Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh

25th Annual Progress Report
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Chapter 10: Development of Tidal Analysis Routines

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10 Development of Tidal Analysis Routines

10.1 Introduction

The DWR Tidal Analysis package was developed in Java and designed to be linked to VPlotter and RMA Tools (an RMA2 model output postprocessor developed by DWR). The package includes routines to calculate tidal datums and stage/current phasing. When used with RMA tools, the routines can be used to calculate tidal datums and stage/current phasing for every node in the RMA model grid. (NOTE: This tool currently is designed only for use with RMA2.) The result can be plotted as a contour plot (Figure 10.1) or as a profile plot (Figure 10.2) using RMA Plot.

A tidal datum is a vertical reference based on some phase of the tide. The National Oceanic and Atmospheric Administration (NOAA) has defined 11 principal tidal datums. This chapter describes the methodology that was developed to calculate tidal datums in the Sacramento-San Joaquin Delta and in the Suisun Marsh.

DWR-Suisun Marsh Planning will be using tidal datums to:

- Analyze new data collected with the NAVD88 datum to establish accurate vertical control in the Delta and Marsh, and

- Create tidal datum contours of RMA2 model output for model study comparison.

Stage / current phasing is a measure of the difference in phase between stage and flow. DWR Division of Environmental Services Suisun Marsh Planning Section will be using stage / current phasing results along with other parameters to evaluate the potential for tidal trapping and tidal pumping, which are two important mixing processes in the Bay-Delta System.[1,2]

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[1] Tidal trapping is a tidal dispersion mechanism caused by geometric features that change the timing of currents. Channels tend to have more "progressive" wave characteristics where stage and flow are nearly correlated. Shoals, dead end sloughs, and bays generate "standing" waves due to wave reflection. When these geometric features interact, there can be radical mixing.

[2] Tidal pumping is a non-tidal phenomena caused by asymmetries in the tidal currents. For example, in levee breaches, flow enters as a jet and leaves as potential or "sink" flow. In the net, the center of the breach flows in, the edges of the breach flow out.

