ANALYSIS OF STREAM FLOW DATA

IN TIDAL STREAMS OF THE TEXAS COAST

(This report has been edited to only include Texas mid-coast streams)

Submitted to the Texas Parks and Wildlife Department
for
the Use Attainability Assessment Project

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ABSTRACT

Texas Parks and Wildlife Department (TPWD) has collected physical, chemical, and biological data on five tidal streams along the mid- Texas Gulf Coast in an effort to develop a standardized methodology for assessing health of tidal streams. As part of this project, the TPWD collected stream flow data in 2003 and 2004. The Texas Water Development Board (TWDB) then provided an analysis of this data for use in understanding water movements in tidal streams. Specifically, this report provides summary discharge and velocity data and when possible, results of analyses separating tidal and residual components of flow. All sites, discharge is highly variable and exhibits no pattern of seasonality. The highest recorded levels of discharge occurred in September 2003 in the mid-coastal. Directional flows and tidal currents were assessed at the middle station on all three streams. Generally, these stations showed characteristic oscillations in the magnitude or direction of water flow indicating tidal cycles influence stream flow at least as far upstream as the middle station. The relative contribution of tidal currents depended on downstream discharge, strength of the tidal cycle and river morphology. In the mid-coast streams, upstream current velocities frequently are as strong as downstream currents. Typically, downstream flows are much stronger than upstream flows but are weakened by the influence of tidal cycles. Tidally influenced streams may have instances of bi-directional flows, where a saltwater wedge pushes upstream beneath a surface layer of freshwater moving downstream. However, no instances of bi-directional flows were detected at any of the study sites, despite the influence of tidal cycles on freshwater stream discharge.

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INTRODUCTION

Tidal streams are important nursery habitats for many commercially important fish and shellfish found along the Gulf Coast of Texas. Some of these streams are listed as impaired but cannot be evaluated as such, because there is no generally accepted methodology for assessing the health of tidal streams. While instream flow is widely recognized as an influential component of stream health, few studies have documented the hydrology of tidal streams beyond the basic knowledge that tidal streams continually oscillate between freshwater and saltwater conditions as downstream freshwater inflow intersects tidal flow being carried upstream. The constantly changing conditions of tidal streams increase complexity of the stream ecosystem as well as complicate efforts to determine health and impairment according to more commonly employed methodologies.

The Texas Commission on Environmental Quality (TCEQ) and Texas Parks and Wildlife Department (TPWD) are working to develop a set of useful criteria for assessing aquatic life use within tidally influenced streams. In support of this effort, and under contract, the Texas Water Development Board (TWDB) has assisted TPWD project staff by processing and reporting flow data collected in 2003 and 2004 from three tidally influenced streams along the Texas Coast. TPWD project staff selected the study sites (West Carancahua Creek, Garcitas Creek and the Tres Palacios River) and collected stream flow data using Doppler technology. This report contains basic analysis of this data, including summary discharge and velocity data, as well as results of analyses conducted to separate tidal and residual components of flow and determine the presence of bi-directional flows.

METHODS

Study Sites

The TPWD selected 9 study sites on three tidally influenced streams in the Mid-Texas Coast (Table 1). Sites were selected as part of a broader study to determine the appropriate aquatic life use designation for these streams. Garcitas Creek and the Tres Palacios River were chosen, because data suggest they experience problems with low dissolved oxygen. West Carancahua Creek was selected to serve as references site for mid-coast region. All study streams included sites located at the upper, middle and lower reaches. A more complete description of each study site is provided in the TPWD's *Methodology for Determining Site-Specific Uses and Criteria within Tidally Influenced Streams in Texas.*

Table 1. Sites selected by the TPWD as part of a broader use attainability analysis of

tidally influenced streams along the Texas Coast.

Location on Texas Coast	Study Stream	Stream Reach	Station Name
Mid-Coast	West Carancahua Creek	upstream middle down stream	WC1 WC2 WC3
	Garcitas Creek	upstream middle down stream	GC1 GC2 GC3
	Tres Palacios River	upstream middle down stream	TP1 TP2 TP3

Data Collection by TPWD

Stream flow data was collected using a relatively new method employing acoustic Doppler technology, which measures water motion by transmitting sound through the water column at a fixed frequency and then measuring the Doppler-shifted echoes. The echoes are influenced by backscatter from scatterers (plankton and sediment) in the water and are converted to along beam (acoustic) velocity components. There are two main methods of deploying these instruments. The first involves mounting the instrument to a boat and making transects across an area of interest. The second involves mounting the instrument on a fixed structure, either on the river bed looking up or submerged at the river's edge looking sideways.

Boat-mounted SonTek River Surveyor acoustic Doppler current profilers (3 MHz; ADCP) were used to record instantaneous measurements of velocity and discharge in the stream channel. The bottom-mounted, up-looking SonTek Argonaut XR acoustic Doppler velocimeter (ADV) was used to measure stream flow direction and velocities over periods of time to include at least one complete tidal cycle. Both instruments use the same technology and provide a detailed level of cross-sectional data that is unprecedented in the history of stream flow data collection. Additionally, documents on appropriate techniques for use and analyses of these data have been made available from the U.S. Geological Survey (USGS) testing and open file reports (e.g., Rantz et al. 1982, Morlock 1996, Norris 2001, Morlock and Fisher 2002). Since different companies have different nomenclature for these instruments and since some instruments can be used in both roles, we refer to the boat-mounted current profilers as ADCP and the stationary up-looking velocimeters as ADV.

Measuring Stream Discharge

When performing water-current surveys covering large areas, or when monitoring river discharge, it is often convenient to use a boat-mounted system. Following the USGS basic stream flow protocol for collecting flow data with boat-mounted ADCPs (Norris 2001), the TPWD recorded instantaneous measurements of velocity and calculated volume transport at each of the 9 stations on all three streams for most sampling events occurring between April 2003 and November 2004 (Table 2). Flow measurements taken in April and May 2003 were made using RD Instruments Rio Grande ADCPs. These meters apply the same technology to measure flows as the SonTek ADCPs, which are the source of most data for this project. The only important difference is that software used by the RDI ADCP generated data files differing in format from the majority of data reported in this study.

Table 2. Number of ADCP transects conducted at study sites along five tidal streams on the upper and mid-Texas coast during 2003 and 2004.

Study Stream	Station Name	2003						2004					
		April	May	June	Aug	Sept	Nov	March	May	July	Aug	Sept	Nov
West Carancahua Creek	WC1	11	4	4	4	4	4	4	--	4	4	3	2
	WC2	5	5	4	4	4	4	4	--	4	4	4	3
	WC3	--	4	3	4	4	4	4	--	4	4	4	3
Garcitas Creek	GC1	2	4	4	4	2	4	4	8	4	4	3	3
	GC2	3	6	4	4	3	4	4	2	4	5	3	3
	GC3	2	4	4	4	4	4	4	5	4	4	3	3
Tres Palacios River	TP1	1	4	4	4	4	4	4	--	4	4	3	7
	TP2	1	4	4	4	4	4	4	--	4	4	3	7
	TP3	3	4	4	4	4	4	4	--	4	4	5	8

When operating from a moving platform, an ADCP measures relative currents. As such, it is important to measure independently the speed of the platform so that it can be subtracted from the instrument's measure of raw current. This procedure then establishes residual water currents relative to the fixed Earth. It is generally desirable to perform these calculations in real-time (SonTek 2005a). This usually is done either by the ADCP tracking the river bed (bottom-tracking) or by using differential GPS. Both techniques require driving the platform or boat along transects across an area of interest. During which time, velocities are measured in 'depth bins', which are accumulated to give total stream discharge for a stream cross-section. Hence, this technique can obtain very accurate instantaneous flow discharge measurements over a large area.

The USGS protocol recommends performing four transects in close succession at a site to establish accuracy of the stream discharge measurements. For typical streams under steady-flow conditions, the USGS expects replicate measurements of total discharge to differ by no more than 5% (Norris 2001). Expectations for this kind of agreement are unrealistic for tidal streams. Within a tidal stream segment, there is continual variation in the forces acting on stream waters. This complicates the implicit assumption that the four transects replicate flow. In tidal waters, the USGS therefore suggests reducing the time variant element in estimates of flow by using individual transects as representative measures of discharge (Norris 2001). This is in contrast to their recommendation to conduct more than four transects in turbulent water, but recognizes the difficulty of measuring discharge under rapidly changing conditions. Clearly, there is no standard methodology for tidal streams, but by conducting four or more transects the range of variability can be documented for future use in determining an appropriate methodology. Table 2 documents the number of transects conducted during each sampling event. Field conditions and scheduling problems occasionally interfered with meeting the objective of performing four transects. Cases with more than four transects reflect additional effort to ensure accurate measurements. All measurements of discharge for replicate transects were compared to assess typical variability in flow data during a sampling event. For each site and sampling event, ADCP transects were summarized and compared on the basis of total discharge (AbsQ). Total discharge is a function of the velocities measured by the instrument and a volume transport estimated in the cross-sectional areas where the instrument cannot record data.

ADCPs and ADVs (discussed separately below, see Measuring Velocity) cannot measure flow across the entire width of the channel. The ADCP technology and methods of deployment prevent measuring flow near the surface and bottom layer, as well as any portion of the channel too shallow for boat access. These non-measured areas must therefore be estimated. Discharge in the surface and bottom layers is estimated according to a power equation by the ADCP software. Discharge along the stream edges also is estimated according to an equation that the user selects based on the expected angle (steep or shallow) of the bank. In this equation, the distance between the last good measurement and the edge of the bank is necessary to accurately estimate flow along the non-measured edges. In large channels and rivers, the non-measured portion of the channel may be very small. For small streams and shallow bayous, the non-measured portion may be relatively large compared to the area directly measured. For comparison among the streams in this study, this is not likely to be a problem; however, the difference between measured and estimated discharge is documented.

Measuring Velocity

Time-series data is invaluable when investigating flow regimes affected by tidal currents and freshwater inflow, such as in these tidally influenced study streams. To measure variations in velocity and direction of stream discharge over time, up-looking acoustic Doppler velocimeters (SonTek Argonaut XR; ADV) were installed at the middle station in each of the study streams, for a total of three deployed instruments. Although ADVs were not deployed at upstream and downstream stations, the general impact of tidal ebb and flood on stream flow discharge was expected to be relatively greater at the downstream station and relatively weaker at the upstream station.

ADVs represent flow by averaging velocity across the water column from surface to bottom. They are usually either mounted on river beds looking upward or submerged at one edge of the river looking sideways. These instruments measure a cone-shaped segment of the water column over a user defined start and end distance. The cone is divided into 'bins' that are then averaged to obtain a measure of current velocity. Since ADVs can be installed for extended periods of time, they are useful for obtaining flow history at a site.

The Doppler technology employed by the ADV instruments is reliable for low flow situations, as is found in many coastal streams, because there is no minimum velocity detection level (SonTek 2005b). However as with any technique, there are concerns for establishing the accuracy and reliability of the data. One of the main drawbacks of these instruments is that based on the river profile and size there may be significant parts of the water column that are not captured by the cone of measurement. Although velocity measurements given by the ADV are reliable, measures of stream discharge may be inaccurate for this reason, though reliable estimates can be obtained by applying the ADV velocity data to a rating curve generated by ADCP data. Rating curves are determined from measures of stream discharge collected by an ADCP for various flow regimes. The USGS uses this technique for their stream gage program. Additionally, the USGS has established a considerable body of literature documenting and testing appropriate practices for using ADVs and analyzing associated data (e.g., Lipscomb 1995, Norris 2001). However, much of the literature concerns non-tidally influenced streams and it is not known how well these procedures work in tidal streams.

Analysis of Flow Data by TWDB

Data File Names

Raw data files were received from field operators with non-standardized names. In order to facilitate data analyses and for archival purposes, all files were renamed following a standard convention to enable accurate identification. Original and standardized file names for the ADCP data are given in Appendix 1. Field sheets accompanying the data provided definitive connection between the data file and field effort.

Processing of Flow Data

SonTek ADCP data was processed and exported through SonTek's River Surveyor and ViewADP software. The ViewADP software provides information about conditions during the time of data collection, as well as a graphic display of discharge rates across the river cross-section and quantitative measurements of river discharge and velocity. An example of this output is shown in Appendix 2A. The ViewADP software is limited in its ability to conduct more complex analysis. Hence, basic discharge data was obtained through a sequence of steps outlined in Appendix 3A. The basic data was then processed and analyzed using other scripts and FORTRAN programs (Appendix 3C, D). The results of which are presented in this report.

In April and May 2003, stream discharge data was collected using an ADCP from RD Instruments. Processing of this data is similar to the procedure described above for the SonTek ADCP, except that the transect summaries of discharge are given by RDIs WinRiver software (Appendix 2B). Processing with WinRiver also yields voluminous transect-specific data tables which can be processed to provide additional details about flow variation with depth and across the transect profile.

Processing of Velocity Data

SonTek ADV time-series velocity data was processed and exported using the SonTek ViewArgonaut software, similar to the procedure used for ADCP data. The ViewArgonaut software provides information about stream conditions during sampling including discharge summaries and velocity data. As with ViewADP, the ViewArgonaut software has limited ability for analyzing the data. Therefore, additional data processing was conducted using other scripts and FORTRAN programs (Appendix 3B). An example of such a file is given in Appendix 2C.

Calculating Rating Curves

Typically, ADCP data are used to provide a rating curve enabling stream flow discharge volume to be calculated from the time-series velocity data recorded by the ADV. This way a time series discharge measurement can be calculated for a particular location on the river. The UAA work was not designed to provide that information. However, because in most cases ADV and ADCP data overlapped in time, there may be data sets which can be used to suggest rating curves. Appendix 4 gives the basic procedure used to match data sets.

Detecting Bi-directional Flows

Bi-directional flows occur when both tidal and freshwater currents are equally strong and when channel depth is greater than the depth of mixing near the surface layer. Under these conditions, an inverse, or upstream, current may form along the stream bottom during flood tide. This strong salt wedge creates a vertical flow structure with the denser saltwater flowing upstream as less dense freshwater flows downstream. ADCP data from all events at all stations were examined for evidence of bi-directional flow. To detect bi-directional flows, average magnitude and direction of flow within each bin were plotted. In this format, evidence of bi-directional flows is indicated by at least a 120° change in the direction of water flow between adjacent bins.

Determining Tidal and Non-tidal Components of Flow

ADV velocity data provide a time series of average velocity for a segment of the water column. There are several methods that can be used to separate tidal currents from measured non-tidal currents, thus providing an indication of water movement resulting from tidal action as opposed to stream discharge and wind driven currents. The sub-tidal component is also called the residual or non-tidal component in time series analysis. In general, the accuracy of analysis, whether spectral, harmonic, or filtering, is dependent upon the length of measurement and the sampling interval. A longer time-series of data collection yields more accurate results. Because of the limited record of flow data, this study used a filtering method to quantify the tidal and residual currents, rather than the more commonly used method of harmonic analysis. Moreover, the filtering method was applied only to those data sets containing more than 60 hours of continuous measurement. This requirement was necessary to establish confidence limits for residual currents and for characteristics of the low-pass filter used here.

Several kinds of low-, high-, and band pass filters may be used to distinguish between tidal and non-tidal signals in the data. Following Doodson (1928), we used a low pass filter (Doodson X0) to extract the non-tidal components of flow from raw measurements. The Doodson X0 filter is a symmetric convolution low pass filter which does not lead to distortion due to time lag and is commonly used in oceanography. This technique is capable of quantifying the magnitude of non-tidal currents associated with freshwater and wind driven currents in tidally influenced areas. The classic method of averaging data for 24 hours to remove the tidal signal does not give accurate residual currents in tidally influenced areas, because the 24 hour average cuts off all frequencies that are multiples of one cycle per day. Therefore, it lets through a fair percentage of other tidal constituents. As a consequence, to determine pure residual flow a simple summation of data for 24 hours may result in a 15 - 20% error in the estimate of tidal currents. The low pass filtering method used herein has a 5% residual error for each component of velocity.

Assurance of Data Quality

Transect Agreement

The quality of flow measurements collected during a sampling event at each station was established by ensuring that replicate transects yielded discharge values within a 5% level of agreement. For each replicate transect i, agreement (Ai) between separate estimates of flow (Q_i) was determined by calculation of relative error and is expressed as:

$$A_i = \frac{\left|\hat{Q} - Q_i\right|}{\hat{Q}}$$

where $\hat{Q}$ is the mean flow value from all of the measurements made at a station during a sampling event, and Q_i is the flow measurement for transect i. Per USGS recommendation (Norris 2001), a transect measurement is considered "Good" when its calculated relative error is less than 5%. Additionally, a mean flow measurement for a sampling event is considered "Good" when all flows used in calculating the mean have relative errors less than 5%. A record of this calculation procedure for all ADCP measurements is given in Appendix 5. Table 3 provides an example of transect agreements for data recorded in June 2003. In general, replicate measurements of flow have better agreement when discharge is high than when it is low.

Table 3. Example transect agreements for replicate transects measuring volume transport in study streams during June 2003. Quality assurance is based on ADCP field measurements of flow (Q) and is not based on total flow (AbsQ), which would include estimates of flow along the surface, bottom, right and left banks. Transects with less than 5% relative error are defined as "Good" (Norris 2001). Appendix 5 records transect agreements for all sampling events.

