Principal Investigator and Management Team
Responses to the North Delta Salmon Outmigration Study (NDSOS) Review

Figures

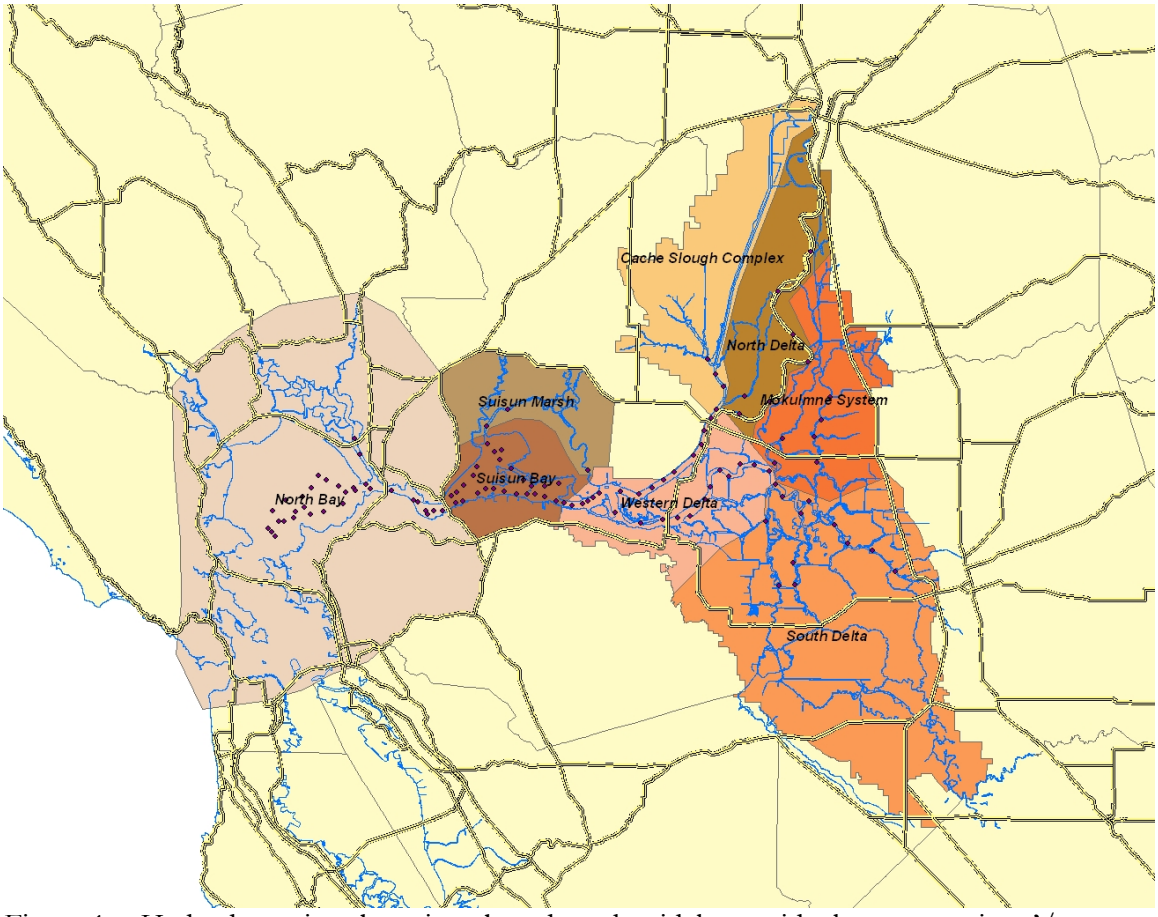

Figure 1 - Hydrodynamic sub-regions based on the tidal to residual current ratio, u'/<u> shown in figure 2.