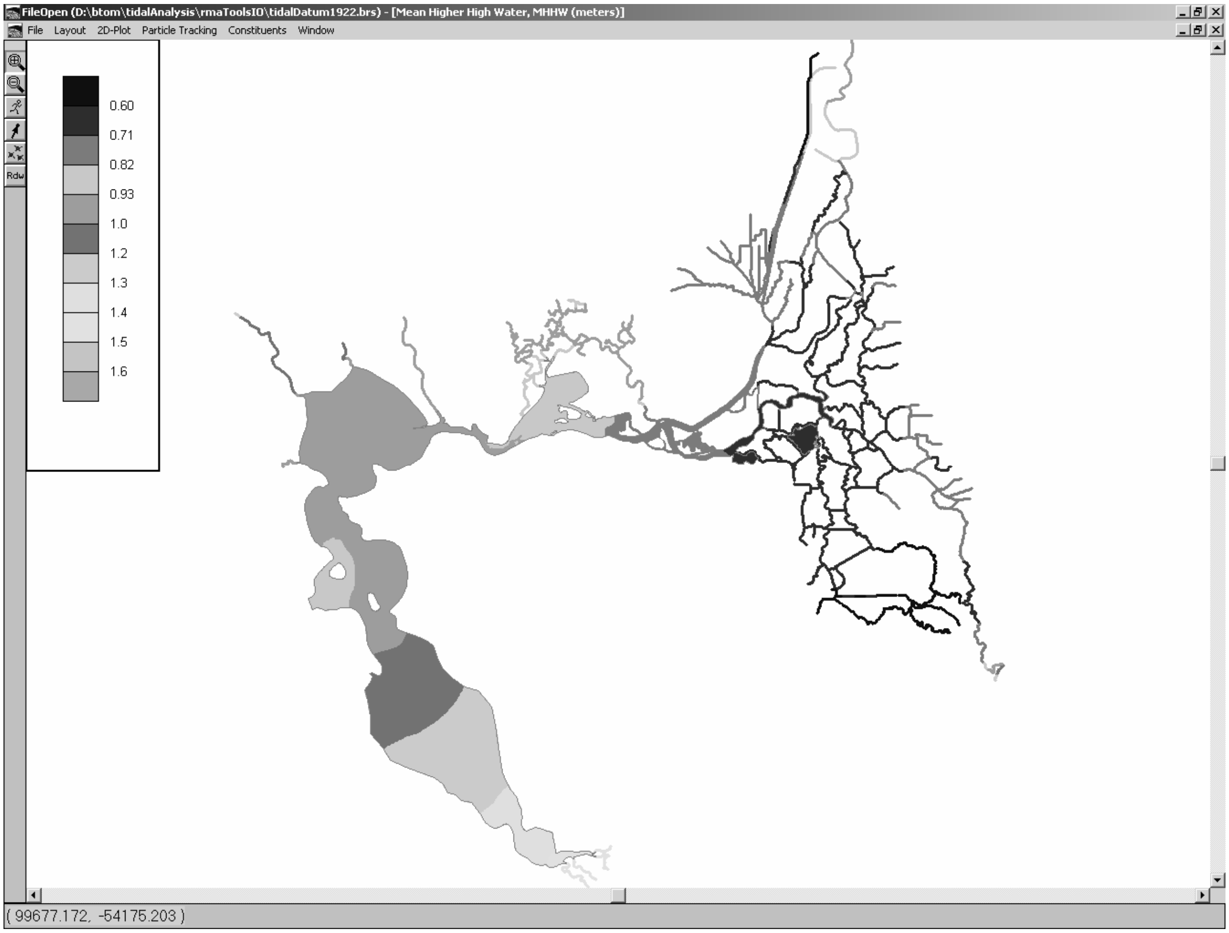

Figure 10.1: Contour Plot of MHHW (Mean Higher High Water) Using RMA2 Output.

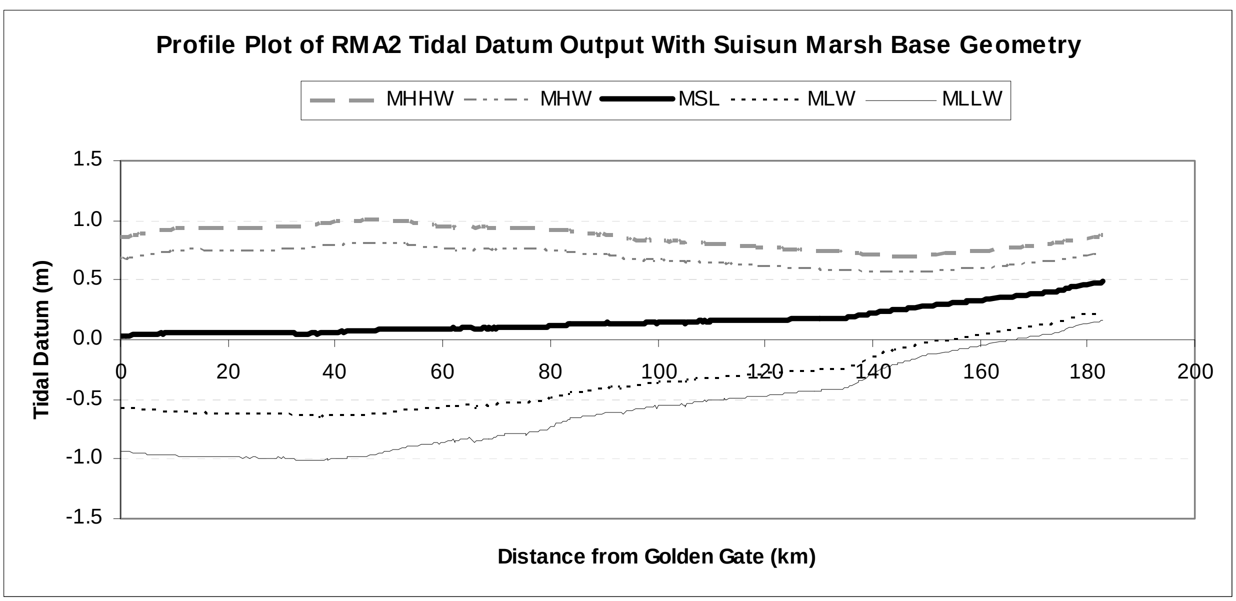

Figure 10.2: Tidal Datum Profile.

