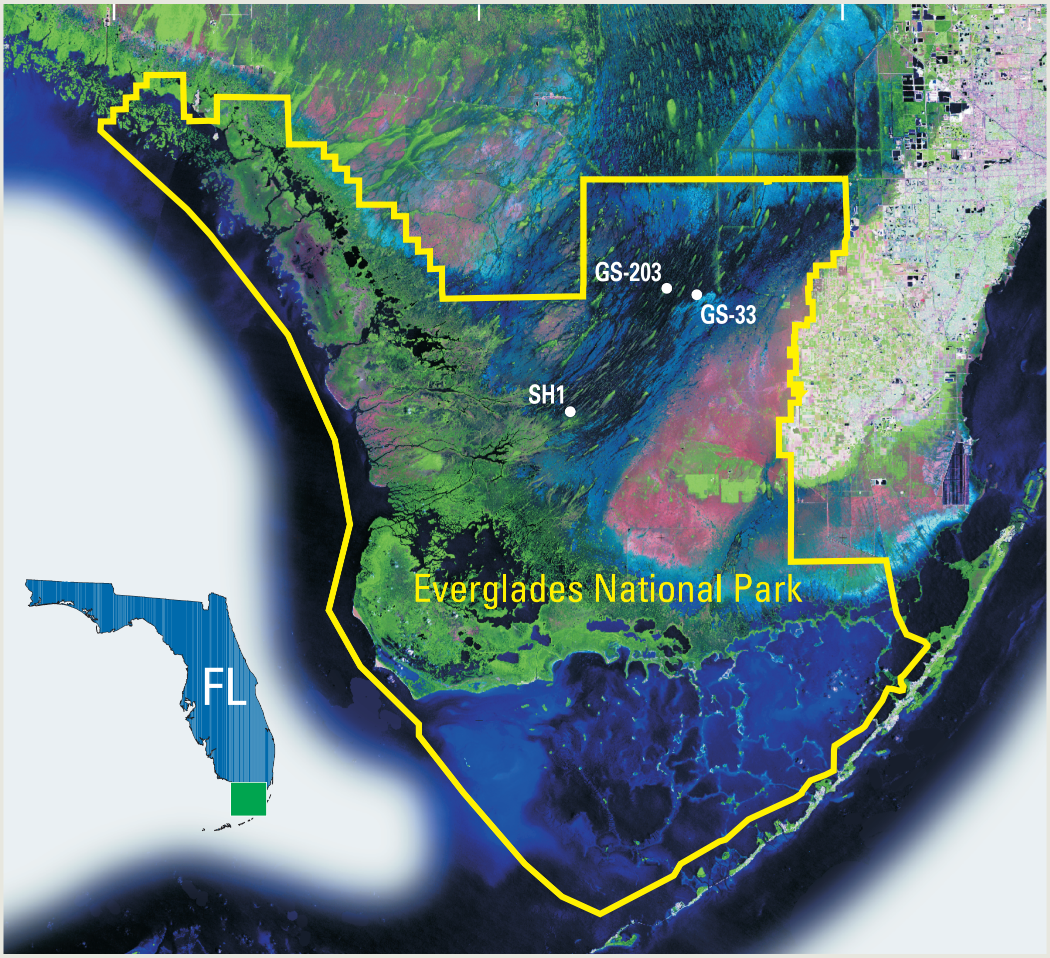
FLOW VELOCITY, WATER TEMPERATURE, AND CONDUCTIVITY IN SHARK RIVER SLOUGH, EVERGLADES NATIONAL PARK, FLORIDA: JULY 1999 – AUGUST 2001

Open File Report 02-159



U.S. Department of the Interior
U.S. Geological Survey

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By Ami L. Riscassi and Raymond W. Schaffranek

U.S. GEOLOGICAL SURVEY
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U.S. DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS AND ABBREVIATIONS

Divide	By	To obtain
	Length	
millimeter (mm)	25.4	inch (in)
centimeter (cm)	2.54	inch (in)
meter (m)	0.3048	foot (ft)
kilometer (km)	1.609	mile (mi)
	Velocity	
centimeter per second (cm/s)	30.48	foot per second (ft/s)
	Temperature	
degrees (°C)	0.555(+32)	degrees (°F)

Direction of flow is given in degrees clockwise from magnetic north (°CW from MN).
Frequency of velocity measurements is given in hertz (Hz).
Salinity is given in parts per thousand (ppt).
Specific Conductance is given in microsiemens per centimeter (μS/cm).

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ABSTRACT

A project within the U. S. Geological Survey Place-Based Studies Program is focused on investigation of "Forcing Effects on Flow Structure in Vegetated Wetlands of the Everglades." Data-collection efforts conducted within this project at three locations in Shark River Slough, Everglades National Park, during the 1999-2000 and 2000-2001 wet seasons are described in this report. Techniques for collecting and processing the data and summaries of daily mean flow-velocity, water-temperature, and conductivity data are presented. The quality-checked and edited data have been compiled and stored on the USGS South Florida Information Access website.

INTRODUCTION

A major thrust of the current Everglades restoration effort, according to the Comprehensive Everglades Restoration Plan (CERP) which is available on the World Wide Web at http://www.evergladesplan.org, is to restore the natural functioning of the ecosystem to pre-drainage conditions, an objective that requires knowledge of the hydrologic and hydraulic factors that affect the flow of water. The heterogeneous vegetation, small topographic gradient, and ridge-and-slough topography of the landscape variously affect flows through the vast mosaic of sloughs, marshes, and wet prairies that constitute the Everglades. Flow-velocity, water-temperature, and conductivity data collected in Shark River Slough within Everglades National Park (ENP) during the 1999-2000 and 2000-2001 wet seasons and documented in this report are intended to identify the temporal and spatial variability of the extremely slow flow of shallow water through the low-gradient landscape and to provide insight into the hydrologic and hydraulic processes that affect its behavior.

This project, which is part of the U. S. Geological Survey (USGS) Place-Based Studies Program, is focused on providing information on the nature and behavior of flows through the vegetated wetlands of the Everglades for the development of newly improved hydrologic models to evaluate water-management scenarios to restore the ecosystem. The flow data documented in this report were collected in direct support of the development of the Tides and Inflows in the Mangrove Ecotone (TIME) model (Schaffranek, 2001). A complementary project objective is to investigate and identify the internal and external forcing mechanisms that affect wetland flow behavior for use in analyzing hydrologic conditions in conjunction with related hydrologic investigations being conducted within the USGS South Florida Ecosystem Program (Schaffranek, 1999).

Description of Study Area and Monitoring Program

Shark River Slough is the dominant path of surface water flow in ENP. It conveys freshwater inflows released from hydraulic control structures and discharged through culverts along Tamiami Trail to the coastal mangrove ecotone of the southwest coast of Florida. The freshwater wetlands of Shark River Slough are a mixture of tree islands, sawgrass marshes, wet prairies, creeks, and ponds.

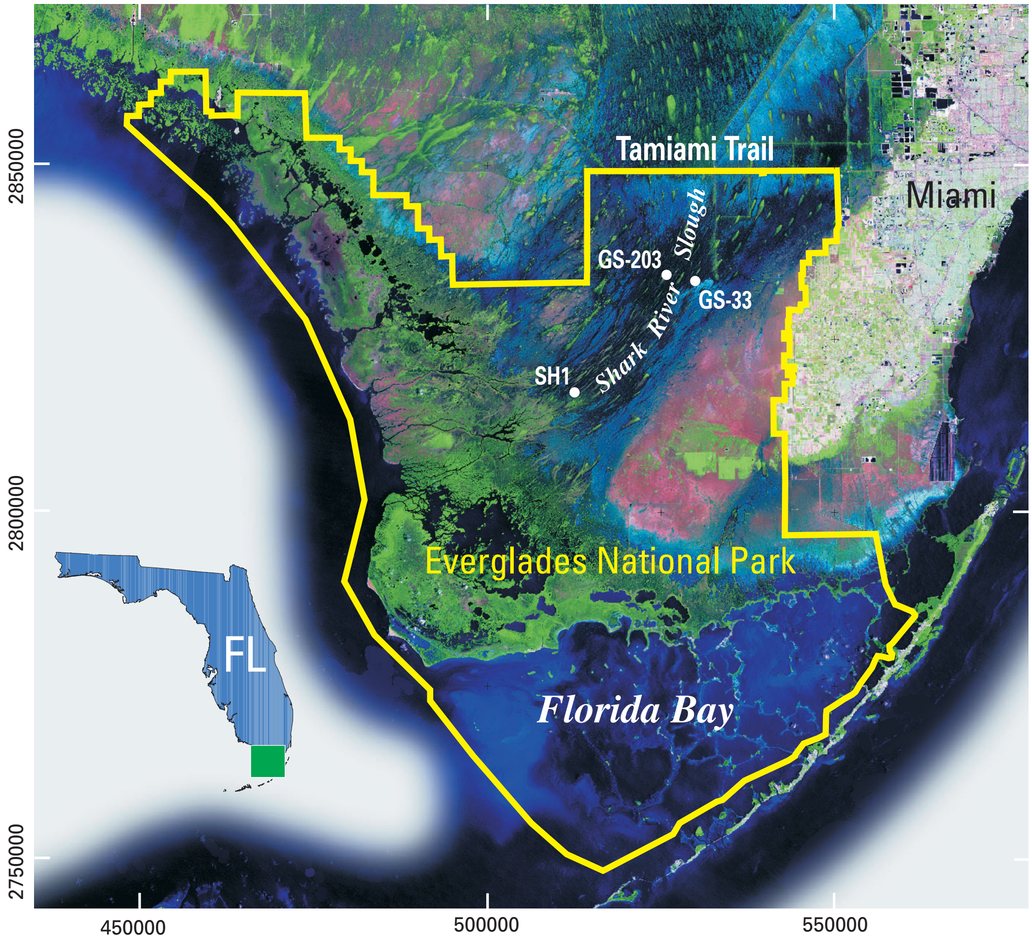
Three stations (SH1, GS-203, and GS-33) were established in 1999 and 2000 to monitor flows and related hydrologic conditions in differing vegetative communities within Shark River Slough (fig. 1). Flow velocities, water and air temperatures, and conductivities were monitored from July 1999 through August 2001. At all three sites, water and air temperatures were monitored at 5- or 30-minute intervals in 5- or 10-cm increments above the plant-litter layer using thermistors (thermally sensitive resistors) cabled together in a string. At two of the sites, velocities were monitored hourly or bi-hourly at a fixed point in the water column using acoustic Doppler velocity (ADV) meters. At one of the two ADV monitoring sites, conductivities and water temperatures were monitored bi-hourly near the plant-litter layer using a water-quality meter.

Purpose and Scope of Report

This report describes the instrumentation used, documents the deployment techniques, discusses the data-processing methodologies, illustrates examples of raw and filtered horizontal flow-velocity data, presents a sample water-temperature profile, and identifies horizontal flow-velocity magnitudes and directions at the monitoring sites. Daily mean flow velocities, conductivities, and water temperatures are presented. Quality checked and edited data are available for downloading from the Data Exchange page of the USGS South Florida Information Access (SOFIA) website http://sofia.usgs.gov/.

Acknowledgments

Tom Smith and Gordon Anderson, both of USGS, provided initial logistical support and ancillary stage data from their hydrologic monitoring station. Kevin Kotun, NPS/ENP, provided ancillary stage data from ENP hydrologic monitoring stations. Ed German and Sandra Kinnaman, both of USGS, contributed meteorological data from their evapotranspiration monitoring station. Michael Duff, USGS, developed the ADV filtering and plotting programs used to process, analyze, and display the data.



Base from U.S. Geological Survey South Florida satellite image map, 1993
Geographic Coordinates, NAD 83, Zone 17 Meters

Figure 1. Satellite image of south Florida covering Everglades National Park, showing locations of flow-monitoring stations GS-203, GS-33, and SH1, 1:500,000 scale.

MEASUREMENT TECHNIQUES

Acoustic Doppler Velocity (ADV) Meter

Flow velocities were measured using SonTek ADVField units (SonTek, 2001) that consist of a processing module and a conditioning module with an attached three-dimensional (3-D) acoustic probe (fig. 2A). The processing module is a waterproof canister containing processor electronics, a circuit board for internal data recording, and battery packs for autonomous operation. The conditioning module contains the internal acoustic receiver electronics, a built-in magnetic compass, a tilt sensor, and a temperature sensor mounted in the end cap opposite the probe. An external conductivity/temperature meter optionally can be integrated with the ADV unit.

The 3-D acoustic probe consists of three receivers mounted on short stems positioned in 120-degree arcs around an acoustic transmitter in a down-looking orientation (fig. 2B). The ADV meter measures the frequency shift between a short acoustic pulse of known frequency and its reflectance from particles moving with the flow in a remote sampling volume. A 10 MHz probe with a 5-cm distance from the transmitter to the cylindrical sampling volume ($\approx$ 0.25 cm^3) was used. Local water temperature and salinity data were used to compute site-specific sound speed, which is needed to convert Doppler frequency shift to flow velocity. The ADV meter records 3-D velocity components at a user-specified sampling rate to a resolution of 0.1 mm/s with an accuracy of 1% of measured velocity (SonTek, 2001). The internal magnetic compass and tilt sensor allow the instrument processor to internally convert Cartesian coordinate (XYZ) velocity components to Geodetic East, North, and Up (ENU) coordinates.

