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To determine current patterns. The drogues are usually deployed from a boat.

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approximately 50 feet. These average values were used in the permit application for the marina.

An example record of the calculated velocities, 3 seconds apart, is shown in Figure 7 for Flood Drogue #1. One cause of the velocity fluctuations shown on the figure is believed to be incident waves with periods of the same order of magnitude as the 3 second GPS position sampling rate. The velocity is either increased or decreased by the orbital velocity of the waves. If the GPS sampling rate is commensurate with the wave period, the waves induce a bias in the current velocity. This is unlikely; rather, the wave-induced velocity will appear as an oscillation about the mean velocity because of the variability in wave periods. (No wave measurements were made in the present study; however, the photograph in Figure 4 shows some small waves present in the inlet.) Figure 7 also shows a 19-point moving average (57-second average) of the individual velocities. Obviously, the individual velocity measurements are quite variable because of waves and the limited accuracy with which the drogue’s exact position is determined. Other errors arise because of the drogue’s inertia (it does not respond quickly to changes in velocity) and the drag imposed by the tether.

Figure 8 is an analysis of the difference of the individual velocities from the 57-second moving average values, i.e., the residuals. The residuals were ranked and assigned a probability using the Weibull formula (Maidment, 1991),
\[ P(X \leq x) = \frac{r}{N + 1} \]

in which \( P(X \leq x) \) is the probability that the value will be not be exceeded, \( r \) is the rank \((r = 1 \text{ for the smallest value})\), and \( N \) is the number of values. The probabilities, \( P(X \leq x) \), are transformed by taking the standard normal inverse and plotted on a linear scale. This is equivalent to plotting the data on normal probability paper. Thus the values on the abscissa are standard deviations above and below the zero mean. (For example, +1 standard deviation is approximately equivalent to the 84\(^{th}\) percentile and -1 standard deviation is equivalent to the 16\(^{th}\) percentile.) For Flood Drogue #1, the standard deviation of the individual velocity readings is 0.075 knots or 68\% \((84\% - 16\%)\) of the individual velocity readings are within \( \pm 0.075 \) knots. This represents about a 10\% error for the lowest velocities measured by this drogue.

The \( r^2 \) value is a measure of how well the errors are approximated by a normal distribution. The standard deviation is a measure of the errors due to waves and in determining the drogue’s position and thus of the individual velocity calculations. These values for the other drogue deployments are given in Tables 1 and 2. The poorer correlations (lower \( r^2 \) values) indicated for the ebb current measurements in Table 2 may be attributed to inexperience leading to occasional pulls on the tether. (The ebb current measurements were the first conducted.)
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is over. The quantity of data can be overwhelming which is why spatial averages over approximately 50 feet of displacement were made in the final analysis for use in the permit application. The relatively large mass of the drogue needed to house the GPS receiver makes it less responsive to changes in current velocity; thus, where accelerations occur (including when changes in current direction occur) the inertia of the drogue slows its response and introduces errors into the measurements.

REFERENCES


Table 1  Deviation from Mean – Flood Current Measurements

<table>
<thead>
<tr>
<th>Drogue No.</th>
<th>Standard Deviation of (\frac{(V-V_{\text{mean}})}{V_{\text{mean}}}) (dimensionless)</th>
<th>(r^2)</th>
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<tr>
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<tr>
<td>6</td>
<td>0.0423</td>
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Table 2  Deviation from Mean – Ebb Current Measurements

<table>
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<th>Drogue No.</th>
<th>Standard Deviation of (\frac{(V-V_{\text{mean}})}{V_{\text{mean}}}) (dimensionless)</th>
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<tr>
<td>9</td>
<td>0.0437</td>
<td>0.9893</td>
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Figure 3  Drogue
Figure 4  Deployed Drogue with Slack Tether to Boat
Figure 5  Path Lines during Maximum Ebb Currents, Absecon Inlet, 10 March 2005 (NJ State Plane Coordinate System)
Figure 6  Path Lines during Maximum Flood Currents, Absecon Inlet, 10 March 2005 (NJ State Plane Coordinate System)
Figure 7  Calculated Velocities at 3-Second Intervals as a Function of Cumulative Distance Traveled, Flood Drogue #1.
Figure 8  Statistics of the Difference between Individual Velocity Values from the 57-Second Moving Average Value, Flood Drogue #1.