10.2 NOAA Computational Techniques

The principal tidal datums defined by NOAA are listed in Table 10.1. All of these tidal datums (with the exception of MSL) are calculated using averages of the high and/or low tide values for tidal day at a given location. A continuous time series of stage data is needed to calculate tidal datums. A tidal datum calculation routine must locate the high highs, low highs, low lows, and high lows. NOAA (2003) uses a computational scheme that involves:

1. Fitting a polynomial curve to a small portion of each peak / valley,
2. Finding the absolute maximum of each peak / absolute minimum of each valley, and
3. Using the peak maximums and valley minimums from Step 2 to calculate the tidal datum.

This method does not use real data values to calculate tidal datums, and is not adequate for calculating tidal datums in tidal estuaries like the Sacramento-San Joaquin Delta and Suisun Marsh.

Table 10.1: Principal Tidal Datums Defined by NOAA.

Tidal Datum	Abbreviation	Computation
Mean Higher High Water	MHHW	Average of all high highs
Mean High Water	MHW	Average of all highs
Mean Sea Level	MSL	Average of all values
Mean Low Water	MLW	Average of all lows
Mean Lower Low Water	MLLW	Average of all low lows
Mean Tide Level	MTL	Average of MHW and MLW
Diurnal Tidal Level	DTL	Average of MHHW and MLLW
Mean Range	Mn	MHW - MLW
Diurnal High Water Inequality	DHQ	MHHW - MHW
Diurnal Low Water Inequality	DLQ	MLW - MLLW
Great Diurnal Range	Gt	MHHW - MLLW

10.3 Sacramento / San Joaquin Delta and Suisun Marsh Data

Water levels in many areas of the Delta and Suisun Marsh are influenced by man-made structures, such as the Delta Cross Channel and the Clifton Court Forebay (CCF) gates. The operation of these structures changes the maximum and/or minimum stage values at nearby locations, which changes tidal datum values.

For example, when the CCF gates are opened at or near high tide, water levels in nearby locations drop suddenly (see Figure 10.3). This can change the shape of the curve in two ways. First, it can create a spike near or at the peak, which would change the shape of any curve fit. Second, it can reduce the maximum stage value. Although these man-made structures are not part of the natural system, they are permanent and will continue to influence tidal datum values in the foreseeable future.

For this reason, when working with observed data, real data is used to compute tidal datums. A high / low tide will be defined as the absolute maximum / minimum value in the vicinity of the peak / valley of the curve fit.

