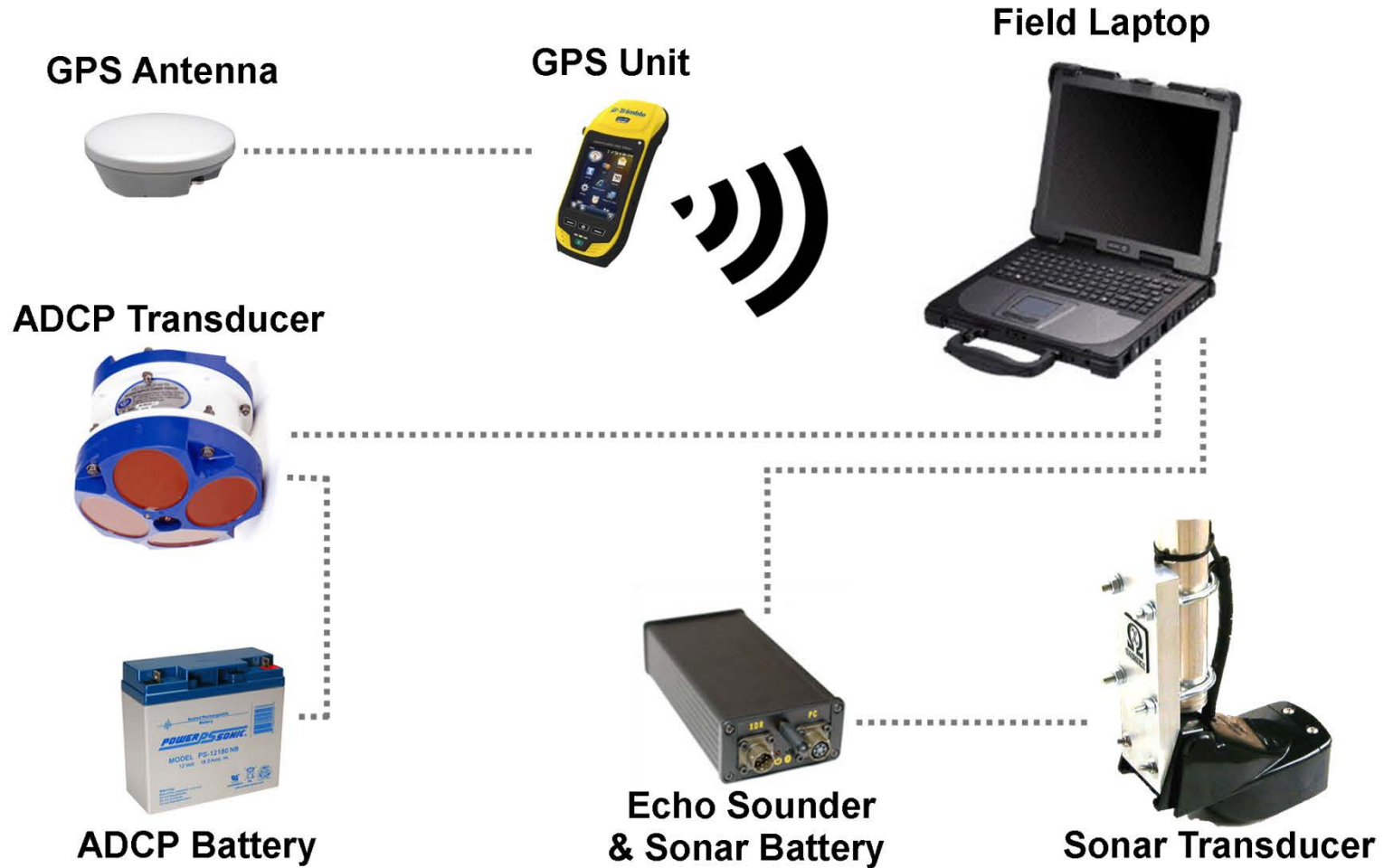
SM&I Dive Boat



Sonar

ADCP

Equipment Set up





Caltrans Uses of ADCPS

Aquisition of
Bathymetric
Data

D

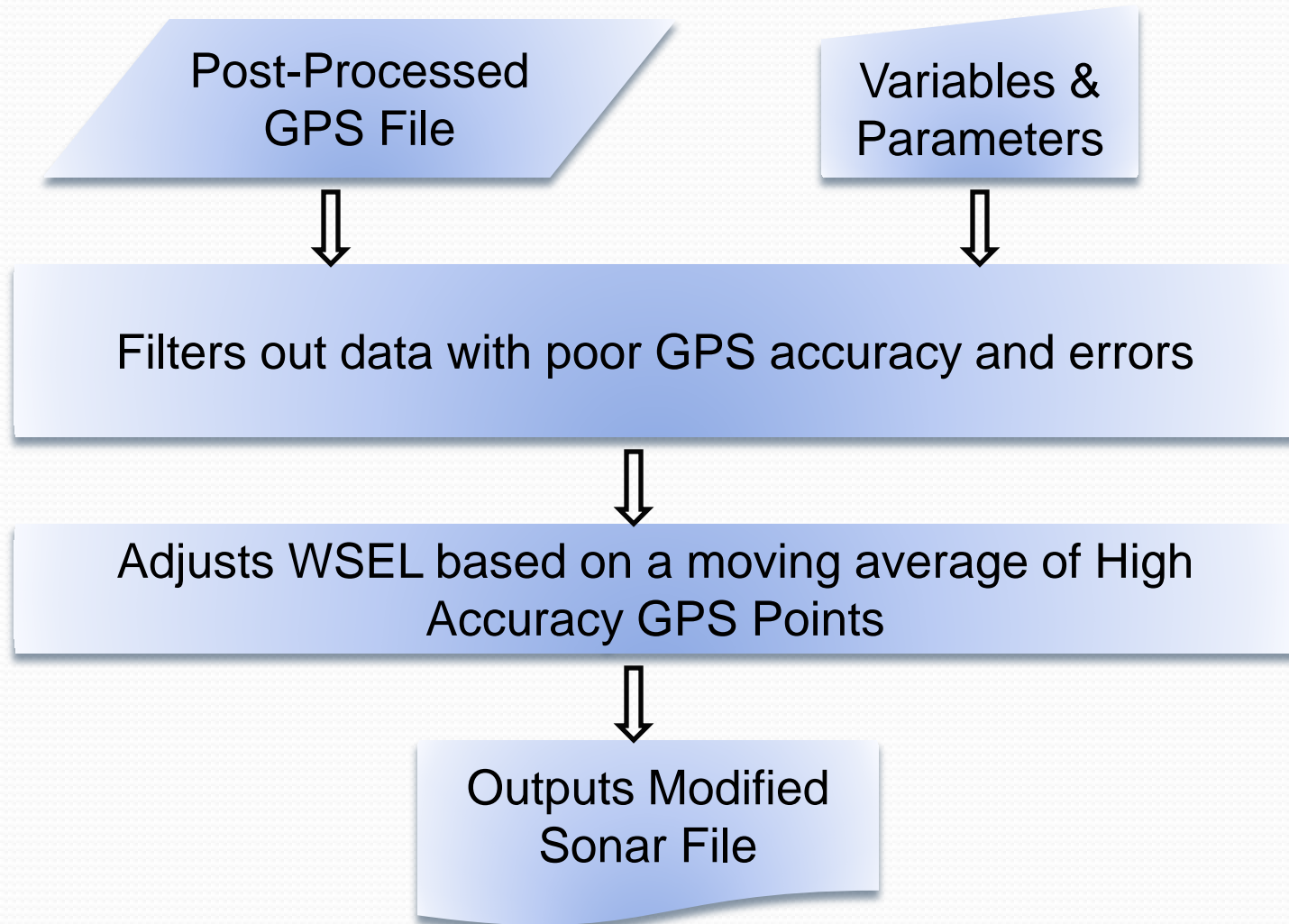
C

P

Combine ADCP/Sonar/GPS Data

- In house Program written in VBA for Microsoft Excel
- Provides a means to improve bathymetric surveys by intelligently combining GPS, Sonar and ADCP depth data
- Outputs in a CSV format for easy input into 2D models

PART 1 - Sonar/GPS Filter Flowchart



Sonar/GPS Filter Macro

1. Sonar/GPS Filter

2. ADCP/Sonar Synchronization

3. Charting and Data Analysis

1 Select the Sonar file to be modified

Browse

2 Utilize GPS-referenced WSEL?

Yes No

3 Adjust the vertical datum?

No Yes

4 Output all available data?

Yes No, output data in time interval:

5 Enter the depth of the Sonar transducer head

>> (ft)

6 Enter the GPS horizontal error limit to smooth WSEL

>> (ft)

7 Enter max horizontal error to keep GPS points

>> (ft)

8 Enter max depth observed

>> (ft)

Command Window - SNR/GPS Filter

Run SNR/GPS Filter Clear Page (redo) Use Previous Settings

Use Default Settings

Instructions

1. Select the .snr file you would like to correct. By default, this file should be found in the "Export" folder of the project directory. This file was created by GPS Pathfinder Office.

2. If GPS elevations for the water surface elevation are too inconsistent (e.g. underneath bridges) then a constant WSEL can be added manually. NOTE: Make sure to add a WSEL based on the datum used by the GPS points, not the bridge.

3. The GeoExplorer GPS unit automatically utilizes the NGVD 88 vertical datum. To switch to other vertical datums, check the Vertcon website online to find the difference at any particular site. NOTE: Converting NGVD 88 to NAVD 29 is a negative value.

4. Choose if all the data or only a certain time interval of data will be outputted. This only controls what is outputted, as all available data is still processed by the Sonar/GPS filter regardless of this decision. If time interval is chosen, enter a start and end time in the available boxes once the NO option is clicked. This feature is particularly useful when troubleshooting inconsistencies with ADCP transect times in the ADCP/Sonar Synchronization Tool. NOTE: Please utilize the <hh:mm:ss> or <h:mm:ss AM/PM > time format.

5. Estimate the depth of the Sonar transducer head below the water surface. Note that this value may vary depending on the effects of the boat wake as well as pitching and rolling. Recommended value to be used is 0.5 ft.

6. Variation in WSEL points due to GPS errors are smoothed out in this program.

Sonar/GPS Filter Macro

Chart Management Tool

Export chart as image Return to Program

Series Options

WSEL: Pre-procd. WSEL: Pre-proc. _Extra
 WSEL: Post-procd.

Axis Zoom Options

Zoom X Zoom X&Y Zoom Y U

+ + + ▲

▲ ▲ ▲ ▼

▼ ▼ ▼ D

- - - L R

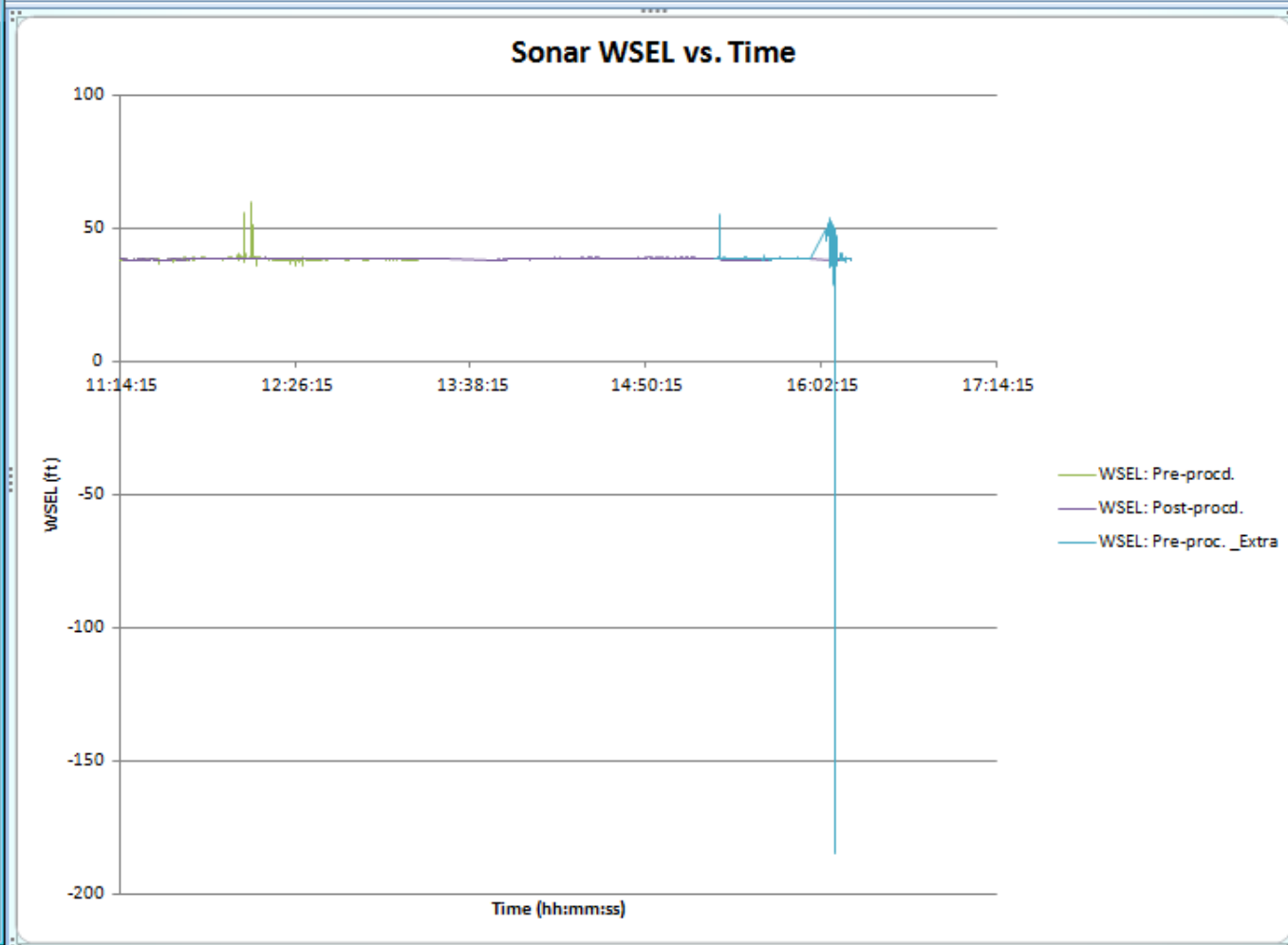
Axis Limits

----- X-axis ----- ----- Y-axis -----
(hh:mm:ss) (feet)