Conductivity/Temperature Meter

Conductivity and temperature data were measured using a MicroCAT model SBE 37-SI meter developed by Sea-Bird Electronics (1999). The MicroCAT meter measures conductivity to a 0.1 µS/cm (microSeimen/centimeter) resolution with an accuracy of 3.0 µS/cm and temperature to a 0.0001 °C resolution with an accuracy of 0.002 °C (Sea-Bird Electronics, 1999). Conductivity and temperature data measured by the MicroCAT meter were integrated into the data set recorded by the ADV unit.

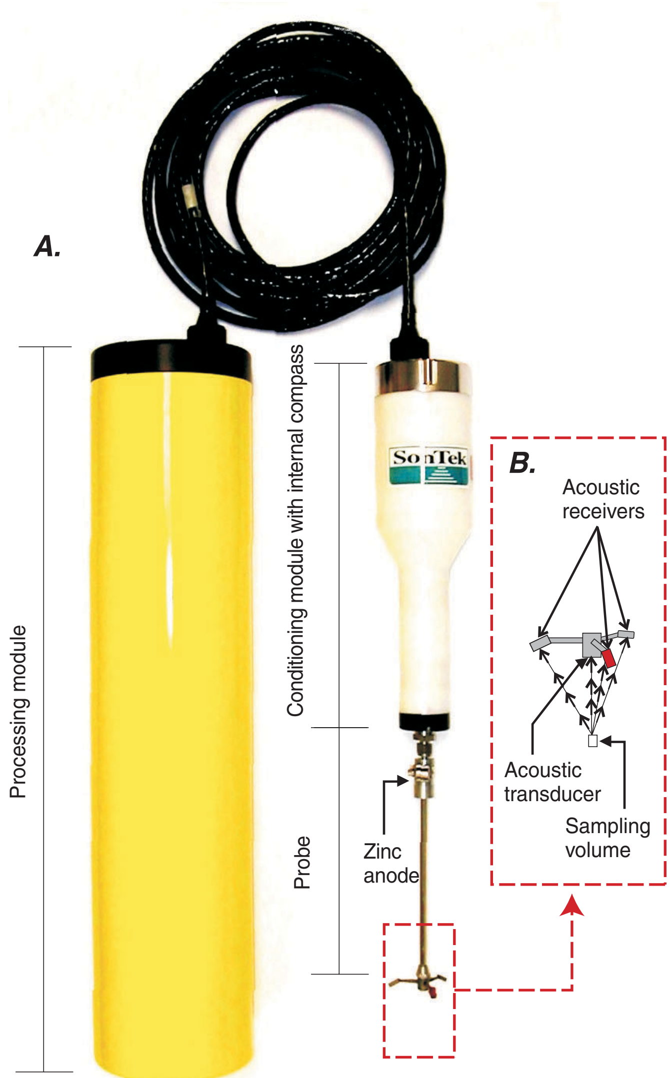


Figure 2. Photograph showing ADVField system including (*A*) processing module, conditioning module, and (*B*) 3-D acoustic probe. (Red receiver is X-axis of probe.)

Thermistor String

Water and air temperatures were measured using glass-encapsulated thermistors made by Yellow Springs Instruments (YSI) having a standard 10K ohm resistance at 25 °C and an accuracy (as defined by interchangeability) of ±0.1 °C over 0 to 70 °C (Yellow Springs Instruments, 1998). The thermistors were individually molded and cabled together in a string. Ten thermistors were grouped together in two sets of five individually spaced 10 cm apart. The two sets were spaced 1 m apart to facilitate overlapping the cable to achieve 5-cm spacing between thermistors. An eleventh thermistor was attached at the end of the string on a 1-m length of cable or thin TV-type 2-conductor wire. The eleventh thermistor was either deployed at a fixed elevation in the air above the plant-litter layer or encapsulated in styrofoam to float on the water surface. The thermistor string was wired to a Campbell Scientific Instruments (CSI) CR10X datalogger programmed to sample the thermistors at pre-determined intervals and perform the resistance to temperature conversions. Measured resistances were converted to temperatures in the datalogger program using the Steinhart and Hart equation (Yellow Springs Instruments, 1998):

$$1/T = a + b (\ln R) + c (\ln R)^3$$

in which:

T = temperature in Kelvin units (°C + 273.15),
a, b, c = calibration coefficients, and
ln R = natural logarithm of resistance in ohms.

The coefficients a = 1.040312e-3, b = 2.370987e-4, and c = 1.663151e-7 were determined in controlled measurements over a range of 0-70 °C for the YSI thermistors.

SELECTION AND DESCRIPTION OF FLOW-MONITORING SITES

Locations of the flow-velocity and water-temperature monitoring stations SH1, GS-203, and GS-33 are shown in figure 1. Stations GS-203 and GS-33 are near established ENP hydrologic monitoring stations, NP-203 and P33, and SH1 is co-located with an existing USGS hydrologic monitoring station. Thermistor strings were deployed at all three sites. ADV units were deployed at GS-203 and SH1. The ADV unit at GS-203 included an integrated MicroCAT conductivity/temperature meter.

Each station was established within a different vegetative community. The SH1 ADV probe and thermistor string were deployed in an area dominated by spikerush (*Eleocharis cellulosa*) on the edge of a sawgrass (*Cladium jamaicense*) stand (fig. 3). The GS-203 ADV probe and thermistor string were deployed in an area of medium-density sawgrass (fig. 4). The GS-33 thermistor string was deployed in a spikerush community with a heavy periphyton concentration (fig. 5). Geodetic coordinates, site descriptions, and instrumentation lists for all three monitoring stations are provided in table 1.

DEPLOYMENT TECHNIQUES AND PARAMETER SETTINGS

The ADV conditioning module with attached 3-D probe (fig. 2), was suspended vertically from a rigid frame with the acoustic sampling volume at a fixed position in the water column above the plant-litter layer (fig. 3). A pair of stainless steel rods, used to secure the conditioning module to the frame, readily permitted vertical re-positioning (raising or lowering) of the probe in the water column during field visits in response to changing water depths (fig. 3). Software programs were executed during probe installation and during subsequent field visits to set site-specific parameters that initiate data collection, protect data integrity, verify meter performance, and ensure the collection of high-quality data. Parameter settings are user-specified values input to the ADV processor that assign the duration and frequency of sampling as well as specify the sound speed required for velocity determinations. ADV-deployment parameter settings at SH1 and GS-203 are provided in table 2.

Figure 3. Photograph taken looking southwest towards the ADV meter deployed at SH1 in a spikerush area on the edge of a sawgrass stand.

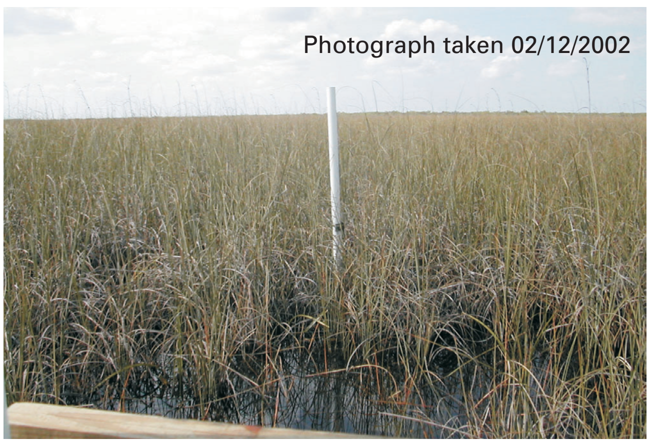


Figure 4. Photograph taken looking northwest at the thermistor string deployed at GS-203 in a sawgrass area.

Figure 5. Photograph taken looking north at the thermistor string deployed at GS-33 in a spikerush community.

The MicroCAT meter, integrated into the GS-203 ADV unit, measures and records data at the same frequency as the ADV meter and therefore has no unique user-specified parameter settings. The MicroCAT meter was deployed immediately above the plant-litter layer near the ADV probe.

The temperature-string deployment techniques and parameter settings consisted of specification of the thermistor-spacing increment and the recording interval. The resistance-to-temperature conversion equation and the recording interval were stored in the CR10X datalogger using the PC208W (V 3.0) communication and storage module software (Campbell Scientific Inc., 1999). The recording interval can be readily modified using the CSI PC208W programming software. Thermistor positions, in relation to the top of the plant-litter layer, and temperature recording intervals at the SH1, GS-203, and GS-33 sites are listed in table 3.

ADV-Meter Deployment Procedures and Programs

The setting of data-collection parameters and initiation of the ADV-meter deployment were typically accomplished in the field by connecting the processor unit to the serial port of a laptop computer. A set of software programs provided with each ADV unit facilitated design of the sampling strategy, assignment of acoustic signal-processing parameters, initiation of the data-collection sequence, and subsequent downloading of data from the datalogger. Prior to deployment of the ADV probe at each site, the ADV compass was calibrated in accordance with the manufacturer's instructions and the ADFcheck diagnostic program (SonTek, 2001) was executed. The ADFcheck program is used to verify meter performance and to identify hardware problems, such as a bent probe or malfunctioning transmitter, which can cause the loss or corruption of data. The ADFcheck program produces a plot of the signal strength for the three acoustic receivers and a tabular summary of diagnostic parameters that are useful in post-processing analyses. Prior to probe deployment, a log file was created on the laptop to record all parameter settings assigned during field initiation of the ADV meter. This included recording of output from configuration, setup, system, deployment, and sensor commands. A complete description of software programs and applicable commands to invoke and use the programs to make parameter assignments is available in the manufacturer's documentation (SonTek, 2001).

During field visits, the water depth at the probe location was measured, the signal pathway between the acoustic transmitter and sampling volume was inspected and cleared of vegetation if necessary, and the acoustic probe was cleared of any biological growth. The recording interval and location of the sample volume in relation to the top of the plant-litter layer are provided in table 4 for each ADV deployment. Approximate minimum, maximum, and average water depths determined from water levels recorded at nearby hydrologic stations also are listed in table 4.

ADV Parameter Settings

The ADV meter takes multiple flow-velocity measurements per second, referred to as pings, to produce a single

Table 1. Site locations and instrumentation for flow-velocity and water-temperature monitoring stations

Site name	UTM Coordinates NAD 83, Zone 17 East (m)	North (m)	Location	Instrumentation
GS-203	526133	2833920	160 m from NP-203 hydrologic station at 22.7 degrees west of south	ADV unit, MicroCAT meter, thermistor string, data logger, solar panel
GS-33	529637	2833457	440 m from P33 hydrologic station at 30.6 degrees west of north	Thermistor string, data logger, solar panel
SH1	515249	2817258	10 m southwest of SH1 hydrologic station	ADV unit, thermistor string, data logger, solar panel

Table 2. Deployment parameter settings for SH1 and GS-203 ADV units

Deployment period[1]		Recording interval (min)	Deployment Parameters Temp (°C)	Salinity (ppt)	Vel range (cm/s)	Coord system
			SH1			
			1999-2000 Wet Season			
7/28/99 1530 - 8/29/99 1830	EST	30	16.1	0.1	+/- 10	ENU
9/9/99 1200 - 11/13/99 1200	EST	60	16.1	0.1	+/- 10	ENU
12/8/99 1200 - 1/10/00 0000	EST	30	16.1	0.1	+/- 10	ENU
1/25/00 1400 - 2/27/00 0200	EST	30	16.1	0.1	+/- 10	ENU
			2000-2001 Wet Season			
4/5/00 1400 - 5/8/00 200	EST	30	25	0.1	+/- 10	ENU
7/26/00 1400 - 9/5/00 1100	EST	30	25	0.1	+/- 10	ENU
9/5/00 - 10/23/00 [2]	EST	30	25	0.1	+/- 10	ENU
10/23/00 - 11/30/00 [2]	EST	30	25	0.1	+/- 10	ENU
11/30/00 - 1/19/01 [2]	EST	30	25	0.1	+/- 10	ENU
			GS-203			
			2000-2001 Wet Season			
8/17/00 1411 - 8/24/00 1711 [3]	EDT	30	20	0	+/- 250	XYZ
9/6/00 1146 - 9/22/00 2046 [3]	EDT	30	30	0	+/- 250	XYZ
10/26/00 1341 - 11/16/00 1611 [3]	EDT	30	25	0	+/- 10	XYZ
11/30/00 1244 - 1/13/01 1944 [3]	EST	30	25	0	+/- 10	XYZ

[1] excludes initial and final data segments when probe was out of water or disturbed
[2] no data recorded due to recorder malfunction
[3] data collection inadvertently initiated at uneven recording interval

Table 3. Deployment specifications and parameter settings for SH1, GS-203, and GS-33 temperature strings

