V.3.2 Discussion of Results

Analyses of the tide and bathymetric data provided insight into the hydrodynamic characteristics of each system. Harmonic analysis of the tidal time series produced tidal amplitude and phase of the major tidal constituents, and provided assessments of hydrodynamic 'efficiency' of each system in terms of tidal attenuation. This analysis also yielded an assessment of the relative influence of non-tidal, or residual, processes (such as wind forcing) on the hydrodynamic characteristics of each system.

V.3.2.1 Stage Harbor System and South Coast Embayments

V.3.2.1.1 Tidal Harmonic Analysis

Figure V-16 shows the tidal elevation for the period July 23 through August 27, 2000 at three locations: offshore Cockle Cove Beach in Nantucket Sound (Location C1), Little Mill Pond (Location C2), and Mill Pond (Location C3). The curves have a predominant 12.42-hour variation around the lunar semi-diurnal (twice-a-day), or M_2, tidal constituent. There was also a strong modulation of the lunar and solar tides, resulting in the familiar spring-neap fortnightly cycle. The spring (maximum) tide range was approximately 6 feet, and occurred on July 30. The neap (or minimum) tide range was 2.2 feet, occurring August 13th.

Tidal elevations are shown for the next three locations in Figure V-17: Oyster Pond (Location C4), Sulphur Springs (Locations C5), Taylors Pond (Locations C6). Oyster Pond closely follows the tidal elevations for the previous three locations. Sulphur Springs and Taylors Pond drain to Nantucket Sound through shallow, narrow meandering creeks (Bucks Creek and Mill Creek, respectively). The tide signals in these two estuaries, as compared to the offshore signal, show the effects of significant frictional damping. The frictional damping is indicated by the substantial reduction in tide range between the offshore gage and locations within each estuarine system.

Harmonic analyses were performed on the time series from each gage location. Harmonic analysis is a mathematical procedure that fits sinusoidal functions of known frequency to the measured signal. The amplitudes and phase of 23 known tidal constituents result from this procedure. Table V-1 presents the amplitudes of the eight largest tidal constituents. The M_2, or the familiar twice-a-day lunar semi-diurnal, tide is the strongest contributor to the signal with an amplitude of 1.79 feet in Nantucket Sound (offshore Cockle Cove). The range of the M_2 tide is twice the amplitude, or 3.58 feet. The diurnal tides, K_1 and O_1, possess amplitudes of approximately 0.3 feet. Other semi-diurnal tides, the S_2 (12.00 hour period) and N_2 (12.66-hour period) tides, strongly contribute with amplitudes of 0.19 feet and 0.52 feet, respectively. The M_4 and M_6 tides are higher frequency harmonics of the M_2 lunar tide (exactly half the period of the M_2 for the M_4, and one third of the M_2 period for the M_6), results from frictional attenuation of the M_2 tide in shallow water. The M_4 and M_6 have a very small amplitude in the offshore gage (about 0.13 feet and 0.08 feet. The M_{sf} is a lunarsolar fortnightly constituent with a period of approximately 14 days, and is the result of the periodic conjunction of the sun and moon.

Table V-1. Tidal Constituents, Stage Harbor and South Coast Embayments of Chatham, July-August 2000

	Amplitude (feet)							
Constituent	M2	M4	M6	S2	N2	K1	O1	Msf
Period (hours)	12.42	6.21	4.14	12.00	12.66	23.93	25.82	354.61
Offshore	1.79	0.13	0.08	0.19	0.52	0.35	0.29	0.14
Mill Pond	1.86	0.09	0.08	0.19	0.52	0.35	0.29	0.14
Little Mill Pond	1.85	0.09	0.08	0.19	0.52	0.35	0.29	0.12
Oyster Pond	1.80	0.07	0.04	0.18	0.47	0.35	0.30	0.13
Sulphur Springs	1.17	0.21	0.02	0.12	0.25	0.29	0.27	0.16
Taylors Pond	1.60	0.11	0.04	0.14	0.40	0.32	0.29	0.18

The observed astronomical tide is therefore the sum of several individual tidal constituents, with a particular amplitude and frequency. For demonstration purposes a graphical example of how these constituents add together is shown in Figure V-26.

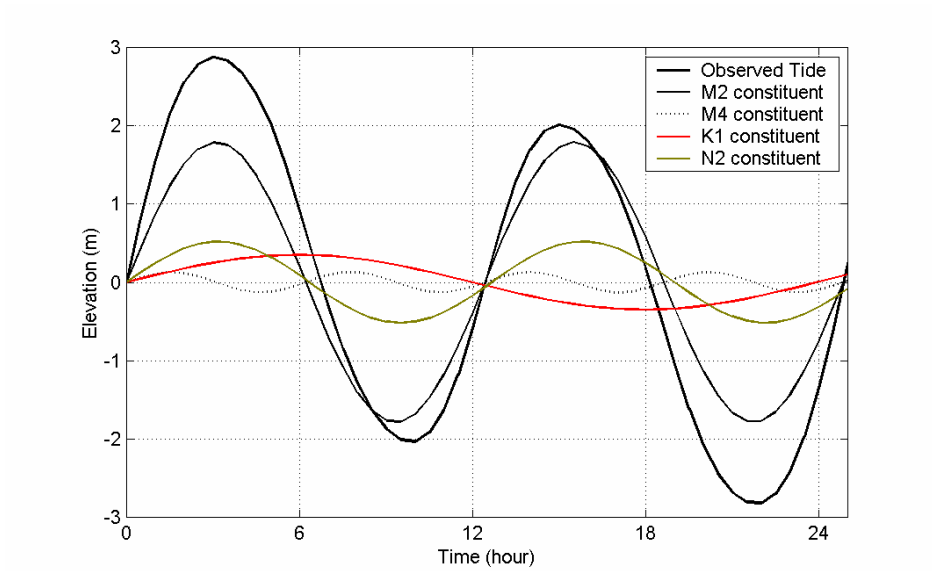

Figure V-26. Example of observed astronomical tide as the sum of its primary constituents. Constituents for offshore Cockle Cove Beach were used in this example.

Table V-1 also shows how the constituents vary as the tide propagates into the estuaries. Note the reduction in the M_2 amplitude between Nantucket Sound and the upper reaches of Sulphur Springs and Taylors Pond. The loss of amplitude with distance from the inlet is described as tidal attenuation. Frictional mechanisms dissipate tidal flow energy, resulting in a reduction of the height of the tide. Usually, frictional damping is most evident as a decrease in the amplitude of M_2 constituent. A portion of the energy lost from the M_2 tide is transferred to higher harmonics (i.e., the M_4 and M_6), and is observed as an increase in amplitude of these constituents over the length of an estuary. This is seen in the tide at Sulphur Springs, where there is a significant growth of the M_4 constituent from offshore. In contrast, an apparent reduction in the M_2 constituent occurs as the tide propagates from Nantucket Sound in the Stage Harbor System (especially into Mill and Little Mill Ponds). This growth in the M_2 constituent is likely due to a transfer of energy from other constituents.

Table V-2 presents the phase delay of the M_2 tide at all tide gage locations compared to the offshore gage at Cockle Cove Beach. Phase delay is another indication of tidal damping, and results with a later high tide at inland locations. The greater the frictional effects, the longer the delay between locations. The delays in Mill Pond and Little Mill Pond are nearly equal, as a result of their proximity to each other. More significant damping is seen in another area of Stage Harbor, at Oyster Pond, with a delay of 36.5 minutes, which is more than twice the delay of the Mill Ponds. This difference is primarily due to the flooding of tidal flats in the Oyster Pond River/Oyster Pond system, as well as the shallow constricted channel of Oyster Pond River. Similar to the behavior of the amplitude of M_2 tide, the largest delay of one hour occurs in Sulphur Springs (location C5) relative to offshore. Taylors Pond also exhibits a significant delay of almost a half hour.

Analysis of the data shows that the Oyster Pond, Sulphur Springs, and Taylors Pond systems, with shallow intertidal flats, expansive salt marsh regions, and winding channels and creeks, distorts the tide significantly relative to offshore Cockle Cove Beach, in Nantucket Sound. This distortion of the tide is evidenced as reduction in M_2 tide amplitude and M_2 phase delays.

Table V-2. M_2 Tidal Attenuation Stage Harbor and South Coast Embayments, Chatham, July-August 2000 (Delay in minutes relative to offshore of Cockle Cove Beach).

TDR Location	Delay (minutes)
Offshore	--
Little Mill Pond	12.89
Mill Pond	13.95
Taylors Pond	27.39
Oyster Pond	36.47
Sulphur Springs	59.22

For Oyster Pond and the South Coast Embayments flow restrictions modify the duration of the ebb and flood tide stages to a longer ebb duration (a slower, gradual draining of the estuary) and a briefer flood tide (Figure V-27). Nantucket Sound tides have a flood duration of approximately 7 hours, with an ebb duration of approximately 5 hours. The top plot of Figure V-27 demonstrates the modification to the tide signal in Oyster Pond relative to the remainder of the Stage Harbor complex and the offshore tide. In the lower two plots, the shorter duration of the flood tide in Sulphur Springs and Taylors Pond is more clearly seen with a flood duration of approximately 4 hours and an ebb of approximately 8 hours in duration.