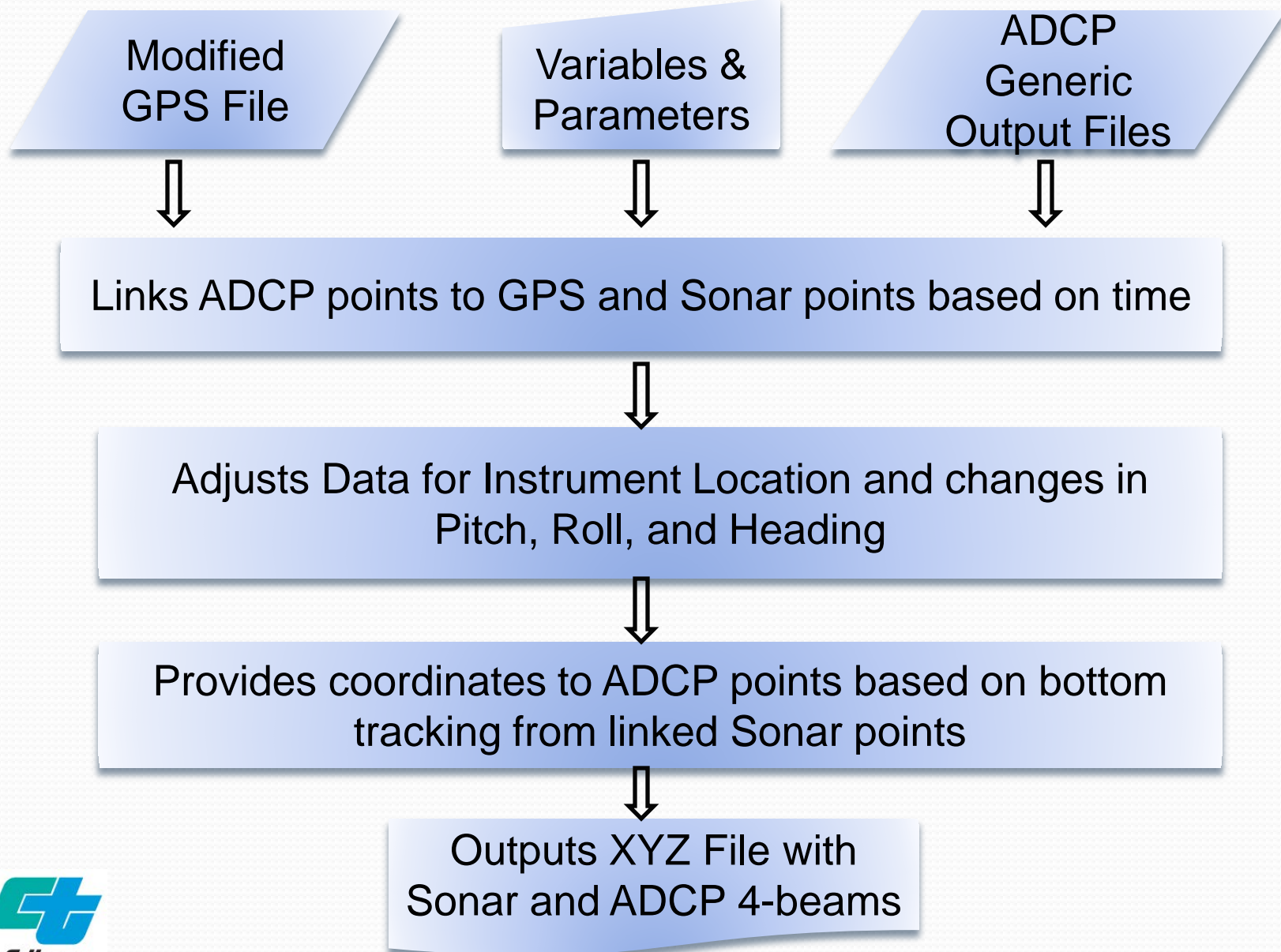
Start = Min =
End = Max =

Rescale X Rescale Y

Auto Rescale X Auto Rescale Y



PART 2 - ADCP/Sonar Synchronization Flowchart



Sonar/GPS Filter Macro

- 1. Sonar/GPS Filter
- 2. ADCP/Sonar Synchronization
- 3. Charting and Data Analysis

1 Select the first ADCP text file

Browse

2 Select the last ADCP text file

Browse

Click Here If Only Processing A Single Transect

3 Select the modified Sonar file

Browse

4 Select all, all-minus-one, or one output data point

Beam 0 (Sonar) Beam 1 Beam 3

Beam 2 Beam 4

5 Would you like to offset the time?

No Yes

6 Enter the depth of the ADCP transducer head

>> (ft)

7 Enter the depth of the Sonar transducer head

>> (ft)

8 Enter the X and Y distances from the ADCP to Sonar unit

Distance X (lengthwise) = (ft)

Distance Y (widthwise) = (ft)

Command Window - ADCP/SNR Synchronization

Run ADCP/SNR Sync Clear Page (redo) Use Previous Settings

Use Default Settings

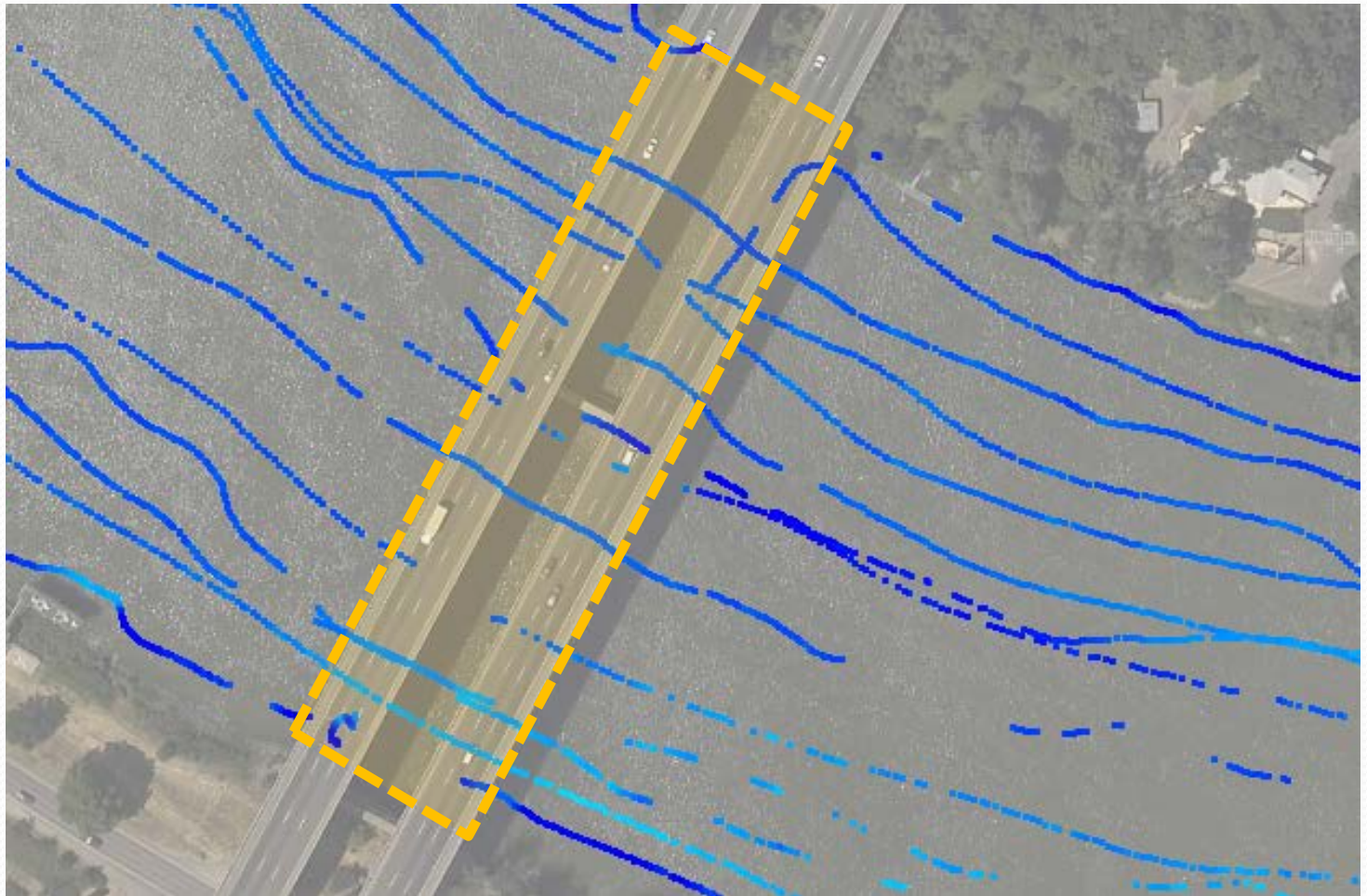
Instructions

1. Choose the first or single ADCP transect text file that was created by WinRiverII in the measurements folder. By default the lowest sequential filename will be "4beamcorrection_000_ASC.txt". NOTE: Each text files refers to an individual ADCP transect. A transect encompasses the time when the ADCP begins and stops pinging.
2. Choose the ASCII file with the highest sequential file name (e.g. "4beamcorrection_014_ASC.txt") in the same folder as Step 1. If only a single transect will be processed, please click on the option available under the prompt.
3. Choose the .SNR(mod) file newly created by the Sonar/GPS Filter in the main project "Export" folder.
4. To assist in delineating between Sonar depths and ADCP corrected depths, please select the the type of data points to output. Either ALL beams, ONE beam, or FOUR beams can be chosen.
5. If the Sonar clock and ADCP clock are not synced prior to data collection, there will be a constant time difference between two instantaneous data points measured by the devices. Analyze the .snr and ADCP text files to identify this constant time difference. Then enter the time difference in seconds (e.g., 1 hour = 3600 seconds). If the ADCP is lagged 1 hour after the Sonar, then input a positive (+) number, if Sonar lags, then enter a negative (-) number. NOTE: Sometimes transects have time errors in which the time offset will be different amongst the transects. If this is the case, only subsets of transects with the same time "base" can be processed. Outliers can then be processed individually.
6. Estimate the depth of the ADCP transducer head below the water surface. Note that this value may vary depending on the effects of the boat wake as well

