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Current Direction and Velocity Measurements Using GPS Receivers Mounted on Floats at Tom Bevill Lock and Dam

by Michael F. Winkler and Ronald T. Wooley

PURPOSE: To present the hardware and methodology for collecting current direction and velocity data using Global Positioning System (GPS) receivers mounted on floats. This method has been used on several projects by the U.S. Army Engineer Research and Development Center (ERDC) Principal Investigators to map the currents in both open river conditions and near locks and dams. This method has proved to be a quick and inexpensive method to map currents for verification of hydraulic models or investigation of existing conditions. The information herein was collected at Tom Bevill Lock and Dam on the Tennessee Tombigbee Waterway as part of the Monitoring Completed Navigation Projects (MCNP) Program.

INTRODUCTION: Tracking floats submerged to the depth of loaded barges has been the preferred method for collecting prototype data to be used in large-scale physical models. The prototype data collected can be analyzed to determine the effect of currents on tows using inland waterways. In conjunction with the MCNP Program it was determined that collecting float data at Tom Bevill Lock and Dam would allow current direction and velocities to be compared prior to construction at the site and after construction is completed. Field data collected using floats has been used to calibrate or verify these hydraulic models when such data were available. However, due to the difficulty and time involved for collection of float data, other types of data such as point velocity measurements, water-surface profiles, and Acoustic Doppler Current Profiler (ADCP) data have been used for verification of the hydraulic models. Float measurements show the overall trend in the current patterns by showing the average current direction and velocities. While these average current direction and velocities provide the best indication of the effects of currents on tows, this type of data was difficult to obtain in the field prior to GPS. With the development of GPS, a new method of tracking floats in the field has been developed. GPS receivers are mounted on the floats to track their paths over large areas and long reaches with great flexibility.

EQUIPMENT: A float was designed to accept a GPS unit mounted near its top to reduce any interference to the signals from the GPS satellites. The float was constructed in 1.2-m (4-ft) sections so the depth of the float could be adjusted to either a 1.2-m (4-ft) or 2.4-m (8-ft) draft by screwing the two sections together (Figure 1). The float was constructed of 7.6-cm (3-in.) diam PVC pipe attached to a 30.5-cm (12-in.) diam high density Styrofoam buoy. Four sheet metal fins were mounted to the PVC pipe to increase the effective area of the float. The 15.2-cm (6-in.) sheet metal fins increased the resistance of the float, insuring that the float would move at the speed of the current. The metal fins also increased the weight of the float to make it stand vertical in the water column (Figure 2).

Numerous makes and models of GPS receivers can be used to track the path of the float. However, the cost of the unit should be a consideration. Although the chance of a float being lost is slim, there

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Figure 1. Assembled float

Figure 2. Submerged float

is always a possibility the float could be snagged by a submerged log or some other object and not recovered. There are several GPS receivers that cost under $4,000 that will provide the features and accuracy required for current direction and velocity data. The basic requirement for the GPS receiver is that it must be capable of recording the raw satellite signals or pseudorange data for post-processing at a selected time interval. The size and weight of the GPS receiver should also be considered due to it being mounted near the top of the float. A GPS receiver with a radio link to a base station can be used to record Real-Time Kinematic (RTK) positions. However, these receivers are more expensive and heavier due to the radio and batteries.

The procedures outlined in this CHETN will concentrate on the Magellan GPS ProMARK X-CP receiver as it was used to collect float data at Tom Bevill Lock and Dam. However, the procedures for collection and processing of the data would be similar using other GPS receivers. The Magellan GPS ProMARK X-CP is a small robust light receiver that can log 9 hr of both pseudorange and carrier phase satellite data for post-processing. The ProMARK X-CP cost approximately $4,000 and was still available at the time of this technical note.