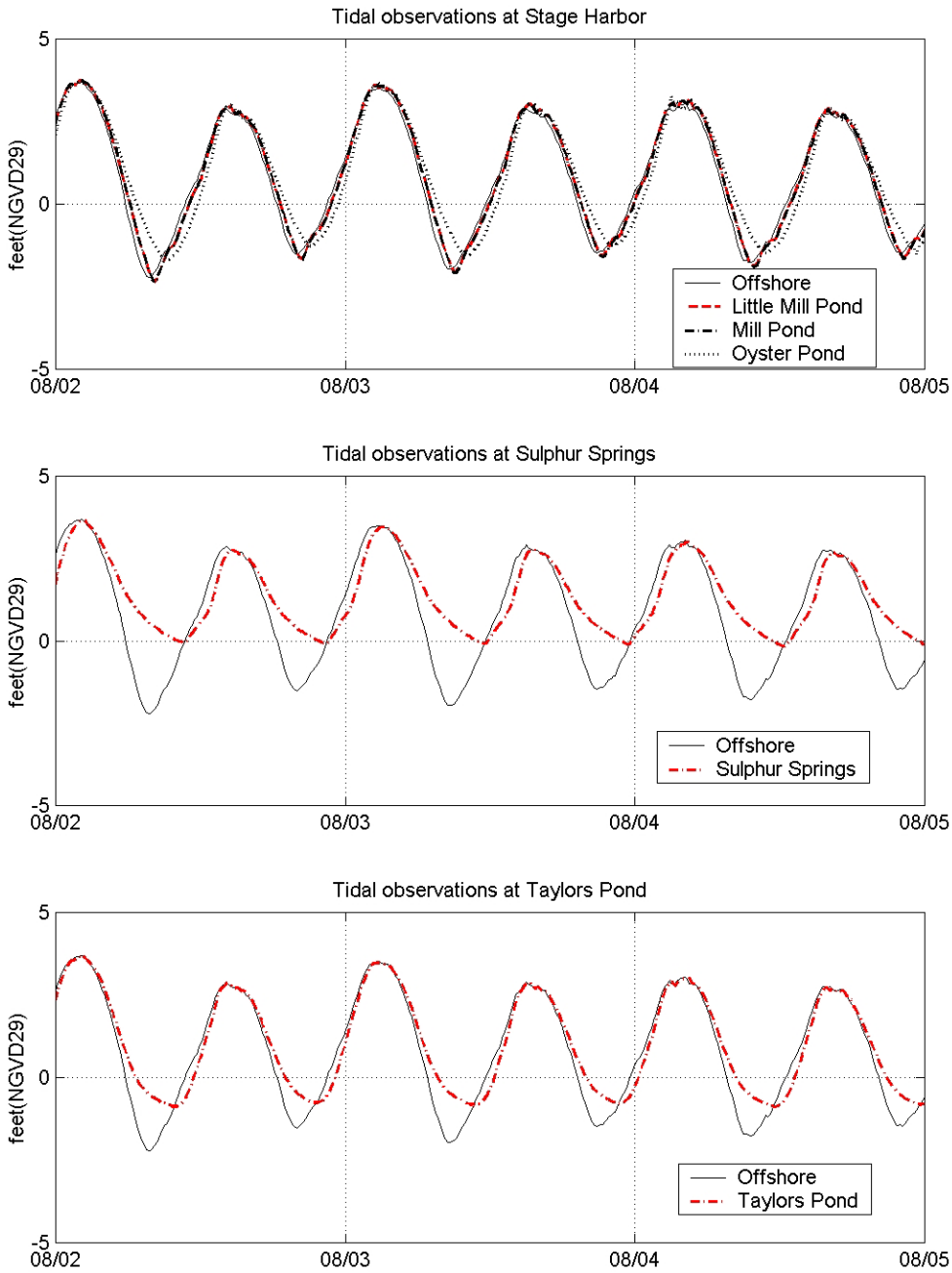

Figure V-27. Water elevation variations for a 3-day period in the Stage Harbor, Sulphur Springs, and Taylors Pond systems. Each plot depicts the Nantucket sound signal (offshore) overlaid with measurements obtained in the inland estuaries. Notice the reduced amplitude as well as the delay in times of high- and low- tide relative to offshore due to frictional damping through the systems.

For locations where the flood tide is shorter in duration than the ebb tide (e.g., Sulphur Springs), currents during the flood stage will be greater than during the ebb, since approximately the same amount of water volume must enter the system on the flood as leaves on the ebb. An example of this phenomenon is the Oyster Pond River inlet, where measured

tidal currents were greater during the flood cycle than the ebb cycle. Estuarine systems of this type are referred to as 'flood-dominant'. Flood dominant systems tend to be sediment traps, where sediments transported into the system during flood tide often settle, causing long-term accretion or shoaling. The characteristics of the tidal signal can be utilized to indicate whether an estuarine system is likely to be a sediment trap for fine-grained materials, since trapping of organic sediments is often related to increased benthic flux during the summer months.

In addition to the tidal analysis, the data were further evaluated to determine the importance of tidal versus non-tidal processes to changes in water surface elevation. These other processes include wind forcing (set-up or set-down) within the estuary, as well as sub-tidal oscillations of the sea surface. Variations in water surface elevation can also be affected by freshwater discharge into the system, if these volumes are relatively large compared to tidal flow. The results of an analysis to determine the energy distribution (or variance) of the original water elevation time series for Stage Harbor and the South Coast Embayments is presented in Table V-3, compared to the energy content the astronomical tidal signal (re-created by summing the contributions from the 23 known harmonic constituents). Subtracting the tidal signal from the original elevation time series resulted with the non-tidal, or residual, portion of the water elevation changes. The energy of this non-tidal signal is compared to the tidal signal, and yields a quantitative measure of how important these non-tidal physical processes can be to hydrodynamic circulation within the estuary.

Table V-3. Percentages of Tidal versus Non-Tidal Energy, Stage Harbor and South Coast Embayments, July to August 2000

TDR Location	Total Variance ($ft^2 \cdot sec$)	Total(%)	Tidal (%)	Non-tidal (%)
Offshore	1.929	100%	98.9	1.1
Little Mill Pond	2.042	100%	98.6	1.4
Mill Pond	2.057	100%	98.7	1.3
Oyster Pond	1.909	100%	98.8	1.2
Sulphur Springs	0.874	100%	97.3	2.7
Taylors Pond	1.530	100%	98.7	1.3

Table V-3 shows that the percentage of tidal energy was largest in the offshore signal in Nantucket Sound; as should be expected given the tidal attenuation through the system. In general, the energy of the signal decreases with distance from the offshore gage, with the lowest energy found in upper regions of the ponds. The analysis also shows that tides are responsible for almost 99% of the water level changes in the Stage Harbor system and South Coast Embayments; wind effects in these data sets were negligible. In Sulphur Springs, tides are still responsible for over 97% of the elevation variation, with inputs from other sources accounting for the remaining energy. This relative increase in non-tidal energy within this system is likely due to the decrease in tidal energy as a result of frictional forces rather than a growth of residual forces.

V.3.2.1.2 Current Measurements

Current measurements in the Stage Harbor region, surveyed on August 16, 2000, provided observation of the temporal and spatial variability of the flow regime during a tidal cycle. The survey was designed to observe tidal flow through the Stage Harbor inlet, and how it was divided between the Oyster Pond River inlet, and the mouth of Mill Pond at hourly intervals. The current measurements observed during the flood and ebb tides at each constriction can be seen in FiguresV-28 throughV-33. Positive along-channel currents (top panel) indicate the flow

is moving into the estuary, while positive cross-channel velocities (middle panel) are oriented 90° clockwise of positive along-channel. For example, at the Stage Harbor inlet, positive along-channel is in the direction of northeast, and positive cross-channel is in the direction of southeast. In the lower left panel of the figures, the mean current or average currents across the channel are shown relative to the shoreline. The lower right panel indicates the stage of the tide during the transect illustrated (shown by a vertical line through the water elevation curve).

Tidal currents through the Stage Harbor inlet reached maximum speeds of approximately 3.3 ft/sec directed out of the estuary. During periods of maximum currents (flood and ebb) the inlet tidal flows were vertically coherent, with negligible stratification (FiguresV-28 andV-29) and ran parallel to the main navigation channel. During slack-water periods, there was an indication of mildly stratified flows, evidenced by an abrupt change in horizontal current direction in the water column. Maximum volume flux through the Stage Harbor inlet during flood tide was 5,750 ft^3/sec, while the maximum flux during ebb conditions was slightly more, -7,250 ft^3/sec. These flow measurements are consistent with the tide plots in Figure V-28, which show a longer duration flood stage relative to the duration of the ebb stage of the tide at Stage Harbor Inlet.

The channel through the Oyster Pond River inlet is along the north bank of the river, on average resulting in stronger currents along the northern side of the inlet reaching a maximum of approximately 2.0 ft/sec. During flood conditions, the currents are focused through the channel (Figure V-30), compared to ebb conditions where the flow is distributed relatively evenly across the inlet (Figure V-31). Volume flow rates reached a maximum of 2,310 ft^3/sec during flood conditions, and a maximum ebb flow rate of –1,790 ft^3/sec at the mouth of the Oyster Pond River. These flow measurements are consistent with the tide plots in Figure V-27, which show a longer duration ebb stage relative to the duration of the flood stage of the tide at Oyster Pond.

The third transect, measured south of the bridge at the mouth of Mill Pond showed the most variability in the along-channel tidal currents. The bridge begins approximately 210 feet along the transect (denoted by black line across top panel in Figure V-32), however the flow under the bridge is attenuated at the surface by wooden boards across the first two sets of pilings on the western side. As a result, the tidal currents are focused towards the center of the bridge through the largest opening, which is apparent during the ebb tide in Figure V-33, with a maximum current of approximately 2.0 ft/sec. At the mouth of Mill Pond, the maximum flood flow rate was 870 ft^3/sec, and the maximum ebb flow rate was –890 ft^3/sec. Again, these flow measurements are consistent with the tide plots in Figure V-27, which show a longer duration flood stage relative to the duration of the ebb stage of the tide at Mill Pond.