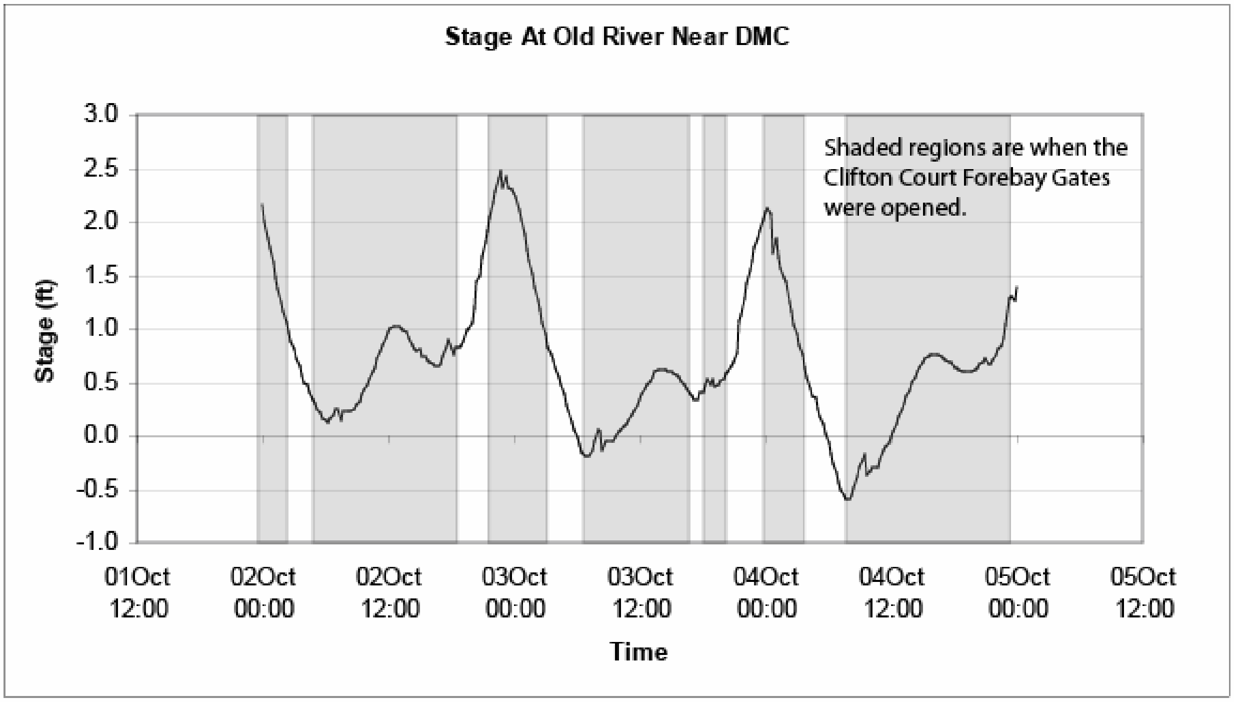

Figure 10.3: Stage at Old River near Delta Mendota Canal (ROLD047) in Oct. 1996.

10.4 DWR Tidal Analysis Package

The DWR Tidal Analysis package is written in Java and was designed to be linked to VPlotter and RMA Tools. The Tidal Analysis package contains a routine to calculate the principal tidal datums defined by NOAA, and a separate routine to calculate stage / current phasing.

10.4.1 Tidal Datum Routine

The tidal datum routine requires the following input:

- Continuous, regular time series stage data.
- *Backward and forward moving average length*. For stage data in the Delta and Suisun Marsh, three hours was found to be the best value.
- *Data search length.* This parameter is defined below. For stage data in the Delta and Suisun Marsh, three hours was found to be the best value.

The Tidal Analysis package uses the following algorithm (Figure 10.4) to calculate tidal datum:

1. Fit a curve to the stage data, using a six-hour centered moving average repeated 3 times. This new fitted curve will be used to identify the high and low tides. An example of a moving average based curve fitted to Old River near the Delta Mendota Canal (DMC) intakes is shown in Figure 10.5.

2. Create an irregular time series consisting of the local maximum values of the curve fit created in Step 1. Create another irregular time series for all the local minimum values.

3. Use the local maximum and minimum values of the curve fit to find the high and low tides in the stage data. For each local maximum value found in Step 2, find the absolute maximum stage value that is within the range specified by the *data search length* parameter. This is a high tide. For each local minimum value found in Step 2, find the absolute minimum stage value that is within the range specified by the data search length. This is a low tide. A three-hour data search length was used for all Delta and Suisun Marsh locations. Figure 10.6 shows the high and low tides calculated by using the curve fit local maximums and minimums.

4. Divide the high tides into higher high (HH) and lower high (LH) tides and the low tides into lower low (LL) and higher low (HL) tides. Go through the high tides two values at a time. The higher high (HH) tide is the larger of the two values, and lower high (LH) tide is the smaller or the two values. Repeat the procedure for the low tides; the lower low (LL) tide is the smaller of the two values, and the higher low (HL) tide is the smaller of the two values.