Study Stream	Site	Year	Month	Transect Name	Q (cfs)	Mean Q (cfs)	Relative Error	Sample Quality
Cow Bayou	CB1	2003	June	COWUS0306251552	106	103.0	2.9%	Good
				COWUS0306251556	84		18.4%	Bad
				COWUS0306251600	98		4.9%	Good
				COWUS0306251603	124		20.4%	Bad
	CB2	2003	June	COWDS0306251830	528	526.3	0.3%	Good
Garcitas Creek	GC1	2003	June	GARUS0306241512	146	91.5	59.6%	Bad
				GARUS0306241519	133		45.4%	Bad
				GARUS0306241528	56		38.8%	Bad

Study Stream	Site	Year	Month	Transect Name	Q (cfs)	Mean Q (cfs)	Relative Error	Sample Quality
				GARUS0306241536	31		66.1%	Bad
	GC2	2003	June	GARMS0306241226	79	50.8	55.7%	Bad
				GARMS0306241237	55		8.4%	Bad
				GARMS0306241245	53		4.4%	Good
				GARMS0306241255	16		68.5%	Bad
	GC3	2003	June	GARDS0306241345	326	391.5	16.7%	Bad
				GARDS0306241358	407		4.0%	Good
				GARDS0306241408	410		4.7%	Good
				GARDS0306241417	423		8.0%	Bad
Tres Palacios	TP1	2003	June	TREUS0306250935	51	44.8	14.0%	Bad
				TREUS0306250942	54		20.7%	Bad
				TREUS0306250948	60		34.1%	Bad
				TREUS0306250954	14		68.7%	Bad
	TP2	2003	June	TREMS0306250838	34	19.0	78.9%	Bad
				TREMS0306250847	9		52.6%	Bad
				TREMS0306250856	9		52.6%	Bad
				TREMS0306250902	24		26.3%	Bad
	TP3	2003	June	TREDS0306250739	351	276.3	27.1%	Bad
				TREDS0306250742	351		27.1%	Bad
				TREDS0306250746	194		29.8%	Bad
				TREDS0306250749	209		24.3%	Bad
West Carancahua	WC1	2003	June	CARUS0306241931	59	69.0	14.5%	Bad
				CARUS0306241941	74		7.2%	Bad
				CARUS0306241946	74		7.2%	Bad
	WC2	2003	June	CARMS0306241850	14	12.5	12.0%	Bad
				CARMS0306241854	19		52.0%	Bad
				CARMS0306241858	8		36.0%	Bad
				CARMS0306241902	9		28.0%	Bad
	WC3	2003	June	CARDS0306241759	864	885.3	2.4%	Good
				CARDS0306241803	810		8.5%	Bad
				CARDS0306241808	891		0.6%	Good
				CARDS0306241812	976		10.3%	Bad

Cross-sectional Area of Study Sites

Study sites differ in cross-sectional area with downstream sites having much larger channels. Mid-coastal sites generally have a steady increase in cross-sectional area between the upstream and downstream stations. Figure 4 does not include area estimates for the surface and bottom blanking distances nor for the shallow edges along the bank.

Table 4. Mean cross-sectional area (ft2) ± SD of all stations on study streams. Mean area was determined based on measurements recorded by the SonTek ADCP. Estimates do not include areas associated with the surface and bottom blanking distances or shallow edges. Figure 1 provides a graphical representation of this information. Therefore, estimates of cross-sectional area should not be used to calculate channel discharge from the ADV data.

Stream Station	West Carancahua	Garcitas Creek	Tres Palacios River
1	712 ± 77	816 ± 289	833 ± 119
2	739 ± 80	1,256 ± 347	1,168 ± 153
3	1,391 ± 296	1,785 ± 349	1,203 ± 267

Interpreting Vector Plots

Velocity vectors are displayed in time-series plots, which visually demonstrate the dynamics of flow in these tidal streams showing both daily variation and inflow events (Figs. 2 - 9). Measurement velocities are given in northward, eastward and upward components. Resultant velocity vectors were calculated using standard geometric methods. All velocity plots indicate north, and for all sites except West Carancahua Creek, upstream currents are represented by vectors pointing northward and downstream currents are represented by vectors pointing southward. At West Carancahua Creek, river currents flow east to west; hence, northward vectors represent downstream flow and southward vectors represent upstream flow.

Tidal Filtering of Time-series ADV Data

For those events in which sufficient data were collected (>60 hours of continuous measurement), tidal flow and residual flows were extracted from the raw time-series data (Figs. 10 - 12). The accuracy of ADV measurements is ±0.5 cm/s, which is suitable for this analysis as flows with velocities less than 0.5 cm/s were not considered in the analyses presented herein.

RESULTS

Flow data (discharge and velocity) was recorded in three tidal streams. The coastal streams studied are small, with limited channel inputs between stations. Instantaneous discharge measurements (ADCP data) were collected at all study sites, when possible, during 12 sampling events between April 2003 and November 2004. Generally, replicate measures of flow were not sufficiently consistent (within the USGS recommended 5% agreement) to calculate mean discharge with confidence according to USGS procedures. However, recognizing the dynamic nature of tidal streams and the difficulty associated with obtaining accurate measures of flow, mean discharge was calculated based on all reasonable recorded estimates of stream discharge (AbsQ) to provide a general estimate of mean discharge (ft3/s) at each site during each event (Table 3) and over time (Table 5; see also Appendix 6).

This study is among the first to use Doppler technology to quantify flow within the shallow tidal streams along the Texas Gulf coast. Presently, there is no accepted methodology for analyzing and reporting flow data under such conditions, except to take upwards of eight transects per site per event or to report only the values obtained for one transect (Norris 2001). Following the USGS standard protocol of conducting four transects, this study documents variation in stream discharge and velocities over relatively short periods of time in tidal streams. In addition to stream discharge, time-series of current velocity measurements (ADV data) were collected from the middle station in each study stream between June 2003 and November 2004. Although results of analyses for each site are discussed below, a few general patterns regarding stream discharge at these sites are worth noting here.

Peak flows were recorded in September 2003 at sites along the mid-Texas (Table 5). When the two years are considered separately, peak flows occurred in different months. For the Mid-coast sites in 2004, recorded peak flows occurred in different months for each station (Table 5), though the highest flows probably occurred in May 2004. Stream discharge in May 2004 was recorded only at Garcitas Creek, due to flooding at West Carancahua and Tres Palacios. Peak flows did not occur in August at any site in either year.

Detecting Bi-directional Flows

Stream discharge measurements were recorded at a total of 9 tidally influenced stations in three coastal streams. Out of all events recorded at these sites between June 2003 and November 2004, none exhibited bi-directional flows. If such flows had been recorded, they would have been identified by a change of 120° or more in the direction of flow between recorded bins. In this data set, the maximum difference in directional flow between adjacent bins was 63°.

Table 5. Mean discharge (ft3/s) at study sites on three tidal streams on the mid-Texas coast. Means were calculated from estimates of volume transport given by replicate transects obtained using an ADCP during each sampling event between April 2003 and November 2004. Mean discharge in each month was determined using all replicate transects with reasonable estimates of discharge. Additional descriptive statistics are provided in Appendix 6B.

Study Stream	Site Name	2003						2004					
		April*	May	June	Aug	Sept	Nov	March	May	July	Aug	Sept	Nov
West Carancahua	WC1	107	141	108	158	691	62	98	--	78	140	354	97
	WC2	244	96	26	82	729	149	69	--	29	112	405	59
	WC3	--	557	1,645	1,105	2,965	774	845	--	545	127	274	672
Garcitas	GC1	172	76	142	57	1,345	118	141	--	38	29	355	34
	GC2	186	426	97	138	1,631	336	314	--	86	199	813	217
	GC3	218	555	559	102	1,922	251	823	--	30	222	274	95
Tres Palacios	TP1	31	182	53	375	3,513	--	184	--	113	213	34	859
	TP2	497	401	41	404	3,605	58	173	--	141	80	244	1,993
	TP3	1,050	1,409	458	345	4,302	639	121	--	918	74	207	2,146

* Replicate measures of mean discharge during most events was not sufficiently consistent (within USGS recommended 5% agreement) to calculate mean discharge with confidence. Values are reported here to provide a general estimate of stream discharge at these sites.

Table 6. Mean discharge (ft3/s) ± SE over time (from April 2003 to November 2004) for each study site on three tidal streams on the Mid-Texas coast. Mean discharge was determined using all replicate transects with reasonable estimates of discharge. Additional descriptive statistics are provided in Appendix 6A.

Stream Station	West Carancahua	Garcitas Creek	Tres Palacios River
1	184 ± 27	183 ± 49	625 ± 183
2	186 ± 32	575 ± 150	642 ± 169
3	958 ± 130	692 ± 158	1,085 ± 195

Flow Characteristics of Tidal Streams on the Mid-Texas Coast

Flow data was recorded in three tidal streams on the mid-Texas coast; West Carancahua Creek, Garcitas Creek, and the Tres Palacios River. All streams drain into the Matagorda Bay system. West Carancahua Creek is located in Jackson County and is a tributary of Carancahua Creek which flows into Carancahua Bay. Garcitas Creek demarcates the boundary of Victoria and Jackson counties and flows into Lavaca Bay. The Tres Palacios River is located in Matagorda County and flows into Tres Palacios Bay. Considering the geographic characteristics of these sites, river discharge will be subjected to tides, local rainfall, winds, and resonance of bays. Mean discharge over time at the downstream station of each stream was calculated including all sampling periods from May 2003 to November 2004. Mean discharge over time was highest at the Tres Palacios River (1,085 ft3/s ± 1,262) as compared to West Carancahua Creek (958 ft3/s ± 812) and Garcitas Creek (692 ft3/s ± 1,011). As with sites on the Upper Texas Coast, flow was highly variable in these mid-coastal streams. See Table 5 to compare stream discharge at each station during each sampling event, Table 6 for mean discharge at each station for the period April 2003 to November 2004, and Appendix 6A for additional descriptive information. Within this data set, simultaneous measures of current velocity were collected at the middle station in all three streams during July 2004. For this date only, flow at these stations is directly comparable.

West Carancahua Creek

West Carancahua Creek – Flow Characteristics

Mean discharge over time at the upstream and middle stations in West Carancahua Creek was low (<190 ft3/s; Table 6). Though flows were variable, they were relatively low similar to the upstream and middle stations on the Tres Palacios River and Garcitas

Creek (Figs. 13, 14). The downstream station on West Carancahua Creek had greater discharge, ranging 125 to 3,000 ft3/s with a mean of 960 ft3/s (Table 5 and Appendix 6B). In June 2003, current velocity was measured for less than 36 hours. Therefore, it is difficult to interpret patterns of flow for this event (Fig. 2A). In August 2003, currents were measured for a longer time period and the sampling interval overlapped with measurements taken at the middle station on the Tres Palacios River. From these data, we know that current velocities in West Carancahua Creek (Fig. 2B) were substantially lower than at Tres Palacios (Fig. 7B). Although current velocities also were lower than at Garcitas Creek (Fig. 4B), the streams were sampled on separate days and so are not directly comparable. Mean stream discharge at all three sites in August 2003 was relatively low (Fig. 13D). Consistent downstream flows were recorded at West Carancahua Creek during the September 2003 sampling period, and current direction appears to have no influence from the tidal cycle (Fig. 2C). Note strong downstream currents at the Tres Palacios station for this same time period (see below, Fig. 7C). In November 2003, current velocities were very low, but showed upstream and downstream flows consistent with tidal events (Fig. 2D). Current velocity was nominal during March 2004 with no strong directional currents recorded (Fig. 3A). In May 2004, the Argonaut was deployed for a week at the midstream site where it captured strong downstream currents (>1ft/s) for a three day period (Fig. 3B). July 2004 measurements of velocity again were relatively low with some tidal influence indicated by the changing direction of currents (Fig. 3C). November 2004 measurements were insufficient to characterize current velocity or direction (Fig. 3D).

West Carancahua – Tidal Influence on Stream Discharge

In total, eight sampling events recorded stream flow data from West Carancahua Creek. However, the filtering method used to separate tidal and residual flows was applied only to data collected in May 2004 (Fig. 10). During the five day recording period, residual currents were strongly downstream (Fig. 10C), thus preventing the detection of tidal currents by the low pass filter method (Fig. 10B).

Garcitas Creek

Garcitas Creek – Flow Characteristics

The five downstream stations selected for study represent locations that are most likely to be influenced by tides in each of these streams. When comparing mean discharge over time among the downstream stations, Garcitas Creek had the lowest mean discharge (690 ft3/s) of the five streams (Table 6; Figs. 13, 14). Current velocities were measured for only one day in June 2003 and August 2003, during which flow was influenced by tidal changes as indicated by the changing direction of vectors in Figs. 8a and 8b, respectively. In September 2003, flows at Garcitas Creek were downstream and showed no tidal influence (Fig. 4C). This may be due to a recent rainfall event increasing the level of instream flow or due to winds. During November 2003 and

March 2004, measured flows were low and influenced by tidal cycles (Figs. 4D, 5A). Measurements taken in May 2004 are erratic, but show a curious abrupt change in flow around noon on May 13 (Fig. 5B). At this time, flows were strongly downstream for several hours. In July 2004, flow measurements recorded over two days indicated some tidal influence with flows directed upstream between intervals of downstream flow (Figs. 5C, 11). These results are similar to those found at the middle Tres Palacios station (Fig. 8C) and West Carancahua Creek (Fig. 3C) during this same time period. Current velocity was fairly strong during the sampling period in August 2004 with distinct upstream and downstream periods of flow (Fig. 6A) that appear to be strongly influenced by tidal currents (Fig. 12B). A similar pattern of flow occurs again in September 2004. Velocities are stronger, possibly due to spring tides which create a large difference between high and low tide (Fig. 6B). November 2004 data is erratic and uninformative (Fig. 6C).

Garcitas Creek – Tidal Influence on Stream Discharge

Ten sampling events recorded stream flow data from Garcitas Creek. Of these, data from two sampling events were processed to separate tidal and residual flows (July and August 2004). The remaining data was not sufficient in length to resolve tidal and residual currents. The combined period of time for these two dates provided measurements across five tidal cycles, but from each event, the filtering process yielded results for only one tidal cycle (Figs. 11B, 12B). Generally, current velocities were weak, and tidal currents were stronger than residual currents, thus influencing the direction of flow in Garcitas Creek.

Tres Palacios River

Tres Palacios River – Flow Characteristics

Mean discharge over time (from May 2003 to November 2004) at the downstream station on the Tres Palacios River was the highest of all three mid-coastal study streams (Table 6). While mean discharge over time at the upper and middle stations on the Tres Palacios was only 60% of that at the downstream station, these estimates for the Tres Palacios River, as well as for other mid-coast study streams, were influenced by the high values measured in September 2003. At all stations on the Tres Palacios River, mean discharge in September 2003 was two to six times higher than in any other month. When the estimate of mean discharge over time excludes such extreme events, the upstream-downstream pattern of discharge remains the same, though the values are much lower (ranging 250 ft3/s to 745 ft3/s, rather than the reported mean values of 625 ft3/s to 1,100 ft3/s, Table 6).

Velocity measurements at the middle station on the Tres Palacios River generally were not collected for more than 24 hours, thus making it difficult to characterize patterns of flow. In June and August 2003, tidal influences are apparent in the short-time series of available data (Fig. 7A, B). August 2003 data was collected during the same tidal period for the Tres Palacios and West Carancahua Creek. Though a detailed comparison is difficult to conduct with this data, two features are readily apparent. First, flow in the Tres Palacios River (Fig. 7B) had much higher velocities than in West Carancahua Creek (Fig. 2B). Second, the strength of the tidal signal indicated by the direction of currents is stronger in the Tres Palacios River. In September 2003, flow was uniformly downstream and very strong (Fig. 7C). Current velocities in November 2003 and March 2004 were relatively weak, but exhibited flow patterns indicative of tidal influences (Figs. 7D, 8A). Again, in May 2004 stream flow was consistently downstream during the 24 hour sampling period (Fig. 8B).

In July 2004, current velocities in all mid-coastal study streams were measured during the same 48-hour period which allowed for comparison of flows among streams. Flows in the Tres Palacios and in Garcitas Creek were similar in magnitude with a similar pattern of switching between phases of upstream and downstream flow (Fig. 8C and Fig. 5C, respectively). West Carancahua Creek, however, had lower current velocities and the tidal signal is not as distinct (Fig. 3C). Flows measured in August and September 2004 at the middle station on the Tres Palacios indicate a fairly strong current with directional changes over the 24 hour period (Fig. 9A, B). November 2004 flows were much weaker but still exhibited signs of tidal influence (Fig. 9C).

Tres Palacios River – Tidal Influence on Stream Discharge

Ten sampling events recorded stream flow data at the middle station on the Tres Palacios River; however, none of the time series were long enough to apply the filtering method.

DISCUSSION

Using data collected by the TPWD between April 2003 and November 2004, herein the TWDB has documented and characterized basic patterns of flow in three streams on the mid-Texas coast. The coastal streams studied are small, with limited channel inputs between stations. Flow within streams and at particular stations is highly variable over time. Peak flows occurred in May, June, September and November. Flows were generally lower in April and August at all sites. However, infrequent events (as in September 2003 and May 2004) resulted in extremely high levels of stream discharge that exceed by 20 to 40 times the lowest recorded measures. Although during these events all study sites (upper, middle and downstream reaches) on a particular stream increase in flow, generally, flows at upstream and middle stations are nearly half of the measured flows at the downstream station.

For the mid-coast region, mean flow was highest in the Tres Palacios River. For all study streams, tidal influence in the middle reaches was documented by characteristic oscillations in the direction and magnitude of flow. This oscillation pattern is present during most events indicating regular tidal influence. There is no similarly recorded information for the upstream and downstream stations. However, tidal influence was expected to be relatively greater at downstream sites. For the upstream sites, tidal influence was expected to be weaker. Because the relative contribution of tidal currents depended on downstream discharge, strength of the tidal cycle and river morphology, under low flow conditions or during a weak tidal cycle, upstream stations may not be influenced by tides. Additional data collection will be required to address this point.

The narrow width and shallow depth of the study streams, combined with the ameliorating effects of the bays and estuaries, decrease the likelihood that tidal currents will create a salt-wedge and hence bi-directional flow within the water column. However, the absence of bi-directional flows in the study streams does not indicate a lack of tidal impact, but rather the absence of a distinct layer of freshwater overlying saltwater within the water column at sites in the middle reaches of these study streams during the periods of observation. Tidal impact to flow was evident in the varied estimates of stream discharge obtained from replicate transects (ADCP data) during sampling events.

The results of this study provide a quantitative assessment of the influence of tidal cycles on flows within coastal streams and rivers. However, additional studies are needed to determine an appropriate methodology for collecting and analyzing flow data in tidally influenced streams. Such a methodology will help to standardize measurements, thus reducing variation and improving estimates of tidal influence. From this point, it then will be possible to better assess the impacts of tidal cycles on aquatic life use of coastal streams, particularly in relation to seasonal variation in instream flow.