POSITION ACCURACY: Tracking floats to define the current directions and velocities for analysis or calibration of a hydraulic model does not require a high degree of accuracy. Using post-processing software, pseudorange GPS data recorded by the ProMARK X-CP can be post-processed differential to achieve 1-3 m (3.3-9.8 ft) horizontal accuracy. The accuracy between two points in the same track is better than 1 m (3.3 ft) in most cases. The accuracy degrades to 1-3 m (3.3-9.8 ft) when the number of satellites the GPS unit is recording changes due to the movement of the satellites over time. Therefore, the 1-3 m (3.3-9.8 ft) difference tends to be an offset between tracks not between points in the same track. The velocities of floats are generally averaged over a distance of 61 to 122 m (200 to 400 ft). An overall error of 1 m (3.3 ft) in the distance of a float traveling 61 m at 1.5 m/sec (200 ft at 4.9 fps) is about plus or minus 0.024 m/sec (0.08 fps). This magnitude of error is negligible when compared to the changes in velocity of the currents through the reach.

Post-processing of GPS receiver data requires satellite data from both the rover receiver (receiver on the float) and from a base station (a receiver set up at a known point). The base station must record raw data during the time of rover data collection and at the same time interval or a multiple of that time interval. There are several programs available from the U.S. Geological Survey (USGS) that will reduce Receiver Independent Exchange Format (RINEX) base data to the same time interval as the rover receiver. However, this adds a step to the post-processing and should be avoided if a base station is established for the purpose of recording base data.

PROCEDURE: To achieve the required accuracy the GPS data collected on the float must be post-processed against data collected by a GPS receiver at a known point (base station). The base station data can be from an existing Continuous Operating Reference Station (CORS) or from a GPS receiver set up for the purpose of recording data during the collection effort.

It is recommended that data from a CORS be used to post-process the float data. This eliminates the need for one GPS receiver and recovering or establishing a point with accurate coordinates. The CORS log data at 30-sec intervals and the U.S. Coast Guard places the data on the Internet in 1-hr files approximately 1 hr after the data are collected. To find out more about CORS visit the U.S. Coast Guard Web site.

The GPS receiver on the float should be set to record data at a time interval that will provide sufficient positions to plot the path of the float. The velocity of the currents in navigable rivers rarely exceed 1.5 m/sec (4.9 fps) under normal flow conditions, therefore, data recorded at 3-sec intervals would provide positions every 4.5 m (14.8 ft). Positions every 4.5 m (14.8 ft) are sufficient to plot the path and velocity of the float. If a base station is established to record data, the data collection rate of the base station must be the same as the GPS receiver mounted on the float. Refer to the GPS receiver manual for instructions on setup of the receiver.

DATA COLLECTION: The GPS receiver is mounted near the top of the buoy to minimize any interference with the GPS antenna. Mounting the GPS receiver to the buoy also minimizes the risk of losing the receiver if the bottom section of the float is snagged on an underwater object and breaks free. A two-man crew per boat is required to drop, track, and retrieve the float. The boat operator positions the boat at the drop site, while the second crew member turns on the GPS receiver and places the float over the side. Data were collected at Tom Bevill Lock and Dam using two floats and one boat due to the limited area of coverage. However, experience with floats in large rivers indicates that a boat should track each float. In some cases, floats dropped close together will separate making it difficult or impossible for one boat to keep track of two floats. Also in large rivers, for safety reasons and protection of the floats, it is best to have two boats dropping floats in case one boat stalls at a critical time. In large rivers, such as the Mississippi, the boat should stay close to the float in case it needs to be retrieved due to tow traffic. During float retrieval, if possible the boat needs to be located upstream or alongside the float. Allowing the boat to become positioned downstream could possibly cause the current to pin the float to the boat and possibly break the lower section of the float.

After selecting the area of coverage and the desired spacing of the floats, the positions for dropping the floats can be identified by aligning with objects along the bank and estimating the distance from the bank. However, better coverage of the data collection area can be achieved by using a hand-held GPS receiver with mapping capabilities or some other mapping program to position and track the boat. The start positions for the floats can be entered into the hand-held receiver and used to position the boat. After dropping the float, the hand-held receiver can be used to record and plot the track of the boat, which will approximately represent the path of the float. If the hand-held receiver shows the float is following the path of a previous float, the float can be retrieved. This method speeds up the data collection by reducing the number of float track required to cover the area and shows any gaps in the float tracks. When the float is retrieved, the GPS receiver on the float is powered off so the float track is recorded in a unique file.

