CURRENTS IN THE LOS ANGELES AREA

During the past two years, we have been collecting data on the properties of the currents at a variety of locations in the Los Angeles area. The purposes of these measurements were many: To determine the distributions of speed and direction of flow in order to help in estimating the initial dilutions produced by the outfalls; to examine the temporal variations of the flows as a function of direction to assist in predicting the sedimentation patterns and rates of deposition of effluent-related particulates (and the overall dispersion of wastewater) in the vicinity of the outfall(s); to examine the likelihood that the sediments in the outfall area are reworked by resuspension; to provide some insight into the rate of exchange between the inshore water over the nearshore shelf (water depths between 0 and 100 m) with the offshore flows; and, perhaps, to shed some light on the dynamics of the subpycnocline coastal currents.

The results of this effort have shown that the properties of the currents in the Los Angeles area are generally quite similar to those in the San Diego area. Median speeds of the currents on the shelf at a depth of 41 m are on the order of 9 to 11 cm/sec, hence current-enhanced initial dilutions may occur frequently. Periods of weak currents (< 3-4 cm/sec) on the shelf were found to be sufficiently short in duration that the degradation of the initial dilution process by weak currents can be ignored in comparison with the variations due to other processes.

The net speeds, over periods of three months or longer, were between 2 and 5 cm/sec. Off Newport Beach and the Palos Verdes peninsula, the net movement was upcoast (as was the case off San Diego); in Santa Monica Bay, it was downcoast. This suggests the presence of an eddy within Santa Monica Bay.

The major fluctuations in the currents on the shelf are in the longshore direction; in the canyon, they are along the axis of the canyon. Typical root-mean-square (rms) speeds for these fluctuations are in the range of 6 to 11 cm/sec. On the shelf, the longshore component of the
currents are dominated by fluctuations which vary more slowly than the diurnal (24 hour) tidal periods. Within the canyon, tidal and higher frequency fluctuations dominate. Near the head of Santa Monica Canyon, relatively intense, rapidly varying currents are frequently observed near the bottom. These flows are sufficiently strong to resuspend organically enhanced sediments and appear to be associated with internal waves which are trapped by the canyon.

Deep in the canyon (383 m), the net movement was downcanyon; near the head (in a different year), it was upcanyon. One hypothesis about the circulation within the canyon leads to the prediction of pockets of enhanced sedimentation, with one of these pockets near the canyon head.

Currents on the slope offshore from Santa Monica Bay are similar in characteristics to those on the shelf, but are about two thirds to three quarters the strength of the shelf flows.

**Station Locations and Periods of Observation**

The locations of the current meter moorings during this study are shown in Figure 1. The associated periods of record, the water depth at each site, and the elevation of

![Figure 1. Location of current meter stations are indicated by the crosses.](image)
the meter above the bottom are tabulated in Table 1. Three of the locations are on the nearshore shelf and are in the general vicinity of the Orange County, Whites Point, and

<table>
<thead>
<tr>
<th>Location</th>
<th>Water Depth (m)</th>
<th>Meter Elevation (m)</th>
<th>Date of Record</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newport Shelf</td>
<td>56</td>
<td>15</td>
<td>6/18-10/23/79</td>
</tr>
<tr>
<td>Newport Shelf</td>
<td>56</td>
<td>15</td>
<td>11/26-12/19/79</td>
</tr>
<tr>
<td>Palos Verdes Shelf</td>
<td>56</td>
<td>15</td>
<td>4/16- 9/18/79</td>
</tr>
<tr>
<td>Santa Monica Bay Shelf</td>
<td>56</td>
<td>15</td>
<td>4/16- 5/17/79</td>
</tr>
<tr>
<td>Santa Monica Bay Shelf</td>
<td>56</td>
<td>15</td>
<td>8/ 3- 9/ 5/78</td>
</tr>
<tr>
<td>Santa Monica Bay Shelf</td>
<td>56</td>
<td>15</td>
<td>11/22-12/20/78</td>
</tr>
<tr>
<td>Santa Monica Bay Shelf</td>
<td>56</td>
<td>0.7</td>
<td>2/ 6- 3/ 6/78</td>
</tr>
<tr>
<td>Santa Monica Canyon</td>
<td>168</td>
<td>3</td>
<td>9/29-10/13/78</td>
</tr>
<tr>
<td>Santa Monica Canyon</td>
<td>168</td>
<td>107</td>
<td>9/29-10/13/78</td>
</tr>
<tr>
<td>Santa Monica Canyon</td>
<td>384</td>
<td>1</td>
<td>9/12-10/ 4/74</td>
</tr>
<tr>
<td>Santa Monica Slope</td>
<td>476</td>
<td>41</td>
<td>5/ 8- 6/12/78</td>
</tr>
</tbody>
</table>

Table 2. Net motion and principal variations.