Without ADCP Beams

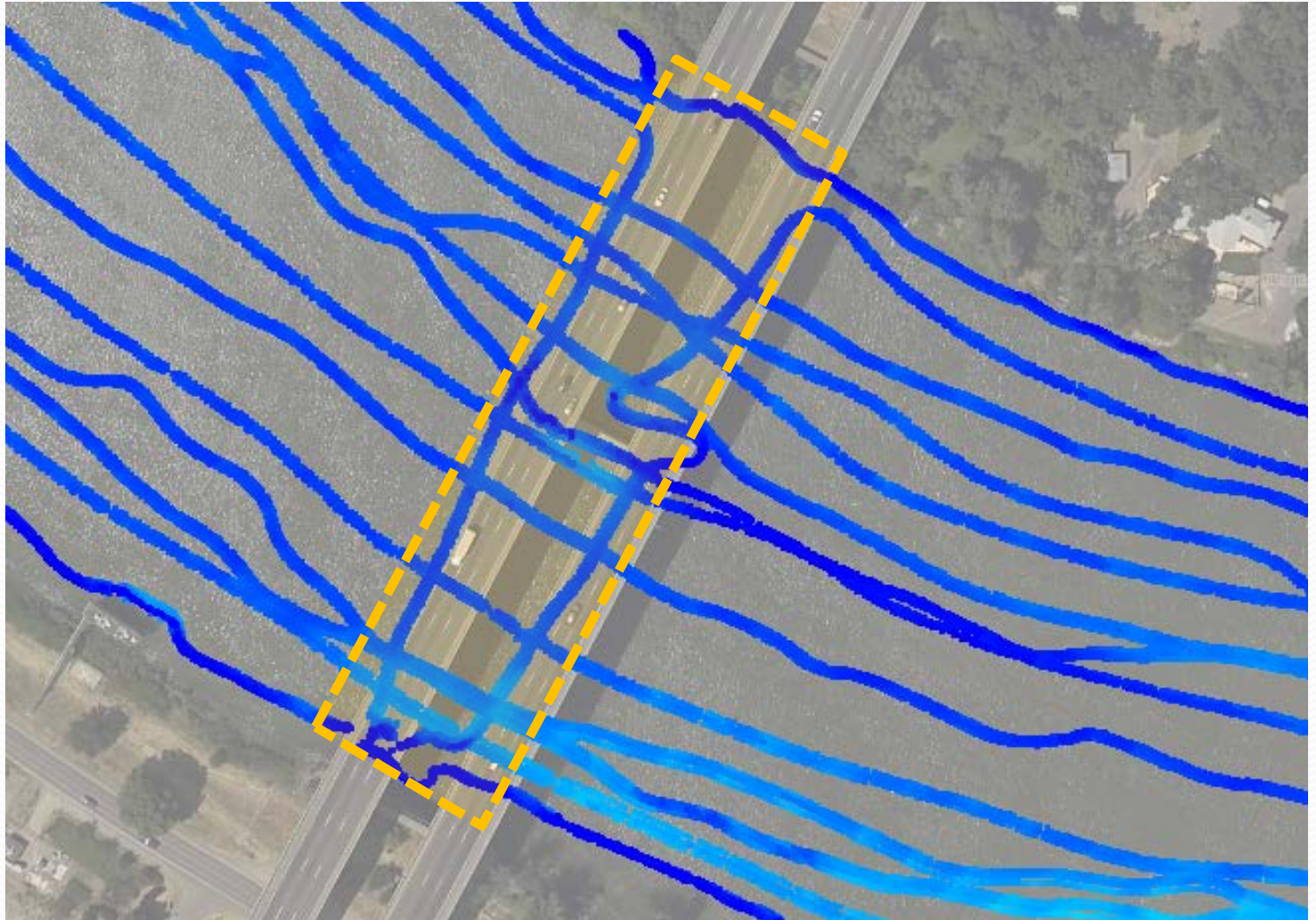
Sonar Data Using Only GPS Under Bridge

➔ *1121 points*



With ADCP Beams and Bottom Tracking

Combined Sonar & ADCP Data Under Bridge → 10,221 points





Caltrans Uses of ADCPS

Discharge
Measurements

Aquisition of
Bathymetric
Data

P

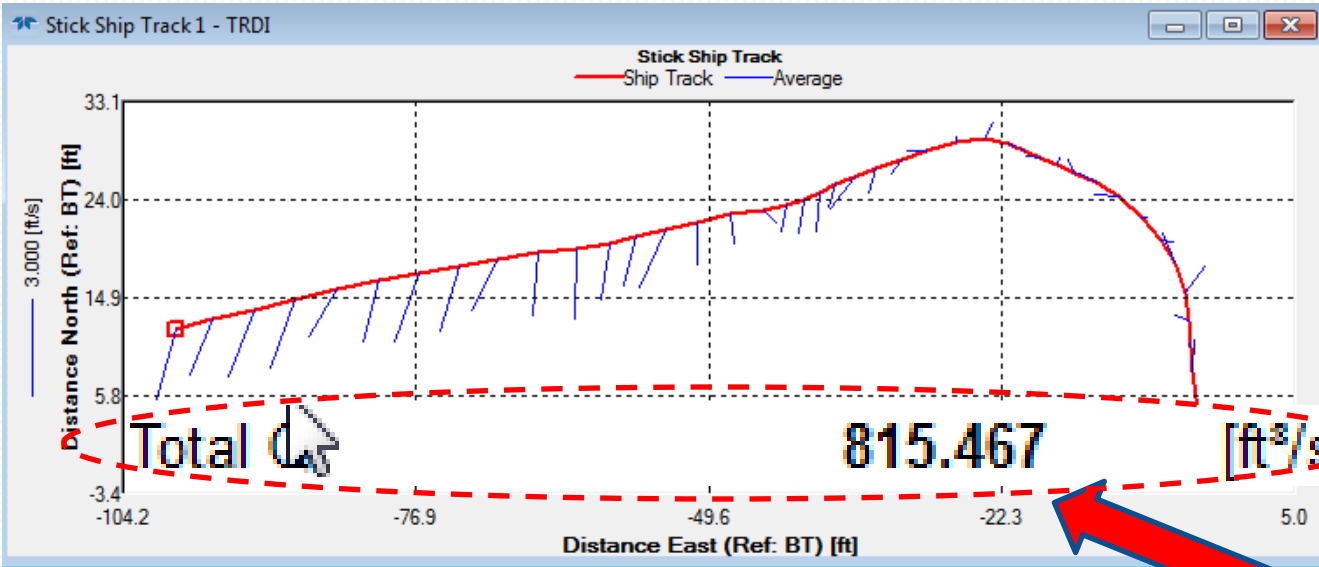
C

Discharge Measurements

- Obtained Simply by Traversing the Channel
- Velocity Data and Depth is Measured Simultaneously
- Estimates at the Edges and Top and Bottom of the Water Profile are automatically made
- Data is accumulated to obtain the Flow Rate

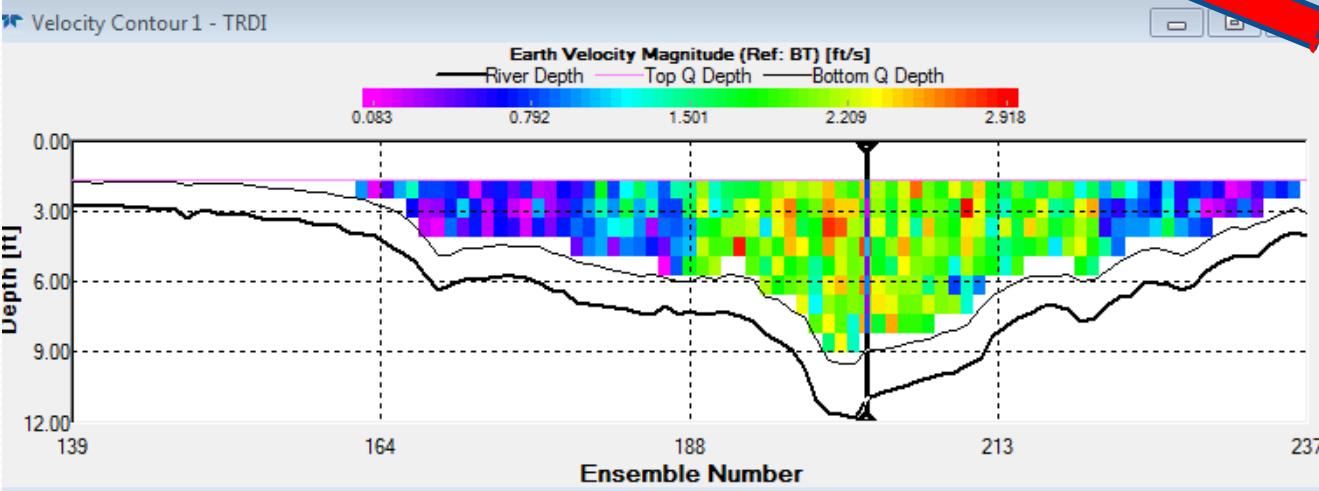
- Discharge Data will be useful for Model Calibration and during Flood Events

Discharge Measurements



Composite Tabular 1 - TRDI

| Ens. Numb. | Numb. of Ens. | Lost Ens. |
|------------------------------------|----------------|---------------------------|
| 202 | 64 | 0 |
| Bad Ens. | %Bad Bins | Delta Time |
| 23 | 0% | 0.75 |
| August 12, 2014 13:25:08.17 | | |
| Pitch | Roll | Heading |
| -0.61° | -0.19° | 283.99° |
| Temp. | Press. Sensor | |
| 69.96°F | NA | |
| Discharge (Ref: BT) Left to Right | | |
| Good Bins | 8 | |
| Top Q | 156.888 | [ft ³ /s] |
| Measured Q | 511.386 | [ft ³ /s] |
| Bottom Q | 154.449 | [ft ³ /s] |
| Left Q | -7.256 | [ft ³ /s] |
| Right Q | 0.000 | [ft ³ /s] |
| Total Q | 815.467 | [ft³/s] |
| MBT Corrected | | [ft ³ /s] |
| Navigation (Ref: BT) | | |
| Boat Speed | 4.740 | [ft/s] |
| Boat Course | 253.73 | [°] |
| Water Speed | 2.278 | [ft/s] |
| Water Dir. | 195.75 | [°] |
| DS Depth | 10.958 | [ft] |
| Length | 120.19 | [ft] |
| Distance MG | 99.93 | [ft] |
| Course MG | 276.89 | [°] |
| Duration | 43.29 | [s] |



Measured Flow Rates

(Q=26,400 cfs with Standard Deviation < 2%)

| Transect | Start Bank | # Ens. | Start Time | Total Q ft ³ /s | Delta Q % |
|--------------------|------------|--------|------------|-------------------------------|--------------|
| Butte12-4-12-01000 | Left | 145 | 10:10:10 | 26890.865 | 1.74 |
| Butte12-4-12-01001 | Right | 153 | 10:15:57 | 26194.577 | -0.89 |
| Butte12-4-12-01002 | Left | 132 | 10:21:07 | 25860.402 | -2.15 |
| Butte12-4-12-01003 | Right | 128 | 10:26:19 | 26447.183 | 0.07 |
| Butte12-4-12-01004 | Left | 133 | 10:30:54 | 25788.939 | -2.42 |
| Butte12-4-12-01005 | Right | 123 | 10:35:47 | 26131.926 | -1.13 |
| Butte12-4-12-01006 | Left | 238 | 10:40:24 | 27041.511 | 2.31 |
| Butte12-4-12-01009 | Left | 172 | 11:02:18 | 27082.249 | 2.47 |
| Average | | 153 | | 26429.707 | -0.00 |
| Std Dev. | | 38 | | 519.854 | 1.97 |
| Std./ Avg. | | 0.25 | | 0.02 | 0.00 |



Caltrans Uses of ADCPS

- D**ischarge Measurements
- A**quisition of Bathymetric Data
- C**alibration of Hydraulic Models
- P**

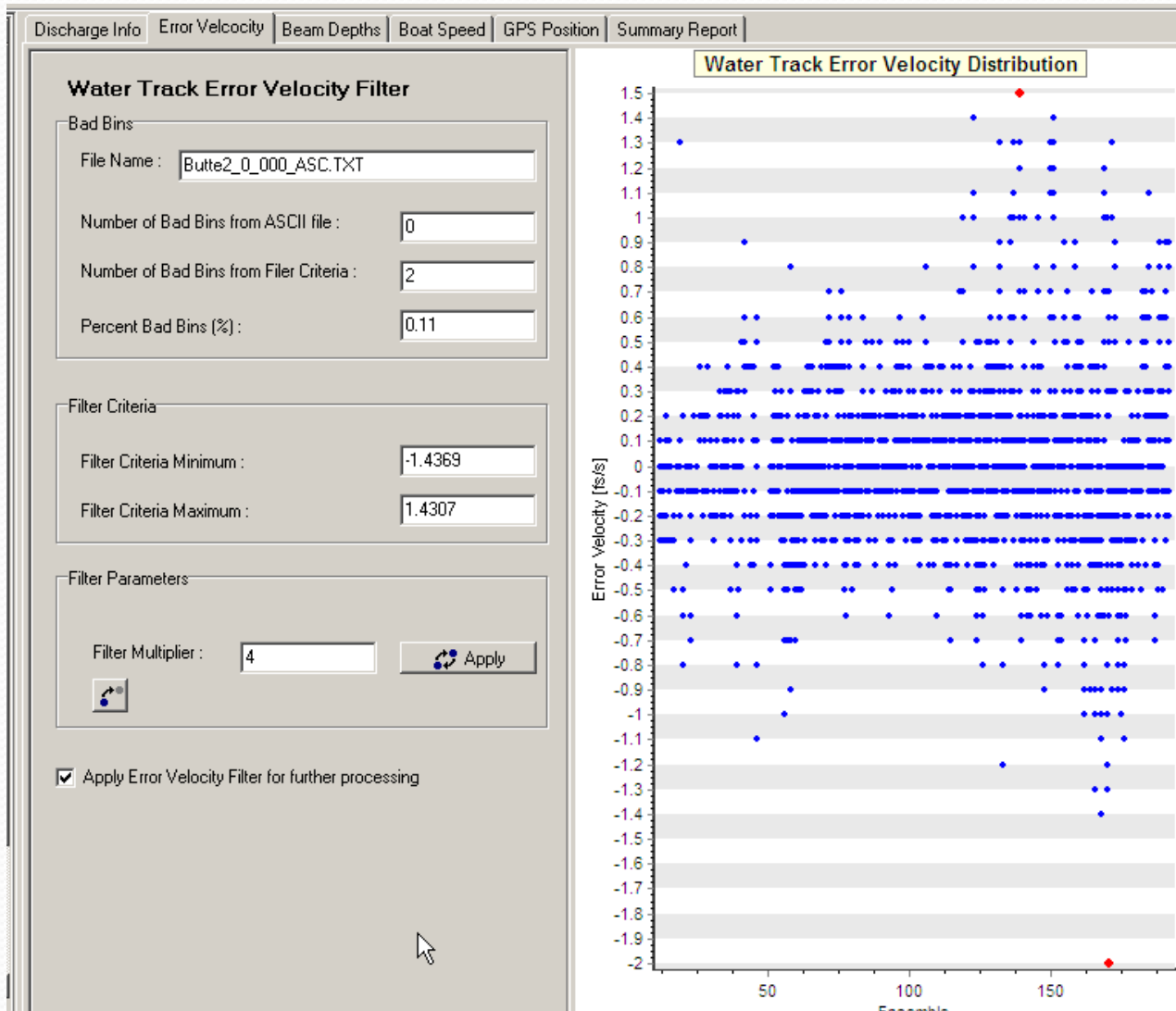
ADCP Calibration Post-processing for Hydraulic Models