DATA PROCESSING: Processing the data and displaying the results as vectors require several processing steps. The first step is processing the rover data against base station data to output accurate position data for each data point in the rover file. This step is usually accomplished using proprietary software provided by the GPS receiver's manufacturer. There are some software packages available that will process numerous manufacturers' GPS data. Post-processing GPS data requires data collected at the same time from both the rover receiver and a base station receiver. The base station receiver can be either a Continuously Operating Reference Stations (CORS) or a GPS receiver set up at a known point during the collection effort. Using CORS data is cost-efficient and can produce accurate positioning. CORS data is collected at many locations and placed on the National Oceanic and Atmospheric Administration (NOAA) CORS Internet site. The data is collected in 1-hr blocks and placed on the Internet approximately 1 hr after the collection period. CORS data can be downloaded from the NOAA site *http://www.ngs.noaa.gov/CORS/welcome.htm*. Following the instructions, find a CORS close to the area of data collection and then download the CORS data for the selected station and time period of rover data collection. The CORS data must be downloaded as Rinex2 format. The CORS data can be downloaded as is or at an interpolated data rate. Most CORS data are collected and stored as 30-sec data. The accompanying data sheet will give the details of data rate and position of the station. If the data are interpolated using the program on the Web site, the data should be interpolated as 1-sec data. Using the interpolate program on the Web site requires some time and the site will only allow 2 hr of 1-sec data to be processed and downloaded at one time. Many hours of data can be downloaded as is and interpolated on the PC. If the CORS data are downloaded as is the data must be prepared for post-processing by interpolating the data to a 1-sec data rate using the INTERPO program available on the Internet from NOAA.

Follow the instruction provided in the software's user guide to differentially correct the mobile GPS file by processing the mobile data against the base station data file. The geographic position for the CORS can be found in the position file downloaded along with the Rinex data. If GPS data from a base station are set up for the data collection period, use the established positions for that receiver. Some software packages provide several options for the output format; Geographic, State Plane or UTM coordinates. To display the data in a CAD program, the position data needs to be in either State Plane or UTM coordinates. If the software package outputs Geographic Coordinates, the positions can be converted to either State Plane or UTM coordinates using the CORSCON program available from the U.S. Army Corps of Engineers Topographic Engineering Center, Alexandria, VA.

The corrected data can then be displayed in a CAD program such as AutoCAD in several formats. Float data collected at Tom Bevill Lock and Dam, Tombigbee Waterway at different flow conditions are shown in Figures 3 and 4. The direction of the currents is shown as a vector and the velocity of the currents is shown in text printed over the vector. The data shown in each figure were collected using two floats and one boat and required 1 day for each flow condition.

Using floats to collect information about currents provides an economical option to obtain information about a waterway. It is recommended that the data collected and processed from the floats be validated. Validation can be done as simply as using $Q = V*a$ solving for velocity over a given cross section.