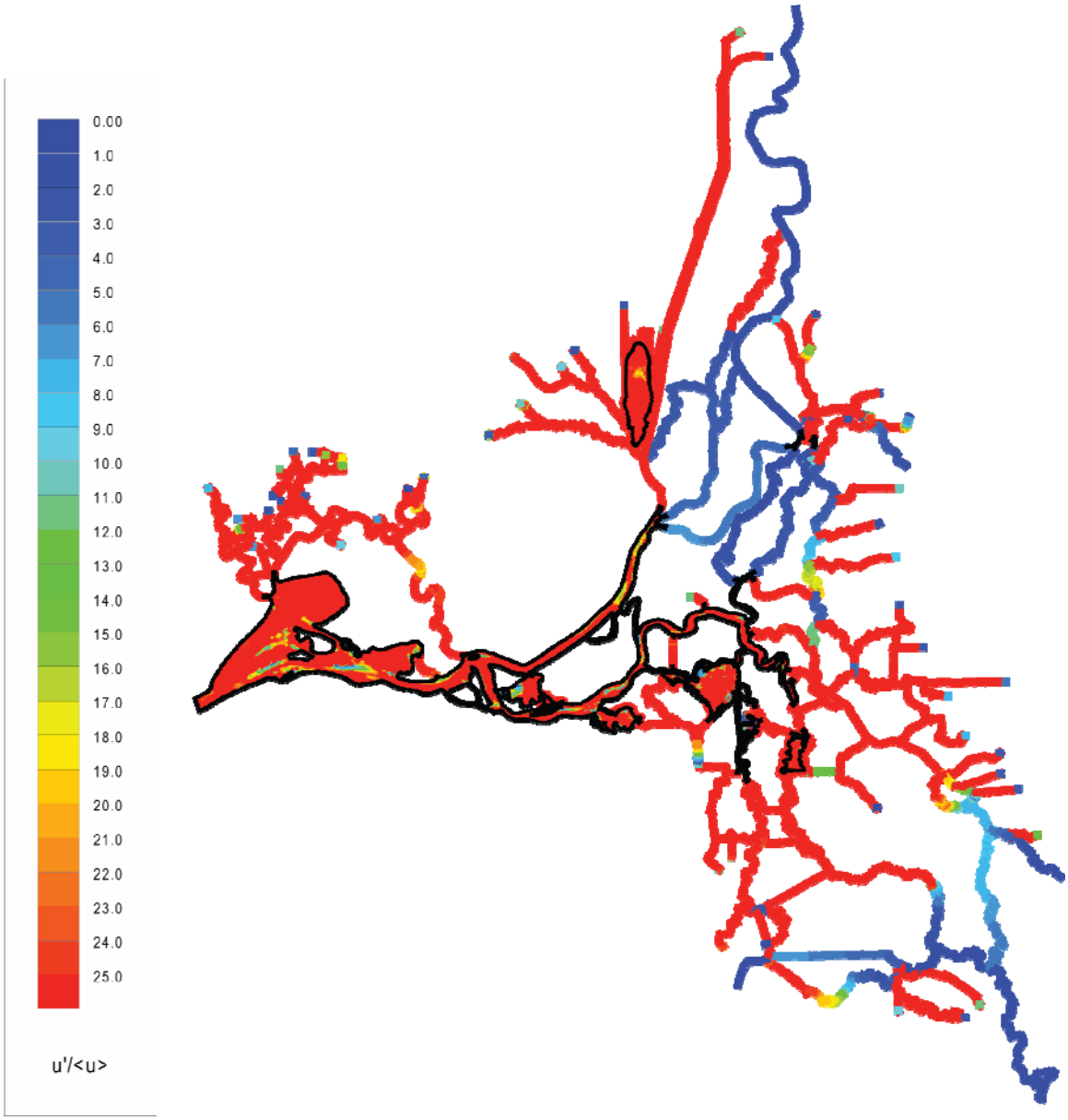

Figure 2 – Color plot of the tidal current amplitude, u', to residual current, <u>, ratio u'/<u>. Cooler colors are indicative of regions that are dominated by the net currents, whereas the warmer colors indicate regions dominated by the tidal currents. Modeling and graphics courtesy of RMA, calculation of u'/<u> ratio courtesy of Brad Tom and Chris Enright, DWR.

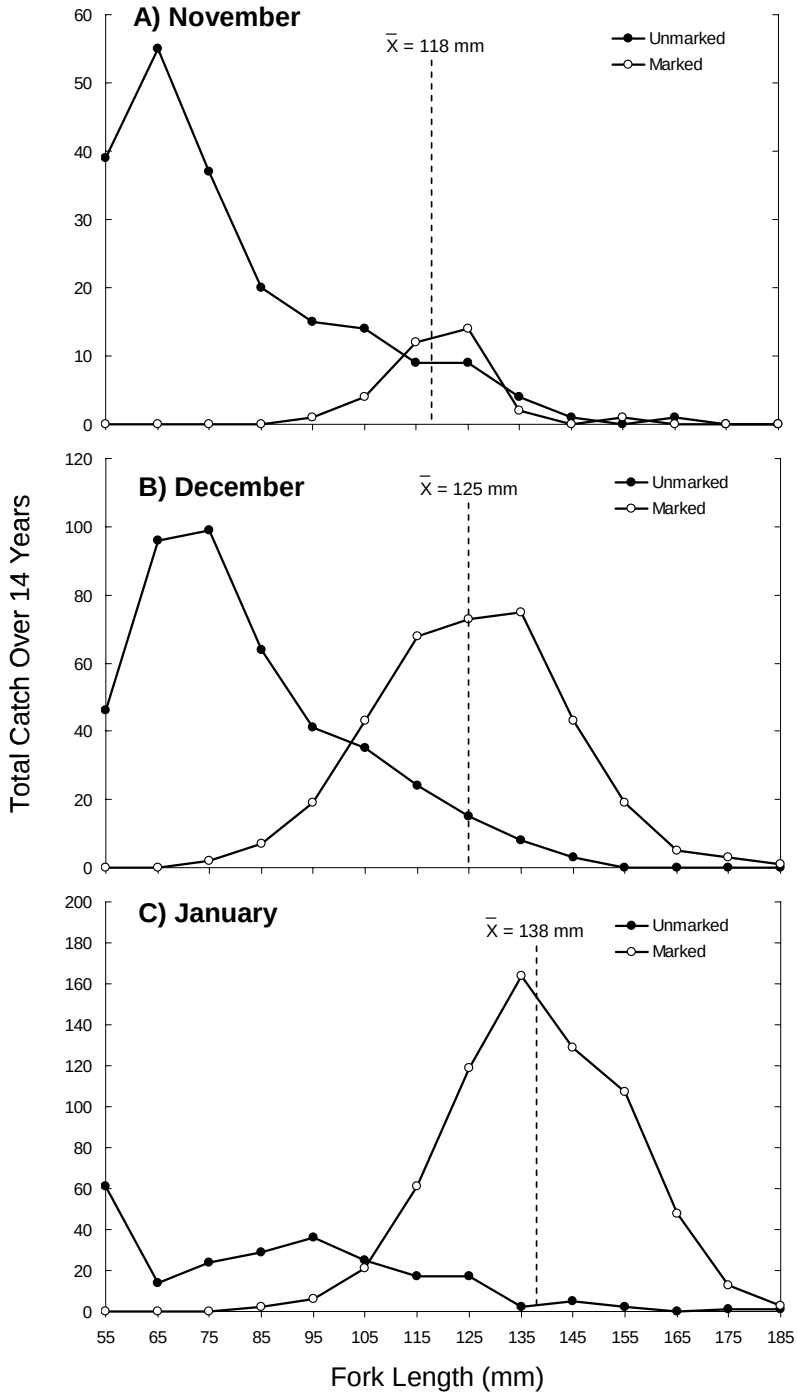

Figure 3 - Size frequency distributions for unmarked (solid marker) and marked (open marker) juvenile Chinook salmon captured in the Kodiak trawl at Sherwood Harbor (Sacramento River) during (A) November, (B) December and (C) January, for all trawls conducted between 1994 and 2008, inclusive. Broken vertical lines show mean sizes of marked fish. Data provided by Pat Brandes, USFWS.

