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

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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


Mesh Module Scour 2011 Event

Flow

Pier 21

Pier 22

Pier 23

U.S. Survey Feet

0

60

-6.0

-2.0

2.0

6.0

10.0

14.0

18.0

22.0

26.0

30.0
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

Acoustic

Doppler

Profiler

Current
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

- GPS Antenna
- GPS Unit
- Field Laptop
- ADCP Transducer
- ADCP Battery
- Echo Sounder & Sonar Battery
- Sonar Transducer
Caltrans Uses of ADCPs

Acquisition of Bathymetric Data
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

Post-Processed GPS File

 Filters out data with poor GPS accuracy and errors

Variables & Parameters

Adjusts WSEL based on a moving average of High Accuracy GPS Points

Outputs Modified Sonar File
Sonar/GPS Filter Macro

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**
   - > > [Blank] (ft)

6. **Enter the GPS horizontal error limit to smooth WSEL**
   - > > [Blank] (ft)

7. **Enter max horizontal error to keep GPS points**
   - > > [Blank] (ft)

8. **Enter max depth observed**
   - > > [Blank] (ft)

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**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

- **Series Options**
  - WSEL: Pre-procd.
  - WSEL: Pre-proc. Extra
  - WSEL: Post-procd.

- **Axis Zoom Options**
  - Zoom X
  - Zoom X&Y
  - Zoom Y

- **Axis Limits**
  - **X-axis**
    - Start =
    - End =
  - **Y-axis**
    - Min =
    - Max =

- **Rescale Options**
  - Rescale X
  - Rescale Y
  - Auto Rescale X
  - Auto Rescale Y

Graph:

Sonar WSEL vs. Time

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

Time (hh:mm:ss)
PART 2 - ADCP/Sonar Synchronization Flowchart

1. **Modified GPS File**
   - Links ADCP points to GPS and Sonar points based on time
   - Adjusts Data for Instrument Location and changes in Pitch, Roll, and Heading
   - Provides coordinates to ADCP points based on bottom tracking from linked Sonar points
   - Outputs XYZ File with Sonar and ADCP 4-beams

2. **Variables & Parameters**

3. **ADCP Generic Output Files**
Sonar/GPS Filter Macro

1. Select the first ADCP text file
   - Browse

2. Select the last ADCP text file
   - Browse

3. Select the modified Sonar file
   - Browse

4. Select all, all-minus-one, or one output data point
   - Beam 0 (Sonar)
   - Beam 1
   - Beam 2
   - Beam 3
   - 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)

Instructions:
1. Choose the first or single ADCP transect text file that was created by WinRiver in the measurements folder. By default, the lowest sequential filename will be "4beamcorrection_000_ASC.txt". NOTE: Each text file 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 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 as pitching and rolling. Recommended within 0.5 ft.
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
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

- Total discharge: 815.467 ft³/s
- Discharge details:
  - Boat Speed: 4.740 ft/s
  - Boat Course: 253.73°
  - Water Speed: 2.278 ft/s
  - Water Dr. (Depth): 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%)

<table>
<thead>
<tr>
<th>Transect</th>
<th>Start Bank</th>
<th># Ens.</th>
<th>Start Time</th>
<th>Total Q ft³/s</th>
<th>Delta Q %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butte12-4-12-01000</td>
<td>Left</td>
<td>145</td>
<td>10:10:10</td>
<td>26890.865</td>
<td>1.74</td>
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<tr>
<td>Butte12-4-12-01001</td>
<td>Right</td>
<td>153</td>
<td>10:15:57</td>
<td>26194.577</td>
<td>-0.89</td>
</tr>
<tr>
<td>Butte12-4-12-01002</td>
<td>Left</td>
<td>132</td>
<td>10:21:07</td>
<td>25860.402</td>
<td>-2.15</td>
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<tr>
<td>Butte12-4-12-01003</td>
<td>Right</td>
<td>128</td>
<td>10:26:19</td>
<td>26447.183</td>
<td>0.07</td>
</tr>
<tr>
<td>Butte12-4-12-01004</td>
<td>Left</td>
<td>133</td>
<td>10:30:54</td>
<td>25788.939</td>
<td>-2.42</td>
</tr>
<tr>
<td>Butte12-4-12-01005</td>
<td>Right</td>
<td>123</td>
<td>10:35:47</td>
<td>26131.926</td>
<td>-1.13</td>
</tr>
<tr>
<td>Butte12-4-12-01006</td>
<td>Left</td>
<td>238</td>
<td>10:40:24</td>
<td>27041.511</td>
<td>2.31</td>
</tr>
<tr>
<td>Butte12-4-12-01009</td>
<td>Left</td>
<td>172</td>
<td>11:02:18</td>
<td>27082.249</td>
<td>2.47</td>
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<tr>
<td><strong>Average</strong></td>
<td></td>
<td>153</td>
<td></td>
<td>26429.707</td>
<td>0.00</td>
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<tr>
<td><strong>Std Dev.</strong></td>
<td></td>
<td>38</td>
<td></td>
<td>519.854</td>
<td>1.97</td>
</tr>
<tr>
<td>**Std./</td>
<td>Avg.</td>
<td>**</td>
<td></td>
<td>0.25</td>
<td></td>
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</table>
Caltrans

Uses of ADCPs

Acquisition of Bathymetric Data

Discharge Measurements

Calibration of Hydraulic Models
ADCP Calibration Post-processing for Hydraulic Models

VMS - ADCP Velocity Mapping Software

(IHHR, 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

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

- **ADCP Velocity**
- **Improved Velocity**
- **Original Velocity**
Caltrans Uses of ADCPs

- Acquisition of Bathymetric Data
- Discharge Measurements
- Calibration of Hydraulic Models
- 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
Spatial Averaging of Data

Post-processing with ADCPxp Software

Bed Shear Stress and Shear Velocity Estimates
Post-processing with ADCPxp Software

Velocity Profiles
Post-processing with ADCPxp Software

Velocity Fluctuations and Turbulence Quantities
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?
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](https://www.paraview.org) for Postprocessing
- 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 Velocity Data

Depth-averaged_velocity
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?

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