Deployment period		Recording interval (min)	Thermistor height [1] (cm)
SH1			
1999-2000 Wet Season			
12/8/99 1400 - 1/24/00 1030	EDT	30	0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 110
5/16/00 1940 - 5/25/00 1105	EDT	5	0, 10, 15, 20, 25, 30, 35, 40, 45, 55, 65
2000-2001 Wet Season			
7/21/00 1130 - 7/26/00 1055	EDT	5	0, 10, 15, 20, 25, 30, 35, 40, 45, 55, 65
7/26/2000 1100 - 9/6/00 1000	EDT	30	0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 110
9/6/00 1430 - 10/26/00 1100	EDT	30	0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 110
10/26/00 1130 - 11/30/00 1200	EDT	30	0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 110
11/30/00 1600 - 1/19/01 1230	EDT	30	0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 110
6/26/01 1530 - 8/15/01 1200	EDT	30	0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 110
GS-203			
2000-2001 Wet Season			
8/16/00 1530 - 9/5/00 1300	EDT	30	0, 10, 20, 25, 30, 35, 40, 45, 55, 65, water surface
9/5/00 1330 - 10/26/00 1300	EDT	30	0, 10, 20, 25, 30, 35, 40, 45, 55, 65, water surface
10/26/00 1330 - 11/30/00 1330	EDT	30	0, 10, 20, 25, 30, 35, 40, 45, 55, 65, water surface
11/30/00 1400 - 1/19/01 1130	EDT	30	0, 10, 20, 25, 30, 35, 40, 45, 55, 65, water surface
1/19/01 1200 - 8/8/01 1700 [2]	EDT	30	0, 10, 20, 25, 30, 35, 40, 45, 55, 65, water surface
GS-33			
2000-2001 Wet Season			
8/17/00 1130 - 9/5/00 1400	EDT	30	0, 10, 20, 25, 30, 35, 40, 45, 55, 65, water surface
9/5/00 1430 - 10/26/00 1400	EDT	30	0, 10, 20, 25, 30, 35, 40, 45, 55, 65, water surface
10/26/00 1430 - 11/30/00 1400	EDT	30	0, 10, 20, 25, 30, 35, 40, 45, 55, 65, water surface
11/30/00 1430 - 1/19/01 1100	EDT	30	0, 10, 20, 25, 30, 35, 40, 45, 55, 65, water surface
1/19/01 1130 - 8/8/01 1530 [3]	EDT	30	0, 10, 20, 25, 30, 35, 40, 45, 55, 65, water surface

[1] measured from 1-2 cm below top of plant-litter layer
[2] all thermistors out of water from approximately 2/16/01 - 7/15/01
[3] all thermistors out of water from approximately 3/18/01 - 7/8/01

velocity estimate, or sample, each second. The ADV probe is designed to ping as frequently as possible. The rate under normal operating conditions ranges from 150 to 250 times per second, but varies with the velocity range setting (SonTek, 2001). Standard velocity range settings for the 10 MHz ADV unit are ±3, ±10, ±30, ±100, and ±250 cm/s; the default range setting is ±250 cm/s. Accurate velocity measurements are dependent on setting a representative velocity range anticipated during the deployment period. Velocity range settings specified for each deployment are listed in table 2. The number of pings averaged within a sample is set to meet a user-specified sampling rate within the range of 0.1 to 25 Hz.

To reduce memory requirements and conserve battery power, all autonomous deployments use a burst, rather than a continuous, sampling strategy. A burst is a collection of samples taken over a programmable time or ‘burst’ interval. Individual samples are stored for subsequent analysis. During all deployments at both ADV measurement sites, velocities were sampled at 10 Hz in one-minute bursts yielding 600 individual 3-D component velocity samples at hourly or bi-hourly intervals.

Representative constant salinity and temperature values were input to the ADV processor for sound-speed calculation for each deployment (table 2). Although there is a deployment option to use time-varying water temperatures measured by the internal sensor of the ADV meter to compute sound speed, the end cap of the conditioning module housing the temperature probe was never submerged during the deployments. Therefore, an externally measured constant temperature was specified. However, post-processing allows for overriding the specified constant salinity and temperature with time-varying values, including those measured by the MicroCAT meter, if the specified constant values subsequently are found to be unrepresentative of conditions over the deployment period.

During deployment initiation, the coordinate system was set to either XYZ for recording 3-D velocity component data in Cartesian coordinates relative to the fixed probe position or to ENU, which signals the ADV unit to use data from

Table 4. ADV data-collections summaries for SH1 and GS-203

Deployment period [1]		Data recorded?	Recording interval (min)	Sample volume location above top of litter (cm)	Approximate water depth range (avg) (cm)
			SH1		
			1999-2000 Wet Season		
7/28/99 15:30 - 8/29/99 1830	EST	Yes	30	5	37-53 (42)
9/9/99 1200 - 11/13/99 1200	EST	Yes	60	11	55-88 (70)
12/8/99 1200 - 1/10/00 0000	EST	Yes	30	11	52-63 (59)
1/25/00 1400 - 2/27/00 0200	EST	Yes	30	11	40-48 (44)
			2000-2001 Wet Season		
4/5/00 1400 - 5/8/00 0200	EST	Yes [2]	30	11	8-22 (17)
7/26/00 1400 - 9/5/00 1530	EST	Yes	30	11	22-39 (32)
9/5/00 - 10/23/00	------	No [3]	------	------	------
10/23/00 - 11/30/00	------	No [3]	------	------	------
11/30/00 - 1/19/01	------	No [3]	------	------	------
			GS-203		
			2000-2001 Wet Season		
8/17/00 1541 - 8/24/00 1711 [4]	EDT	Yes [2]	30	15	17-21 (19)
9/6/00 1146 - 9/22/00 2046 [4]	EDT	Yes	30	10	24-30 (27)
10/26/00 1341 - 11/16/00 1611 [4]	EDT	Yes	30	10	37-40 (40)
11/30/00 1244 - 1/13/01 1944 [4]	EST	Yes	30	10	16-31 (25)

1 excludes initial and final data segments when probe was out of water or disturbed
2 probe in and out of water
3 no data recorded due to recorder malfunction
4 data collection inadvertently initiated at uneven recording interval

the internal compass and tilt sensor to transform the velocity data to Earth coordinates. Any data initially recorded in XYZ coordinates during the deployments documented in this report were converted to ENU coordinates in post-processing. A complete list of parameters assigned for each deployment is provided in table 2.

The ADV unit has several data-recording options for compass readings, internal and external sensor output, and statistical information for the 3-D velocity-component samples. The ability to effectively analyze and quality check the samples is dependent on obtaining ancillary information about the acoustic signal processing that can be optionally recorded by the ADV unit. Statistical correlations of the individual acoustic pings within a sample were used extensively in editing and analyzing the velocity data as discussed subsequently. The default settings for recording this additional information vary for each option and are identified in the manufacturer's documentation (SonTek, 2001). For the deployments documented in this report, all available statistical information was recorded for post-processing and analyses.

METHODS OF DOWNLOADING DATA

Downloading of the ADV dataloggers was typically accomplished using the manufacturer-provided software after retrieving the processing module from the field. Due to the large quantity of data generated during each deployment, downloading of files (up to 40 mb in size) required 4 to 5 hours, which would have made downloading in the field problematic and impractical. After the data were downloaded and the datalogger was formatted, the processing module was returned to the field site for re-deployment. Temperature-string data files (< 3 mb in size) were downloaded on site via a laptop computer using the PC208W communication and storage module software (http://cambellscientific.com).

ADV DATA-REDUCTION AND PROCESSING TECHNIQUES

The processing methods described in this report for data-collection efforts employing autonomous ADV units are an extension of techniques and methods developed and documented previously for instantaneous data-collection efforts employing non-recording ADV units (Ball and Schaffranek, 2000). A preliminary data-inspection process, a pre-editing data-conversion process, two complementary automated data-editing processes, and a visual qualitative inspection process were used to edit, verify, and otherwise process the recorded flow-velocity, signal-quality, statistical-correlation, and ancillary data downloaded from the ADV datalogger. The entire set of ADV data post-processing techniques consisted of the following steps:

- inspection of the downloaded data set to identify periods when the probe was known to be out of the water or disturbed followed by appropriate truncation of the data file;
- pre-editing sound-speed correction and coordinate-system conversion using the manufacturer's software;
- automated filtering based on statistical correlation and number of samples per burst, flagging of suspect bursts based on percent difference and maximum value, and initial calculation of burst-averaged 3-D component and horizontal velocities and daily mean horizontal flow speeds and directions including flagged values, using USGS-developed software;
- visual qualitative inspection of flow velocities using meteorological data and other available information and subsequent flagging of additional suspect bursts; and
- automated recalculation of burst-averaged 3-D component and horizontal velocities and daily mean horizontal flow speeds and directions excluding flagged suspect bursts, using USGS-developed software.

Prior to initiating the automated data-editing process, data were scrutinized to identify any values that might have been recorded before the conditioning module and probe were cabled to the processing module or the probe was submerged. Several situations occurred where it was necessary to initiate an ADV meter for deployment using the program software prior to gaining access to the field site to position the probe. Data recorded during site visits, when flow velocities were affected by onsite arrival, departure, or cleaning of the acoustic probe also were identified. Affected data were removed in an initial pre-data-editing process by appropriately assigning an exclusive burst range for the exporting of time-series and header text files discussed subsequently. (Alternatively, affected data could have been removed subsequently from the fully exported time-series and header files using a text editor.) Data collected when the probe was suspected of intermittently being out of the water during the deployment period due to low water levels were initially retained for further inspection by automated and qualitative means to ensure that no valid measurements were errantly discarded.

The first data-processing technique, utilizing software provided by the manufacturer, consisted of pre-processing data at the sample level. Data remaining after known initial bad values were eliminated were first pre-processed with the SonTek ViewHydra (V 2.71) program to re-compute velocities in ENU coordinates, if necessary, and to substitute more representative temperature and salinity values for sound-speed calculation, if appropriate. Velocities were converted to ENU coordinates in the ViewHydra program either by selecting the appropriate velocity-coordinate-system option or by entering an applicable probe axis rotation for the specific deployment. (User-specified input of the probe rotation was necessary for those ADV meter deployments that were initiated prior to gaining access to the field site). The speed of sound was recalculated based on constant mean temperature and salinity values determined from time-varying temperature and conductivity data measured by the MicroCAT meter or obtained from nearby hydrologic stations. (The MicroCAT meter converts conductivity to salinity using the 1978 Practical Salinity Scale (Sea-Bird Electronics, 1999). There is an option in the ViewHydra program to use time-varying temperature and salinity values measured by the MicroCAT meter to compute instantaneous sound speed; however, a comparison of velocities computed using individual sound speed values to those computed using a constant mean value for the entire deployment period yielded insignificant differences on the order of hundredths of a millimeter-per-second, well beyond the ADV meter accuracy. Generally, a temperature change of 5 °C or a salinity change of 12 ppt results in a change in sound speed of 1 % (SonTek, 2001). Specific deployment parameters and post-processing correction values are listed in table 5.

Using the new sound-speed parameters, burst statistics were recomputed and control, time-series, and header ASCII text files were exported by the ViewHydra program. The control file contains the water-quality parameters and instrument-specific information used to compute velocity components and site-specific data for identification purposes; it is not used in filter processing. The time-series file contains 3-D velocity, signal strength, and correlation component values for each sample. The correlation value is a general data-quality parameter expressed as a percent that can identify poor velocity data resulting from a variety of factors, such as an instrument malfunction or a fouled probe. Signal strength values are a measure of the intensity of the reflected acoustic signal and can be converted to signal-to-noise ratios (SNR) by subtracting the ambient noise and converting to units of decibels (dB). The header file contains the mean 3-D velocity component values for each measurement, or 'burst' interval, and all date and time information associated with each burst.

The USGS-developed data-processing technique, described herein, consisted of automated data editing and processing at both sample and burst levels. This technique involved use of a filtering program, ADVFilter1.pl, available for downloading from the manuals/software page of the TIME website located at http://time.er.usgs.gov on the World Wide Web. The filter can be used with any ADV time-series and header text files exported by the ViewHydra program from the binary data file recorded by the ADV processing unit or extracted by other SonTek programs. The ADVFilter1 program contains statistical-correlation, percent-difference, and maximum-value functions with control parameters that can be set by the user based on individual ADV data attributes. The program computes burst-averaged 3-D velocity components, horizontal magnitudes, and flow directions and also optionally calculates the value difference between successive velocity magnitudes. The statistical-correlation function consists of two processes that remove 3-D velocity component samples and bursts from the exported data file. The first process removes all 3-D velocity component samples composed of pings that have a statistical correlation less than a specified minimum percentage for either

Table 5. Post-processing changes to ADV-deployment parameter settings for SH1 and GS-203

Deployment period [1]		Temperature Old (°C)	Temperature New (°C)	Salintiy Old (ppt)	Salintiy New (ppt)	Coordinate system Old	Coordinate system New
SH1							
1999-2000 Wet Season							
7/28/99 1530 - 8/29/99 1830	EST	16.1	30 [2]	0.1	------	ENU	------
9/9/99 1200 - 11/13/99 1200	EST	16.1	30 [2]	0.1	------	ENU	------
12/8/99 1200 - 1/10/00 0000	EST	16.1	23	0.1	------	ENU	------
1/25/00 1400 - 2/27/00 0200	EST	16.1	20 [2]	0.1	------	ENU	------
2000-2001 Wet Season							
4/5/00 1400 - 5/8/00 0200	EST	25	25 [2]	0.1	------	ENU	------
7/26/00 1400 - 9/5/00 1100	EST	25	29	0.1	------	ENU	------
GS-203							
2000-2001 Wet Season							
8/17/00 1411 - 8/24/00 1711 [3]	EDT	20	29	0.1	0.17	XYZ	ENU
9/6/00 1146 - 9/22/00 2046 [3]	EDT	30	29	0.1	0.16	XYZ	ENU
10/26/00 1341 - 11/16/00 1611 [3]	EDT	25	24	0.1	0.18	XYZ	ENU [4]
11/30/00 1244 - 1/13/01 1944 [3]	EST	25	18	0.1	0.26	XYZ	ENU [4]

1 excludes initial and final data segments when probe was out of water or disturbed
2 estimated values based on available data
3 data collection inadvertently initiated at uneven interval
4 converted with user specified rotation

their East/West or North/South component. The second process removes any burst having less than a specified minimum number of samples that pass the statistical-correlation filter. The optional percent-difference and maximum-value functions also flag data bursts for subsequent validation or elimination from the exported data file. The pre-processed data files generated by the ADVFilter1 program subsequently can be reprocessed to exclude flagged values from applicable computations, such as the evaluation of burst-averaged and daily mean velocities.