<table>
<thead>
<tr>
<th>Topography</th>
<th>Location</th>
<th>Water</th>
<th>Meter</th>
<th>Isobaths</th>
<th>Mean Motion</th>
<th>Princ. Var.</th>
<th>Mean</th>
<th>Major Var.</th>
<th>Minor Var.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nearshore shelf</td>
<td>Newport Beach</td>
<td>56</td>
<td>41</td>
<td>~278°</td>
<td>274°</td>
<td>272°</td>
<td>4.5</td>
<td>9.2</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td>Palos Verdes</td>
<td>56</td>
<td>41</td>
<td>~278°</td>
<td>284°</td>
<td>275°</td>
<td>5.5</td>
<td>8.1</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td>S. M. Bay</td>
<td>56</td>
<td>41</td>
<td>~300°</td>
<td>298°</td>
<td>304°</td>
<td>-2.2</td>
<td>9.2</td>
<td>6.6</td>
</tr>
<tr>
<td>Canyon</td>
<td>S. M. Bay</td>
<td>168²</td>
<td>61</td>
<td>~120°²</td>
<td>125°</td>
<td>115°</td>
<td>2.0</td>
<td>7.0</td>
<td>4.8</td>
</tr>
<tr>
<td></td>
<td>S. M. Bay</td>
<td>168²</td>
<td>165</td>
<td>~90/38⁴</td>
<td>96°</td>
<td>35°</td>
<td>3.2</td>
<td>11.1</td>
<td>4.6</td>
</tr>
<tr>
<td></td>
<td>S. M. Bay</td>
<td>384⁵</td>
<td>383</td>
<td>~210°</td>
<td>215°</td>
<td>219°</td>
<td>5.8</td>
<td>6.6</td>
<td>3.2</td>
</tr>
<tr>
<td>Slope</td>
<td>S. M. Bay</td>
<td>472</td>
<td>431</td>
<td>~298°</td>
<td>302°</td>
<td>280°</td>
<td>0.2</td>
<td>6.8</td>
<td>3.6</td>
</tr>
<tr>
<td>Nearshore shelf</td>
<td>(near bottom)</td>
<td>S. M. Bay</td>
<td>56</td>
<td>55</td>
<td>~278°</td>
<td>254°</td>
<td>209°</td>
<td>3.3</td>
<td>2.8</td>
</tr>
</tbody>
</table>

¹Root-mean-square speeds, minor axis perpendicular to major axis.

²Meter on side of canyon, canyon depth 220 m.

³Orientation of inshore 60 m isobath

⁴Meter at bend of canyon: 90° approx. orientation offshore, 38° approx. orientation inshore.

⁵Meter on side of canyon; canyon depth approx. 455 m (exact location uncertain).
Hyperion municipal wastewater ocean outfalls. Two of the locations are in Santa Monica Canyon, downcanyon from the terminus of the Hyperion seven mile sludge outfall. One of the sites is on the slope offshore from Santa Monica Bay in the general vicinity of CalCOFI Station 87.35.

DISTRIBUTION OF SPEEDS

Shelf Currents

The distributions of observed current speeds at a depth of 41 m on the nearshore shelf areas are shown in Figure 2a. The median speeds off Newport Beach and in Santa Monica Bay are about 10.7 cm/sec; off the Palos Verdes peninsula the median speed is 9.4 cm/sec, or about 12 percent less. Physical model studies (Roberts, 1977) have indicated that there exists a threshold speed for discharges from a line source such that speeds stronger than this speed can lead to an enhancement in the initial dilution produced by the outfall. For the outfalls in the Los Angeles area, this threshold speed is on the order of 4.5 to 5.5 cm/sec, hence enhanced dilutions may be expected to occur approximately 80 to 90 percent of the time. The actual magnitude of the enhancement, however, will depend on the orientation of the flow relative to the outfall diffuser as well as the speed of the flow.