Figure 4 – Proposed transecting locations for the unmanned survey vessels (USV's) fitted with downward-looking ADCP's. Two vessels will be used to continuously measure the internal velocity structure along the Walnut Grove bend, one USV will be primarily operating in the DCC area, the other in Georgiana Slough. Transects will always be conducted up-current of the bend, so flood (green) and ebb tide (yellow) transects will differ. Under conditions without reversing flows (e.g. Sacramento River flows that exceed > 20,000 cfs), only the ebb tide (yellow) transects will be measured. The proposed positions of upward-looking UL-ADCP's are shown as red circles. Research vessels will be positioned on the outside of the bend to provide optimal viewing of the USV operations.

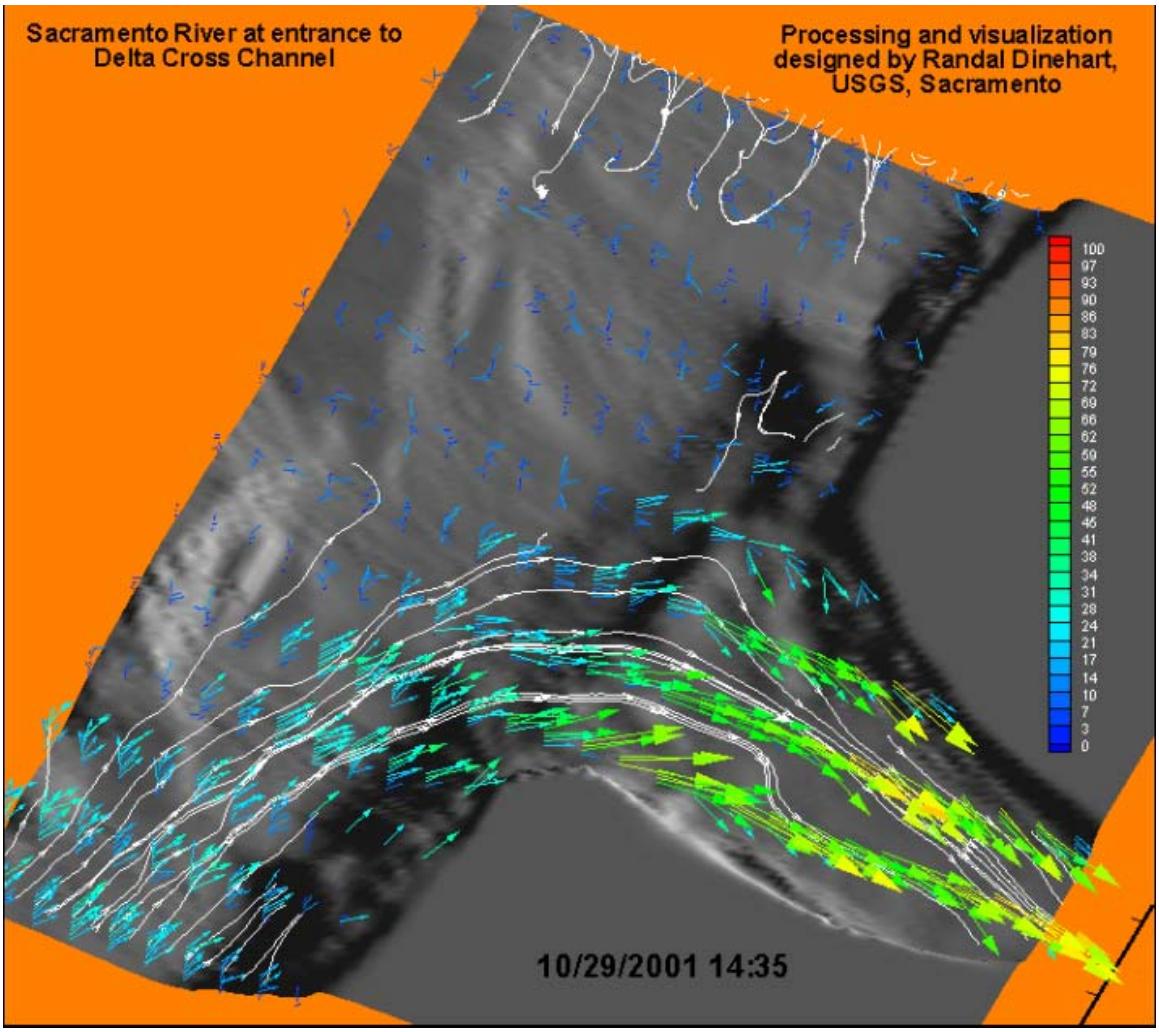

Figure 5 – Interpolated flow field from ADCP transects after the method described in Dinehart and Burau, 2005. The velocity distribution on a flood tide is shown.