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The report was compiled by Carla Guthrie from information and data analyses provided by various members of the Bays and Estuaries staff and from comments by Dave Buzan, Cindy Contreras, Janet Nelson, Jim Tolan, and Adam Whisenant

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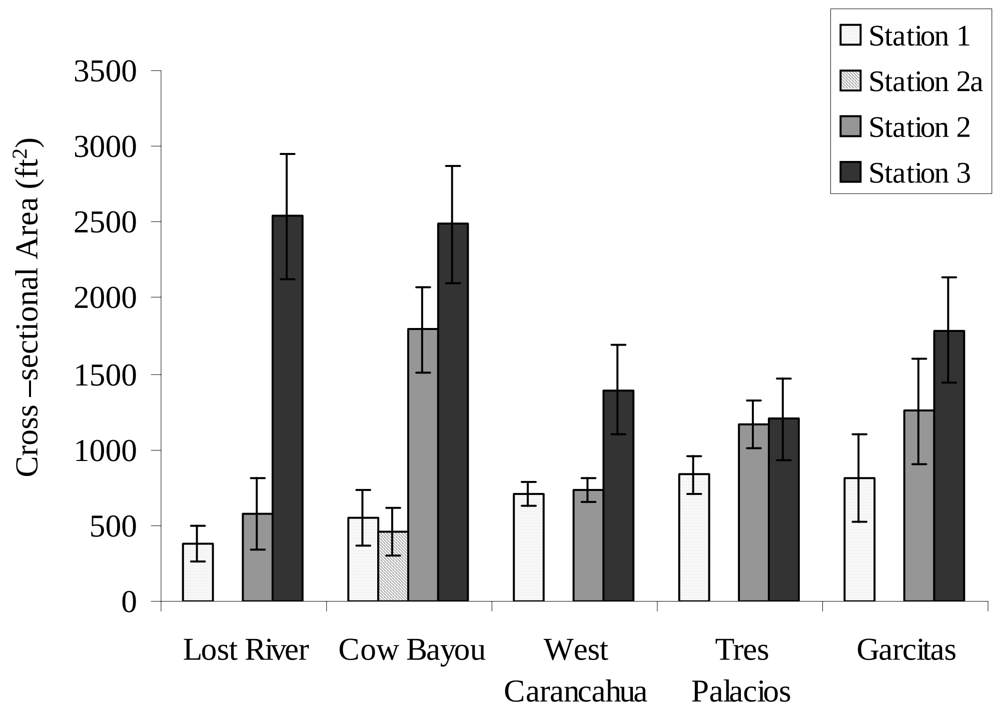

Figure 1. Mean cross-sectional area of stations on all study streams. Mean area was determined based on measurements recorded by the SonTek ADCP. Estimates do not include areas associated with the surface and bottom blanking distances or shallow edges. This figure shows the dramatic increase in cross-sectional area between upstream and downstream sites for the Upper Texas Coast (Lost River and Cow Bayou), as compared to the Mid-Coast sites (West Carancahua Creek, Tres Palacios River and Garcitas Creek).

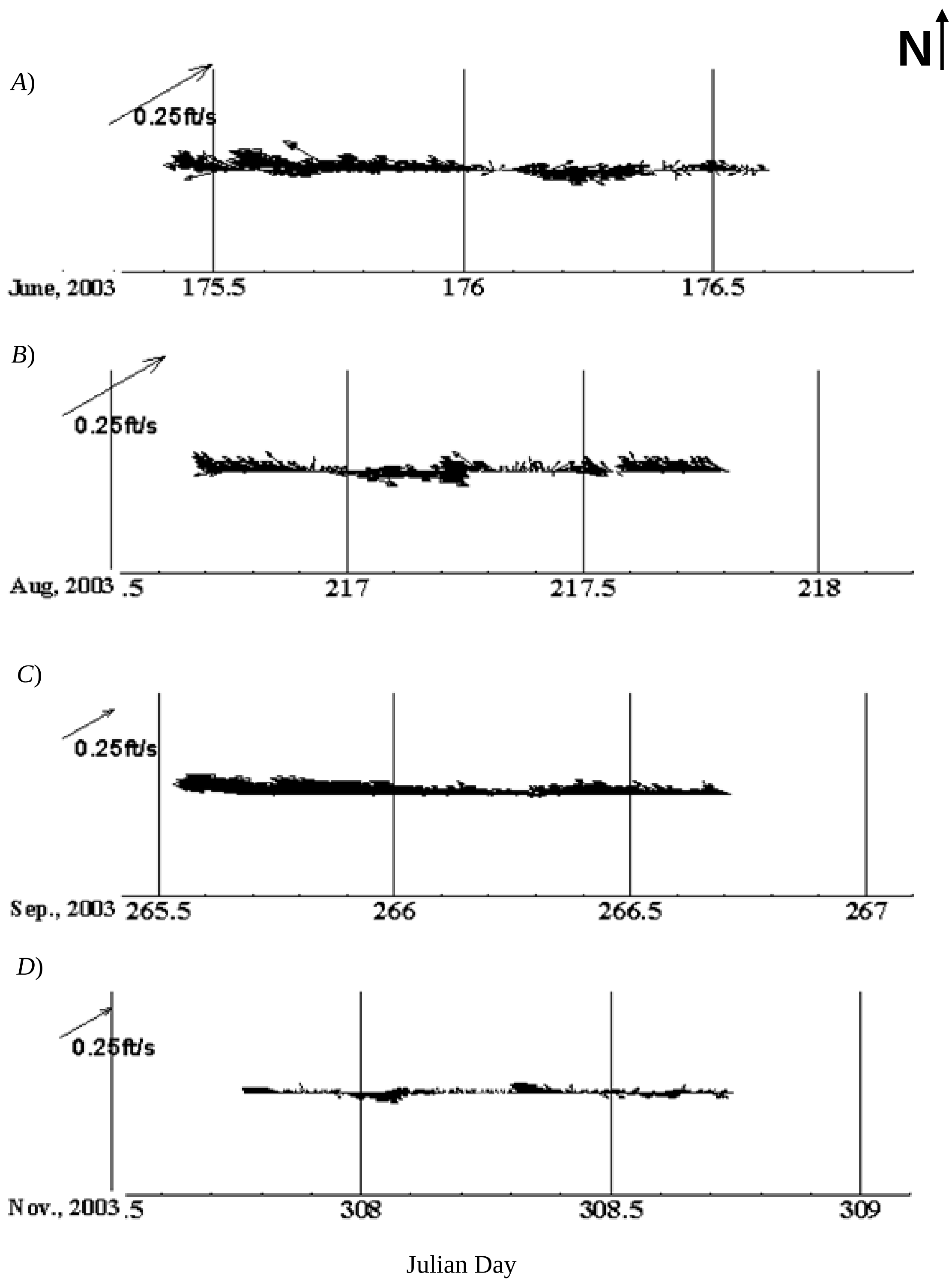

Figure 2. Total current velocities measured at West Carancahua Creek in 2003. (*A*) 24-25 June, (*B*) 4-5 August, (*C*) 22-23 September, and (*D*) 3-4 November. *x*-axis is Julian day with half day intervals noted by vertical gridlines. Upstream is indicated by southward pointing vectors.

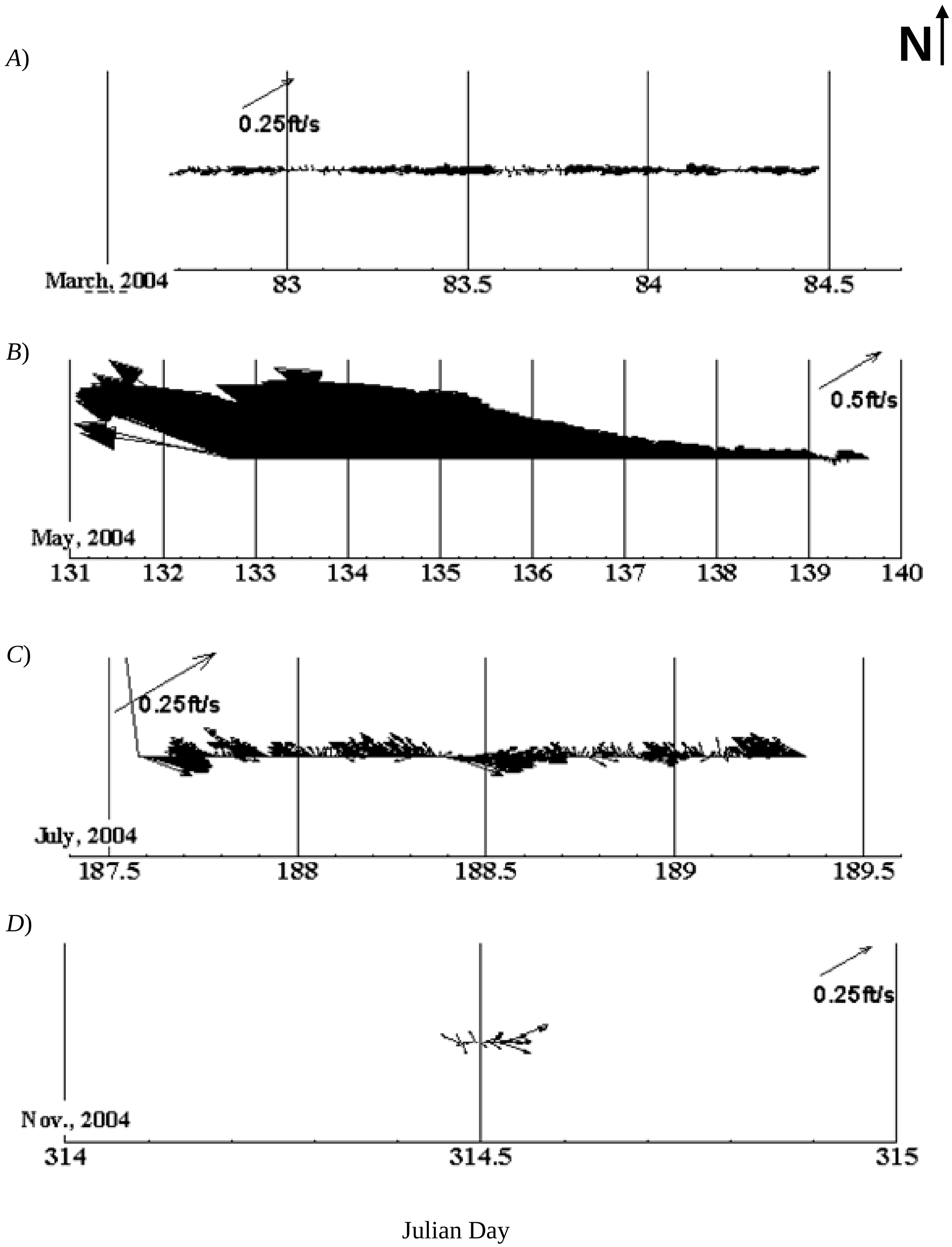

Figure 3. Total current velocities measured at West Carancahua Creek in 2004. (*A*) 23-24 March, (*B*) 12-19 May, *(C)* 6-8 July, and (*D*) 10 November. *x*-axis is Julian day with half day intervals noted by vertical gridlines. Upstream is indicated by southward pointing vectors.

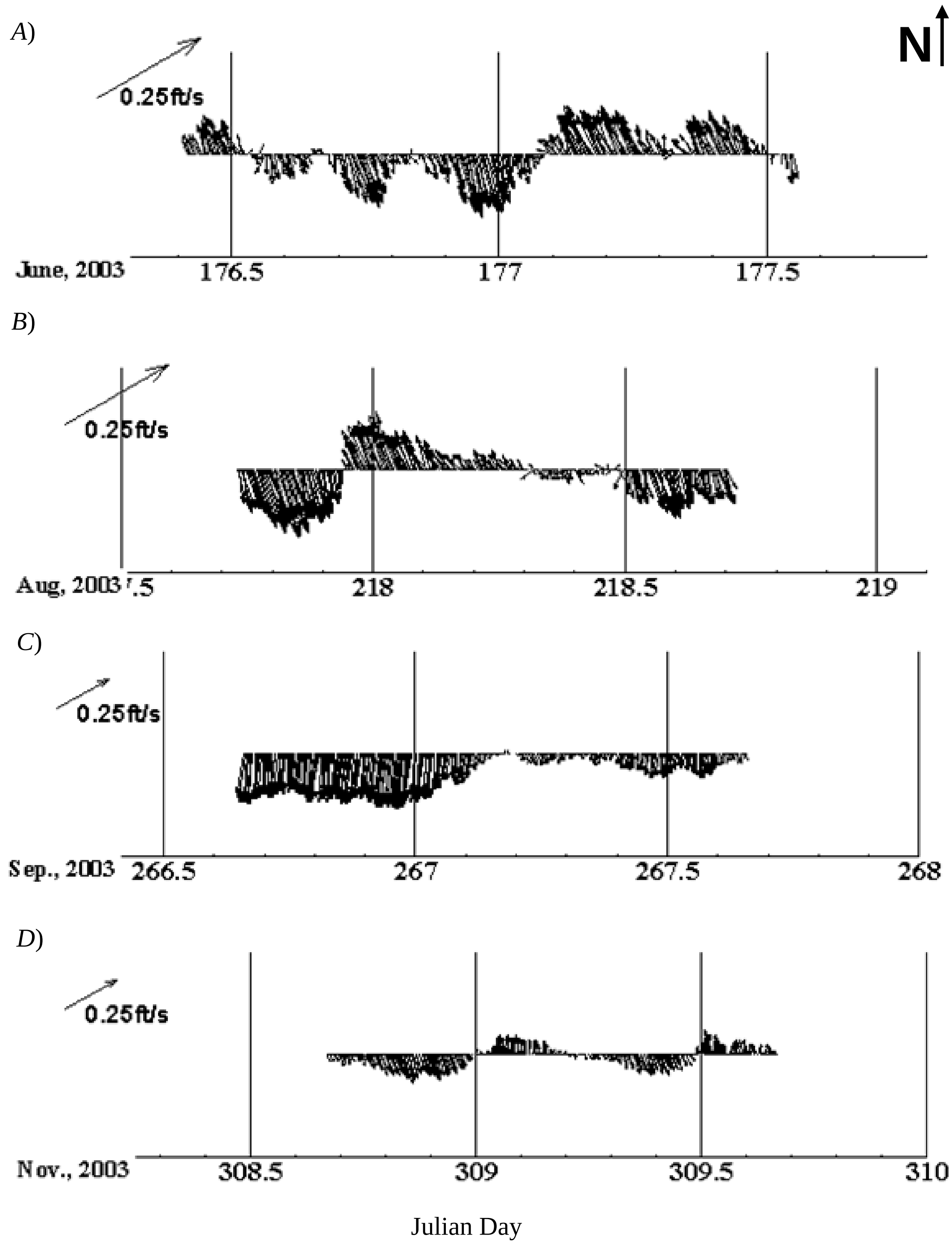

Figure 4. Total current velocities measured at Garcitas Creek in 2003. (*A*) 25-26 June, (*B*) 5-6 August, (*C*) 23-24 September, and (*D*) 4-5 November. *x*-axis is Julian day with half day intervals noted by vertical gridlines. Upstream is indicated by northward pointing vectors.

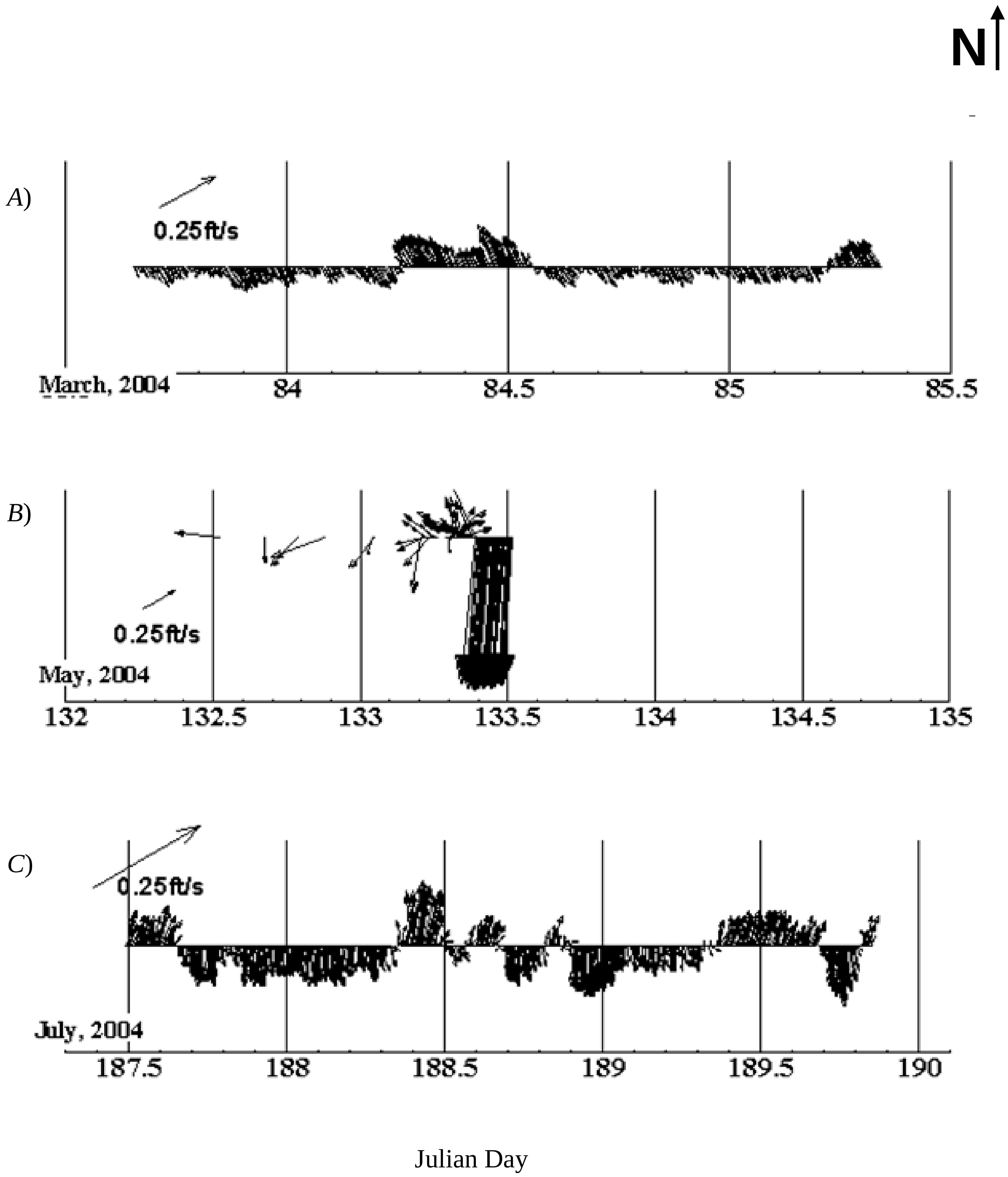

Figure 5. Total current velocities measured at Garcitas Creek in early 2004. (*A*) 24-25 March, (*B*) 12-13 May, and *(C)* 6-8 July. *x*-axis is Julian day with half day intervals noted by vertical gridlines. Upstream is indicated by northward pointing vectors.