The six output files, three of which are optional, created by the ADVFilter1 program contain the following:

- velocity samples and associated correlation, amplitude, and SNR (optional) values for each 3-D component;
- burst-averaged velocity and associated correlation, amplitude and SNR (optional) values for each 3-D component;
- daily mean horizontal velocity magnitude and flow direction plus water temperature, conductivity, salinity, and specific conductance, if optional MicroCAT meter integrated with ADV unit;
- burst-averaged temperature, conductivity, salinity, and specific conductance, if optional MicroCAT meter integrated with ADV unit;
- percent differences between successive burst-averaged horizontal velocity magnitudes (optional); and
- value differences between successive burst-averaged 3-D velocity components (optional).

A visual, qualitative inspection of burst-velocity magnitudes and flow directions in conjunction with ancillary stage, rain, and other meteorological data, also was conducted as a final processing technique to isolate any additional suspect velocity data that might have been affected by sporadic perturbations in the water column or otherwise contaminated. Upon inspection of the data, anomalous velocities were identified and evaluated for potential correlation to a meteorological event. If no meteorological event could be attributed to an anomalous value, individual samples within the suspect burst were inspected and the burst was flagged if the samples were found to exhibit inexplicable fluctuations in velocity magnitude and (or) flow direction.

Flagged data, including those identified by percent difference or maximum value filters as well as by qualitative inspection, optionally are removed from the final data set using a second automated filter program ADVFilter2.pl, also developed by the USGS and available at the TIME website located at http://time.er.usgs.gov on the World Wide Web. This program re-generates burst-averaged 3-D velocity components excluding bursts that have been flagged in the initial data set and re-calculates daily mean horizontal flow speeds and directions with the reduced number of bursts.

PROCESSING ADV, CONDUCTIVITY, AND TEMPERATURE DATA

The editing and filtering criteria used to process the ADV data documented in this report included those suggested by the manufacturer to detect suspect data attributed to poor signal quality (SonTek, 2001) and those developed during the processing and concurrent analysis of the flow-

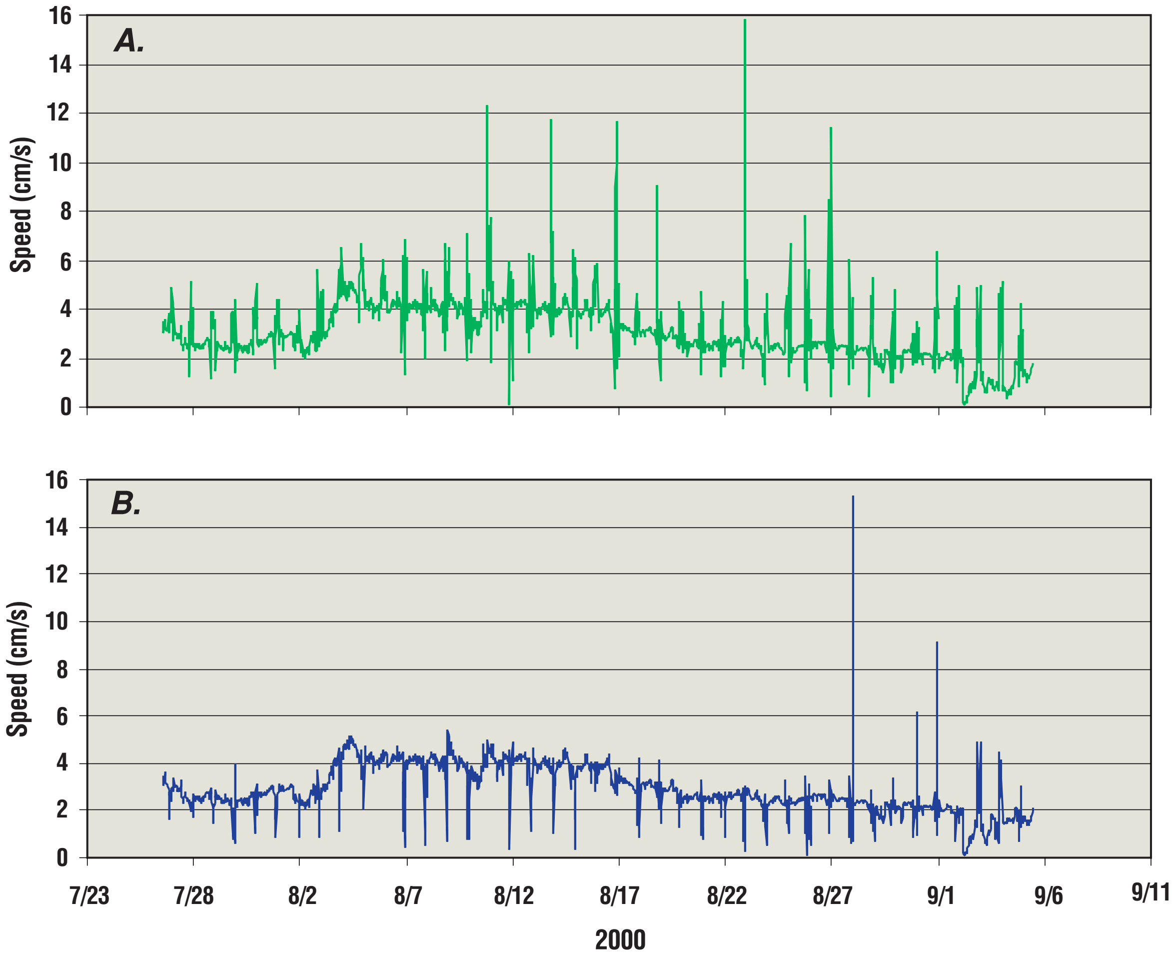


Figure 6. Graphs showing flow speeds at SH1 in Shark River Slough, Everglades National Park, during July 26–September 5, 2000, obtained from bursts containing (*A*) all samples and (*B*) only samples with a 70 percent minimum correlation.

velocity data. Evaluation of the flow-velocity data during each processing step, selection of editing parameters based on data attributes, and analyses of detected data anomalies are discussed and presented in this section of the report. Processing of the MicroCAT temperature and conductivity data, calculation of specific conductances, and discussion of the temperature profile data also are presented in this section.

ADV Data

Minimum SNR and statistical-correlation values of 5 dB and 70 %, respectively, are suggested as being indicative of good acoustic signal quality (SonTek, 2001). A minimum SNR value of 5 dB is considered reliable for the computation of mean velocities. The high clarity of water at the ADV measurement sites yielded reflections that were close to the noise floor of the ADV meter, but still within acceptable limits, ranging from approximately 5 to 15 dB at SH1 and from 5 to 20 dB at GS-203 during all deployments. As a consequence, SNR values were computed for each burst and included with the filtered data made available for downloading from the SOFIA website; however, they were not used as a filter-editing criterion.

The initial automated data-editing process consisted of the application of two filter criteria based on minimal statistical correlations and minimum number of valid samples per burst. A minimum correlation value of 70 % was used as the statistical-filtering criterion. Unfiltered and filtered horizontal velocity magnitudes, determined from 3-D velocity components measured at SH1 and GS-203, are illustrated for comparison in figures 6 and 7, respectively. Flow-speed differences resulting from the statistical-correlation filtering process are clearly evident.

A second criterion was employed subsequently to evaluate the statistical-correlation-filtered data based on a specified minimum number of valid samples required to compute a representative burst-averaged horizontal flow velocity. The minimum number of samples required per burst to produce a burst-averaged velocity was determined by examination and assessment of differences found using various filter criteria on data sets from both SH1 and GS-203. The filter initially was applied using criteria of 600, 500, 400, 300, 200, 100, and 1 minimum samples per burst. Differences between daily mean horizontal flow velocities computed using the strictest samples-per-burst filter (all 600

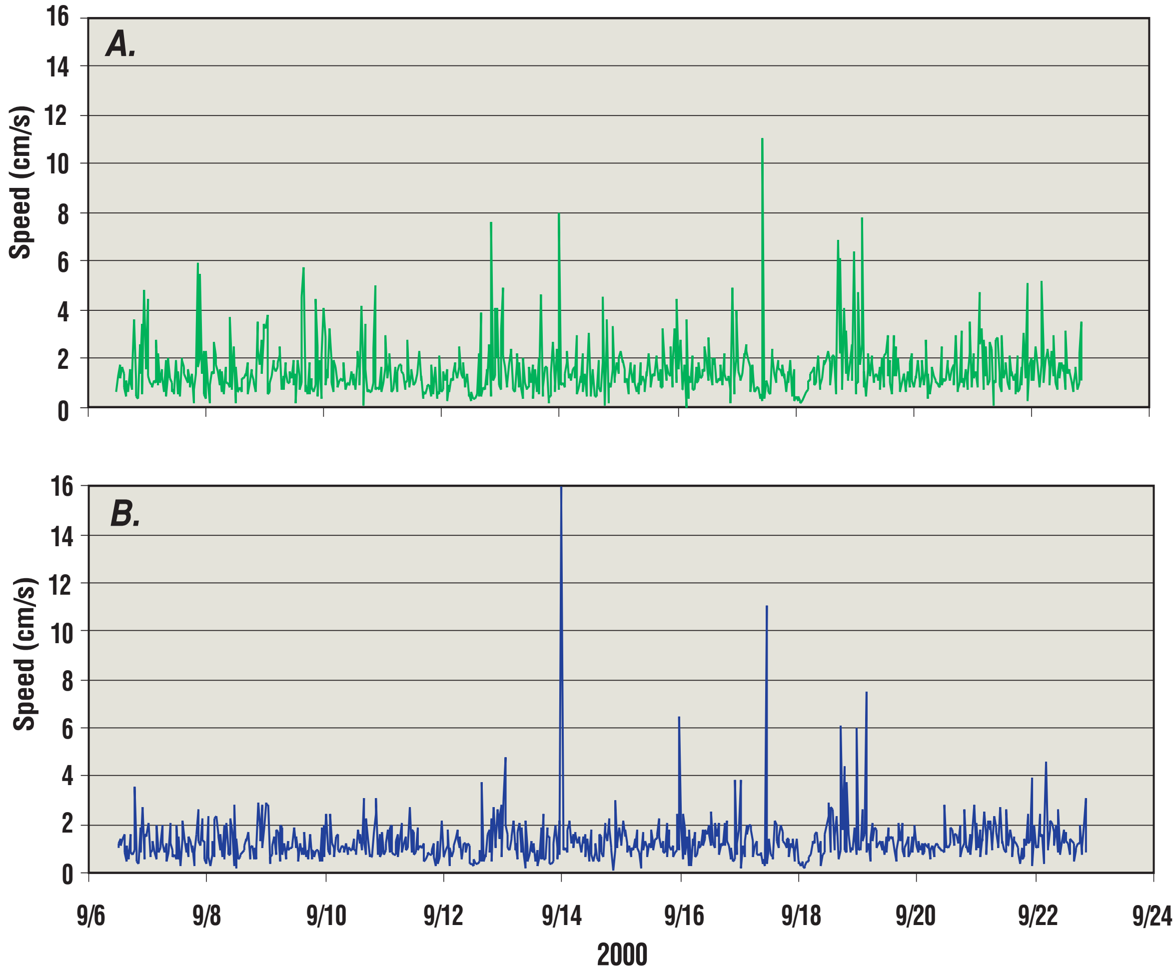


Figure 7. Graphs showing flow speeds at GS-203 in Shark River Slough, Everglades National Park, during September 6-22, 2000, obtained from bursts containing (*A*) all samples and (*B*) only samples with a 70 percent minimum correlation.

samples must pass) and three others (400, 200, and 1) were minimal as shown in figures 8 and 9 for two sets of data recorded at SH1 and GS-203, respectively. However, comparisons of burst-averaged horizontal flow velocities revealed the various filter sensitivities illustrated in figures 10 and 11. Burst-averaged horizontal flow velocities computed using 100, 200, and 300 minimum samples per burst are shown in figures 10 and 11 for two sets of 70 % statistical-correlation-filtered data recorded at SH1 and GS-203, respectively. Whereas some low-velocity spikes in the SH1 data set (fig. 10) and some high-velocity spikes in the GS-203 data set (fig. 11) were successively filtered out, none of the three samples-per-burst criteria entirely removed all bursts that appeared to yield unreasonable flow velocities. The 100-minimum filter criterion appeared to be too inclusive of suspect data and the 300-minimum criterion appeared to be overly exclusive of apparently valid data; consequently, a compromise criterion of 200 was selected as the most appropriate samples-per-burst filter and it was subsequently used to process all ADV data sets.