Canyon, Slope, and Near-Bottom Currents

The median speeds within Santa Monica Canyon, over the slope offshore from Santa Monica Bay, and near the bottom (within the bay) are all less than the median speeds at the 41 m deep level on the shelf. The distributions of these speeds are illustrated in Figure 2b. It is noteworthy, however, that at the 90 percent probability level the observations at a depth of 165 m (168 m water depth) near the head of the canyon were higher than at the shelf stations. About five percent of the time, these speeds exceeded 27 cm/sec, which is sufficiently strong to resuspend even slightly organically enriched sediments (SCCWRP, 1976). In contrast, the nearbottom currents on the shelf were quite weak during the period of observation—speeds of less than 10 cm/sec occurred approximately 90 percent of the time. If this relatively short record of nearbottom currents on the shelf is representative of the typical nearbottom currents, resuspension processes on the shelf are likely to be very weak in comparison with those in the canyon.

The observations at a depth of 435 m over the slope offshore from Santa Monica Bay had a median speed of 6

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FIGURE 2a. Distribution of current speeds - shelf stations. This figure indicates what fraction of the observations at each location had speeds which were less than, or greater than, some chosen value. For example, the median speeds at all three outfalls are about 10 cm/sec, about 10 percent of the time, the speeds are less than 3-4 cm/sec, or greater than 17-18 cm/sec. All the measurements are at a depth of 41 m.

FIGURE 2b. Distribution of current speeds - canyon, slope, near-bottom. The median speeds within the canyon, over the offshore slope, and near the bottom on the shelf. At the 165 m level in the canyon (3 m above the bottom), about 15 percent of the speeds exceed 18 cm/sec, hence, speeds about 18-20 cm/sec occur near the bottom and near the head of the canyon on a more frequent interval than at any of the other sites.
cm/sec. The 500 m depth is frequently assumed to be a level of no significant motion when estimating the strength and direction of flows at shallower depths by using the assumption of geostrophically balanced flow and the observed distributions of temperature and salinity. From these current meter observations, it is evident that geostrophically calculated flows based on a 500 m reference depth should be viewed with some suspicion when the calculated speeds are weak.

**Direction of Flow**

The current meters were deployed for, or serviced on, approximately one month intervals. Each such record was analysed to determine the speed and direction of the net movement over that period. This mean motion was then subtracted from the record, and the resulting flows were analysed for the principal direction of the fluctuations in the current (about the mean flow). The corresponding rms speed for the fluctuations along that direction were also calculated. A second axis was then chosen, perpendicular to the axis of the principal fluctuations, and the rms speed along this minor axis was calculated.

Table 2 summarizes the results of this analysis. For records longer than one month, the individual monthly results were vector averaged for the total duration of the records. In general, both the direction of the net flow and the orientation of the principal axis for the variations were aligned approximately parallel with some nearby topological features, such as the local isobaths (contours of constant water depth). Both the net flow and the major fluctuations are, therefore, essentially oriented in the longshore or alongcanyon direction, with the minor axis for the fluctuations oriented in the cross shore or cross canyon direction. The principal exception to this generalization was the record for the nearbottom currents on the shelf, inshore from the head of Santa Monica Canyon, where the net flow was toward the head of the canyon.

**SPEEDS OF THE NET FLOW AND THE VARIABLE FLOWS**

**Shelf Currents**

Table 2 also lists the speed of the net flow and the rms speeds along the major and minor axes of variation. At the 41 m depth (on the shelf), the net movement was upcoast at speeds of 4.5 to 5.5 cm/sec at both the Newport Beach and the Palos Verdes locations. In Santa Monica Bay, the net
movement was downcoast at a speed of 2.2 cm/sec. This downcoast movement suggests the presence of an eddy within Santa Monica Bay at the 41 m depth, but longer simultaneous records at several locations will be required to test this hypothesis. The speeds of these net flows are comparable to the net speeds of 2 to 4 cm/sec found off Point Loma (San Diego area) during observations of several months duration.

Typical rms speeds at the 41 m depth for the longshore direction are in the range of 8 to 9 cm/sec, or 1.5 to 4 times as strong as the net motion. The sedimentation of effluent-related particulates can be expected to occur on both the upstream and the downstream sides of the outfall at all three locations. Since the net speed was the smallest at the Santa Monica Bay site, this area will show the most symmetrical sedimentation pattern in the longshore direction. The rms speeds in the cross shore direction are about two-thirds as strong as in the longshore direction.