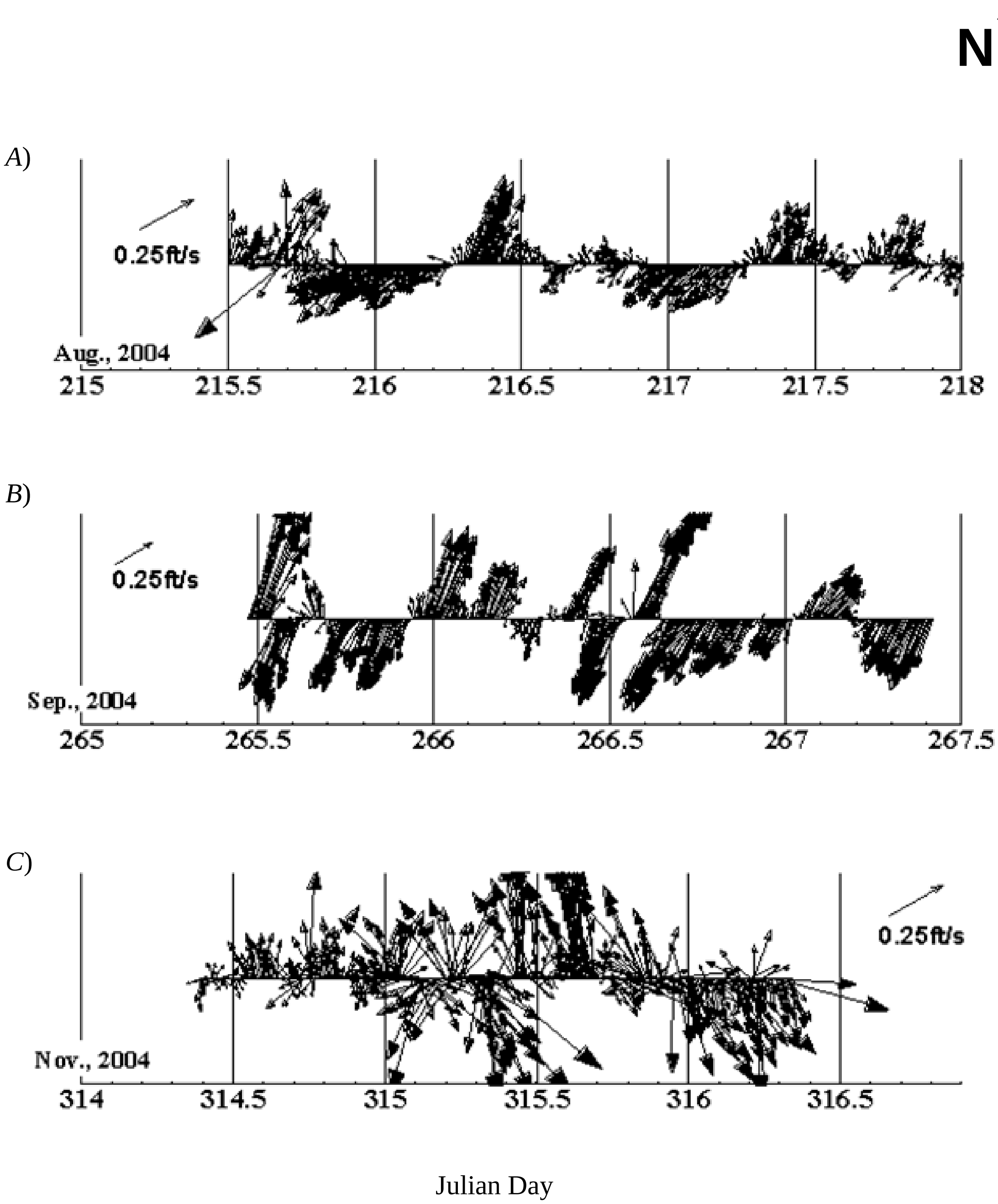

Figure 6. Total current velocities measured at Garcitas Creek in late 2004. (*A*) 3-5 August, (*B*) 22-24 September, and (*C*) 10-12 November. *x*-axis is Julian day with half day intervals noted by vertical gridlines. Upstream is indicated by northward pointing vectors.

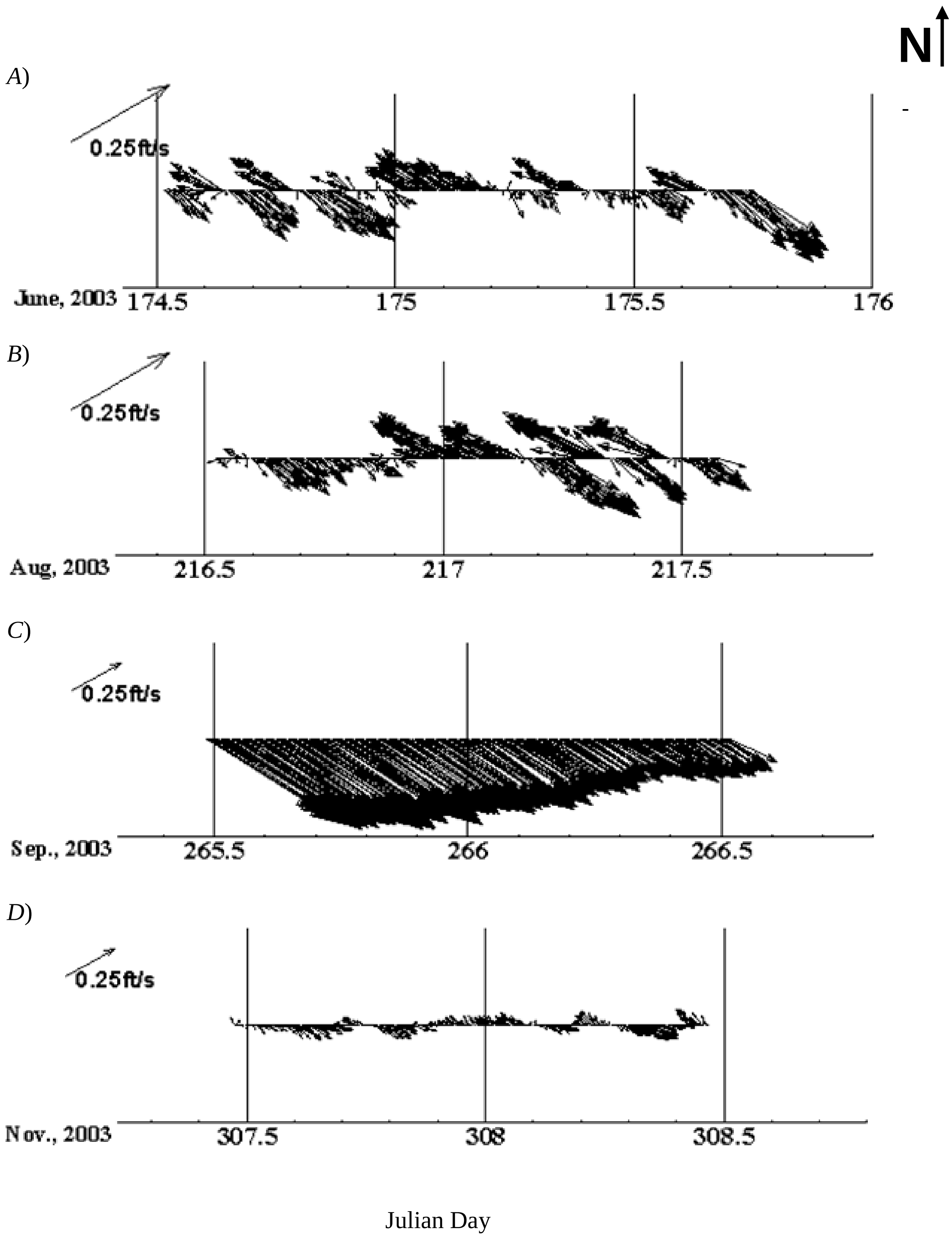

Figure 7. Total current velocities measured in the Tres Palacios River in 2003. (*A*) 23-25 June, (*B*) 4-5 August, (*C*) 22-23 September, and (*D*) 3-4 November. *x*-axis is Julian day with half day intervals noted by vertical gridlines. Upstream is indicated by northward pointing vectors.

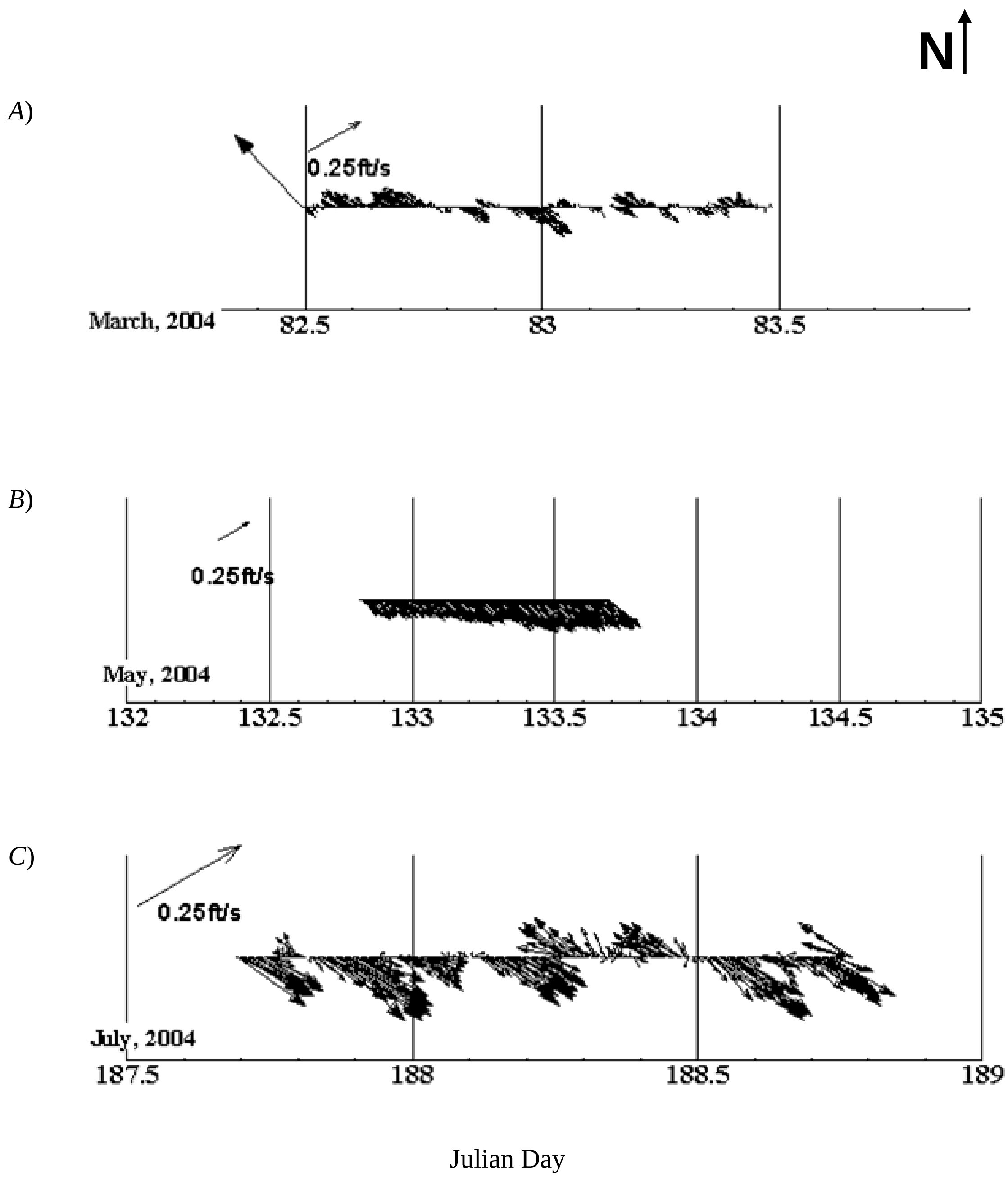

Figure 8. Total current velocities measured in the Tres Palacios River in early 2004. (*A*) 23-24 March, (*B*) 12-14 May, and *(C)* 6-7 July. *x*-axis is Julian day with half day intervals noted by vertical gridlines. Upstream is indicated by northward pointing vectors.

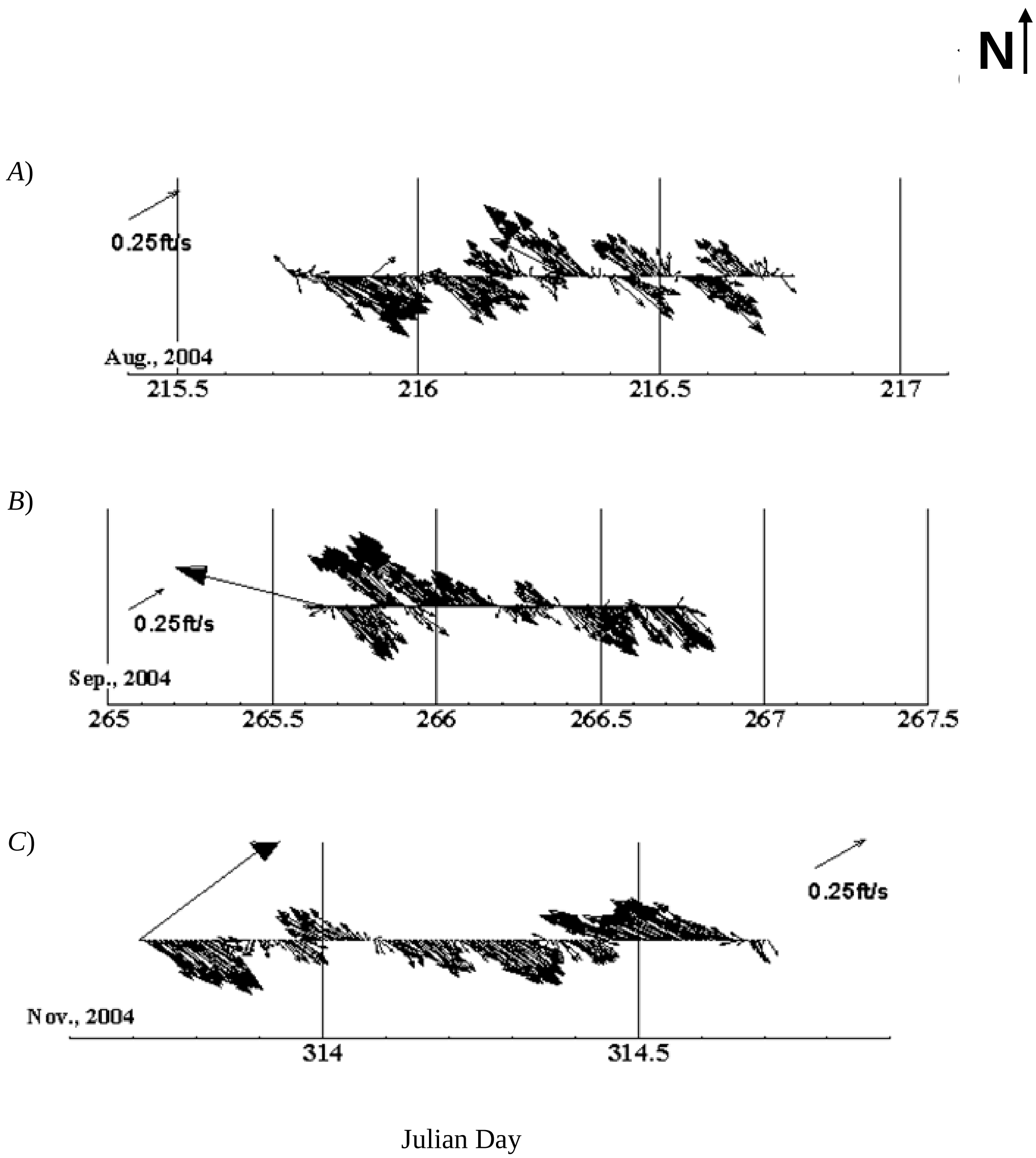

Figure 9. Total current velocities measured in the Tres Palacios River in late 2004. (*A*) 3-4 August, (*B*) 22-24 September, and (*C*) 9-10 November. *x*-axis is Julian day with half day intervals noted by vertical gridlines. Upstream is indicated by northward pointing vectors.