VMS - *ADCP Velocity Mapping Software*

(IIHR, USGS and USACE)

- Data Filtering of outliers
- Spatial Averaging of Velocity

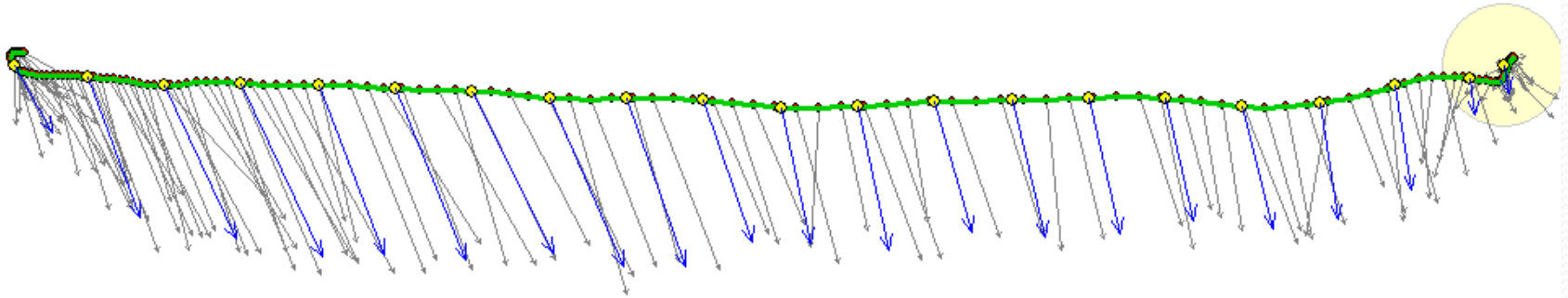
Post-processing with VMS Software



Data Filtering

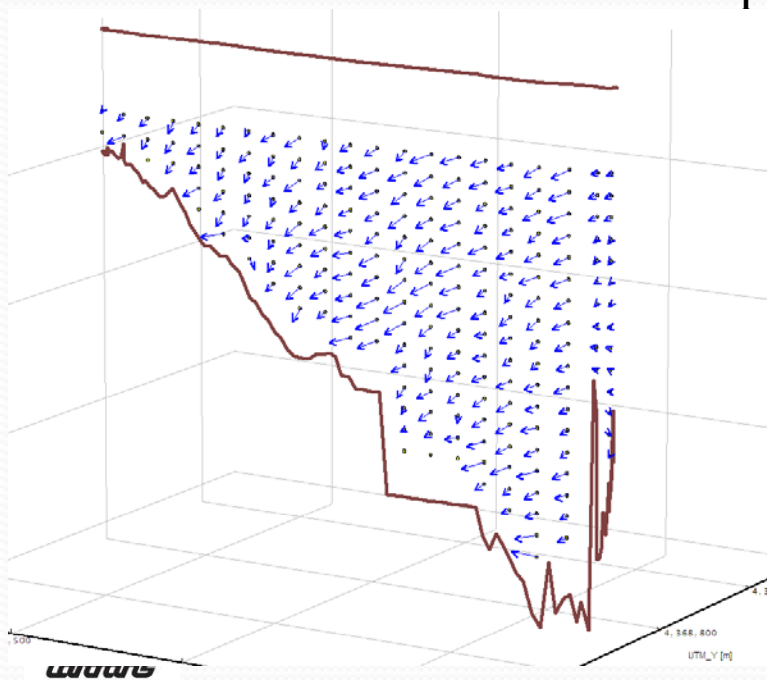
- Discharge
- Error Velocity
- Beam Depths
- Boat Speed

Post-processing with VMS Software



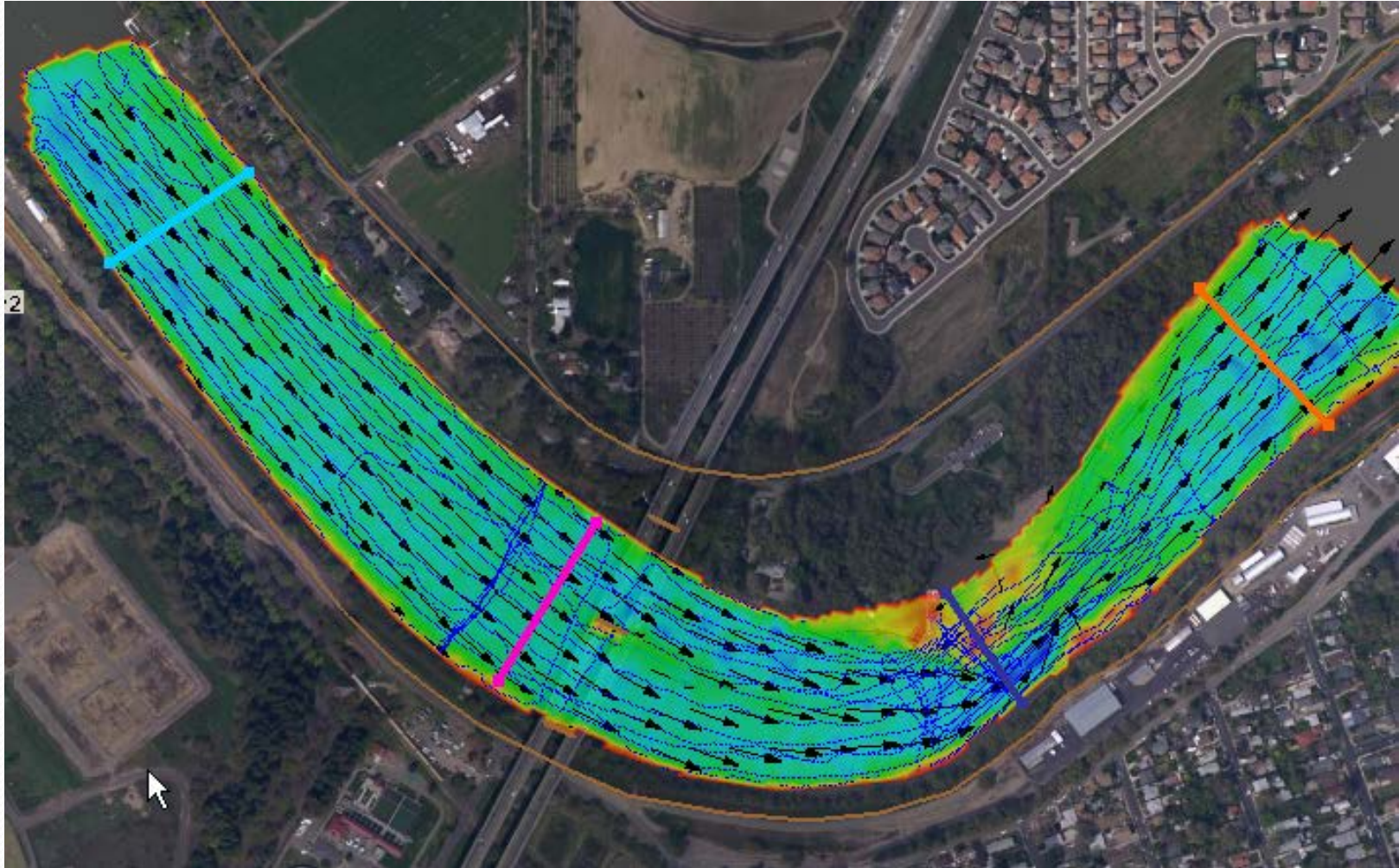
12

Spatial Averaging of Data

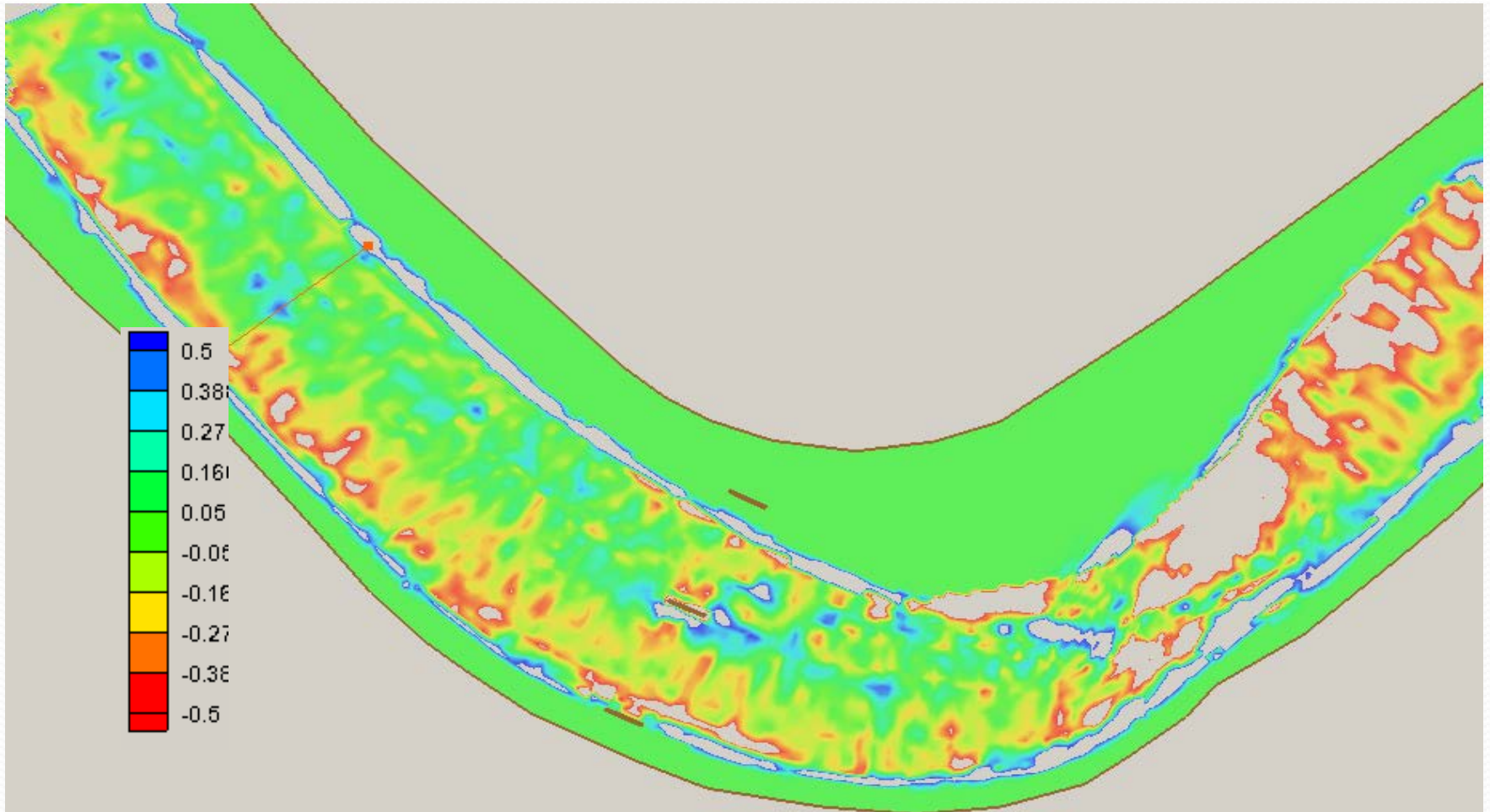


Spatially Averaged ADCP Velocities

(9170 pts)