Although the automated filtering processes provided a first-cut in identification of anomalous data and identified data of poor signal quality, the processes still did not always detect all suspect data. Suspect data do not necessarily imply data of poor signal quality. They might result from flow perturbations caused by a variety of factors influencing the sampling volume, such as fish, rain, vegetation, and probe instability. Extraneous perturbations can be readily transmitted through the slowly moving water within the acoustic sampling volume.

A secondary qualitative processing technique included the generation of plots of filtered data to detect any remaining anomalous horizontal flow speeds and directions. Data found to exhibit such anomalies were examined in conjunction with stage, wind, and other available meteorological data. In most cases, suspect bursts were not found to coincide with any identified meteorological event. These bursts were analyzed further by inspection of individual velocity samples within the suspect and surrounding bursts. Bursts containing anomalies found to be a result of inconsistent velocity samples were flagged and removed from the data set. If the individual samples within a burst showing evidence of a flow anomaly were found to be consistent, the burst was not removed from the data set. Typically, the majority of

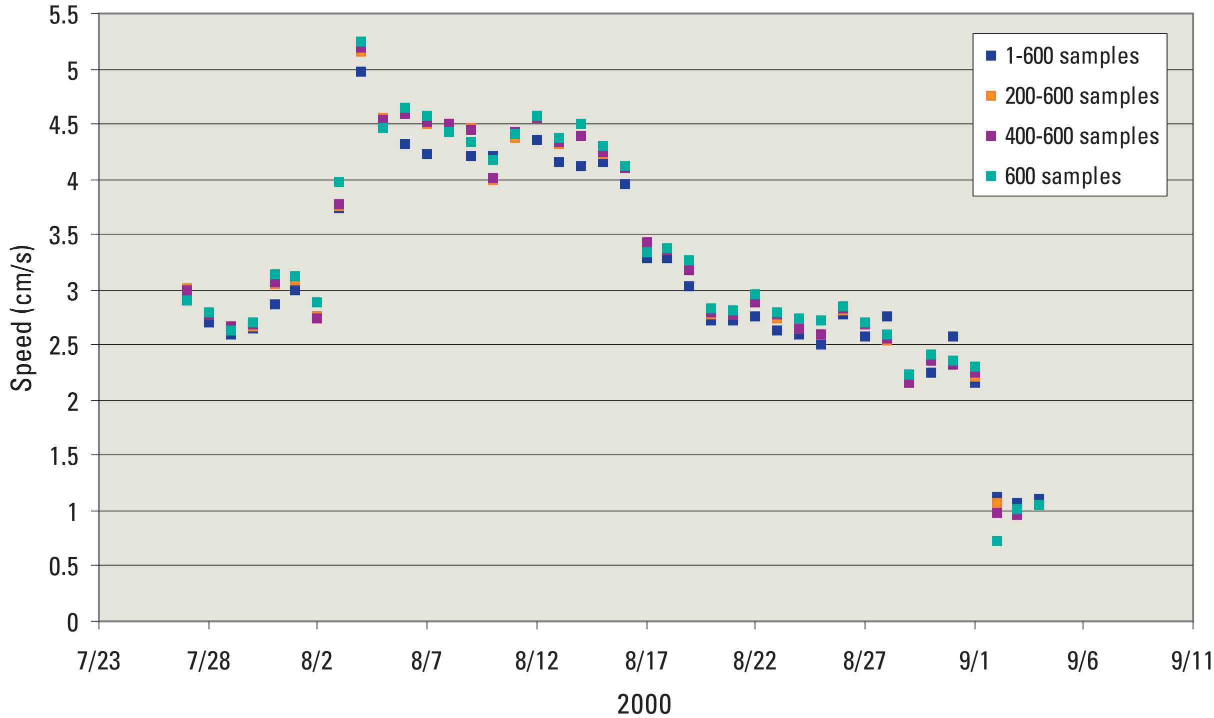


Figure 8. Graphs showing daily mean flow speeds at SH1 in Shark River Slough, Everglades National Park, during July 27–September 4, 2000, obtained from bursts containing 1-600, 200-600, 400-600, and 600 samples with a 70 percent minimum correlation.

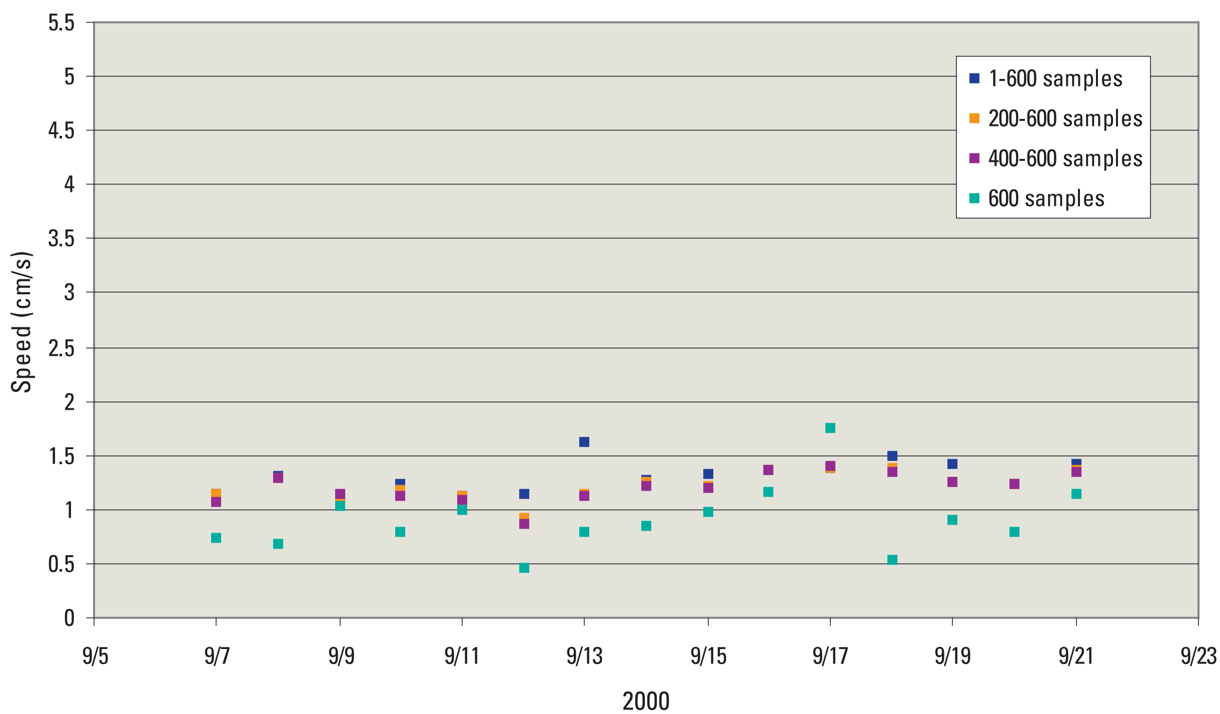


Figure 9. Graphs showing daily mean flow speeds at GS-203 in Shark River Slough, Everglades National Park, during September 7–21, 2000, obtained from bursts containing 1-600, 200-600, 400-600, and 600 samples with a 70 percent minimum correlation.

such cases were anomalous flow directions associated with the extremely small velocities (< 1 mm/s) recorded at GS-203. For all deployments at GS-203 for which valid data were obtained (see table 4), all velocity data are available except for two 5-day periods, one 7-day period, and 18 individual bursts that were removed in the qualitative analyses. The qualitative inspection resulted in the removal of 25 individual velocity bursts from the deployments at SH1. The

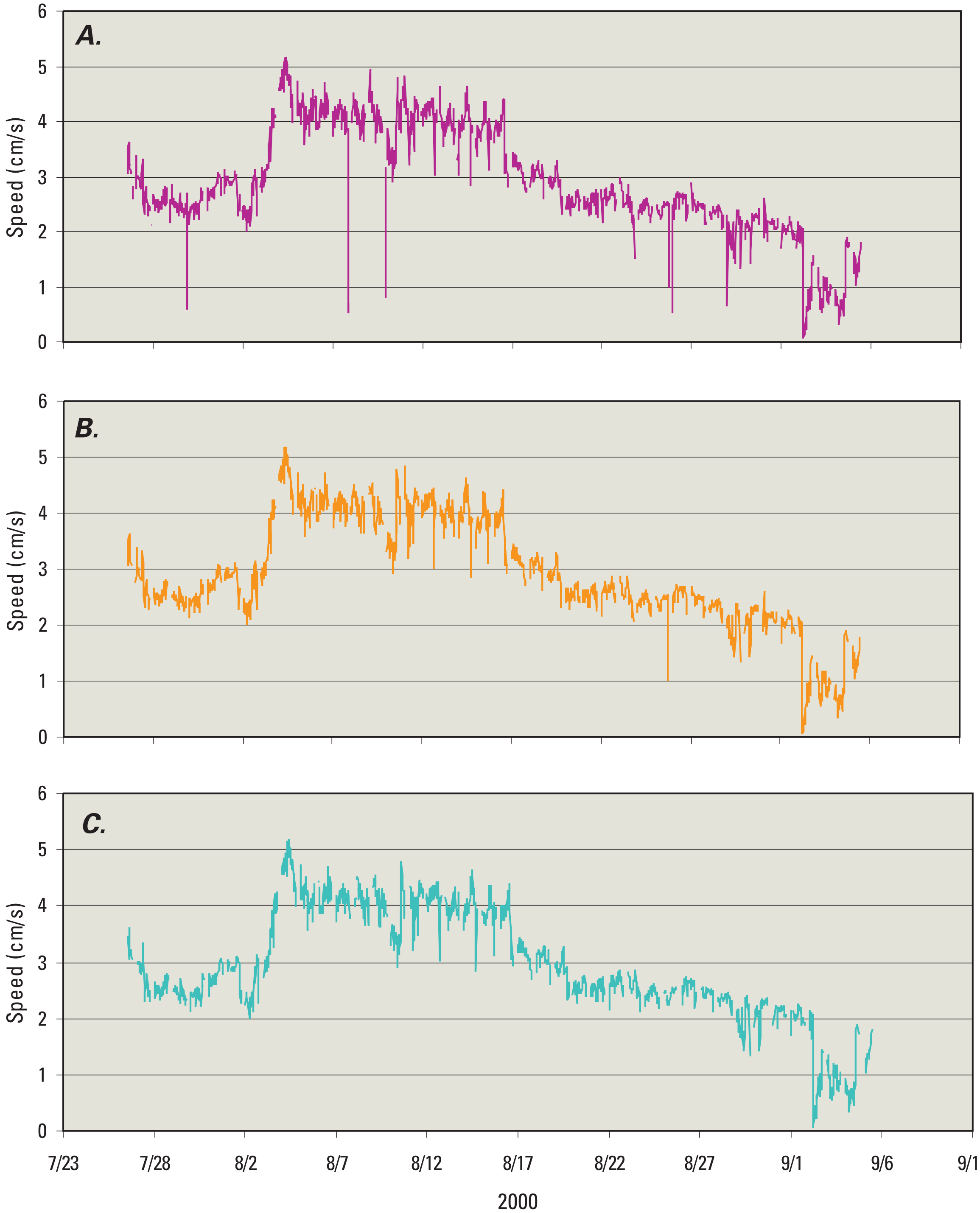


Figure 10. Graphs showing flow speeds at SH1 in Shark River Slough, Everglades National Park, during July 26–September 5, 2000, obtained from bursts containing (*A*) 100-600, (*B*) 200-600, and (*C*) 300-600 samples with a 70 percent minimum correlation.

percentage of bursts that did not pass the automated filter and qualitative analysis processes for each ADV deployment period is identified in the daily mean flow summaries reported in appendix tables A, B, and C. The removal of individual velocity bursts by qualitative analysis did not change the resultant daily mean velocity magnitudes or flow directions significantly. The percent difference and maximum-value filter options, as well as the value difference calculations, all of which are available in the ADVFilter1 program, were not utilized in these analyses.