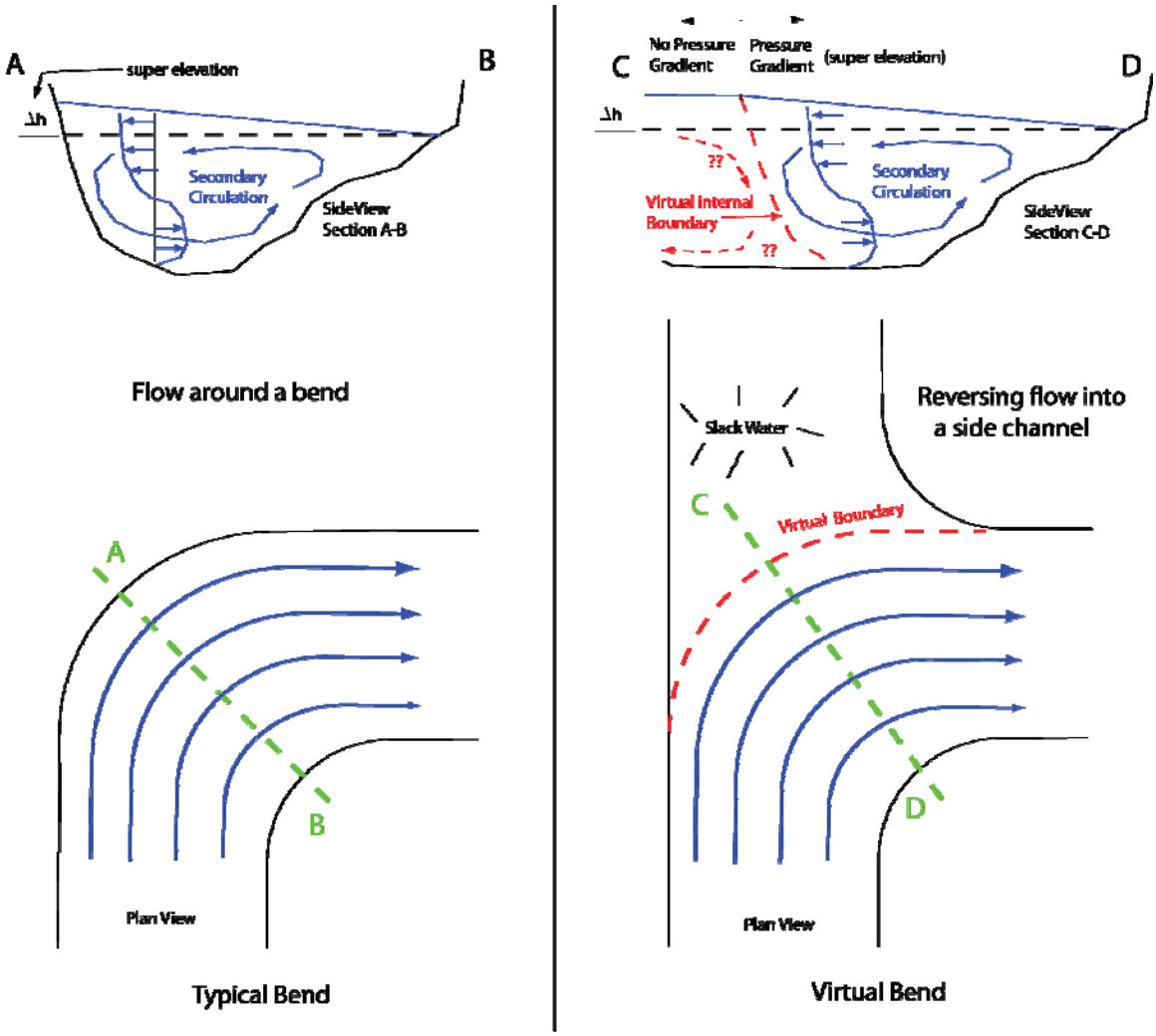

Figure 6 – Schematic comparing the flows paths in a typical river bend (left) and what we speculate occurs in a virtual bend (right). In order to maintain a lateral momentum balance, super-elevation and secondary circulation occur in both the "typical" and "virtual" bends (see for example figure 7), however, the water surface profile along section C-D and the response upstream of the virtual internal boundary has not, to our knowledge, been measured in the field.

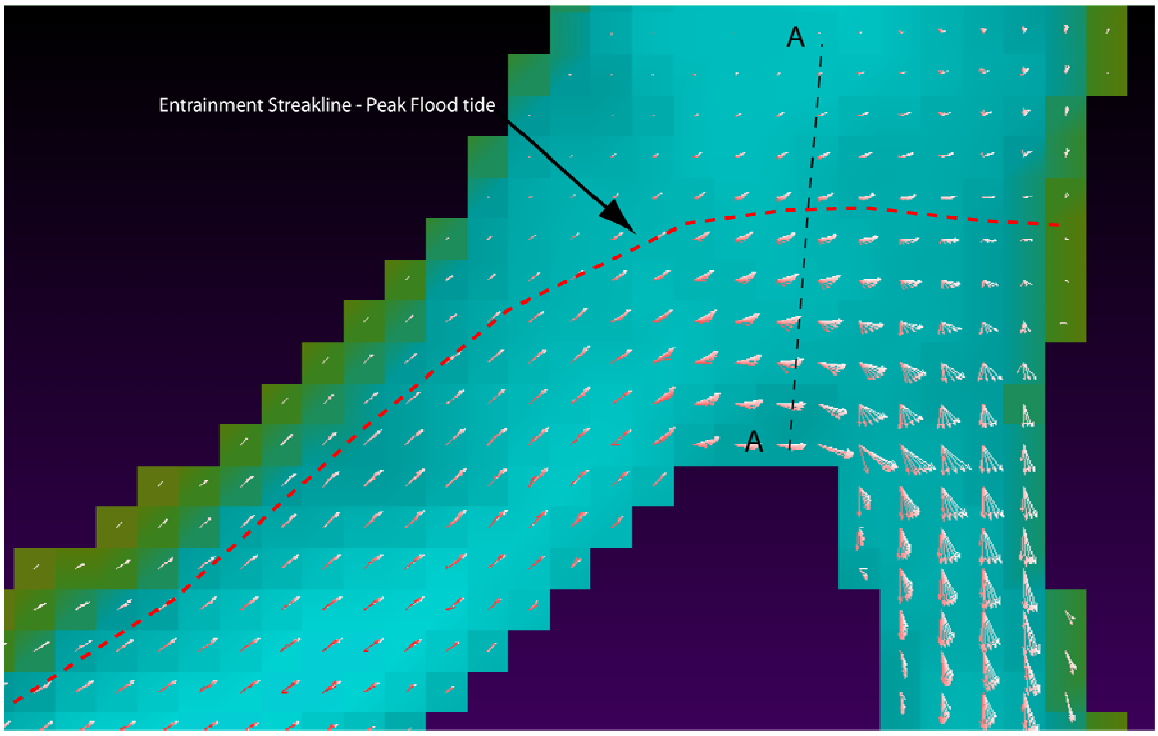

Figure 7 – Velocity vector field computed by Si3d. Surface currents are given in white and near-bed currents are in red (Courtesy of J. Donovan and P.Smith, USGS). During the phase of the tide shown the water is divided between Georgiana Slough and the Sacramento River as indicated by the entrainment streakline. These results show that water strongly enters Georgiana Slough on flood tides creating secondary circulation in the Sacramento River and within Georgiana Slough. Secondary circulation is particularly strong in Georgiana Slough owing to (1) the extremely tight radius "virtual" bend created when water enters the slough from downstream and (2) due to acceleration of the flow as it enters the relatively narrow cross sections in the Slough. It is unclear whether this concentrates juvenile salmon on Georgiana Slough's east bank and/or disorients them, increasing their vulnerability to predation. We hope to observe some of the tagged predators in this region during the study.