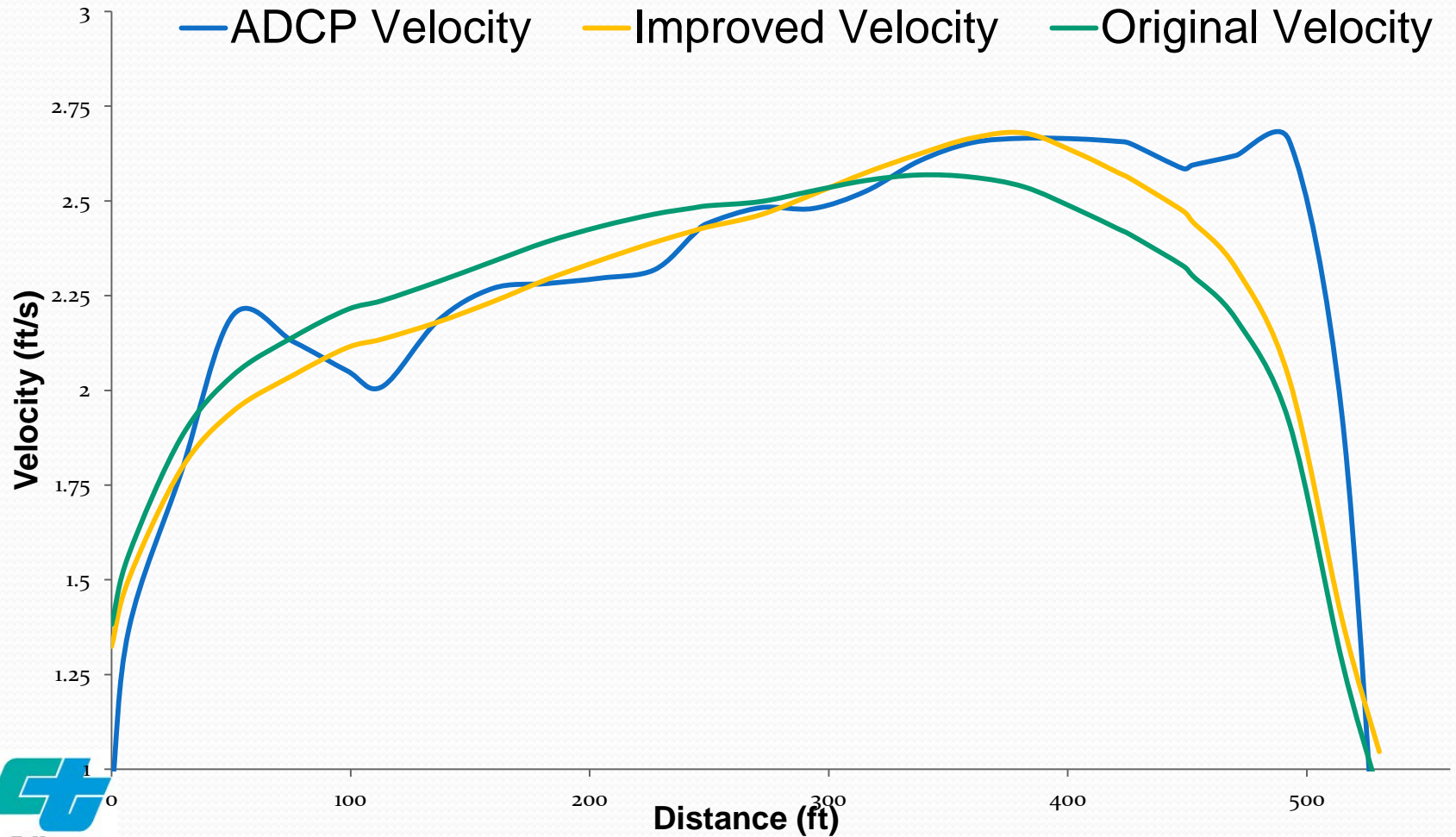
Difference between Measured and Modeled Velocity Magnitude (ft/s)



SMS with Revised Mannings Values



Velocity Comparison after Calibration





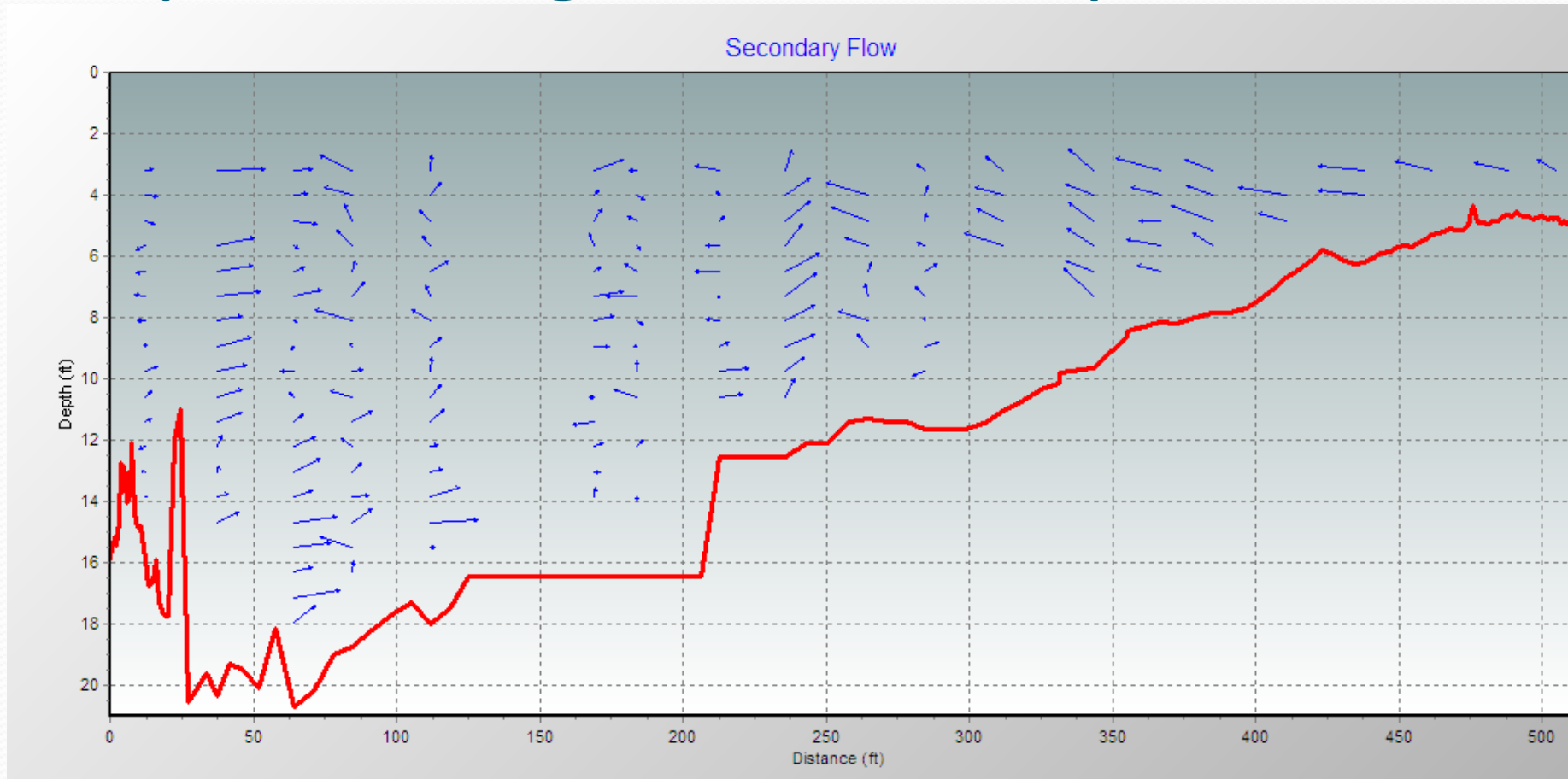
Caltrans Uses of ADCPS

- A** Acquisition of Bathymetric Data
- D** Discharge Measurements
- C** Calibration of Hydraulic Models
- P** Performance Studies

Additional ADCP Post-processing

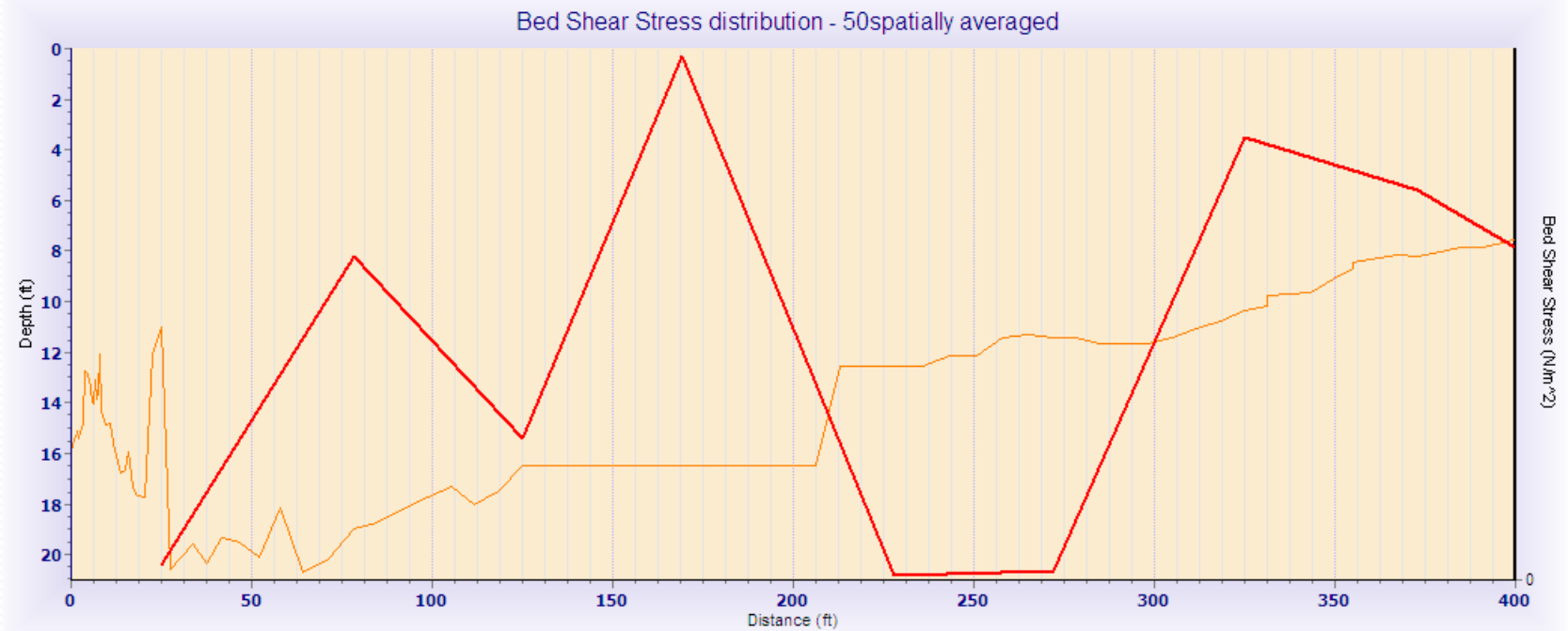
-
- **ADCPxp** - *University of Iowa's IIHR*
 - Transect Analysis
 - Velocity Profile Analysis
 - Turbulence Quantities