5. Calculate the rest of the NOAA tidal datum parameters using the computational scheme shown in Table 10.1.

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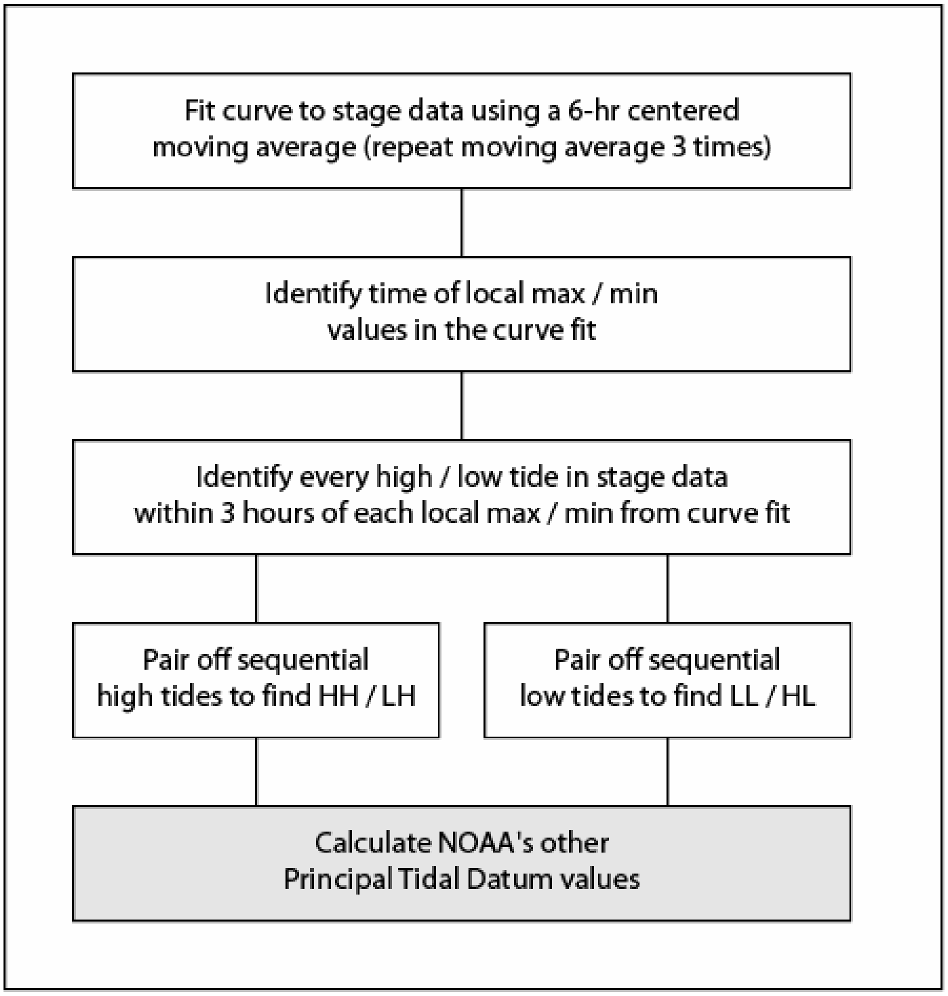

Figure 10.4: Tidal Datum Algorithm.