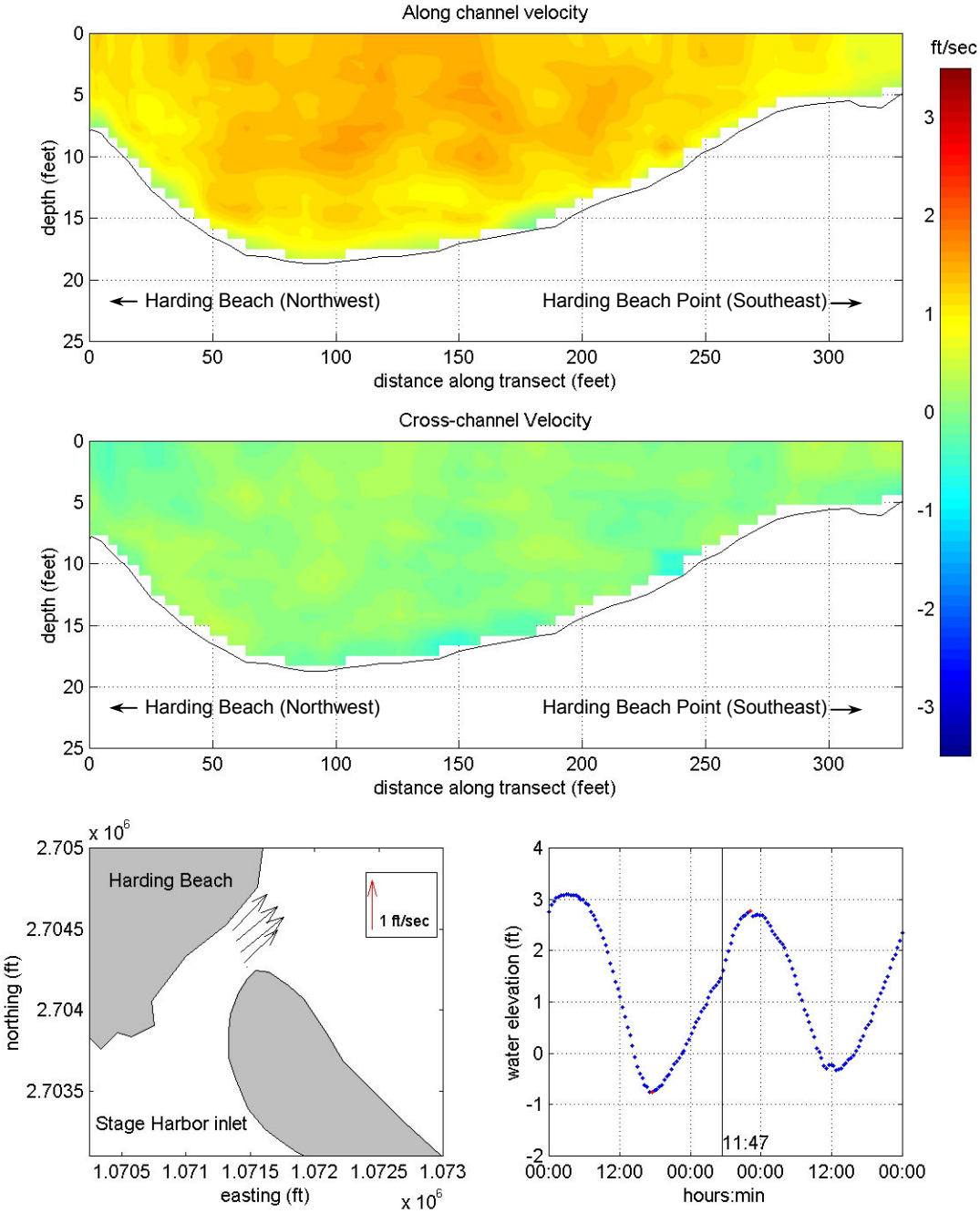

Figure V-28. Color contour plots of along-channel and cross-channel velocity components for transect line 1 run northwest-to-southeast across the Stage Harbor inlet measured at 11:47 on August 16, 2000 during the flood tide. Positive along-channel currents (top panel) indicate the flow is moving into the estuary, while positive cross-channel velocities (middle panel) are oriented 90° clockwise of positive along-channel.

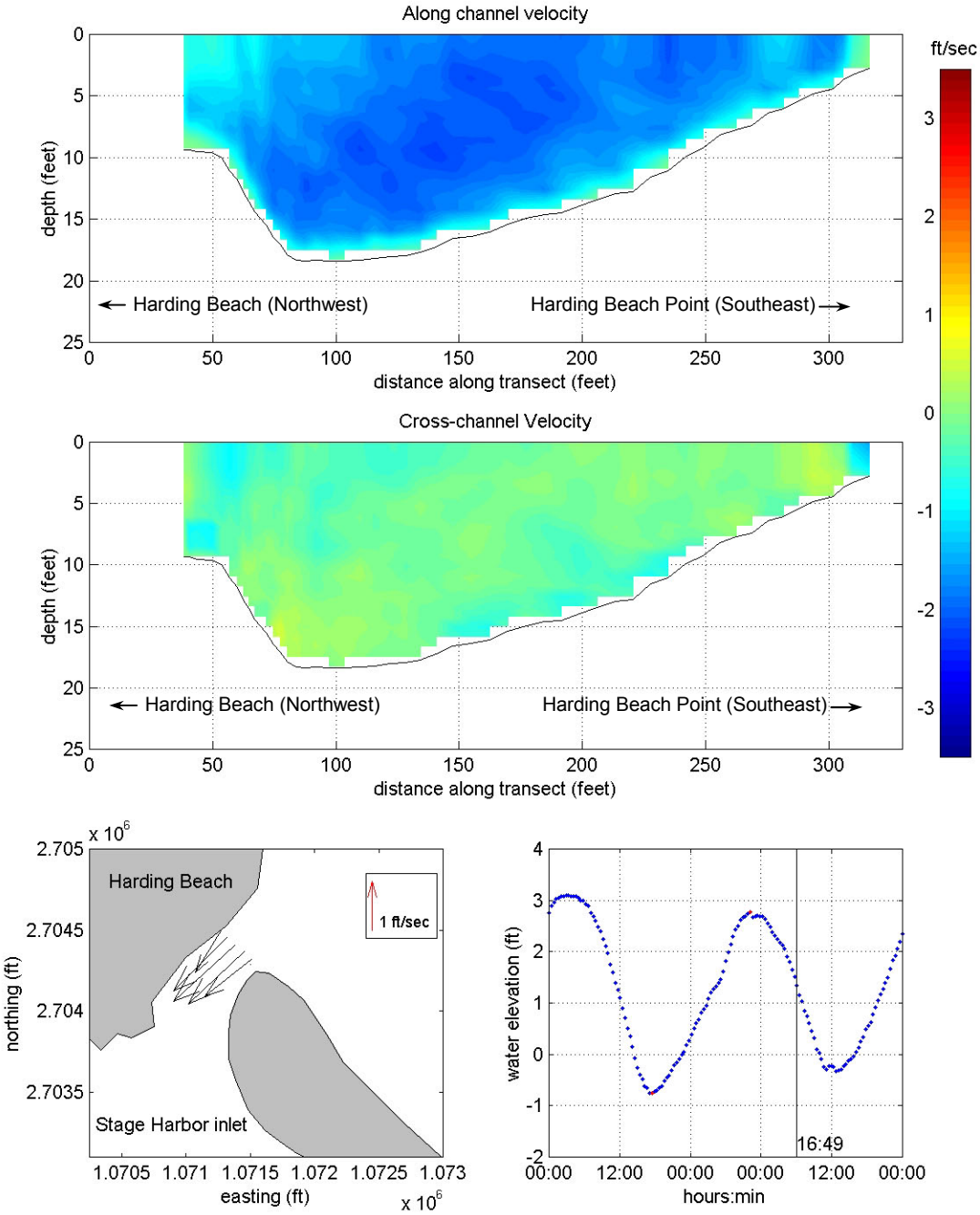

Figure V-29. Color contour plots of along-channel and cross-channel velocity components for transect line 1 run northwest-to-southeast across the Stage Harbor inlet measured at 16:49 on August 16, 2000 during the ebb tide. Positive along-channel currents (top panel) indicate the flow is moving into the estuary, while positive cross-channel velocities (middle panel) are oriented 90° clockwise of positive along-channel.