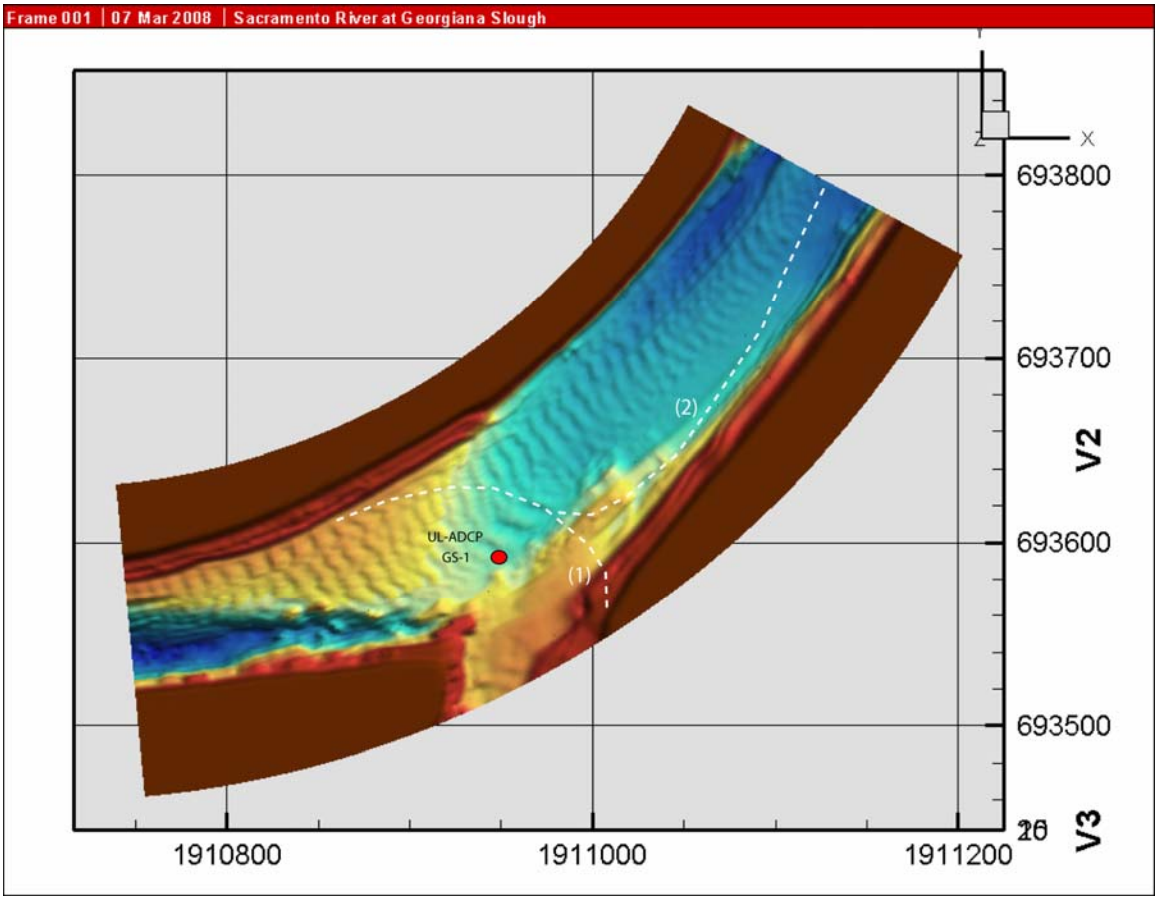

Figure 8 – Bathymetry in the Sacramento River – Georgiana Slough junction. The white dashed line indicates the line of entrainment that occurs during flood tides when the Sacramento River discharges are low during conditions when: (1) all of the flow enters Georgiana Slough and (2) during conditions when a portion of the flow bypasses Georgiana Slough. The proposed location of an upward-looking ADCP (UL-ADCP), shown as a red circle, is intended to measure the secondary circulation in both the flood and ebb flow directions in the Sacramento River in front of Georgiana Slough.