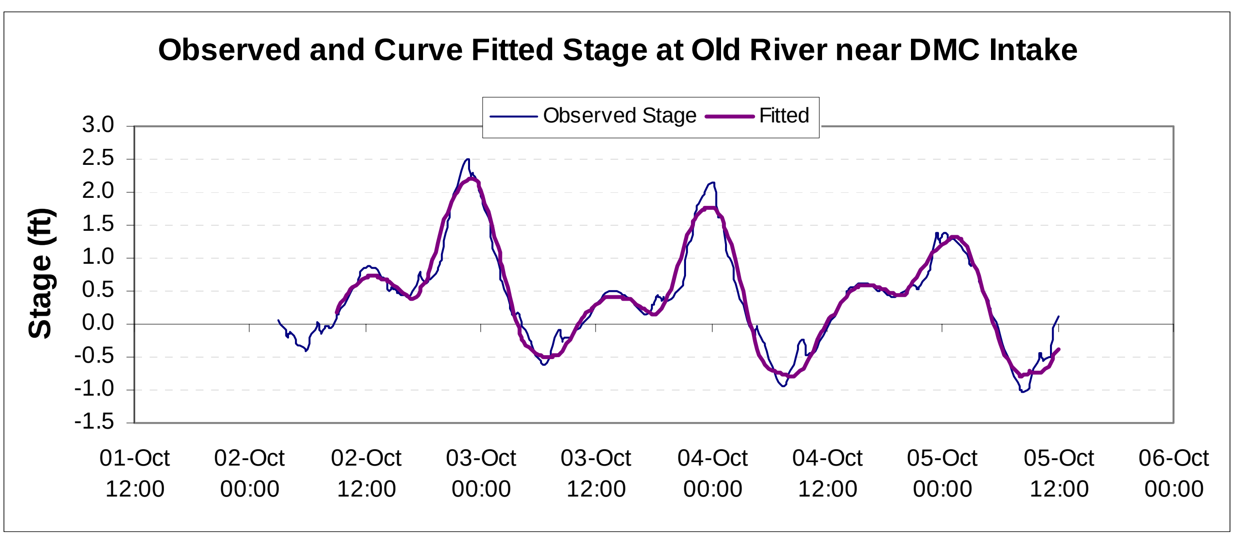

Figure 10.5: Curve Fitted to Observed Stage Data from Old River near the Delta Mendota Canal (DMC) Intake for Oct. 1996.

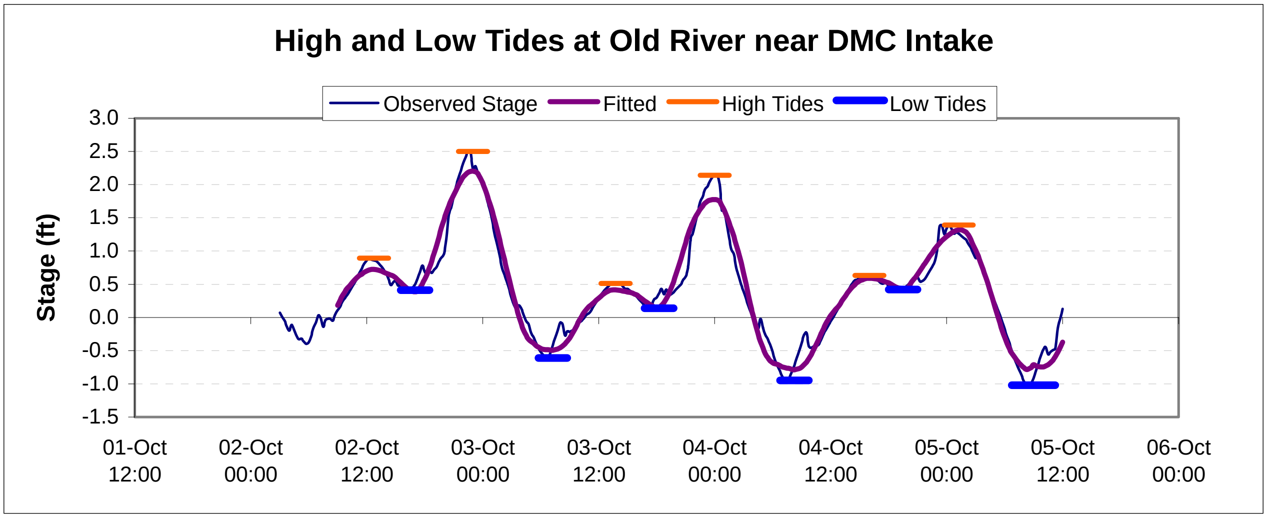

Figure 10.6: High and Low Tides Based on Curve Fitted Stage Data at Old River near the Delta Mendota Canal (DMC) Intake for Oct. 1996.

10.4.2 Stage / Current Phasing Routine

The Stage/Current Phasing routine requires the following input:

- Continuous, regular time series of stage data.
- Continuous, regular time series of flow data or velocity magnitude. The RMA2 model calculates x and y velocities instead of flow. The velocity magnitude is the square root of the sum of the squares of the x and y velocities.
- *Backward and forward moving average length*. For stage data in the Delta and Suisun Marsh, three hours was used.
- *Data search length*. This parameter is defined above (see Section 10.4.1). For stage data in the Delta and Suisun Marsh, three hours was used.