Conductivity/Temperature Data

The primary intent of integration of the external MicroCAT conductivity/temperature meter with the ADV

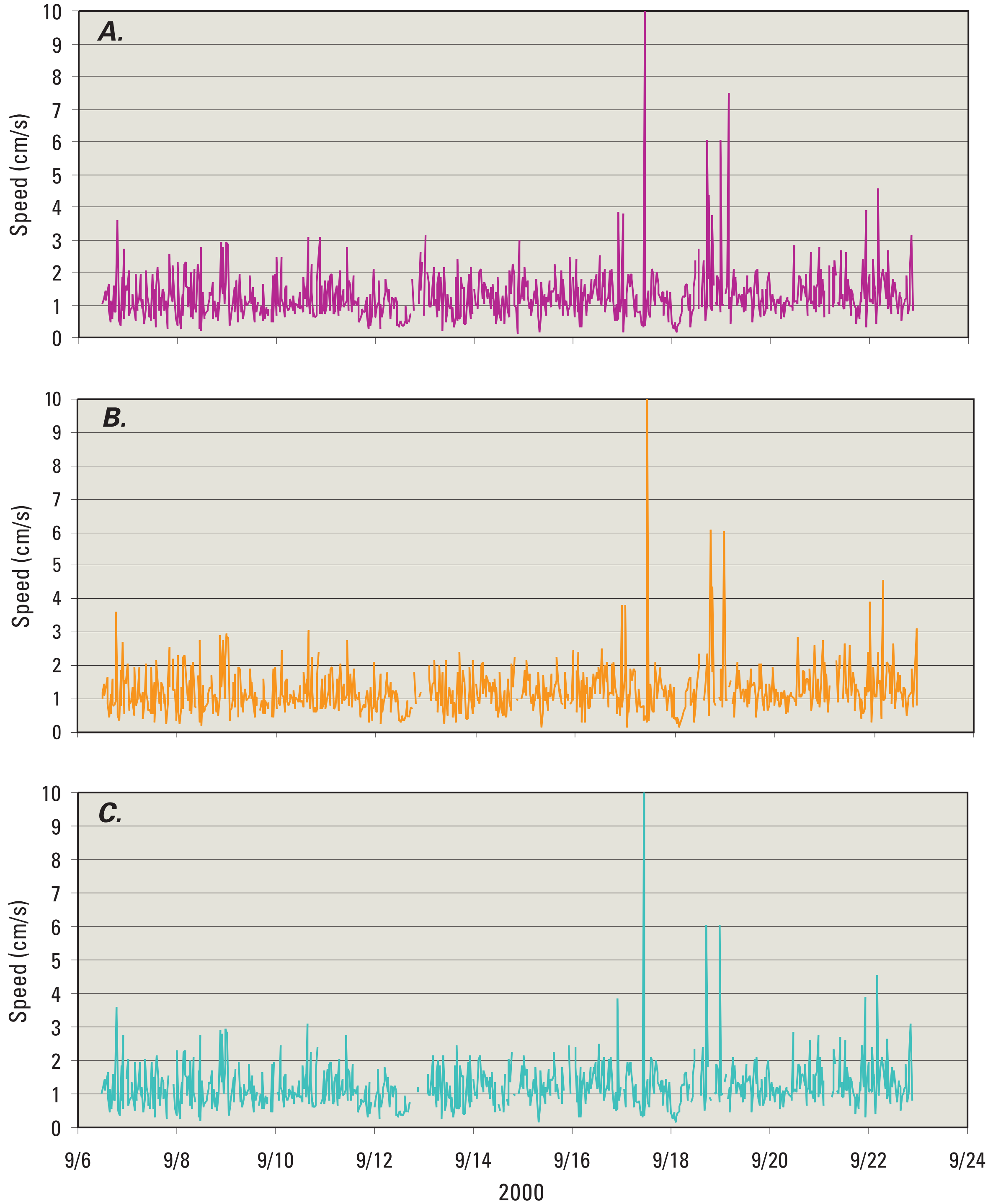


Figure 11. Graphs showing flow speeds at GS-203 in Shark River Slough, Everglades National Park, during September 6–22, 2000, obtained from bursts containing (*A*) 100-600, (*B*) 200-600, and (*C*) 300-600 samples with a 70 percent minimum correlation.

unit was to accommodate use of the instruments in saline environments where time-varying salinity and temperature measurements are needed for site-specific sound-speed calculations. A secondary use of the MicroCAT temperature data at the GS-203 site was as a reference check for the thermistor data. Temperatures measured by the MicroCAT meter near the top of the plant-litter layer at GS-203 were compared to temperatures measured by the thermistor in the temperature string located approximately 8-9 cm above the litter layer. Good agreement was found between the two sets of data for all deployments, with the mean temperature measured by the MicroCAT about 0.01 °C greater than the mean thermistor temperature. No anomalies were found in the MicroCAT temperature data; therefore, the data are made available on the SOFIA website as originally recorded. Daily mean temperatures derived from data measured by the MicroCAT meter are reported in appendix table C.

Conductivity data measured by the MicroCAT meter were compared to conductivity measurements taken with a hand-held portable meter during field visits. No suspect conductivity readings were detected during field visits. All but the first set of MicroCAT conductivity data contained reasonable measurements. The first data set contained two segments of unusually low conductivity readings (< 0.0300 seimens/meter), at the end of the deployment as well as one period in the middle (fig. 12A). Any foreign material or biological growth that passes through the conductivity cell of the MicroCAT meter or air entrainment or sediment buildup within the cell will contaminate the measurements (Sea-Bird Electronics, 1999). The uncharacteristically low conductivity readings recorded from 0711 to 1241 on August 8, 2000, are characteristic of a cell-contamination problem and, as a consequence, these measurements were arbitrarily increased by 0.016 seimens per meter (S/m) to align the readings with surrounding conductivity values (fig. 12B). Data recorded after 1711 on August 24, 2000, were discarded because a reasonable constant offset value could not be determined and applied to the suspect data. Conductivity data concurrently recorded at GS-203 are available on the SOFIA website.

Daily mean specific conductivity values are reported in appendix table C. Conductivity data are recorded in seimens per meter (S/m) and converted to specific conductance in microseimens per centimeter (µS/cm) for reporting purposes using the following formula:

specific conductance (µS/cm) = (10000C)/(1+ A(T-25)),

in which:

A = 0.020, thermal coefficient of conductivity for natural salt ion solutions,
C = conductivity measured (S/m), and
T = water temperature at time of C measurement (°C).
(American Public Health Association, 1989).

Temperature Profile Data

All temperature profile data from the thermistor strings were plotted and inspected for anomalies. No suspect data were found. Times when all thermistors were out of the water, thus measuring only air temperatures, are identified in

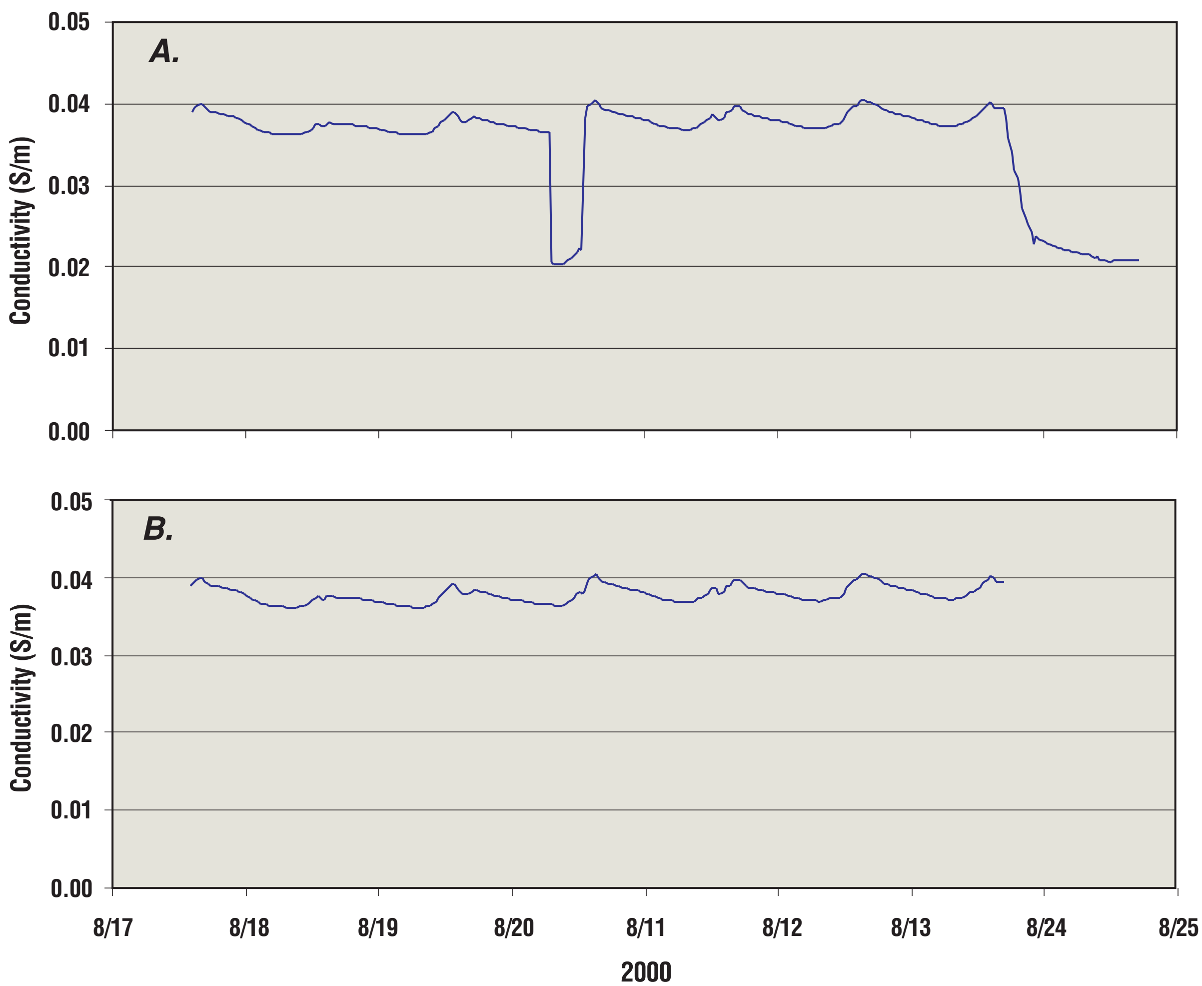


Figure 12. Graphs showing conductivities at GS-203 in Shark River Slough, Everglades National Park, during August 17–24, 2000, (*A*) as originally measured and (*B*) with adjusted values.

table 3. The measured and recorded temperature profile data documented in this report are available on the SOFIA website.

FLOW-VELOCITY, CONDUCTIVITY, AND TEMPERATURE DATA

Flow-Velocity Data

Valid flow-velocity data were not obtained from five ADV deployments during the 2000-2001 wet season (two at GS-203 and three at SH1). For the initial ADV deployment at GS-203 on August 17, 2000 (table 2), the acoustic probe was subsequently determined to be out of the water during the majority of the deployment period due to unexpected low water levels (table 4); therefore, no valid velocity data were recorded. During the second deployment at GS-203 on September 6, 2000 (table 2), the velocity range setting for the ADV meter reverted to the instrument default of ±250 cm/s, instead of a more appropriate setting of ±10 cm/s, making the probe less sensitive to detecting the very small velocities at the GS-203 site. As a consequence, no valid data are available from this deployment. During three consecutive deployments at SH1 (table 2), the ADV unit failed to record data due to an instrument malfunction, a real-time clock failure, or a communication error between the laptop and the unit during initiation; no data are available for these three periods.

Vectors showing velocity magnitudes and flow directions in the horizontal plane, relative to magnetic north, computed for the remaining successful deployments during the 1999-2000 and 2000-2001 wet seasons at each site are illustrated in figures 13 and 14. Horizontal velocity magnitudes generally ranged from 1.5 to 2.5 cm/s at SH1 during the 1999-2000 wet season (fig. 13A) and from 2.0 to 4.5 cm/s during the 2000-2001 wet season (fig. 13B). Horizontal velocity magnitudes ranged from 0.0 to 0.75 cm/s at GS-203 during the 2000-2001 wet season (fig. 14). Horizontal flow directions at both locations in both seasons generally ranged from 200 to 250 degrees, clockwise with respect to magnetic north. The horizontal flow direction at SH1 averaged approximately 210 degrees in both 1999-2000 and 2000-2001 wet seasons. The horizontal flow direction at GS-203 averaged about 235 degrees during the 2000-2001 wet season. Daily mean horizontal flow velocities, determined from the remaning edited burst averages are reported in tabular format in Appendixes A and B for SH1 and in Appendix C for GS-203 deployments.