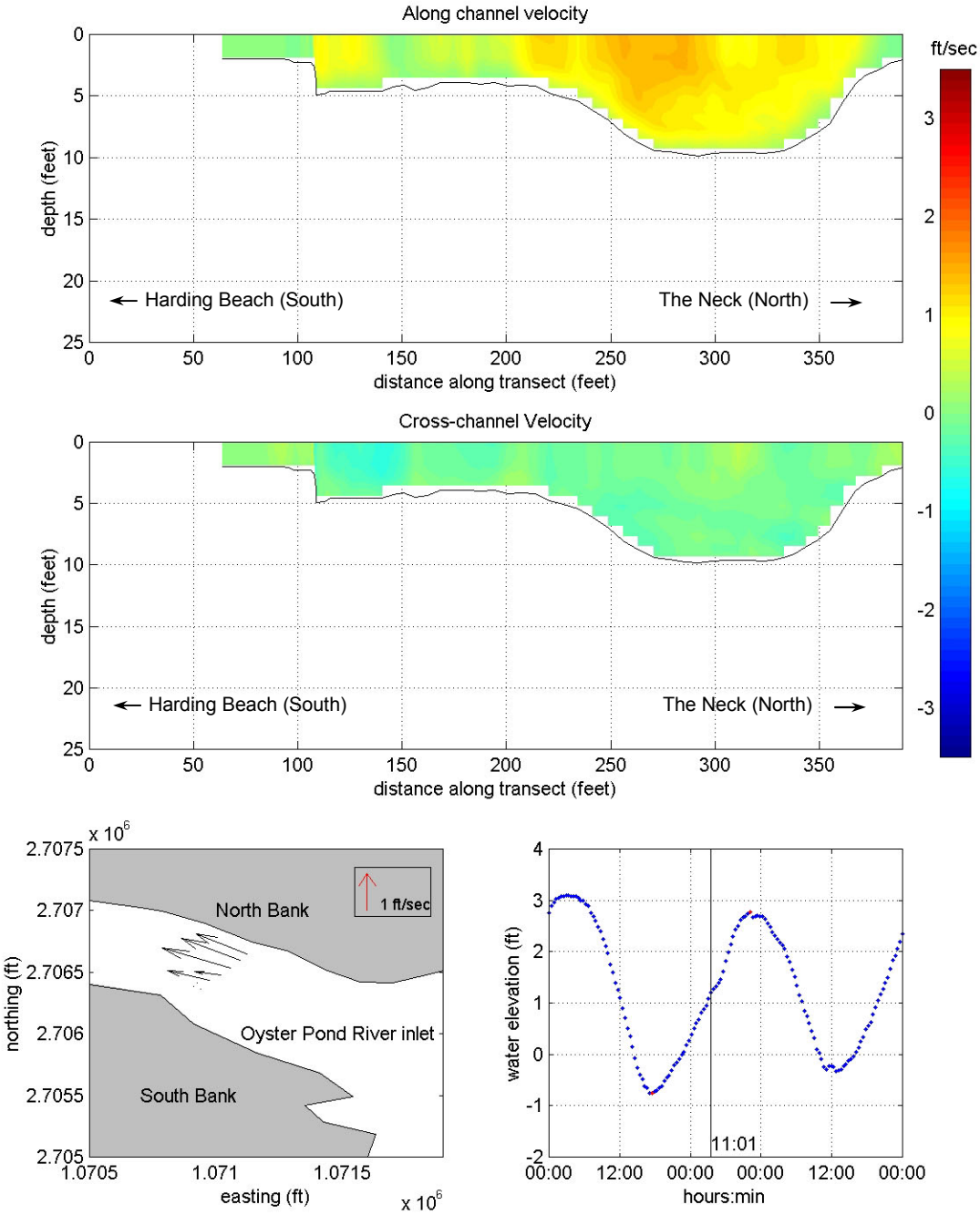

Figure V-30. Color contour plots of along-channel and cross-channel velocity components for transect line 2 run south-to-north across the Oyster Pond River inlet measured at 11:01 on August 16, 2000 during the flood tide. Positive along-channel currents (top panel) indicate the flow is moving into the estuary, while positive cross-channel velocities (middle panel) are oriented 90° clockwise of positive along-channel.

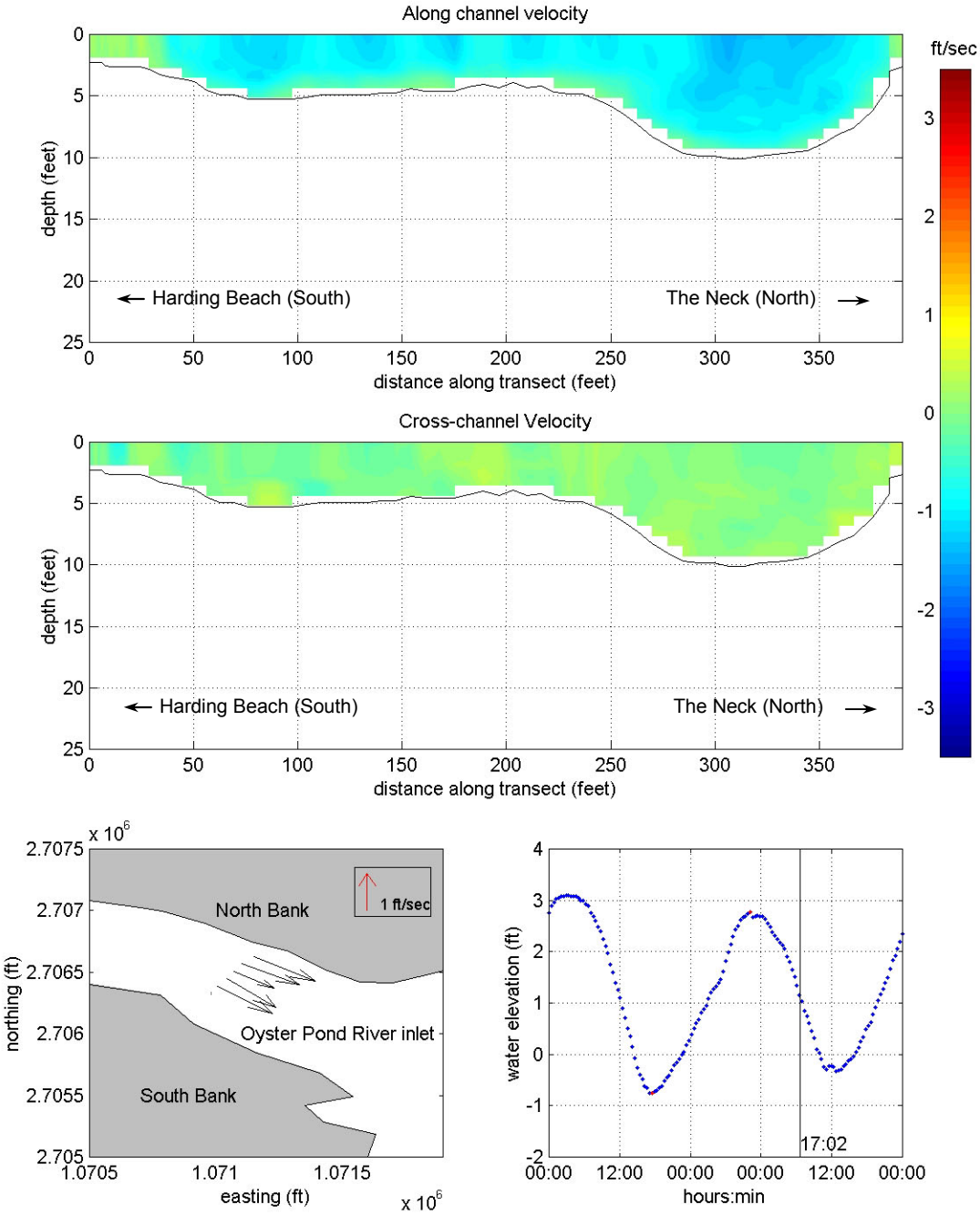

Figure V-31. Color contour plots of along-channel and cross-channel velocity components for transect line 2 run south-to-north across the Oyster Pond River inlet measured at 17:02 on August 16, 2000 during the ebb tide. Positive along-channel currents (top panel) indicate the flow is moving into the estuary, while positive cross-channel velocities (middle panel) are oriented 90° clockwise of positive along-channel.