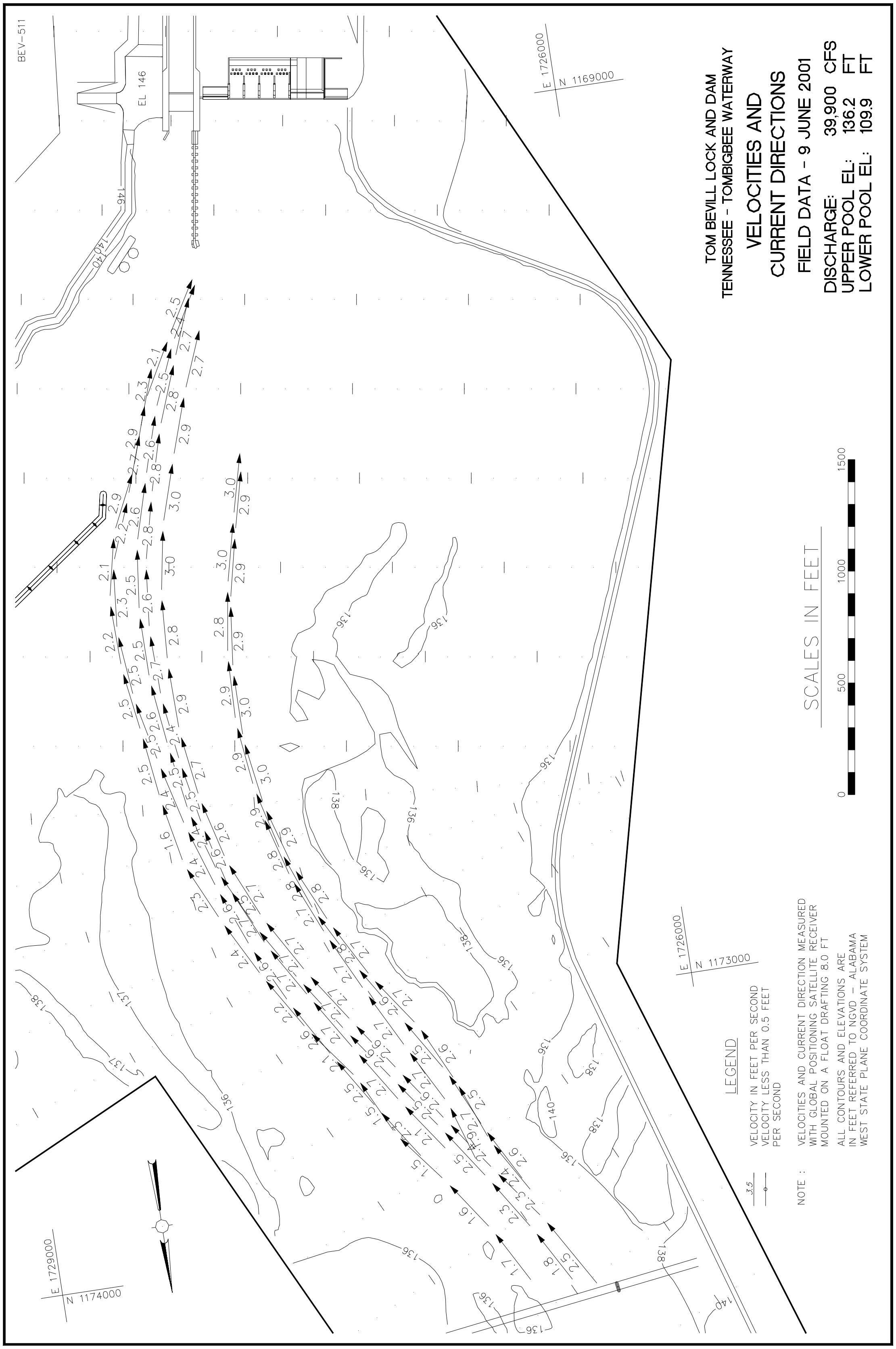

Figure 3. Current direction and velocities, discharge = 1,129.8 cu m/sec (39,900 cfs) (To convert feet to meters, multiply by 0.3048)