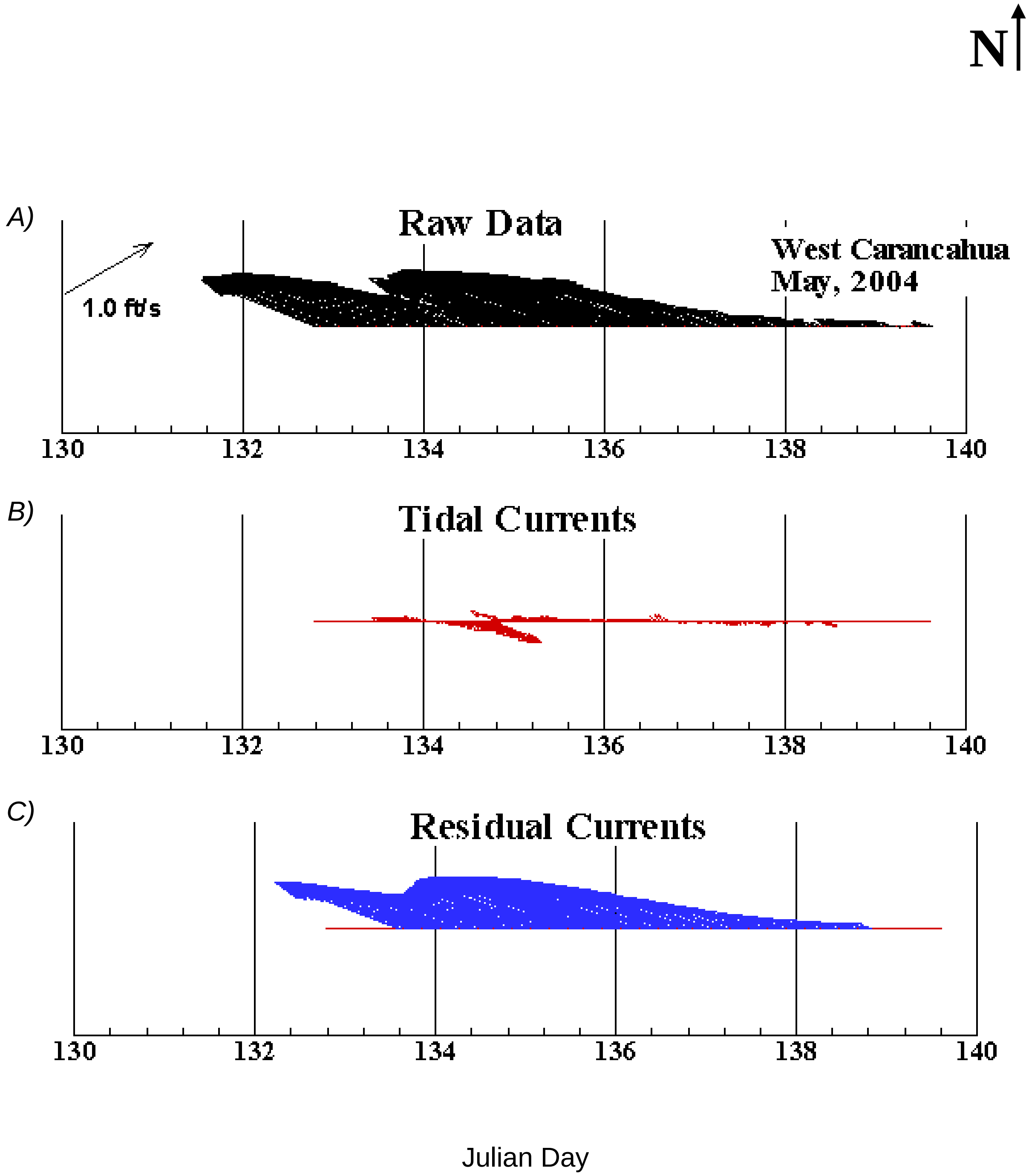

Figure 10. Flow composition at Carancahua, 12-19 May 2004. (*A*) Raw flow data with (*B*) tidal and (*C*) residual currents extracted. *x*-axis is Julian day with two-day intervals noted by vertical gridlines. Upstream is indicated by southward pointing vectors.

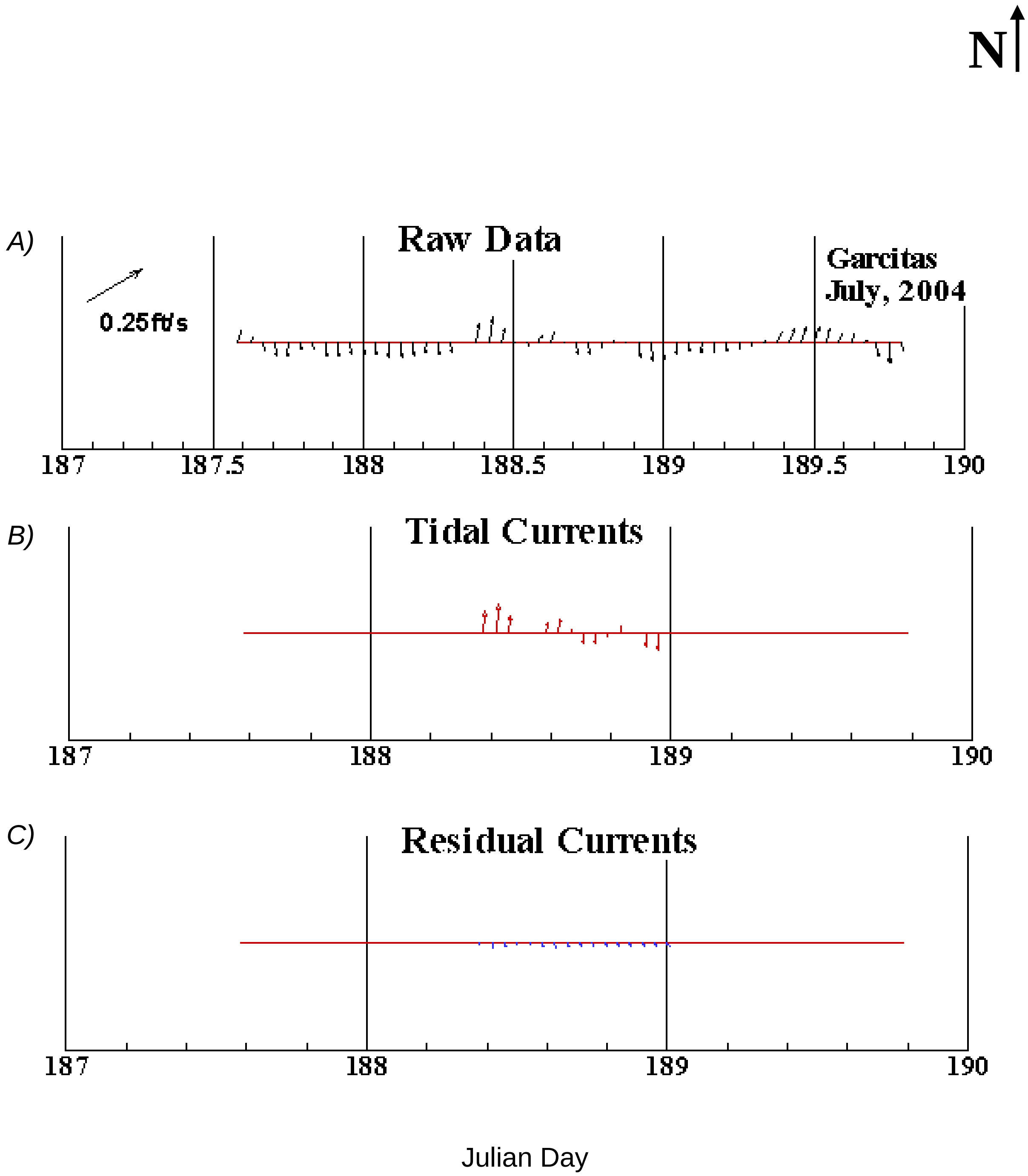

Figure 11. Flow composition at Garcitas, 6-8 July 2004. (*A*) Raw flow data with (*B*) tidal and (*C*) residual currents extracted. *x*-axis is Julian day with day intervals noted by vertical gridlines. Upstream is indicated by northward pointing vectors.

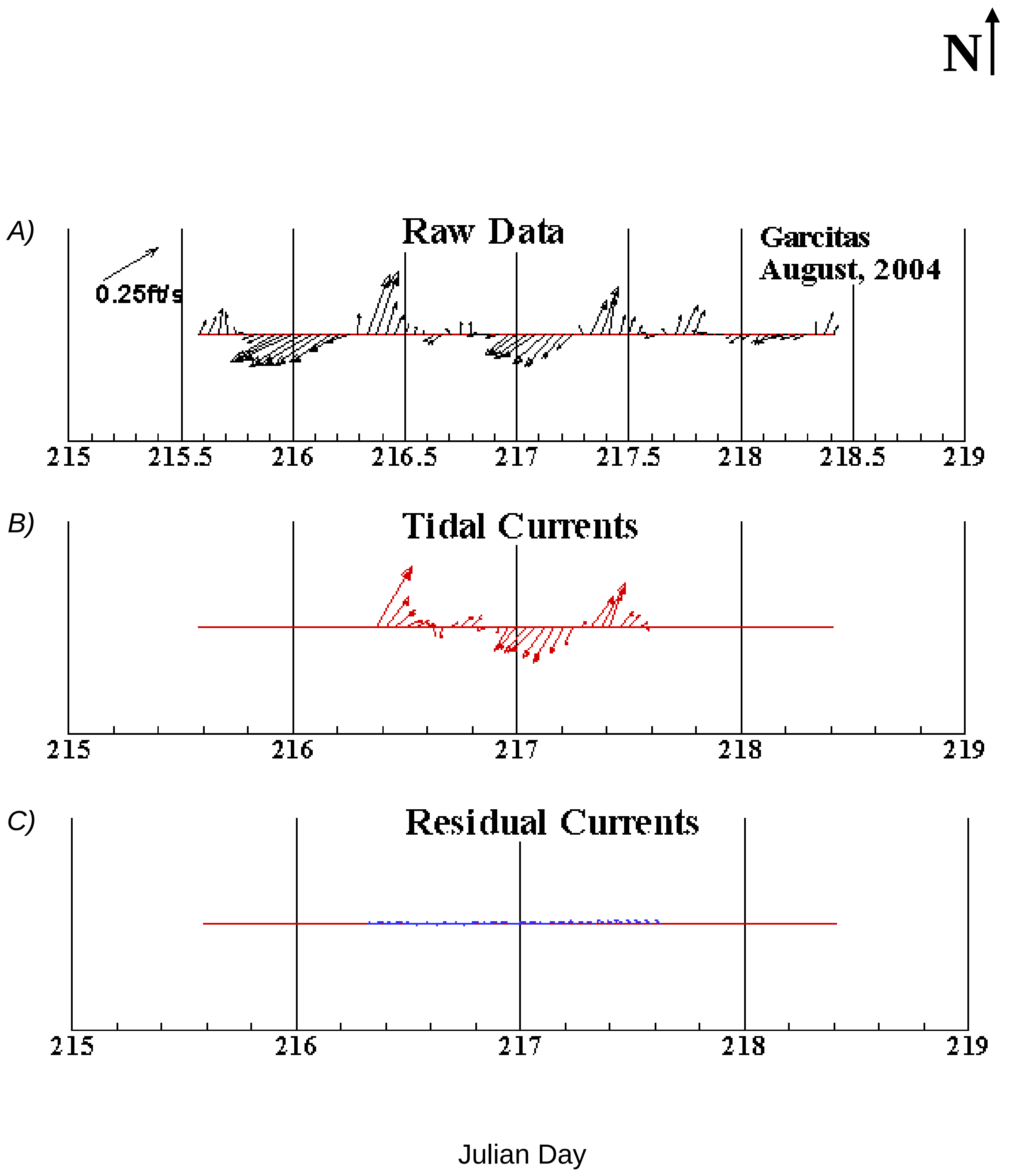

Figure 12. Flow composition at Garcitas, 3-5 August 2004. (*A*) Raw flow data with (*B*) tidal and (*C*) residual currents extracted. *x*-axis is Julian day with day intervals noted by vertical gridlines. Upstream is indicated by northward pointing vectors.

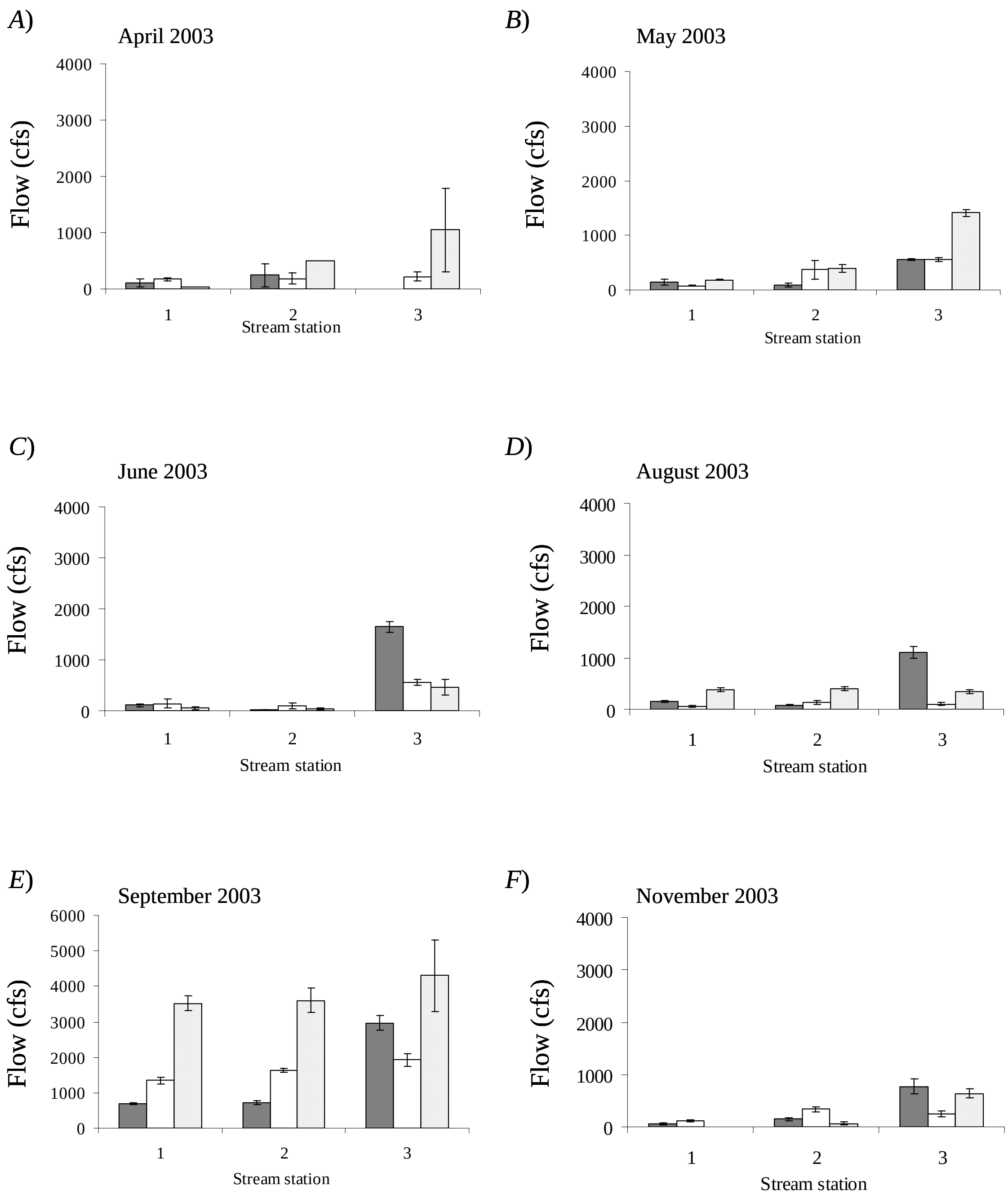

Figure 13. Mean flow (cfs) ± 1 SD at study sites along three tidal streams on the Mid-Texas Coast, West Carancahua Creek (the reference site, dark grey), Garcitas Creek (white), and the Tres Palacios River (light grey), for *A*) April, *B*) May, *C*) June, *D*) August, *E*) September, and *F*) November 2003. Stream stations are: (1) upstream, (2) middle, and (3) downstream.

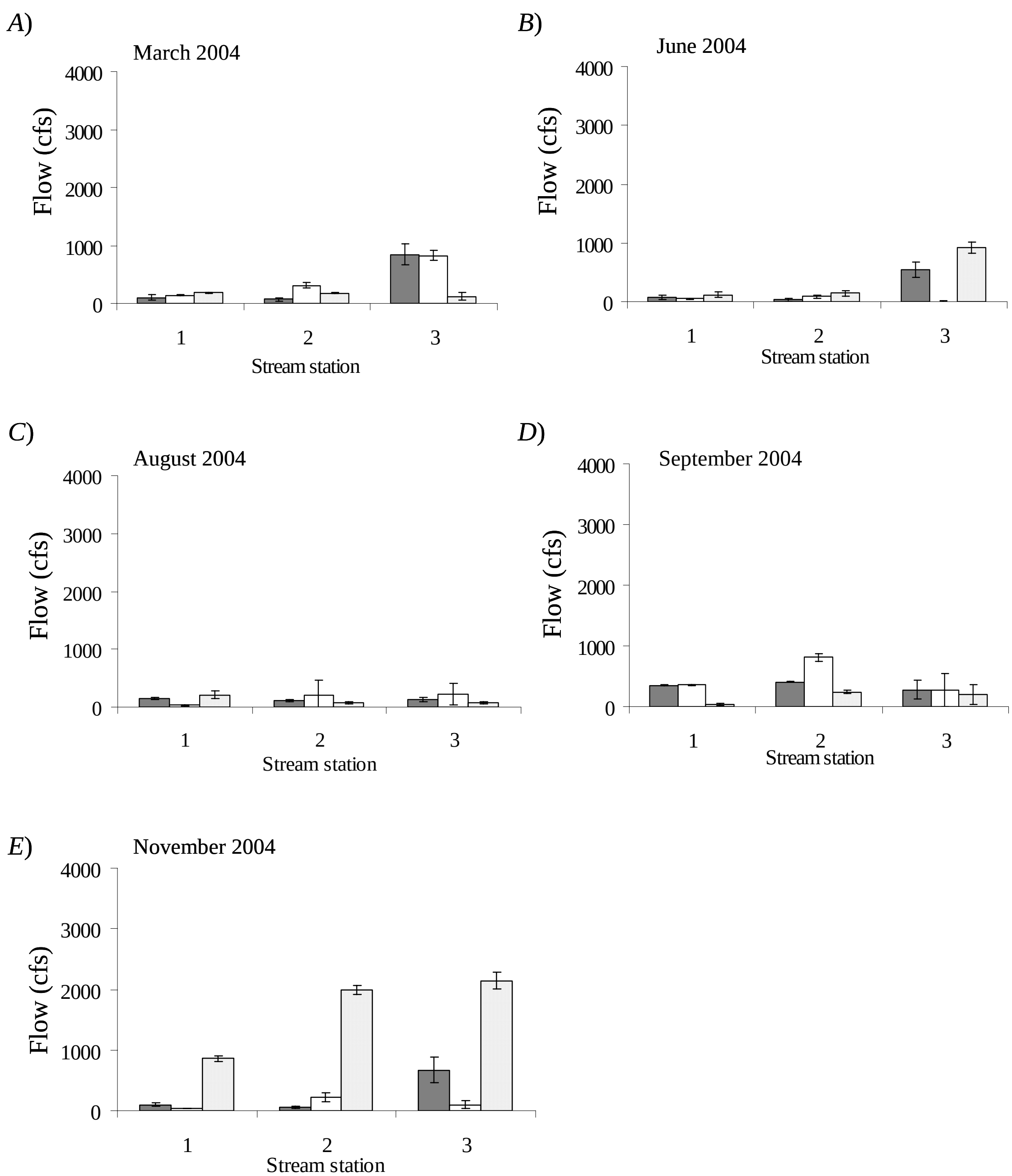

Figure 14. Mean flow (cfs) ± 1 SD at study sites along three tidal streams on the Mid-Texas Coast, West Carancahua Creek (the reference site, dark grey), Garcitas Creek (white), and the Tres Palacios River (light grey), for *A*) March, *B*) June, *C*) August, *D*) September, and *E*) November 2004. Stream stations are: (1) upstream, (2) middle, and (3) downstream.