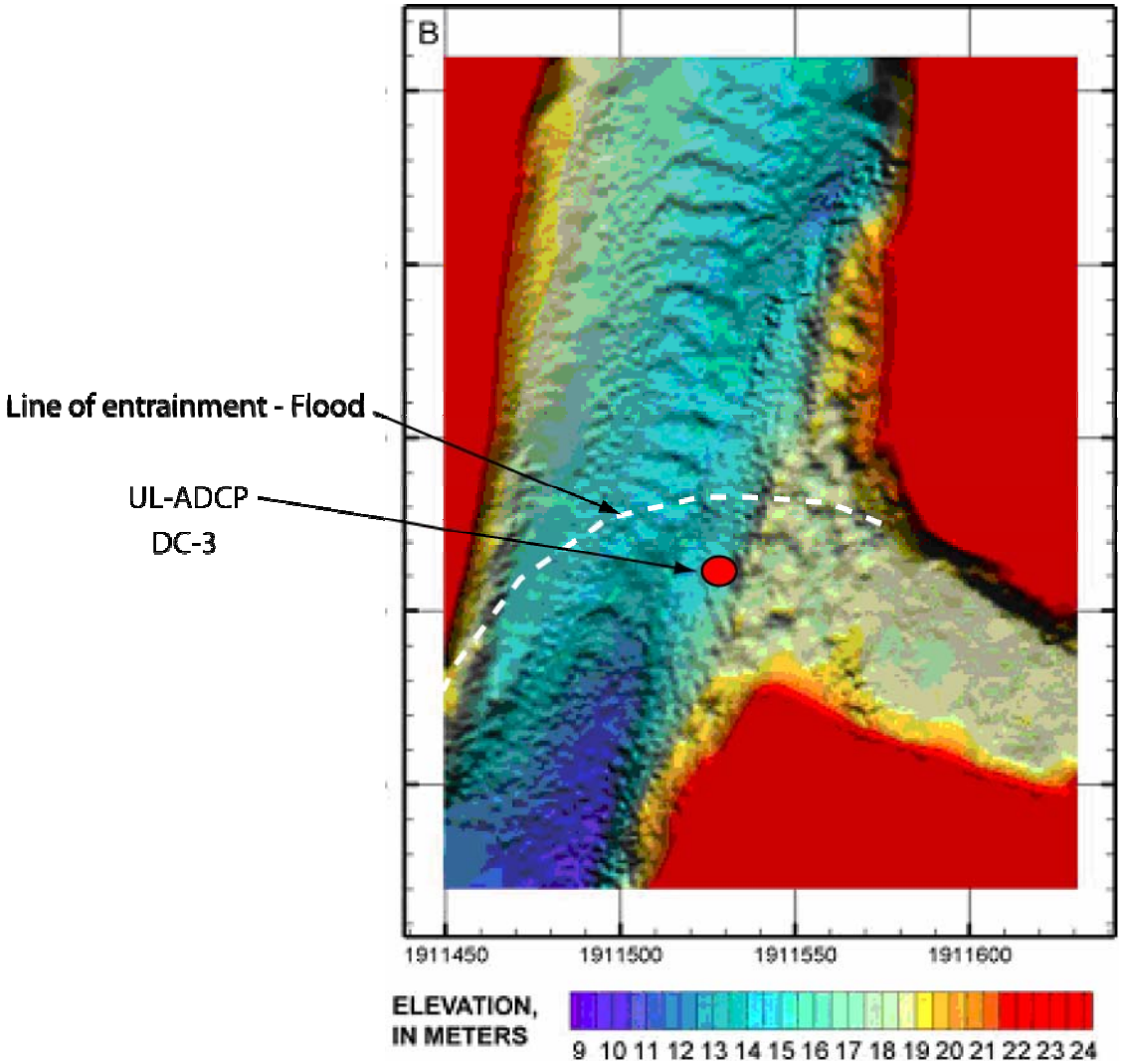

Figure 9 – Bathymetry in the Sacramento River – Delta Cross Channel junction. The white dashed line indicates the flood line of entrainment that occurs at low Sacramento River discharges. The proposed location of an upward-looking ADCP (UL-ADCP), shown as a red circle, is intended to measure (1) the secondary circulation in ebb direction as the flow in the Sacramento River bypasses the DCC and (2) in the flood direction as it enters the DCC.

Figure 10 – Photograph of a RDI 600 khz horizontal ADCP (blue, with red transducers) mounted on a bi-axial rotator. Each SL-ADCP will be mounted on a bi-axial rotator so that we can aim the acoustic beams to minimize acoustic interference with the hydrophones associated with the acoustic telemetry network.

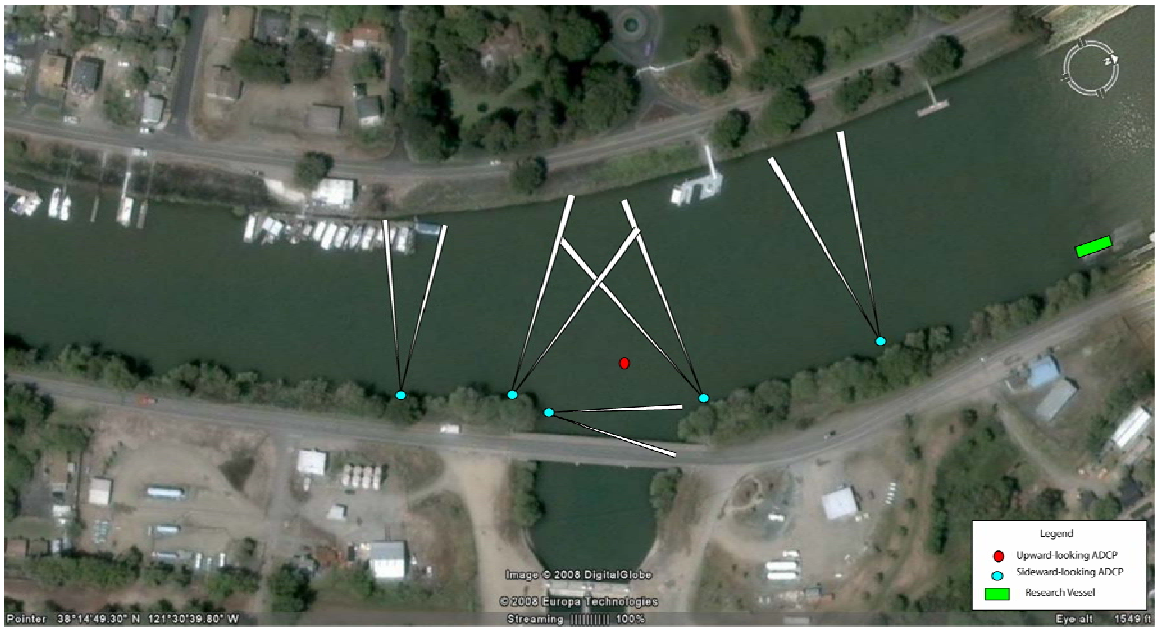

Figure 11 - Aerial photograph of the junction of the Sacramento River and Delta Cross Channel. Light blue circles indicate the proposed positions of sideward-looking SL-ADCP's where the orientation and beam widths of the acoustic beams are shown as thin white triangles (e.g. 2 degree beam width and 20 beam degree angle). The proposed position of an upward-looking UL-ADCP is shown as red circle and the proposed research vessel location is shown as a green rectangle. The UL-ADCP is placed to measure secondary circulation during (1) ebb tides when the gates are closed and (2) during flood tides with the gates open. Data from all of the instruments shown will be used to interpolate time series (15 minute averaged) of velocity fields.