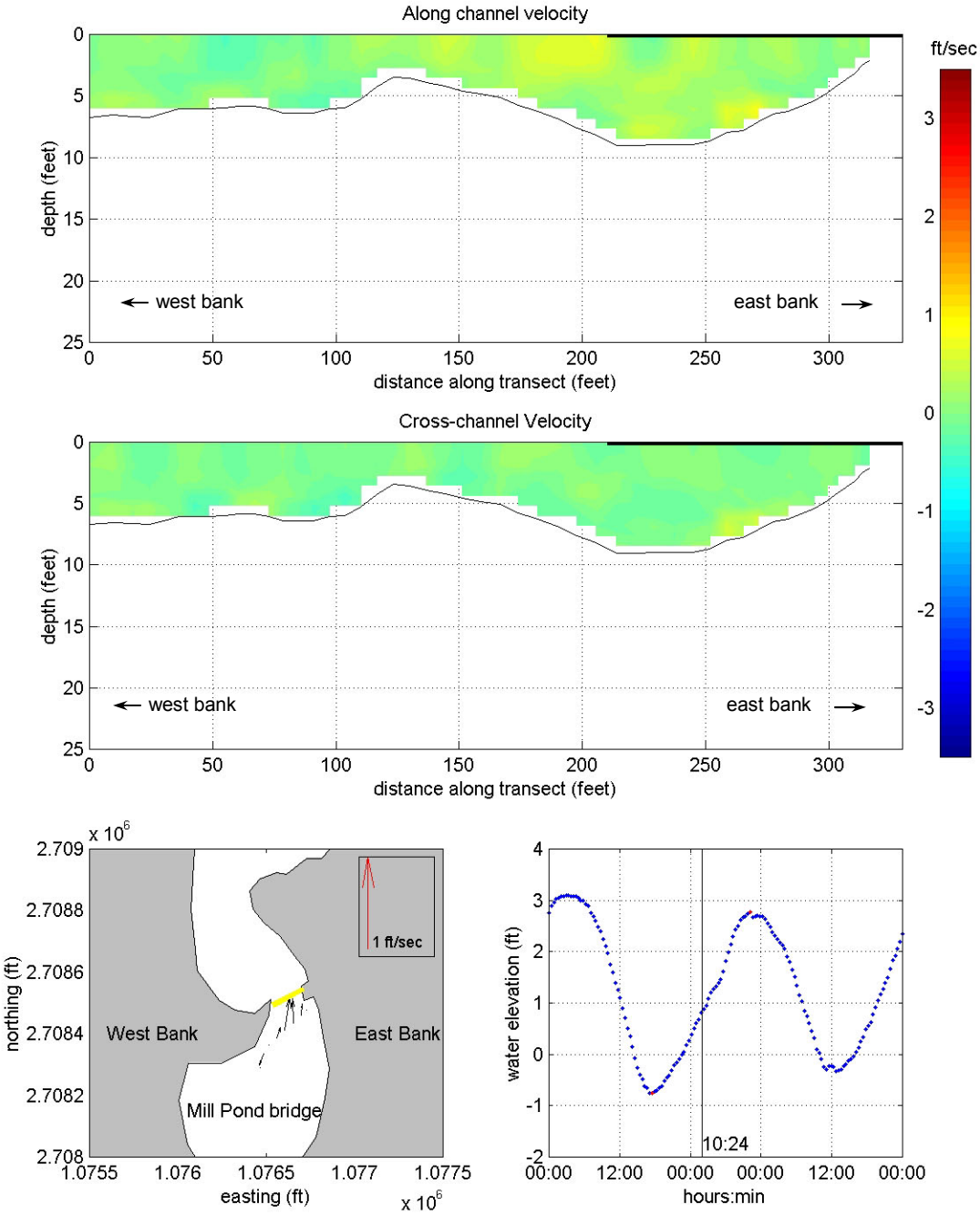

Figure V-32. Color contour plots of along-channel and cross-channel velocity components for transect line 3 run southwest-to-northeast across the south side of Mill Pond bridge measured at 10:24 on August 16, 2000 during the flood tide. The location of the bridge is indicated by a heavy black line at 0 ft depth from 210 to 350 feet along the transect in the top and middle panels, and a yellow line in the lower left panel.

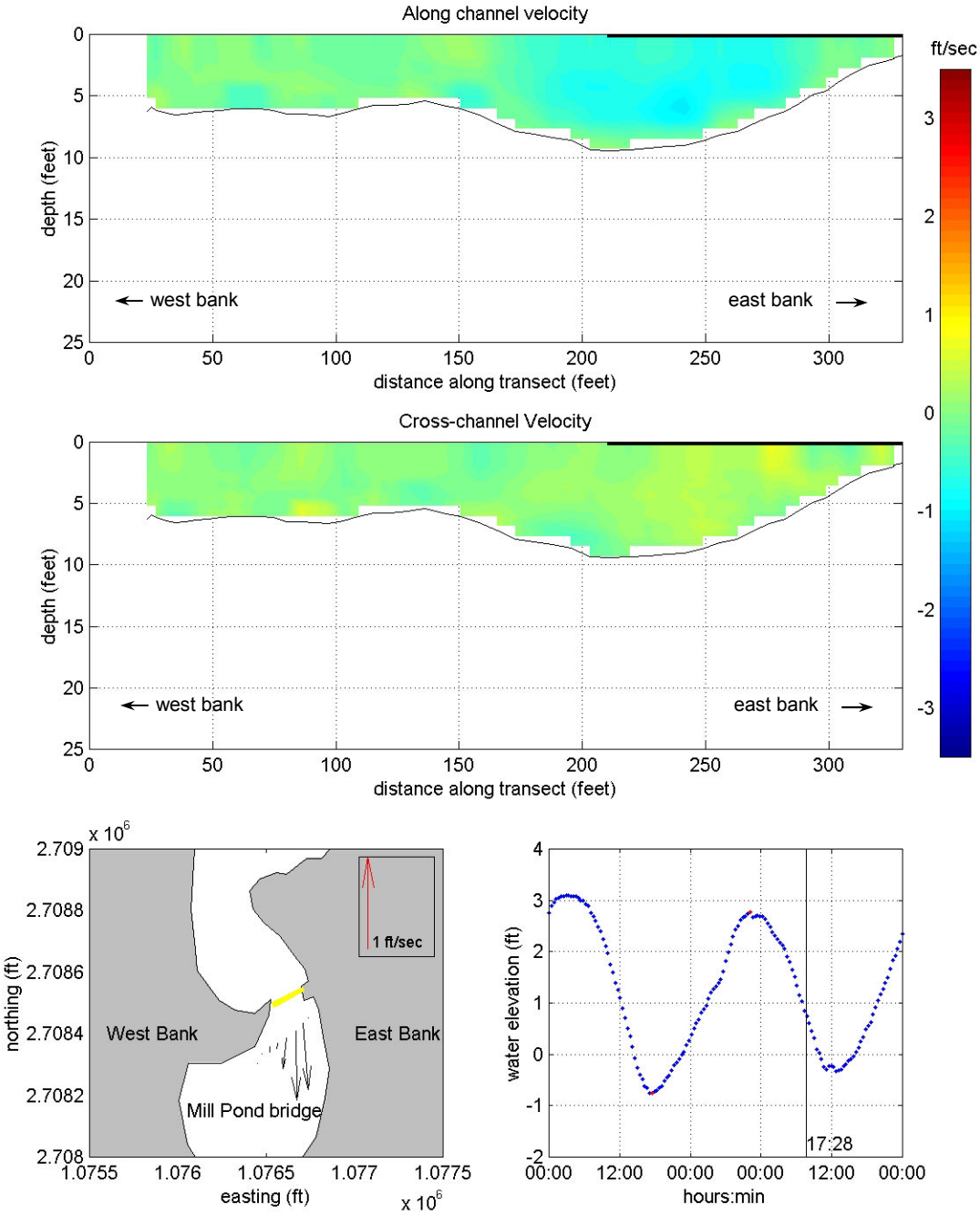

Figure V-33. Color contour plots of along-channel and cross-channel velocity components for transect line 3 run southwest-to-northeast across the south side of Mill Pond bridge measured at 17:28 on August 16, 2000 during the ebb tide. The location of the bridge is indicated by a heavy black line at 0 ft depth from 210 to 350 feet along the transect in the top and middle panels, and a yellow line in the lower left panel.

V.3.2.2 Pleasant Bay Region

V.3.2.2.1 Tidal Harmonic Analysis

Figure V-18 shows tidal elevations for the period August 22 through September 27, 2000 at five locations: Chatham Yacht Club (location P1 in Figure V-15), Crows Pond (location P2), Ryder Cove (location P3), Frost Fish Creek (location P4), and Muddy Creek (location P5). The curves have a predominant 12.42-hour variation around the lunar semi-diurnal (twice-a-day), or M_2, tidal constituent. The maximum (spring) tide range occurred on August 28 with a magnitude of approximately 5.5 feet, and the minimum (neap) tide range of approximately 2.6 feet occurred on September 8. Muddy Creek and Frost Fish Creek are long, narrow estuaries that are constricted at their entrances to the larger estuaries by culverts. The flow control features (i.e., culverts and weirs) of these two systems substantially attenuate the tidal signal.

The amplitudes of the eight largest tidal constituents from the tidal harmonic analysis are presented in Table V-4. The strongest contributor to the signal is the M_2 tide with an amplitude of 1.81 feet in Pleasant Bay (Chatham Yacht Club) and a range (twice the amplitude) of 3.62 feet. The diurnal tides, K_1 and O_1, possess amplitudes of approximately 0.25 feet. Other semi-diurnal tides, the S_2 (12.00 hour period) and N_2 (12.66-hour period) tides, contribute with amplitudes of 0.23 feet and 0.36 feet, respectively.

Table V-5 presents the phase delay of the M_2 tide at all of the tide gage locations in the Pleasant Bay region compared to the Chatham Yacht Club gage. This comparison reinforces the lack of attenuation in Bassing Harbor, Ryder Cove and Crows Pond relative to Pleasant Bay. The flow restriction by culverts in Frost Fish Creek and Muddy Creek result in significant phase delays of the M_2 tide of over 2 hours in both systems. Muddy creek and the upper reaches of Frost Fish Creek drain to the larger estuaries through culverts, which inhibits the tidal flow, resulting in damping of the tidal signal.

Although the Chatham Yacht Club gage originally was intended as the forcing tide for both the Bassing Harbor and Muddy Creek systems, the tide phase at the Yacht Club indicated that it would be inappropriate to act as the model forcing for the Bassing Harbor system. Instead, the Ryder Cove data was utilized as the forcing data for Bassing Harbor. A more complete description of this approach is discussed in the modeling section.

Table V-4. Tidal constituents for Bassing Harbor/Muddy Creek, Chatham, August-September 2000

	Amplitude (feet)							
Constituent	M2	M4	M6	S2	N2	K1	O1	Msf
Period (hours)	12.42	6.21	4.14	12.00	12.66	23.93	25.82	354.61
Chatham Yacht Club	1.811	0.277	0.035	0.231	0.362	0.248	0.273	0.244
Ryder Cove	1.862	0.203	0.060	0.242	0.374	0.245	0.275	0.245
Crows Pond	1.860	0.228	0.049	0.243	0.377	0.250	0.275	0.256
Frost Fish Creek	0.161	0.036	0.004	0.027	0.041	0.052	0.064	0.114
Muddy Creek	0.296	0.051	0.003	0.037	0.055	0.077	0.088	0.205

Table V-5. M_2 Tidal Attenuation Bassing Harbor/Muddy Creek systems August-September 2000 (Delay in minutes relative to Chatham Yacht Club)	
TDR location	Delay (minutes)
Ryder Cove	-15.95
Crows Pond	-12.12
Chatham Yacht Club	--
Frost Fish Creek	122.13
Muddy Creek	141.81

Table V-6 shows the relative energy of tidal versus non-tidal processes at the tide gage locations in the Pleasant Bay region. The signal variance (or energy) of each time series was computed to calculate the percentages. Tides are responsible for approximately 97% of the water level changes at Chatham Yacht Club, Ryder Cove, and Crows Pond; wind effects in the data for these three estuaries were negligible. In the creeks, tides are only responsible for approximately 70% of the elevation variation, with inputs from other sources accounting for the remaining energy. This relative increase in non-tidal energy within the creeks is likely due to the decrease in tidal energy as a result of attenuation of the flow through the constrictions rather than a growth of residual forces. Variations in the water surface elevation of the creeks are also affected by freshwater discharge into the systems.