Conductivity Data

Specific conductance, which was calculated from measured conductivities, ranged from approximately 322 to 562 µS/cm. Water temperatures recorded by the MicroCAT near the top of the litter layer at GS-203 ranged from approximately 28 to 30 °C during the first three deployments (August 17 – November 15, 2000, non-continuous) and from 15 to 25 °C in the last deployment (November 31 2000 – January 12, 2001, continuous). In all deployments, tempera-

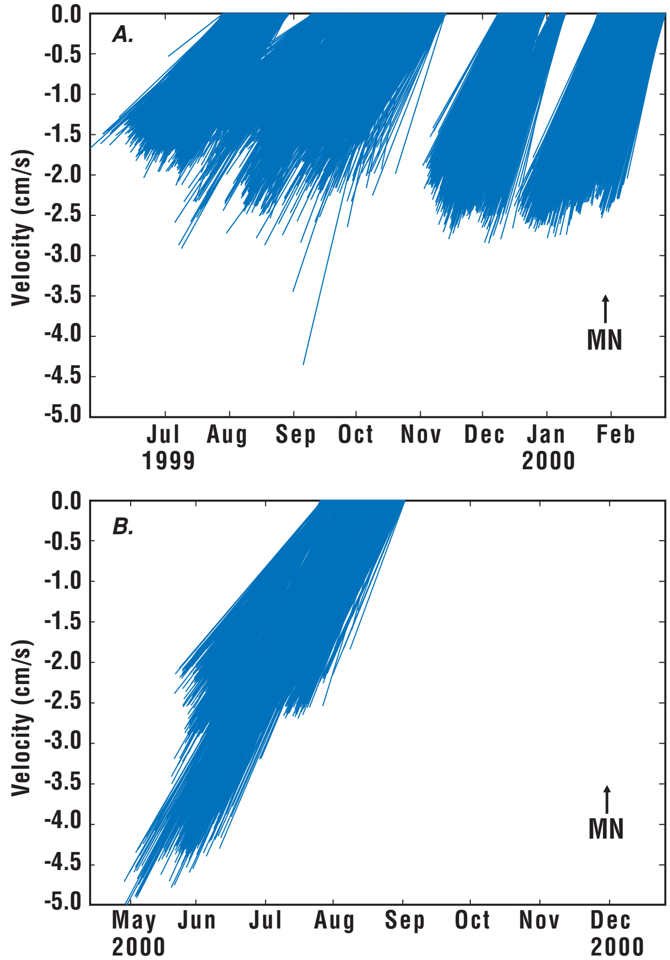


Figure 13. Plots showing burst-averaged flow velocities, shown as vectors relative to magnetic north, at SH1 in Shark River Slough, Everglades National Park, during the (*A*) 1999-2000 and (*B*) 2000-2001 wet seasons.

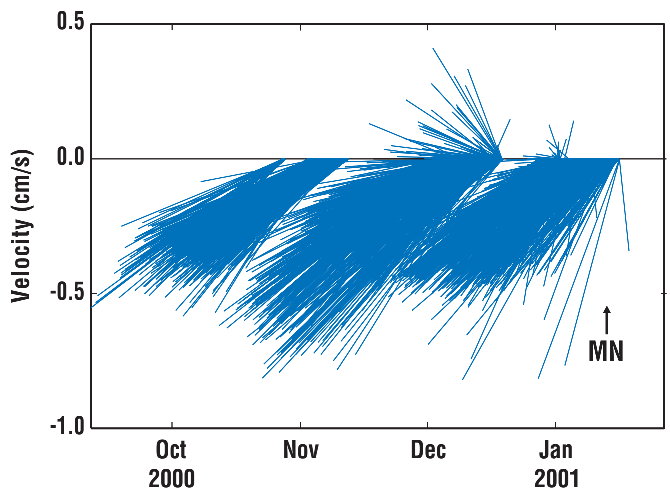


Figure 14. Plot showing burst-averaged flow velocities, shown as vectors relative to magnetic north, at GS-203 in Shark River Slough, Everglades National Park, during the 2000–2001 wet season.

tures fluctuated several degrees in a diel pattern. Daily mean water temperature and specific conductivity values are reported in Appendix C for GS-203.

Temperature Data

Temperatures throughout the water column for all deployments ranged from approximately 15 to 25 °C and 22 to 35 °C in the fall to winter and spring to summer seasons, respectively, while exhibiting a highly dynamic behavior and structure. Temperature profile data, as recorded concurrently by the thermistors, are needed to investigate the relationship between flow velocity and daily temperature patterns (Schaffranek and Jenter, 2001). A typical diel pattern can be observed in the horizontal flow velocities measured at SH1 during September 1-4, 2000, and is presented in figure 15. As indicated by the data in figure 15, which is representative of most ADV deployments at SH1, data during the late evening through early morning hours were typically filtered out due to low statistical correlations (< 70 %).

Temperature data measured and recorded every 30 minutes at SH1 during September 1-4, 2000, illustrate a typical pattern found in most temperature profile data sets (fig. 16). The submerged thermistors (10, 20, and 30 cm) indicated that during the day, the water column became thermally stratified and during the night, cooling of the water column occurred. The water column was thermally non-stratified vertically twice during the day—just after sunrise and just after sunset. The effects of diel water temperature changes on flow-velocity structure are currently under investigation.

DATA AVAILABILITY

The quality-checked and edited flow-velocity, water-temperature, and conductivity data documented in this report are available through the World Wide Web. Three-dimensional velocity component sample data (including associated statistical correlation and SNR values for each component), water-temperature and specific conductivity, and water- and air-temperature profile data are available for downloading from the Data Exchange page of the USGS South Florida Information Access (SOFIA) website (http://sofia.usgs.gov). Velocity data are also available for downloading from the Data page of the Tides and Inflows in the Mangroves of the Everglades (TIME) website (http://time.er.usgs.gov).

SUMMARY

The acquisition, processing, and evaluation of flow-velocity, water-temperature, and conductivity data collected at three locations (sites SH1, GS-203, and GS-33) in Shark River Slough, Everglades National Park, during the 1999-2000 and 2000-2001 wet seasons are documented in this report. Water-column temperatures were monitored at 5- or 30-minute intervals at all three sites, 3-D component flow velocities were monitored at a fixed point in the water column hourly or bi-hourly at SH1 and GS-203, and conductivities and temperatures were monitored bi-hourly near the top of the plant-litter layer at GS-203. Techniques for measuring and processing the data are documented and summaries of daily mean horizontal velocity, temperature, and conductivity data are presented. Velocity vectors illustrating the horizon-

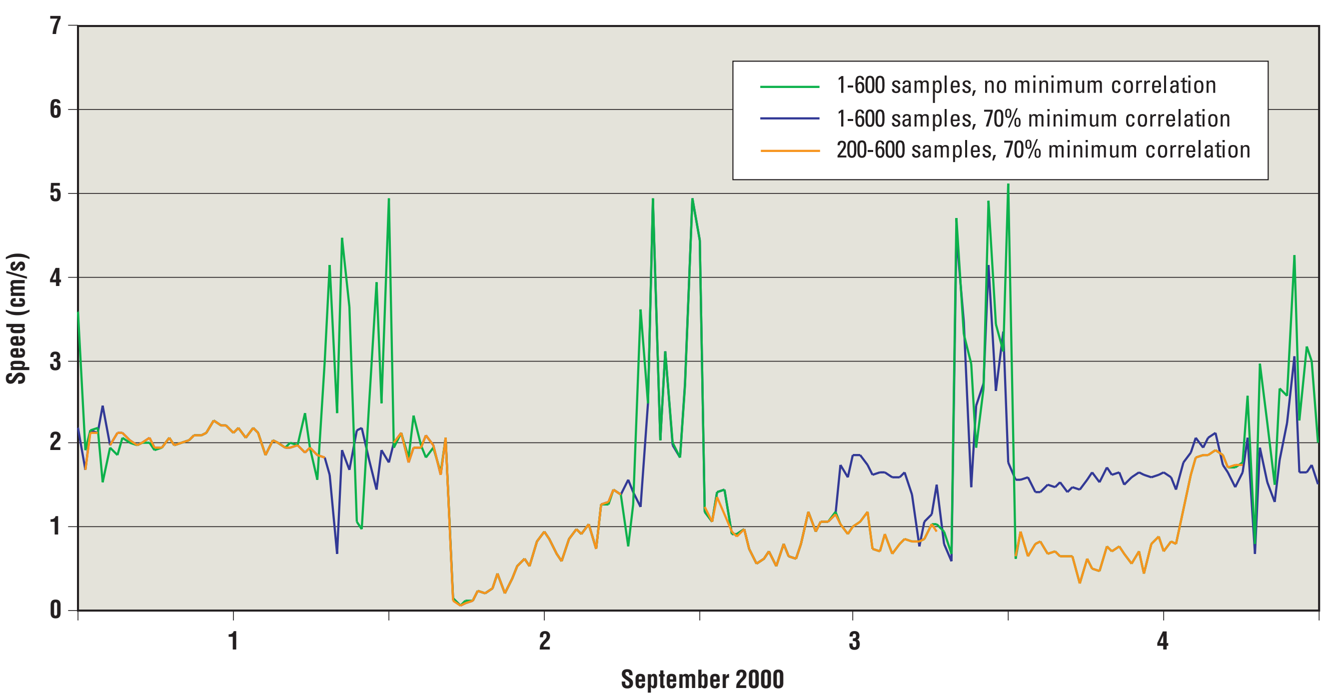


Figure 15. Graph showing flow speeds at SH1 in Shark River Slough, Everglades National Park, during September 1–4, 2000, obtained from bursts containing all samples, bursts containing 1–600 samples with a 70 percent minimum correlation, and bursts containing 200–600 samples with a 70 percent minimum correlation.

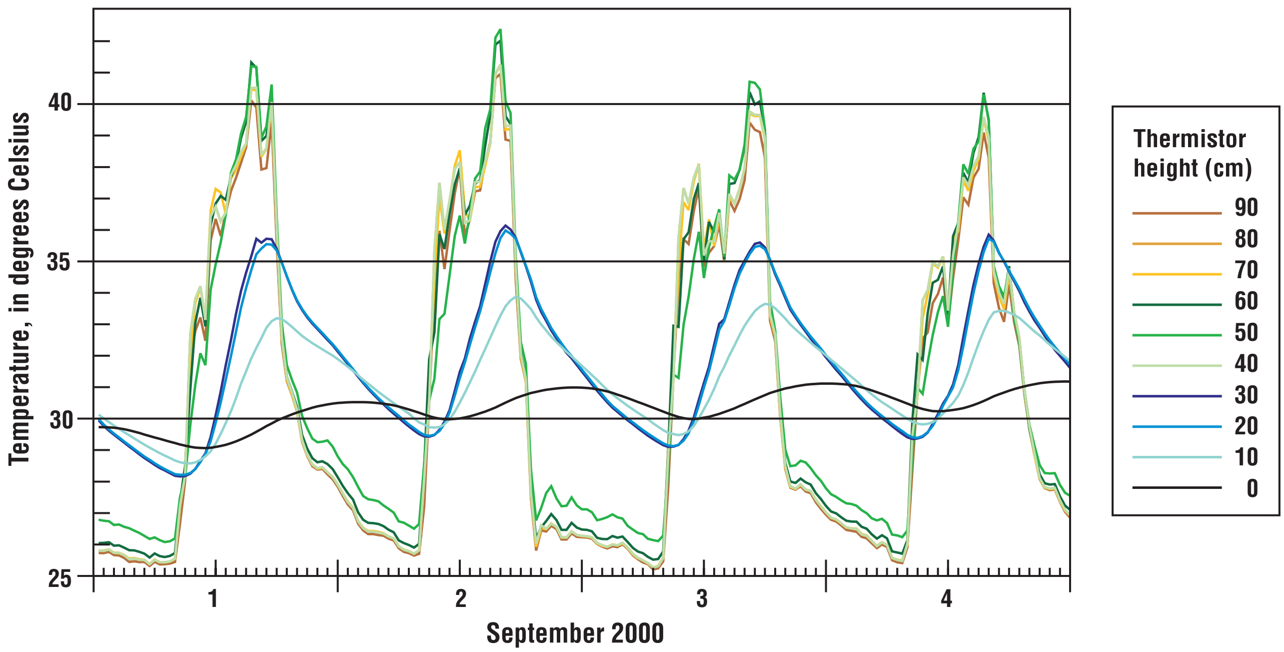


Figure 16. Graph showing water (10-30 cm), air (40-90 cm), and plant-litter (0 cm) temperatures recorded at SH1 in Shark River Slough, Everglades National Park, during September 1–4, 2000. (Thermistor height measured from within the plant-litter layer.)

tal flow speeds and directions measured at the SH1 and GS-203 sites also are presented. The quality-checked and edited data have been compiled and stored on the USGS South Florida Information Access (SOFIA) and Tides and Inflows in the Mangrove Ecotone (TIME) websites.