**Canyon Currents**

Within the canyon, a net downcanyon movement at a speed of 3.8 cm/sec was observed at the 384 m depth. In contrast, at the 168 m deep site, the net movement was upcanyon at a similar speed of 3.3 cm/sec. Although both records were collected during the months of September and October, they were collected in different years. Therefore, we cannot determine if the reversal in the net direction of flow is due to variability from year to year, or whether vertical circulation cells exist within the canyon. If the latter is the case, particulates from the Hyperion seven-mile outfall, or resuspended material from the shelf, might be expected to collect at the nodal points of these cells. Since the movement was upcanyon near its head, and the nearbottom currents inshore from the canyon were directed toward the head of the canyon, the head of the canyon might be one such nodal point.

The highest rms speeds observed in any record and at any location were associated with the 165 m deep record, near the head of the canyon, with a value of 11.1 cm/sec. In addition, this location had the greatest ratio between the rms speeds along the major and the minor axes of variation.

**Slope Currents**

The net movement at the slope site was 0.2 cm/sec which is experimentally equivalent to a speed of zero. The rms speeds for the variation about the mean flow were about three-quarters of the values on the shelf in the longshore
direction, and about two-thirds the values in the cross-shore direction. They are slightly greater than the rms speeds at the 383 m depth in the canyon.

Near-Bottom Shelf Currents

The net speed near the bottom on the shelf inshore from the head of Santa Monica Canyon was 3.3 cm/sec, which is comparable with the net speeds within the canyon. The rms speeds, however, were substantially less than in any of the other locations with values of about 2 and 3 cm/sec along the minor and major axes respectively.

VARIABILITY OF THE CURRENTS IN TIME

Shelf Currents

The variability of the currents in time is an important consideration in considering the dispersion of effluent related particulates, or in estimating the average concentration of effluent in the water column at some particular location. Strong, but rapidly fluctuating currents may not be as effective in advecting the wastefield to some area as weaker, but more slowly varying currents. The time variability of the longshore and cross-shore components of the 41 m deep currents at the three shelf sites is illustrated in Figure 3. A 24.75-hour running average has been used on the original data to suppress tidal and higher frequency fluctuations.

A comparison of the longshore and the cross-shore components shows that the longshore fluctuations are substantially greater than the cross-shore variations. This is particularly true in the Palos Verdes area, where the width of the nearshore shelf is substantially less than in the other two areas.

In the longshore direction, strong fluctuations with periodicities in the range of 14 to 30 days are evident at the Newport Beach location and in Santa Monica Bay. Similar fluctuations are present off Palos Verdes, but are not so conspicuous. We are presently exploring the possible mechanisms that might lead to such fluctuations.

In Figure 4 the cumulative variance of the fluctuations for the Newport Beach and Palos Verdes records are plotted as a function of the periodicity of the variations. For example, the total variance at the Newport site in the longshore direction is slightly less than 100 cm²/sec², with a corresponding rms speed of about 10 cm/sec (=√100). If all the fluctuations with a periodicity equal to, or shorter than, the diurnal period (≈ 24 hours) are eliminated, the
FIGURE 3. Longshore and cross-shore flows at the 41 m depth on the shelf. The solid line represents the daily average (24.75 hr) flow in the longshore and the cross-shore directions. The dash-dot line indicates the net movement. This shows that the variations are stronger than the net flow and occur over extended periods of time (2-4 weeks). As a result, the distributions of particulates which settle near the outfalls will be primarily related to the strength and duration of these fluctuations, and hence, the patterns will be elongated in the longshore direction.

NOTE: The August-September and November-December measurements in Santa Monica Bay were collected in 1978, the others were collected in 1979.
remaining variance would still be about 78 cm²/sec² (and the rms speed would be about 8.8 cm/sec). Off Palos Verdes, only about 50 percent of the variance remains after supressing the tidal and higher frequency contributions. Since the variance is initially somewhat greater at the Newport site, and the lower frequency (longer period) components of the variability will be more effective in advecting wastewater from the outfall, outfall related particulates in the Newport Beach area will be dispersed over a larger area than the particulates from the Whites Point outfall. As a result, the outfall associated sedimentation rates will be less in the Newport area if the settling characteristics of the particulates in the two effluents are similar.