Table V-6. Percentages of tidal versus non-tidal energy Bassing Harbor/Muddy Creek August-September 2000.				
TDR location	Total Variance ($ft^2 \cdot sec$)	Total(%)	Tidal (%)	Non-tidal (%)
Chatham Yacht Club	1.998	100%	97.0	3.0
Ryder Cove	2.082	100%	97.1	2.9
Crows Pond	2.092	100%	97.0	3.0
Frost Fish Creek	0.037	100%	70.7	29.3
Muddy Creek	0.105	100%	73.9	26.1

V.3.2.2.2 Current Measurements

Cross-channel current measurements were surveyed through a tidal cycle in the Bassing Harbor system on September 1, 2000 to resolve spatial and temporal variations in tidal current patterns. The survey was designed to observe tidal flow through Bassing Harbor inlet, and the division of flow between Crows Pond and Ryder Cove/Frost Fish Creek at hourly intervals. FiguresV-34 throughV-39 show color contours of current measurements observed during the flood and ebb tides at each of the three transects. Positive along-channel currents (top panel) indicate the flow is moving into the estuary, while positive cross-channel velocities (middle panel) are oriented 90° clockwise of positive along-channel. For example, at the Bassing Harbor inlet, positive along-channel flow is westerly, and positive cross-channel flow is moving north. In the lower left panel of the figures, the mean current or average currents across the channel are shown relative to the shoreline. The lower right panel indicates the stage of the tide that the survey was taken by a vertical line through the water elevation curve.

The complex geometry of Bassing Harbor inlet results in an unequal distribution of currents across the entrance. During flood tide, maximum currents were focused through the primary channel in a west-southwest direction (Figure V-34), with additional flow across the southern portion of the inlet. The curvature of the shoreline of Bassing Harbor and the presence of Fox Hill appears to modify the flow out of the harbor on the ebb tide. In Figure V-35 (lower left panel), ebb currents are distributed more evenly across the inlet, and flow almost perpendicular to the direction of maximum flood currents. In a system with a linear channel, dominant flood and ebb currents flow along the same line, but in opposite directions (180°). In Bassing Harbor, the curvature of the channel with the shoreline complicates the rotation of currents into along-channel and cross-channel components. As a result of the rotation based on the assumption of a linear channel, the color contours in Figure V-35 (top and middle panel) show that a large portion of the tidal flow energy in contained in the cross-channel component during the ebb tide. Tidal currents through the Bassing Harbor inlet reached a maximum of approximately 3.2 ft/sec directed out of the harbor during ebb tide. The maximum volume flow rate through the Bassing Harbor inlet was 4,880 ft^3/sec during the flood tide, and the maximum ebb volume flow rate was –1,670 ft^3/sec.

The second transect was measured from east-to-west across the mouth of Ryder Cove, which also connects to Frost Fish Creek. The dominant flood tidal currents were focused through the channel at a maximum velocity of approximately 2.3 ft/sec (Figure V-36). The transect was begun to the south of a pier on the east side of the inlet, which may account for the presence of currents directed out of the estuary along the east bank. During the ebb tide, the current profiles were moderately stratified in the channel (Figure V-37), with stronger out-estuary velocities in the upper layers of the water column, and weaker in-estuary flow near the bottom of the channel. At the entrance to Ryder Cove/Frost Fish Creek, the volume flow rate reached a maximum during flood tide of 1,800 ft^3/sec, and a maximum of -990 ft^3/sec during the ebb tide.

The geometry of the shoreline at the mouth of Crows Pond shifts the cross channel position of the strongest currents from one side to the other during the flood-ebb tidal cycle. At the wide entrance to Crows Pond, the strongest flood currents into the estuary occur on the north side (Figure V-38), and the strongest ebb currents out of the estuary occur on the south side of the channel (Figure V-39). Maximum along-channel velocities were observed during the ebb tide at magnitudes of 3.2 ft/sec, but strong cross-channel components of ebb tidal currents are also seen as a result of rotation of currents relative to a linear channel. Volume flow rates reach a maximum of 1,600 ft^3/sec during the flood tide, and a maximum of -1,240 ft^3/sec during the ebb tide at the entrance to Crows Pond.

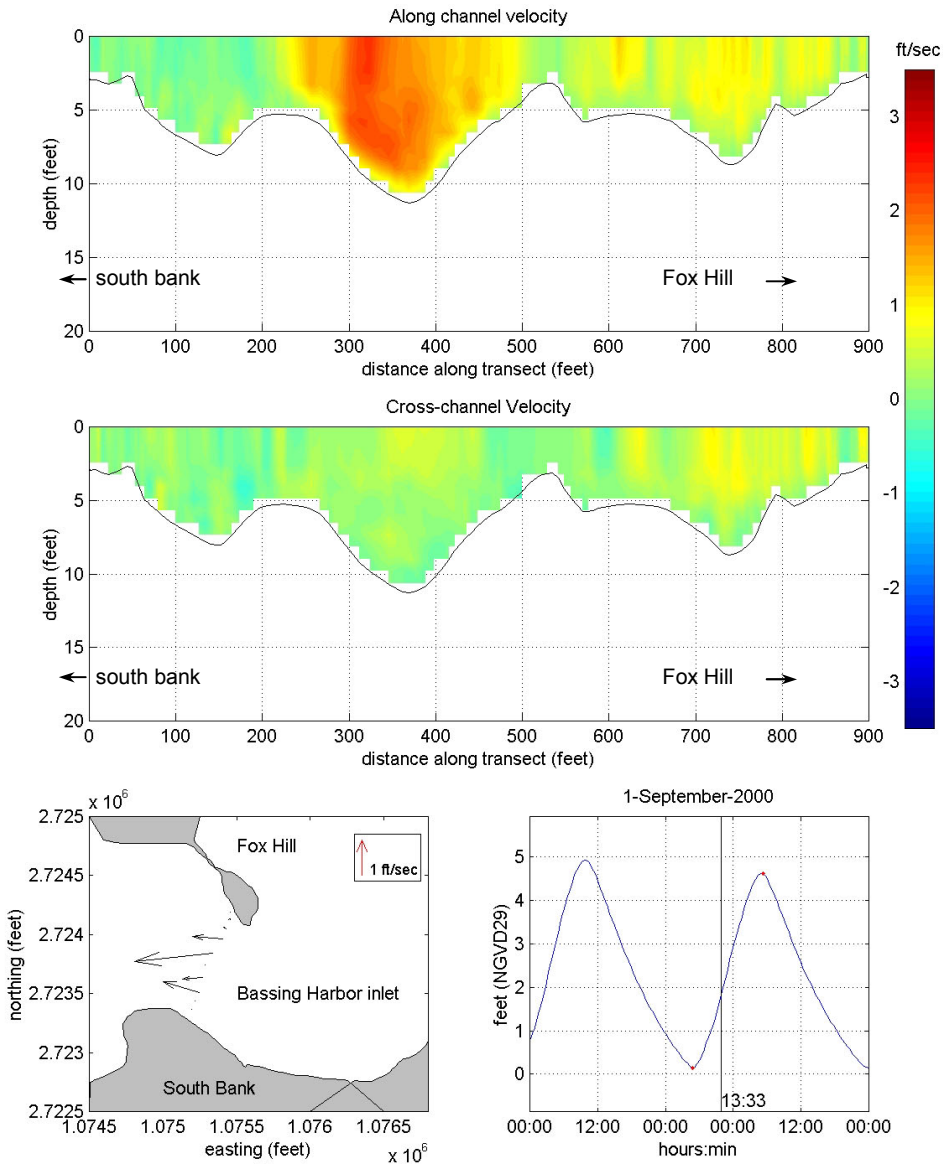

Figure V-34. Color contour plots of along-channel and cross-channel velocity components for transect line run south-to-north across the Bassing Harbor inlet measured at 13:33 on September 1, 2000 during the flood tide. Positive along-channel currents (top panel) indicate the flow is moving into the estuary, while positive cross-channel velocities (middle panel) are oriented 90° clockwise of positive along-channel.