Sub Appendix 1. Original and standardized file names for data collected with SonTek ADCPs.

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TP030309221036	TREDS0309221036
TP030309221041	TREDS0309221041
TP030309221047	TREDS0309221047
TP30311031108	TREDS0311031108
TP30311031112	TREDS0311031112

TPMID0407071002	TREMS0407071002
TPMID0407071011	TREMS0407071011
TPMID0407071019	TREMS0407071019
TPMID0407071026	TREMS0407071026
3PMID0408041046	TREMS0408041046
3PMID0408041052	TREMS0408041052
3PMID0408041056	TREMS0408041056
3PMID0408041100	TREMS0408041100
TPMD0409210844	TREMS0409210844
TPMD0409210852	TREMS0409210852
TPMD0409210858	TREMS0409210858
PALUS0306250935	TREUS0306250935
PALUS0306250942	TREUS0306250942
PALUS0306250948	TREUS0306250948
PALUS0306250954	TREUS0306250954
PALUS0308060123	TREUS0308060123
PALUS0308060126	TREUS0308060126
PALUS0308060130	TREUS0308060130
PAL10403221253	TREUS0403221253
PAL10403221257	TREUS0403221257
TPUPS0407071108	TREUS0407071108
TPUPS0407071113	TREUS0407071113
TPUPS0407071119	TREUS0407071119
TPUPS0407071126	TREUS0407071126
3PUS0408040957	TREUS0408040957
3PUS0408041002	TREUS0408041002
3PUS0408041005	TREUS0408041005
3PUS0408041009	TREUS0408041009
TPUP0409210944	TREUS0409210944
TPUP0409210950	TREUS0409210950
TPUP0409210956	TREUS0409210956
PAL10403221253	TREUS0403221253
PAL10403221257	TREUS0403221257
TPUPS0407071108	TREUS0407071108
TPUPS0407071113	TREUS0407071113
TPUPS0407071119	TREUS0407071119
TPUPS0407071126	TREUS0407071126
3PUS0408040957	TREUS0408040957
3PUS0408041002	TREUS0408041002
3PUS0408041005	TREUS0408041005
3PUS0408041009	TREUS0408041009
TPUP0409210944	TREUS0409210944
TPUP0409210950	TREUS0409210950
TPUP0409210956	TREUS0409210956

TP30311031116	TREDS0311031116
TP30311031118	TREDS0311031118
PAL30403221104	TREDS0403221104
PAL30403221109	TREDS0403221109
PAL30403221112	TREDS0403221112
PAL30403221115	TREDS0403221115
TPLOW0407070905	TREDS0407070905
TPLOW0407070909	TREDS0407070909
TPLOW0407070913	TREDS0407070913
TPLOW0407070916	TREDS0407070916
3PDS0408041148	TREDS0408041148
3PDS0408041151	TREDS0408041151
3PDS0408041154	TREDS0408041154
3PDS0408041157	TREDS0408041157
TPDS0409210747	TREDS0409210747
TPDS0409210752	TREDS0409210752
TPDS0409210801	TREDS0409210801
TPDS0409210837	TREDS0409210837
PALMD0306250838	TREMS0306250838
PALMD0306250847	TREMS0306250847
PALMD0306250856	TREMS0306250856
PALMD0306250902	TREMS0306250902
PALMD0308060215	TREMS0308060215
PALMD0308060219	TREMS0308060219
PALMD0308060224	TREMS0308060224
PALMD0308060228	TREMS0308060228
TP020309221155	TREMS0309221155
TP020309221201	TREMS0309221201
TP020309221207	TREMS0309221207
TP020309221213	TREMS0309221213
TP20311031200	TREMS0311031200
TP20311031210	TREMS0311031210
TP20311031216	TREMS0311031216
TP20311031224	TREMS0311031224
TP20311031301	TREMS0311031301
TP20311031307	TREMS0311031307
TP20311031313	TREMS0311031313
TP20311031318	TREMS0311031318
PAL20403221149	TREMS0403221149
PALUS0308060133	TREUS0308060133
TP010309221249	TREUS0309221249
TP010309221253	TREUS0309221253
TP010309221258	TREUS0309221258
TP010309221302	TREUS0309221302

PAL10403221253	TREUS0403221253

PAL10403221243	TREUS0403221243
PAL10403221248	TREUS0403221248

Sub Appendix 2. Examples of software output for the SonTek ADCP ViewADP software (Appendix 2A), RD Instruments WinRiver software (Appendix 2B), and the SonTek ADV ViewArgonaut software (Appendix 2C).

Sub Appendix 2 A. Example of ADCP data output from SonTek ViewADP software for West Carancahua at the downstream study site on August 6, 2003. All data files processed for this study are archived on the CD.

Site.dir compass direction of flow in each bin, with large numbers for subriverbinlayers
16 171.4 259.8 3276.7 3276.7 3276.7 3276.7 3276.7 3276.7
Site.dis Data output by profile number across channel
ADP Data File: CARDS0308060448.adp　　Start Date + Time: 06/08/2003 04:48:42
All Track Calculations use: Bottom Track data　　All Flow Velocities Relative to: Bottom Track　　English Units

Profile	Time	Distance (ft)	DMG (ft)	DistEast (ft)	DistNorth (ft)	GPS Latitude (deg)	GPS Longitude (deg)	Depth1 (ft)	Depth2 (ft)	Depth3 (ft)	uVess (ft/s)	DirVess (deg)	uFlow (ft/s)	DirFlow (deg)	StdDev (ft/s)	DQI	# Valid Cells	Q (ft^3/s)	Q Cumul (ft^3/s)
1	04:48:42	10.2	10.2	2.0	-10.0	0.00000000	0.00000000	4.49	4.33	4.86	2.04	553.2	0.55	190.5	0.11	1.2	2	-9.93	-9.9
2	04:48:46	21.2	20.6	8.6	-18.7	0.00000000	0.00000000	4.56	4.40	4.95	2.19	468.9	0.79	119.9	0.12	1.2	2	16.25	6.3

site.lay Lay out for Tec Plot Graphic
#!MC 900
$!VarSet |LFDSFN1| = '"CARDS0308060448dir.plt"'
$!VarSet |LFDSVL1| = '"V1" "V2"'
$!SETSTYLEBASE FACTORY
$!PAPER
 BACKGROUNDCOLOR = WHITE

Site.plt Plot file for Tech Plot graphic
0.600000024 154.937927 29.0000000
 0.780000031 167.613800 29.0000000
 0.960000038 151.282150 28.0000000

Site.spd Water velocity for each bin, with large numbers for below river layers
 16 17.1 12.3 3276.7 3276.7 3276.7 3276.7 3276.7 3276

Site.sum Summary data report
SonTek RiverSurveyor v3.50 Discharge Measurement Report

Date: 06/08/2003　　Start Time: 04:48:42　　End Time: 04:51:31
ADP Data File: CARDS0308060448.adp　　System Frequency: 3000 kHz

Site.ve Velocity eastward
16 2.6 -12.1 3276.7 3276.7 3276.7 3276.7 3276.7 3276
Site.vn Velocity northwar
16 -16.9 -2.2 3276.7 3276.7 3276.7 3276.7 3276
Site.vu Velocity upward
16 -4.3 2.3 3276.7 3276.7 3276.7 3276.7 3276
Site.dirplt Data for directional plot
51.7791176 46.1954308
 51.1711693 44.6670876
 53.2289391 44.1065826
Compar.lis Comparing discharge calculated by two methods

Site	Qadp	Qcal.	Cr-Area	Cr-dis	CR-vel	Al-Vel	AveE	AveN	dirV	DirBoat
CARDS0308060448	534	-534	889.2	218.4	-0.5	0.2	0.0	0.0	122.1	-139.2

Sub Appendix 2 B. Example of data summary output from RD Instruments WinRiver software for processing ADCP data.

```
File name                      = V:\HeMon\ENVIRO\Brock\UAA\2nd Trip
05.06.03\Carancahua\caran000r.000
Date [yy/mm/dd]                = 03/05/08
First ensemble time            = 08:28:07
Last ensemble time             = 08:33:28
First ensemble number          = 9
Last ensemble number           = 256
Number of ensembles            = 248
Distance made good [ft]        = 78.91
Length [ft]                    = 93.05
Transect time [s]              = 321.06
Max depth [ft]                 = 13.89
Area [ft2]                     = 928.19
River width [ft]               = 105.61
Average boat speed [ft/s]      = 0.29
Average boat course [deg]      = 176.32
Flow speed [ft/s]              = 0.10
Flow direction [deg]           = 299.66
Total discharge [ft3/s]        = -80.74
Top discharge [ft3/s]          = -13.28
Measured discharge [ft3/s]     = -39.96
Bottom discharge [ft3/s]       = -10.31
*Right shore discharge [ft3/s]= -2.21
*Left shore discharge [ft3/s] = -14.98
Begin Shore                    = Left
*Right shore distance [ft]     = 7.70
*Left shore distance [ft]      = 19.00
*Right shore velocity [ft/s]   = 0.09
*Left shore velocity [ft/s]    = 0.49
*Right shore depth [ft]          = 9.12
*Left shore depth [ft]         = 4.54
*Right shore area [ft2]          = 35.10
*Left shore area [ft2]         = 43.17
WinRiver version               = 1.03.000
Firmware version               = 10.07
Beam angle [deg]               = 20
Bottom mode                    = 5
Water mode                     = 8
Bin size [cm]                  = 10
ADCP transducer depth [ft]     = 1.00
Magnetic variation [deg]       = 0.00
Beam 3 misalignment [deg]      = 0.00
Compass one cycle K            = 0.0000
Compass one cycle offset       = 0.0000
Compass two cycle K            = 0.0000
Compass two cycle offset       = 0.0000
Speed of sound correction type= 0
Projection angle [deg]         = 0.00
Crossectional area type        = 2
Top discharge method           = POWER
```

```
Bottom discharge method       = POWER
Power curve coefficient       = 0.1667
Cut top bins                  = 0
Cut bins above sidelobe       = 0
Left area coefficient         = 0.3535
Right area coefficient        = 0.3535
Number of shore pings         = 10
Velocity reference            = ADCP
Depth reference               = ADCP
```

Sub Appendix 2 C. Example of ASCII file format obtained from the SonTek ViewArgonaut software used in processing ADV data. Ascii data files are included on the CD.

Site	Jun-03	Aug-03	Sep-03	Nov-03	Mar-04	May-04	Jul-04	Aug-04	Sep-04	Nov-04
GARMS	1.1	1	1	1	1.7	1	2.4	2.9	1.95	1.95
CARMS	1.1	1.1	1	1	1.7	6.9	1.8	1.7		0.06
TREMS	1.2	1.1	1	1	1	0.9	1.1	1	1.1	1

Sub Appendix 3. Data processing procedures using scripts and FORTRAN for SonTek ADCP River Surveyor data (Appendix 3A), SonTek ADV Argonaut data (Appendix 3B), for generating Rose Plots (Appendix 3C) and for calculating ADCP SumQ (Appendix 3D).

Sub Appendix 3 A. Data processing procedure for ADCP transect data generated by the SonTek River Surveyor.

```
----------------DATA PROCESSING PROCEDURE FOR ADP-TRANSECT DATA--------------
FOR EACH TRANSECT DATA
1) RUN "RIVERSURVEYOR"
2) RUN "VIEWADP"
SOFTWARE BY SONTEK PROVIDE SEVERAL KINDS OF DATA AS FOLLOWS:
.SPD  : MAGNITUDE OF VELOCITY
.DIR  : VELOCITY DIRECTION
.VE   : E-W COMPONENT VELOCITY
.VN   : N-S COMPONENT VELOCITY
.VZ   : VERTICAL VELOCITY
.SUM  : SUMMARY DATA OF TRANSECT
.DIS  : DISTANCE TRAJECTORY OF TRANSECT
FOR THE DETAILED DATA FORMAT REFER TO THE SONTEK USER'S MANUAL

FOR APPLIED PROCESSING OF THESE DATA REFER TO  Appendix 3c: PROCROSEPLOT.DOC
Appendix 3d: PROCSUMQ.DOC
```

Sub Appendix 3 B. Data processing procedure for ADV data generated by the SonTek Argonaut XR.

```
-------------------PROCEDURES FOR THE ARGONAUT TIME SERIES DATA ------------
* WORKING DIRECTORY:~\ARG2003-2004   ARGONAUT DATA ALL ARE IN THIS DIRECTORY.
1) MAKE LIST FILE OF ARGONAUT DATA,"argfile.lis", using Dos command: dir/o/n
*.dat >argfile.lis
2) Edit "argfile.lis" appropriately WITHOUT DOCUMNETATIONS, LEAVING ONLY FILE
NAMES.
3) RUN "LISTARR.EXE"
   INPUT:ARGFILE.LIS
  OUTPUT:argfileinfo.lis
------------------------ ARGFILEINFO.LIS ----------------------------------
               STARTING        ENDING
FILE NAME      YEARMMDDHHMISE  YEARMMDDHHMISE       TIDSEP*   PERIOD(HOURS)
arg200306cowb  2003 624 84333  2003 625115833                   DT=      35.0
arg200306garc  2003 62510 0 0  2003 6261310 0                   DT=      37.0
arg200306lost  2003 623123826  2003 626 71826   TIDE SEPARABLE  DT=      79.0
*TIDSEP: FOR THE SEPARATION OF THE TIDAL AND RESIDUAL COMPONENT, DT IS AT
LEAST GEATER THAN 62 HOURS.
----------------------------------------------------------------------------

4) RUN "ARGRAWVEC"
   INPUT:ARGFILE.LIS
  OUTPUT:XXXXXXrawvec.plt
WHERE XXXXXX IS INPUT FILENAME OF ARGONAUT FROM 'ARGFILE.LIS'
FOR EXAMPLE, arg200306cowb IN JUNE, 2003 AT COW BAYOU

------------------------ arg200306cowbrawvec.plt --------------------------
dj: JULIAN DATE, ve:E-W VELOCITY vn:N-S VELOCITY, AND vz:VERTICAL VELOCITY
  dj         ve      vn     0.0     vz
 175.364  -0.070   0.030   0.000  -0.010
 175.367  -0.050   0.030   0.000  -0.020
 175.371  -0.070   0.020   0.000  -0.010
...
...
----------------------------------------------------------------------------
5) RUN "SMOOTH"
   INPUT:"ARGFILE.LIS"
  OUTPUT:XXXXXXH.LIS,XXXXXXF.LIS, AND XXXXXXF.PLT
"XXXXXXF.LIS" IS THE SAME AS "XXXXXXF.PLT" EXCEPT FOR FILE HEAD.
EACH OUTPUT FILE HAS THE FILE HEAD, SO NO NEED DETAILS.
```

Sub Appendix 3 C: Procedure for generating Rose Plots (PROCROSEPLOT.DOC)

```
How to make ROSE PLOTS for each ADCP-transect data.

1)Make a file, "flowdir.fil" using DOS Command in the directory ~\All-ADP-
processed data\
dir/o/n *.dir > flowdir.fil

2)Edit "flowdir.fil" using text editor
  leave only file names and erase all other documents.

3)run "Roseplot"
    input file:"g.lay"
    ouput file:xxxxxx.plt, and xxxxxxdir.plt
where xxxxxx is filename provided by "flowdir.fil"

For example, xxxxxx.plt=CARDS0306241803.plt Carancahua Downstream transected
on 24th June 2003, 18:03

-------------------------------- CARDS0306241803.plt ------------------------
depth(m)      Average-direction       Sampling #
0.600000024     154.947617            42.0000000
...
...
...
2.58000016      161.699997            3.00000000
------------------------------------------ --------------------------------

------------------------------- CARDS0306241803dir.plt ---------------------
xxxxxxdir.plt are imported into the tecplot utility for drawing Roseplots.

 Rel-x : relative x-coordinate in the tech plot
 Rel-y : relative y-coordinate in te tech plot

 Rel-x                Rel-y
 51.7784767         46.1951332
...
...
...
 55.6707039         32.8533745
-----------------------------------------------------------------------------
```

Sub Appendix 3 D. Procedure for calculating ADCP Sum Q (PROCSUMQ.DOC)