Post-processing with ADCPxp Software



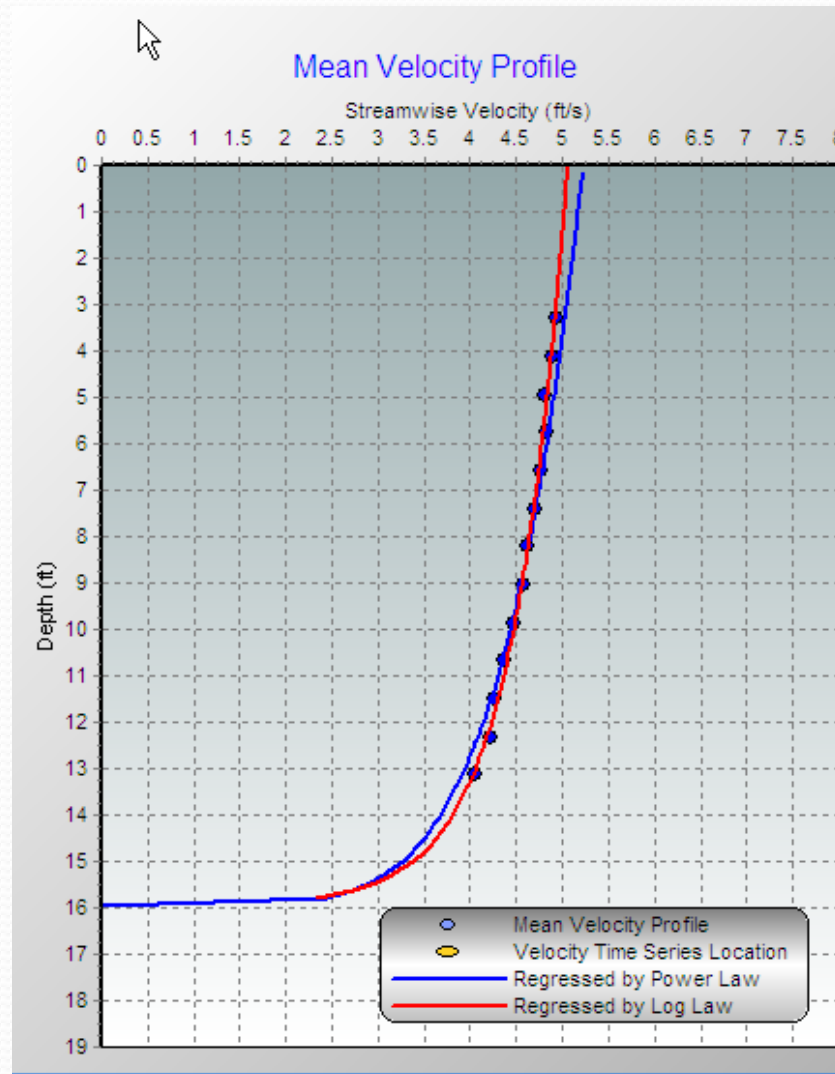
Visualization of Secondary Currents

Post-processing with ADCPxp Software

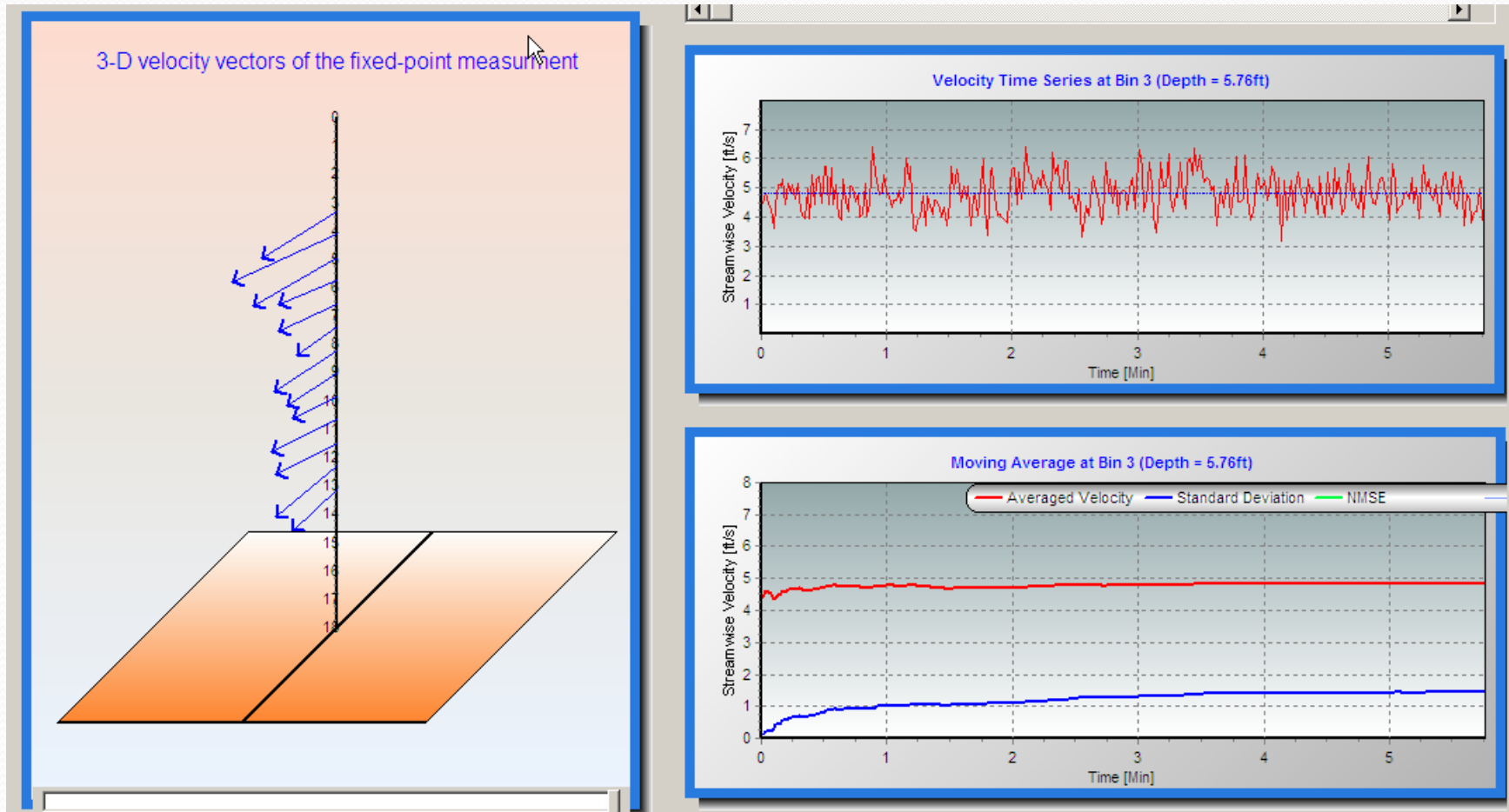


Bed Shear Stress and Shear Velocity Estimates

Post-processing with ADCPxp Software



Post-processing with ADCPxp Software



Future Improvements for the Use of the ADCP

- Best Practice for using ADCP Data for estimating roughness for calibrating 2D Models
- Learn how to process and utilize turbulence information in 3-dimensional CFD models