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Appendix A. Daily mean flow velocity at SH1 station during the 1999-2000 wet season

Table A - 1. Daily mean flow velocity at SH1 station, deployment 7/28/99 1530 - 8/29/99 1830
[CW = clockwise, MN = magnetic north]

Date	Flow velocity (cm/s)	Flow direction (°CW from MN)
7/29/99	1.76	213
7/30/99	1.88	210
8/31/99	1.85	212
8/1/99	1.77	213
8/2/99	1.77	213
8/3/99	1.80	215
8/4/99	1.79	213
8/5/99	1.88	213
8/6/99	1.77	214
8/7/99	1.73	214
8/8/99	1.67	215
8/9/99	1.78	212
8/10/99	1.79	215
8/11/99	1.69	214
8/12/99	1.74	216
8/13/99	1.79	214
8/14/99	1.81	209
8/15/99	1.79	211
8/16/99	1.91	218
8/17/99	1.90	215
8/18/99	1.97	218
8/19/99	1.85	217
8/20/99	1.88	219
8/21/99	1.88	218
8/22/99	1.95	217
8/23/99	1.96	216
8/24/99	2.04	217
8/25/99	2.10	215
8/26/99	2.10	216
8/27/99	2.06	214
8/28/99	1.98	216
MINIMUM	1.67	209
MAXIMUM	2.10	219
AVERAGE	1.86	215
PERCENT BURSTS MISSING	16	

Table A - 2. Daily mean flow velocity at SH1 station, deployment 9/9/99 1200 - 11/13/99 1200
[CW = clockwise, MN = magnetic north]

Date	Flow velocity (cm/s)	Flow direction (°CW from MN)
9/10/99	1.76	222
9/11/99	1.58	221
9/12/99	2.13	216
9/13/99	1.83	220
9/14/99	1.93	220
9/15/99	1.82	221
9/16/99	1.65	222
9/17/99	1.70	220
9/18/99	1.73	220
9/19/99	1.58	221
9/20/99	1.88	216
9/21/99	1.98	214
9/22/99	1.62	217
9/23/99	2.20	207
9/24/99	2.18	208
9/25/99	2.40	208
9/26/99	2.31	210
9/27/99	2.15	211
9/28/99	2.08	212
9/29/99	2.03	213
10/30/99	1.97	213
10/1/99	1.97	213
10/2/99	1.98	211
10/3/99	1.87	212
10/4/99	1.85	213
10/5/99	1.78	214
10/6/99	1.84	214
10/7/99	1.85	214
10/8/99	1.94	215
10/9/99	2.12	216
10/10/99	2.13	217
10/11/99	2.21	216
10/12/99	2.31	214
10/13/99	2.33	216
10/14/99	2.57	213
10/15/99	2.58	208
10/16/99	2.17	226
10/17/99	2.30	220
10/18/99	2.31	213
10/19/99	2.13	213
10/20/99	2.18	212
10/21/99	1.98	218
10/22/99	2.10	213
10/23/99	2.05	214
10/24/99	2.07	211

Table A - 2. Daily mean flow velocity at SH1 station, deployment 9/9/99 1200 - 11/13/99 1200
[CW = clockwise, MN = magnetic north]

Date	Flow velocity (cm/s)	Flow direction (°CW from MN)
10/25/99	2.12	211
10/26/99	2.04	208
10/27/99	2.04	209
10/28/99	1.99	208
10/29/99	1.96	216
10/30/99	2.03	213
10/31/99	2.05	215
11/1/99	1.85	214
11/2/99	1.76	219
11/3/99	1.72	223
11/4/99	1.76	218
11/5/99	1.87	219
11/6/99	1.80	219
11/7/99	1.70	226
11/8/99	1.62	222
11/9/99	1.67	215
11/10/99	1.79	216
11/11/99	1.83	214
11/12/99	1.86	211
MINIMUM	1.62	208
MAXIMUM	2.12	226
AVERAGE	1.87	216
PERCENT BURSTS MISSING	11	

Table A - 3. Daily mean flow velocity at SH1 station, deployment 12/8/99 1200 - 1/10/00 0000
[CW = clockwise, MN = magnetic north]

Date	Flow velocity (cm/s)	Flow direction (°CW from MN)
12/09/99	2.08	202
12/10/99	2.18	200
12/11/99	2.27	199
12/12/99	2.08	200
12/13/99	2.05	202
12/14/99	1.86	202
12/15/99	1.86	201
12/16/99	2.12	201
12/17/99	2.21	199
12/18/99	2.56	199
12/19/99	2.42	200
12/20/99	2.30	200
12/21/99	2.31	199
12/22/99	2.34	198
12/23/99	2.32	198
12/24/99	2.32	199
12/25/99	2.33	198
12/26/99	2.38	198
12/27/99	2.38	197
12/28/99	2.31	199
12/29/99	2.09	202
12/30/99	2.01	204
01/31/00	2.11	204
01/01/00	*	*
01/02/00	2.41	200
01/03/00	2.39	201
01/04/00	2.30	202
01/05/00	2.28	201
01/06/00	2.33	200
01/07/00	2.18	200
01/08/00	2.17	200
01/09/00	2.48	200

*all bursts filtered out

MINIMUM	1.86	197
MAXIMUM	2.56	204
AVERAGE	2.24	200
PERCENT BURSTS MISSING	10	

Table A - 4. Daily mean flow velocity at SH1 station, deployment 1/25/00 1400 - 2/27/00 0200
[CW = clockwise, MN = magnetic north]

Date	Flow velocity (cm/s)	Flow direction (°CW from MN)
1/26/00	2.43	199
1/27/00	2.52	198
1/28/00	2.63	197
1/29/00	2.43	200
1/30/00	2.56	197
1/31/00	2.57	196
2/1/00	2.39	196
2/2/00	2.38	196
2/3/00	2.24	197
2/4/00	2.17	196
2/5/00	2.20	197
2/6/00	2.26	196
2/7/00	2.31	196
2/8/00	2.01	196
2/9/00	2.01	197
2/10/00	2.00	197
2/11/00	2.13	196
2/12/00	2.05	197
2/13/00	2.06	197
2/14/00	2.26	197
2/15/00	2.19	198
2/16/00	2.32	199
2/17/00	2.36	200
2/18/00	2.17	203
2/19/00	1.97	204
2/20/00	2.12	202
2/21/00	2.14	201
2/22/00	1.94	203
2/23/00	1.98	201
2/24/00	2.06	201
2/25/00	2.27	197
2/26/00	2.19	197
MINIMUM	1.94	196
MAXIMUM	2.63	204
AVERAGE	2.23	198
PERCENT BURSTS MISSING	11	

Appendix B. Daily mean flow velocity at SH1 station during the 2000-2001 wet season

Table B - 1. Daily mean flow velocity at SH1 station, deployment 7/26/00 1400 - 9/5/00 1100
[CW = clockwise, MN = magnetic north]

Date	Flow velocity (cm/s)	Flow direction (°CW from MN)
07/27/00	3.01	213
07/28/00	2.79	212
07/29/00	2.66	216
07/30/00	2.68	215
07/31/00	3.04	211
08/01/00	3.09	211
08/02/00	2.76	218
08/03/00	3.76	206
08/04/00	5.16	208
08/05/00	4.55	205
08/06/00	4.59	206
08/07/00	4.50	205
08/08/00	4.50	207
08/09/00	4.47	209
08/10/00	3.99	207
08/11/00	4.37	207
08/12/00	4.55	206
08/13/00	4.32	206
08/14/00	4.38	206
08/15/00	4.23	207
08/16/00	4.12	206
08/17/00	3.42	207
08/18/00	3.36	208
08/19/00	3.17	208
08/20/00	2.78	209
08/21/00	2.78	209
08/22/00	2.88	208
08/23/00	2.75	207
08/24/00	2.65	204
08/25/00	2.65	205
08/26/00	2.82	207
08/27/00	2.68	211
08/28/00	2.55	213
08/29/00	2.16	210
08/30/00	2.35	209
08/31/00	2.34	211
09/01/00	2.21	210
09/02/00	2.14	211
09/03/00	*	*
09/04/00	*	*

*all bursts filtered out

MINIMUM	2.14	204
MAXIMUM	5.16	218
AVERAGE	3.35	209
PERCENT BURSTS MISSING	28	

Appendix C. Daily mean flow velocity, water temperature, and specific conductance at GS-203 station during the 2000-2001 wet season

Table C - 1. Daily mean flow velocity, water-temperature and specific conductance at GS-203 station, deployment 8/17/00 1411 - 8/24/00 1711
[CW = clockwise, MN = magnetic north]

Date	Flow velocity (cm/s)	Flow direction (°CW from MN)	Temperature (°C)	Specific conductance (μS/cm)
08/18/00	*	*	28.5089	345
08/19/00	*	*	28.3790	349
08/20/00	*	*	28.7292	353
08/21/00	*	*	28.8896	353
08/22/00	*	*	29.4425	353
08/23/00	*	*	29.3747	351

*** all bursts filtered out qualitatively, ADV probe determined to be out of water**

MINIMUM			28.3790	345
MAXIMUM			29.4425	353
AVERAGE			28.8873	351
PERCENT DATA MISSING	100		0	14

Table C - 2. Daily mean flow velocity, water-temperature and specific conductance at GS-203 station, deployment 9/6/00 1146 - 9/22/00 2046
[CW = clockwise, MN = magnetic north]

Date	Flow velocity (cm/s)	Flow direction (° CW from MN)	Temperature (° C)	Specific conductance (μS/cm)
09/07/00	*	*	29.1298	372
09/08/00	*	*	28.5403	370
09/09/00	*	*	28.3493	366
09/10/00	*	*	28.2067	363
09/11/00	*	*	28.2860	349
09/12/00	*	*	28.2860	327
09/13/00	*	*	28.9449	325
09/14/00	*	*	29.6226	328
09/15/00	*	*	28.5974	327
09/16/00	*	*	27.8226	329
09/17/00	*	*	27.4533	325
09/18/00	*	*	27.6008	322
09/19/00	*	*	28.5065	327
09/20/00	*	*	28.5026	323
09/21/00	*	*	29.1396	332

* all bursts filtered out qualitatively, probe velocity range set to +-250 cm/s

MINIMUM			27.4533	322
MAXIMUM			29.6226	372
AVERAGE			28.4659	339
PERCENT DATA MISSING	100		0	0

Table C - 3. Daily mean flow velocity, water-temperature and specific conductance at GS-203 station, deployment 10/26/00 1341 - 11/16/00 1611
[CW = clockwise, MN = magnetic north]

Date	Flow velocity (cm/s)	Flow direction (°CW from MN)	Temperature (°C)	Specific conductance (μS/cm)
10/27/00	0.72	233	24.7681	342
10/28/00	*	*	24.9978	337
10/29/00	*	*	25.3853	336
10/30/00	*	*	25.1297	339
10/31/00	*	*	25.0428	341
11/01/00	0.59	234	24.2241	339
11/02/00	0.63	231	23.8260	340
11/03/00	0.59	232	23.4940	342
11/04/00	0.62	237	23.3592	345
11/05/00	0.62	236	23.7396	349
11/06/00	0.64	235	24.2850	354
11/07/00	0.63	237	24.4583	362
11/08/00	0.63	233	24.7128	371
11/09/00	0.62	237	24.6662	375
11/10/00	0.61	238	25.2540	384
11/11/00	0.58	235	25.3090	399
11/12/00	*	*	24.4921	397
11/13/00	*	*	24.2039	403
11/14/00	*	*	24.1747	411
11/15/00	*	*	24.0858	412

* all bursts filtered out

MINIMUM	0.58	231	23.3592	336
MAXIMUM	0.72	238	25.3853	412
AVERAGE	0.62	235	24.4804	364
PERCENT DATA MISSING	49		0	0

Table C - 4. Daily mean flow velocity, water-temperature and specific conductance at GS-203 station, deployment 11/30/00 1244 - 1/13/01 1944
[CW = clockwise, MN = magnetic north]

Date	Flow velocity (cm/s)	Flow direction (°CW from MN)	Temperature (°C)	Specific conductance (μS/cm)
12/01/00	0.72	235	20.4346	512
12/02/00	0.77	232	20.7714	522
12/03/00	0.67	233	20.2255	528
12/04/00	0.55	240	18.5757	540
12/05/00	0.47	246	18.2600	547
12/06/00	0.49	248	18.3024	551
12/07/00	0.44	236	19.5368	555
12/08/00	0.46	236	20.4617	557
12/09/00	0.53	234	21.4532	561
12/10/00	0.69	227	22.2616	550
12/11/00	0.77	236	22.6208	517
12/12/00	0.71	237	23.2196	498
12/13/00	0.64	242	23.7694	493
12/14/00	0.54	242	23.7258	495
12/15/00	0.42	246	23.8183	500
12/16/00	0.51	252	23.4644	507
12/17/00	0.33	264	23.7257	522
12/18/00	*	*	20.8080	526
12/19/00	*	*	20.3532	525
12/20/00	*	*	17.2401	524
12/21/00	*	*	15.0232	522
12/22/00	*	*	16.6430	526
12/23/00	*	*	17.1320	533
12/24/00	*	*	18.3740	537
12/25/00	0.57	230	18.2046	536
12/26/00	0.60	228	18.2100	538
12/27/00	0.55	228	18.4494	539
12/28/00	0.51	233	18.9941	542
12/29/00	0.59	223	19.0845	550
12/30/00	0.31	229	16.4867	548
12/31/00	0.47	229	13.9182	547
01/01/01	0.45	239	12.5162	545
01/02/01	0.52	224	13.1311	542
01/03/01	0.50	224	13.6078	543
01/04/01	0.51	220	14.2811	544
01/05/01	0.59	221	12.3353	546
01/06/01	0.51	232	13.3865	548
01/07/01	0.51	232	14.3712	550
01/08/01	0.44	234	15.4915	556
01/09/01	0.53	230	16.8359	559
01/10/01	0.44	238	13.7131	561
01/11/01	0.42	241	14.9409	562
01/12/01	0.37	232	15.9496	563

* all bursts filtered out

MINIMUM	0.31	220	12.3353	493
MAXIMUM	0.77	264	23.8183	563
AVERAGE	0.53	235	18.2351	536
PERCENT DATA MISSING	19		0	0

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