How to make time series plots for the volume transport measured by ADCP transect.

```
1)Make a file, "flowsumfile.lis" using DOS Command in the directory ~\All-
ADP-processed data\
dir/o/n *.sum > flowsumfile.lis

2)Edit "flowsumfile.lis" using text editor
  leave only file names and erase all other documents.

3)run "sum.exe"
    input file: "flowsumfile.lis"
   output file: "sumq.lis"

-------------------------------- sumq.lis ----------------------------------
Site    Date    Stime    Etime    ADP-measured Assign   TotalQ  old file name
CARDS0306241759 01/01/1995 01:04:11 01:07:11    -863.7    -769.4      -1633.1     CARDS0306241759
.........
.........
.........
TREUS0411081414 08/11/2004 14:13:57 14:16:47     -91.5     -24.8       -116.3      TPUP0411081414
------------------------------------------------------------------------------

4)run "sumqplot.exe"
    input file: "sumq.lis"
   output file: "sumq.plt","summean.txt"
-------------------------------- sumq.plt ----------------------------------
This is a tecplot format.
ZONE T=     "CARUS"    :carANCAHUA uPsTREAM
THE FIRST COLUMN      6:MONTH FROM JAN. 2003
THE SECOND- 4TH COLUMN : MEAN TRANSPORT(FT^3/S),STANDARD DEV, AND RELATIVE
DEVIATION IN %

TITLE = " Time series of stream flow "
VARIABLES = "YYMM  " " MEAN " "   STD" " REL.%"
ZONE T= "CARUS"
 6     114.133    41.555    36.409
 8     158.300    15.915    10.054
------------------------------------------------------------------------------
------------------------------------------------------------------------------

-------------------------------- summean.txt --------------------------------
#: Transects tried by ADP
Measured: ADCP MEASURED
Assigned: ADCP not covered (top, bottom, and both banks)

#  Filename   Measured    Variance   Assigned   Variance     Total    Variance
3 TREUS041108 63.2000008 9.15368557 51.9333344 48.5716324 114.133331 41.5553093
------------------------------------------------------------------------------
------------------------------------------------------------------------------

5) COPY SUMQ.PLT ~\timeseriesplots\

6) IMPORTING "SUMQ.PLT" INTO "TECPLOT" in the ~\timeseriesplots
   AND SAVE A LAYOUT FILE OF GRAPHIC WITH PROPER FILENAME
```

Sub Appendix 4. Procedure for matching ADCP transect data with ADV data to produce a rating curve. On the CD, matched files are provided in matchadparglis.out, and example of a matched file is given below.

```
SEEKING FOR MATCHING ARGONAUT DATA WITH adp-TRANSECT, IT CAN BE ONLY
PROCESSED
AFTER FINISHING ADP AND ARGONAUT DATA, GETTING 'argfileinfo.lis' AND
'sumq.lis'

RUN "MATCHADPARG"

INPUT FILE:ALL ARGONAUT FILES AND ALL ADP TRANSECT FILES WHICH ARE
IMPORTED
           BY BOTH FILE 'argfileinfo.lis' AND 'sumq.lis'
OUTPUT FILE: matchadparglis.out, AND matchadparglis.txt

FILE HEADINGS OF EACH FILE ARE DOCUMENTED WELL.
```

```
TRANSECT   ADP         FILE NAME OF    STARTING TIME   ENDING TIME     ARG(E-W) ARG(N-S)
ADP(E-W) ADP(N-S) MEASURED NOTMEASURED TOTAL
SITES   YEARMMDDHHMN     ARGONAUT     YEARMMDDHHMNSS  YEARMMDDHHMNSS    argve    argvn
adpve    adpvn    ADPM     ASS      TQ

 CARDS  2003 6241759 ! arg200306wcar  2003 624113254  2003 625143754    -3.96     0.46
11.61   -15.83  -863.70  -769.40 -1633.10
 CARDS  2003 62418 3 ! arg200306wcar  2003 624113254  2003 625143754    -3.56     0.20
9.95   -16.59   810.00   680.00  1490.00
 CARDS  2003 62418 8 ! arg200306wcar  2003 624113254  2003 625143754    -3.25     0.30
10.78   -17.47  -890.90  -827.10 -1718.00
 CARDS  2003 6241812 ! arg200306wcar  2003 624113254  2003 625143754    -3.05     0.20
9.16   -19.22   975.50   763.90  1739.40
 CARMS  2003 6241850 ! arg200306wcar  2003 624113254  2003 625143754    -2.29     0.46
-0.55    -0.05    13.70    -0.80    12.90
 CARMS  2003 6241854 ! arg200306wcar  2003 624113254  2003 625143754    -2.13     0.46
2.76    14.29   -18.60   -47.60   -66.20
 CARMS  2003 6241858 ! arg200306wcar  2003 624113254  2003 625143754    -2.13     0.41
-3.31   -13.64     8.40     6.50    14.90
 CARMS  2003 62419 2 ! arg200306wcar  2003 624113254  2003 625143754    -2.03     0.30
1.61    10.67    -8.80    19.10    10.30
 CARUS  2003 6241931 ! arg200306wcar  2003 624113254  2003 625143754    -1.42     0.51
8.77     2.23    59.00    55.90   114.90
 CARUS  2003 6241937 ! arg200306wcar  2003 624113254  2003 625143754    -1.83     0.71
-6.57    -8.69   -56.90   -98.40  -155.30
 CARUS  2003 6241941 ! arg200306wcar  2003 624113254  2003 625143754    -2.13     0.51
11.72     2.56    73.70    -1.50    72.20
 LOSDS  2003 9231937 ! arg200309lost  2003 92319 416  2003 924181916     0.15    -1.37
3.35     0.71   158.60   121.40   280.00
 LOSMS  2003 9231913 ! arg200309lost  2003 92319 416  2003 924181916    -0.41     0.30
1.05     1.29     0.10     9.00     9.10
 TREMS  2003 9221155 ! arg200309tres  2003 9221135 0  2003 9231225 0    17.17   -10.57
45.81   -44.99 -2343.50  -809.20 -3152.70
 TREMS  2003 92212 1 ! arg200309tres  2003 9221135 0  2003 9231225 0    16.97   -10.16
39.91   -36.97  2623.40   883.60  3507.00
 TREMS  2003 92212 7 ! arg200309tres  2003 9221135 0  2003 9231225 0    17.07   -10.06
46.52   -43.02 -2851.30  -977.00 -3828.30
 TREMS  2003 9221213 ! arg200309tres  2003 9221135 0  2003 9231225 0    17.53   -10.21
47.32   -43.10  2948.10   985.10  3933.20
 TREUS  2003 9221249 ! arg200309tres  2003 9221135 0  2003 9231225 0    17.17   -11.28
43.14   -51.41  2485.80  1209.00  3694.80
 TREUS  2003 9221253 ! arg200309tres  2003 9221135 0  2003 9231225 0    16.92   -10.82
```

```
46.68   -51.99 -2303.70 -1115.90 -3419.60
 TREUS  2003 9221258 ! arg200309tres  2003 9221135 0  2003 9231225 0    16.92   -10.82
44.02   -50.26  2174.30  1091.20  3265.50
 TREUS  2003 92213 2 ! arg200309tres  2003 9221135 0  2003 9231225 0    16.76   -10.36
46.85   -51.96 -2449.90 -1222.40 -3672.30
 CARMS  2003 9221616 ! arg200309wcar  2003 9221615 7  2003 92317 5 7    -8.53     1.22
-19.40     4.40  -483.50  -282.80  -766.30
 CARMS  2003 9221620 ! arg200309wcar  2003 9221615 7  2003 92317 5 7    -8.43     1.32
-19.19     5.29   492.80   294.10   786.90
 CARMS  2003 9221625 ! arg200309wcar  2003 9221615 7  2003 92317 5 7    -8.23     1.32
-17.86     4.86  -427.40  -249.80  -677.20
 CARUS  2003 9221659 ! arg200309wcar  2003 9221615 7  2003 92317 5 7    -8.94     1.73
10.70   -12.87   452.90   238.80   691.70
```

Sub Appendix 5. Record of transect agreements for replicate transects measuring volume transport in study streams. Quality assurance is based on ADCP field measurements of flow (Q) as determined by the ADCP and is not based on estimated total flow (SumQ), which would include estimates of flow along the surface, bottom, right and left banks. Transects with less than 5% relative error are defined as “Good” (Norris 2001).

Study Stream	**Site**	**Year**	**Month**	**Transect Name**	**Q (cfs)**	**Mean Q (cfs)**	**Relative Error**	**Sample Quality**
Garcitas Creek	GC1	2003	April	UAA0403010r	2	15.1	89.4%	Bad
				UAA0403011r	27		80.1%	Bad
				UAA0403012r	30		99.3%	Bad
				UAA0403013r	2		90.1%	Bad
			May	DATA_006r	66	55.9	18.2%	Bad
				DATA_007r	54		3.8%	Good
				DATA_008r	58		3.4%	Good
				DATA_009r	46		17.7%	Bad
			June	GARUS0306241512	146	91.5	59.6%	Bad
				GARUS0306241519	133		45.4%	Bad
				GARUS0306241528	56		38.8%	Bad
				GARUS0306241536	31		66.1%	Bad
			Aug.	GARUS0308062226	20	34.0	41.2%	Bad
				GARUS0308062230	32		5.9%	Bad
				GARUS0308062235	36		5.9%	Bad
				GARUS0308062239	48		41.2%	Bad
			Sept.	GC010309222016	791	778.5	1.6%	Good
				GC010309222021	766		1.6%	Good
			Nov.	GC10311041045	86	80.1	7.0%	Bad
				GC10311041033	75		6.1%	Bad
				GC10311041039	69		14.3%	Bad
				GC10311041027	91		13.4%	Bad
		2004	March	GARUS0403231042	100	93.8	6.7%	Bad
				GARUS0403231048	105		12.0%	Bad
				GARUS0403231053	87		7.2%	Bad
				GARUS0403231059	83		11.5%	Bad
			May	GARUS0405111207	961	651.4	47.5%	Bad
				GARUS0405111227	412		36.7%	Bad
				GARUS0405111237	134		79.4%	Bad
				GARUS0405111240	651		0.1%	Good
				GARUS0405111250	763		17.1%	Bad
				GARUS0405111259	782		20.1%	Bad

Study Stream	Site	Year	Month	Transect Name	Q (cfs)	Mean Q (cfs)	Relative Error	Sample Quality
				GARUS0405111307	774		18.8%	Bad
				GARUS0405121156	734		12.7%	Bad
			July	GARUS0407061240	11	24.3	54.6%	Bad
				GARUS0407061249	20		17.5%	Bad
				GARUS0407061256	36		48.5%	Bad
				GARUS0407061303	30		23.7%	Bad
			Aug.	GARUS0408031335	21	25.5	17.6%	Bad
				GARUS0408031341	36		41.2%	Bad
				GARUS0408031346	27		5.9%	Bad
				GARUS0408031350	18		29.4%	Bad
			Sept.	GARUS0409211828	234	235.7	0.7%	Good
				GARUS0409211835	233		1.1%	Good
				GARUS0409211841	240		1.8%	Good
			Nov.	GARUP0411091308	20	15.5	30.0%	Bad
				GARUP0411091305	21		37.1%	Bad
				GARUP0411091302	5		67.0%	Bad
	GC2	2003	April	UAA0403004r	6	14.7	58.9%	Bad
				UAA0403005r	0		100.0%	Bad
				UAA0403008r	21		44.5%	Bad
				UAA0403009r	32		114.4%	Bad
			May	UAA000r	76	152.2	49.8%	Bad
				UAA001r	125		17.8%	Bad
				UAA002r	177		16.5%	Bad
				UAA003r	230		51.1%	Bad
			June	GARMS0306241226	79	50.8	55.7%	Bad
				GARMS0306241237	55		8.4%	Bad
				GARMS0306241245	53		4.4%	Good
				GARMS0306241255	16		68.5%	Bad
			Aug.	GARMD0308062131	59	74.5	20.8%	Bad
				GARMD0308062139	66		11.4%	Bad
				GARMD0308062146	77		3.4%	Good
				GARMD0308062153	96		28.9%	Bad
			Sept.	GC020309221927	973	993.7	2.1%	Good
				GC020309221936	1,034		4.1%	Good
				GC020309221941	974		2.0%	Good
			Nov.	GC20311040944	238	219.6	8.3%	Bad
				GC20311040928	215		2.2%	Good
				GC20311040936	175		20.4%	Bad
				GC20311040952	251		14.3%	Bad
		2004	March	GARMS0403231006	192	219.8	12.6%	Bad

Study Stream	Site	Year	Month	Transect Name	Q (cfs)	Mean Q (cfs)	Relative Error	Sample Quality
				GARMS0403231009	222		1.0%	Good
				GARMS0403231012	250		13.8%	Bad
				GARMS0403231016	215		2.2%	Good
			May	GARMI0405121118	3,265	3,313.7	1.5%	Good
				GARMI0405121127	3,363		1.5%	Good
			July	GARMS0407061343	58	43.8	32.6%	Bad
				GARMS0407061354	41		6.3%	Bad
				GARMS0407061404	41		6.3%	Bad
				GARMS0407061415	35		20.0%	Bad
			Aug.	GARMS0408031246	3	159.8	98.1%	Bad
				GARMS0408031248	453		183.6%	Bad
				GARMS0408031250	104		34.9%	Bad
				GARMS0408031254	79		50.5%	Bad
			Sept.	GARMS0409211730	581	570.3	1.9%	Good
				GARMS0409211738	606		6.3%	Bad
				GARMS0409211745	524		8.1%	Bad
			Nov.	GARMD0411091227	180	129.9	38.5%	Bad
				GARMD0411091224	74		42.9%	Bad
				GARMD0411091222	136		4.4%	Good
	GC3	2003	April	UAA0403000r	22	19.7	13.5%	Bad
				UAA0403001r	34		72.5%	Bad
				UAA0403002r	10		49.1%	Bad
				UAA0403003r	12		36.9%	Bad
			May	DATA_000r	374	398.7	6.2%	Bad
				DATA_001r	379		4.9%	Good
				DATA_002r	401		0.5%	Good
				DATA_003r	417		4.6%	Good
				DATA_004r	391		1.9%	Good
				DATA_005r	430		7.9%	Bad
			June	GARDS0306241345	326	391.5	16.7%	Bad
				GARDS0306241358	407		4.0%	Good
				GARDS0306241408	410		4.7%	Good
				GARDS0306241417	423		8.0%	Bad
			Aug.	GARDS0308062035	59	74.3	20.5%	Bad
				GARDS0308062042	97		30.6%	Bad
				GARDS0308062048	74		0.3%	Good
				GARDS0308062055	67		9.8%	Bad
			Sept.	GC030309221846	1,406	1,243.8	13.0%	Bad
				GC030309221848	1,249		0.4%	Good
				GC030309221852	1,158		6.9%	Bad

Study Stream	Site	Year	Month	Transect Name	Q (cfs)	Mean Q (cfs)	Relative Error	Sample Quality
				GC030309221856	1,162		6.6%	Bad
			Nov.	GC30311040828	204	172.0	18.4%	Bad
				GC30311040846	275		60.1%	Bad
				GC30311040817	4		97.9%	Bad
				GC30311040838	206		19.5%	Bad
		2004	March	GARDS0403230928	474	549.8	13.8%	Bad
				GARDS0403230932	577		5.0%	Bad
				GARDS0403230935	558		1.5%	Good
				GARDS0403230939	590		7.3%	Bad
			May	GARDS0405121000	222	2,155.3	89.7%	Bad
				GARDS0405121010	3,114		44.5%	Bad
				GARDS0405121021	3,130		45.2%	Bad
			July	GARDS0407061454	83	26.3	216.2%	Bad
				GARDS0407061509	16		39.0%	Bad
				GARDS0407061518	2		92.4%	Bad
				GARDS0407061526	4		84.8%	Bad
			Aug.	GARDS0408031206	264	204.0	29.4%	Bad
				GARDS0408031210	62		69.6%	Bad
				GARDS0408031213	286		40.2%	Bad
			Sept.	GARDS0409211634	53	198.0	73.2%	Bad
				GARDS0409211641	120		39.4%	Bad
				GARDS0409211647	421		112.6%	Bad
			Nov.	GARDS0411091144	51	64.4	20.9%	Bad
				GARDS0411091146	32		50.0%	Bad
				GARDS0411091142	110		70.9%	Bad
Tres Palacios	TP1	2003	April	UAA0403014r	13	12.5	0.0%	Good
			May	TRESPAL2000r	120	120.9	0.7%	Good
				TRESPAL2001r	116		3.9%	Good
				TRESPAL2002r	128		6.0%	Bad
				TRESPAL2003r	119		1.4%	Good
			June	TREUS0306250935	51	44.8	14.0%	Bad
				TREUS0306250942	54		20.7%	Bad
				TREUS0306250948	60		34.1%	Bad
				TREUS0306250954	14		68.7%	Bad
			Aug.	PALUS0308060130	238	232.9	2.1%	Good
				PALUS0308060133	215		7.8%	Bad
				PALUS0308060126	216		7.1%	Bad
				PALUS0308060123	263		12.8%	Bad
			Sept.	TP010309221249	2,486	2,353.5	5.6%	Bad

Study Stream	Site	Year	Month	Transect Name	Q (cfs)	Mean Q (cfs)	Relative Error	Sample Quality
				TP010309221253	2,304		2.1%	Good
				TP010309221258	2,174		7.6%	Bad
				TP010309221302	2,450		4.1%	Good
		2004	March	TREUS0403221243	118	124.3	5.0%	Bad
				TREUS0403221248	114		8.2%	Bad
				TREUS0403221253	131		5.4%	Bad
				TREUS0403221257	134		7.8%	Bad
			July	TREUS0407071108	110	76.5	43.8%	Bad
				TREUS0407071113	57		25.5%	Bad
				TREUS0407071119	91		19.0%	Bad
				TREUS0407071126	48		37.3%	Bad
			Aug.	TREUS0408040957	182	157.0	15.9%	Bad
				TREUS0408041002	169		7.6%	Bad
				TREUS0408041005	184		17.2%	Bad
				TREUS0408041009	93		40.8%	Bad
			Sept.	TREUS0409210944	1	19.7	94.9%	Bad
				TREUS0409210950	22		11.9%	Bad
				TREUS0409210956	36		83.1%	Bad
			Nov.	TPUP0411081408	73	390.6	81.3%	Bad
				TPUP0411011617	619		58.4%	Bad
				TPUP0411081414	92		76.6%	Bad
				TPUP0411081411	82		78.9%	Bad
				TPUP0411011612	585		49.8%	Bad
				TPUP0411011607	659		68.6%	Bad
				TPUP0411011621	625		59.9%	Bad
	TP2	2003	April	UAA0403020r	120	-	-	-
			May	TRESPAL004r	299	249.7	19.8%	Bad
				TRESPAL005r	326		30.4%	Bad
				MIDTRESPAL000r	205		18.0%	Bad
				MIDTRESPAL001r	169		32.2%	Bad
			June	TREMS0306250838	34	19.0	78.9%	Bad
				TREMS0306250847	9		52.6%	Bad
				TREMS0306250856	9		52.6%	Bad
				TREMS0306250902	24		26.3%	Bad
			Aug.	PALMD0308060228	231	265.3	13.0%	Bad
				PALMD0308060215	301		13.4%	Bad
				PALMD0308060219	255		4.0%	Good
				PALMD0308060224	275		3.7%	Good
			Sept.	TP020309221155	2,344	2,691.5	12.9%	Bad
				TP020309221201	2,623		2.5%	Good