Future Deployment – R/C Boat

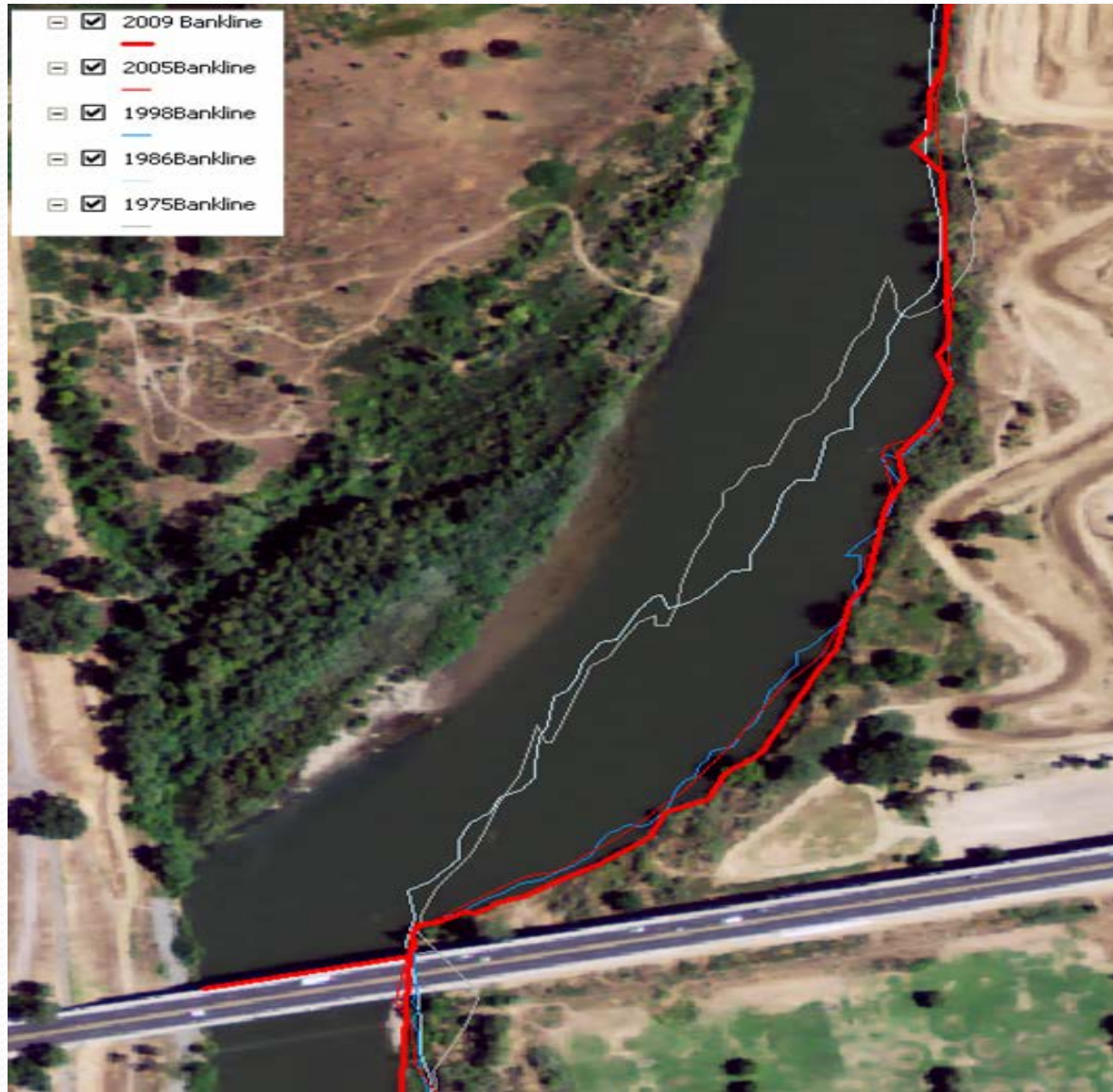


- Smaller
- Safer
- Quickly Deployable
Anywhere

Future Improvements for the Feather River



Feather River - Erosion of the east bank from 1975 to 2009



Feather River - Spur Design Issues



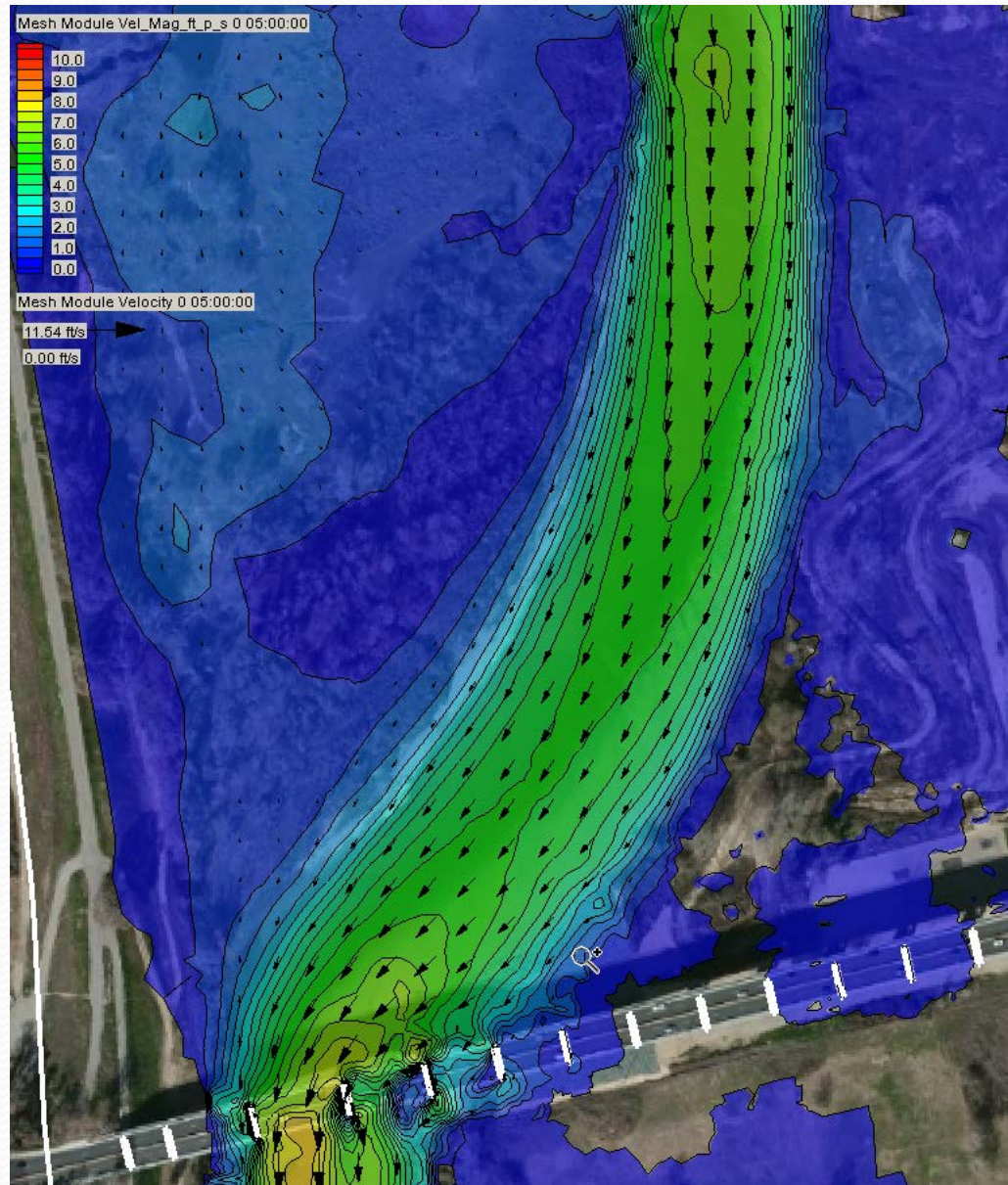
Design Questions

1. How many spurs?
2. How far into the water?
3. Orientation of spurs?
4. Spacing between spurs?

Preliminary 2D Hydraulic Modeling – SRH2D

Existing Condition

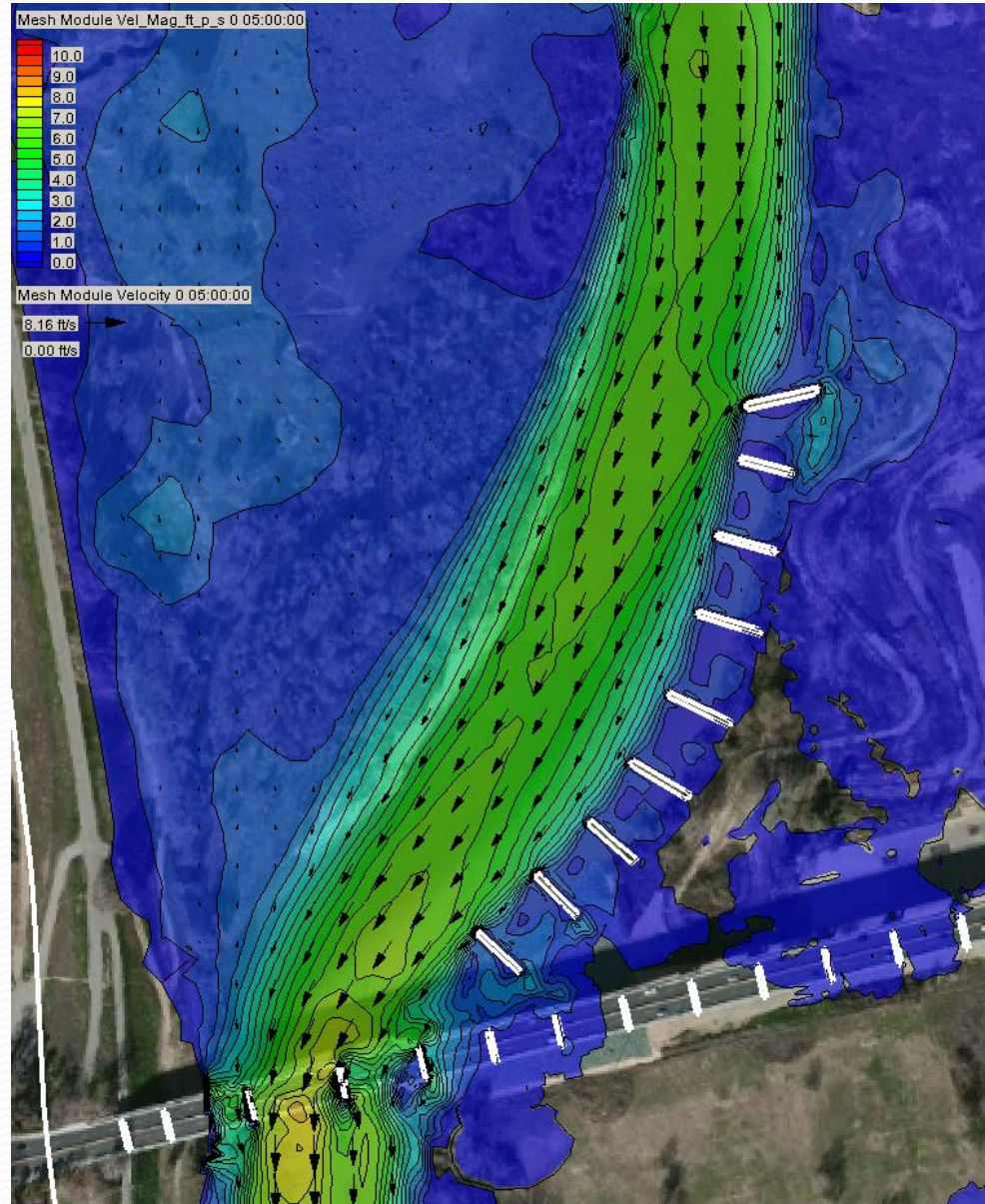
$Q = 44,500$ cfs
(March 2011)



Preliminary 2D Hydraulic Modeling – SRH2D

Case with Spurs

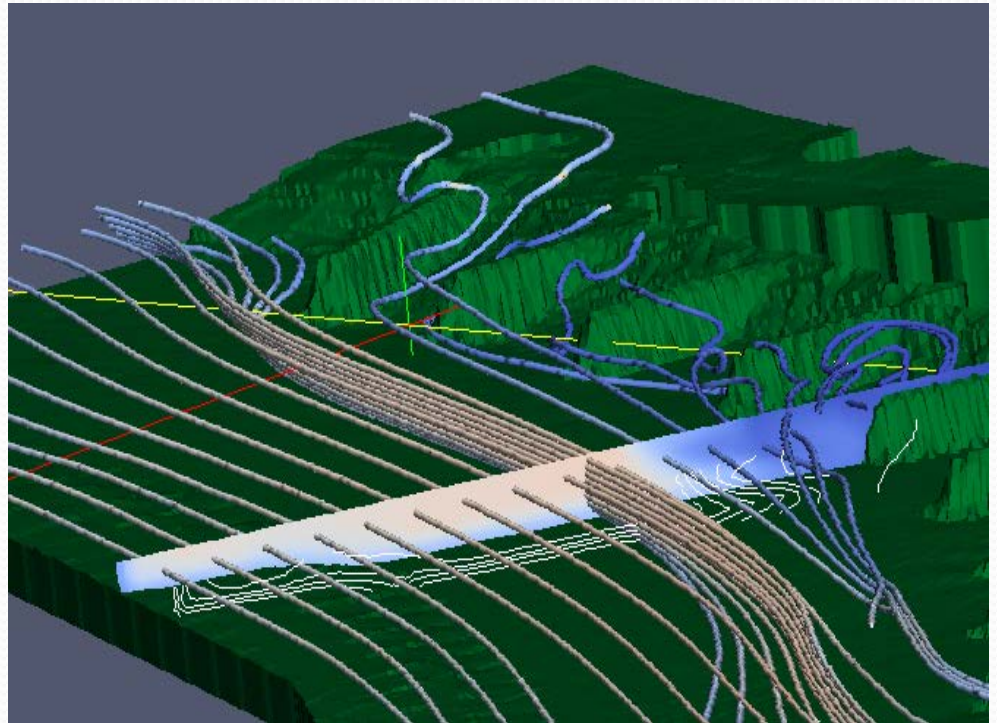
$Q = 44,500$ cfs
(March 2011)



Future Modeling using CFD

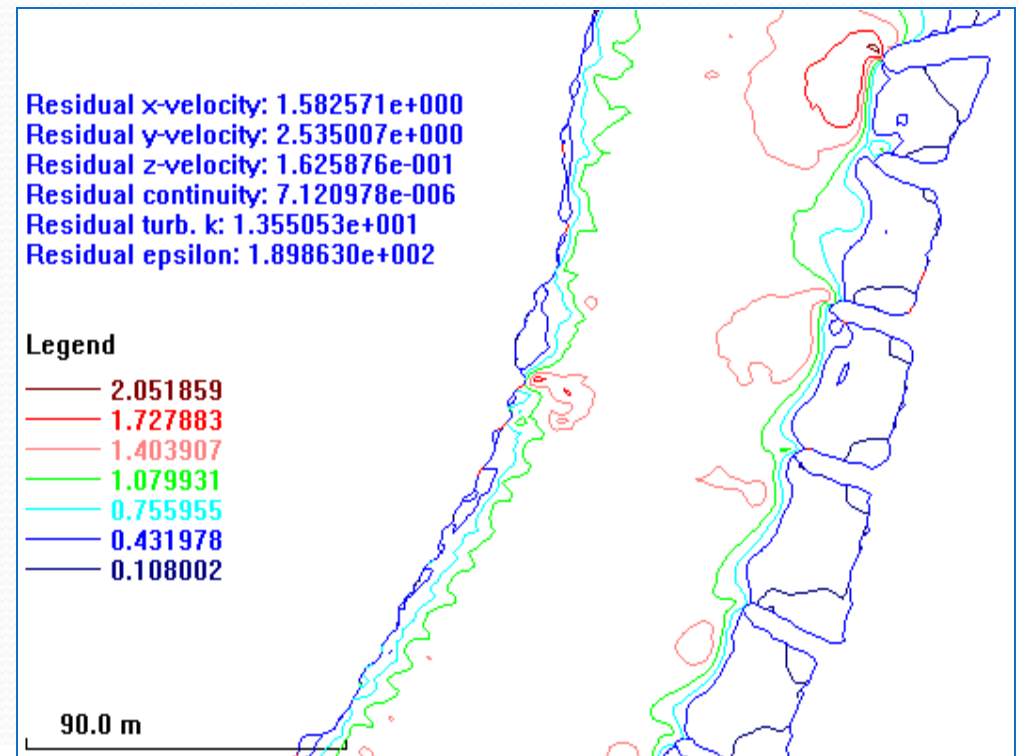
- SSIIM – Sediment Simulation In Intakes with Multiblock
- The Norwegian University of Science and Technology, Norway, Trondheim
- Dr. Nils Reidar Olsen

- CFD for Rivers
- Unstructured Mesh
- 1990's GUI



Strengths of SSIIM

- Free
- Documentation
- Efficient Computational Resources
- Real-time Graphical Monitoring



- Exports to  **ParaView** for Postprocessing
Parallel Visualization Application
- Designed for Riverine Applications

Riverine Capabilities of SSIIM

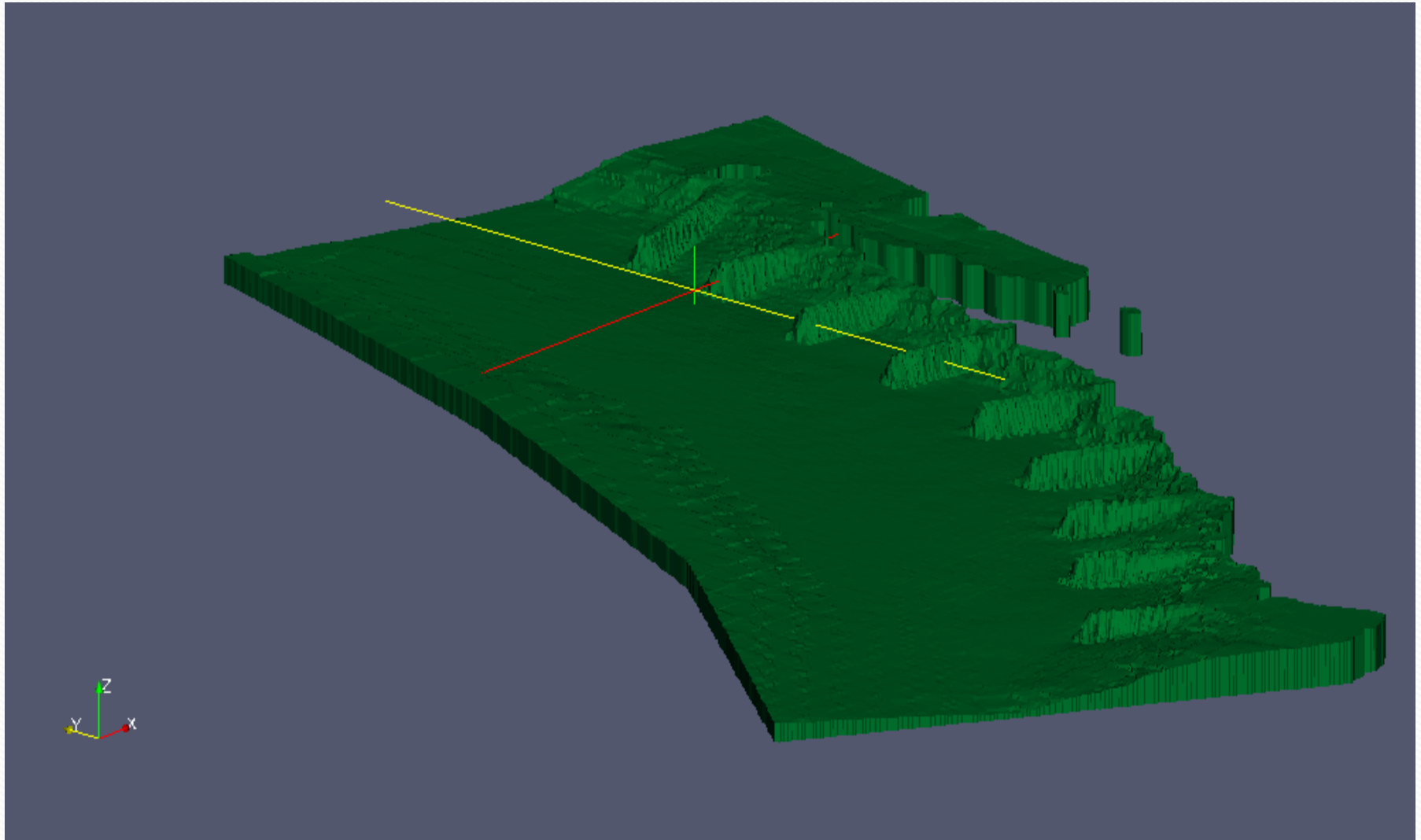
- Wetting and Drying
- Steady and Unsteady Flow
- Sediment Transport
- Vegetation
- Mixed Grain Sizes
- Scour and Deposition