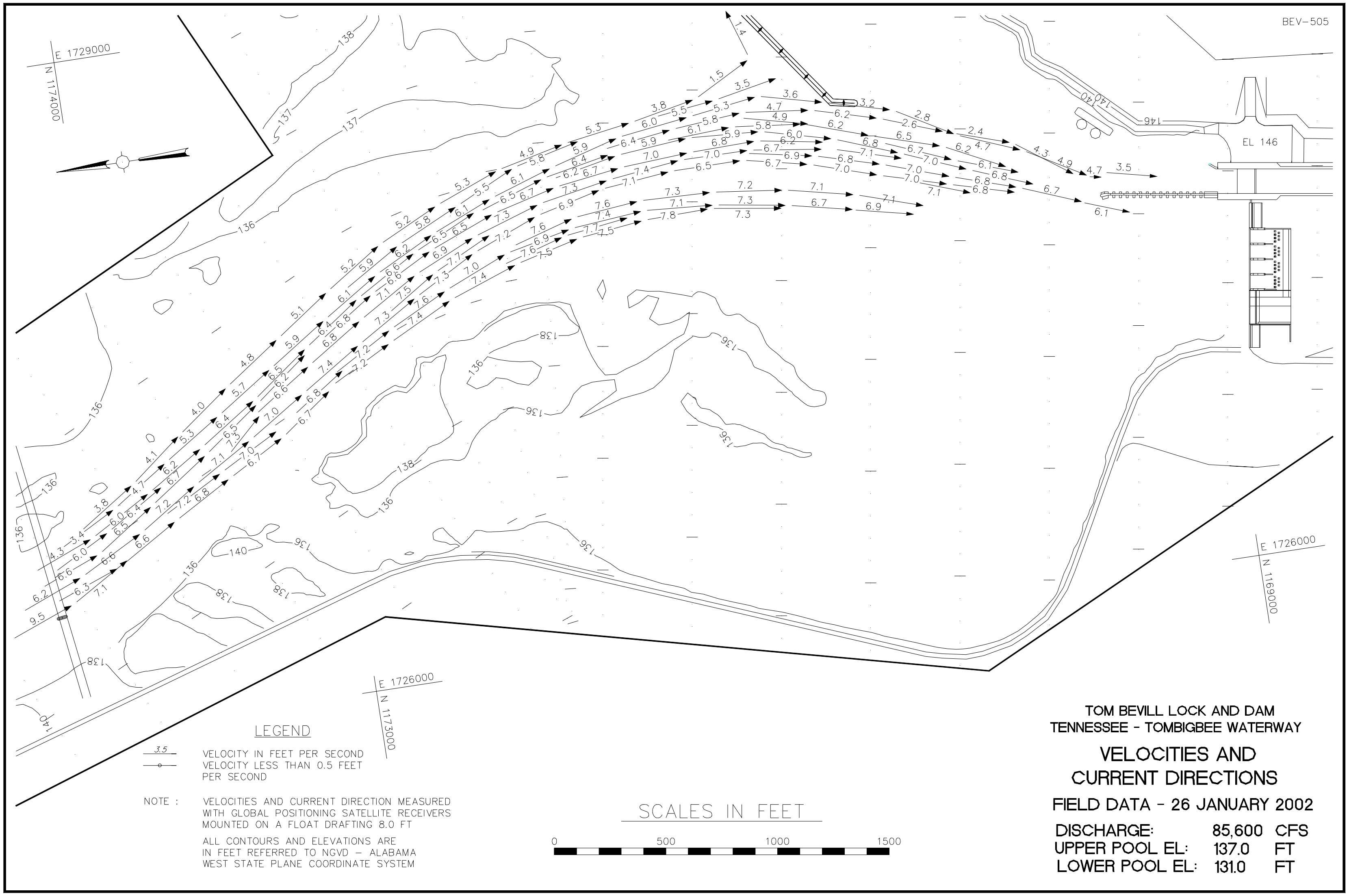

Figure 4. Current direction and velocities, discharge = 2,429.6 cu m/sec (85,800 cfs) (To convert feet to meters, multiply by 0.3048)

CONCLUSIONS: The methodology used to collect current direction and velocity data at Tom Bevill Lock and Dam, Tombigbee Waterway was very successful and provided relatively accurate data with limited effort. This method may provide an inexpensive and accurate means of collecting current direction velocities at other sites for calibration of hydraulic models or investigation of existing conditions.

ADDITIONAL INFORMATION: Questions about this CHETN can be addressed to Mr. Michael Winkler (601)634-2652; e-mail: Michael.F.Winkler@erdc.usace.army.mil. This CHETN should be cited as follows:

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