The algorithm used by the Tidal Analysis package to calculate NOAA's tidal datum parameters (see Section 10.4.1) was modified to also calculate the peak velocity magnitudes and then compare the timing of the velocity peaks with the high and low tides.

1. Fit a curve to the stage data, using a six-hour centered moving average repeated three times. This new fitted curve (Figure 10.5) will be used to identify the high and low tides.
2. Create an irregular time series consisting of the local maximum values of the curve fit created in Step 1. Create another irregular time series for all the local minimum values.
3. Use the local maximum and minimum values of the curve fit to find the high and low tides in the stage data. For each local maximum value found in Step 2, find the absolute

maximum stage value that is within the range specified by the *data search length* parameter. This is a high tide. For each local minimum value found in Step 2, find the absolute minimum stage value that is within the range specified by the data search length. This is a low tide. A three-hour data search length was used for all Delta and Suisun Marsh locations. Figure 10.6 shows the high and low tides calculated by using the curve fit local maximums and minimums.

4. Create an irregular time series consisting of all the local maximum velocity magnitudes. Since the velocity magnitude is based on the square root of the sum of the squares of the x and y (north-south and east-west) velocity components, it will always be a positive value.

5. Each velocity magnitude peak should have a corresponding stage peak (local max or min). Find the closest (in time) stage peak to each velocity peak, and calculate the time difference between the two. Average the values for the entire time series.

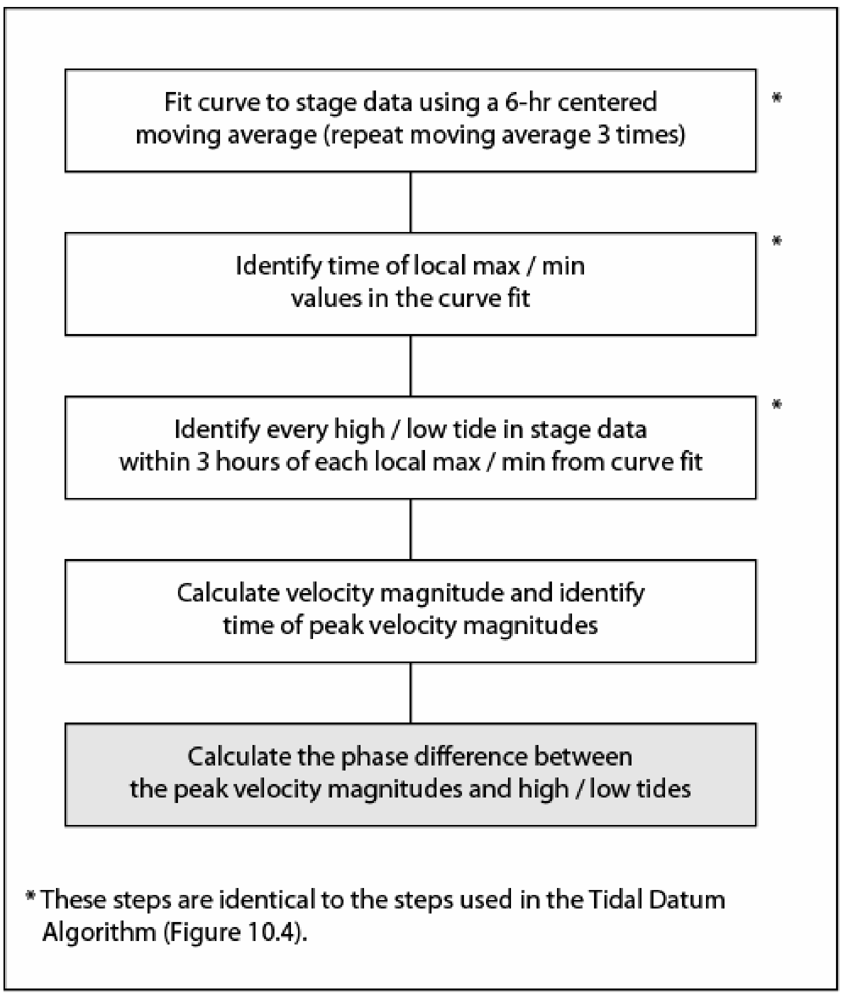

Figure 10.7: Stage / Current Phasing Algorithm.