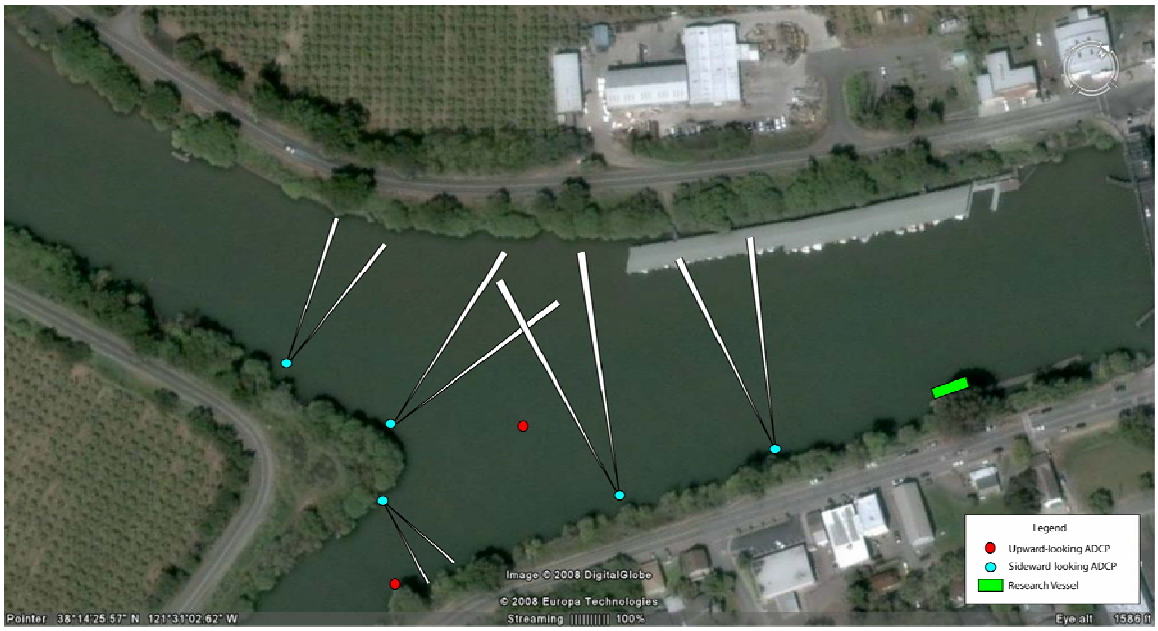

Figure 12 - Aerial photograph of the junction of the Sacramento River and Georgiana Slough. Light blue circles indicate the proposed positions of sideward-looking SL-ADCP's where the orientation and beam widths of the acoustic signals are shown as thin white triangles (e.g. 2 deg beam width and relative transducer face orientation at 20 deg). The proposed positions of upward-looking UL-ADCP's are shown as red circles and the proposed research vessel location is shown as a green rectangle. The UL-ADCP's are placed to measure secondary circulation and to aid in interpolation of the velocity fields. Data from all of the instruments shown will be used to interpolate time series (15 minute averaged) of velocity fields.

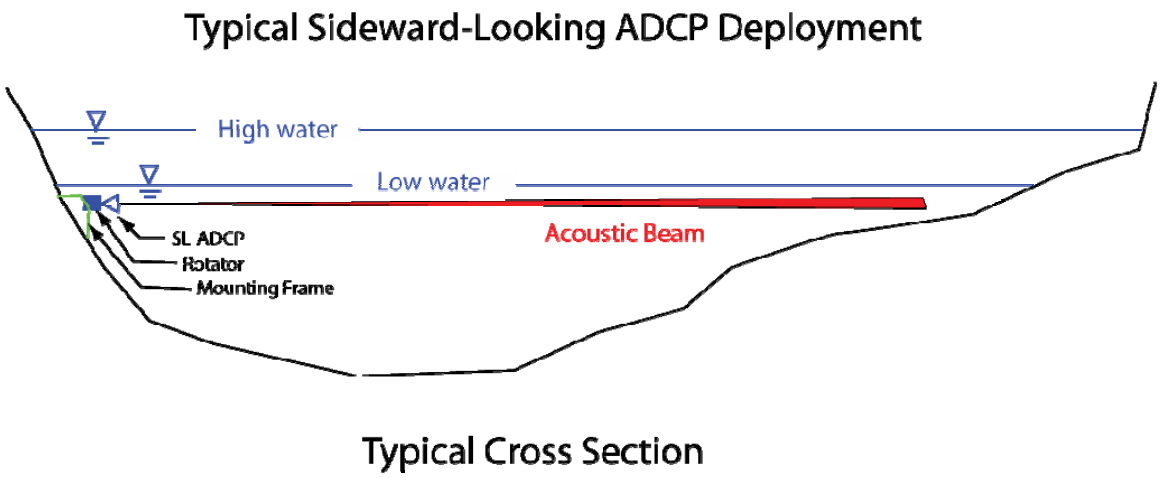

Figure 13 – Schematic of SL-ADCP deployment. Instruments will be deployed during low water conditions in September with the acoustic beams of each of the SL-ADCP's aimed so that they are parallel to the water surface using a dual-axis rotator as is shown in figure 10. Unfortunately, however, the SL-ADCP will not be repositioned for higher water and thus these instruments will not exactly be measuring the surface currents during high water periods. Fortunately, vertical velocity profiles in strictly barotropic flows are near vertical within roughly 70% of the depth measured from the surface.