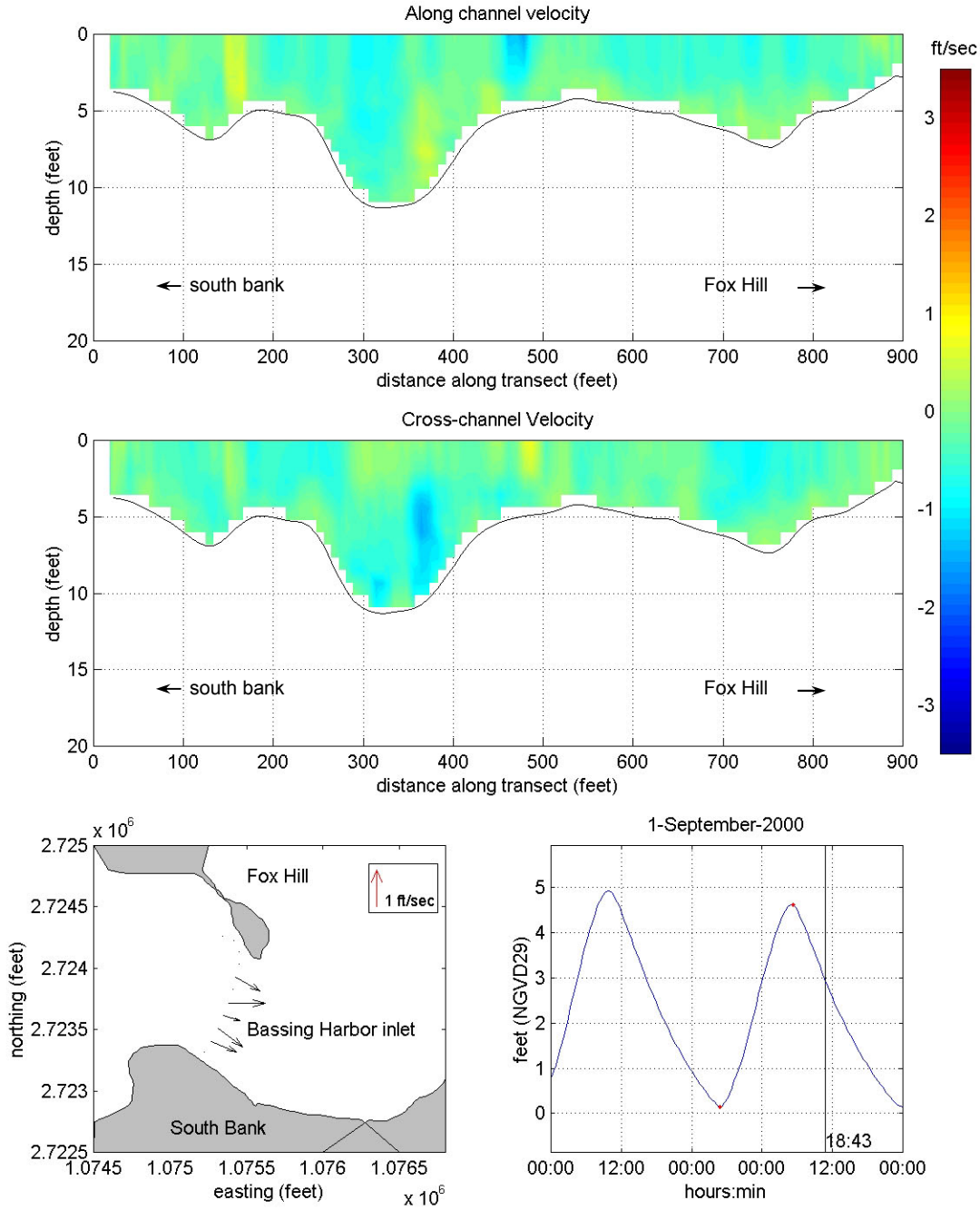

Figure V-35. Color contour plots of along-channel and cross-channel velocity components for transect line run south-to-north across the Bassing Harbor inlet measured at 18:43 on September 1, 2000 during the ebb tide. Positive along-channel currents (top panel) indicate the flow is moving into the estuary, while positive cross-channel velocities (middle panel) are oriented 90° clockwise of positive along-channel.

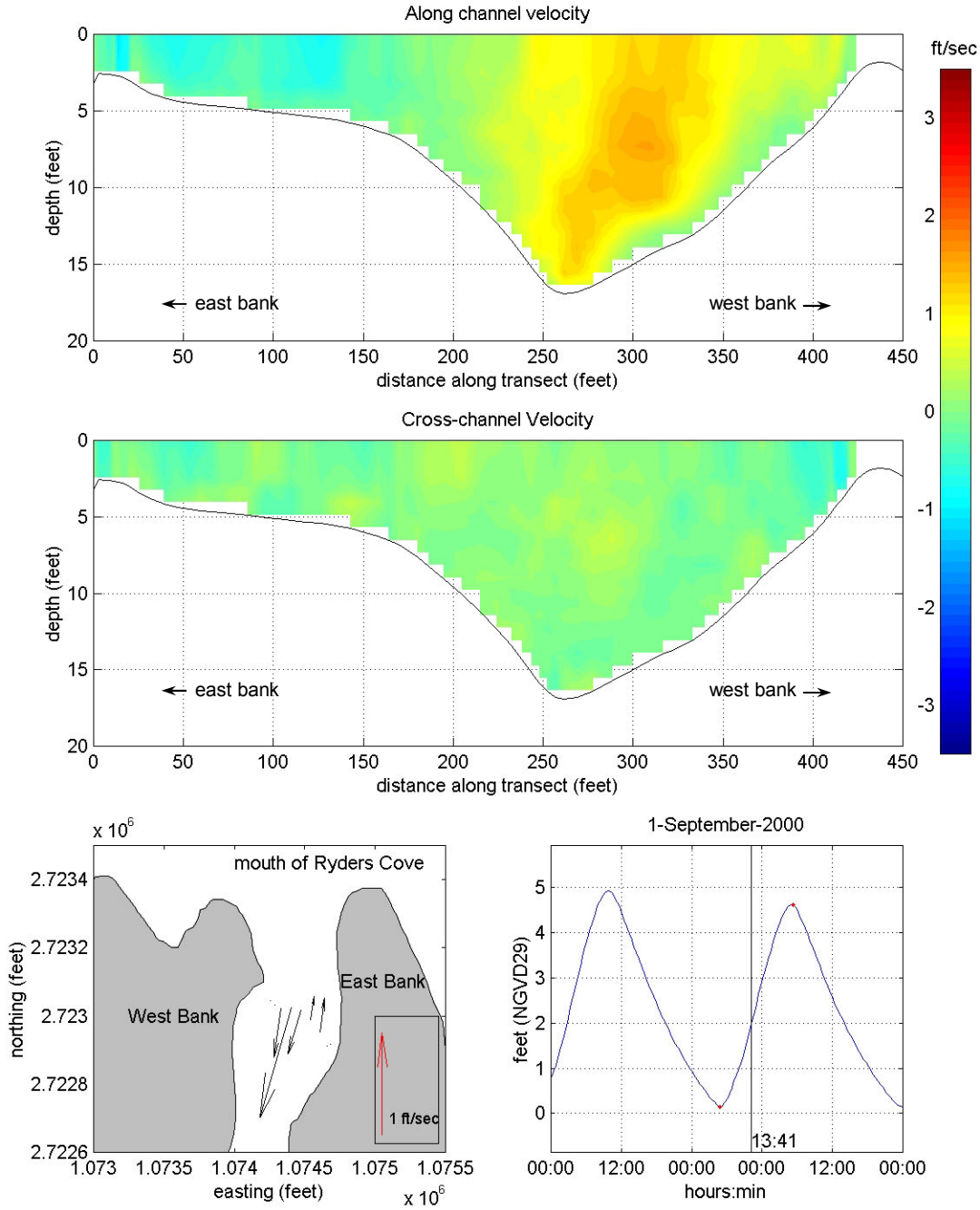

Figure V-36. Color contour plots of along-channel and cross-channel velocity components for transect line run east-to-west across the mouth of Ryder Cove measured at 13:41 on September 1, 2000 during the flood tide. Positive along-channel currents (top panel) indicate the flow is moving into the estuary, while positive cross-channel velocities (middle panel) are oriented 90° clockwise of positive along-channel.

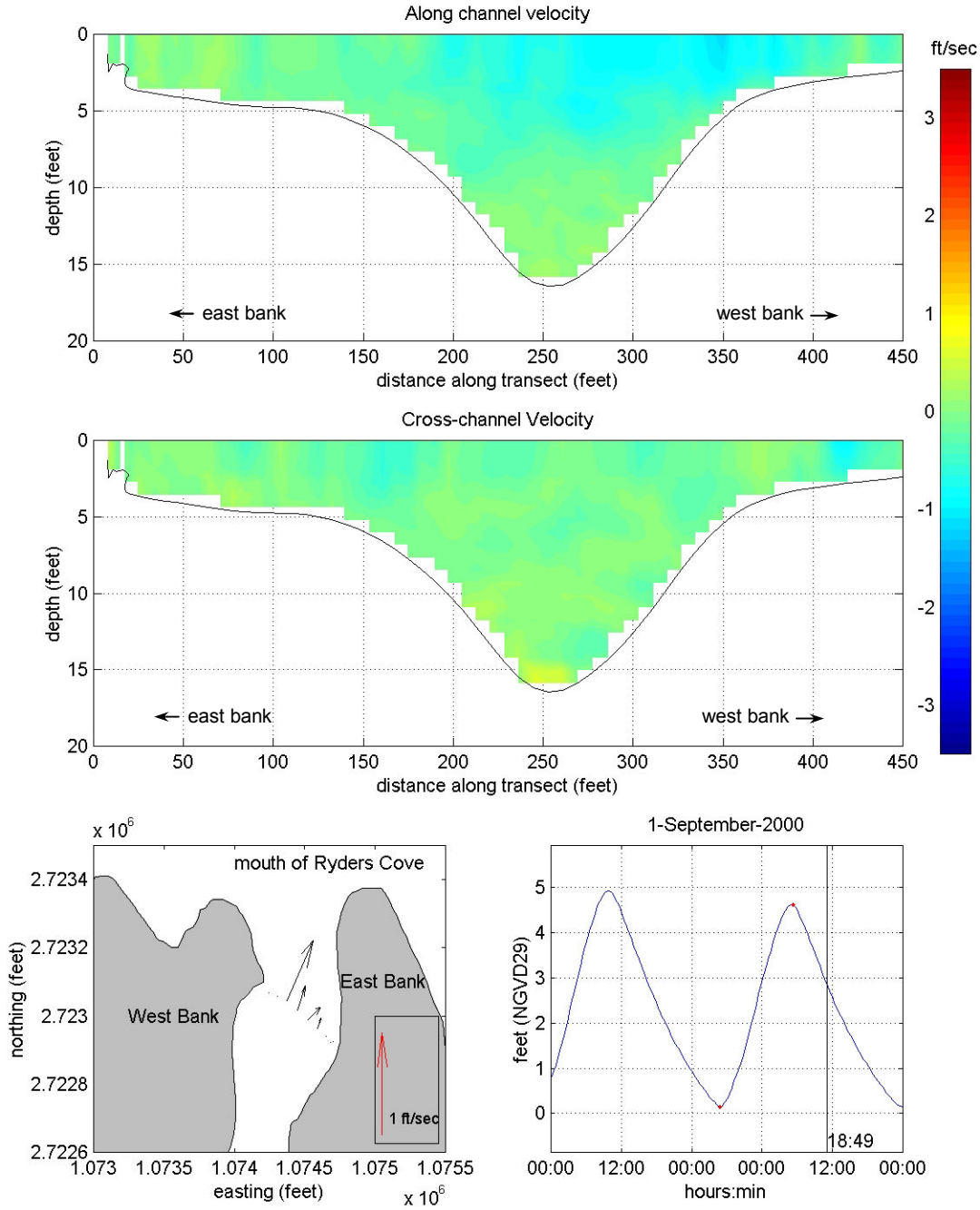

Figure V-37. Color contour plots of along-channel and cross-channel velocity components for transect line run east-to-west across the mouth of Ryder Cove measured at 18:49 on September 1, 2000 during the ebb tide. Positive along-channel currents (top panel) indicate the flow is moving into the estuary, while positive cross-channel velocities (middle panel) are oriented 90° clockwise of positive along-channel.