10.5 Tidal Transitions

Tidal transitions can be difficult to analyze. Figure 10.8 is a plot of stage data and tidal analysis results on Old River near Delta Mendota Canal. The resulting high tide time series has an extra high tide in it, which could affect results.

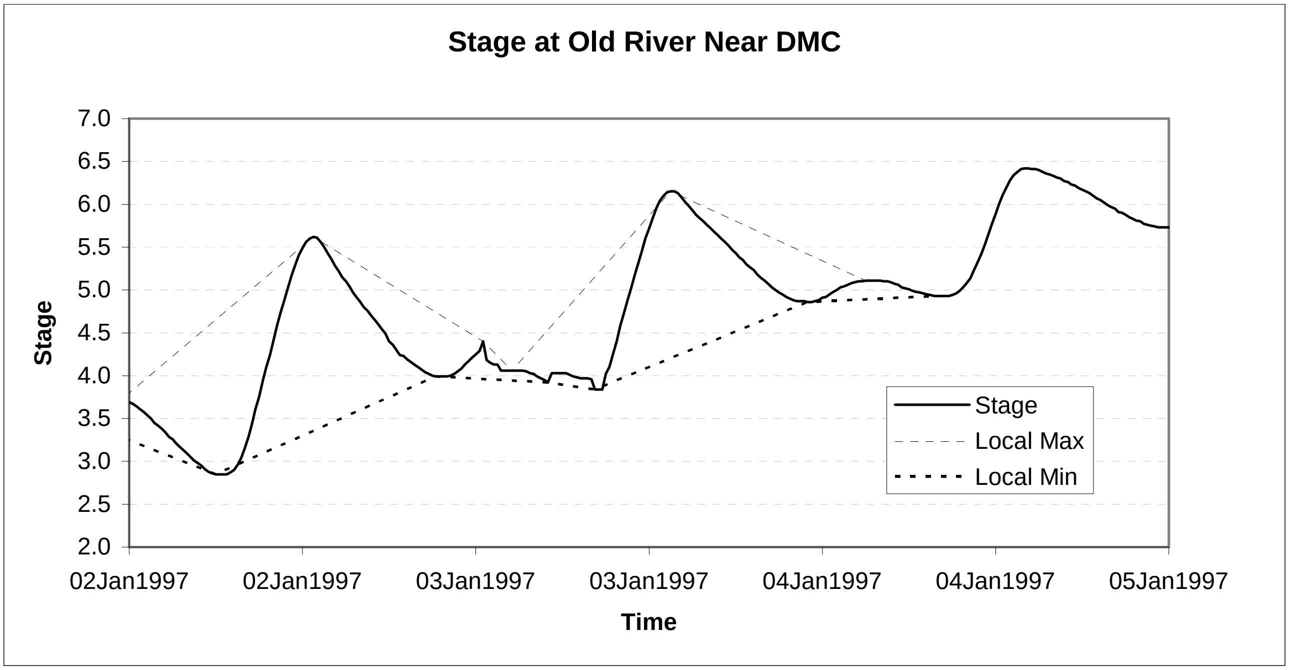

Figure 10.8: Example of Extra High and Low Tides Found in Stage Data During a Tidal Transition.

10.6 Future Directions

The Tidal Analysis package has not been thoroughly tested at the time of this writing. Tests planned for the summer of 2004 will use both observed data and RMA2 model output and include sensitivity analyses of the data search length parameter and a closer examination of how tidal transitions are being handled and their impact upon results.

10.7 Reference

National Oceanic and Atmospheric Administration. (2003). *Computational Techniques for Tidal Datums Handbook.*