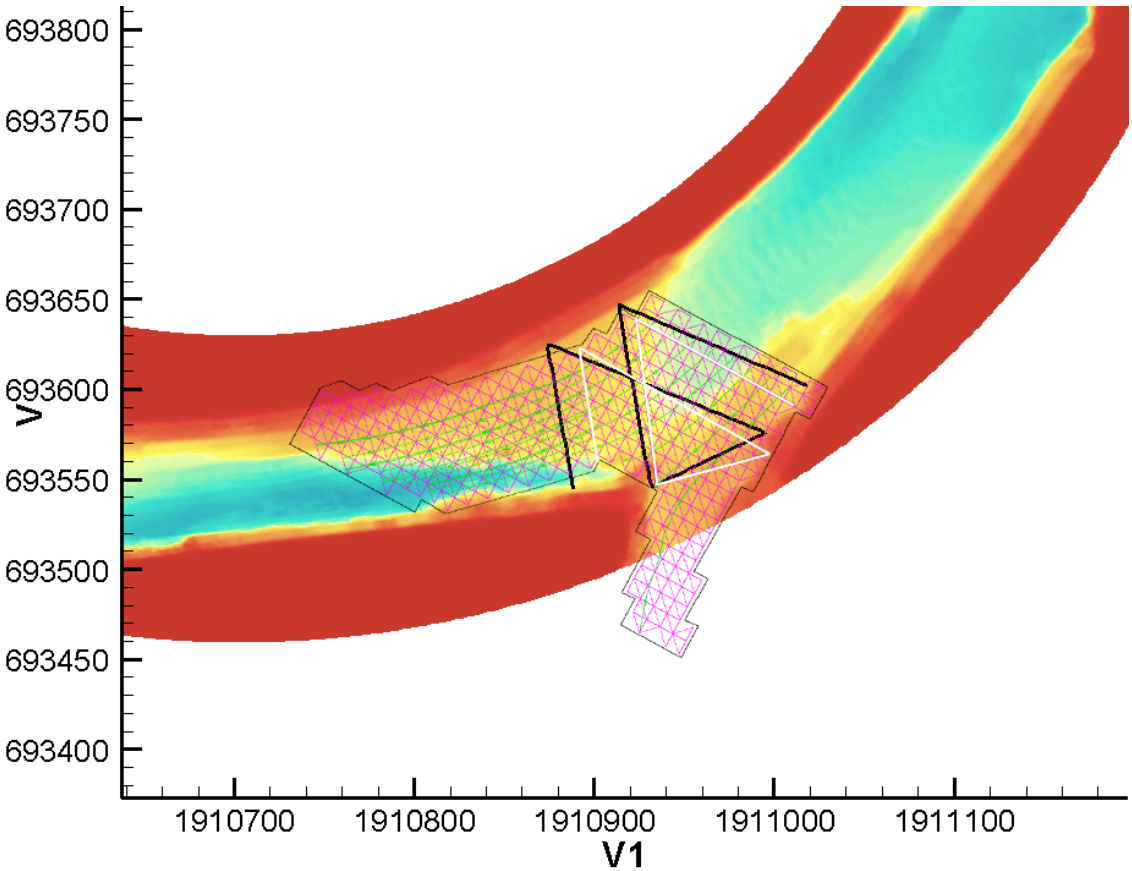

Figure 14 - Interpolation mesh (magenta) and two different fictitious SL-ADCP configurations (black and white lines).

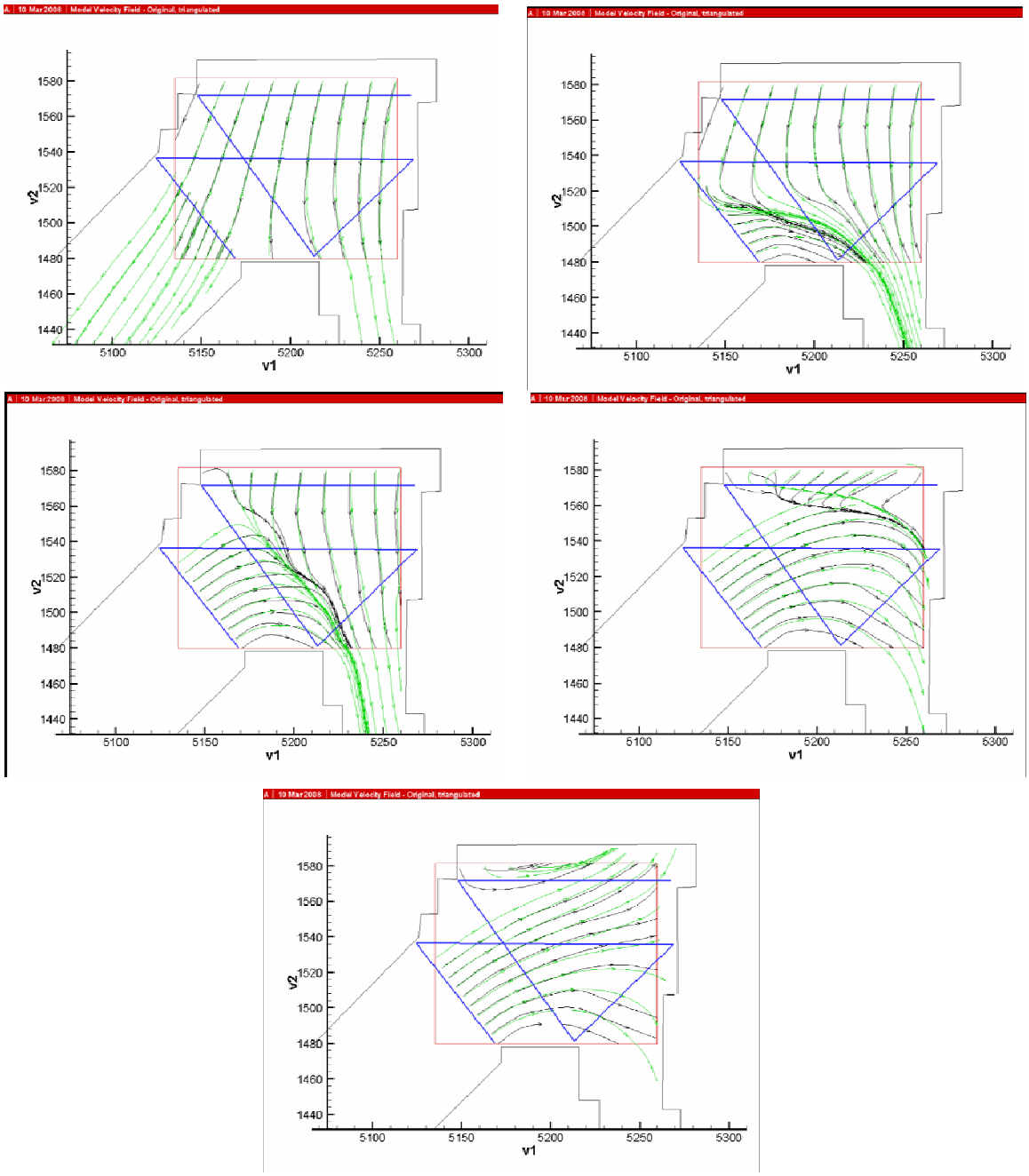

Figure 15 – Interpolated velocity fields in the junction of the Sacramento River and Georgiana Slough at various phases of the tide. Green – Si3D generated synthetic velocity field and Black – interpolated velocity field from velocity transects taken along the blue lines (e.g. mimicking SL-ADCP transects).