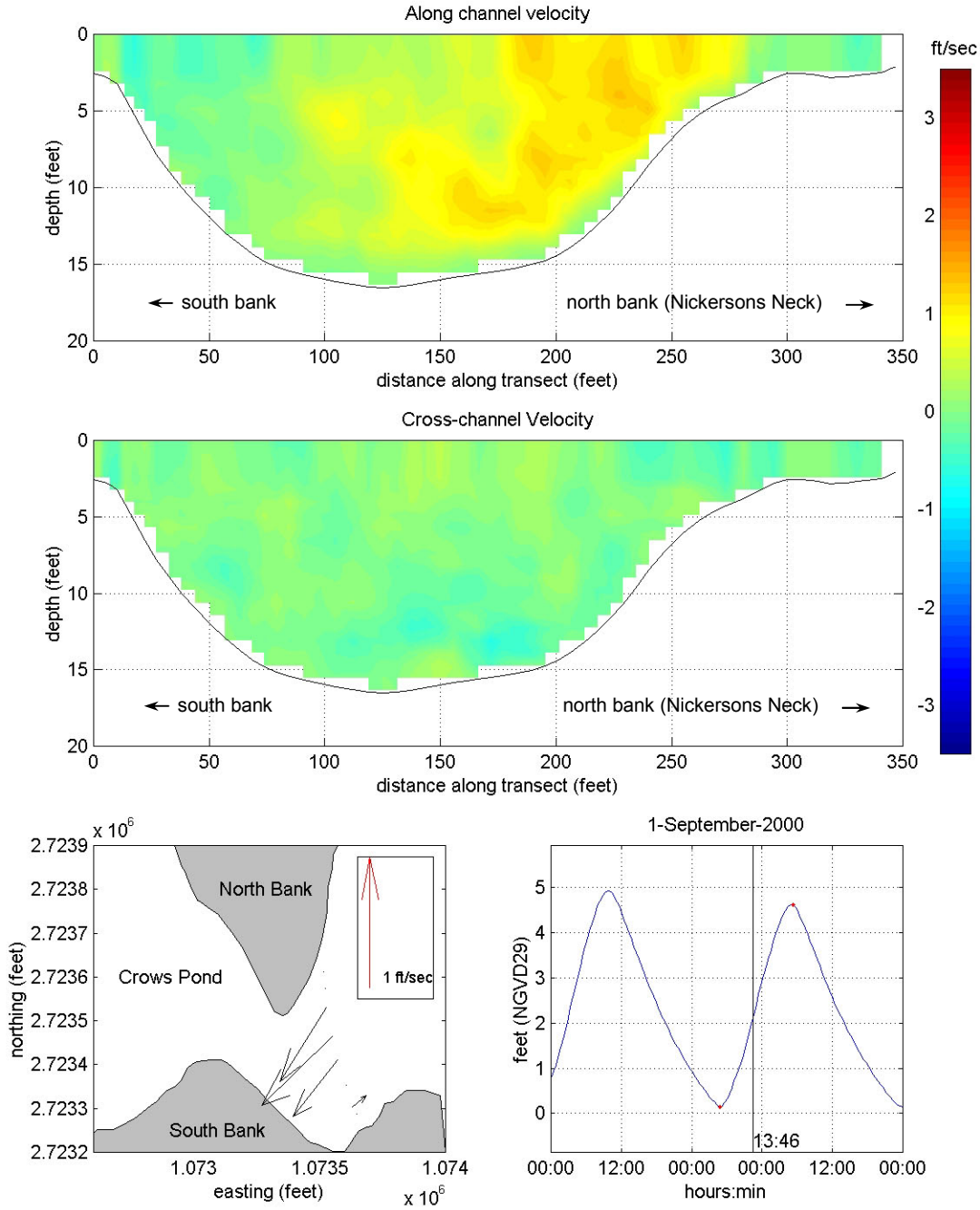

Figure V-38. Color contour plots of along-channel and cross-channel velocity components for transect line run south-to-north across the mouth of Crows Pond measured at 13:46 on September 1, 2000 during the flood tide. Positive along-channel currents (top panel) indicate the flow is moving into the estuary, while positive cross-channel velocities (middle panel) are oriented 90° clockwise of positive along-channel.

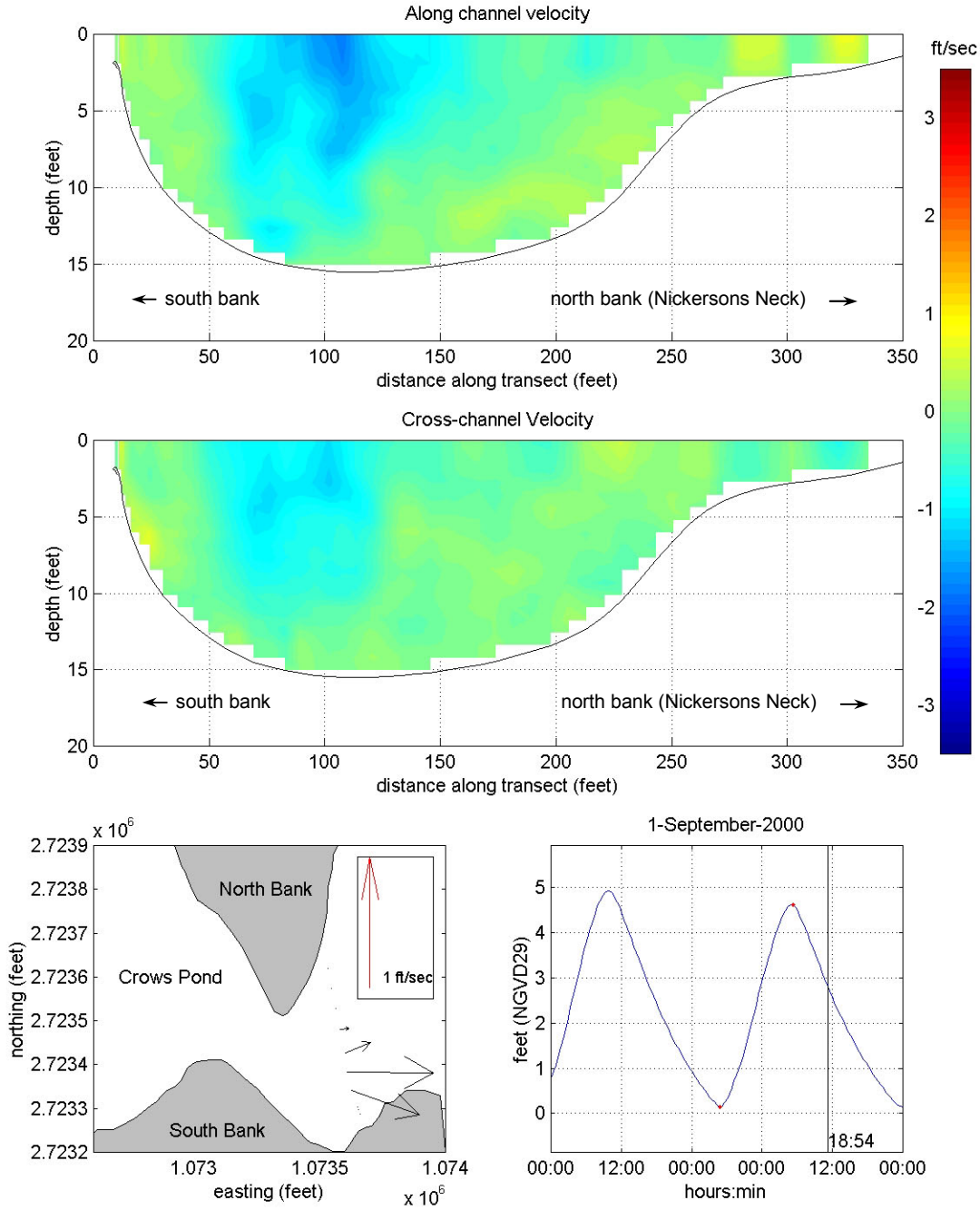

Figure V-39. Color contour plots of along-channel and cross-channel velocity components for transect line run south-to-north across the mouth of Crows Pond measured at 18:54 on September 1, 2000 during the ebb tide. Positive along-channel currents (top panel) indicate the flow is moving into the estuary, while positive cross-channel velocities (middle panel) are oriented 90° clockwise of positive along-channel.