Study Stream	Site	Year	Month	Transect Name	Q (cfs)	Mean Q (cfs)	Relative Error	Sample Quality
				TP020309221207	2,851		5.9%	Bad
				TP020309221213	2,948		9.5%	Bad
			Nov.	TP20311031318	37	42.9	15.0%	Bad
				TP20311031307	47		9.7%	Bad
				TP20311031313	31		29.0%	Bad
				TP20311031301	9		80.0%	Bad
				TP20311031210	75		74.7%	Bad
				TP20311031224	28		35.7%	Bad
				TP20311031216	60		38.6%	Bad
				TP20311031200	59		36.7%	Bad
		2004	March	TREMS0403221149	135	134.0	0.7%	Good
				TREMS0403221157	137		2.2%	Good
				TREMS0403221202	120		10.4%	Bad
				TREMS0403221209	144		7.5%	Bad
			July	TREMS0407071002	154	105.3	46.3%	Bad
				TREMS0407071011	99		5.9%	Bad
				TREMS0407071019	62		41.1%	Bad
				TREMS0407071026	106		0.7%	Good
			Aug.	TREMS0408041046	56	60.3	7.1%	Bad
				TREMS0408041052	61		1.2%	Good
				TREMS0408041056	41		32.0%	Bad
				TREMS0408041100	83		37.8%	Bad
			Sept.	TREMS0409210844	140	171.0	18.1%	Bad
				TREMS0409210852	192		12.3%	Bad
				TREMS0409210858	181		5.8%	Bad
			Nov.	TPMID0411011521	1,679	957.2	75.4%	Bad
				TPMID0411081326	222		76.9%	Bad
				TPMID0411081331	227		76.3%	Bad
				TPMID0411081335	200		79.1%	Bad
				TPMID0411011505	1,513		58.1%	Bad
				TPMID0411011453	1,433		49.7%	Bad
				TPMID0411011513	1,428		49.1%	Bad
	TP3	2003	April	UAA0403005r	103	220.8	53.3%	Bad
				UAA0403010r	349		58.2%	Bad
				UAA0403007r	210		4.9%	Good
			May	TRESPAL000r	949	850.9	11.5%	Bad
				TRESPAL001r	844		0.8%	Good
				TRESPAL002r	848		0.4%	Good
				TRESPAL003r	763		10.3%	Bad
			June	TREDS0306250739	351	276.3	27.1%	Bad

Study Stream	Site	Year	Month	Transect Name	Q (cfs)	Mean Q (cfs)	Relative Error	Sample Quality
				TREDS0306250742	351		27.1%	Bad
				TREDS0306250746	194		29.8%	Bad
				TREDS0306250749	209		24.3%	Bad
			Aug.	PALDS0308060027	230	250.4	8.0%	Bad
				PALDS0308060014	238		4.9%	Good
				PALDS0308060005	238		5.1%	Bad
				PALDS0308060020	295		18.0%	Bad
			Sept.	TP030309221031	3,052	2,496.0	22.3%	Bad
				TP030309221036	2,997		20.1%	Bad
				TP030309221041	1,631		34.7%	Bad
				TP030309221047	2,304		7.7%	Bad
			Nov.	TP30311031118	390	390.4	0.1%	Good
				TP30311031116	427		9.4%	Bad
				TP30311031112	302		22.6%	Bad
				TP30311031108	442		13.3%	Bad
		2004	March	TREDS0403221104	149	74.8	99.3%	Bad
				TREDS0403221109	43		42.5%	Bad
				TREDS0403221112	58		22.4%	Bad
				TREDS0403221115	49		34.4%	Bad
			July	TREDS0407070905	631	579.5	8.9%	Bad
				TREDS0407070909	512		11.6%	Bad
				TREDS0407070913	588		1.5%	Good
				TREDS0407070916	587		1.3%	Good
			Aug.	TREDS0408041148	39	72.0	45.8%	Bad
				TREDS0408041151	144		100.0%	Bad
				TREDS0408041154	52		27.8%	Bad
				TREDS0408041157	53		26.4%	Bad
			Sept.	TREDS0409210747	36	148.3	75.7%	Bad
				TREDS0409210752	46		69.0%	Bad
				TREDS0409210801	195		31.5%	Bad
				TREDS0409210837	316		113.2%	Bad
			Nov.	TPDS0411081205	60	737.0	91.9%	Bad
				TPDS0411081157	22		97.0%	Bad
				TPDS0411081209	90		87.8%	Bad
				TPDS0411081202	4		99.4%	Bad
				TPLOW0411011324	1,398		89.7%	Bad
				TPLOW0411011327	1,481		100.9%	Bad
				TPLOW0411011333	1,473		99.9%	Bad
				TPLOW0411011317	1,367		85.5%	Bad
West Carancahua		2003	April	UAA0403000r	9	29.7	70.0%	Bad

Study Stream	Site	Year	Month	Transect Name	Q (cfs)	Mean Q (cfs)	Relative Error	Sample Quality
				UAA0403001r	18		39.7%	Bad
				UAA0403002r	59		98.7%	Bad
				UAA0403003r	34		13.2%	Bad
				UAA0403004r	31		3.4%	Good
				UAA0403005r	7		75.4%	Bad
				UAA0403006r	50		69.8%	Bad
			May	CARAN001r	65	76.6	15.4%	Bad
				CARAN000r	40		47.8%	Bad
				CARAN002r	88		15.4%	Bad
				CARAN003r	113		47.9%	Bad
			June	CARUS0306241931	59	69.0	14.5%	Bad
				CARUS0306241941	74		7.2%	Bad
				CARUS0306241946	74		7.2%	Bad
			Aug.	CARUS0308060619	93	102.0	8.8%	Bad
				CARUS0308060622	113		10.8%	Bad
				CARUS0308060625	101		1.0%	Good
				CARUS0308060628	101		1.0%	Good
			Sept.	WCR010309221659	453	454.0	0.2%	Good
				WCR010309221705	468		3.1%	Good
				WCR010309221709	446		1.8%	Good
				WCR010309221714	449		1.1%	Good
			Nov.	WCR10311031755	43	34.9	22.6%	Bad
				WCR10311031751	30		13.5%	Bad
				WCR10311031742	34		1.4%	Good
				WCR10311031746	32		7.7%	Bad
		2004	March	CARUS0403221649	87	64.8	34.4%	Bad
				CARUS0403221653	40		38.2%	Bad
				CARUS0403221655	87		34.4%	Bad
				CARUS0403221659	45		30.5%	Bad
			July	CARUS0407061915	40	61.0	34.4%	Bad
				CARUS0407061920	58		4.9%	Good
				CARUS0407061924	65		6.6%	Bad
				CARUS0407061930	81		32.8%	Bad
			Aug.	CARUS0408031750	115	100.0	15.0%	Bad
				CARUS0408031753	119		19.0%	Bad
				CARUS0408031755	87		13.0%	Bad
				CARUS0408031759	79		21.0%	Bad
			Sept.	CARUS0409211418	254	251.0	1.2%	Good
				CARUS0409211423	254		1.2%	Good
				CARUS0409211428	245		2.4%	Good

Study Stream	Site	Year	Month	Transect Name	Q (cfs)	Mean Q (cfs)	Relative Error	Sample Quality
			Nov.	CARUP0411090947	57	60.1	5.2%	Bad
				CARUP0411090945.adp	63		5.2%	Bad
	WC2	2003	April	UAA0403000r	1	28.1	97.9%	Bad
				UAA0403001r	54		91.8%	Bad
				UAA0403002r	47		67.6%	Bad
				UAA0403003r	11		61.6%	Bad
			May	DATA_007r	52	51.8	0.7%	Good
				DATA_008r	67		28.5%	Bad
				DATA_009r	73		41.6%	Bad
				DATA_010r	42		19.1%	Bad
				DATA_011r	25		51.8%	Bad
			June	CARMS0306241850	14	12.5	12.0%	Bad
				CARMS0306241854	19		52.0%	Bad
				CARMS0306241858	8		36.0%	Bad
				CARMS0306241902	9		28.0%	Bad
			Aug.	CARMD0308060533	61	54.3	12.4%	Bad
				CARMD0308060537	61		12.4%	Bad
				CARMD0308060542	37		31.8%	Bad
				CARMD0308060546	58		6.9%	Bad
			Sept.	WCR020309221611	453	464.3	2.4%	Good
				WCR020309221616	484		4.3%	Good
				WCR020309221620	493		6.2%	Bad
				WCR020309221625	427		8.0%	Bad
			Nov.	WCR20311031703	118	96.0	22.9%	Bad
				WCR20311031714	84		12.8%	Bad
				wcr20311031656	107		11.6%	Bad
				WCR20311031710	75		21.7%	Bad
		2004	March	CARMS0403221608	65	59.3	9.7%	Bad
				CARMS0403221611	69		16.5%	Bad
				CARMS0403221615	81		36.7%	Bad
				CARMS0403221619	22		62.9%	Bad
			April	UAA0403004r	15	-	-	-
			July	CARMS0407061830	0	26.0	100.0%	Bad
				CARMS0407061835	9		65.4%	Bad
				CARMS0407061840	34		30.8%	Bad
				CARMS0407061844	35		34.6%	Bad
			Aug.	CARMS0408031704	63	70.3	10.3%	Bad
				CARMS0408031709	59		16.0%	Bad
				CARMS0408031713	85		21.0%	Bad
				CARMS0408031718	74		5.3%	Bad

Study Stream	Site	Year	Month	Transect Name	Q (cfs)	Mean Q (cfs)	Relative Error	Sample Quality
			Sept.	CARMS0409211326	285	276.5	3.1%	Good
				CARMS0409211332	280		1.3%	Good
				CARMS0409211338	279		0.9%	Good
				CARMS0409211346	262		5.2%	Bad
			Nov.	CARMD0411090916	56	42.2	31.9%	Bad
				CARMD0411090918	29		31.7%	Bad
				CARMD0411090914	42		0.2%	Good
	WC3	2003	May	DATA_000r	379	373.6	1.4%	Good
				DATA_001r	377		1.0%	Good
				DATA_002r	380		1.6%	Good
				DATA_005r	359		4.0%	Good
			June	CARDS0306241759	864	885.3	2.4%	Good
				CARDS0306241803	810		8.5%	Bad
				CARDS0306241808	891		0.6%	Good
				CARDS0306241812	976		10.3%	Bad
			Aug.	CARDS0308060448	534	534.3	0.0%	Good
				CARDS0308060453	594		11.2%	Bad
				CARDS0308060455	490		8.3%	Bad
				CARDS0308060458	519		2.9%	Good
			Sept.	WCR030309221512	1,519	1,604.5	5.3%	Bad
				WCR030309221516	1,644		2.5%	Good
				WCR030309221519	1,527		4.8%	Good
				WCR030309221523	1,728		7.7%	Bad
			Nov.	WCR30311031618	333	453.6	26.6%	Bad
				WCR30311031624	455		0.2%	Good
				WCR30311031615	570		25.7%	Bad
				WCR30311031621	457		0.7%	Good
		2004	March	CARDS0403221523	267	422.3	36.8%	Bad
				CARDS0403221527	486		15.1%	Bad
				CARDS0403221532	444		5.2%	Bad
				CARDS0403221534	492		16.5%	Bad
			July	CARDS0407061747	373	364.5	2.3%	Good
				CARDS0407061750	345		5.3%	Bad
				CARDS0407061754	448		22.9%	Bad
				CARDS0407061758	292		19.9%	Bad
			Aug.	CARDS0408031613	105	96.8	8.5%	Bad
				CARDS0408031616	159		64.3%	Bad
				CARDS0408031622	46		52.5%	Bad
				CARDS0408031625	77		20.4%	Bad
			Sept.	CARDS0409211232	78	189.8	58.9%	Bad

Study Stream	Site	Year	Month	Transect Name	Q (cfs)	Mean Q (cfs)	Relative Error	Sample Quality
				CARDS0409211237	118		37.8%	Bad
				CARDS0409211241	331		74.4%	Bad
				CARDS0409211312	232		22.3%	Bad
			Nov.	CARDS0411090830	442	406.4	8.9%	Bad
				CARDS0411090834	270		33.6%	Bad
				CARDS0411090837	507		24.7%	Bad

Sub Appendix 6. Descriptive statistics of stream discharge (AbsQ) at all stations.

Sub Appendix 6 A. Descriptive statistics of stream discharge (ft3/s) for each study site during the period of April 2003 to November 2004. Calculated means are based on ADCP estimates of total discharge (AbsQ) collected at a station during the study.

Study Stream	Site	n	Mean Discharge (ft^3/s)	SD	SE	Minimum Discharge (ft^3/s)	Maximum Discharge (ft^3/s)	Range
West Carancahua	WC1	45	184	178	27	29	739	710
	WC2	44	186	215	32	7	787	780
	WC3	39	958	812	130	80	3,194	3,115
Garcitas Creek	GC1	37	183	296	49	24	1,412	1,388
	GC2	44	575	994	150	30	4,748	4719
	GC3	41	692	1,011	158	1.6	4,450	4,448
Tres Palacios	TP1	35	625	1,082	183	17	3,695	3,678
	TP2	42	642	1,093	169	12	3,933	3,921
	TP3	42	1,085	1,262	195	50	5,144	5,094

Sub Appendix 6 B. Descriptive statistics of stream discharge (ft3/s) at all study sites for all sampling events (from April 2003 to November 2004). Calculated means are based on ADCP estimates of total discharge (AbsQ) collected at a station during a sampling event.

Study Stream	Site	Year	Month	n	Mean	Std Dev	Std Error	Min	Max
West Carancahua	WC1	2003	April	11	107	90	27	0	261
			May	4	141	53	26	81	201
			June	4	108	36	18	72	155
			August	4	158	16	8	145	181
	WC1	2003	September	4	691	34	17	664	739
			November	4	62	20	10	37	86
		2004	March	4	98	46	23	55	140
			July	4	78	39	20	29	124
			August	4	140	18	9	123	159
			September	3	354	8	5	349	364
			November	2	97	32	22	75	120
	WC2	2003	April	5	244	207	92	54	529
			May	5	96	38	17	43	138
			June	4	26	27	13	10	66
			August	4	82	11	5	68	92
			September	4	729	56	28	677	787
			November	4	149	26	13	124	179
		2004	March	4	69	30	15	29	97
			July	4	29	24	12	7	50
			August	4	112	17	9	91	131
			September	4	405	12	6	387	412
			November	3	59	14	8	43	72
	WC3	2003	May	4	557	18	9	541	584
			June	4	1,645	113	57	1,490	1,739

Study Stream	Site	Year	Month	n	Mean	Std Dev	Std Error	Min	Max
			August	4	1,105	118	59	996	1,263
			September	4	2,965	204	102	2,760	3,194
			November	4	774	151	76	602	970
		2004	March	4	845	184	92	577	994
			July	4	545	137	68	421	728
			August	4	127	41	21	80	171
			September	4	274	155	77	85	453
			November	3	672	217	125	431	853
Garcitas Creek	GC1	2003	April	3	172	31	18	139	200
			May	4	76	9	4	71	90
			June	4	142	81	40	55	218
			August	4	57	21	10	32	77
			September	2	1,345	95	67	1,278	1,412
			November	4	118	25	13	89	150
		2004	March	4	141	16	8	126	160
			May	--	--	--	--	--	--
			July	4	38	24	12	7	58
			August	4	29	16	8	9	44
			September	3	355	14	8	340	363
			November	3	34	4	2	31	39
	GC2	2003	April	3	186	104	60	125	306
			May	6	426	155	63	170	554
			June	4	97	53	26	30	156
			August	3	138	36	21	109	178
			September	3	1,631	49	28	1,598	1,688
			November	4	336	45	22	280	386
		2004	March	4	314	45	22	274	377
			May	2	4,696	73	52	4,644	4,748

Study Stream	Site	Year	Month	n	Mean	Std Dev	Std Error	Min	Max
			July	4	86	32	16	57	123
			August	5	199	255	114	4	645
			September	3	813	58	33	749	861
			November	3	217	78	45	133	288
	GC3	2003	April	3	218	78	45	155	305
			May	4	555	41	21	513	607
			June	4	559	62	31	467	605
			August	4	102	32	16	73	143
			September	4	1,922	183	91	1,764	2,170
Garcitas Creek	GC3	2003	November	4	251	171	85	2	392
		2004	March	4	823	87	44	702	902
			May	2	4,426	34	24	4,402	4,450
			July	4	30	51	25	2	106
			August	4	222	189	95	53	408
			September	3	274	272	157	70	583
			November	3	95	64	37	33	160
Tres Palacios	TP1	2003	April	1	31	--	--	31	31
			May	4	182	9	4	171	193
			June	4	53	32	16	21	91
			August	4	375	36	18	336	416
			September	4	3,513	207	103	3,266	3,695
		2004	March	4	184	14	7	168	199
			July	4	113	47	23	69	157
			August	3	213	68	39	135	264
			September	3	34	15	8	17	43
			November	4	859	39	20	815	911
	TP2	2003	April	1	497	-	-	497	497
			May	4	401	74	37	322	477

Study Stream	Site	Year	Month	n	Mean	Std Dev	Std Error	Min	Max
			June	4	41	16	8	22	56
			August	4	404	37	18	368	453
			September	4	3,605	352	176	3,153	3,933
			November	8	58	29	10	12	104
		2004	March	4	173	9	5	160	180
			July	4	141	48	24	93	207
			August	3	80	18	11	61	97
			September	3	244	33	19	206	264
Tres Palacios	TP2	2004	November	3	1,993	80	46	1,927	2,080
	TP3	2003	April	3	1,050	738	426	353	1,823
			May	4	1,409	66	33	1,353	1,490
			June	4	458	159	80	308	612
			August	4	345	43	21	306	406
			September	4	4,302	1,012	506	3,003	5,144
			November	4	639	90	45	530	732
		2004	March	4	121	72	36	56	223
			July	4	918	89	45	788	991
			August	3	74	20	11	52	87
			September	4	207	164	82	50	391
			November	4	2,146	137	69	2,014	2,305