Limitations of SSIIM

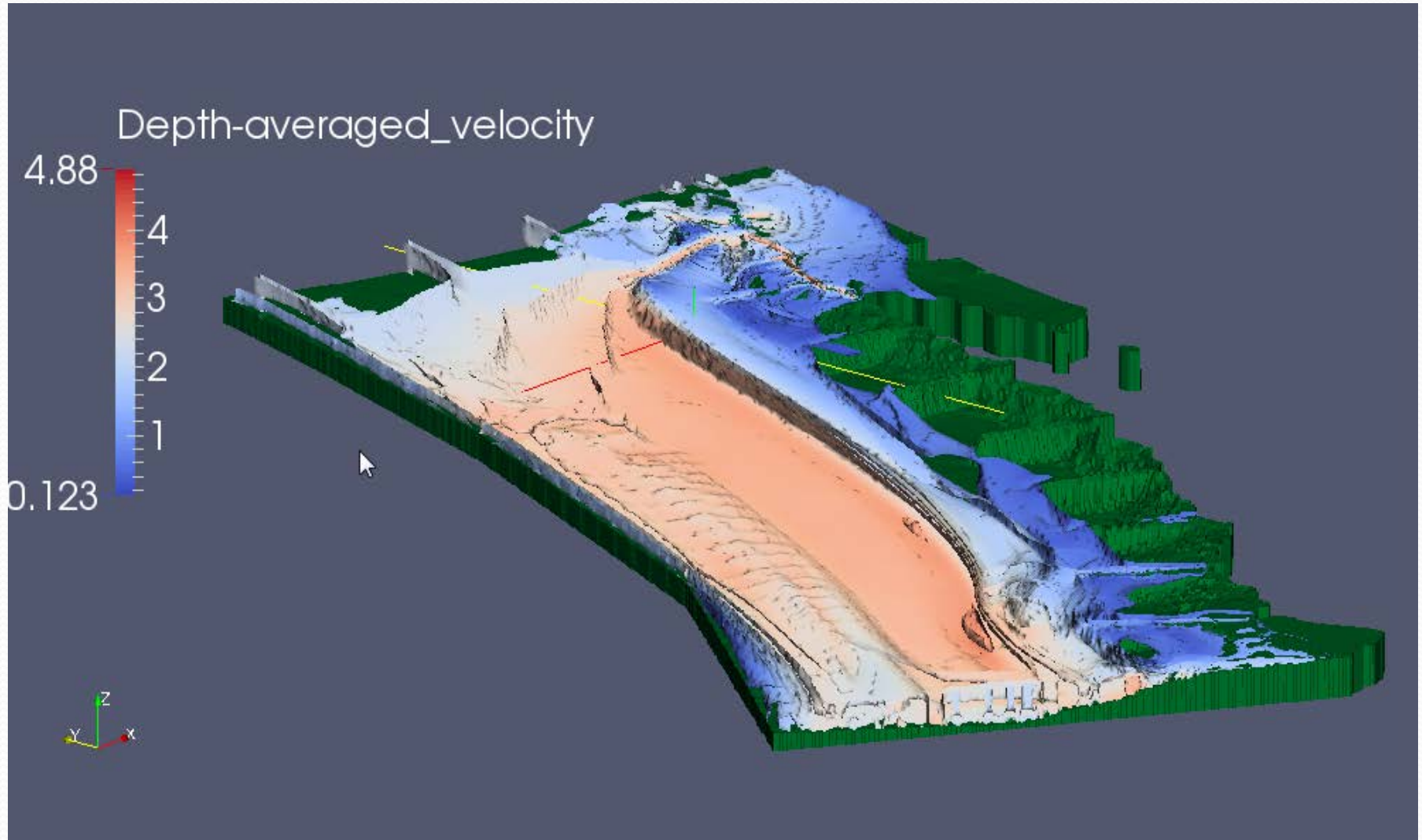


- Academic Code
- Free, but not Open Source
- Limited Support / User Community
- Unable to Mesh Complex Geometries (e.g., complex pier shapes)
- User Interface is dependent on ascii text files

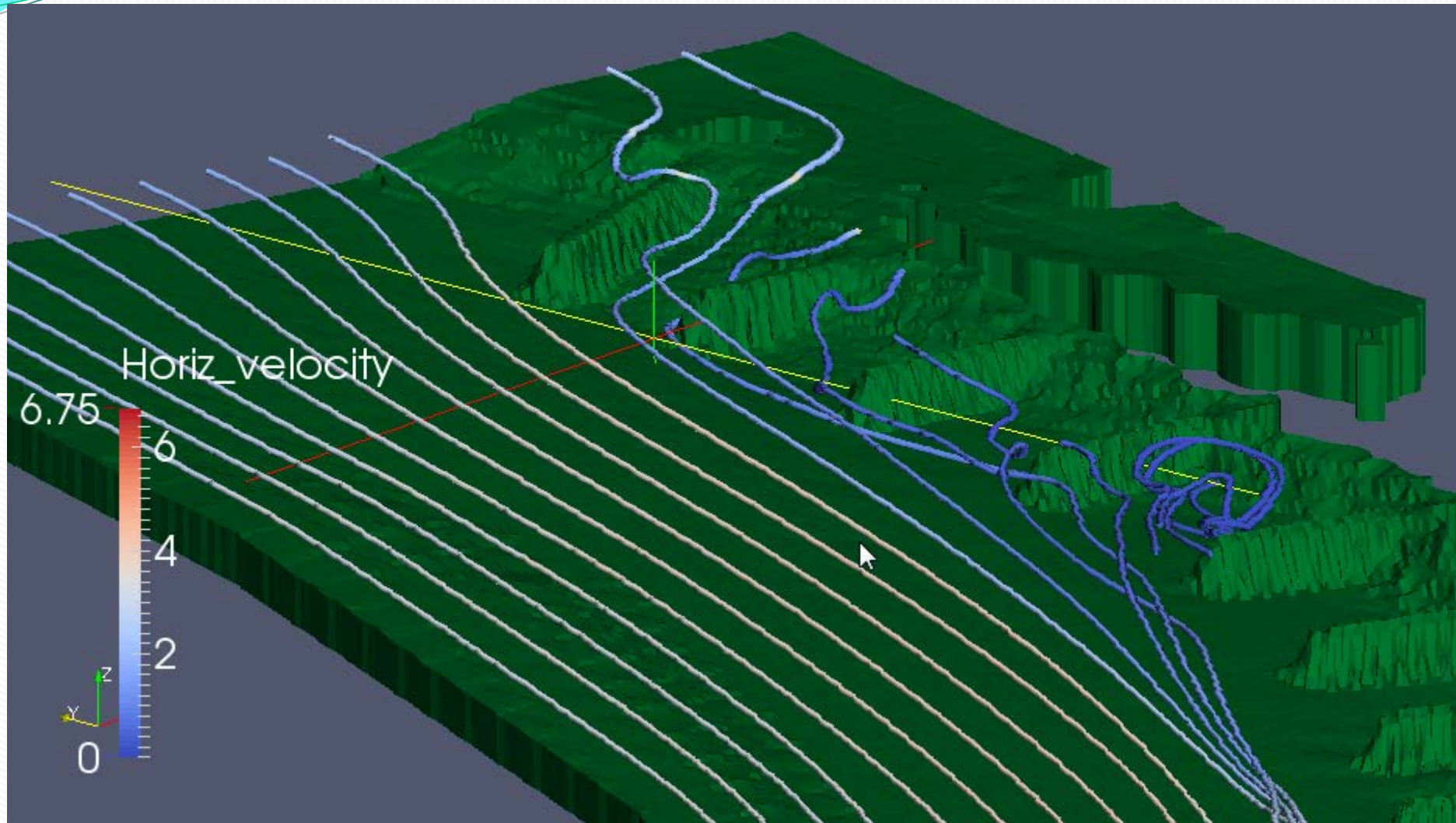
SSIIM Example Results



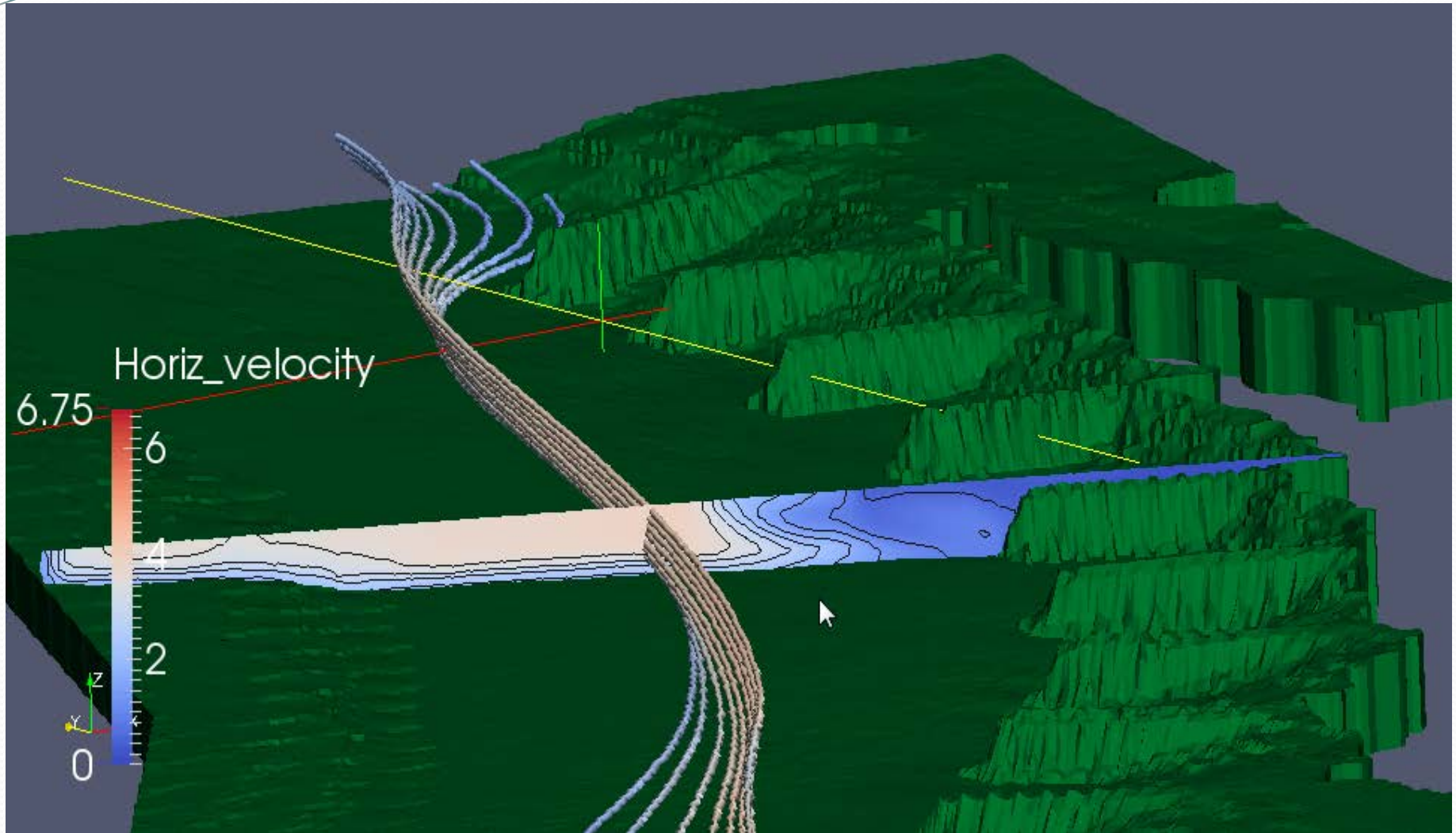
SSIIM Velocity Data



SSIIM 3-Dimensional Flow Paths



Vertical and Transverse Velocities



Key Answers?

- What's up with the Feather River?
A lot – if your not convinced yet, listen to the next set of presentations!
- What other tools are out there that can help me do my work better?
 - ADCP
 - VMS
 - ADCPxp
 - SSIIM – CFD for Rivers



Your Questions?

Kevin Flora

kevin_flora@dot.ca.gov

916-227-8036