An examination of the fluctuations at the tidal periods in these two areas also showed that some differences existed. At the diurnal tidal periods, enhanced fluctuations occur in both the longshore and the cross-shore directions off Newport, but only in the longshore direction off Palos Verdes. At the semi-diurnal tidal periods, the greatest enhancements occur in the cross-shore direction in the Newport area, but in the longshore direction off Palos Verdes. Both these areas appear to have substantial

![Graph](image-url)

**FIGURE 4.** Magnitude of the fluctuating portion of the currents. The ordinate is a measure of the cumulative variance of the longshore (upper pair of lines) and the cross-shore components of the fluctuating portion of the flows as a function of decreasing “period.” The solid curve is at a depth of 41 m off Newport Beach; the dashed, off Palos Verdes.
contributions to the fluctuations by internal waves of approximately semi-diurnal periodicity (internal tides).

**Slope Currents**

The longshore spectral characteristic of the slope currents are similar to those on the shelf, with about 65 percent of the variance contributed by fluctuations with periodicities longer than one day. In the cross-shore direction, only about 4 percent of the variance is contributed by these long term fluctuations. A sharp diurnal spike is observed in the longshore component of the flow; a broad peak (suggestive of internal tide generated motion) is observed at the semi-diurnal tidal period. These enhancements are absent in the cross-slope direction.

**Canyons**

In the canyons, in both the along canyon and the cross canyon directions, the primary source of the variability is due to tidal and higher frequency fluctuations. At a depth of 383 m, there is a broad enhancement around the diurnal period and relatively sharp enhancements at the semi-diurnal tidal period and its first harmonic. These features are absent in the cross canyon direction. Approximately 75 percent of the variance in the along canyon direction is associated with the region bounded by the diurnal and semi-diurnal tidal periodicities. In the cross canyon direction periodicities shorter than two hours account for 75 percent of the variance.

Near the bottom at the station with a water depth of 168 m, there is also considerably more energy in the along canyon direction than in the cross canyon direction for periodicities between the diurnal and semi-diurnal periods. This dominance, however, continues to much shorter periods, including the region with periodicities of two hours or less.

At this latter location, the first two harmonics of the principal lunar semi-diurnal tide (i.e. periods of 6.2 and 4.1 hours respectively) are stronger than the semi-diurnal tidal fluctuation. The intensification of the nearbottom, along canyon component of the currents within the canyon, relative to the currents just above the canyon is consistent with the hypothesis of trapped internal waves proposed by Gordon and Marshall (1976). In this theory, the intrusion of a canyon into a shelf area can result in the focusing of energy associated with internal waves (propagating over the shelf) into the bottom of the canyon. The presence of harmonics of the semi-diurnal tidal period suggest that the dynamics of this process are highly non-linear.
Since the strong speeds found near the bottom in the vicinity of the head of the canyon are associated with relatively rapid fluctuations, they may not be very effective in directly transporting resuspended particulates out of that area. Resuspended particulates may be dispersed from the area, however, by a diffusion-like process and by the net circulation existing at that site.

**Duration of Periods of Weak Currents**

In the following section, it is indicated that the extent to which the initial dilution produced by an ocean outfall might be diminished during periods of very weak currents (<3-4 cm/sec) is not only dependent on the speed of the current, but also on the length of time that these weak flows exist.

We examined multiple twenty-five day (600 hour) long records from each of the three shelf locations to determine how long periods of weak currents may last. The results are shown in Figure 6. The procedure was to choose some reference speed, \( v_r \), and then examine the current meter record until a speed less than \( v_r \) was encountered. The number of hours that subsequently elapsed before a speed equal to, or greater than, \( v_r \) occurred was then recorded. The longest such period within each twenty-five day period is plotted in Figure 6. From these results, it is estimated that a duration longer than the upper limit indicated by the dot-dash line in Figure 6 would occur (at a particular location) with a frequency of less than once a year.

A comparison of the observed durations of periods of weak currents for this area, with the development times required for a substantial reduction in the expected initial dilution to occur (see Figure 2 in the following paper), indicates that such reductions will rarely occur.

**ACKNOWLEDGEMENTS**

The difficult part of this study—the deployment, servicing and recovery of the current meters in a hostile environment—was ably carried out by Harold Stubbs and Mike Moore of SCCWRP. Mike Schoenzeit efficiently and accurately translated the data recorded by the current meters into a format compatible for computer analysis.
FIGURE 5. Observed maximum duration of currents with a speed less than some reference value. The ordinate represents the duration of the maximum period during a 600 hour record for which the currents were always less than the reference value, \( v_r \). Occurrences with durations longer than indicated by the dot-dashed line will occur less frequently than once a year.
REFERENCES
